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MYOSIN PREPARATIONS FROM THE MERISTEMATIC TISSUE OF FRESH SPROUTS OF VINE *(VITIS VINIFERA* L., *CV. CARDINAL)*

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(Received: 30 January 1983)

KCl-myosin is prepared from the meristematic tissue of vine sprouts. The yield of gel-filtered myosin from 100 g fresh sprouts is about 9.5 mg. This myosin contains 20–30 mol P/mol myosin. With the use of a phosphorylating mixture the phosphate content of the myosin can be increased to 100–150 mol P, depending on the phosphorylating conditions. The P content of the myosin reaches its maximum value at about 1 mM ATP, within an incubation time of 2 minutes.

After basic hydrolysis, P-Arg, P-Lys and two P-His-s (as well as derivatives of traces of 2–3 minor compounds) are found in the control myosin, while the phosphorylated samples contain a further 3 compounds, together with peak No. 9 as the presumed most labile P-containing derivative.

Introduction

Actomyosin plays a central role in the basic phenomena of movement in animal organisms. Actomyosin is also found in low grade organisms, e.g. amoebas and slime moulds (Wooley 1972, Clarke and Spudich 1974).

It is presumed from the evidence of other investigations (see the survey by Wagner 1979) that actomyosin may also be ubiquitous throughout the plant kingdom.

Myosin was previously isolated from a monocotyledonous plant species, maize (*Zea mays* L.; hybrid SZE DC 384) (Nehéz *et al.* 1985). Myosin preparations and their properties are now reported from a dicotyledonous plant species, vine (*Vitis vinifera* L., cv. Cardinal).

About 5–12 mg gel-filtered myosin were obtained from 100 g minced vine sprouts, depending on the meristematic cell content of the sprouts.

The rate of phosphorylation, the total phosphate content and the basic amino acid content were also studied. Evidence is given of the "active phosphate content of myosin", which may play an important role in cytokinetic movements and transport processes, e.g. in the phloem.

Material and methods

The cv. Cardinal was selected, since the numerous shoots of this variety grow very vigorously in a short period, during the first half of June, and this variety therefore requires very intensive green work.

Sampling was performed at about 8 a.m. on 8th and 15th June 1982. It is very important that primary cell walls should be absent, and that the myosin should be prepared practically from meristematic tissues.

A larger quantity of sprouts (800–1000 g) was collected in a vessel containing crushed ice and stored at 0 °C until the preparation.

The myosin was prepared by the method described by NEHÉZ *et al.* (1985), except that the precipitate (gained by dialysis) was sedimented out at a higher centrifugal rate (105,000xg) to increase the yield of crude myosin precipitated from the first, voluminous extract.

Protein, lipid and P lipid content determinations, phosphorylation, and the separation of basic amino acid phosphates were carried out as described by FAZEKAS *et al.* (1981a, 1981b).

The phosphorylation is currently being investigated intensively at different ATP concentrations and points of time, in order to obtain information about the kinetics of phosphate saturation.

Results and discussion

The dry matter content of fresh sprouts in the first half of June, the period of intensive growth, averaged 8.8 ($\pm$2.3)%. At this time the sprouts grew about 10–15 cm per day.

The ultracentrifuging and DEAE-cellulose treatment of the crude myosin removed much accompanying matter. The purification was completed by gel-

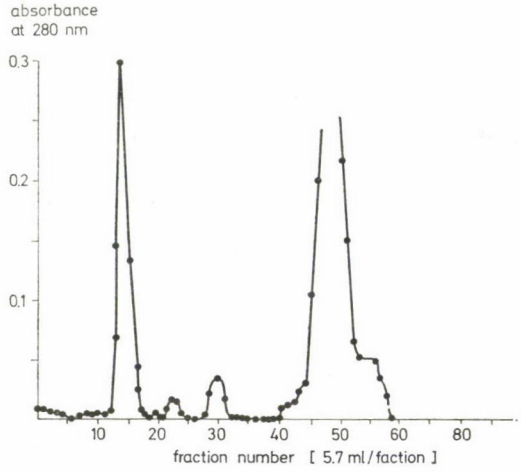

Fig. 1. UV absorbance of gel-filtered myosin. Gel-filtration profile of vine myosin produced from meristematic tissues on a Sepharose 4B column (2.1×74 cm). The column was equilibrated with 0.5 M KCl solution containing 8 mM $NaHCO_3$ and 0.5 mM DTT. 5.5 ml total sample was poured on to the top of the column and eluted with the same buffer. 0.5 ml fractions were collected. The flow rate was about 18.6 ml per hour. The protein content was followed in every tube via the UV absorbance, monitored at 280 nm. The solutions relating to the first peak were collected as myosin, and used for PAGE, phosphate saturation, time-dependent phosphate incorporation and basic amino acid phosphate investigations

Abbreviations

Chl = chloroform, DTT = dithiothreitol, HC = heavy chain, LC = light chain, MeOH = methanol, P = macroerg organic phosphate, Pi = inorganic phosphate, SDS = sodium dodecyl sulphate, TLC = thin layer chromatography

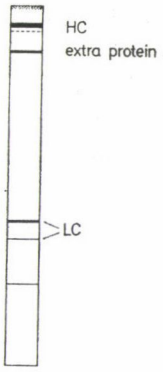

Fig. 2. Gel electrophoretic pattern of gel-filtered myosin. Electrophoretic movement of subunits of vine myosin product (in a 7.5% PAG system). The protein sample was solubilized in 1% SDS, 2 mM 2-mercaptoethanol and TRIS-HCl buffer (pH 7.2) and then heated in a boiling water bath for 20 min. In this case, about 20 microg protein was applied in a 1 microlitre per gel tube. The electrophoresis, colouring and destaining were performed by the method of WILKINSON *et al.* (1972). In the separation, TRIS-HCl buffer was used in place of sodium phosphate

filtration on a Sepharose 4B column. The gel-filtration profile of the ultracentrifuged product is shown in Fig. 1.

The molecular mass of the myosin was estimated from the elution profile to be 480,000 D. This value was used for calculations.

The gel-filtrated myosin had a low Ca^{2+}-activated ATPase activity (2–5 nmol Pi mg^{-1} min^{-1}), which may be increased about fivefold by rabbit skeletal muscle actin in the presence of Mg^{2+}.

Polyacrylamide gel electrophoresis (PAGE) was performed in 7.5% gel with 1% SDS, and led to the separation of one heavy chain (HC) and two light chains (LC-s) of myosin, together with an extra protein in the interval 70,000–90,000 D (Fig. 2).

This protein is a permanent component accompanying gel-filtered myosin in varying amounts. After purification with ammonium sulphate, this component is usually not detectable. This purification was omitted, to avoid an appreciable loss of myosin and a decrease in its biological function.

The P content of the gel-filtered myosin was 20–30 mol/mol, a considerable amount of this being P lipids (average 10.2 mol/mol myosin).

The phosphate content of the vine myosin preparation may be increased by means of a suitable phosphorylation solution. The myosin is saturable up to 100–150 mol P/mol myosin.

This observation suggests that the binding sites of gel-filtered myosin are only partly saturated. The expressions "preparative myosin content" and "preparative phosphate content" are therefore permitted. It is necessary to know the appropriate length of time for the phosphorylation (the period of

incubation) of myosin and the optimum ATP concentration range in kinetic investigations. The effect of ATP concentration on phosphate absorption (incubated for 90 s) is shown in Fig. 3.

At low concentration (10^{-4}–10^{-6} M), ATP has no effect on phosphate incorporation. As a consequence of incubation (and perhaps of the procedure

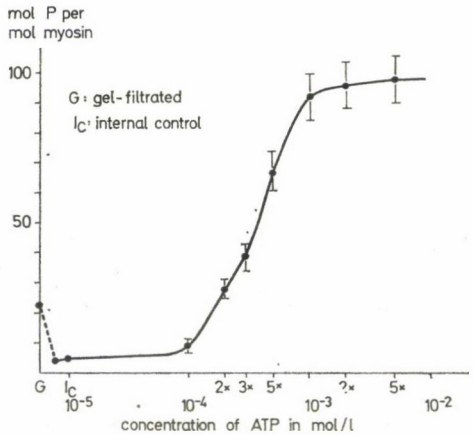

Fig. 3. Effect of ATP concentration on phosphate saturation. The ATP concentration in the incubation solution of gel-filtered myosin was increased as shown on the abscissa. The phosphorylation was achieved by incubation at 30 °C for 1.5 min, and terminated with 6–8 vol ice-cooled acetone. The samples were then stored at 0–4 °C overnight for the protein to flocculate. The precipitated protein was collected by centrifugation, washed 5 times with washing solution, followed by a procedure designed to liberate it from lipids (with Chl : MeOH 2 : 1 by vol). The lipid-free proteins were used for P content determinations, and the parallel samples for the analysis of ribose traces, to control nucleotide or RNA residues. A gel-filtered internal control (I_C; incubated without ATP) was applied. The results were calculated for 480,000 D proteins, as the presumed molecular mass of myosin

employed for the removal of surplus nucleotides and lipids), the P content of gel-filtered myosin at such ATP concentrations decreases to the value of the internal control (I_C; i.e. incubated without ATP). The presence of about 2×10^{-4} M ATP in the incubation mixture prevents a decrease in the P content. At higher ATP concentrations, the P content of the myosin increases, and at about 1 mM ATP the P content is saturated.

The influence of the length of the incubation period on the presence of 1 mM ATP is shown in Fig. 4.

This shows that myosin attains its maximum phosphate content on incubation for approximately 2 minutes. With a longer incubation time, there is a partial loss of P content and a lower stable phosphate content (53–60 mol) in the myosin.

The decrease in the P contents of the incubated and control samples (in incubations at low concentrations) and the effect of the incubation time revealed the mobility of the phosphate groups, i.e. the incorporated labile

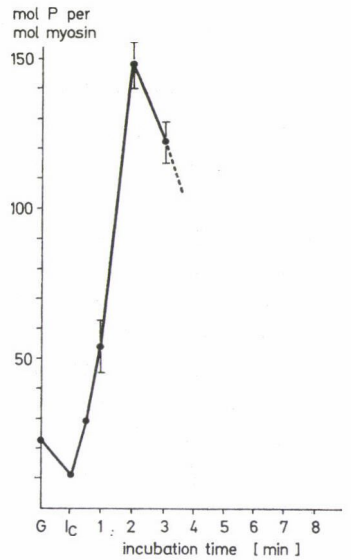

Fig. 4. Phosphate incorporation during incubation. Effect of incubation period on the phosphate incorporation of gel-filtered myosin in the presence of 1 mM ATP. The incubation times are shown on the abscissa. The further procedure was as described in Fig. 3

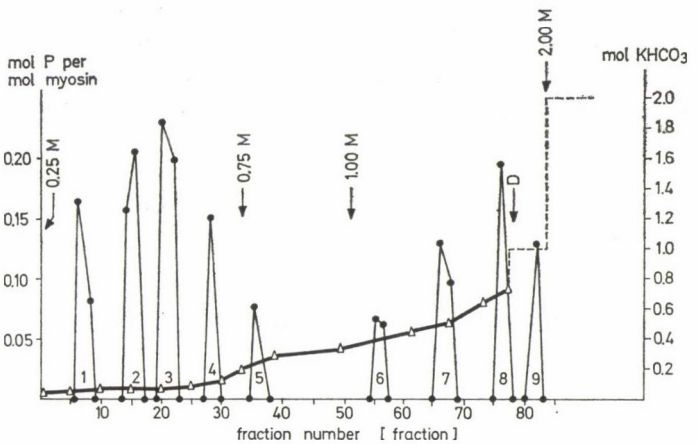

Fig. 5. Basic amino acid phosphates from hydrolysed myosin. Chromatographic separation of alkali-stable amino acid phosphates from the hydrolysate of phosphorylated and lipid-free vine myosin on a Dowex 1 X8 (0.9×6 cm) column. The hydrolysate of 13.8 mg lipidfree-myosin was applied to the column, diluted 300-fold with distilled water to about. 0.008–0.01 M KOH, and chromatographed by a linear gradient step method. The mixing chamber (with a capacity of 160 ml) was filled with 0.01 M $KHCO_3$, and the reservoir first with 150 ml 0.25 M, then with 0.75 M and 1 M $KHCO_3$ (the changes are shown by the arrows). Point D shows the application of 1 M $KHCO_3$ (direct pouring without a mixing chamber). Under the conditions applied, the neutral and basic amino acids are not bound by the ion-exchange resin. 2 M KCl was applied for the regeneration of the column. The P content was traced in 1.75 ml eluates (0.5 ml molybdate reagent and 0.25 ml 1% ascorbic acid solution). Only the molybdate-positive tubes were pooled, then lyophilized and used for further analyses

phosphates in the peptide chains of the myosin are involved in very different types of chemical bonds.

The movement of phosphate incorporated in the myosin may be stopped, and phosphate participating in the most labile chemical bonding may be retained, if the incubation is stopped with 6–8 volumes ice-cooled acetone after about 1.5–2 minutes.

Following the classical washing procedure, the alkaline hydrolysate of the lipid-free myosin (with 3 M KOH at 105 °C for 10 h) contained the total phosphate, with the exception of 3–6% bound covalently. Basic amino acid phosphates in the hydrolysate were separated on a Dowex 1 X8 column. The elution profile in the separation is demonstrated in Fig. 5.

The elution profile (derived fro experiments with synthetic amino acids, by means of specific reactions for amino acids, with TLC comparative analyses) permitted identification of the phosphates of 3 amino acids (P-Arg, P-Lys and two P-His-s). The phosphorylated samples gave 9 peaks, and the control (non-phosphorylated) samples usually only 5–6 peaks (not shown). The control samples do not contain peaks Nos 1, 2, 6 and occasionally 9 (at most in traces).

The percentage contents of the phosphates from the phosphorylated myosin are listed in Table 1.

Previous studies on myosin in the meristematic tissues of a monocotyledonous plant (root tips of maize seedlings) have now been extended to myosin in a dicotyledonous plant (young vine sprouts).

On average 9.0 ($\pm$2.5) mg gel-filtered myosin was obtained from 100 g fresh vine sprouts. The total P content was 25–30 mol/mol myosin.

Table 1

Distribution of basic amino acid phosphates in a sample of phosphorylated vine sprout KCl-myosin

No.	Fraction	Micromol per fraction	%
1.	+	0.496	13.41
2.	+	0.736	19.86
3.	P-Arg	0.786	21.20
4.	Pi	0.244	6.60
5.	P-Lys	0.155	4.25
6.	+	0.275	7.44
7.	N^{π}-P-His	0.522	14.20
8.	N^{τ}-P-His	0.252	6.80
9.	+	0.245	6.62
	Total	3.711*	100.38

* 4.05 micromol of hydrolysate of 13.8 mg lipid-free myosin applied to column. Recovery about 91.2%.

+ These fractions are unidentified.

The myosin includes a considerable amount of lipids, and part of the P content (average 10.2 mol) is found in the lipids.

In spite of its P content, the myosin has a very low Ca^{2+}-dependent ATPase activity (2–5 nmol Pi mg^{-1} min^{-1}); it may be activated with rabbit actin. The phosphorylation kinetics demonstrate that the phosphate content reaches its maximum value, about 150 P/mol myosin, in the presence of about 1 mM ATP and within the first 2 minutes of incubation.

The kinetics of phosphate saturation indicate that long incubation periods are not suitable for the recognition of the primary intrinsic properties of myosin. The hydrolytic effect of myosin seems to be a secondary property and does not show the principal function of myosin. This conclusion was also reached by CARDON and BOYER (1978), SLEEP *et al.* (1978, 1980) and ARIKI and BOYER (1980). Experiments with ^{18}O-labelled ATP suggest that the phosphate group of myosin changes its position about 100 times before it becomes inorganic phosphate, i.e. the formation of one molecule of P_i from ATP requires that the ATP pass through the skeletal muscle myosin about 100 times.

Factors of primary importance in the phosphorylation of myosin include not only the formation of basic amino acid phosphates (P-Arg, P-Lys, P-His-s and others), as macroerg phosphates of N–P bonds, but also an increase in general polarity, i.e. in the negative charges of the molecule, which is equivalent to the situation when myosin is "suitable for contraction".

Table 1 lists 8 covalently bonded organic and one P_i P component of myosin. It is suprising that in the control (non-phosphorylated) peaks, Nos 1 (probably more basic than P-Arg), 2 and 6 are found only in traces. The phosphorylated No. 9 seems to be the most labile compound. This peak is eluable with 1 M $KHCO_3$ solution (it has not been identified). It may be a diphospho-histidine or an unhydrolysed peptide residue.

As stated above, myosin is considered to be an autophosphorylating system.

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EFFECT OF WATER STRESS ON GERMINATION AND SEEDLING METABOLISM OF GRAM *(CICER ARIETINUM* L.)

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(Received: 12 April 1983)

Moisture stress decreased fresh weight, dry weight and amounts of soluble proteins, free pool amino acids, starch and soluble sugars in the cotyledons and the embryo axis. Protease activity did not change significantly with moisture stress. High starch and low soluble sugar contents in the embryonic axis were accompanied by low levels of α- and β-amylases. The decreased water potential influenced seed germination either by retardation of water imbibition or by altering the general metabolism especially inhibition of starch breakdown in the embryo axis which seems to be a major factor in controlling the growth of embryo axis.

Introduction

Crop plants vary in their response to water stress and even different stages in their life cycle differ markedly in resistance to moisture stress. Seed germination and the early seedling growth are more sensitive than later stages of development. The effect of decreased water potential on seed germination has been studied by several workers (HUNTER and ERICKSON 1952, AYER 1952, EVANS and STICKER 1961, SAINT-CLAIR 1976, RANDHAWA 1976 and GALMOND *et al.* 1978) but the biochemical mechanism contributory to the inhibition of germination due to water stress are not fully understood. To fill this lacunae, we selected gram *(Cicer arietinum)*, a major pulse crop of India, known to be the crop most sensitive to water stress, as an experimental material for the present studies. In our studies we attempted to determine the way in which water deficit disturbed the general metabolism during seed germination and seedling growth.

Material and method

Uniform sized, surface sterilized seeds of *Cicer arietinum* cv. 214 (50 seeds/petri plate) at 26 $\pm$ 2 °C in dark at 0, 0.6 and 0.8 MPa water stress using polyethylene glycol (PEG 600) as suggested by PARMER and MOORE (1960) were sown. The sample referred to as control was sown in distilled water. Samples were taken at 24 h interval up to 72 h. The imbibed and germinated seeds were dissected into the cotyledons and the embryo axis. The extraction and biochemical analyses of soluble proteins (LOWRY *et al.* 1951), starch (MCCREADY *et al.* 1950) reducing sugars and soluble amino nitrogen (LEE and TAKAHASHI 1966) were done in both the seed parts. For the enzyme extractions, duplicate batches of 50 seed parts of known number/weight were homogenized at 0 °C in a chilled pestle and mortar with 0.1 M Tris-malecate to buffer, pH 7.0, containing 1 mM dithiothritol. The homogenate was centrifuged at 10,000 $\times$ g

for 20 min at 0 °C. The supernatant was used for enzyme assays. The activities of protease (PENNER and ASHTON 1967), α-amylase (DAVIS 1977) and β-amylase (BERNFELD 1955) were also determined. The experiments were repeated and the data are the average of duplicate experiments, and expressed on per seed part basis (Cot pair^{-1} and embryo axis^{-1}).

Results

Fresh weight, dry matter and hydration level

Fresh weight of the cotyledons and the embryo axis increased linearly with the incubation period up to 72 h. With moisture stress a similar trend in fresh weight was observed (Table 1). Under high osmotic stress conditions

Table 1

Changes in fresh weight, dry matter, moisture content (mg^{-1} seed part) in germinating seeds of chick pea (Cicer arietinum) var. C-214 under water stress

Time of incubation (hr)		Fresh weight			Dry weight			Moisture content		
		Osmotic potential (MPa)								
		0	0.6	0.8	0	0.6	0.8	0	0.6	0.8
0	C	172	—	—	103	—	—	69	—	—
	E	3.74	—	—	1.20	—	—	2.54	—	—
24	C	221	204	197	110	106	119	111	98	78
	E	4.80	4.03	4.14	1.30	1.28	1.42	3.50	2.75	2.72
48	C	225	224	200	103	103	109	123	111	95
	E	35	3.16	3.54	10.20	1.59	1.45	24.70	3.92	2.09
72	C	207	193	184	97	104	116	110	89	88
	E	58	3.93	3.77	6.50	1.37	1.37	51.50	2.55	2.43

C = Cotyledons. E = Embryo axis

Table 2

Changes in the level of soluble proteins, soluble amino nitrogen of chick pea (Cicer arietinum)

Incubation time (hr)	Seed part	Proteins			Soluble amino nitrogen		
		Osmotic potential (MPa)					
		0	0.6	0.8	0	0.6	0.8
0	C	18.60	—	—	0.18	—	—
	E	0.304	—	—	0.008	—	—
24	C	19.80	23.20	23.60	0.17	0.13	0.15
	E	0.631	0.32	0.41	0.02	0.008	0.001
48	C	25.60	20.70	18.00	0.37	0.17	0.18
	E	1.54	0.70	0.54	0.09	0.004	0.004
72	C	32.00	23.50	25.05	0.62	0.33	0.21
	E	2.25	0.89	0.67	0.21	0.004	0.004

C = Cotyledons. E = Embryo axis

fresh weght decreased. Dry matter of both the seed parts increased up to 24 h, followed by a decrease up to 72 h. Under severe osmotic stress dry matter of the cotyledons and the embryonic axis slightly decreased as compared with the control.

Soluble proteins, soluble amino nitrogen, starch and soluble sugars

The data in Table 2 show changes in the amount of soluble proteins, free amino acids, starch and reducing sugars in the germination seeds. The amount of soluble protein cotyledonary increased continuously up to 72 h of germination in both conditions. However, under water stress (0.6 and 0.8 MPa), its amount was less. In the embryo axis a comparable trend was made out. Water stress resulted in a decrease in total free amino acid in the cotyledons and the embryo axis of germinating seed. Water stress caused accumulation of starch in the cotyledons. However, starch content of embryo axis decreased continuously in the control, while a sharp increase was noticed under water stress conditions. Soluble sugars decreased with the germination period under water stress in both the seed parts.

Hydrolytic enzymes

The activity patterns of protease, and amylases in the cotyledons and the embryo axis of germinating gram seeds, are given in Table 3. Protease activity in the cotyledons did not vary significantly in both these situations However, under stress, its activity decreased at 24 h followed by an enhancement. The activity of α-amylase in the cotyledons abruptly declined up to

reducing sugars (mg^{-1} seed part) and starch (%) in germinating seeds var. 214 under water stress

Incubation time (hr)	Seed part	Starch			Reducing sugars		
		Osmotic potential (MPa)					
		0	0.6	0.8	0	0.6	0.8
0	C	13.60	—	—	102	—	—
	E	1.999	—	—	4.56	—	—
24	C	15.15	20.60	18.59	80	30	24
	E	0.43	0.68	0.78	12.58	1.96	2.2
48	C	16.97	14.22	15.98	68	48	45
	E	0.45	0.95	1.18	32.60	1.58	1.54
72	C	16.82	15.90	10.58	114	81	58
	E	1.19	1.76	10.90	115	2.60	2.54

Table 3

Changes in the activities of enzymes protease (μg Tyr^{-1} seed part), α-amylase (Δ 620^{-1} seed part), β-amylase (μg maltose^{-1} seed part) in germinating seeds of chick pea (Cicer arietinum) var. C-214 under water stress

Incubation time (hr)	Seed parts	Protease			α-amylase			β-amylase		
		Osmotic potential (MPa)								
		0	0.6	0.8	0	0.6	0.8	0	0.6	0.8
0	C	83.25	—	—	6.3	—	—	500	—	—
	E	1.84	—	—	0.003	—	—	56	—	—
24	C	25	25	58.3	1.1	1	1	1000	300	150
	E	0.9	1.3	3	0.1	12.8	27.8	28	13	27.8
48	C	25	58	25	1.6	1	0.8	1250	2750	2500
	E	1.3	0.9	1.1	0.04	6	0.02	181	6	9
72	C	2.83	25	25	1.5	1.4	1.2	2000	1250	1200
	E	2.8	1.0	0.3	1.1	26	10.6	100	20	11

C = Cotyledons. E = Embryo axis

24 h, followed by a gradual increase. Water stress resulted in a remarkable decrease at all stages. In the embryo axis, the activity of α-amylase was negligible. Under severe water stress, the activity of this enzyme increased enormously.

The activity of β-amylase in the cotyledons and embryo axis increased with progress in germination. In cotyledons, water stress resulted in an increase in activity. In the embryo axis, water stress resulted in decrease in the activity of β-amylase.

Discussion

The uptake of water in the cotyledons of germinating seeds was more rapid than in the embryo axis. The imposed water stress reduced water absorption in the cotyledons and embryo axis. Fresh weight increase of the cotyledons following germination may be due to the growth of the cotyledons themselves (LOTT 1970). A general decrease in the dry matter of the cotyledons with germination might be due to the utilization of metabolites. Contrarily, gradual decrease in the dry matter of the cotyledons under moisture stress suggests that water stress inhibited the translocation of hydrolytic products, rather than the inhibition of hydrolysis. With the onset of germination, dry matter of the embryo axis did not decrease, indicating that the embryo axis did not utilize the endogenous substrate of the cotyledons for its growth. Some interesting correlation existed between water content of two seed parts in the control and osmotic stress conditions. For instance, water

content of the cotyledons was high, up to 24, and thereafter it declined. On the contrary, gradual rise in water content was noticed in the embryonic axis. Under osmotic stress, amount of water content was low in both the seed parts. Clearly, water stress affected the process of water absorption of the seeds.

It is apparent from our studies that total soluble proteins content of the cotyledons in the control increased continously up to 72 h of germination, suggesting that the synthesis and/or activation of proteins begins quite early during germination. This may be due to the formation of polysomes from the pre-existing ribosomes and RNA (MARCUS and FEWLEY 1964a). However, the imposed water stress reduced soluble proteins in the cotyledons of seeds. The embryo axis exhibited a comparable trend. It has been previously suggested that decrease in proteins under moisture stress could be due to the effect on the rate of protein synthesis (NIR *et al.* 1970) on its degradation or on both the processes. The data presented here rule out the second possibility since the increase in free pool amino acids was not significantly high in both the seed parts under imposed water stress. On the contrary, a slight decrease in free amino acid level of both the seed parts was noticed. Such a decrease could be attributed to the inhibition of their synthesis at high moisture stress. Furthermore, a change in the proteolytic activity would be apparent, which we failed to observe. HSIAO (1973) has suggested that the inhibition of protein synthesis under low water potential could due to disrupting polysomes. It is quite likely that severe moisture stress caused either the delayed hydrolysis of protein or inhibited the synthesis of new protein during seed germination.

We also noticed accumulation of starch in the cotyledons while it decreased in the embryo axis with the onset of germination in control. When water stress was imposed, a decreasing trend in the cotyledonary starch was observed. However, water stress caused accumulation of starch in the embryo axis. Soluble sugars content was low in the cotyledons of the control, but under water stress no direct correlation was observed. In contrast to this, the embryo axis had high amount of starch but low content of soluble sugars under water stress. Histochemical studies also supported the biochemical observations. KALS (1976) also reported a decrease in the soluble sugars under water stress in *Cicer arietinum*. In *Cucumber* SUBBOTIANA (1962) postulated that decrease in soluble sugars under moisture stress was possibly due to their increased utilization during enhanced respiration rate for high energy output. In the embryo axis increased accumulation of starch may be attributed to its less utilization during its growth. Increased starch accumulation was correlated with low levels of α- and β-amylase in the growing embryo axis.

SHEORAN *et al.* (1979) made similar observation in *Cyamopsis tetragonoloba*. The accumulation of starch was more marked in the hypocotyl than in the radicle under water stress. Our histochemical observations (plate) are in

close agreement with the results obtained by the latter authority and provide a satisfactory explanation for the inhibition of the embryo axis growth. Also, we did not observe direct correlation between the activity of α-amylase and starch degradation. From our studies, it can be inferred that a decrease in water potential affects seed germination substantially, and seedling growth partially, by the retardation of water uptake or altering general metabolism, especially starch breakdown. The latter appears to be a major factor in controlling the embryo growth by proper utilization of sugars.

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FERTILITY AND FRUIT QUALITY OF BESZTERCEI PLUM CLONES

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At three growing sites (Érd, Dömsöd, Magyarnándor) 61 "Besztercei" plum clones were tested for fertility and fruit size over 6 to 9 years. As regards fertility, the clones showed essential differences in all plantations. The two (plus and minus) extremes were represented by the clones 105-58, Slapanicka, 157/1-58 and 3-61, 228-58, C. 93, respectively. The clones also differed considerably in fruit size, both in high- and low-yielding years. The commodity proportion of fruits larger than 30 mm in size was remarkably high at the 3 growing sites in the case of the following types: 80/1-58, 80/2-58, 157/1-58, 54-58, 105-58 and Slapanicka. As a result attained so far in selection mainly for improving the fruit size, the clones 80/1-58 and 54-58 have been given state certification under the names Bt. 1 and Bt. 2, respectively. The other clones listed above may also receive the same recognition, because the greatest problem of the basic variety is a tendency to become small-fruited.

Introduction

The "Besztercei" is the most widespread plum variety in Central and East Europe. In Hungary it represents 70–80% of the total plum-tree stock. Its leading role is due to its large number of favourable properties. The fruit can be mechanically harvested and transported without any considerable damage. The aromatic, tasty fruit can be used in many ways; it is suitable for fresh consumption, cannery and distillery processing, quick freezing, etc.

As a result of centuries of cultivation and its wide distribution, the variety is no longer homogeneous (GROH 1960, TÓTH and SURÁNYI 1980). It is composed of individuals often very different from one another even in major properties (TÓTH 1975). This attracted the serious attention long ago; and, in most countries cultivating this variety, a search for the most valuable specimens has started (BERNDT and DORNER 1948, GROH 1960, HARSÁNYI 1974). In Hungary the Horticultural Research Institute organized national "Besztercei" plum competitions in 1958–1964. The trees from which promising samples were sent to the competition have been propagated by budding; the grafts planted partly in a central variety collection for the purpose of observation, and partly in various regions of the country.

Material and methods

The observations under discussion were made at 3 sites: at Érd, in the central variety collection, and further in commercial plantations at Dömsöd and Magyarnándor. From the centre of Budapest Érd lies 27 km to the south-west, Dömsöd 50 km to the south and Magyarnándor 96 km to the north. Brief information on the soil conditions is given in Table 1. Of the

Table 1

Some average characteristics of soils at the sites of investigation

Characteristics	Dömsöd	Érd	Magyarnándor
pH (aqueous)	7.7	7.0	7.4
Humus %	2.7	2.2	1.2
P_2O_5 mg/100 g soil	26.0	8.0	15.0
K_2O mg/100 g soil	17.0	13.0	12.0

total number of 61 clones included in the trial, 47 were of Hungarian, 11 of Czechoslovakian and 3 of German origin. Of the clones, 53 were tested at one site only, and 8 in two other places. Originally all clones were planted in the central collection; however, owing to viral infections, most of them had to be removed over the course of years. In each place one-year-old grafts with myrobalan seedling stocks were planted. The number of trees planted was 2 at Érd, and 5 at Dömsöd and Magyarnándor each per clone, all placed side by side.

The yield of trees having turned into bearing was recorded every year on the basis of the estimated weight of the ripe fruits collected in crates. Sometimes the weight of fruit collected in crates could not be estimated and in such cases we relied upon the estimated weight of the ripe fruit in the tree before the harvest.

Of the ripe fruit 100 were picked at random from one tree of each clone, and graded by lateral diameter. According to the MSZ (Hungarian Standard) 6391—66 first grade was the fruit the lateral diameter of which was at least 30 mm. On the basis of its percentage we determined the absolute and relative quantity of the first grade fruit for the total yield of the tree (Tables 2 and 3). The figures show the absolute values of annual yield and first grade fruit per tree on the average of the years of investigation. For basis of comparison, the average values of all clones included in one and the same trial were used.

Results

(1) *Fertility*

Érd (Fig. 1). There was a remarkable difference in fruit yield between the clones planted in 1966 (100 and 4%). Clones named Hasító and marked 59-64, respectively were found to be the most productive.

The experimental average of productivity at Érd was the best with the clones planted in 1967. Slapanicka, the clone seen at the head of the list exceeded in productivity even the best clones of the previous year's experimental plantation. Domaci Svestka Muskatova occupies a close second place in productivity. All the 6 examined clones were of Czechoslovakian origin.

Magyarnándor (Fig. 2). The results here were poor compared to those at Érd. In this comparison the two recently state-certified Besztercei clones,

Table 2

Average annual yields of clones, and percentage of first grade fruit
(Érd 1971–1977)

Clone	1966 plantation		
	Total first grade fruit yield		
	kg/tree	kg/tree	%
Hasító	33.7	2.4	7.1
59-64	33.3	2.9	8.7
76/a-64	25.0	13.8	55.2
Elv. 15	24.1	1.0	4.1
64-64	23.9	2.2	9.2
63-64	22.3	3.1	13.9
1-64	21.0	0.3	1.4
Elv. 17	20.0	0.9	4.5
Fey (Hauszwetsche)	18.9	3.8	20.1
67/b-64	15.3	5.7	37.3
Esslingen (Hauszwetsche)	15.1	2.1	13.9
Kruft (Hauszwetsche)	14.9	10.2	68.5
Elv. 1	14.1	1.7	12.1
Elv. 14	12.7	1.9	15.0
67/a-64	10.9	4.2	38.5
Elv. 18	10.0	1.6	16.0
Kishartyán	8.7	0.7	8.0
46-64	7.3	2.7	37.0
76/b-64	6.4	3.5	54.7
38-64	5.0	1.0	20.0
Elv. 4	4.6	0.0	0.0
54-64	4.1	2.2	53.7
47-64	2.6	1.1	42.3
3-61	1.3	0.1	7.7

Clone	1967 plantation		
	Total first grade fruit yield		
	kg/tree	kg/tree	%
Slapanicka (Domaci svestka)	35.0	16.5	47.1
Muskatova (Dom. sv.)	32.6	1.9	5.8
Walterova (Dom. sv.)	27.6	2.6	9.4
Svehlova (Dom. sv.)	26.3	1.3	4.9
Rizkova (Dom. sv.)	18.0	1.4	7.8
Kourimska (Dom. sv.)	10.4	3.0	28.8

Bt. 1 (80/1-58) and Bt. 2 (54-58) are included. It can be seen that they were exceeded in productivity by several clones (157/1-58, 89/b-58, and partly 71-58). The clones greatly differed in productivity at this site also.

Dömsöd (Fig. 3). The best yield data were obtained in this place. The explanation is that, for technical reasons, the observations began only in the 8th year after plantation, and were carried on over 9 years. Some role may

Table 3

Average annual yields of clones, and percentage of first grade fruit

Magyarnándor 1967–1972

Clone	Total first grade fruit yield		
	kg/tree	kg/tree	%
157/1-58	25.2	13.8	54.8
89/b-58	22.3	9.7	43.5
54-58	16.8	10.4	61.9
71-58	15.8	9.5	60.1
80/1-58	14.8	14.7	99.3
104/2-58	14.7	7.4	50.3
C. 161	12.8	9.8	76.6
89/a-58	11.7	7.0	59.8
58-58	10.8	7.8	72.2
166/3-58	9.8	2.3	23.5
C. 130 (Domaci svestka)	6.7	6.5	97.0
80/2-58	6.0	5.4	90.0
18-58	5.7	3.2	56.1
70/2-58	4.8	4.1	85.4
20-58	4.3	3.8	88.4
39/a-58	4.2	1.9	45.2
166/1-58	4.2	3.6	85.7
127/1-58	3.5	2.8	80.0
228-58	3.5	2.4	68.6

Dömsöd 1969–1977

Clone	Total first grade fruit yield		
	kg/tree	kg/tree	%
105-58	45.8	37.7	82.3
109-58	43.4	18.8	43.3
80/2-58	42.4	33.3	78.5
Pukavce (Dom. sv.)	42.1	10.5	24.9
166/2-58	41.6	16.6	39.9
80/1-58	40.4	31.7	78.5
157/1-58	38.9	13.3	34.2
70/2-58	38.6	28.3	73.3
50-58	37.9	23.6	62.3
C. 224 (Dom. sv.)	36.1	6.7	18.6
104/1-58	35.3	19.9	56.4
70/1-58	34.8	25.9	74.4
127/2-58	34.3	23.6	68.8
20-58	33.8	24.6	72.8
18-58	33.3	23.7	71.2
26-58	32.9	23.3	70.8
127/1-58	32.9	20.5	62.3
C. 35 (Dom. sv.)	29.4	11.6	39.5
C. 130 (Dom. sv.)	25.3	17.8	70.4
C. 93 (Dom. sv.)	13.1	8.0	61.1

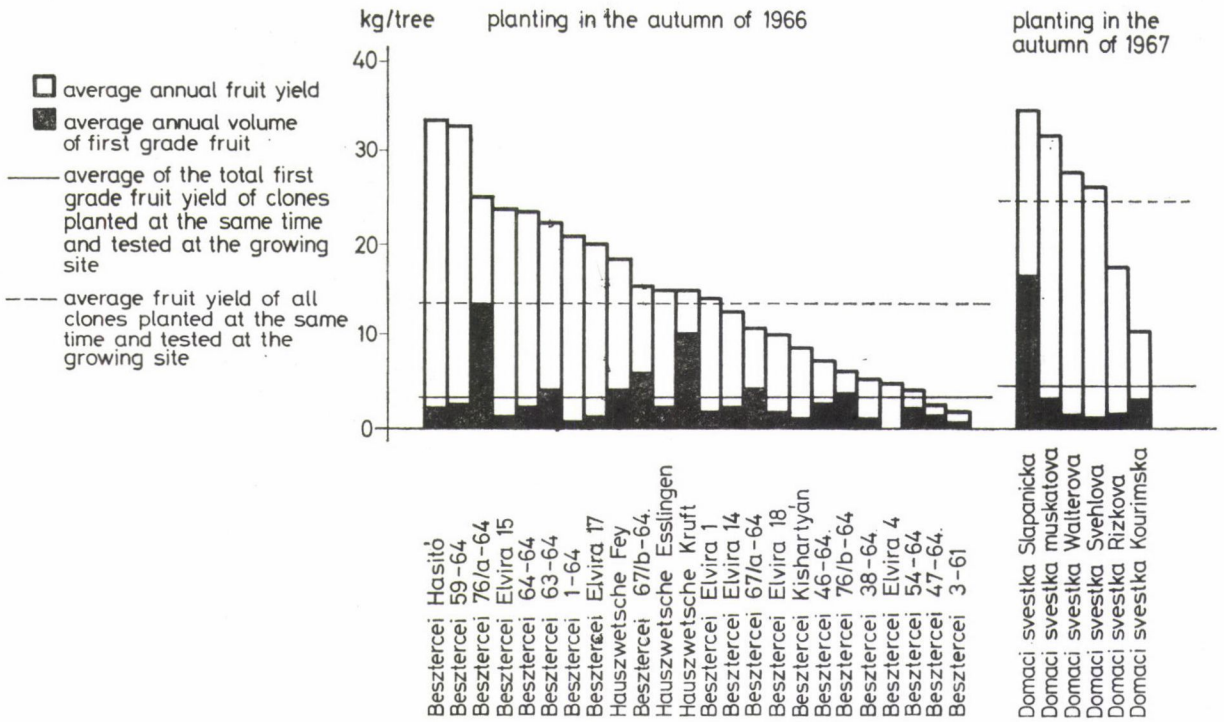

Fig. 1. Fertility and fruit quality of Besztercei plum clones at Érd. The yield data are averages of the years 1971–1977

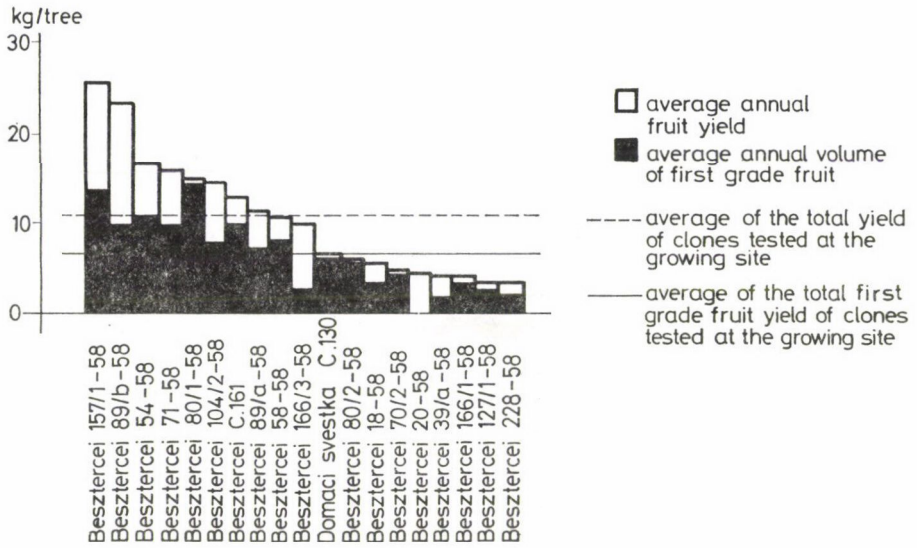

Fig. 2. 1967–1972 average of yield and 1969–1971 averages of fruit size of Besztercei plum clones planted in the autumn of 1962 at Magyarnándor

have as well been played by the better nutrient status of the soil (Table 1). The difference in yield between the clones was, again, considerable. The clone 80/1-58 was included in the trial at this site too, but was placed sixth among a total of 20 clones.

(2) *Fruit size*

Érd. Among the clones planted in 1966, the difference in fruit size was even larger than that shown in yield (100 and 1%). The clone 76/a-64 producing the best quality fruit (almost 14 kg first grade fruit) was placed third on the basis of productivity. The quality of fruit is considered good in the German clone Kruft, but its yield was medium. Kruft was also the best clone as regards the percentage of the first grade fruit — more than two-third of the total yield — though more than half of the yield of 76/a-64 was also first grade.

In the Érd trial the performance of clones, both from quantitative and qualitative points of view, was best in those planted in 1967. Nevertheless, the clones showed very great differences in that year too (100 and 10%). Slapanicka exceeded considerably the other clones as regards both the absolute and relative amount of first grade fruit. As seen above, this clone was the best for its volume of fruit yield as well.

Magyarnándor. In the average quality of fruit — even if not in productivity — the Magyarnándor clones were undoubtedly better than the Érd clones. The diversity of clones was also considerable at this site (100 and 24%).

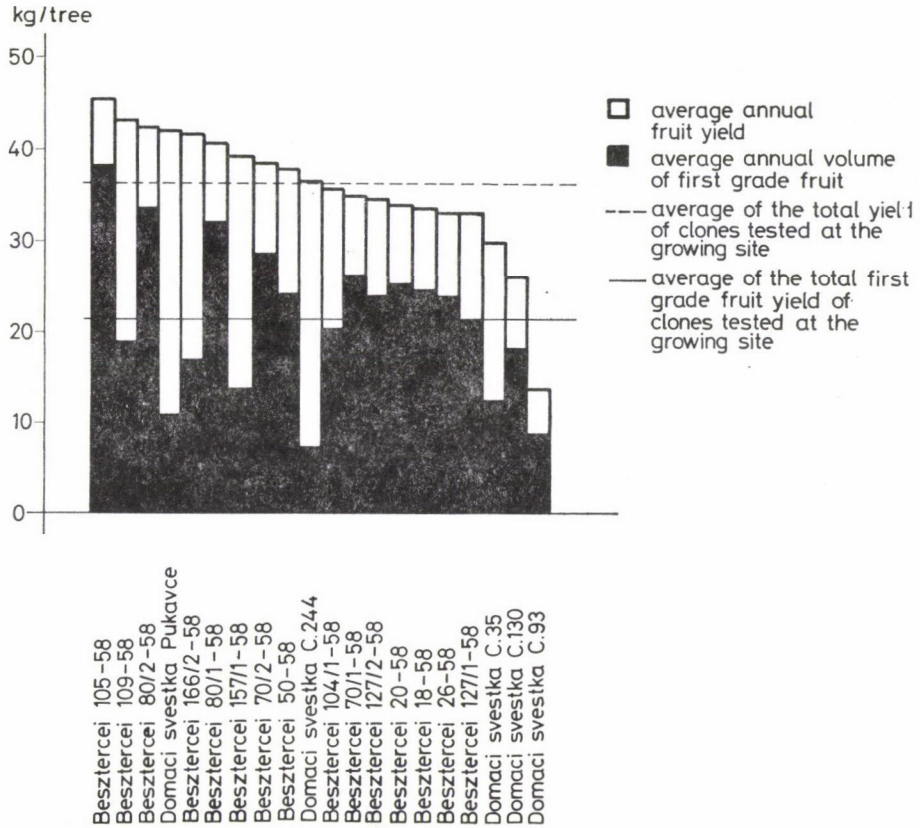

Fig. 3. Fertility and fruit quality of Besztercei plum clones planted in the autumn of 1961 at Dömsöd, on the average of 1969–1977

The largest amount of first grade fruit was produced by the clones 80/1-58, 157/1-58 and 54-58. The relative quantity of first grade fruit was outstandingly good in clone 80/1-58, where nearly the total fruit yield was first grade. Similarly high were the proportions of first grade fruit in clones C. 130, 80/2-58 and 20-58, but the yields were regrettably poor. Clones 157/1-58 and 54-58 were among the highest yielding ones, while 80/1-58 showed only medium productivity.

Dömsöd. For the previously mentioned reasons, not only the yield but also the quality of fruit was the highest at Dömsöd, with fairly great variations from clone to clone (100 and 23%). Clones excelling in the quantity of first grade fruit were: 105-58, 80/2-58 and 80/1-58. The same clones proved best as regards the proportion of first grade fruit to the total yield; more than three-quarters of their yields were first grade. The three clones were at the same time among the most productive ones.

Discussion

Although it is a well-known fact that the quantity and size of the fruit are in inverse relation, we must not leave the properties of variety and clone, respectively, out of consideration. In our selection, we try to find "Besztercei" clones that produce sufficiently large fruits beside a satisfactory yield.

The results of our investigations suggest that this aim is not unattainable. One of the most promising clones is 105-58, which is the best among those tested at Dömsöd, from both quantitative and qualitative standpoints. At Érd two clones are worth further study: Slapanicka and 76/a-64. Observations of these three clones were made only in one place. The somewhat lower productivity clone 80/1-58 produced good quality fruit at both sites, as did 80/2-58, a still lower yielding clone. The clones 157/1-58, Hasító, 59-64 and 109-58, while sufficiently fertile, had no satisfactory fruit size. In several clones, on the other hand, the quality of fruit was excellent while the yield insufficient. These were C. 130, 70/2-58, 166/1-58, 20-58, 18-58 and others. Kruft, a clone with a similarly good fruit size, differed in colour and taste from the "Besztercei" plum, most popular in Hungary.

Let us see whether the behaviour of clones studied at two different sites was the same at both. Productivity was equally good in 157/1-58 and 80/1-58, and poor in 127/1-58 and C. 130. As for fruit quality the clones 18-58, 20-58, 70/2-58, 80/1-58, 80/2-58 and 127/1-58 were found to be equally good. The other clones did not yield the same results at the different sites of observation, either in productivity or in fruit quality. This was partly due to the fact that the same clones were not compared at the different sites of investigation.

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QUANTITATIVE CHANGES IN THE REDUCING SUGAR CONTENTS OF FOUR GRASSES IN THE VEGETATIVE AND REPRODUCTIVE PHASES OF DEVELOPMENT

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The registered grass varieties *Bromus inermis* Leyss. cv. K-51, *Dactylis glomerata* L. cv. K-54, *Festuca arundinacea* Schreb. cv. K-50 and *Phalaroides arundinacea* (L.) Rausch. cv. K-52 were examined for water soluble carbohydrate content in the vegetative organs and inflorescence, on the basis of changes in the quantity of reducing sugars expressed in terms of glucose equivalent from shooting to ripening (harvesting of grain crop) in April–June 1981. The carbohydrate reserves in the vegetative organs were low at the time of shooting, increased slightly with the development of the assimilating surface, then decreased again during the vigorous development of the inflorescence and at flowering. In the meantime, the reducing carbohydrate content of the panicle became high, only decreasing at the time of grain formation, while a slow, gradual rise took place in the vegetative organs. High summer temperatures and a shortage of precipitation were observed to have a modifying effect on the quantity of carbohydrates. The reducing carbohydrate content was the lowest in the underground vegetative organs, medium in the stalk, leaf-sheaths and leaf-blades, and the highest in the reproductive organs. The order of the analysed plants according to their average reducing carbohydrate contents is as follows: *Bromus inermis*, *Festuca arundinacea*, *Dactylis glomerata*, *Phalaroides arundinacea*.

Introduction

All the organic compounds found in plants contain energy, and under certain conditions most of them can be metabolized for growth or for survival during unfavourable periods. In critical transition periods during ontogeny (e.g. rapid growth of vegetative organs, regeneration of assimilating surfaces after defoliation) the performance of the assimilation system cannot cover the requirements of the growth of plant organs, and the utilization of nutrient reserves accumulated in the storing ground tissue systems becomes necessary. On the other hand, if, during the process of photosynthesis, compounds with high energy contents are formed in a measure exceeding the demand for growth and development, the accumulation of nutrient reserves becomes possible.

The most important reserve nutrients are the carbohydrates, though water-soluble protein-nitrogen is also an important factor in initiating early spring growth. The group of utilizable, non-structural carbohydrates is composed of reducing and non-reducing sugars, starch, dextrine and fructosanes (SINGH *et al.* 1980). In the current experiments it was aimed to follow changes

in the carbohydrate reserves of *Bromus inermis*, *Dactylis glomerata*, *Festuca arundinacea* and *Phalaroides arundinacea* by determining the quantities of reducing sugars between shooting and ripening.

The grasses studied *(Poaceae)*, being of circumpolar and Eurasian-Mediterranean habitat, form mainly saccharose and fructosane as nutrient reserves in their vegetative organs, as is characteristic of grasses found in the northern hemisphere. It was on this basis that DECUGNAC (cit. OKAJIMA and SMITH 1964) distinguished the Northern-adapted grasses from the tropical grasses, which store mainly saccharose and starch in their vegetative organs. More than 70% of the carbohydrate reserves in the tissues of stem bases and rhizomes consists of fructosane in *Dactylis glomerata* and *Phalaroides arundinacea*, and of saccharose in *Bromus inermis*. In the stem bases of *Festuca arundinacea*, fructosane and saccharose are stored in equally large quantities. The rest of the utilizable water soluble carbohydrates consists almost exclusively of glucose, though phosphorylated sugars also occur (OKAJIMA and SMITH 1964, SMITH and GROTELUESCHEN 1966, MCWHORTER 1974).

The quantity of carbohydrate reserves in the storage tissues constantly changes under the influence of individual and environmental factors. The characteristic features of quantitative changes in the carbohydrates were summarized by SINGH *et al.* (1980). The morning minimum is followed by a peak in the afternoon, while during the evening and night *Bromus inermis*, for example uses up one-third of its daily production of non-structural carbohydrates. The level of carbohydrate reserves undergoes seasonal changes too, and in the storage organs of perennial grasses shows a U- or V-shaped annual course. In the winter period of dormancy the reserves are substantially reduced. In the course of spring growth the elongation of the internodes of the stalk and the growth of new roots precede the full development of the assimilating surface; therefore, the amount of carbohydrates shows a rapid further decrease, then having reached the bottom of the V-shaped annual course, begins to accumulate at a fast rate. In the case of a U-shaped annual course, on the other hand, the carbohydrates remain at a low level until the rate of plant growth slows down; then the accumulation of carbohydrates becomes more and more intensive in both types of course, up to the time when winter sets in.

At the time of rapid spring growth, the use of carbohydrate reserves in *Dactylis glomerata* was slowed by low temperature and increased by near-optimum daily temperatures (REYNOLDS 1969). According to the observations of BROWN and BLASER (1965–1970) *Dactylis glomerata* and *Festuca arundinacea* formed reserve carbohydrates in spite of a small leaf area when the growth rate was decreased due to low temperature.

Water deficiency generally increase the quantity of reserve carbohydrates. When water deficiency checks the growth of *Dactylis glomerata* the carbohydrate content of the stalk and foliage increases, and the protein and

amino acid contents in the storage organs decreases (BROWN and BLASER 1965, 1970).

A rich nutrient content in the soil, which promotes growth, often reduces the carbohydrate reserves. In the case of *Dactylis glomerata*, nitrogen fertilization decreases the reserves; in fact, if a high dose of nitrogen fertilizer is followed by dry weather, the reserves fall to such a critical level as to cause damage to the plants. On the other hand, on soils rich in nutrients the carbohydrate reserves of the plants were found to increase over a long period. It is possible that in the early phase of growth nitrogen fertilization decreases the level of carbohydrates, and later, through the increased amount of photosynthetizing tissue formed under its influence, increases it (BROWN and BLASER 1970, SINGH *et al.* 1980).

The tillering of *Phalaroides arundinacea* and *Bromus inermis* shows a close correlation with the quantity of reserve carbohydrates (SINGH *et al.* 1980), as does the tillering of *Dactylis glomerata* and *Festuca arundinacea*, though in the latter case the modifying effect of day length and the intensity of radiation was demonstrated (AUDA *et al.* 1966).

Materials and methods

The experiments were carried out in stands of elite reproduction grade of the state registered varieties* *Bromus inermis* Leyss. cv. K-51, *Dactylis glomerata* L. cv. K-54, *Festuca arundinacea* Schreb. cv. K-50 and *Phalaroides arundinacea* (L.) Rausch** cv. K-52, in the

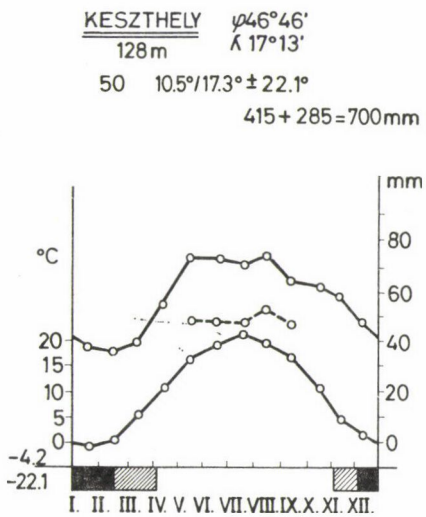

Fig. 1. Climate diagram for Keszthely

* For a description of the varieties see: List of Plant Varieties State Registered by the National Institute for Agricultural Variety Testing.

** *Typhoides arundinacea* (L.) Mönch. See: I. SZABÓ, 1980, Bot. Közlem., **67**, 49–57.

Table 1

Agrotechnical data

Variety	Date of sowing	Fertilization kg/ha active ingredient		Weed control l/ha active ingredient	Date of cutting
Bromus inermis K-51	March 1975	Oct. 1980	N 30 P 70 K 70		
		March 1981	N 80	April 1981 Dikotex 40 EC 3.5 June 1981 Glialka spot spraying	9 July 1981
Dactylis glomerata K-54	March 1975	Oct. 1980	N 30 P 70 K 70		
		March 1981	N 80	April 1981 Dikotex 40 EC 3.5	30 June 1981
Festuca arundinacea K-50	Sept. 1975	Oct. 1980	N 30 P 70 K 70		
		March 1981	N 80	April 1981 Dikotex 40 EC 3.5	30 June 1981
Phalaroides arundinacea K-52	Sept. 1975	Oct. 1980	N 30 P 70 K 70		
		March 1981	N 80	April 1981 Dikotex 40 EC 3.5 May 1981 row cultivation	21 June 1981

experimental fields of the Agronomical Faculty of the Keszthely University of Agricultural Sciences. The soils of the fields were: medium heavy loam, brown forest soil with clay infiltrations and with sandstone rubble in places. The experimental fields were at a distance of 0.3–1.5 km from an agrometeorological station. The climate diagram for Keszthely is shown in Fig. 1, while the precipitation and temperature conditions during the experimental period can be seen in Fig. 2a. The agrotechnical data are summarized in Table 1.

The samples were taken parallel with the growth analyses, in April–June 1981, usually at 10 a.m. After separating the material into aboveground and belowground parts and into dead and living portions the soil particles were removed and the plant samples were dried at 70 °C to constant weight. The samples were then further classified into

(a) panicle
(b) leaf blade
(c) stem and leaf sheath
(d) stem base, rhizome and root system in the 0–10 cm soil
(e) root system in the 10–40 cm soil layer

In the experiments, the filtrate of an aqueous solution of the fraction of the ground plant parts which could pass through a 0.4 mm screen was analysed using Hagedorn—Jensen's iodometric titration modified by the protein precipitation method of BRUGOVITZKY (1956), (BÁLINT and HEGEDÜS 1955, MÁZOR 1963) in three replications. The quantity of reducing sugars was expressed as glucose equivalent per 100 g dry matter, and taken as an indicator of the amount of readily available water-soluble reserve carbohydrates (hereinafter abbreviated to carbohydrates).

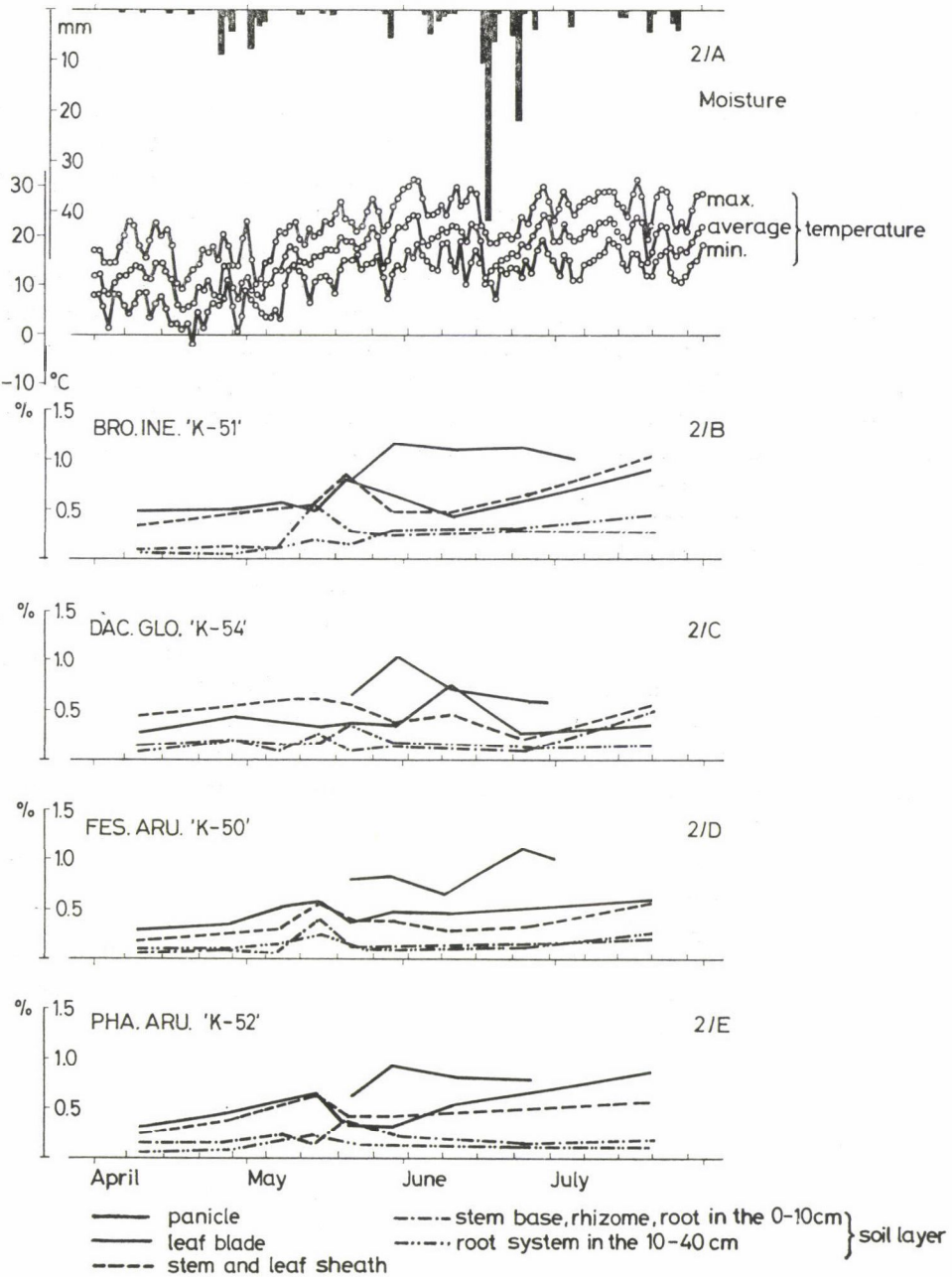

Fig. 2a. Precipitation and temperature data for the experimental period. *2b–e.* Changes in the reducing sugar contents of the examined plants during the experimental period

Results

The carbohydrate content in the root system and rhizomes of *Bromus inermis* was lower than in the aboveground parts, changing, especially in the 10–40 cm soil layer, in a similar manner to the carbohydrate content of aboveground parts, but with less fluctuations. Here, as in all the species examined, the carbohydrate content was the lowes in the belowground parts, higher in the stem, leaf-sheaths and leaf-blades, and highest in the panicle. At the beginning of flowering the carbohydrate content of the panicle rapidly increased, then, after remaining at a high level over a fairly long period, decreased at the time of maturing. Parallel with the increase in the carbohydrate content of the inflorescence, the quantity of carbohydrates in the foliage and stem fell almost to the level found at the time of shooting and leaf formation, then gradually rose compared to the carbohydrate content of the root system (Fig. 2ab, Table 2).

Dactylis glomerata showed a somewhat different behaviour. The carbohydrate content of the belowground plant parts was more or less the same in the two soil layers examined, but the changes followed those in the aboveground parts more closely in the 0–10 cm than in the 10–40 cm layer, where the carbohydrate content of the root system changed only after some delay and within narrower limits. The changes in the carbohydrate content of the panicle and the vegetative organs mostly showed opposing tendencies. The carbohydrate contents of the stem and leaf-sheaths decreased from flowering until shortly before grain ripening. A similar trend for changes in the carbohydrate content of the leaf-blades was broken by an outstandingly high value at flowering, at a time when the carbohydrate content of the stem and leaf-sheath also showed a sharp change. This may have been caused by the long period of high temperature without rain. The accumulation of sugars is an important factor in the drought tolerance of plants. After rainfall between 16–19 June, and from 22–24 June the quantity of carbohydrates almost reached the previous average level. The carbohydrate content of the panicle gradually decreased after flowering (Fig. 2c, Table 2).

The carbohydrate content of the root system of *Festuca arundinacea* decreased at a fast rate after the emergence of the panicle, becoming less in the 0–10 cm soil layer than in the 10–40 cm layer; then, having stagnated for a considerable time, it increased slowly in both layers. After an initial decrease, the carbohydrate content of the leaves did not follow the trend shown by the other vegetative organs, but remained at a higher level, then very slowly increased. The carbohydrate content of the panicle began to rise later in comparison to the other plant parts (Fig. 2d, Table 2).

The changes in the carbohydrate contents of *Phalaroides arundinacea* organs examined in the two soil layers were different. In the stem, leaf-sheaths

Table 2

Reducing sugar contents of grasses (g/100 g dry matter)

Date	10–40 cm soil layer	0–10 cm soil layer	Stem + leaf-sheath	Leaf-blade	Panicle	10–40 cm soil layer	0–40 cm soil layer	Stem + leaf-sheath	Leaf-blade	Panicle
	Bromus inermis					*Dactylis glomerata*				
10 April	0.12	0.12	0.34	0.45		0.1	0.12	0.47	0.3	
28 April	0.12	0.13	0.45	0.5		0.2	0.19	0.55	0.45	
8 May	0.15	0.15	0.49	0.57		0.13	0.11	0.6		
15 May	0.2	0.53	0.55	0.48		0.18	0.28	0.61	0.56	
22 May	0.15	0.28	0.86	0.84	0.74	0.35	0.1	0.52	0.38	0.68
30 May	0.28	0.24	0.48	0.7	1.13	0.17	0.15	0.36	0.33	1.06
11 June			0.47	0.48	1.09			0.48	0.77	0.74
25 June	0.3	0.3	0.64	0.56	1.2	0.12	0.1	0.21	0.27	0.56
21 July	0.44	0.28	1.03	0.9		0.14	0.24	0.58	0.35	
	Festuca arundinacea					*Phalaroides arundinacea*				
10 April	0.2	0.1	0.22	0.34		0.06	0.2	0.28	0.31	
28 April	0.18	0.12	0.27	0.39		0.08	0.16	0.4	0.46	
8 May	0.15	0.1	0.3				0.24			
15 May	0.24	0.4	0.57	0.55		0.23	0.14	0.63	0.64	
22 May	0.15	0.13	0.39	0.37	0.8	0.14	0.38	0.43	0.34	0.59
30 May	0.12	0.12	0.34	0.49	0.84	0.12	0.24	0.42	0.34	0.51
11 June			0.28	0.46	0.65			0.44	0.53	0.82
25 June	0.12	0.14	0.36	0.5	1.1	0.1	0.13			0.79
21 July	0.23	0.2	0.57	0.57	0.9	0.1	0.13	0.56	0.84	

and leaf-blades the amount of carbohydrates first increased, then decreased after the emergence of the panicle, finally rising again more steeply and from a lower level in the stem and leaf-sheaths than in the leaf-blades. The carbohydrate content of the panicle showed a sudden increase at the time of flowering, while towards grain ripening it slowly decreased (Fig. 2e, Table 2).

On the basis of the quantity of reducing sugars expressed as glucose equivalent per 100 g dry matter, the plants examined can be placed in the following order:

	Reducing sugar content g/100 g	
	average	maximum
(1) *Bromus inermis*	0.66	1.2
(2) *Festuca arundinacea*	0.5	1.1
(3) *Dactylis glomerata*	0.45	1.06
(4) *Phalaroides arundinacea*	0.4	0.9

A correct evaluation of the results will be promoted by the following comments. The reduction in the carbohydrate content of the panicle by the time of seed ripening is only apparent, and can be explained by the metabolism of the reducing sugars studied, which are transformed into fructosane

and starch polymers. In the experiments the amount of reducing sugars actually present was measured, not the quantity of available carbohydrates transformed into reducing sugars in the course of the analysis, which is why the values given are lower than those obtained by the authors cited in the literature. According to the works referred to in the present paper, the quantity of reducing sugars follows the changes in the fructosane and starch contents. The mean values are not weighted according to the share of each organ in the phytomass production.

On the basis of the investigations, the following additions can be made to current knowledge on the quantitative changes in carbohydrates. According to the observations of some authors (cit. SINGH *et al.* 1980), although carbohydrates are contained at lower average concentrations in the roots system than in other organs, owing to the larger volume of the root system the total amount stored in the roots exceeds the carbohydrate contents of other organs. In the present experiments, particularly in the case of *Dactylis glomerata* and *Festuca arundinacea*, this statement was true only for certain phases in the life cycle of the plants, because after a winter favourable for the plants the volume of the aboveground parts soon exceeded the quantity of roots. The changes in the carbohydrate content of the root system (as the place of storage and utilization farthest from the site of photosynthesis) were of smaller amplitude and had a lower growth rate than in other organs, because of the characteristic rate and extent of carbohydrate translocation.

According to SINGH *et al.* (1980) the reproductive organs are often formed through the utilization of carbohydrate reserves rather than through the current photosynthesis. If, however, the increase in the carbohydrate content of the panicle at the time of flowering and fruit formation proceeds at a faster rate than the decrease in the vegetative organs, as seen in the varieties included in the experiment, the assimilating capacity of the inflorescence must be assumed to have a relatively autonomous role.

The common Hungarian parlance does not distinguish the expressions of the richness of several materials in certain ingredients frequently. The undistinguished shade of meaning of content and concentration is wrong usage and the reader is right to explain the concentration of reducing sugars consequently.

Acknowledgements

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EFFECT OF ENVIRONMENTAL FACTORS ON GROWTH, DEVELOPMENT AND ALKALOID PRODUCTION OF POPPY (*PAPAVER SOMNIFERUM* L.) III. NUTRITION AND LIGHT

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Growth, development and alkaloid formation of poppy were studied at different levels of nutrition under phytotron conditions. High-dose nutrition (18.0 mg N, 3.7 mg P, 18.0 mg K week^{-1} · Plant^{-1}) had a toxic effect on dry-matter production under insufficient light conditions, but became effective above 16 klx illumination. Average capsule mass (0.45 g) increased under light up to 0.70 g, while at the same time seed production from 0.58 g to 0.63 g. The maximum of morphinane, benzyl- and phthalideisoquinoline alkaloid accumulation (12.15 mg/g) has been obtained at high nutrition and illumination level. However, a rather characteristic influence of nutrition at 16 klx illumination has been noticed. Under extremely low (8 klx) and high (32 klx) illumination, the effect of nutrition seemed to be of secondary importance.

Introduction

The influence of day-length and light intensity as well as of various temperature programs on growth, development, dry-matter and alkaloid production of poppy was studied by us (BERNÁTH and TÉTÉNYI 1979, 1981). We became particularly interested in establishing other factors which may effect alkaloid formation. The role of nutritive factors especially interested us, because literature data contained many contradictions on this subject. Thus nitrogen supply has been reported to be favourable around the maximum (NOWACKI *et al.* 1976), whereas others emphasise the advantages of low nutrient doses for alkaloid production (GEORGETA and OLTEA 1977). The relationship between nutrients and morphine content is characterized as an optimal effect (SCHRÖDER 1966). Dry-matter production can be modified by variation of nutrient supply rather than the morphine content (FÖLDESI 1978). To eliminate contradictions it became necessary to carry out experiments under controlled conditions. The application of different light conditions seemed to be advisable on the basis of our previous results.

Material and methods

The Hungarian standard spring poppy cultivar "Kék Duna" (of morphine character) was chosen for our investigations. This provided the opportunity to compare results with those of previous experiments (BERNÁTH and TÉTÉNYI 1979). To ensure genetic homogeneity, inbred I_3 seeds were sown.

Investigation have been carried out in phytotron chambers of E-15 and modified G-30-type made in Canada (Conviron). Plants were grown in a mixture of washed sand and perlite (1 : 1 volume ratio). Water capacity of the growing medium was maintained at 70% after the germination period. Water supply was provided by demineralizated water every 2 to 3 days. The relative humidity at germination from 80% reduced to 70% during growing

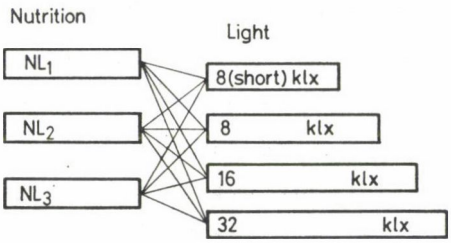

Fig. 1. Combinations of treatments applied in the course of experiments

period. The air temperature programme conformed to our earlier experiments (BERNÁTH and TÉTÉNYI 1981), using "warm condition" programme as follows:

1st– 5th week	12.5/7.5 °C (day-night)
6st–11th week	18.5/11.5 °C
12th–17th week	22.0/13.0 °C
18th–	26.0/16.0 °C

Variation are shown in Fig. 1. General Electric F72T12(VW)VHO fluorescent tubes were used, and supplement given by electric bulbs as light sources. The illumination period employed was 10 h in the short-day, and 14 h in the long-day cycle.

Plants have been grown in modified Knop solution. Quantities of macro-nutrients are given in Table 1, calculated per plant and per week. Nitrogen was employed in form of KNO_3 and $Ca(NO_3)_2$, phosphorus as NaH_2PO_4, magnesium and sulphur as $MgSo_4$. Micro-elements were supplemented by using Hoagland nutritive solution.

Continuous morpho-phenological investigation of 25 to 50 individuals was performed in the case of all treatments (BERNÁTH and TÉTÉNYI 1979, 1981). Production of organs was measured after ripening of capsules. Both dry matter production and the accumulation of morphinane, phthalide-, and benzyl-isoquinoline alkaloids have been determined. The alkaloid analysis were made by thin-layer chromatographic method (DÁNOS 1968). Quantitative values were investigated by the Hewlett—Packard HPLC equipment.

Table 1

Quantities of macro-nutrients used in pot experiment

	Nutrition level* (mg · week^{-1} · plant^{-1})		
	NL_1	NL_2	NL_3
N	6.00	12.00	18.00
P	1.23	2.46	3.69
K	6.30	12.60	18.90
Ca	5.95	11.90	17.85
Mg	1.08	2.17	3.25
S	1.45	2.90	4.35

* Amounts have been doubled from the end of rosette stage and trebled after butonisation (quantity was calculated on the basis of pre-experiments).

Results

Changes of development and dry-matter production

Development was delayed at relative nutrient abundance (NL_3) for about 5 to 8 days. Changes in dry-matter production calculated to one poppy capsule are shown in Fig. 2. Toxic high limiting value was represented by

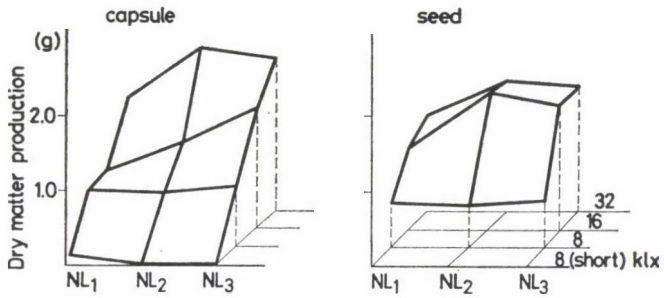

Fig. 2. Effect of nutrition and light on dry matter production of poppy-capsule

nutrition abundance (NL_2 and NL_3) if low illumination intensity and short-day conditions were applied. However, optimum increase was achieved at 16 to 32 klx intensities, using the same nutrient supply. So the effect of nutrients on dry matter production seems to be a light-dependent phenomenon.

Quantitative and qualitative changes of alkaloid formation

Characteristics of the accumulated three main alkaloid groups in capsules are shown in Fig. 3. At low light intensity (8 klx) and short-day conditions, as well as at high intensity (32 klx), nutrition had only a slight influence. On the other hand, nutrition became an important regulating factor at 16 klx illumination. Abundance or insufficiency in comparison to the medium nutrient

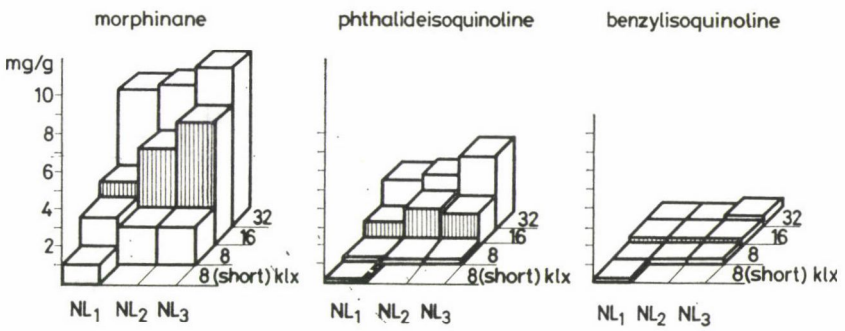

Fig. 3. Effect of nutrient-light interaction on formation of main alkaloid groups

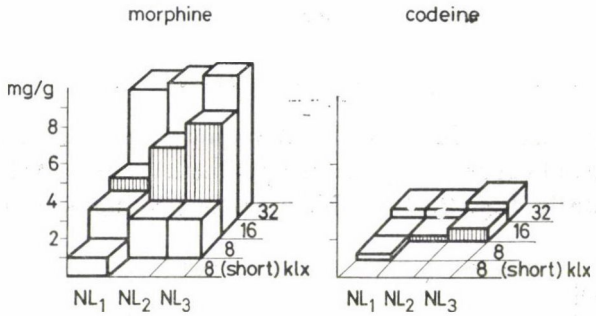

Fig. 4. Nutrient-light interaction on accumulation of morphinane group (morphine, codeine)

level (NL_2) modificated values from 14 to 35%. Thus a strong light nutrient interaction has been proved in formation. Analogous changes could be observed in the morphinane group (Fig. 4).

Total alkaloid production of individuals is demonstrated in Table 2. As the mutual result of dry-matter formation and alkaloid accumulation at low nutrition level, 5.22 mg morphinane, phthalide-, and benzylisoquinoline

Table 2

Total alkaloid production of individual plants affected by nutrition-light interaction (mg/plant)

Nutrition level	Light conditions klx	Alkaloid groups			Total production, mg/plant
		morphinane, mg/plant	isoquinoline, mg/plant		
			phthalide-	benzyl-	
NL_1	32	11.23	4.43	0.16	15.82
	16	2.57	0.92	0.10	3.59
	8	1.31	0.09	0.01	1.41
	8 (short)	0.03	0.00	0.00	0.03
	average	3.79	1.36	0.07	5.22
NL_2	32	15.98	6.34	0.33	22.65
	16	5.61	2.12	0.09	7.82
	8	0.88	0.04	0.01	0.93
	8 (short)	0.00	0.00	0.00	0.00
	average	5.61	2.13	0.11	7.85
NL_3	32	14.69	5.97	0.24	20.90
	16	10.82	2.37	0.13	13.32
	8	1.74	0.08	0.02	1.84
	8 (short)	0.00	0.00	0.00	0.00
	average	6.81	2.11	0.10	9.02
$SD_{5\%}$	nutrition	1.53	0.58	—	1.98

alkaloids were produced by one plant. This amount increased up to 7.85 mg at medium (NL_2), while up to 9.02 mg at high nutrition supply (NL_3). On the basis of our results the morphinane groups seems to be the most sensitive.

Discussion

Using field condition systems, contradictory results have been published on poppy nutrition. The uncertainity was particularly pronounced in regards to the influence on alkaloid formation: negative, positive and weak relationships have been described equally. According to our present results, the effect of nutrient supply can be explained by its interaction with other factors. Under the modifying effect of light described earlier (BERNÁTH and TÉTÉNYI 1979) the same nutrient level may result in both sufficient and toxic effects. Thus the optimum concept of SCHRÖDER (1966) has been justified from another standpoint. The effect of nutrition could be analysed about the optimum illumination (16 klx). The role of nutrition becomes secondary (even enters into toxic intervals) at low and high light intensity. As a result of different nutrition levels, some quantitative and qualitative modifications could be established in alkaloid formation. The magnitude of changes was also limited by light intensity. The increase of nutrient supply may stimulate the alkaloid formation process and the accumulation of the total alkaloid mass of individual plants. The yield produced by one plant is regulated by the modification of alkaloid accumulation and dry-matter production equally.

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A STUDY ON THE INFLUENCE OF CYCOCEL AND ALAR 85 ON GROWTH, FLOWERING AND ACTIVE INGREDIENTS OF *CALENDULA OFFICINALIS* L.

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Calendula officinalis L. attains its therapeutic activity due to its content of sterols and triterpenes. Oleanolic acid is found in the flowers, as well as in all the plant parts. ABOU-ZEID and ABOU-DAHAB (1972) found that the oleanolic acid content increased in calendula flowers after treatment with 5000 ppm of B-9. ABDEL AZIZ (1971) reported that CCC treatments resulted in greater size and heavier weight of chrysanthemum flowers. Meanwhile, SCOTT (1971) demonstrated that it had no adverse effect on the flower size of geraniums. SHANUMGAM and MATHUSWAMY (1974) indicated that CCC reduced the flower number of treated chrysanthemum. By contrast, other investigators reported an increase in flower number in Cycocel-treated plants (CATHY 1964, MCDOWELL and LARSON 1966, JOINEN and SHEEHAN 1969, HALEVY—SHILO 1970, ABDEL AZIZ 1971, JANSEN 1973, FAWZI 1974, STAHN 1975). ABDEL AZIZ (1971) demonstrated that treating *Chrysanthemum* with B-9 resulted in a significant increase in flower weight. JAFFE and ISENBERG (1965), working on petunia, found that the number of flowers produced was not affected by B-9 application. On the other hand, treating several plants with B-9 promoted the initiation of floral buds and increased the flower number (BATJER *et al.* 1964, CATHY 1964, MCDOWELL and LARSON 1966, JASA *et al.* 1971).

Material and methods

This work was done at the experimental farm of El-Minia University during two seasons (1974/75 and 1975/76). The seeds of *Calendula officinalis* L. were sown in 8 cm clay pots on 7th October in both years. 40 days after sowing, the seedlings were transplanted into plots of 1.5 m². Each plot contained 9 evenly spaced plants.

The growth retardants Cycocel (2-chloroethyl-trimethyl ammonium chloride) and Alar 85 (succinamic acid 2,2-dimethyl hydrazide) were applied as foliage spray in 4 concentrations each (250, 500, 1000 and 2000 ppm). 1 ml/l of Misrol, as a wetting agent, was added to every solution. The control plants were sprayed with 1 ml/l Misrol added to distilled water. The plants were sprayed three times at two-week intervals, beginning on December 1st. The experimental design was complete randomized blocks, and each treatment was replicated three times.

Flowering began by the last week of January and ended by the last week of June. Flowers were collected twice weekly. Data were recorded on flower number and dry weight for each plot. The average weight of a single flower was calculated on a dry weight basis.

Estimations of the oleanolic acid and the identified phytosterols in the flowers were carried out monthly from January to June as follows:

1 g dried powdered flowers was macerated with petroleum ether (40–60 °C). The petroleum ether was left to evaporate and the residue was chromatographed on thin layer plates using silica gel G as adsorbent. The developing solvent system was 86 : 14 (v/v) benzene + ethyl acetate. The spots corresponding to the oleanolic acid, β-sitosterol and stigmasterol were identified using authentic samples of these substances. The spots were detected by 20% H_2SO_4 in absolute ethyl alcohol. The density of the colour of each spot was measured using a densitometer (Joian semi-automatic recording photometer) at a wavelength of 445 nm. The concentrations of these components were plotted from standard curves of the three authentic samples obtained from the Pharmaceutical Science Laboratory and the Natural Product Laboratory, National Research Centre, Cairo. The yield of oleanolic acid and phytosterols (g/plot) was calculated. Statistical analyses were carried out according to SNEDECOR (1966).

Results and discussion

Effect of Cycocel and Alar on vegetative growth: The data presented in Table 1 show that treatment with any of the growth retardants used raised the average vegetative growth dry weight of the plants. The increase was significant only when 1000 and 2000 ppm of Cycocel and 500 and 1000 ppm of Alar were sprayed. The increase through the use of Cycocel is in agreement with the findings of ROFAEEL (1976).

Effect of Cycocel and Alar on flowering: When sprayed during the first season at any of the concentrations used, Cycocel significantly raised the average flower dry weight per plot (Table 1). An exception occurred when 250 ppm spray was used. During the second season, only 1000 ppm resulted in a significant increase.

Spraying with Cycocel increased the average flower number (Table 1). The increase during the two seasons was significant when 500 and 1000 ppm were used. Similar results were reported by JOINER and SHEEHAN (1969) and JASA *et al.* (1971). JANSEN (1973) reported

Table 1

Effect of Cycocel and Alar on vegetative growth dry weight (g/plant), *flower dry weight* (g/plot), *flower number* (flowers/plot) *and single flower dry weight* (g/flower) *at the end of the two experimental seasons 1974/75 and 1975/76*

	First season				Second season			
	Veg. growth dry weight, g	Flower dry weight, g	Flower number	Single flower dry weight, g	Veg. growth dry weight, g	Flower dry weight, g	Flower number	Single flower dry weight, g
Control	167.00	1020.32	4813.3	0.15	182.66	1118.08	4715.6	0.154
Cycocel								
250 ppm	174.00	1107.04	5093.6	0.16	179.33	1170.78	5063.3	0.162
500 ppm	193.66	1130.48	5301.0	0.15	207.66	1155.01	5147.3	0.160
1000 ppm	208.70	1156.08	5356.0	0.16	206.33	1254.35	5187.3	0.158
2000 ppm	228.33	1114.00	5190.3	0.16	223.00	1207.56	4739.3	0.159
Alar								
250 ppm	173.66	1219.92	5509.6	0.17	190.00	1255.30	5263.3	0.164
500 ppm	202.66	1274.00	5689.3	0.17	210.00	1264.51	5429.3	0.166
1000 ppm	223.00	1296.56	5715.0	0.17	228.00	1324.90	5615.7	0.162
2000 ppm	228.00	1089.68	5117.6	0.16	235.33	1195.80	5120.3	0.160
$LSD_{5\%}$	27.52	91.36	389.12	n.s.	25.74	99.62	394.03	n.s.

Table 2

Effect of Cycocel and Alar 85 treatments on the oleanolic acid and phytosterols percentage of Calendula flowers during the two experimental seasons

Treatments	January			Febuary			March			April			May			June		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
First season 1974/75																		
Control	0.37	0.11	0.14	0.37	0.09	0.08	0.37	0.09	0.10	0.39	0.08	0.06	0.43	0.09	0.09	0.40	0.08	0.08
Cycocel																		
250 ppm	0.40	0.13	0.13	0.37	0.08	0.08	0.34	0.08	0.08	0.40	0.09	0.08	0.43	0.08	0.08	0.38	0.09	0.06
500 ppm	0.38	0.13	0.09	0.39	0.09	0.08	0.39	0.10	0.09	0.40	0.10	0.08	0.47	0.10	0.08	0.37	0.12	0.06
1000 ppm	0.39	0.11	0.16	0.37	0.09	0.06	0.39	0.08	0.07	0.37	0.09	0.06	0.50	0.10	0.07	0.37	0.11	0.07
2000 ppm	0.38	0.08	0.11	0.39	0.10	0.08	0.37	0.08	0.08	0.38	0.09	0.08	0.43	0.12	0.10	0.39	0.10	0.08
Alar 85																		
250 ppm	0.37	0.10	0.15	0.37	0.08	0.06	0.39	0.08	0.08	0.37	0.09	0.08	0.50	0.15	0.14	0.40	0.12	0.10
500 ppm	0.39	0.10	0.13	0.39	0.08	0.07	0.39	0.06	0.08	0.40	0.10	0.07	0.48	0.12	0.08	0.39	0.11	0.09
1000 ppm	0.37	0.09	0.09	0.37	0.09	0.08	0.43	0.10	0.09	0.34	0.08	0.08	0.50	0.10	0.08	0.39	0.11	0.10
2000 ppm	0.39	0.11	0.09	0.37	0.10	0.09	0.37	0.06	0.08	0.37	0.08	0.09	0.48	0.09	0.08	0.37	0.09	0.11
Second season 1975/76																		
Control	0.34	0.09	0.07	0.40	0.12	0.12	0.46	0.12	0.14	0.42	0.10	0.13	0.38	0.10	0.15	0.37	0.08	0.11
Cycocel																		
250 ppm	0.34	0.08	0.09	0.40	0.08	0.08	0.48	0.10	0.15	0.39	0.14	0.15	0.37	0.09	0.15	0.39	0.09	0.09
500 ppm	0.34	0.09	0.06	0.39	0.08	0.08	0.47	0.17	0.20	0.39	0.10	0.16	0.39	0.12	0.16	0.39	0.09	0.12
1000 ppm	0.38	0.09	0.06	0.43	0.10	0.08	0.50	0.11	0.15	0.43	0.12	0.15	0.39	0.09	0.16	0.38	0.13	0.15
2000 ppm	0.37	0.09	0.06	0.43	0.11	0.08	0.43	0.09	0.15	0.43	0.11	0.13	0.39	0.11	0.12	0.39	0.12	0.15
Alar 85																		
250 ppm	0.34	0.07	0.06	0.46	0.10	0.08	0.46	0.13	0.12	0.40	0.08	0.12	0.39	0.11	0.15	0.39	0.13	0.12
500 ppm	0.43	0.08	0.07	0.38	0.08	0.06	0.50	0.13	0.13	0.09	0.16	0.14	0.39	0.10	0.14	0.37	0.08	0.09
1000 ppm	0.43	0.08	0.08	0.37	0.12	0.07	0.45	0.16	0.14	0.41	0.11	0.15	0.37	0.10	0.13	0.40	0.10	0.13
2000 ppm	0.40	0.09	0.07	0.43	0.13	0.09	0.46	0.10	0.12	0.45	0.10	0.15	0.38	0.12	0.15	0.38	0.10	0.15

1. Oleanolic acid. 2. β-Sitosterol. 3. Stigmasterol.

that Cycocel promotes flower initiation, perhaps by shifting the balance of the endogenous levels of the phytohormones.

It was also noticed from Table 1 that treatments with 500 and 1000 ppm CCC produced the heaviest average dry weight and largest average flower number. However, this may indicate that a correlation exists between the dry weight of the flowers and the number of flowers.

The average weight of a single flower was not significantly affected by any of the Cycocel treatments (Table 1). This in accordance with the findings of SCOTT (1971), who found that Cycocel had no adverse effect on flower weight and size.

Alar, at all the concentrations used, significantly increased the average flower dry weight. The only exception was noted when a concentration of 2000 ppm was used. The highest average was obtained when 1000 ppm was used, followed by 500 ppm (Table 1). Similar results were reported on chrysanthemum by MITLEHNER (1966).

The effect of Alar on the average flower number during the first season was similar to the effect on average flower weight, which was significantly raised due to all the concentrations used except 2000 ppm. The optimum concentration was 1000 ppm, followed by 500 ppm (Table 1). These findings were similar to those obtained by JASA *et al.* (1971) on *Salvia splendens.*

Concerning the average weight of the single flower, it was observed that although all the treatments raised it, the effect was not significant (Table 1). CATHY (1964) also reported that the flower size and dry weight of most plants was not appreciably altered by using growth retardants.

Effect of Cycocel and Alar on the content of oleanolic acid and phytosterols in the flower. Table 2 shows the effect of CCC and Alar on the oleanolic acid and the identified plant sterols, β-sitosterol and stigmasterol, in the flowers.

Apparently, none of the growth retardants had a distinct effect on their average percentage. As the total quantity of oleanolic acid and phytosterols produced depends on the

Table 3

Effect of Cycocel and Alar 85 treatments on the content of oleanolic acid and phytosterols (g/plot) *in lhe two experimental seasons 1974/75 and 1975/76*

	First season			Second season		
	Oleanolic acid	β-sitosterol	Stigma-sterol	Oleanolic acid	β-sitosterol	Stigma-sterol
Control	3.980	0.877	0.849	4.720	1.262	1.594
Cycocel						
250 ppm	4.256	0.902	0.881	5.767	1.356	1.751
500 ppm	4.487	1.140	0.957	5.307	1.650	2.162
1000 ppm	4.533	1.019	0.799	5.243	1.283	1.710
2000 ppm	4.253	0.978	0.938	4.933	1.149	1.613
Alar						
250 ppm	4.277	1.028	0.992	5.106	1.271	1.439
500 ppm	5.310	1.325	0.990	5.763	1.773	1.690
1000 ppm	5.140	1.233	1.085	5.403	1.664	1.737
2000 ppm	4.763	1.011	1.009	5.317	1.288	1.679
$LSD_{5\%}$	0.489	0.154	—	0.323	0.210	0.219
$LSD_{5\%}$	0.677	0.216	—	0.445	0.289	0.302

weight of the flowers and their percentage in the flowers, the monthly percentage of each of the yields was calculated by multiplying the monthly percentage of each of the sterols or oleanolic acid by the dry weight of the flowers produced during that month (Table 3). The whole yield (g/plot) was calculated at the end of the experiment.

The total yield of oleanolic acid was raised by the use of both growth retardants. The increase was significant when Cycocel was applied at 500 ppm, whereas all the Alar concentratiorns except 250 ppm significantly raised it. β-sitosterol was increased through the use of all treatments. However, it was significant when Cycocel and Alar were sprayed at 500 ppm.

Concerning stigmasterol, its averages were raised through the use of all the treatments; however, these increases were not significant. The increase in yield of oleanolic acid, β-sitosterol and stigmasterol may be attributed to the increase in flower dry weight.

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EFFECT OF CEMENT DUST ON THE GROWTH, DEVELOPMENT, MAJOR METABOLIC PROCESSES AND YIELD OF WINTER BARLEY "IN SITU" AND UNDER CONTROLLED CONDITIONS

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The growth, metabolic processes and yield of winter barley, as affected by dust from the Duna Cement and Lime Works, were studied "in situ" and under controlled conditions.

The floating dust from the cement works settled mainly on the leaves of the winter barley, forming a more or less continuous cement crust under the influence of moisture.

Frequent small quantities of precipitation resulted in partial epidermis injuries to the young leaves, caused by the alkaline cement dust.

As a consequence of a higher rate of dust contamination the quantity of pigments considerably decreased, while the intensity of respiration and the activity of the catalase enzyme increased.

The generative organs of dust-contaminated plants showed unfavourable development and growth; the number of flowers and spikelets in the spike became smaller. The alkaline dust neutralized the acidic excretion of the stigma, there by causing a considerable disturbance in fertilization.

The "hidden" damage caused by the unfavourable trend in biological processes, together with the direct harmful effect exercised on the generative organs, resulted in a decrease in yield.

Introduction

Floating dust from cement works settles on plants to various extents depending on the anatomical structure of the plant. In the presence of sufficient amounts of moisture the dust forms a relatively thin crust on the surface of the plant, which is not washed off and is very difficult to remove. In long dry periods a cement crust is not formed owing to the lack of moisture, and the wind or persistent rain can easily remove the accumulated cement dust from the plants.

The dust layer setting on the surface causes disturbances in the radiation, heat and water balance of the flora, has an unfavourable effect on the metabolic processes, and, if found on the stigma, causes fertilization problems due to a shift in the pH value.

Material and method

The experiments were performed with the winter barley variety "Kompolti korai" in the neighbourhood of the Duna Cement and Lime Works, and under simulated conditions in a greenhouse, on plants raised in Kick-Brauckmann pots or in plots measuring 2×5 m in size, with 5 replications in both cases.

In the neighbourhood of the cement works the extent of dust deposition on plants showing "high" contamination (in the direction of the prevailing NW wind under the smoke cloud) and "low" contamination (in directions other than that of the prevailing wind) was continuously determined from the 3–4-leaf stage to the milky ripening stage. These dust concentrations were simulated on plants raised in pots or outdoor plots, so that the extent of contamination always corresponded to that determined for plants grown under natural conditions. The examinations were carried out continuously and parallelly at all growing sites for the same development stage of the plants.

The degree of contamination was determined by heating the leaf-blade.

According to the measurements the ash content per unit area for leaves at the same insertion level was nearly the same. (The threshold for the response of plants to different levels of stress ranged between wider limits than the accuracy of the method, since the margin of error given by the ash content of the leaf was only 5–6%.) Therefore the difference between the heated weight of a contaminated leaf of known area and the ash content of a non-contaminated leaf-blade gave the weight of the solid contaminant.

To determine the extent of contamination, a total of 100 cm^2 of contaminated leaf-blade sections were excised from the basal, central and apical parts of the last three leaves, and placed in an annealing pot of known weight. The samples were heated for 30 minutes at 600 °C, then cooled down in an exsiccator, after which the ash content was weighed with an assay balance. Assuming that the ash content of a leaf-blade of unit area was approximately the same, the weight surplus was equal to the weight of the contaminant.

(The heating method is only suitable for measuring the weight of solid contaminants that do not substantially lose weight when heated — the dust of cement works lost about 6–7% of its weight on heating. In addition, with this method leaf contamination can best be determined for cereals or for small-leaved plants in which the dust concentration is nearly the same all over the leaf. The method is not suitable for determining the contamination of maize, sunflower, tobacco, sugar-beet, etc.)

Among the physiological processes, the intensity of respiration was determined with a Frevil apparatus (Frenyó and Kovács 1976), the catalase enzyme activity by Frenyó's method (Frenyó 1962), and the total pigment content by spectrophotometry (Bruisma 1963). (The cement dust was cleaned off the leaves immediately before the examination, causing as little damage as possible to the leaves.)

Results and discussion

The floating dust continuously emitted by the Cement Works settled mainly on the leaves of the winter barley, and, with water from condensation and rainfall, formed a cement crust covering surfaces of considerable size. From autumn to spring, under the smoke cloud in the direction of the prevailing NW wind, up to a distance of 300–3500 m from the Cement Works, the weight of the dust sedimentation on the first 3–7 leaves was as much as 1/6–1/3 of weight of the leaf, while the dust layer on this area was 0.1–0.7 mm thick (average of 600 samples). From shooting up to flowering the dust load was 12.1 g/m^2 on the leaves of highly contaminated plants and 9.3 g/m^2 on those of less seriously contaminated plants; these values were then simulated on plants raised under controlled conditions. (After flowering the dust contamination of the plants gradually decreased, owing to the senescence and withering of the leaves.)

The threshold of sensitivity to dust stress in winter barley was determined not only by the dust concentration but also by meteorological factors, e.g. the amount and distribution of precipitation.

Under the effect of moderate rainfall on three occasions (less than 2 mm each) within 20 days the alkaline reaction of the cement dust induced epidermis injuries on the young leaves. On entering the cells of these damaged leaves the chemically active solution caused a partial denaturation of the chloroplasts and a decrease in the pigment content (Table 1).

If, for lack of sufficient moisture, the alkaline cement dust on the leaves did not dissolve, or, under the influence of steady rainfall, formed an osmotically inactive cement crust, even a larger dust load only brought about chronic rather than acute damage.

The phenological phases of contaminated winter barley did not perceptibly differ from those of unaffected plants under either natural or controlled conditions.

On the other hand, the area of the contaminated leaves became significantly larger. The growth of the flag leaf was particularly stimulated by cement dust (Table 4).

Owing to the increased absorption of radiation by contaminated leaves there was an increase in their temperature, and consequently in their respiration and catalase enzyme activity (Tables 2 and 3). (Together with several

Table 1

Effect of floating dust from cement works on the total pigment content of winter barley "in situ" and under controlled conditions
(mg/g dry matter)

Treatment	At the time of					
	shooting up		earing		flowering	
	value	%	value	%	value	%
pot						
Control	1.99	100.0	2.79	100.0	2.62	100.0
9 g/m²	2.03	102.0	3.00	107.5	2.73	104.2
12 g/m²	2.00	100.5	2.64	94.6	2.41	92.0
$LSD_{5\%}$						
plot						
Control	2.03	100.0	3.04	100.0	2.78	100.0
9 g/m²	2.07	102.0	3.26	107.2	2.89	104.0
12 g/m²	2.03	100.0	2.94	96.7	2.68	96.4
$LSD_{5\%}$						
"*in situ*"						
Control	2.01	100.0	2.90	100.0	2.69	100.0
9 mg/m²	2.00	99.5	3.00	103.4	2.74	101.9
12 mg/m²	1.94	96.5	2.82	97.2	2.62	97.4
$LSD_{5\%}$						

Table 2

Effect of floating dust from cement works on the respiration intensity of winter barley "in situ" and under controlled conditions between 11 and 12 a.m. (μg CO_2/min/0.5 cm^2)

Treatment	At the time of					
	shooting up		earing		flowering	
	value	%	value	%	value	%
pot						
Control	0.43	100.0	0.49	100.0	0.48	100.0
9 g/m²	0.50	116.3	0.58	118.4	0.59	122.9
12 g/m²	0.50	116.3	0.59	120.4	0.59	122.9
$LSD_{5\%}$						
plot						
Control	0.40	100.0	0.46	100.0	0.46	100.0
9 g/m²	0.45	112.5	0.53	115.2	0.54	117.4
12 g/m²	0.45	112.5	0.54	117.4	0.54	117.4
$LSD_{5\%}$						
"in situ"						
Control	0.40	100.0	0.47	100.0	0.47	100.0
9 g/m²	0.44	110.0	0.52	110.6	0.53	112.8
12 g/m²	0.44	110.0	0.53	112.8	0.53	112.8
$LSD_{5\%}$						

Table 3

Effect of floating dust from cement works on the catalase enzyme activity in winter barley "in situ" and under controlled conditions between 11 and 12 a.m. (ml O_2/2 min/20 leaf discs of 5 mm ∅)

Treatment	At the time of					
	shooting up		earing		flowering	
	value	%	value	%	value	%
pot						
Control	0.27	100.0	0.29	100.0	0.34	100.0
9 g/m²	0.32	118.5	0.35	120.7	0.43	138.7
12 g/m²	0.32	118.5	0.35	120.7	0.41	120.6
$LSD_{5\%}$						
plot						
Control	0.25	100.0	0.27	100.0	0.28	100.0
9 g/m²	0.29	116.0	0.32	118.5	0.34	121.4
12 g/m²	0.28	112.0	0.32	118.5	0.34	121.4
$LSD_{5\%}$						
"in situ"						
Control	0.24	100.0	0.29	100.0	0.31	100.0
9 g/m²	0.27	112.5	0.32	110.3	0.36	116.1
12 g/m²	0.27	112.5	0.33	113.8	0.36	116.1
$LSD_{5\%}$						

Table 4

Effect of floating dust from cement works on the average and flag-leaf area of winter barley at the time of earing, "in situ" and under controlled conditions
(average of 100 leaves)

Treatment		Pot		Plot		"In situ"	
		value	%	value	%	value	%
Average leaf area	control	16.82	100.0	17.40	100.0	17.12	100.0
	9 g/m²	17.82	105.9	18.23	104.7	17.53	102.3
	12 g/m²	18.10	107.1	18.61	106.9	18.21	106.4
	$LSD_{5\%}$						
Area of flag-leaf	control	14.84	100.0	16.28	100.0	15.34	100.0
	9 g/m²	16.10	108.5	17.47	107.3	16.04	104.6
	12 g/m²	16.86	113.5	17.97	110.4	16.62	108.3
	$LSD_{5\%}$						

Table 5

Effect of floating dust from cement works on the generative parts, yield and germinating vigour of winter barley "in situ" and under controlled conditions
(average of 100 plants)

Treatment		Pot		Plot		"In situ"	
		value	%	value	%	value	%
Length of spike (cm)	control	5.17	100.0	5.89	100.0	5.54	100.0
	9 g/m²	4.93	95.4	5.78	98.1	5.42	97.8
	12 g/m²	4.91	95.0	5.73	97.3	5.40	97.5
	$LSD_{5\%}$	—	—	—	—	—	—
No. of flowers per plant	control	43.12	100.0	45.22	100.0	43.58	100.0
	9 g/m²	40.19	93.2	43.41	96.0	41.75	95.8
	12 g/m²	40.03	92.8	43.47	96.1	41.58	95.4
	$LSD_{5\%}$	—	—	—	—	—	—
Number of spikelets	control	20.48	100.0	23.12	100.0	22.37	100.0
	9 g/m²	19.15	93.5	22.22	96.1	21.27	95.1
	12 g/m²	19.02	92.9	22.26	96.3	21.05	94.1
	$LSD_{5\%}$	—	—	—	—	—	—
No. of grains per spike	control	26.42	100.0	28.13	100.0	25.87	100.0
	9 g/m²	23.87	98.7	26.98	95.9	24.37	94.2
	12 g/m²	23.72	89.1	26.47	94.1	24.27	93.8
	$LSD_{5\%}$	0.034***	1.3	3.1*	11.0	0.52***	2.0
Grain weight per spike (g)	control	1.20	100.0	1.36	100.0	1.28	100.0
	9 g/m²	1.08	90.0	1.27	93.4	1.22	95.3
	12 g/m²	1.05	87.5	1.28	94.1	1.20	93.8
	$LSD_{5\%}$	0.02***	1.6	0.04***	2.9	0.04**	3.1
Grain yield g/plot kg/plot	control	45.32	100.0	0.554	100.0	0.492	100.0
	9 g/m²	39.40	86.9	0.512	92.4	0.454	92.3
	12 g/m²	38.64	85.3	0.504	91.0	0.456	92.7
	$LSD_{5\%}$	4.36***	9.6	0.29**	5.4	0.28*	5.7
Germinating vigour (%)	9 g/m²	91.2		95.6		93.8	
	12 g/m²	88.4		94.2		92.2	

other factors, this may be one reason for the more intensive growth of contaminated leaves.)

The unfavourable change in physiological processes due to the effect of cement dust, and the upset in the balance of biochemical reactions also manifested themselves in a quantitative and qualitative decrease in yield.

In response to contamination by cement dust the spike became shorter and the number of flowers and spikelets lower. The grain number and thousand-grain-weight were substantially reduced (Table 5).

The great loss in yield was thus due to the unfavourable development of the generative organs and the deficient fertilization of the contaminated flowers. The acidic excretion of the stigma turned alkaline under the effect of cement dust, a condition unfavourable for pollen germination. Laxial spikes were therefore frequently encountered.

The germinating vigour of dust contaminated grains was reduced (Table 5). Consequently, seed production of winter barley is not recommended on contaminated areas.

In spite of the fact that, depending on climatic factors, acute damage could also be observed in the winter barley, the decrease in yield and the deterioration of quality can be traced back not only to the unfavourable development of the generative organs and to fertilization problems, but also to various metabolic disorders. Owing to the partial destruction of the epidermis, on occasion dissolved cement dust was easily able to enter the intercellular spaces and the cells themselves, causing damage to the microscopic ultrastructure of the cell organelles.

Due to its alkaline reaction the dust almost certainly caused a change of potential and increased permeability in the membrane systems, and plasmolysis and denaturation of the plasma colloids. The dust covering the leaves dissolved in liquid derived from condensation, and this solution became hypertonic and osmotically active compared to the cells. In this solution the cells and tissues showed convex plasmolysis.

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MAIZE SEEDLINGS RAISED IN AIR SPACE CONTAINING SULPHUR DIOXIDE

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As part of an attempt to lay down the basic principles required to forecast the effect of atmospheric background contamination on living organisms, the effects of sulphur dioxide were studied using maize (*Zea mays* L.) as the test plant.

It was found that an increase in the concentration of sulphur dioxide influenced the ultrastructure of the chloroplast: at a concentration of 1 mg/m^3, SO_2 had a decidedly damaging effect on the development of both the thylakoids and of the whole inner membrane system.

Furthermore, as the SO_2 concentration increased the dry matter content decreased, while the inorganic sulphur content in the plants increased.

Introduction

It is a well-known fact that the sulphur requirement, the dynamics of the sulphur balance and the disturbing effects of sulphur may vary greatly with the plant species. Observations have been made on various plants raised in air space containing SO_2 (JÄGER and STEUBING 1970, GUDERIAN 1970, RABE and KREEB 1976).

PAUL (1979) carried out experiments on *Phaseolus vulgaris* seeplings placed in air spaces with different sulphur dioxide concentrations, and found the leaves to be sensitive to sulphur dioxide.

ROBERTS *et al.* (1979) studied the effect of sulphur dioxide on the growth of cereals and clovers and pointed out that the high sulphur dioxide concentration in the air of industrial areas significantly decreased the increase in dry matter content in the plants.

HUTCHINSON (1979) dealt with the transformation of sulphur compounds in relation to plants and soil. He found that in the vicinity of industrial areas the sulphur content in the leaves of plants was 30–100% higher compared to the plants in the control areas.

In the current experiments the effects of sulphur dioxide on maize seedlings were studied.*

* The experiments were financed by the National Bureau for Environmental Protection and Nature Conservation.

Material and method

Plant raising

The maize variety used in the experiments was Martonvásári SC 429, a state registered maize hybrid produced at Martonvásár. This variety is cultivated in many places in Hungary.

For fungicidal purposes the maize grains were treated with 3% hydrogen peroxide, then thoroughly washed with distilled water through which air was bubbled for 3 hours. The grains thus prepared were placed between paper wadding and filter paper layers wetted with distilled water, and germinated for 3 days in the dark. The optimum temperature for germination (25 ± 1 °C) was ensured in a Mitron air-conditioner. Subsequently the germs were placed in closed-system glass pots.

In some of the experiments Hochenbocka quartzsand placed at the bottom of the glass pots was used as soil. The analytical data obtained from the factory were:

Composition:	SiO_2	93.39 –99.50%	
	Fe_2O_3	0.014– 0.044%	
Grain size analysis:	0.50 –1.00	mm	9.40%
	0.25 –0.50	mm	45.40%
	0.125–0.25	mm	40.50%
	less than 0.125	mm	4.60%

Thus, the sand used as soil was almost entirely silicon dioxide, wetted only with distilled water. So it can be reasonably stated that the plants were only able to utilize the reserve nutrients of the maize grains and the SO_2 introduced in the ambient air. To prevent the SO_2 from entering the soil the sand was covered with aluminium foil, leaving a gap 10 mm in diameter to let the plantlets to come through.

The plants were raised for two weeks; this time proved long enough for the reserve nutrients in the grain to ensure development. In the course of growth, alternate day and night (12-hour light; 10,000 lux, and 12-hour dark) periods were programmed in the air-conditioner.

In the glass pots various concentrations of sulphur dioxide (0.1 mg/m³, 0.25 mg/m³, 0.5 mg/m³, 0.75 mg/m³, 1.0 mg/m³) were adjusted. The control was 0.1 mg/m³ SO_2 in each experimental series. The plants thus raised were examined at one and two weeks of age. They were cut at the prop root to divide them into aboveground shoots and roots. The fresh and dry weight, length, organic and inorganic sulphur content were measured for the shoot and root separately, and electron microscope photos were taken of the chloroplasts of the leaf for the purpose of studying ultrastructural changes.

Adjusting and controlling the sulphur dioxide concentration

The air and SO_2 gas mixtures with various concentrations required for the experiments were produced in several stages using a Digamix 2M 300a-F gas mixer made by Wösthoff. The apparatus is suitable for mixing two different gases over a 0–100% range of concentration. The mixing ratio can be adjusted at 1% stages.

The mixer is able to work against an overressure of 100 water column mm (approx. 1000 Pa), whereby a steady concentration can be ensured in the pots. (The entrance of air due to leakage can be eliminated.) For making the gas mixtures, sulphur dioxide gas cylinders manufactured by the Budapest Chemical Works and air pressure bottles made by the Oxygen and Dissolved Acetylene Gas Factory were used. The concentration was controlled with an HB URAS 2T infrared gas analyser. The transformation factor needed to achieve the required concentration was 1 ppm SO_2 = 2.86 mg/Nm³ = 2.66 mg/m³ at 25 °C.

Sulphur analysis

The sulphur content in the leaves of the test plants was established by fractional sulphur determination according to the method of JÄGER and STEUBING 1970 and NYOMÁRKAY and SÜDI 1981.

Results and discussion

The laboratory experiments were graphically summarized. The graphic values were obtained by averaging 36 measurements for each of three analytical series (Figs 1–4).

For the purpose of examination the one- and two-week-old plants were cut at the prop roots. Thus, separate measurements were made of the aboveground shoots and of the root system with the remains of the seed, since the stored nutrients in the grains served for two weeks as sources of development for the plant.

The diagrams clearly that apart from minor fluctuations well-reproducible values were obtained.

Although macroscopically show the plants appeared to have survived the two weeks well, their growth and colour reflected the effect of the sulphur dioxide, depending on the concentration. Since, apart from the reserve nutrients, the seedlings were only given distilled water with a pH value of 6.9,

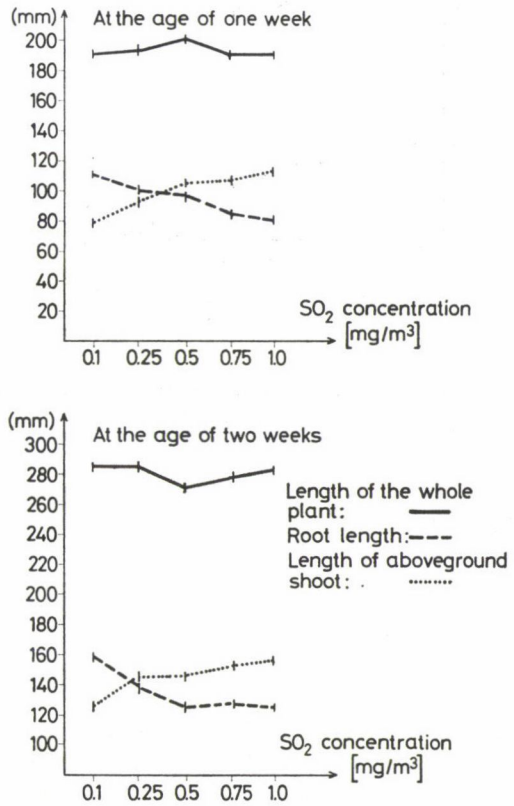

Fig. 1. Changes in the growth of maize seedlings in air spaces with various SO_2 concentrations

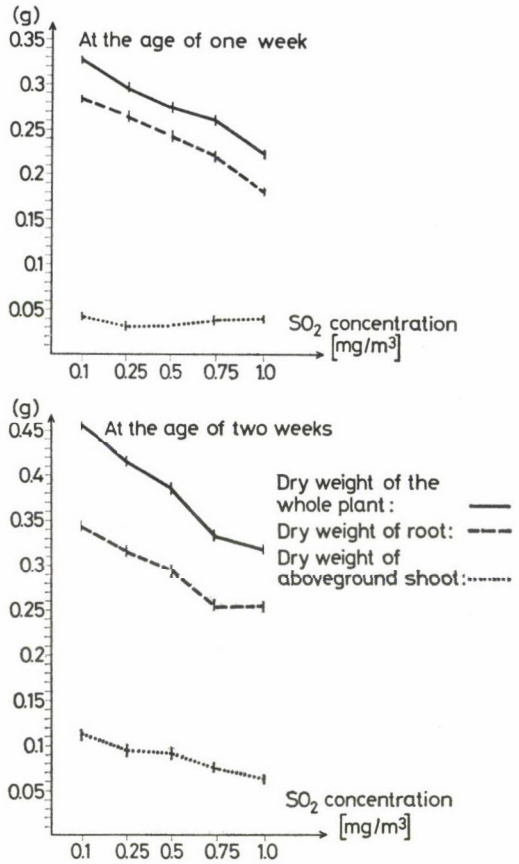

Fig. 2. Changes in the dry weight of maize seedlings in air spaces with various SO_2 concentrations

and since in the case of the 0.25 mg/m^3 concentration of SO_2, they were not much arrested in growth, it may reasonably be supposed that they used up part of the sulphur dioxide.

The organic sulphur content of the roots and aboveground shoots characteristically fluctuated around a given value, and is therefore not shown in a separate diagram.

The sulphur content of the maize grain was also weighed: the total sulphur content was 1.9596 mg/g dry matter, of which 3556 mg/g was inorganic sulphur. The average weight of one grain is 0.2559 g in the rase of the variety Mv SC 429.

The inorganic sulphur content showed changes similar to those in the total sulphur content, but numerically they were naturally lower: the difference between the two gave the organic sulphur content. This observation is equally true for the aboveground shoots and the roots.

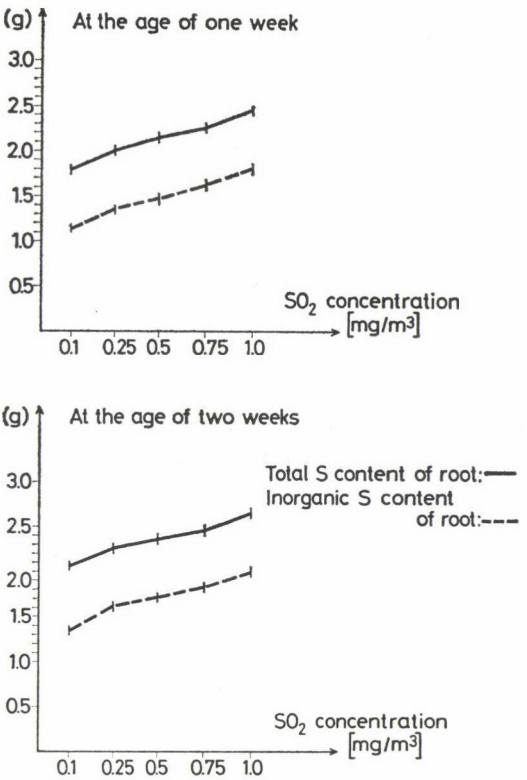

Fig. 3. Changes in the sulphur content of maize roots in response to various SO_2 concentrations in the air

Hypothesis examination

An examination was made of the differences in parallel data from three series of measurements chosen at random. The zero hypothesis assumed that the parallel series would give identical results (with non-significant differences). The level of decision was 95%, which meant that the zero hypothesis was discarded if the probability of its realization was lower than 5%, i.e. if the F and t (or d) values pertaining to the 5% significance level in the statistical tables were lower than the corresponding values calculated.

The standard deviations were compared using the F-test, and the average values with a two-sample t-test. The samples were assumed to be of normal distribution, independent, and of identical standard deviation; the latter was checked using the F-test. When the standard deviations appeared to be different, the d-test was applied instead of the t-test.

The formulae used were:

$$S_x = \frac{(x_1 - \bar{x})/^2}{n - 1}$$

$$F = \frac{S_1^2}{S_2^2} \qquad \text{if } S_1 > S_2$$

$$F = \frac{S_2^2}{S_1^2} \qquad \text{if } S_2 > S_1$$

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{S_x^2 + S_y^2}}$$

$$d = \frac{\bar{x} - \bar{y}}{\sqrt{S_{\bar{x}}^2 + S_{\bar{y}}^2}}$$

where x_1 = the i-th member of the 1st series of measurements
$\bar{x}$ = the average of the 1st series of measurements
S_1 = the standard deviation of the 1st series of measurements
n = the number of data in the 1st series of measurements
S_2 = the standard deviation of the 2nd series of measurements
$\bar{y}$ = the average of the 2nd series of measurements

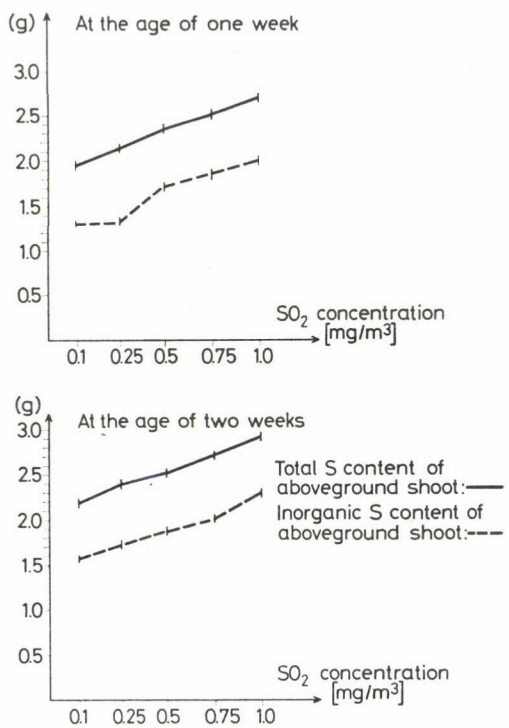

Fig. 4. Changes in the sulphur content of the aboveground shoots of maize in response to various SO_2 concentrations in the air

$S_{\bar{x}}$ = the standard deviation of the average of the 1st series of measurements

$S_{\bar{y}}$ = the standard deviation of the average of the 2nd series of measurements

Since the number of data was the same in each series of measurements, the formulae for the *t*- and *d*-statistics were identical.

The random examinations (parallel measurements in the 1st and 2nd or the 2nd and 3rd series of measurements were compared) did not show any significant differences.

The above experiments were complemented with electron microscope photos.

In the leaves of maize and other C_4 plants two kinds of chloroplasts can be found. The chloroplasts in the mesophyll cells show the usual granum-stroma organization and do not contain starch grains. The chloroplasts in the cells of the bundle sheath contain individual thylakoids rather than grana, but there are a large number of starch grains. In each chloroplast a peripheral membrane system consisting of interfused tubuli is found; this is called the peripheral reticulum (REINER 1980).

The normal chloroplasts in the mexophyll cells of maize (*Zea mays* L.) are characterized by a well-developed inner lamellar system, also known as the thylakoid-system, which is the site of photosynthesis (Fig. 5). Similarly characteristic are the well developed grana, in which the thylakoids are stuck together. In some of the grana the number of thylakoids is about 10, while in the majority there are considerably more thylakoids, sometimes as many as 20–30 or even more. The system of stroma thylakoids, which are not stuck together, is fairly dense. In general every 2nd or 3rd granum thylakoid is continued in a stroma thylakoid which connects the grana. In the basic substance of the stroma, plastid ribosomes and plastoglobuli, lipid-containing bodies, which are highly osmiophilic and therefore conspicuously dark, can be observed.

A 0.5 mg/m^3 concentration of SO_2 has perceptible quantitative and qualitative effects on the ultrastructure of the chloroplasts (Fig. 6). The number of grana decreases to about two-thirds. Generally, some 20% fewer thylakoids take part in building up the grana, so the grana are smaller, and there are fewer stroma thylakoids, which indicates that the connection between the grana is less strong. A moderate dilatation of the stroma thylakoids can also be observed, which is manifested as a larger width of the inner space of the thylakoid and involves an increase in the intrathylakoidal substance. The quantitative decrease in the photosynthetic membrane system results in an apparent increase in the basic stromal substance. No disorders in the development of the plastid ribosomes and plastoglobuli can be detected, which sug-

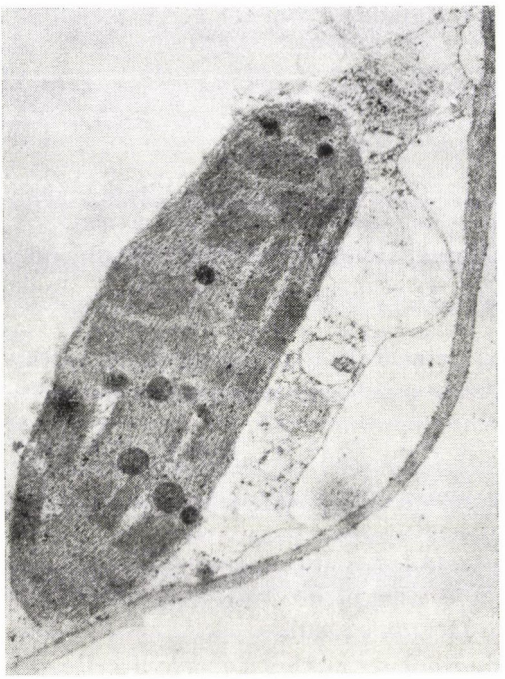

Fig. 5. Ultra-thin section of a chloroplast in the mesophyll cell of maize, with a normal inner membrane system. Control. (Electron microscope photo)

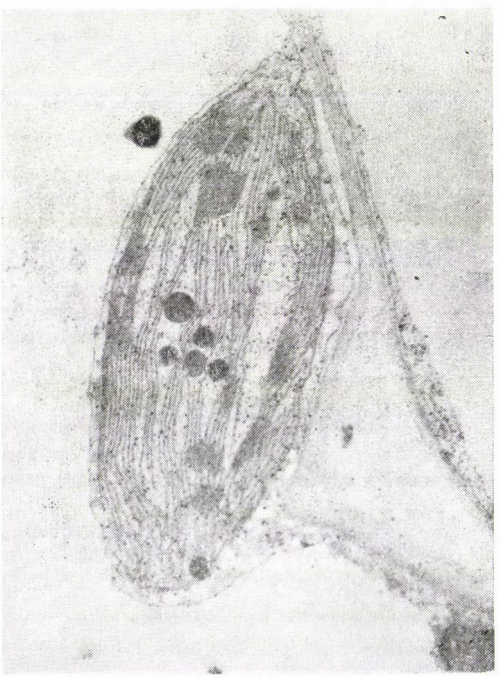

Fig. 6. Chloroplast of a plant raised at an SO_2 concentration of 0.5 mg/m³, with advanced ultrastructural changes. (Electron microscope photo)

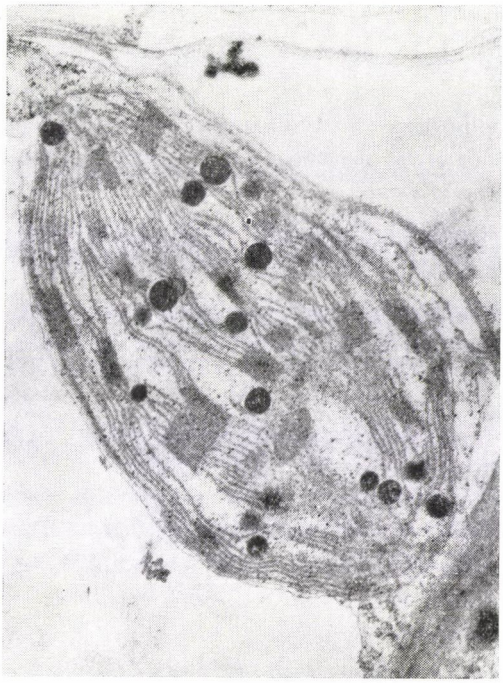

Fig. 7. Swollen chloroplast of a plant raised at an SO_2 concentration of 1 mg/m³, with a damaged inner membrane system. (Electron microscope photo)

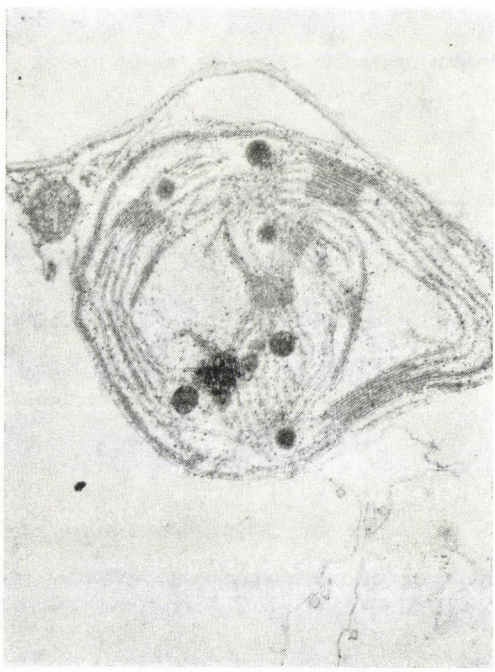

Fig. 8. Deformed chloroplast of a plant raised at an SO_2 concentration of 1 mg/m³, with a seriously damaged thylakoid system. (Electron microscope photo)

gests that the special protein synthesis and lipid metabolism of the chloroplast did not suffer any damage.

In the case of a SO_2 concentration of 1 mg/m^3 considerable morphological and ultrastructural changes can be observed in the chloroplasts (Figs 7 and 8). The chloroplasts swell and may become irregular in shape. The photosynthetic membrane system conspicuously diminishes as regards both the number of grana and the quantity of thylakoids. Ultimately only a few smaller grana are left, and the stroma thylakoids become scarce, and ondulated or irregular in shape. The dilatation of the thylakoids spreads to the grana, and in the stroma thylakoids it becomes still stronger than in the previous (0.5 mg/m^3) treatment. Furthermore, the widening of the intrathylakoidal spaces in the stroma is not uniform. In the highly increased stromal substance there are fewer plastid ribosomes and the plastoglobuli also decrease in number. This indicates that the 1 mg/m^3 concentration of SO_2 has a negative influence not only on the photosynthetic processes, but also on the protein synthesis and lipid metabolism.

To sum up, it can be stated that when the SO_2 pollution of the air reaches a certain level (in the current experiments 0.5 mg/m^3) it influences the ultrastructure of the chloroplasts, while above that level, at a concentration of 1 mg/m^3, it has a decidedly damaging effect on the development of the thylakoids and of the whole membrane system, and thereby on the photosynthetic processes.

The conclusion drawn corresponds to observations made by ROBERTS *et al.* (1979), that an increase in the concentration of sulphur dioxide results in a decrease in the dry matter content of the plants.

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PHENOMETRICAL CHARACTERISTICS OF PLUMS REGARDING THE AIR TEMPERATURE REQUIREMENTS OF FLOWERING AND RIPENING

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The author studied 50 plum varieties between 1959 and 1970 in the major phenophases, placing them in four groups by the following aspects: fertility (self-fertile, partially self-fertile, practically self-sterile and self-sterile), fruit colour (blue, violet, red + yellow, green) as well as temperature requirements for flowering and ripening, respectively, and found significant differences among these groups. The correlations of phenophases calculated from 15 groups proved very close and, as to their character, most confirmed the correlations obtained earlier by a botanical-taxonomical grouping. To calculate the temperature threshold of flowering, the author used various methods. Specifically, he examined the scatter of temperature sums above a daily mean temperature between —3 °C and +3 °C in the following periods: from the beginning and middle of November, from the beginning and middle of December and from the beginning of February to the time of flowering, respectively. In the early February examinations he evaluated the temperature thresholds up to +7 °C. He obtained a standard deviation below 7% when he reckoned with temperature thresholds of —1 °C for 26 varieties, —2 °C for 20 varieties and —3 °C for 4 varieties, from 1 November. To determine the temperature threshold of fruit ripening, the author summed up the degrees above a mean temperature between 0 and +7 °C. Accordingly, the smallest scatter of temperature sum is at 0 °C in 15 varieties, at +2 °C in 8 varieties, and at +5 °C and +7 °C in 14 and 13 varieties, respectively. With the biological zero point taken for basis, the temperature sums required by the plum varieties for flowering range from 707.8 to 1030.7 °C. Temperature sums required for ripening may vary between 1465.1 and 2292.4 °C depending on the temperature threshold. Examination of the distribution of correlation groups reveals that the frequency of the fertility-fruit colour- and flowering-, respectively, as well as of the fruit colour-ripening groups is rather reliable; but, in the frequency of correlation between fruit colour and flowering groups, change plays an important role. With this study the author has completed the phenometrical evaluation of the conventional plum varieties, and is now going to begin testing the current varieties and the cultivars in process of acclimatization. In the meantime, the phenometrical characteristics of plum varieties included in the present study will also be taken into consideration in carrying out a more complete and up-to-date systematization of plus varieties, with the knowledge of the morphological features of vegetative and reproductive organs.

Introduction

The first phytophenological calendar was prepared by LINNÉ, but the statistica methodology of phenology was elaborated only in the last century, by QUETELET. At the Vienna Congress on Statistics in 1857 a proposal was made on carrying out systematic pheno-

logical observations. This was reasonable because, although irregular observations had already begun around 1810, their results were incomparable.

The foundation of investigations in Hungary was laid down by STAUB (1882) who summarized the earlier literary material, and constructed the first Hungarian phytophenological map, on the basis of flowering data of 17 plant species between 1851 and 1870. A further summarization was made by KEÖPECZY-NAGY (1943), who systemized observations between 1870 and 1930, including the flowering of plum.

HEGYFOKY (1926) analysed the causes of fluctuations in flowering on the basis of earlier and own experiences, and studied the effect of the most important factor temperature, in a number of species. Further important factors of fluctuation are height above sea level, degree of latitude, rapidity of warming up and coming of spring, number of sunshine hours and intensity of solar radiation, amount of precipitation, humidity of air, extent of night eradiation, sum temperature in June of the previous year, and finally, dormancy (PHILLIPS 1922). The exposure of flowers, the physical properties and nutrient status of the soil, the type of root-stock and bearing branches also affect the process of flowering (BEREZENKO 1963, BUDING 1960).

The other phenophases, e.g. fruit ripening, are influenced by similar factors, though the researchers pay less attention to these, in favour of flowering (MIHĂESCU 1973, SCHNELLE 1955, TUROVCEV 1976, VACHŮN 1974).

From differences in the time when the individual phenophases begin in different years, the authors have arrived at the conclusion that the required sums of air temperature calculated from various dates are of a constant nature. Application is based on the relation between radiation balance and temperature sum. The temperature sums given for the different phenophases or for the whole vegetation period are approximately constant (STANOJEVIĆ 1967), but they are so regarded as contant that the fulfilment of the conditions is investigated. A further problem is the temperature value to be taken for basis, for threshold, as each phenophase has a different critical value. The temperature or temperature sum, when emphasized to play an exclusive role, involves at the same time leaving the other meteorological elements out of consideration (VARGA-HASZONITS 1977).

The great diversity of calculation forms might be best explained by this, since the opinions concerning the starting point, the critical value of temperature, or even its calculation (mean temperature, average of maximum and minimum temperatures, daily mean temperature or day-time temperature mean, etc.) are different (GANRY 1978, TAMÁS 1959, VARGA-HASZONITS 1977).

According to KOBEL (1954) there is no simple relation between temperature sum and flowering time. The geographic situation greatly modifies the values of temperature sum and differences are shown in the character and dynamism of onset of phenophases. Spring shooting is slower at lower degrees of latitude than towards the poles, and temperature otherwise acts on flowering and ripening in different ways (PHILLIPS 1922).

For cherry and sour-cherry, 5 °C is generally regarded as threshold in summing up temperature means from 1 January (EFIMOV 1963, SMOLEA 1975), though there are temperature sums calculated from the middle of January (WIERSZYLLOWSKI *et al.* 1979, EISENSMITH *et al.* 1980), or from the end of dormancy, incidentally from 1 March (WILLING 1960) as starting point. Similar methodological differences can be seen in flowering analyses of apricot (MORÁVEK 1964, NYUJTÓ and TOMCSÁNYI 1959, MOLNÁR and STOLLÁR 1971, MOLNÁR and TURI 1974, VACHUN 1974) and peach MIHĂESCU 1973, PISANU 1968).

KEÖPECZY-NAGY (1943) established, on the basis of 80-year data of flowering, that flowering began at 11.5–11.8 °C, while ripening above 22 °C in the plum varieties. The relation between daily mean temperature and flowering in various *Prunus* species was indicated by OVERCASH (1962, 1963). PASCALE and RUGGIERO (1963) after 20 years of observation con-

sidered 7 °C, while VITANOV (1963) 0 °C, as threshold. From 1 February to the time of flowering the active sum of temperature is 399 °C, DRAGANOV *et al.* (1964) obtained a very high threshold value (+10 °C) on the basis of calculations, consequently the temperature sum is also smaller. HORNEY (cit. BRÓZIK and NYÉKI 1975), on the other hand, reckoned with hourly temperature values above 5 °C from 1 January, which meant a temperature sum of 3045 °C for plum varieties.

According to the opinion of Yugoslav authors, it is enough to take the daily (average) temperature data from 1 February into consideration (KAPETANOVIĆ and PIRNAT 1977), although when analysing 50 varieties we found a different optimum calculation. We obtained the steadiest values of temperature sum on the basis of 12 years when reckoning from 1 November (SURÁNYI 1980).

Detailed description and thorough systemization of plum varieties were carried out by DAHL 1935, DOMIN 1944, HERRERO 1951, KÁRPÁTI 1967, RÖDER 1940, TÓTH 1957, VONDRACEK 1975. We have recently worked upon and partly published eararlier observations at Cegléd (SURÁNYI 1980a, 1980b).

Material and methods

In 1953–1954 a large number of plum varieties grafted to myrobalan seedlings were planted and 50 of them continuously surveyed between 1959 and 1970 in the following phenophases: beginning of leaf-bud opening, beginning and end of flowering, end of shoot growth, beginning of fruit colouring and -ripening, beginning of leaf colouring, beginning and end of leaf abscission.

The phenophase data were expressed as related to the initial date of the year, and from the basic data several synthetic index numbers were formed:

— *lenght of flowering* (= end of flowering — beginning of flowering)
— *length of shoot growth* (= end of shoot growth — beginning of leaf-bud opening)
— *length of ripening* (= end of ripening — beginning of ripening)
— *accumulation* (= beginning of leaf colouring — end of shoot growth)
— *length of leaf abscission* (= end of leaf abscission)
— *length of vegetation* (= end of leaf abscission — beginning of leaf-bud opening)
— *length of dormancy* (= 365 — length of vegetation).

In 1969–1971 bud samples were collected from the plum-trees every 10–12 days from 1 June to 10 September Five buds from each bearing spur of southern exposure were fixed in 70% alcohol, and examined by Elman's method (SURÁNYI 1980b), with BUMBAC's (1975) report also taken into consideration.

Throughout the whole period of investigation, the observations of the Cegléd Agrometeorological Station were used in calculating the mean temperatures. The monthly temperature data of the successive years were compared and subjected to variance analysis.

Fifteen of the 50 varieties were self-fertile, 9 partially self-fertile, 10 practically self-sterile and 16 self-sterile. The distribution by fruit colour was: 29 blue, 12 violet, 1 red + 3 yellow, and 5 green (TÓTH 1957 and 1967). Distribution by the temperature thresholds of flowering and ripening could be established after methodological studies on flowering and ripening in the individual varieties.

The critical temperature of flowering was determined by various methods. First the temperature sums from 1 and 15 November, or from 1 and 15 December to the time of flowering were calculated for 50 plum varieties at critical temperatures between —3 °C and +3 °C.

The variety for which the lowest CV% value was obtained was also taken into consideration in the individual analyses of varieties.

The temperature sums of varieties from 1 November proved to be most stable between —1 °C and —3 °C, consequently the scatter is the least. Evaluation was made in a similar way for the period between 1 February and the time of flowering.

The constancy of sums of daily mean temperatures between 0 °C and 15 °C from the beginning of flowering to the beginning of ripening was studied both for the varieties as a whole and for each variety separately. The value regarded as threshold with the 50 varieties is naturally different from those calculated for the individual varieties on the basis of percentage scatter.

Accordingly, in the distribution of the 50 varieties by the temperature threshold of flowering, the critical value is —1 °C in 26 varieties, —2 °C in 20 and —3 °C in 4 varieties. In distribution by the temperature threshold of fruit ripening, the lowest scatter of temperature sums was shown with a critical value of 0 °C in 15 varieties, with +2 °C in 8 varieties, and with +5 °C and +7 °C as thresholds in 14 and 13 varieties, respectively, between 1959 and 1970.

The frequency of the four groups was evaluated by Chi^2-test; then correlations between the phenophases and synthetic values were calculated and, of the characteristic and proved correlations, graphs plotted.

Finally, the average time of onset of the individual phenophases of the varieties was determined by variance analyses, with repetitions varying in number with the groups of self-fertility, fruit colour, and temperature thresholds of flowering and ripening, respectively, as partly described in earlier papers in connection with other plum varieties (SURÁNYI 1980a, 1980b, 1980c).

Results and discussion

The monthly and yearly air temperature means during the phenophase investigations are seen in Table 1. A comparison of 30-year mean values reported by VARGA-HASZONITS (1977) for Cegléd, to the data of the 1959–1970 period, reveals that the temperature in that

Table 1

Monthly and annual mean values of air temperature

Year	Months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Aver-age
1959	0.2	0.1	7.9	11.9	16.3	19.4	23.1	20.6	15.5	9.9	6.4	3.4	11.2
1960	—1.9	—0.1	6.2	11.2	15.7	20.6	20.3	21.1	15.4	12.6	5.2	4.1	10.9
1961	—1.3	2.2	8.6	14.2	14.9	20.9	20.1	20.8	18.2	13.0	7.8	4.5	12.0
1962	0.0	0.2	1.8	12.9	15.4	18.7	19.7	23.1	15.1	10.9	6.3	0.0	10.3
1963	—6.9	—5.1	2.8	12.4	17.4	20.8	23.5	21.6	17.6	10.4	6.1	—2.6	9.9
1964	—8.7	—0.3	2.7	12.0	15.9	22.6	21.4	19.4	16.2	10.9	9.5	—5.2	9.7
1965	0.1	—2.1	5.9	9.5	14.4	19.3	21.4	18.4	16.9	9.5	7.0	0.2	10.1
1966	—4.0	6.4	5.9	13.5	17.1	20.2	21.7	20.7	16.8	15.1	2.9	2.1	11.5
1967	—3.1	1.8	7.6	11.4	19.1	20.3	24.8	22.0	19.0	12.6	5.2	1.7	11.9
1968	—2.6	3.2	6.5	14.2	18.3	22.6	22.8	20.0	16.9	11.4	5.3	0.4	11.5
1969	—3.9	—0.3	3.8	11.4	19.6	19.1	22.6	20.5	17.3	11.5	6.8	—1.7	10.6
1970	—2.2	4.5	4.7	11.0	15.1	20.5	22.1	20.7	15.8	10.0	7.9	—2.1	10.6
Mean	—2.8	0.9	5.4	12.1	16.6	19.5	21.9	20.7	17.5	11.6	6.4	0.4	10.8
$LSD_{5\%}$	2.1	1.9	1.8	1.9	0.8	0.9	1.0	0.8	0.9	0.7	1.7	1.8	—

period showed an average trend. The mean temperature of February was higher than the usual average, and the annual temperature mean in 1961 and 1967 similarly exceeded the average. Between 1963 and 1965, on the other hand, the annual mean temperature was far below the average, due mainly to an unusually early (and long) winter (Table 1).

According to the fluctuation of the effective temperature sum calculated from 1 November and 1 February, respectively, the onset of flowering in the 50 plum varieties was the most stable at —1 °C. With any other hypothesis, the CV% was higher. The effective temperature sum of 796.6 °C can relate only to the plum varieties as a whole (Table 2), as confirmed by

Table 2

Average temperature sums required for flowering in the case of different initial dates (on the basis of 12 years)

Initial date / Temperature threshold	Temperature sum, °C	CV%
1 November −1 °C	796.6 ± 39.0	4.9
1 November 0 °C	685.8 ± 55.9	8.1
1 February 0 °C	410.9 ± 27.3	6.6
1 February +3 °C	195.7 ± 41.0	20.9

Table 3

Scatter of active temperature sums required for flower opening in three different groups of biological temperature threshold

Initial date / Temperature threshold	Scatter, CV%		
	—1 °C	—2 °C	—3 °C
	groups of biological zero point		
1 December 0 °C	9.7	11.3	11.0
1 December Biological 0 point	6.1	5.0	4.8
1 February 0 °C	9.8	10.5	10.5
1 February +3 °C	23.7	24.1	23.3
	$SD_{5\%} = 3.45$		

Table 4

Temperature sums of flowering on the basis of average temperatures from 1 November (50 varieties)

Groups	Meteorological		Biological	
	zero point			
	Temperature sum, °C	CV%	Temperature sum, °C	CV%
−1 °C n = 26	682.3 ± 19.0	5.8	797.8 ± 32.1	4.0
−2 °C n = 20	676.4 ± 23.2	5.4	913.0 ± 32.6	3.6
−3 °C n = 4	700.0 ± 10.3	4.5	1030.7 ± 33.4	3.2

Table 5

Temperature sums for flowering calculated on the basis of average temperature data from 1 February (50 varieties)

Groups	Meteorological		Biological	
	zero pointe			
	Temperature sum, °C	CV%	Temperature sum, °C	CV%
−1 °C n = 26	412.2 ± 26.2	6.4	189.9 ± 20.8	10.9
−2 °C n = 20	409.6 ± 21.2	5.2	189.3 ± 16.8	8.9
−3 °C n = 4	416.7 ± 10.3	2.5	191.9 ± 9.2	4.8

Table 6

Average temperature sums required for ripening (on the basis of 12 years)

Temperature threshold	Temperature sum C°	CV%
0 °C	2217.3 ± 78.7	3.5
+ 2 °C	2035.1 ± 89.0	4.4
+ 5 °C	1671.2 ± 70.5	4.2
+ 7 °C	1415.2 ± 95.5	6.7
+10 °C	1080.2 ± 85.6	7.9
+12 °C	839.1 ± 91.3	9.7
+15 °C	485.7 ± 81.7	16.7

Tables 3 and 4: we found the lowest value of scatter when taking the biological zero point of November for basis (Tables 3 and 4). The higher temperature values at the beginning of November and the February calculations indicated too wide a fluctuation, which consequently suggest unreliability (Table 5).

From the temperature means of the period between the beginning of flowering and beginning of fruit ripening, the effective temperature sum was calculated in the threshold range of 0 to +15 °C, and the smallest scatter was found at 0 °C. That is, through the summation of the positive temperature degrees (Table 6), the varieties mostly fit in the 0 °C, +2 °C, +5 °C and +7 °C threshold groups (Table 7). The total temperature sum varied between 2207 °C and 2301 °C in the different varieties, while the active temperature sum of ripening ranged from 1465 °C to 2292 °C, indicating a very wide — some 65 days — interval of ripening in the plum varieties (TÓTH 1957) (Table 8).

We accordingly grouped the varieties on the basis of self-fertility, fruit colour, flowering and ripening temperature threshold; the characterization are contained in Table 9, and

Table 7

Scatter of active temperature sums required for ripening in four groups of biological temperature threshold

Temperature threshold	Scatter, CV%			
	0 °C	+2 °C	+5 °C	+7 °C
	groups of biological zero point			
0 °C	6.8	8.0	11.1	9.5
Biological 0 point	6.8	6.5	8.4	6.0
$SD_{5\%} = 2.51$				

Table 8

Temperature sums required for ripening on the basis of average temperature data between the beginning of flowering and beginning of ripening (50 varieties)

Groups	Meteorological		Biological	
	zero point			
	Temperature sum, °C	CV%	Temperature sum, °C	CV%
0 °C n = 15	2292.4 ± 125.0	5.4	2292.4 ± 125.0	5.4
+2 °C n = 8	2207.5 ± 241.8	10.9	2028.3 ± 87.9	4.3
+5 °C n = 14	2269.7 ± 254.5	11.2	1708.9 ± 158.9	9.3
+7 °C n = 13	2301.8 ± 185.2	8.0	1465.1 ± 102.2	6.9

Table 9

Characterization of plum varieties included in the study

Varieties	Fertility	Fruit colour	Groups of	
			flowering	ripening
Blau Herrenspflaume	SF	B	−1	+2
Kaiser von Milan	SF	B	−1	+5
Königin von Bosnia	SF	B	−1	+5
Besztercei Szilva	SF	B	−1	+7
Bühler Frühzwetsche	SF	B	−1	+7
Anna Späth	SF	B	−2	0
Italian Prune	SF	B	−2	+5
Bódi Szilva	SF	B	−2	+5
Wangenheim	SF	B	−2	+7
Agen	SF	V	−2	+7
Gustave Egger	SF	G	−1	0
Ontario	SF	G	−2	+2
Angoulème	SF	G	−2	+7
Prince of Wales	SF	R	−1	0
Letricourt	SF	Y	−1	+5
Belle de Louvain	PSF	B	−1	0
Early Favourite	PSF	B	−1	+5
Bertha Waschmann	PSF	B	−1	+7
Grand Sugar	PSF	B	−1	+7
Englebert	PSF	B	−2	+7
Gömöri Nyakas	PSF	B	−3	0
Beregi Datolya	PSF	B	−3	+5
Procureur	PSF	V	−1	+7
Haffner	PSF	V	−2	+7
Sasbacher Frühzwetsche	PSS	B	−1	+2
Grand Duke	PSS	B	−1	+5
Frankfurter	PSS	B	−2	0
Dark-blue Eggplum	PSS	B	−2	0
Ruth Gerstetter	PSS	B	−2	+5
Pougna d'Italia	PSS	V	−1	0
Althann	PSS	V	−1	+2
Primate	PSS	V	−1	+7
Szigeti Zöld	PSS	G	−1	0
Green Gage	PSS	G	−1	+2
Angeline Burdett	SS	B	−1	0
Königin der Mirabelle	SS	B	−1	0
Kirke's Plum	SS	B	−1	+2
Montfort	SS	B	−1	+2
Tragedia	SS	B	−1	+5
Daniel	SS	B	−2	+5
Blue Dateplum	SS	B	−3	0
Catalan	SS	B	−3	+7
Pond's Seedling	SS	V	−1	0
Red Nectarine	SS	V	−2	0
Burton	SS	V	−2	+2
Pacific	SS	V	−2	+7
Reine-Claude de Nancy	SS	V	−2	0
Jodoigne	SS	V	−2	+5
Herrnhauser Mirabelle	SS	Y	−2	+5
Washington	SS	Y	−2	+5

Note: SF = self-fertile; PSF = partially self-fertile; PSS = practically self-sterile; SS = self-sterile; B = blue; V = violet; G = green; R = red; Y = yellow

the distribution in Table 10. According to the Chi²-test, the correlations between self-fertility and fruit colour, self-fertility and temperature requirement of flowering, as well as between fruit colour and temperature requirement for ripening are rather definite. Otherwise chance plays an important role (Table 11).

The phenophases and synthetic values of the groups were compared by all aspects of the four groups. The phenophase averages of the varieties show 1–2-day differences, compared with the results published in an earlier paper on other varieties. This suggests that the phenophases and synthetic index numbers are related with definite varietal characteristics, as apparently confirmed by the numerical data (SURÁNYI 1980b).

The data of the flowering-, ripening- and vegetative phenophases are very close to those reported by TÓTH (1957), although the growing sites were different. It is otherwise true that most of the varieties were identical at the two sites. A number of papers mention certain taxonomical problems, but these are mostly restricted to morphological features; nevertheless, such observations may result in a better, more reliable systematization of presently known plum varieties (TÓTH 1957, DAHL 1935, RÖDER 1940, VONDRAČEK 1975, SURÁNYI 1980a).

As to the beginning of leaf colouring and duration of leaf abscission, the groups are similar; while in the case of the other phenophases, significant differences can be pointed out

Table 10

Biological evaluation groups of the plum varieties tested

Characteristics	Flowering groups			Fruit colouring groups				Together
	—1 °C	—2 °C	—3 °C	0 °C	+2 °C	+5 °C	+7 °C	
Blue plums								
SF	5	5	0	1	1	4	4	10
PSF	5	2	2	2	0	2	5	9
PSS	5	3	0	3	2	2	1	8
SS	6	6	2	6	3	3	2	14
Not-blue plums								
SF	3	2	0	2	1	1	1	5
PSF	0	0	0	0	0	0	0	0
PSS	2	0	0	1	1	0	0	2
SS	0	2	0	0	0	2	0	2
Together	26	20	4	15	8	14	13	50

Table 11

Distribution of groups according to the aspects of analyses (Chi²-test)

Correlations	Chi²-value	P%
Self-fertility — Fruit colour	12.1	30
Self-fertility — Flowering groups	7.7	30
Self-fertility — Ripening groups	10.3	50
Fruit colour — Flowering groups	3.6	90
Fruit colour — Ripening groups	12.0	30
Flowering groups — Ripening groups	3.1	90

Table 12

Phenometrical characterization of plum varieties belonging to different fertility groups

Measurement	SF (a)	PSF (b)	PSS (c)	SS (d)	F-value	$LSD_{5\%}$	Significance
Beginning of leaf bud opening (1)	91.3	93.9	90.4	92.1	2.02	1.33	a—b, b—c, b—d, c—d
Beginning of flowering (2)	105.6	105.2	104.4	104.8	1.01	0.76	a—c, a—d, b—c
End of flowering (3)	118.3	116.7	115.7	117.6	1.99	1.17	a—b, a—c, c—d
Length of flowering (3—2)	13.2	11.9	12.0	12.6	1.48	0.72	a—b, a—c
End of shoot growth (4)	184.9	185.1	181.8	183.4	1.06	2.05	a—c, b—c
Length of shoot growth (4—1)	93.5	91.2	91.1	91.3	0.57	2.34	a—c
Beginning of fruit colouring (5)	214.9	210.7	208.8	208.4	1.18	4.40	a—c, a—d
Beginning of flower differentiation (6)	214.0	216.6	215.7	218.5	0.67	2.14	a—b, b—c, c—d
Beginning of fruit ripening (7)	227.4	223.1	221.2	218.9	1.57	4.66	a—c, a—d
Length of ripening (7—5)	12.2	12.4	12.3	10.5	1.35	1.22	a—d, b—d, c—d
Length of fruiting (7—2)	109.0	106.4	106.4	103.5	0.48	5.36	a—d
Beginning of leaf colouring (8)	270.3	269.4	270.3	271.1	2.34	1.76	—
Accumulation (8—4)	85.4	84.3	87.6	88.5	0.99	2.83	a—d, b—d
Beginning of leaf abscission (9)	281.7	280.9	283.3	281.4	0.82	1.52	a—c, b—c, c—d
End of leaf abscission (10)	318.3	317.9	318.5	317.0	1.22	0.94	a—d, c—d
Length of leaf abscission (10—9)	35.5	37.0	35.6	35.6	0.33	1.68	—
Length of vegetation (10—1)	226.1	227.4	227.5	225.1	0.59	2.19	c—d
Length of dormancy (1—10)	138.9	137.6	137.5	139.9	0.61	2.14	b—d, c—d

SF = self-fertile; PSF = partially self-fertile; PSS = practically self-sterile; SS = self-sterile

Table 13

Phenometrical characterization of plum varieties of different fruit colour

Measurement	Blue (a)	Violet (b)	Green (c)	Yellow (d)	F-value	$LSD_{5\%}$	Significance
Beginning of leaf bud opening (1)	92.2	92.3	92.9	89.6	1.33	1.24	a—d, b—d, c—d
Beginning of flowering (2)	105.0	104.7	105.0	105.9	3.48	0.77	a—d, b—d, c—d
End of flowering (3)	117.0	117.3	118.0	118.3	0.35	1.23	a—d
Length of flowering (3—2)	12.4	12.9	12.8	12.2	0.31	0.75	—
End of shoot growth (4)	183.8	183.2	185.6	183.6	0.23	2.10	b—c
Length of shoot growth (4—1)	91.6	91.2	93.1	94.2	0.42	2.35	a—d, b—d
Beginning of fruit colouring (5)	208.9	214.0	206.4	215.5	2.44	4.36	a—b, a—d, c—d
Beginning of flower differentiation (6)	217.7	222.0	226.5	212.2	0.77	6.86	a—c, b—d, c—d
Beginning of fruit ripening (7)	221.6	225.2	219.8	225.2	0.57	4.80	b—c, c—d
Length of ripening (7—5)	12.4	10.4	13.0	9.7	2.50	1.17	a—b, a—d, b—c, c—d
Length of fruiting (7—2)	105.2	109.0	101.9	109.0	1.47	5.37	b—c, c—d
Beginning of leaf colouring (8)	269.5	271.5	268.3	271.9	4.44	1.61	a—b, a—d, b—c, c—d
Accumulation (8—4)	86.1	88.7	82.5	88.8	3.05	2.89	a—c, b—c, c—d
Beginning of leaf abscission (9)	281.9	281.7	280.8	280.3	0.37	1.43	a—d
End of leaf abscission (10)	301.7	317.7	318.3	316.6	0.43	20.48	—
Length of leaf abscission (10—9)	36.0	36.3	35.6	33.8	2.51	1.76	a—d, b—d, c—d
Length of vegetation (10—1)	226.6	225.5	225.4	226.5	1.48	2.44	—
Length of dormancy (1—10)	138.4	139.5	139.6	138.5	1.52	2.45	—

between two or more groups, although much smaller differences might be concluded from the F-value (Table 12).

The phenophases of plum varieties of different fruit colour are shown in Table 13; the length of flowering, the end of leaf abscission and the length of vegetation (and dormancy) were the only phenophases that did not prove significant characteristics in the course of separating the groups. The leaf buds open first in varieties with yellow fruits, consequently it is because of the earlier leaf abscission that the groups become equal in the length of vegetation. It is remarkable that the length of the growth period is shorter in varieties with blue and violet fruits than in those with yellow, green and red ones. The fact that flower bud formation is delayed in the latter varieties — except those with yellow fruits — relates with this. The explanation can be found essentially in the different biological and specific characters of the varieties; the small species (*Prunus insititia*, *P. domestica*, etc.) and their varieties show substantial differences on the basis of the phenophases studied (BRÓZIK 1960, SURÁNYI 1980a, TÓTH 1957, VONDRAČEK 1975). The length of the ripening period is related with the fruit colour, in varieties with blue and green fruits ripening is protracted compared to those with yellow fruit. Similar observations were earlier made by TÓTH (1957) (Table 13).

Grouping by self-fertility and fruit colour does not consequently coincide with the taxonomic classification. The relationships are better reflected by a differentiation on the basis of the temperature thresholds of the two generative phenophases. The successive phenophases generally set in earliest in varieties with a temperature threshold of —2 °C; the —1 °C group is of transitional character, while the —3 °C group is characterized by the latest beginning of phenophases (Gömöri Nyakas, Beregi Datolya, Blue Dateplum and Catalan). Varieties with frost sensitivity, suffering from late frosts, mostly have a flowering temperature threshold of —1 °C. Some authors included in the references do not take the climatic effects during dormancy into consideration, as they sum up the temperature means or hourly temperatures only from the beginning of February. Another essential difference is that the authors established a much higher threshold of temperature than the one in the present

Table 14

Phenometrical characterization of groups with different flowering temperature demands

Measurement	—1 °C (a)	—2 °C (b)	—3 °C (c)	$LSD_{5\%}$	F-value	Significance
Beginning of leaf bud opening (1)	92.9	92.4	95.1	3.19	0.79	a—c, b—c
Beginning of flowering (2)	104.8	104.3	105.9	1.60	0.65	b—c
End of flowering (3)	115.5	115.5	115.9	0.16	0.58	—
Length of flowering (3 — 2)	10.7	11.2	10.0	1.29	0.59	a—c, b—c
End of shoot growth (4)	180.7	179.5	179.1	1.09	1.34	a—c
Length of shoot growth (4 — 1)	87.8	86.9	84.0	1.91	1.53	a—c, b—c
Beginning of fruit colouring (5)	211.2	211.5	216.0	0.30	4.78	a—c
Beginning of flower differentiation (6)	220.2	215.7	227.5	1.02	6.83	b—c
Beginning of fruit ripening (7)	222.8	223.7	228.0	0.38	4.60	a—c
Length of ripening (7 — 5)	11.0	12.2	13.7	1.73	1.30	a—c, b—c
Length of fruiting (7 — 2)	104.9	106.1	115.5	1.24	5.20	a—c, b—c
Beginning of leaf colouring (8)	273.5	272.7	276.1	2.25	1.23	a—c, b—c
Accumulation (8 — 4)	92.8	93.2	97.0	1.49	1.90	a—c, b—c
Beginning of leaf abscission (9)	285.7	285.2	289.8	3.85	1.28	a—c, b—c
End of leaf abscission (10)	317.5	316.2	316.8	1.28	1.10	a—b
Length of leaf abscission (10 — 9)	31.8	31.1	26.9	4.33	1.27	a—c, b—c
Length of vegetation (10 — 1)	224.8	224.3	221.7	1.47	1.43	a—c, b—c
Length of dormancy (1–10)	140.2	140.7	143.3	1.47	1.29	a—c, b—c

Table 15

Phenometrical characterization of groups with different ripening temperature thresholds

Measurement	0 °C	+2 °C	+5 °C	+7 °C	F-value	$LSD_{5\%}$	Significance
Beginning of leaf bud opening (1)	91.8	92.0	91.3	93.1	0.87	1.26	a—d, c—d
Beginning of flowering (2)	104.9	104.5	104.8	105.6	0.69	0.78	a—d, b—d, c—d
End of flowering (3)	117.3	117.7	116.7	117.6	0.28	1.24	—
Length of flowering (3—2)	12.5	13.0	12.4	12.4	0.23	0.75	—
End of shoot growth (4)	183.6	181.8	184.6	184.1	0.24	3.15	—
Length of shoot growth (4—1)	91.0	90.6	93.3	91.5	0.24	3.54	—
Beginning of fruit colouring (5)	211.8	205.9	210.3	213.4	0.89	4.44	a—b, b—c, b—d
Beginning of flower differentiation (6)	218.8	222.1	216.6	219.2	0.17	7.14	—
Beginning of fruit ripening (7)	223.1	217.9	221.6	225.0	0.74	4.63	a—b, b—d
Length of ripening (7—5)	11.3	11.1	12.6	11.5	0.65	1.24	b—c
Length of fruiting (7—2)	107.1	101.8	106.7	107.4	0.89	5.37	a—b, b—d
Beginning of leaf colouring (8)	271.8	266.3	270.5	270.7	4.22	1.50	a—b, b—c, b—d
Accumulation (8—4)	88.2	84.7	86.6	86.2	0.47	3.87	a—b
Beginning of leaf abscission (9)	283.2	281.8	280.7	281.4	1.25	1.50	a—c
End of leaf abscission (10)	317.9	318.2	317.2	318.4	0.65	0.96	—
Length of leaf abscission (10—9)	34.0	36.6	36.4	36.7	1.52	1.62	a—c, a—d
Length of vegetation (10—1)	227.6	226.0	225.8	224.7	0.52	2.53	a—d
Length of dormancy (1—10)	127.4	129.2	129.2	130.3	0.61	2.48	a—d

paper. In possession of data series of several years (OVERCASH 1963, PASCUALE and RUGGIERO 1963, VITANOV 1963, BUDING 1960, KAPETANOVIĆ and PIRNAT 1977), we have also tried the other methods, apart from summing up the hourly temperatures. It is at the very temperature values given that the scatter of the annual temperature sums is the smallest. A satisfactory explantation for this is not provided by the fact that the literary data refer to varieties other than those dealt with in this paper, so it is more likely that the great differences between the accepted thresholds were due to the stringent criterion of scatter value (below 7%) (Table 14).

As to groups set up according to the temperature threshold of ripening, the +5 °C and +7 °C values known by the researchers — strikingly enough — did not prove true for 23 of the varieties tested. We found it reasonable — owing to the 7% (CV) — to separate the groups of 0 °C and +2 °C temperature threshold, which represented 46 per cent of the varieties included in the investigation. The character of flowering, and the intensity of shoot growth were similar, and leaf abscission ended almost at the same time in all groups, the differences appearing mostly in the beginning of flowering, fruit colouring and leaf colouring (Table 15).

On the basis of the four aspects of grouping, a total of 15 group averages were obtained in the case of phenophases and these values were used for correlation analyses. The use of

Table 16

Summary of results of correlation calculations

Correlations between	r-value
Leaf-bud opening and Beginning of flowering	+0.578*
Leaf-bud opening and End of shoot growth	−0.197
Leaf-bud opening and Beginning of fruit colouring	+0.676**
Leaf-bud opening and Beginning of flower differentiation	+0.763***
Leaf-bud opening and Beginning of fruit ripening	+0.507*
Leaf-bud opening and Beginning of leaf colouring	+0.294
Leaf-bud opening and Beginning of leaf abscission	+0.527*
Beginning of flowering and End of shoot growth	+0.204
Beginning of flowering and Beginning of fruit colouring	+0.746***
Beginning of flowering and Beginning of flower differentiation	−0.272
Beginning of flowering and Beginning of fruit ripening	+0.822***
Beginning of flowering and Beginning of leaf colouring	+0.491+
Beginning of flowering and Beginning of leaf abscission	−0.256
End of shoot growth and Beginning of fruit colouring	−0.743***
End of shoot growth and Beginning of flower differentiation	+0.505*
End of shoot growth and Beginning of fruit ripening	−0.057
End of shoot growth and Beginning of leaf colouring	+0.218
End of shoot growth and Beginning of leaf abscission	−0.598*
Beginning of fruit colouring and Beginning of flower differentiation	+0.701**
Beginning of fruit colouring and Beginning of fruit ripening	+0.918***
Beginning of fruit colouring and Beginning of leaf colouring	+0.384
Beginning of fruit colouring and Beginning of leaf abscission	−0.980***
Beginning of flower differentiation and Beginning of fruit ripening	−0.330
Beginning of flower differentiation and Beginning of leaf colouring	+0.693**
Beginning of flower differentiation and Beginning of leaf abscission	−0.234
Beginning of fruit ripening and Beginning of leaf colouring	+0.579*
Beginning of fruit ripening and Beginning of leaf abscission	+0.399
Beginning of leaf colouring and Beginning of leaf abscission	+0.743***

+ p = 10%, * p = 5%, ** p = 1%, *** p = 0.1%

these values was thought acceptable because the trends thus obtained agreed in essentials with the results of calculations made on the basis of botanical categories with the representative cultivars (SURÁNYI 1980a) and with the total number of varieties (SURÁNYI 1980b).

The *r*-values of calculations are contained in Table 16. It is remarkable that a large proportion of the significant correlations are positive, although the end of shoot growth and beginning of leaf abscission show a very close negative correlation with some phenophases. The most characteristic correlations are summarized in Table 16; they confirm our earlier analyses in several respects. The beginning of the phenophase of flower differentiation — since the latter was studied in 1969–1971 — was taken into consideration on the basis of the average of the mentioned years. Therefore the phenophase data of 1971 were, in fact, also processed for the purpose of correlation calculations.

The phenometrical examinations of plum varieties are completed with this paper. Subsequently we wish to carry out detailed studies on the floral morphology of the same cultivars. The reporting of the historical varieties called attention to many new aspects of cultural botany researches, which can be applied in our current research work, generally in the evaluation of the large number of introduced *Prunoideae*. The completion of the work at Cegléd formed, in fact, the continuation of the work done earlier by TÓTH (1957) and elsewhere (TÓTH and SURÁNYI 1980), this also means the end of the evaluation of the variety collection of the fifties, because the plantation will be liquidated since a number of varieties of lower production value will not be kept in cultivation.

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EFFECT OF IRON APPLIED THROUGH THE LEAVES OR SOIL ON THE GROWTH AND NUTRIENT CONTENT OF RICE PLANTS

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The dry matter yield increased by the foliar applied-Fe and maximum yield was recorded at 30 ppM $FeSO_4$. The Fe content increased in tops, with increased rate of Fe application. The soil applied-Fe decreased the dry matter yield and content of iron in the tops. P content increased in foliar applied-Fe plants, while a consistent decrease was observed in the case of soil applied-Fe. Foliar application of nutrient seems to be a better fertilizing method, than soil applied method.

Introduction

Iron is considered to be a trace element as far as plant nutrition is concerned; though the total content of iron in soils is high, the amount available to the plant is low. There are many factors such as the pH, $CaCO_3$ and HCO_3^+ content of the soils, interacting trace metal effects, P content, as well as the aeration status of the soil (BROWN 1961, LUCAS and KNEZEK 1972, WALLACE and LUNT 1960) that are all known to influence the uptake of iron; by plants.

According to BROWN (1961) one third of iron disorders in plants are found to occur in calcareous soils in arid and semi-arid regions of the world. Several investigators (MATHERS 1970, MORACHAN *et al.* 1971, MORTVEDT and GIORDANO 1971, OLSON 1951, REUSS and LINDSAY 1963, WITHEE and CARLSON 1959) have used soil and foliar applications of iron compounds with variable success for the control of iron chlorosis in crop plants like grain sorghum and field beans.

Soil applications of inorganic iron salts are not effective in correcting iron deficiencies because soil-applied Fe is precipitated and is not efficiently utilized by plants when applied directly to the soil. Foliar application of Fe seems to be a more acceptable and efficient method for correcting Fe deficiencies than do soil applications (MURPHY and WALSH 1972).

Considering the importance of foliar sprays of Fe on crops, an experiment was planned to study the effect of soil and foliar applications of Fe on the rice plant.

Materials and methods

A pot culture experiment was set up to study the effect of Fe on the dry matter yield and nutrient content of rice plants. The mode of application of the nutrient was foliar spray and soil applications with variable levels (0, 10, 20, 30 and 50 ppm) of ferrous sulphate in 3 replications. One-month-old rice seedlings (cv. IR-6) were transplanted with 3 seedlings per pot, each containing 4.5 kg of medium soil with a pH of 7.8. Basic fertilizer doses (133.3 kg/ha) in the form of ammonium sulphate, 66.6 kg P_2O_5/ha in the form of T.S.P. and 44.4 kg K_2O/ha (as potassium sulphate) were provided to all the pots.

Plants were allowed to grow under submerged conditions throughout the growth. After one week, when the seedlings had fully established themselves iron solution was sprayed onto the plant leaves and a similar iron solution was also applied to the soil.

The plants were harvested after 2 and 4 weeks of iron applications. The samples were washed in distilled water three times and then oven-dried for dry weight determination. The dried materials were chopped into small pieces with stainless steel scissors and mixed uniformly, and a known weight from the respective treatment was put in a conical flask and digested using nitric-sulphuric-perchloric acids. The total iron, manganese and phosphorus were determined colorimetrically as outlined by JACKSON (1958).

Results and discussion

The results of the study are summarized in Table 1 and are discussed below.

Dry matter yield. The dry matter yield of rice plants increased gradually due to foliar-applied iron up to 45 and 60 days of growth (Table 1). This increase in dry matter yield was probably due to an increased Fe supply on the foliage of the rice plant, which was also evident from data on iron uptake by the plant leaves (Table 1). The dry matter yield increased up to 30 ppm at both harvests, above which the yield slightly decreased but was still more than that recorded in the control. The decrease in dry matter yield at higher iron concentrations seems to be due to an ionic imbalance created by the higher iron content in the soil medium. The foliar-applied iron generally accumulated in the plant leaves with an increased rate of iron application. The increase was regular and consistent at the first sampling, but at the second sampling it increased up to 20 ppm, then a slight decrease was observed. The addition of iron to the growth medium has been reported to result in an increase in the iron content of plant tissues (EPSTEIN and STOUT 1951, NAGARAJAH and ULRICH 1966, TANAKA and NARASERO 1966).

Soil-applied iron had a marked effect on the growth of the rice plant. The increased iron level resulted in decreased growth at both harvests. The Fe content in the rice plant

Table 1

Effect of iron on the dry matter yield and nutrient content of rice plants

Levels of $FeSO_4$ (ppm)	Dry matter yield	Nutrient content		Dry matter yield	Nutrient content	
	g/plot	Fe (ppm)	P%	g/plot	Fe (ppm)	P%
			Foliar-applied Fe			
	1st sampling (45 days)			2nd sampling (60 days)		
0	0.75	215	0.17	1.43	256	0.12
10	0.82	335	0.21	1.75	269	0.13
20	0.98	347	0.21	1.89	306	0.14
30	1.21	356	0.24	1.90	279	0.14
			Soil-applied Fe			
10	1.25	210	0.17	1.65	245	0.13
20	0.82	195	0.16	1.55	235	0.11
30	0.87	185	0.13	1.43	210	0.12
50	0.61	172	0.12	1.40	179	0.10

decreased with increased soil-applied Fe at both samplings. With an increase in iron application from 0 to 50 ppm, the iron concentration decreased from 215 to 172 ppm and from 256 to 179 ppm at 45 and 60 days, respectively. BROWN and HENDRICKS (1952) and DINGRA *et al.* (1965) attributed the reduction in iron availability to excessive $CaCO_3$, a component of calcareous soils, causing the conversion of Fe^{2+} to insoluble ferric hydroxide or ferric oxide. At both harvests there was a consistent decrease in Fe content in the leaves with soil-applied Fe; however, at 60 days the Fe content was more than that at 45 days, which was probably due to the high dry matter production.

The metabolic control of iron absorption from the soil to plant roots and its translocation within the plant system is envisaged as consisting of the following steps (TIFFIN 1966): (i) The release of H^+ by the roots lowers the pH of the root zone and thereby favours Fe^{3+} solubility and reduction to Fe^{2+}, (ii) Ferrous iron enters the root, probably by a carrier mechanism, (iii) The absorbed Fe^{2+} is oxidized to Fe^{3+}, chelated by citrate and transported in the xylem to the above-ground plant parts. The effectiveness of soil-applied Fe in the utilization of Fe decreased, probably due to reactions between the applied iron and soil bicarbonate and because of the already prevailing chemical environment of the cell sap.

There was a gradual increase in P concentration at both stages of growth with foliar-applied Fe. This shows that there was probably no interaction between Fe and P within the plant leaves. The application of 0 to 50 ppm iron to the soil decreased the P concentration in plant tops from 0.17 to 0.12% at 45 days and from 0.13 to 0.10% at 60 days of growth, which may be due to the formation of ferric phosphate in the soil system (KITTRICK—JACKSON 1956). WATANABE *et al.* (1965) and TWYMAN (1951) found a decrease in P concentration in plant leaves with an increase in iron application.

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INTERACTION EFFECTS OF P—Zn AND P—Cu ON DRY MATTER YIELD AND MICRONUTRIENT AVAILABILITY TO RICE IN WATER-LOGGED ALFISOLS

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A pot experiment using rice (*Oryza sativa*, variety China-988) as a test crops, to ascertain the effects of interactions of P—Zn and P—Cu on dry matter yield and micronutrients availability under water-logged Alfisols was conducted. The application of 120 ppm P and 10 ppm Zn produced the maximum dry matter yield.

In general, the P applications reduced the concentration of Zn, Cu, Fe and had no effect on Mn in rice plants both at 30 and 60 days of growth periods. However, when the effect of P was studied in light of P—Zn interaction, the concentration of all the four micronutrients got reduced upon P applications both under zero as well as under 10 ppm Zn application at both the growth stages. Similarly the Zn application though increased its concentration, got reduced the concentration of other three micronutrients both in Zero Zn supplied and Zn supplied plants.

The Cu application was observed to increase the concentration of Fe and Mn and decrease to that of Zn when applied in absence of P both at 30 and 60 days of growth periods. But its applications under P additions had no effect on Fe and Mn and increased to that of Zn concentration at both the growth stages. The applications of P increased the Zn concentration under Cu additions and reduced it under zero Cu level.

Introduction

Antagonism and synergysm are well known interactions among various micro elements and between micro and macro elements in the process of absorption, translocation and other functions of plant growth (BROWN 1963). These phenomena, however, have been studied mainly in upland plants such as wheat (GATTANI *et al.* 1976), maize (SAFAYA 1976), barley (DOKYA and MITSUI 1968) and beans (SHÜTTE 1964).

The physico-chemical regime of water-logged soils is quite different to those of upland soils. The availability of some of the nutrients is increased upon waterlogging, while that of others is subject to greater inactivation and fixation. These changes in turn are responsible for great variation in nutrient requirements between lowland and upland crops. Hence, the interactions among various nutrients in such soils may not be the same as are observed in upland soils.

Keeping this in view, the present study reports the results of a pot experiment in which the effect of P—Zn and P—Cu interactions on dry matter yield and micronutrient availability to rice under water-logged Alfisols was studied.

Materials and methods

Clayey thermic napludalfs was the test soil (pH 5.4, organic matter 1.21%, $CaCO_3$ 0.25%), collected from the surface 0–15 cm from the farm of Himachal Pradesh Agricultural University, Palampur (H.P.), India. It was found to be low in available P (Olsen's P, 4.0 ppm) and contained 5.20, 8.76, 0.18 and 0.23 ppm DTPA-extractable Fe, Mn, Cu and Zn respectively. The soil was air-dried and sieved through plastic mesh, after which 5 kg was weighed into each enamel pot. The treatments consisted of three levels of P, i.e. 0 ppm P (P_0), 120 ppm (P_1) and 240 ppm (P_2); two levels of Zn, i.e. 0 ppm Zn (Zn_0) and 10 ppm Zn (Zn_1); and two levels of Cu, i.e. 0 ppm Cu (Cu_0) and 10 ppm Cu (Cu_1). All possible combinations of P and Zn and P and Cu were tested, making the total number of treatments twelve. There were three replications for each treatment. The P was applied as NaH_2PO_4, while Zn and Cu were supplemented as $ZnSO_4$ and $CuSO_4$ respectively. A basal dose of N and K at a rate of 75 and 50 ppm respectively was provided to each pot. The treatments and other basic nutrient inputs were applied as concentrated solutions and mixed with the entire bulk of soil in each pot.

The soil was puddled by hand with the addition of deionized water, and twenty-day-old seedlings of rice (*Oryza sativa*, variety China-988) were transplanted at the rate of five seedlings per pot and two seedlings per hill. The plants were allowed to grow to the flowering stage under submerged conditions by the addition of deionized water from time to time to maintain a water level 3 cm above the soil surface. After a growth period of thirty days (S_1), the above ground portion of one plant from each pot was harvested. The remaining four plants were harvested after a growth period of sixty days (S_2). The plant samples at growth periods S_1 and S_2 were washed first with deionized water, then with 0.01 N HCl, followed by four washings with deionized water. They were dried in an oven at 60 °C to a constant weight. The plant samples from these two growth stages were separately ground in a multimixer having a glass container and steel blade, and were subsequently digested with a diacid mixture (HNO_3—HCO_4) for the determination of Zn, Cu, Fe and Mn on an atomic absorption spectrophotometer.

Results and discussion

Dry matter yield

The data pertaining to the interaction effects of P—Zn and P—Cu on the dry matter yield of rice are shown in Figs 1 and 2. A study of these figures indicates that in general P applications increased the dry matter yield of rice significantly when it was applied either with Zn or with Cu. However, the maximum increase in dry matter yield was recorded up to 120 ppm P application, while a further increase in its application had a depressing effect on dry matter yield. The increase in dry matter yield due to P applications might be because of the low native P status (Olsen's P 4 ppm) of the soil used for the present investigation. Similarly, the application of Zn in general also increased the dry matter yield, while the application of Cu had no significant effect on the dry matter yield of rice.

A study of P—Zn and P—Cu interactions indicates that only the P—Zn interaction had a significant effect on dry matter yield. The application of Zn increased the dry matter yield when it was applied either alone or in combination with 120 ppm P. The application of P increased the dry matter yield significantly up to a dose of 120 ppm. However, a further increase in the P level had no significant effect on dry matter yield at 0 ppm Zn level, but

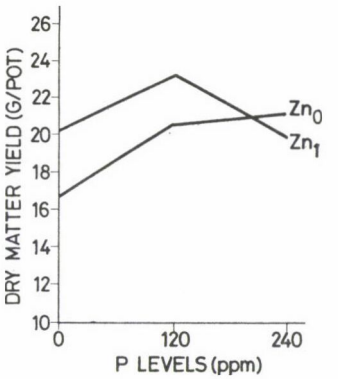

Fig. 1. Interaction effect of P—Zn on dry matter yield

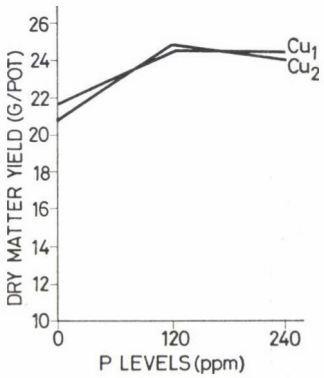

Fig. 2. Interaction effect of P—Cu on dry matter yield

at 10 ppm Zn level the dry matter yield was depressed significantly on a further increase in P levels. Thus, it can be inferred that for the soil under study, a combined application of 120 ppm P and 10 ppm Zn was ideal for producing the maximum rice yield.

Zinc concentration

The concentration of Zn in plants was several times higher in Zn supplied plants compared to those receiving no Zn (Fig. 3). Phosphorus reduced the Zn concentration significantly in both O—Zn and Zn supplied plants, though the Zn concentration in the latter appeared to be unaffected by the application of 0 and 120 ppm P after both 30 and 60 days of growth. These observations were similar to those reported by STUKENHOLTZ *et al.* (1966), PATHAK *et al.* (1975) and WALLACE *et al.* (1978), who reported that P applications reduced the Zn concentration in the above-ground portion of plants, while its applications increased the Zn concentration significantly in the roots, thus indicating a reduced translocation of Zn to plant shoots. SNEHI *et al.* (1975) and SAFAYA (1976) have also reported that P rendered the applied Zn unavailable to the plant shoots by immobilizing almost 40% or more of the total absorbed Zn in the roots. The effect of a low rate of P application on Zn translocation in plants could be counterbalanced by Zn application, but when a higher rate

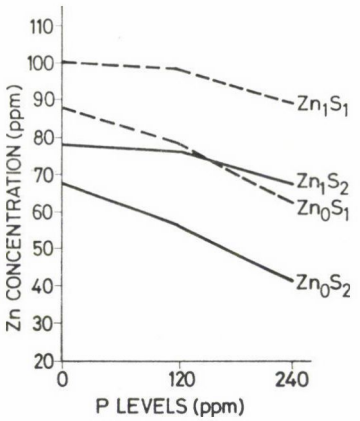

Fig. 3. Interaction effect of P—Zn on Zn concentration

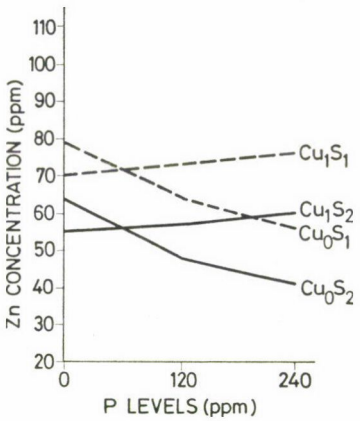

Fig. 4. Interaction effect of P—Cu on Zn concentration

of P was applied, the Zn application (at the rate of 10 ppm) could not overcome the inhibitory effect of P on Zn translocation, resulting in a significant reduction in Zn concentration in Zn supplied plants.

The results for the P—Cu interaction on Zn concentration are shown in Fig. 4. The application of P reduced the Zn concentration in plants when applied without Cu. But when Cu was applied, the P applications significantly increased the Zn concentration in plants at both 30 and 60 days of growth. Copper applications depressed the Zn concentration in plants with O—P application, but increased its concentration in P supplied plants after both 30 and 60 days of growth. From these results it can be inferred that in rice plats Cu had an antagonistic effect on Zn concentration without P application, but the application of P totally reversed this antagonism between Cu and Zn and the application of P and Cu together increased the Zn concentration in plants, indicating that the adverse effects of P and Cu on the Zn concentration in rice were reduced by the application of Cu and P, respectively. These observations are supported by the findings of BROWN *et al.* (1955), who reported that P and Cu when added together were found to be very effective in limiting the absorption and utilization of Fe and increasing that of Zn in rice plants.

Copper concentration

The application of P in general decreased the Cu concentration in rice plants both after 30 and 60 days of growth (Fig. 6). Contrary to this, Cu applications increased its concentration in rice at these two stages of rice growth. The interaction between P—Cu was found to be significant only after a growth period of 60 days. At this stage P

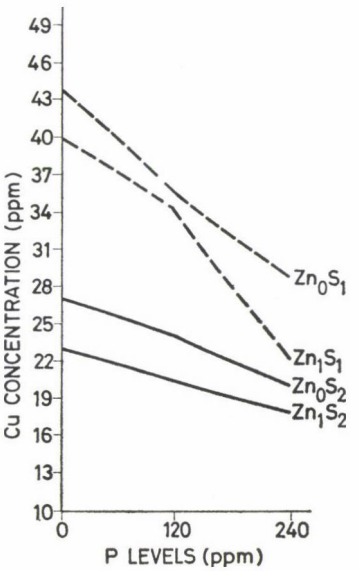

Fig. 5. Interaction effect of P—Zn on Cu concentration

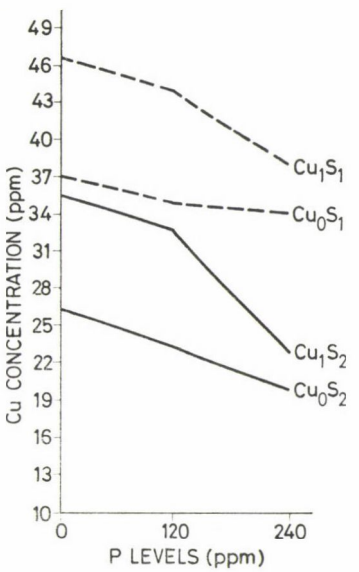

Fig. 6. Interaction effect of P—Cu on Cu concentration

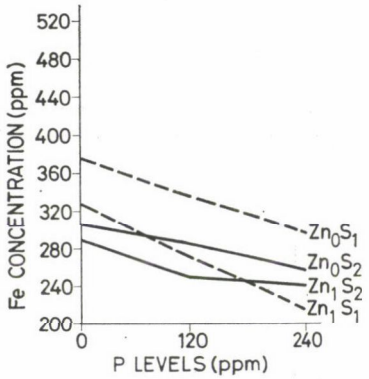

Fig. 7. Interaction effect of P—Zn on Fe concentration

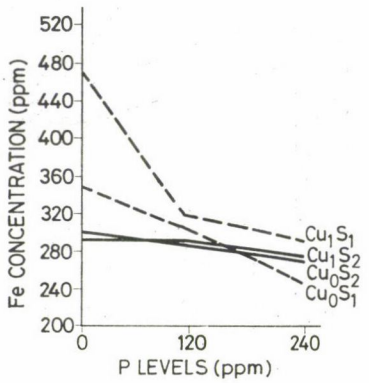

Fig. 8. Interaction effect of P—Cu on Fe concentration

applications reduced the Cu concentration significantly only at its highest level of application both for zero Cu and 10 ppm Cu application. On the other hand, Cu applications increased its concentration at all levels of P applications, with a minimum increase at the highest level of P application. The decrease in Cu concentration due to P application was in accordance with the findings of SPENCER (1966), HULAGAR *et al.* (1975) and WALLACE *et al.* (1978), who reported that P applications reduced the Cu concentration in plants due to the suppressed availability of Cu in the soil. The P applications had little effect on the reduction of the Cu concentration in rice after a 30-day growth period compared to the 60-day growth period both for the zero Cu and the 10 ppm Cu treatments. In the present study the rate of Cu absorption was found to be faster during the early growth period (up to 30 days) and remained mostly unaffected by P applications. But in the subsequent period (30 to 60 days) the rates were found to be considerably reduced by P applications. Similar results for Cu absorption in relation to P levels have also been reported by SAFAYA (1976).

The application of P and Zn individually reduced the concentration of Cu in rice plants after both 30 and 60 days of growth (Fig. 5). LONERAGUM (1970), CHAUDHRY *et al.* (1973) and SAFAYA (1976) have also reported a reduction in Cu concentration due to P application in wheat, maize and rice, respectively.

Iron concentration

Like Zn and Cu, the concentration of Fe decreased in general after P applications both at 30 and 60 days of growth when its effect was studied either in combination with Zn or in combination with Cu (Figs 7 and 8). Similarly, the application of Zn also decreased the Fe concentration at both these growth stages. Contrary to this, the application of Cu increased the Fe concentration at both the growth stages. However, at 30 days of growth, the application of Cu increased the Fe concentration significantly at zero P application, but had no significant effect on the Fe concentration in P supplied plants. After 60 days of growth, the Cu application did not affect the Fe concentration significantly, regardless of whether P was applied or not. It can be inferred from this that during the early growth stages the application of Cu increased the Fe concentration in rice plants, but its

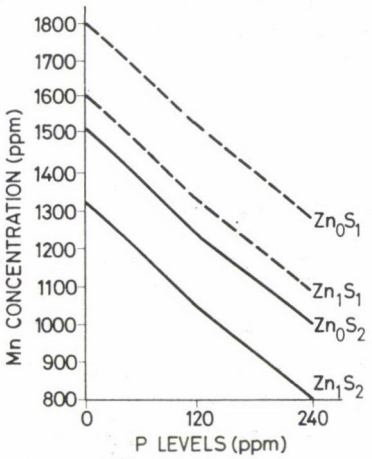

Fig. 9. Interaction effect of P—Zn on Mn concentration

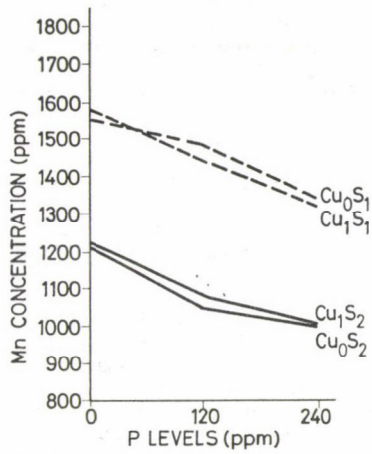

Fig. 10. Interaction effect of P—Cu on Mn concentration

beneficial effect on Fe concentration was reduced when it was applied together with P applications. Similar results have also been reported by BROWN *et al.* (1955).

Similar to some previous observations (WARNOCK 1970 and ADRINE *et al.* 1971), the application of Zn depressed the concentration of Fe in rice tops. This might be due to the antagonistic effect of Zn on Fe at root surfaces or in the roots themselves.

Manganese concentration. The application of P decreased the Mn concentration at 30 and 60 days of growth when its effect was studied in combination with Zn (Fig. 9), but when its effect was studied along with Cu, the applications had no significant effect on the Mn concentration in rice plants (Fig. 10). Similarly, the application of Zn reduced the Mn concentration, while the application of Cu did not show any significant effect on the Mn concentration. ISHIZUKA—ANDO (1968) also reported a reduced Mn concentration due to Zn application which they ascribed to decreased Mn absorption due to Zn application. From this it can be observed that both P and Zn had antagonistic effects on the Mn concentration in rice, but the antagonism of P with Mn was reduced considerably by the application of Cu, as is clear from a study of Fig. 10, where the application of P did not reduce the Mn concentration significantly when combined with Cu additions.

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INFLUENCE OF NITROGEN FERTILIZER AND PLANT DENSITIES ON YIELD AND YIELD COMPONENTS OF HEXAPLOID TRITICALE AND WHEAT

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In experiments over two years with two hexaploid triticale and two wheat varieties conducted under rainfed conditions at two locations: Kecskemét and Szeged, Hungary, the effects of six rates of nitrogen fertilizer and two plant densities on yield and yield components were studied.

Results indicated that all varieties grown at Kecskemét in both seasons produced higher grain yields than in Szeged, and there were no differences over all experiments between varieties in grain yield. The number of spikelets/spike, number of kernels/spike, weight of kernels/spike and spike length in triticale varieties were significantly more than in the two wheats. The maximum rate of N to result in yield response in the two triticale varieties was 90 kg/ha and in the two wheat varieties 120 kg/ha. Grain yield was not affected by plant density, but the number of spikes/m² increased significantly.

Introduction

Hexaploid triticale, a hybrid between wheat (*Triticum turgidum* L., *Triticum durum* L.) and rye (*Secale cereale* L.), seems to possess a great potential as one of the crops of the future (KISS and RÉDEI 1952 and ZILLINSKY and BORLAUG 1971). Triticale is now grown commercially in many countries on more than one million hectares (CIMMYT Review, 1981) and developing countries are expected to catch up very soon.

Environmental factors play a very important role in the realization of the genetic potential of triticale and wheat varieties through their effect on growth, yield and yield components. However, the highest grain yield is obtained when all yield components are optimized for a specific environment.

The present study was organized to evaluate the effect of nitrogen application rate and plant density on yield and yield components of hexaploid triticale and wheat grown at two locations.

Materials and methods

Two varieties of hexaploid triticale (×*Triticosecale* Wittmack) namely, Beagle from CIMMYT, Mexico; KT-77 and two wheat varieties namely, GK Szeged; GK Tiszatáj from Hungary were used in this study. In 1978–79 and 1979–80 split-split plot experiments, in four-replicates, were grown at each of the two locations (Crop Research Farm, Kecskemét and Experimental Station, Szeged, Hungary) with varieties as the main plots, plant density

(400 and 600 germs/m²) as subplots and nitrogen levels as sub-subplots. Each plot was 5.5 m long, 36 rows wide, with 12.5 cm row spacing.

Prior to planting, germination tests were made and the seed weight value obtained for each variety. Both factors were used to calculate seeding rates of 400 and 600 germs/m². Field experiments were fertilized with 0–100–100 kg/ha (N—P—K) during seed bed preparation. Six levels of nitrogen 0, 30, 60, 90, 120 and 150 kg N/ha of ammonium nitrate (34–0–0) were included. Nitrogen was given in two doses: at early spring (early March) before plants began their spring growth and at the time of stem elongation (late April).

The experiments in both locations were planted on October 26–28, 1978 and October 17–19, 1979 during the first and second season, respectively. The plants of the inner 32 rows of each plot were harvested by a Hege 125 harvesting combine on July 12–20, 1979 in the first season and on July 22–30, 1980 in the second season.

Traits measured on each plot at each location included grain yield (weight of grain from the inner 32 rows wide and 5 m long), number of spikes/m², number of spikelets (spike/

Table 1

Means of grain yield (kg/plot) *of triticale and wheat varieties grown under two population densities and six rates of nitrogen fertilizer at two locations during the 1979 and 1980 seasons*

Treatments	Kecskemét		Szeged		Combined means+
	1979	1980	1979	1980	
Variety					
Beagle	5.34	12.93	4.38	12.14	8.70a
KT-77	6.98	11.82	5.84	10.92	8.89a
GK Szeged	5.00	14.26	3.69	12.66	8.90a
GK Tiszatáj	7.51	12.49	5.76	11.89	9.41a
F-test	**	**	**	**	
LSD at 5%	0.93	0.39	0.19	0.94	
Plant density (germs/m²)					
400	5.84	12.80	4.79	11.81	8.81a
600	6.57	12.95	5.05	12.00	9.14a
F-test	**	Not	*	Not	
LSD at 5%	0.32	sig.	0.21	sig.	
Nitrogen rate (kg/ha)					
0	4.79	10.92	3.98	10.12	7.45e
30	5.81	12.19	4.31	11.14	8.36d
60	6.45	13.00	4.76	11.96	9.04c
90	6.78	13.54	5.33	12.69	9.59b
120	6.87	13.86	5.52	12.88	9.78a
150	6.55	13.74	5.61	12.63	9.63ab
F-test	**	**	**	**	
LSD at 5%	0.38	0.35	0.21	0.35	

+ Means followed by the same letter are not significantly different at the 0.05 level of probability

* Significant at the 0.05 level of probability

** Significant at the 0.01 level of probability

Table 2

Means of number of spikes/m² of triticale and wheat varieties grown under two population densities and six rates of nitrogen fertilizer at two locations during the 1979 and 1980 seasons

Treatments	Kecskemét		Szeged		Combined means+
	1979	1980	1979	1980	
Variety					
Beagle	220.9	591.8	187.8	533.8	383.6c
KT-77	314.4	653.4	217.2	591.0	444.0b
GK Szeged	263.6	562.3	124.5	541.2	372.9c
GK Tiszatáj	337.5	682.1	236.8	621.0	469.4a
F-test	**	**	**	**	
LSD at 5%	44.9	14.7	13.9	22.1	
Plant density (germs/m²)					
400	261.7	559.5	179.7	517.3	379.6b
600	306.5	685.3	203.6	626.2	455.4a
F-test	**	**	**	**	
LSD at 5%	10.4	18.8	9.1	25.1	
Nitrogen rate (kg/ha)					
0	232.6	544.6	157.0	486.6	355.2d
30	262.1	590.6	178.2	529.6	390.1c
60	292.1	631.7	189.2	562.4	418.9b
90	295.8	654.9	204.7	613.7	442.3ab
120	305.0	650.6	205.2	622.4	445.8ab
150	317.0	662.0	215.3	615.8	452.5a
F-test	**	**	**	**	
LSD at 5%	12.3	13.3	9.8	15.8	

+ Means followed by the same letter are not significantly different at the 0.05 level of probability

** Significant at the 0.01 level of probability

average for 20 random spikes), number of kernels/spike, weight of kernels/spike, spike length and 1000-kernel weight (average of two 200-kernel samples). The data from each experiment for each character were analyzed statistically as a split-split plot design according to SNEDECOR and COCHRAN (1974).

Results

Grain yield (kg/plot) was significantly affected by variety and nitrogen fertilizer in both seasons and locations, but by plant density only during the first season (Table 1). Each variety produced significantly higher grain yield during 1980 than in 1979 in both locations. However, all triticale and wheat varieties grown at Kecskemét in both seasons produced higher grain yield than in Szeged. Also, grain yield for triticale "KT-77" and wheat "GK Tiszatáj" were higher than those of other varieties during the first season in both locations, but lower in the second season.

When averaging grain yield over all varieties and two populations, application of 120 kg N/ha produced higher grain yield with significant differences over the various nitrogen levels tested (Table 1). On the other hand, when averaging grain yield over all experiments, application of nitrogen at levels of 90 and 120 kg/ha gave significantly more grain yield of triticale and wheat, respectively, as shown in Fig. 1.

The highest number of spikes/m² was obtained in the second season in both locations; however, all varieties under study grown at Kecskemét during the two seasons produced

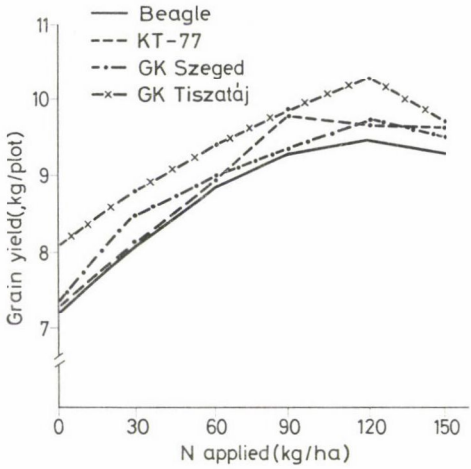

Fig. 1. Effect of nitrogen fertilizer on grain yield (kg/plot) of triticale and wheat varieties over two locations and two seasons

significantly higher number of spikes/m² than in Szeged (Table 2). The average number of spikes/m² over all experiments ranged from 469.4 for wheat "GK Tiszatáj" to 372.9 for wheat "GK Szeged" and both triticale varieties were significantly below wheat "GK Tiszatáj". Increased plant density significantly increased the number of spikes/m² in each experiment. Table 2 also indicates that application of 90 kg N/ha increased significantly the number of spikes/m² in both seasons and locations.

Yield components of the varieties and the effects of plant density and rates of nitrogen application over two seasons and locations are presented in Table 3.

The number of spikelets/spike, number of kernels/spike, weight of kernels/spike and spike length in the two triticale "Beagle; KT-77" varieties were significantly more than in all wheat varieties. However, triticale KT-77 variety had the highest number of spikelets/spike, number of kernels/spike and longest spike but had the lowest of 1000-kernel weight as compared to any other variety and no significant differences were observed within wheat varieties for number of spikelets/spike, number of kernels/spike and 1000-kernel weight, while "GK Tiszatáj" had the lowest weight of kernels/spike.

Application of nitrogen fertilizer at higher levels significantly increased the mean of yield components in triticale and wheat varieties, except for the weight of 1000-kernel which was reduced but remained unaffected at lower levels in each experiment. Moreover, the mean of yield components in each variety under study was not significantly affected when population density increased from 400 to 600 germs/m².

Table 3

Effect of plant density and nitrogen fertilizer on yield components of triticale and wheat varieties over two seasons and two locations

Treatments	No. of spikelets per spike	No. of kernels per spike	Weight of kernels per spike (g)	Length of spike (cm)	1000-kernel weight (g)
Variety					
Beagle	23.22b*	48.67b	2.19a	10.67b	43.44a
KT-77	28.00a	59.50a	2.22a	10.98a	35.78c
GK Szeged	16.20c	39.58bc	1.68b	7.41d	38.57cb
GK Tiszatáj	16.58c	34.80c	1.42c	8.92c	40.21ab
Plant density (germs/m²)					
400	21.25a	46.04a	1.91a	9.56a	39.65a
600	20.74a	45.24a	1.84a	9.43a	39.34a
Nitrogen rate (kg/ha)					
0	20.00e	42.98f	1.74c	8.95d	40.06a
30	20.55d	44.04e	1.80d	9.24c	40.05a
60	21.05c	45.42d	1.87b	9.49b	39.79a
90	21.19c	46.32c	1.93a	9.59b	39.40a
120	21.46b	47.03b	1.97a	9.84a	38.94b
150	21.75a	48.04a	1.97a	9.85a	38.75b

* Means followed by the same letter are not significantly different at the 0.05 level of probability

Discussion

The results of the present investigation suggest that the minimum N requirements of the two triticale varieties were not less than 90 kg N/ha whereas 120 kg N/ha proved satisfactory for the two wheat varieties, and application of nitrogen in greater amounts than needed for maximum response did not decrease yield. Highly significant positive correlations were obtained between grain yield and number of spikes/m². These results are in agreement with ZILLINSKY and LÓPEZ (1973), KISS (1975), MISRA (1977) and AGARWAL (1977, 1979). Who found that application of nitrogen from 60 to 100 kg/ha was required for the best performance of triticale depending on season, strain and fertility level of the soil. GAJARDO *et al.* (1978) affirmed that with increasing N levels, yield and yield components, except kernels/spike, increased in a wheat variety, whereas spike number, kernels/spike and yield increased significantly in a triticale line with kernel weight remaining constant.

Increasing population density from 400 to 600 germs/m² resulted in little or no change in yield and yield components due perhaps to the narrow-range densities used in this study. Similar results were obtained by KISS *et al.* (1977) and KISS (1980) who found that grain yields of triticale and wheat varieties were not significantly affected by plant density but number of spikes/m² increased significantly.

Also, GEBRE-MARIAM and LARTER (1979) reported that grain yield was not significantly affected. 1000-kernel weight, number of kernels/spike and number of fertile spikes/plant exhibited a highly significant linear decrease with increased plant density.

All triticale and wheat varieties produced significantly higher grain yield during the 1980 season than in the 1979 season in both locations. Therefore, further studies are to be carried out at different locations in different years to identify the effect of those environmental components that are likely to be important in establishing the agricultural values of genotypes.

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A STUDY OF ORDER EFFECT FOR HARVEST INDEX IN WHEAT DOUBLE-CROSS HYBRIDS

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Two-hundred-ten double cross hybrids produced by crowwing 28 wheat F_1s (involving 8 varieties) were grown to study various general and specific line effects and variances for harvest index. The variety Norteno 67 showed highest positive average effect and made the most effective combinations with other parents in 2-line, 3-line and 4-line effects when no specific arrangement of parents was followed. The order of parents in which they were involved in a double cross hybrid was the deciding factor for its (hybrid) performance.

Introduction

Although the details of double-cross analysis were available as early as in 1962 (RAWLINGS and COCKERHAM 1962), unlike diallel analysis (which has been used extensively to study the genetic architecture of plant populations), it was unable to attract adequate attention from plant breeders. As a result, its practical application is still confined to a few cases. This is mainly because the method requires relatively more experimental efforts than does the diallel approach.

However, double-cross analysis not only provides information about the relative importance of various components and subcomponents of genetic variation, but also tells what specific order of parents in a cross combination, involving the same parents, performs best. It was therefore thought worthwhile to evaluate 8 homozygous varieties of spring wheat and their 210 possible double-cross hybrids for harvest index.

Materials and methods

Eight varieties of spring wheat, namely, NP876 (tall), Sonalika and Norteno 67 (single dwarf), Kalyan Sona, HD 2009, WG 377 and Shera (double dwarf) and Moti (triple dwarf), numbered as 1–8, were crossed in all possible non-reciprocal combinations in 1975–76. Twenty-eight F_1 hybrids thus produced were further crossed in all possible non-reciprocal combinations in 1976–77, in such a way that one parent appeared in the same double cross once only. All $210 = 3\,(8c_4)$ double-cross hybrids were raised in randomized blocks with three replications in November 1977. Twenty plants from each progeny family were scored for harvest index.

Different kinds of effects (1-, 2-, 3- and 4-line) and variances were worked out following RAWLINGS and COCKERHAM's (1962) method.

Results and discussions

Analysis of variance for double-cross hybrids for harvest index in wheat is presented in Table 1. All the items were highly significant except the 4-line specific effects, which showed borderline (P = 0.05) significance. This indicates that all three kinds of gene effects (additive, dominance and epistatic) were important in controlling harvest index in wheat. Therefore, a method which can exploit both additive and non-additive gene action will be more useful for the improvement of this trait in wheat than applying simple selection procedures.

A reference to Table 2 shows that parent 3 (Norteno 67) was associated with the highest positive average effect, followed by parents 6 (WG 377), 7 (Shera) and 8 (Moti). Values above the diagonal in this table show that with the (ij) (—) arrangement the cross combination (18) (—), i.e. (NP 876 × Moti) (—) performed best. The hybrids (45) (—), i.e. (Kalyan Sona × HD 2009) (—) and (28) (—), i.e. (Sonalika × Moti) (—) came next in order. According to the (i-) (j-) arrangement (values below the diagonal) the hybrid combination (6-) (8-) was best, followed by the combinations (1-) (4-) and (3-) (5-). However, when 2-line effects without respect to any particular arrangement were considered (values in brackets), the hybrids involving variety 3 as one parent with varieties 6, 8 and 7 gave the highest values, in this order.

As regards the 3-line specific effects with the (ij) (k-) arrangement, the triplet (68) (1) formed the most effective combination, followed by the triplets (68) (2) and (78) (1) (Table 3). But when triplets of the varieties were considered irrespective of arrangement, the triplets s368 and s367 were found to be best. In 4-line specific effects with the (ij) (kl) arrangement only one quadruplet of varieties (12) (38) gave a significant value. On the other hand, when these effects (4-line) were considered irrespective of arrangement, the quadruplets s3468 and s3467, in this order, gave the best performance.

The present results show that the variety Norteno 67 was not only the best 1-line general combiner, but also, when no specific arrangement was followed, this variety made the most effective combinations with other parents in 2-line, 3-line and 4-line effects.

The most important finding of the present investigation was that combinations involving the same parents with different arrangements performed differently. For instance, in 2-line effects, the combination (18) (—) performed best when the (ij) (—) arrangement was followed. But with the (i-) (j-) arrangement and irrespective of arrangement the same parents showed significant negative and non-significant negative values, respectively. The situation

Table 1

Analysis of variance for double-cross hybrids for harvest index in wheat

Source	D.F.	M.S.
Hybrids	209	59.75***
1-line general	7	583.61***
2-line specific	20	47.77***
3-line specific	28	12.70***
4-line specific	14	9.49*
2-line arrangement	20	120.76***
3-line arrangement	64	54.63***
4-line arrangement	56	18.70***
Error	418	4.91

* P = 0.05–0.01; *** P < 0.001

Table 2

Estimates of 1-line average and 2-line specific effects for harvest index in wheat

Variety	Average effect of line (gi)	Two-line specific effects with (ij) (—) arrangement (above the diagonal) (with (i-) (j-) arrangement (below the diagonal), and irrespective of arrangement, i.e. s_{ij} (in brackets)							
		1	2	3	4	5	6	7	8
1	−1.15		0.32 (0.12)	0.57 (−0.67)*	−2.43*** (0.21)	0.36 (−0.18)	−0.81 (−0.36)	−0.41 (−0.13)	2.40*** (−0.13)
2	−0.93***	−0.16	−0	1.12* (−0.49)	−1.07* (0.13)	−0.77 (−0.03)	−0.11 (−0.13)	−1.22* (0.05)	1.73*** (−0.56)
3	1.55***	−0.29	−0.56		−1.40 (0.47)	−1.81*** (−0.02)	1.18* (0.93)**	−0.48 (0.66)*	0.82 (0.67)*
4	0.33*	1.22**	0.54	0.70		2.22*** (−0.41)	1.18* (−0.09)	0.95 (−0.02)	0.56 (0.04)
5	−1.37***	−0.18	0.38	0.90*	−1.11*		0.17 (−0.37)	1.28* (−0.44)	−1.45** (0.08)
6	0.59***	0.40	0.05	−0.59	−0.59	−0.08		1.18* (0.33)	−2.78*** (0.29)
7	0.52***	0.21	0.61	0.24	−0.47	−0.64	−0.59		−1.28* (0.08)
8	0.46**	−1.20**	−0.87	−0.41	−0.28	0.73	1.39***	0.64	

Standard errors: $g_i = 0.153$; $t_{ij} = 0.504$; $t_{i.j.} = 0.447$; $s_{ij} = 0.301$

* P = 0.05–0.01; ** P = 0.01–0.001; *** P < 0.001

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Table 3

Estimates of 3-line and 4-line specific effects, with particular arrangement and irrespective of arrangement (ten combinations of each kind giving highest values), *for harvest index in wheat*

Three-line effects:				
(a) with (ij) (k-) arrangement				
$t_{68.1} = 3.49^{**}$	$t_{68.2} = 2.84^{*}$	$t_{78.1} = 2.74^{*}$	$t_{35.2} = 2.56^{*}$	$t_{34.2} = 2.55^{*}$
$t_{12.8} = 2.47^{*}$	$t_{24.1} = 2.28^{*}$	$t_{14.8} = 2.20$	$t_{38.2} = 2.15$	$t_{45.3} = 2.09$
(b) irrespective of arrangement:				
$s_{368} = 1.01^{*}$	$s_{367} = 1.00^{*}$	$s_{347} = 0.62$	$s_{346} = 0.61$	$s_{348} = 0.59$
$s_{145} = 0.53$	$s_{378} = 0.39$	$s_{568} = 0.38$	$s_{124} = 0.28$	$s_{167} = 0.22$
Four-line effects:				
(a) with (ij) (kl) arrangement				
$t_{12.38} = 4.13^{*}$	$t_{13.24} = 3.73$	$t_{23.48} = 3.47$	$t_{17.34} = 2.87$	$t_{37.45} = 2.75$
$t_{13.67} = 2.64$	$t_{12.45} = 2.58$	$t_{58.67} = 2.38$	$t_{38.47} = 2.25$	$t_{13.25} = 2.25$
(b) irrespective of arrangement				
$s_{3468} = 1.89^{*}$	$s_{3467} = 1.86^{*}$	$s_{3568} = 1.65^{*}$	$s_{3478} = 1.11$	$s_{3678} = 1.04$
$s_{1458} = 0.93$	$s_{1247} = 0.71$	$s_{1246} = 0.65$	$s_{1278} = 0.64$	$s_{2567} = 0.60$
Standard errors:				
$t_{i4.k} = 1.139;$	$s_{ijk} = 0.478;$	$t_{ij} \cdot kl = 1.954;$	$s_{ijkl} = 0.741$	

* P= 0.05–0.01; ** P = 0.01–0.001

was similar when 3-line and 4-line effects were considered. The combination (68) (1), which showed the highest value with the (ij) (k-) arrangement, did not occupy an important position when the same parents were considered without respect to any particular arrangement. Similarly, in 4-line effects, the combination (12) (38) which showed the highest value, did not perform well when no particular arrangement was followed.

The present results, along with those of SINGH—CHAUDHRY (1977) for grain yield in barley, indicate that the order of parents in hybrid combinations played a major role in their hybrid performance.

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MELITTOBIA ACASTA WALKER (HYMENOPTERA: EULOPHIDAE), THE MOST DANGEROUS INDIRECT PEST OF LUCERNE SEED PRODUCTION

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During the large-scale hatching of native and USA-impprt populations of the lucerne leaf-cutter bee in Hungary, carbaryl-containing insecticides (e.g. SEVIN) and light traps have been used to kill its parasites; with the latter only the flying adults can be caught. In spite of those control methods, parasites have been left behind to infest the progenies. The removal of coccons 4 m from the nesting place — in accordance with the technological prescriptions of Hungary — does not provide reliable protection against such pests as — according to the evidence of our measurements — are able to crawl as much as 100 metres.

The *Melittobia acasta*, a member of the family *Eulohidae (Chalcidoidea)* could remain dangerous in spite of the contrpl operations so far carried out. In Hungary this species was the main cause of the poor reproduction of lucerne leaf-cutter bees, both in the native and imported pdpulations.

The protracted hatching, relatively long life and high motility of this parasite may not only result in a reinfestation but also cause damages to other hymenopterous pollinators of lucerne. Any attack against *Melittobia acasta* Walker today and in the future in Hungary prometes the success of lucerne seed production.

Introduction

Lucerne seed production was simpler in the past when its success was threatened only by direct pests. These pests include the following insect species: *Contarinia medicaginis* Kieffer, *Asphondylia miki* Wachtl, *Adelphocoris lineolatus* Goeze, — *Lygus* spp. *Heliothis (Chloridea) maritima* Graslin, *H. viriplaca* Hufnagel, *Tychius flavus* Becker, *Bruchophagus roddi* Gusakovskij, etc. They could be successfully controlled by choosing the right time of cutting and using chemical treatments (dusting or spraying the stubble field).

Lucerne seed production was once made uncertain by the relative shortage of pollinating organisms, by their scarcity compared to the number of flowers opening at the same time. When with the view of making up for this deficiency the introduction and propagation of the lucerne leaf-cutter bee began, the *Melittobia acasta* Walker, a parasite of the *Megachile* species — that is an indirect preventer of lucerne seed production — appeared immediately.

The lucerne leaf-cutter bee is a rare pollinator of lucerne in the Hungarian fauna. Its distribution in Hungary is hindered by the asynchronism of nesting places and feed as well as by the large species and individual numbers of parasites. Its propagation — either from inland- or from imported stocks — requires nesting places at the time of swarming, feed, and a possible absence of parasites. Its range of parasites in Hungary is similar to that in the United States; the method of control is also similar.

In 1966–1972, of 1072 broods of *Megachile rotundata* Fabricius reared in reed-roofs of 32 farm buildings housed by animals, 680 were infested by parasites. In 22 of the 32 in same

Melittobia acasta Walker, in 20 *Coelioxys rufocaudata* Smith, in 25 *Anthrenus* sp. and another 20 samples *Trichodes apiarius* Linne were found (MANNINGER 1972).

Between 1972 and 1978, several millions of prepupae were imported from the United States and Canada to Hungary. From this stock in 1981 we were given 1400 prepupae, which were then placed in a lucerne field sown to the variety Tápiószelei 1.

In spite of the well-known control methods applied the lucerne leaf-cutter bees hatched in a very low percentage (26.3%). The main causes of mortality were: infestation by *Melittobia acasta* Walker (48.6%); death at larval, pupal and adult stages (24.8%) and brood calcification (0.3%).

In the relevant literature the number of parasites is followed only until the lucerne leaf-cutter bees begin to hatch (HOBBS 1968). We wanted to count the parasites from the completion of hatching.

Material and method

The empty coccons — 1200 in number — were carried from the lucerne field to the laboratory and kept in polyethylene bags at 21 °C and 70 per cent relative humidity for 50 days. The number of insects hatched was recorded every day. The hatched adults of *Melittobia acasta* Walker were examined for their lifetime in groups of 3 kept loosely and in those of 96 then of 106 jam tight in test-tubes, respectively, under the same conditions of air and humidity, without being fed.

For motility one, four and 100 females per group, respectively, chosen at random were examined under similar microclimatic conditions between 23 and 30 July 1982, so that we followed by drawing the movement of adults on a 1 m wide cardboard towards light, recording the time every half-hour and counting the leaps of the adults, and measured the distance each adult made towards the light.

Results

Under the described conditions, after the completion of hatching one leaf-cutter bee and 4913 *Melittobia acasta* Walker adult hatched from the 1400 lucerne leaf-cutter bee coccons in 50 days.

Under packed conditions the *Melittobia acasta* Walker groups kept unfed died in 14 (11–18 September) and 10 (18–28 September) days, respectively. In another treatment 33 per cent of the loosely kept and 56 and 62 per cent of the packed groups, respectively, died in 13 days.

The first female of *Melittobia acasta* Walker chosen at random covered a distance of 28.55 m in three days between 23 and 25 July (made to run for an hour every day). It made a total of 130 small leaps, 93 in the first, 19 in the second and 18 in the third day.

The four females made to run on the next occasion exceeded the first female by a velocity of 9.3–14.4 m/hour. The directions of motion and traces of the above four specimens and those of specimens from the third group of 100 were so much similar that they could hardly be distinguished.

We have established as a fact that the motion of all *Melittobia acasta* Walker insects tends towards the light. Those leaving the strip of paper sideways took a longer time to make the shorter distance than those moving towards the light. Owing to its span of life and motility, the species is able to travel further than hitherto supposed.

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FAUNAL INVESTIGATION OF GROUND BEETLES *(CARABIDAE)*, IN THE ARABLE SOILS OF HUNGARY

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A survey of soil samples was carried out in the autumn and spring of 1975 by means of a TVG-2 type machine installed on a tractor on 31670 ha of arable land, covering about 2/3 of the area of Hungary. Altogether 1837 imagines and 1604 larvae belonging to 74 species of ground beetles were collected. Of the imagines, the dominance of eleven species exceeded 2%: *Anisodactylus signatus* Panz. (15.51%); *Harpalus pubescens* O. F. Müll. (14.75%); *Agonum dorsale* Pontopp. (13.06%); *Zabrus tenebrioides* Goeze. (9.14%); *Harpalus distinguendus* Duft. (7.18%); *Civina fossor* L. (5.82%); *Pterostichus cupreus* L. (5.71%); *Bembidion properans* Steph. (4.25%); *Trechus quadristriatus* Schrank (3.86%); *Pterostichus sericeus* Fisch. (2.56%); *Harpalus griseus* Panz. (2.01%).

In the autumn the density of individuals of both the imagines (2.31 individuals/m²) and the larvae (2.04 individuals/m²) exceeded the values observed in spring (1.29 and 1.11 individuals, respectively per m²). Hardly any difference was found in species number of both sampling times: in spring the species number was 54 and in the autumn 55. Hibernation types of the 11 dominant species were also established.

The numbers of individuals of the ground beetles larvae (without *Zabrus tenebrioides* Goeze) according to the preceding crops were as follows: 1.77 individuals/m² (maize); 1.42 individuals/m² (winter cereals); and 1.14 individuals/m² (perennial *Papillonaceae*). With the imagines the order was the opposite: 2.39 individuals/m² (perennial *Papillonaceae*); 1.24 individuals/m² (winter cereals) and 1.24 individuals/m² (maize). The number of species was highest after the winter cereals (53 species), followed by maize as preceding crop (38 species) and the lowest species number was observed (24 species) after the perennial *Papillonaceae*.

Besides other factors, the number of both the species and the individuals is greatly affected by individual plot size. The correlation is negative, i.e. the number of species and individuals increases with the decrease of the size of plot. This phenomenon is closely related to the immigration of ground beetles.

Introduction

Up to the present no faunal work has been published in Hungarian zoological literature on the Carabidae of the agriculturally cultivated regions, and only some relevant observations are known (MANNINGER *et al.* 1955, SZARUKÁN 1974). Thus, one of the best known families of beetles, the family of *Carabidae*, has been rather unevenly investigated in the territory of Hungary. Out of the large collection of ground beetles (more than 150 000 individuals) in the Hungarian Museum of Natural History, relatively few originate from agricultural areas and thus the data of this collection can afford only limited ecological and phenological information. In order to obtain appropriate faunal data from the cultivated regions that comprise about two-thirds of the total area of Hungary, large-scale collections carried out by uniform methods are required. For this purpose favourable possibilities were secured by the soil sampling survey started in 1975, which primarily served for the forecast of Arthropoda living in the soil and detrimental to plants.

Material and method

The surveys serving as a basis of the investigations had been carried out by the farms participating in the program with the use of a soil sampling machine, type TVG-2, of Hungarian made. This device can be mounted on a tractor and operated by its hydraulics, on pushing a metal cylinder of 20 cm diameter (314 cm^2) into the soil to a depth of about 50–60 cm. The soil sample lifted from the depth is pushed off the cylinder by means of the piston onto plastic foil placed nearby. Subsequently, the insects removed from the crumbled soil are collected in a sampling glass containing denatured alcohol, and labelled appropriately.

The farms had withdrawn one sample from each hectare and collected ten samples of this type in one sampling glass. Thus, a unit sample represents ten hectares having a total soil surface of 1/3 m^2. Though the sample is not large, it is composed of a great number of small partial samples which had been withdrawn at regular distances along the diagonal of the plot in order to obtain a better distribution. The surveys were carried out partly in spring (April) and partly in autumn (mostly in September—October) of 1975.

The sample glasses were transported, in special boxes supplied for this purpose, to the Department for Plant Protections of the University of Agricultural Sciences in Debrecen.

For the determination of ground beetles, besides the material for comparison of the Museum of Natural Sciences, the works of CSIKI (1946) and HORVATOVICH (1974) were also used.

In the course of evaluating this material, data of the reports made by the farms and forwarded to us were studied since these reports contain such information as site of surveys, the preceding crops applied in the last three years, etc.

Results and discussion

All imagines of the ground beetle species mentioned in this study were found in the soil of field plots. Thus, from faunistical and quantitative aspects, our data are more reliable than those based on ground beetles collected by soil traps and particularly by light-traps, by which the sensitivity to light of the beetles may result in species numbers and individual numbers higher than the real values.

According to the data of the 3167 sample units (the material originating from an area of 31 670 ha having a surface of 1056 m^2) 74 species of ground beetles occurred in cultivated soils (Table 1). However, of these species there were only eleven whose dominance reached the 2% level. These are, in the order of their dominance percentages, as follows:

1. *Anisodactylus signatus* Panz.	15.51%	7. *Pterostichus cupreus* L.	5.71%
2. *Harpalus pubescens* Müll.	14.75%	8. *Bembidion properans* Steph.	4.25%
3. *Agonum dorsale* Pontopp.	13.06%	9. *Trechus quadristriatus* Schrank.	3.86%
4. *Zabrus tenebrioides* Goeze.	9.14%	10. *Pterostichus sericeus* Fisch.	2.56%
5. *Harpalus distinguendus* Duft.	7.18%	11. *Harpalus griseus* Panz.	2.01%
6. *Clivina fossor* L.	5.82%		

The most frequent species of ground beetles are the same as those found earlier (HORVATOVICH *et al.* 1973) at Eszék (Osiek, Jugoslavia), and this agrees with the few Hungarian data available (MANNINGER *et al.* 1955, SZARUKÁN 1974). Their occurrence in cultivated fields in Eastern Europe is supported by relevant data of other, mainly Soviet, authors as well (ZATJAMINA 1970, KASANDROVA and SHAROVA 1971, etc.).

We mention here that, until now, only two cases of the occurrence of the species *Ophonus mendax* Rossi were known (5 at Budapest and 2 at Pécs) according to the collection of

the Museum Natural Science, Budapest. Another individual was now found in the environment of Kötegyán (this is preserved in the above-mentioned Museum).

On comparing the numbers of beetles collected in the autumn and in the spring, respectively (Table 2) we find in the autumn the number of individuals on unit surface was both in the case of the imagines (2.31 m^2) and of the larvae (2.04 m^2) higher than the values observed in spring (1.29 and 1.11 m^2, resp.). The number of species found at the two collection dates (in spring 54, and in autumn 55 species) differed hardly at all. Some deviation was observable between the two lists of species in the case of species represented only by 1–2 individuals (expecting *Asaphidion flavipes* which was found only in spring, represented by 4 individuals). These findings apparently indicate that this population decrease may correlate to winter climate as a decreasing factor.

On the basis of our observations, the ground beetles can be divided into two groups; those hibernating as imagines, and those hibernating as larvae. Species, whose imago density per unit surface decreases strikingly in spring, hibernate as larvae; whereas the species, whose individual density does not vary, essentially exist in winter as imagines. Accordingly, of the more frequent species:

1. species hibernating as imagines are:
   - *Agonum dorsale*
   - *Clivina fossor*
   - *Anisodactylus signatus*
   - *Harpalus distinguendus*
   - *Pterostichus cupreus*

2. species hibernating as larvae are:
   - *Harpalus pubescens*
   - *Harpalus griseus*
   - *Trechus quadristriatus*
   - *Pterostichus sericeus*
   - *Zabrus terenbrioides*
   - *Bembidion properans*

This classification is almost identical with that described by LINDROTH (1945) and TISCHLER (1965). However, they classified the Bembidion species into group 1, and did not include *Anisodactylus signatus* and *Pterostichus sericeus* in their list. The hibernation pattern of *Zabrus tenebrioides* has long been known, and it was observed as well (KADOCSA 1941) that,

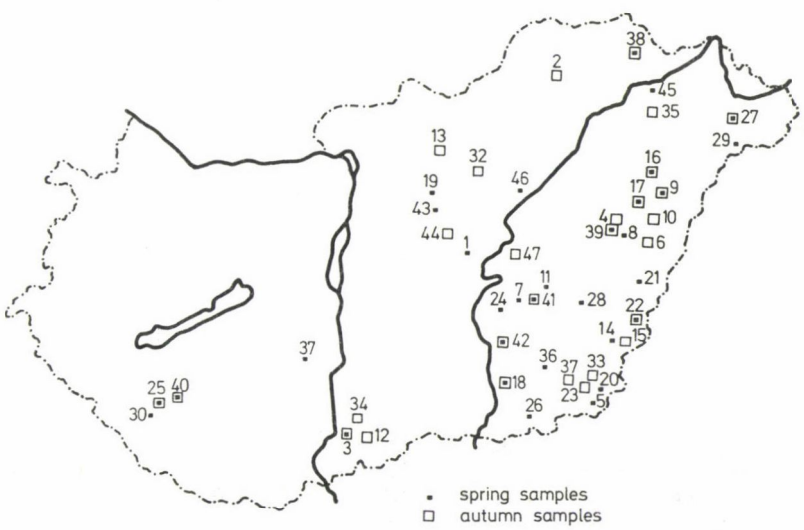

Fig. 1. Distribution of sampling sites in Hungary in 1975

Table 1

Number of individuals of species of ground

Name of farms	Average plot size (ha)	Number of samples	Carabidae (larvae)	*Zabrus tenebrioides* (larvae)	Number of species (imagos)	*Acupalpus meridianus*	*Acupalpus teutonus*	*Agonum dorsale*
1. Abony	170.0	51	24	—	7	—	—	—
2. Aszaló	43.7	12	4	—	—	—	—	—
3. Baja	75.7	40	12	28	1	—	—	—
4. Báránd	36.0	19	4	—	4	1	—	—
5. Battonya	114.2	59	55	—	3	1	—	—
6. Berettyóújfalu	37.7	63	210	36	6	—	—	—
7. Békésszentandrás	43.7	33	32	—	8	—	—	4
8. Biharnagybajom	66.7	22	11	—	5	—	—	3
9. Debrecen	45.5	132	11	—	9	—	—	23
10. Derecske	63.8	50	19	—	12	—	—	—
11. Endrőd	103.6	53	14	—	7	—	—	1
12. Felsőszentiván	132.0	40	32	—	3	—	—	—
13. Gyöngyöspata	72.3	30	12	8	9	—	—	—
14. Gyula	100.0	61	6	—	9	—	—	1
15. Gyulavári	50.3	16	3	—	5	—	—	—
16. Hajdúböszörmény	62.1	236	25	17	18	1	—	22
17. Hajdúszoboszló	48.9	101	36	13	13	—	—	5
18. Hódmezővásárhely	75.3	100	42	3	4	—	—	—
19. Jászfényszaru	198.8	60	61	—	—	—	—	—
20. Kevermes	50.7	33	8	2	3	—	—	3
21. Komádi	108.6	101	16	10	24	1	—	23
22. Kötegyán	25.8	158	102	5	35	10	—	12
23. Kunágota	101.6	45	8	—	—	—	—	—
24. Kunszentmárton	41.8	21	4	—	2	—	—	—
25. Kutas	29.1	89	26	1	13	2	—	2
26. Makó	75.7	55	18	—	5	—	—	1
27. Mátészalka	38.3	132	30	2	16	—	—	2
28. Mezőberény	83.4	72	49	—	9	—	—	3
29. Mérk	125.0	25	60	—	7	—	—	—
30. Nagyatád	42.0	64	50	—	15	1	1	1
31. Nagybánhegyes	91.4	38	69	2	—	—	—	—
32. Nagyfüged	62.8	52	131	6	13	1	—	3
33. Nagykamarás	93.5	30	67	—	7	—	—	2
34. Nemesnádudvar	83.6	36	23	—	2	—	—	—
35. Nyírtelek	71.1	52	4	—	1	—	—	—
36. Orosháza	144.5	30	5	—	4	—	—	—
37. Pálfa	63.9	53	8	—	1	—	—	—
38. Sárospatak	55.5	256	13	15	10	—	—	2
39. Sárrétudvari	41.4	155	12	8	29	—	—	124
40. Somogysárd	32.8	113	110	2	13	—	1	—
41. Szarvas	53.4	96	19	1	1	—	—	—
42. Szentes	105.1	88	11	50	10	—	—	—
43. Szentmártonkáta	218.5	44	20	—	5	—	—	—
44. Tápiószőlős	65.1	66	116	4	7	—	—	1
45. Tiszabercel	55.8	51	11	—	11	—	—	2
46. Tiszanána	55.8	22	—	—	—	—	—	—
47. Törökszentmiklós	30.0	12	1	4	6	—	—	—
Total		3167	1604	217	74	18	2	240

beetles in 1975, in the individual farms

Amara aenea	*Amara apricaria*	*Amara communis*	*Amara consularis*	*Amara convexior*	*Amara crenata*	*Amara eurynota*	*Amara familiaris*	*Amara lucida*	*Amara plebeja*	*Amara similata*	*Anisodactylus signatus*	*Asaphidion flavipes*	*Asaphidion pallipes*	*Bembidion lampros*	*Bembidion obtusum*	*Bembidion properans*	*Bembidion quadrimaculatum*	*Brachynus crepitans*
—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	1	—	—
—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	1	—	—
1	—	—	—	—	—	—	—	—	—	1	12	—	—	—	—	7	1	—
1	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
1	—	—	1	—	—	—	—	4	—	—	1	—	—	—	—	—	—	1
—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—	—	—	55	—	—	—	—	14	1	—
2	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	3	—	—
—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	3	3	—	—	—	—	—	—	4
7	1	—	—	2	1	—	—	4	—	1	7	—	—	—	1	—	1	3
—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	1	—	—	—	8	—	—	—	—	20	—	—
—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	7	—	—	—	—	11	17	2
—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	1
1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	1	9	3	—	—	—	1	4	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	1	—	—	—	1	—	—	—	—	9	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	12	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	1	7	—	—	—	—	—	—	2
2	—	2	6	—	—	—	—	—	1	2	87	—	—	1	—	7	1	11
1	—	—	—	—	—	—	—	—	—	—		1	1	—	6	6	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	3	—	—
—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
—	—	—	1	—	—	—	—	—	—	—	9	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—	2	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—
29	1	4	11	3	1	1	1	8	1	9	285	4	1	1	1	78	28	24

(Table 1 continued)

Name of farms	*Brachynus explodens*	*Brachynus ganglbaueri*	*Broscus cephalotes*	*Calathus melanocephalus*	*Calosoma auropunctatum*	*Carabus cancellatus*	*Claenius spoliatus*	*Clivina contracta*	*Clivina fossor*
1. Abony	—	—	—	—	—	—	—	—	—
2. Aszaló	—	—	—	—	—	—	—	—	—
3. Baja	—	—	—	—	—	—	—	—	—
4. Báránd	—	—	—	—	—	—	—	—	—
5. Battonya	—	—	—	—	—	—	—	—	3
6. Berettyóújfalu	—	—	—	—	—	—	—	—	—
7. Békésszentandrás	—	—	—	—	—	—	—	—	7
8. Biharnagybajom	—	—	—	—	—	—	—	—	—
9. Debrecen	—	—	—	—	—	1	—	—	—
10. Derecske	—	—	—	—	—	—	—	—	—
11. Endrőd	—	—	—	—	—	—	—	—	1
12. Felsőszentiván	—	—	—	—	—	—	—	—	—
13. Gyöngyöspata	—	—	—	—	—	—	—	—	—
14. Gyula	—	—	—	—	—	—	—	—	4
15. Gyulavári	—	—	—	—	—	—	—	—	—
16. Hajdúböszörmény	—	1	—	—	1	—	—	—	1
17. Hajdúszoboszló	—	—	—	—	—	—	—	—	19
18. Hódmezővásárhely	—	—	—	—	—	—	—	—	1
19. Jászfényszaru	—	—	—	—	—	—	—	—	—
20. Kevermes	—	—	—	—	—	—	—	—	—
21. Komádi	2	—	—	—	—	8	—	—	—
22. Kötegyán	2	—	—	—	—	—	—	—	1
23. Kunágota	—	—	—	—	—	—	—	—	1
24. Kunszentmárton	—	—	—	—	—	—	—	—	—
25. Kutas	—	—	—	—	—	—	—	1	11
26. Makó	—	—	—	—	—	—	—	—	1
27. Mátészalka	—	—	1	—	—	—	1	—	13
28. Mezőberény	—	1	—	—	—	—	—	—	3
29. Mérk	—	—	—	—	—	—	—	—	—
30. Nagyatád	—	—	—	—	—	—	—	—	17
31. Nagybánhegyes	—	—	—	—	—	—	—	—	—
32. Nagyfüged	—	—	—	—	—	—	—	—	7
33. Nagykamarás	—	—	—	—	—	—	—	—	—
34. Nemesnádudvar	—	—	—	—	—	—	—	—	—
35. Nyírtelek	—	—	—	—	—	—	—	—	—
36. Orosháza	—	—	—	—	—	—	—	—	—
37. Pálfa	—	—	—	—	—	—	—	—	—
38. Sárospatak	—	—	—	—	—	—	—	—	—
39. Sárrétudvari	—	10	—	1	—	—	—	—	4
40. Somogysárd	—	—	1	—	—	—	—	1	7
41. Szarvas	—	—	—	—	—	—	—	—	—
42. Szentes	—	—	—	—	—	—	—	—	2
43. Szentmártonkáta	—	—	—	—	—	—	—	—	—
44. Tápiószőlős	—	—	—	—	—	—	—	—	—
45. Tiszabercel	—	—	—	—	—	—	—	1	4
46. Tiszanána	—	—	—	—	—	—	—	—	—
47. Törökszentmiklós	—	—	—	—	—	—	—	—	—
Total	4	12	2	1	1	9	1	3	107

Diachromus germanus	*Dolichus halensis*	*Drypta dentata*	*Dyschirius globosus*	*Harpalus aeneus*	*Harpalus anxius*	*Harpalus autumnalis*	*Harpalus azureus*	*Harpalus brevicollis*	*Harpalus calceatus*	*Harpalus diffinis*	*Harpalus dimidiatus*	*Harpalus distinguendus*	*Harpalus fröhlichi*	*Harpalus griseus*	*Harpalus hospes*	*Harpalus melleti*	*Harpalus modestus*
—	—	—	—	—	—	—	—	—	2	—	—	2	—	2	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—
—	—	—	—	—	—	—	—	—	1	—	—	2	1	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	1	6	—	1	—	—	—
—	1	—	—	—	—	—	—	—	2	—	—	1	—	—	1	—	—
—	—	—	1	—	—	—	—	—	—	—	—	15	—	6	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	2	—	—	2	—	2	—	—	—	—	3	—	—	2	—	—
2	—	—	—	1	—	—	1	2	—	3	—	17	—	4	3	2	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	7	—	—	—	—	—
—	—	—	—	—	—	1	—	—	—	—	—	5	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	6	—	2	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	1
—	—	—	—	2	—	—	—	—	—	—	—	—	—	3	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	3	—	1	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
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—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
—	—	—	—	2	—	—	—	—	—	—	—	27	—	2	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	2	—	1	—	—	—
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—	—	—	—	—	—	—	2	—	—	—	—	6	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	2	—	2	1	—	—
—	—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—
—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	1	—	—	—	—	10	—	—	—	—	—
2	1	2	1	6	2	1	6	2	5	3	1	132	2	37	7	2	1

(Table 1 continued)

Name of farms	*Harpalus politus*	*Harpalus pubescens*	*Harpalus punctatulus*	*Harpalus rupicola*	*Harpalus signaticornis*	*Harpalus tardus*	*Harpalus tenebrosus*	*Harpalus sabroides*	*Leistus ferrugineus*	*Microlestes minutulus*
1. Abony	—	—	—	—	—	—	—	—	—	—
2. Aszaló	—	—	—	—	—	—	—	—	—	—
3. Baja	—	—	—	—	—	—	—	—	—	—
4. Bárand	—	5	—	—	—	—	—	—	—	—
5. Battonya	—	—	—	—	—	—	—	—	—	—
6. Berettyóújfalu	—	3	—	—	—	—	—	—	—	—
7. Békésszentandrás	—	3	—	—	—	—	—	—	—	—
8. Biharnagybajom	—	4	—	—	—	—	—	—	—	—
9. Debrecen	—	10	—	—	—	—	—	—	—	—
10. Derecske	—	8	—	—	—	2	—	—	—	—
11. Endrőd	—	2	—	—	—	—	—	—	—	—
12. Felsőszentiván	—	—	—	—	—	—	—	—	—	—
13. Gyöngyöspata	—	—	—	—	1	—	1	—	—	—
14. Gyula	—	2	—	1	—	—	—	—	—	—
15. Gyulavári	—	6	—	—	—	—	—	—	—	—
16. Hajdúböszörmény	—	44	—	—	—	—	—	—	—	—
17. Hajdúszoboszló	—	8	—	—	—	—	—	—	—	1
18. Hódmezővásárhely	—	1	—	—	—	—	—	—	—	—
19. Jászfényszaru	—	—	—	—	—	—	—	—	—	—
20. Kevermes	—	2	—	—	—	—	—	—	—	—
21. Komádi	—	16	—	1	1	9	—	—	—	—
22. Kötegyán	1	42	1	—	1	—	—	—	—	—
23. Kunágota	—	3	—	—	—	—	—	—	—	—
24. Kunszentmárton	—	—	—	—	—	—	—	—	—	—
25. Kutas	—	—	—	—	—	—	—	—	—	—
26. Makó	—	1	—	—	—	—	—	—	—	—
27. Mátészalka	—	29	—	—	—	—	—	—	—	—
28. Mezőberény	—	6	—	—	—	—	—	—	—	—
29. Mérk	—	2	—	—	—	—	—	—	—	—
30. Nagyatád	—	1	—	—	—	—	—	—	—	—
31. Nagybánhegyes	—	—	—	—	—	—	—	—	—	—
32. Nagyfüged	—	6	—	—	—	—	—	—	—	—
33. Nagykamarás	—	8	—	—	—	—	—	—	—	—
34. Nemesnádudvar	—	3	—	—	—	—	—	—	—	—
35. Nyírtelek	—	—	—	—	—	—	—	—	—	—
36. Orosháza	—	4	—	—	—	—	—	—	—	—
37. Pálfa	—	1	—	—	—	—	—	—	—	—
38. Sárospatak	—	15	—	—	—	—	—	—	—	—
39. Sárrétudvari	—	14	—	—	—	—	—	1	1	1
40. Somogysárd	—	2	—	—	—	—	—	—	—	—
41. Szarvas	—	2	—	—	—	—	—	—	—	—
42. Szentes	—	3	—	—	—	—	—	—	—	—
43. Szentmártonkáta	—	2	—	—	—	—	—	—	—	—
44. Tápiószőlős	—	8	—	—	—	—	—	—	—	—
45. Tiszabercel	—	4	—	—	—	—	—	—	—	—
46. Tiszanána	—	—	—	—	—	—	—	—	—	—
47. Törökszentmiklós	—	1	—	—	—	—	—	—	—	—
Total	1	271	1	2	3	11	1	1	1	2

Ophonus mendax	*Pterostichus cupreus*	*Pterostichus longicollis*	*Pterostichus lepidus*	*Pterostichus macer*	*Pterostichus melas*	*Pterostichus punctulatus*	*Pterostichus sericeus*	*Pterostichus vernalis*	*Pterostichus vulgaris*	*Stomis pumicatus*	*Tachys bistriatus*	*Trechus quadristriatus*	*Trichotichnus maculicornis*	*Zabrus tenebrioides*	Number of individuals	Density of individuals (individual/m²)
—	1	—	—	—	—	—	5	—	—	—	—	—	—	5	18	1.06
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.08
—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	10	1.67
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	0.25
—	—	—	—	—	—	—	—	—	—	—	—	4	—	2	14	0.70
—	2	1	—	1	—	—	—	—	—	—	—	—	—	2	23	2.09
—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	13	1.86
—	5	—	—	—	—	—	11	—	—	—	—	—	—	2	61	1.39
—	9	—	—	—	—	—	—	—	—	—	—	1	—	—	46	2.71
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	10	0.56
—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	4	0.31
—	1	—	—	—	—	—	—	—	—	—	—	—	—	8	19	1.90
—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	18	0.90
—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	11	2.20
—	35	1	—	—	—	—	20	—	—	—	—	—	—	1	232	2.94
—	3	—	—	—	—	—	1	—	—	—	—	2	—	8	55	1.62
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	0.12
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	0.64
—	6	3	—	1	1	—	—	2	1	2	—	—	—	5	103	3.03
1	2	13	—	1	—	—	—	—	—	—	1	31	1	13	196	3.70
—	1	—	—	—	—	—	—	—	—	—	—	2	—	1	9	0.60
—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2	0.29
—	2	—	—	—	—	—	—	—	—	—	—	12	—	1	63	2.10
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16	0.89
—	2	1	1	—	—	—	—	—	—	—	—	9	—	1	103	2.34
—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	27	1.13
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	8	1.00
—	1	—	—	—	—	—	—	—	1	—	—	—	—	11	57	2.71
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	3	—	—	1	—	—	—	—	—	—	—	2	—	3	41	2.41
—	3	—	—	—	—	—	1	—	—	—	—	2	—	—	34	3.40
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	0.67
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.06
—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	8	0.80
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.06
—	—	—	—	1	—	—	—	—	—	—	—	1	—	2	33	0.39
—	19	1	—	3	—	1	6	1	—	—	—	2	—	12	352	6.77
—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	30	0.79
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	0.06
—	1	—	—	—	—	—	2	—	—	—	—	1	—	7	30	1.03
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	0.53
—	1	—	—	—	—	—	—	—	—	—	—	—	—	80	106	4.82
—	1	—	—	—	—	—	—	—	—	1	—	—	—	1	28	1.65
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	20	5.00
1	105	24	1	8	1	1	46	3	2	6	1	71	1	168	1837	1.74

Table 2

Number of individuals of species of ground beetles in the spring and autumn of 1975

	Spring		Autumn		Total	
	Indiv.	%	Indiv.	%	Indiv.	%
1. *Acupalpus meridianus*	9	1.18	9	0.84	18	0.99
2. *Acupalpus teutonus*	2	0.26	—	—	2	0.11
3. *Agonum dorsale*	137	17.91	103	9.61	240	13.06
4. *Amara aenea*	6	0.78	23	2.15	29	1.58
5. *Amara apricaria*	—	—	1	0.09	1	0.05
6. *Amara communis*	1	0.13	3	0.28	4	0.22
7. *Amara consularis*	3	0.39	8	0.75	11	0.60
8. *Amara convexior*	2	0.26	1	0.09	3	0.16
9. *Amara crenata*	—	—	1	0.09	1	0.05
10. *Amara eurynota*	—	—	1	0.09	1	0.05
11. *Amara familiaris*	1	0.13	—	—	1	0.05
12. *Amara lucida*	—	—	8	0.75	8	0.43
13. *Amara plebeja*	—	—	1	0.09	1	0.05
14. *Amara similata*	5	0.65	4	0.37	9	0.49
15. *Anisodactylus signatus*	151	19.74	134	12.50	285	15.51
16. *Asaphidion flavipes*	4	0.52	—	—	4	0.22
17. *Asaphidion pallipes*	1	0.13	—	—	1	0.05
18. *Bembidion iampros*	—	—	1	0.09	1	0.05
19. *Bembidion obtusum*	—	—	1	0.09	1	0.05
20. *Bembidion properans*	14	1.83	64	5.97	78	4.25
21. *Bembidion quadrimaculatum*	6	0.78	22	2.05	28	1.52
22. *Brachynus crepitans*	20	2.61	4	0.37	24	1.30
23. *Brachynus explodens*	2	0.26	2	0.19	4	0.22
24. *Brachynus ganglbaueri*	8	1.05	4	0.37	12	0.65
25. *Broscus cephalotes*	2	0.26	—	—	2	0.11
26. *Calathus melanocephalus*	1	0.13	—	—	1	0.05
27. *Calosoma auropunctatum*	—	—	1	0.09	1	0.05
28. *Carabus cancellatus*	8	1.04	1	0.09	9	0.49
29. *Claenius spoliatus*	—	—	1	0.09	1	0.05
30. *Clivina contracta*	2	0.26	1	0.09	3	0.16
31. *Clivina fossor*	68	8.89	39	3.64	107	5.82
32. *Diachromus germanus*	1	0.13	1	0.09	2	0.11
33. *Dolichus halensis*	—	—	1	0.09	1	0.05
34. *Drypta dentata*	2	0.26	—	—	2	0.11
35. *Dyschirius globosus*	—	—	1	0.09	1	0.05
36. *Harpalus aeneus*	5	0.65	1	0.09	6	0.32
37. *Harpalus anxius*	2	0.26	—	—	2	0.11
38. *Harpalus autumnalis*	—	—	1	0.09	1	0.05
39. *Harpalus azureus*	5	0.65	1	0.09	6	0.32
40. *Harpalus brevicollis*	—	—	2	0.19	2	0.11
41. *Harpalus calceatus*	2	0.26	3	0.28	5	0.27
42. *Harpalus diffinis*	2	0.26	1	0.09	3	0.16
43. *Harpalus dimidiatus*	1	0.13	—	—	1	0.05
44. *Harpalus distinguendus*	63	8.24	69	6.44	132	7.18
45. *Harpalus frölichi*	—	—	2	0.19	2	0.11
46. *Harpalus griseus*	14	1.83	23	2.15	37	2.01
47. *Harpalus hospes*	5	0.65	2	0.19	7	0.38
48. *Harpalus melleti*	—	—	2	0.19	2	0.11
49. *Harpalus modestus*	1	0.13	—	—	1	0.05
50. *Harpalus politus*	—	—	1	0.09	1	0.05
51. *Harpalus pubescens*	86	11.24	185	17.26	271	14.75
52. *Harpalus punctatulus*	1	0.13	—	—	1	0.05
53. *Harpalus rupicola*	2	0.26	—	—	2	0.11
54. *Harpalus signaticornis*	2	0.26	1	0.09	3	0.16

(Table 2 continued)

	Spring		Autumn		Total	
	Indiv.	%	Indiv.	%	Indiv.	%
55. *Harpalus tardus*	9	1.18	2	0.19	11	0.60
56. *Harpalus tenebrosus*	—	—	1	0.09	1	0.05
57. *Harpalus zabroides*	1	0.13	—	—	1	0.05
58. *Leistus ferrugineus*	—	—	1	0.09	1	0.05
59. *Microlestes minutulus*	1	0.13	1	0.09	2	0.11
60. *Ophonus mendax*	1	0.13	—	—	1	0.05
61. *Pterostichus cupreus*	41	5.36	64	5.97	105	5.71
62. *Pterostichus lepidus*	—	—	1	0.09	1	0.05
63. *Pterostichus longicollis*	9	1.18	14	1.30	23	1.25
64. *Pterostichus macer*	6	0.78	2	0.19	8	0.43
65. *Pterostichus melas*	1	0.13	—	—	1	0.05
66. *Pterostichus punctulatus*	1	0.13	—	—	1	0.05
67. *Pterostichus sericeus*	8	1.05	39	3.64	47	2.56
68. *Pterostichus vernalis*	2	0.26	1	0.09	3	0.16
69. *Pterostichus vulgaris*	2	0.26	—	—	2	0.11
70. *Stomis pumicatus*	5	0.65	1	0.09	6	0.32
71. *Tachys bistriatus*	—	—	1	0.09	1	0.05
72. *Trechus quadristriatus*	1	0.13	70	6.53	71	3.86
73. *Trichotichnus maculicornis*	1	0.13	—	—	1	0.05
74. *Zabrus tenebrioides*	29	3.79	139	12.97	168	9.14
Total	765	100.0	1072	100.0	1837	100.0
Carabidae larvae	657		947		1604	
Zabrus tenebrioides larvae	30		187		217	
Number of samples	1777		1390		3167	
Total area of sampling holes (m^2)	592.3		463.3		1055.6	
Density of individuals per m^2 (imagos)	1.29		2.31		1.74	
Density of individuals per m^2 (larvae)	1.11		2.04		1.52	

in cases of an unfavourable autumn, the beetles do not lay their eggs in a mass but also hibernate as imagines. Similar to the *Zabrus* species, other species hibernating as larvae (*Harpalus pubescens*, *H. griseus*, *Trechus quadristriatus*, etc.) are capable, in a small proportion, of hibernating as imagines (LINDROTH 1945). The hibernation as imago of *Anisodactylus signatus* is known as well (KASANDROVA and SHAROVA 1971). However, their hibernation cannot be considered to take place only in one way since, as in case of *Zabrus*, the hibernation as imago may also occur among other species; and, in the case of species native to Hungary, it cannot be definitely excluded that larvae of species hibernating otherwise as imagines are capable of hibernating in this latter way, e.g. *Harpalus distinguendus*, as observed by LINDROTH (1945) or by KASANDROVA and SHAROVA (1971).

The reliability of the observations on the pattern of hibernation among the various species would be increased if the collected larvae could be classified exactly. Though a taxonomic key is already available (GHILAROV 1964), this is still to be complemented by some species in order to be suitable for use in Hungary. The larvae of several species can be determined already by an adequate reliability. For example we found that, although the imagines of some species known to be more frequent but hibernating as larvae are present in rather small

Table 3

Number of individuals of ground beetles grouped according to the preceding crops [Number of samples: 1009 (winter cereals), 1533 (maize), 108 (perennial Papillionaceae). I = individual, I/m² ≠ density of individuals]

Name of species	Winter cereals			Maize			Perennial papillionaceae		
	I	%	I/m²	I	%	I/m²	I	%	I/m²
Carabidae larvae	478	71.88	1.42	903	99.67	1.77	41	100.00	1.14
Zabrus tenebrioides larvae	187	28.12	0.56	3	0.33	0.00	—	—	—
Acupalpus meridianus	11	1.48	0.03	3	0.47	0.00	4	4.65	0.11
Acupalpus teutonus	2	0.27	0.00	—	—	—	—	—	—
Agonum dorsale	92	12.42	0.27	95	14.97	0.19	4	4.65	0.11
Amara aenea	10	1.35	0.03	1	0.16	0.00	11	12.79	0.31
Amara communis	1	0.13	0.00	—	—	—	2	2.32	0.06
Amara consularis	5	0.67	0.01	3	0.47	0.00	—	—	—
Amara convexior	1	0.13	0.00	2	0.31	0.00	—	—	—
Amara crenata	1	0.13	0.00	—	—	—	—	—	—
Amara eurynota	1	0.13	0.00	—	—	—	—	—	—
Amara familiaris	1	0.13	0.00	—	—	—	—	—	—
Amara lucida	8	1.08	0.03	—	—	—	—	—	—
Amara plebeja	—	—	—	1	0.16	0.00	—	—	—
Amara similata	2	0.27	0.00	2	0.31	0.00	3	3.49	0.08
Anisodactylus signatus	64	8.64	0.19	157	24.72	0.31	4	4.65	0.11
Asaphidion flavipes	2	0.27	0.00	2	0.31	0.00	—	—	—
Asaphidion pallipes	1	0.13	0.00	—	—	—	—	—	—
Bembidion obtusum	1	0.13	0.00	—	—	—	—	—	—
Bembidion properans	35	4.72	0.10	11	1.73	0.02	3	3.49	0.08
Bembidion quadrimaculatum	18	2.43	0.05	4	0.63	0.01	—	—	—
Brachynus crepitans	7	0.94	0.02	9	1.42	0.02	4	4.65	0.11
Brachynus explodens	4	0.54	0.01	—	—	—	—	—	—
Brachynus ganglbaueri	1	0.13	0.00	5	0.79	0.01	—	—	—
Broscus cephalotes	—	—	—	2	0.31	0.00	—	—	—
Calathus melanocephalus	—	—	—	1	0.16	0.00	—	—	—
Carabus cancellatus	8	1.08	0.02	1	0.16	0.00	—	—	—
Clivina contracta	—	—	—	2	0.31	0.00	—	—	—
Clivina fossor	27	3.64	0.08	77	12.13	0.15	—	—	—
Diachromus germanus	—	—	—	—	—	—	1	1.16	0.03
Drypta dentata	2	0.27	0.00	—	—	—	—	—	—
Dyschirius globosus	1	0.13	0.00	—	—	—	—	—	—
Harpalus aeneus	2	0.27	0.00	3	0.47	0.00	1	1.16	0.03
Harpalus anxius	1	0.13	0.00	—	—	—	1	1.16	0.03
Harpalus azureus	2	0.27	0.00	2	0.31	0.00	2	2.32	0.06
Harpalus brevicollis	2	0.27	0.00	—	—	—	—	—	—
Harpalus calceatus	1	0.13	0.00	2	0.31	0.00	1	1.16	0.03
Harpalus diffinis	—	—	—	2	0.31	0.00	1	1.16	0.03
Harpalus distinguendus	37	4.99	0.11	62	9.76	0.12	5	5.81	0.14
Harpalus frölichi	2	0.27	0.00	—	—	—	—	—	—
Harpalus griseus	10	1.35	0.03	22	3.46	0.04	1	1.16	0.03
Harpalus hospes	2	0.27	0.00	2	0.31	0.00	2	2.32	0.06
Harpalus melleti	2	0.27	0.00	—	—	—	—	—	—
Harpalus modestus	—	—	—	1	0.16	0.00	—	—	—
Harpalus politus	1	0.13	0.00	—	—	—	—	—	—
Harpalus pubescens	104	14.04	0.31	87	13.70	0.17	24	27.91	0.67
Harpalus rupicola	—	—	—	1	0.16	0.00	—	—	—
Harpalus signaticornis	2	0.27	0.00	—	—	—	1	1.16	0.03
Harpalus tardus	11	1.48	0.03	—	—	—	—	—	—
Harpalus tenebrosus	1	0.13	0.00	—	—	—	—	—	—
Harpalus zabroides	—	—	—	1	0.16	0.00	—	—	—

(Table 3 continued)

Name of species	Winter cereals			Maize			Perennial papillionaceae		
	I	%	I/m²	I	%	I/m²	I	%	I/m²
Microlestes minutulus	1	0.13	0.00	1	0.16	0.00	—	—	—
Pterostichus cupreus	33	4.45	0.10	26	4.09	0.05	4	4.65	0.11
Pterostichus lepidus	1	0.13	0.00	—	—	—	—	—	—
Pterostichus longicollis	11	1.48	0.03	2	0.31	0.00	3	3.49	0.08
Pterostichus macer	4	0.54	0.01	4	0.63	0.01	—	—	—
Pterostichus melas	—	—	—	—	—	—	1	1.16	0.03
Pterostichus punctulatus	1	0.13	0.00	—	—	—	—	—	—
Pterostichus sericeus	25	3.37	0.07	3	0.47	0.00	—	—	—
Pterostichus vernalis	1	0.13	0.00	—	—	—	—	—	—
Pterostichus vulgaris	1	0.13	0.00	1	0.16	0.00	—	—	—
Stomis pumicatus	2	0.27	0.00	4	0.63	0.01	—	—	—
Tachys bistriatus	1	0.13	0.00	—	—	—	—	—	—
Trechus quadristriatus	52	7.02	0.15	1	0.16	0.00	3	3.49	0.03
Zabrus tenebrioides	122	16.46	0.36	30	4.72	0.06	—	—	—
Total (Imagos)	741	100.00	2.20	635	100.00	1.24	86	100.00	2.39
Number of species (Imagos)		53			38			24	

numbers in the samples, their larvae are in these samples not at all so rare (e.g. *Broscus cephalotes*).

The insect material evaluated has been collected from the arable fields of 47 farms (Table 1, Fig. 1). Table 1 shows the number of individuals and species, also the population per unit area of the various species of ground beetles grouped for each individual farm. The beetles originate, as shown in Fig. 1, mainly from the Hungarian Plain (44 farms) and particularly from its south-eastern half. However, three farms (Kutas, Nagyatád, Somogysárd) are located in the area of Southern Pannonia, a region richer in precipitate, with a variety of forests and marshes.

The greatest number of species was observed, in a decreasing order, at these villages: Kötegyán (35 species), Sárrétudvari (29 species) and Komádi (24 species).

The number of individuals per unit area was also prominent in the area of three farms (3.70–6.77–3.03 m²), but similarly high values were observed on the confines of Törökszentmiklós (5.00), Tápiószőlős (4.82) and Nagykamarás (3.40) as well.

It must be mentioned here that the majority in some species (*Brachynus crepitans*, *B. ganglbaueri*, *Agonum dorsale*, etc.) was collected in Sárrétudvari, whereas the majority in others (*Acupalpus meridianus*, *Pterostichus longicollis*, *Trechus quadristriatus*, etc.) was found in the village Kötegyán. In Hajdúböszörmény, in turn, the individual count of *Pterostichus cupreus* and *P. sericeus* was prominent.

The absolute and relative numbers of the individuals of ground beetles were established according to the preceding crops (Table 3, Fig. 2). In the Table, only those preceding crops are listed which, owing to the great number of samples, appeared to be sufficient for drawing appropriate conclusions. Namely, ecological investigations carried out up to the present in laboratory and in field prove unequivocally that three abiotic factors (air humidity, air temperature and light) decisively affect the proliferation of ground beetles whereas the role of other factors is rather subordinate (THIELE 1968, KRAUSE 1974). Accordingly, the effect of the various preceding crops also shows up in fact as an effect of these three important factors. The evaluation of the preceding crops in relation to the more significant species is as follows:

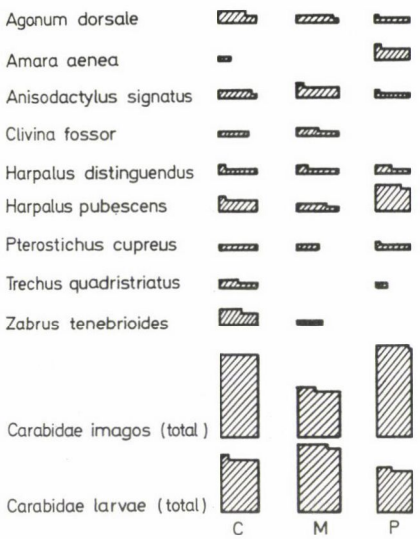

Fig. 2. Density of individuals (individual/m²) of more frequent ground beetles grouped according to the preceding crops (C = winter cereals, M = maize, P = perennial *Papillionaceae*)

Agonum dorsale: In the case of crops where the number of samples is great (winter cereals, maize) both the dominance (12.4–15.0%) and the number of individual insects per unit area (0.27–0.19 individual/m²) are roughly the same. This indicates hibernation as imago.

Amara aenea: After the perennial papillonaceae, a strikingly high occurrence ratio (12.8%) and number of individuals per unit area (0.31/m²) were found. The number of individuals per unit area proved to change as a function of the coverage of soil surface by plants. After winter cereals, the ratio of insects was ten times as high as that after maize.

Anisodactylus signatus: According to the data of soil samples, this species appears to be the most xerophyte. When placed in a Petri dish in a humid atmosphere (at 90–100% humidity of air) the insects died within a few hours. The number of individuals was the highest (24.5% — 0.31/m²) after maize, also being after maize the most dominant. The number of individuals was already much lower after winter cereals (8.6%—0.19/m²) and the lowest after perennial papillonaceae (4.6%—0.11/m²) i.e. exhibiting a tendency quite opposite to that of the former species. In connection with this species it deserves mention that in the Soviet Union its larvae were observed on germinating maize as a parasite (PONOMARENKO 1969).

Clivina fossor: Of the preceding crops, here also maize appears to be prominent with the highest values (12.1%—0.15/m²). Otherwise the order of the preceding crops is similar to that described for *Anisodactylus signatus*. However, the detrimental action of the imagines on germinating beets (HOSSFELD 1972) and maize (DOMENICHINI 1973) must be definitely mentioned here.

Harpalus distinguendus: The observation that this insect is present in all the three investigated cultures with a rather identical number of individuals (0.11–0.12–0.14/m²) points to a xerophyte nature in this species and to hibernation as an imago. Its dominance is the highest after that of the maize.

Harpalus pubescens: Its dominance is high after all three preceding crops, but prominently the highest after the perennial papillonaceae (27.9%). After both other plant cultures, their ratio is almost equal (14.0–13.7%). The values of the density of individuals (0.67 after perennial papillonaceae, 0.31 after winter cereals and 0.17 after maize), and their dominance,

indicate that this species is rather hydrophyte; but at the same time it possesses a wide ecological valence and is rather xerophyte as well. Changes in the number of individuals per unit surface are, similarly to that of the species *Amara aenea*, proportional to the ratio of the soil surface covered by plants.

Pterostichus cupreus: Its dominance (4.1–4.6%) and the density of its individuals (0.05–0.11/m²) are low in all three culture but rather even. This species, similarly to the preceding one, appears to be hydrophyte.

Trechus quadristriatus and *Bembidion properans:* These can be observed in greater amounts only after the winter cereals (with a dominance of 7.0 and 4.7%; and a density of individuals, 0.15 and 0.10, respectively/m²).

Zabrus tenebrioides: According to its well-known way of life, both its dominance and its density of individuals are high (16.5% and 0.36/m²). Obviously, its larva number per unit surface is of similar value (0.56/m²).

It is worth mentioning that though the population density calculated, without *Zabrus tenebrioides*, for all the other larvae of ground beetles is rather even, some smaller differences are still detectable. These are in a decreasing order of individual numbers as follows: maize (1.77/m²), winter cereals (1.42/m²) and perennial papillonaceae (1.14/m²). On comparing this roder with that experienced at the imagines, without *Zabrus tenebrioides* (Fig. 2), it appears that this order is quite opposite to the former: maize (1.24/m²), winter cereals (1.84/m²) and perennial papillonaceae (2.39/m²).

We may mention here also that the total number of species was the highest (53) after the winter cereals whereas maize was following intermediately (38) and the lowest value (24) appeared after the perennial *Papillonaceae*. However, in the last case the number of samples (108) was much (by 10–15) lower than in case of both former cultures.

Great differences were observed in the number of species of ground beetles found in the various farms. In four farms (Aszaló, Jászfényszaru, Nagybánhegyes and Tiszanána) no imagines of ground beetles were found in the soil samples. In another four farms (Baja, Nyír-

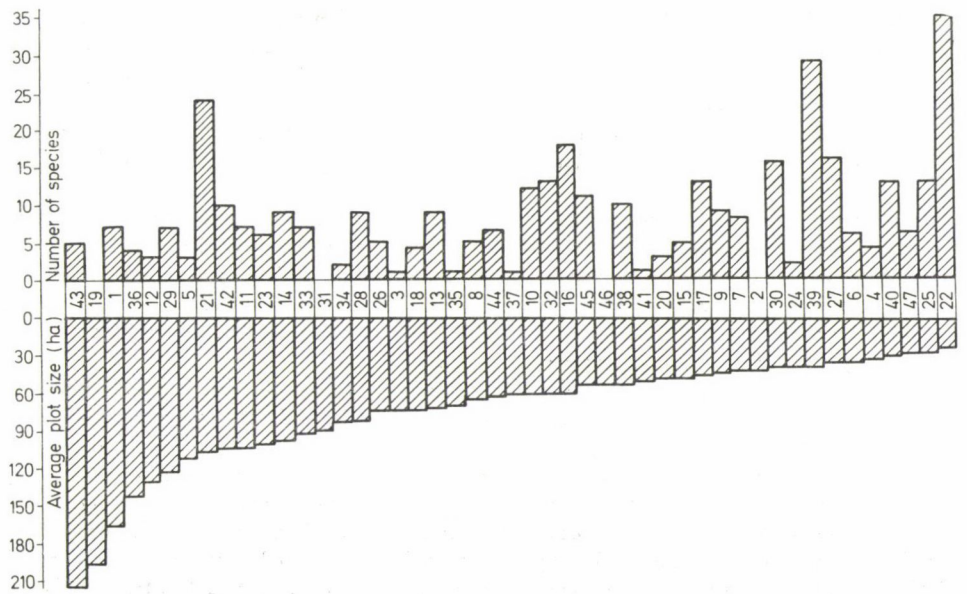

Fig. 3. Correlation between average plot size and number of species in the investigated farms

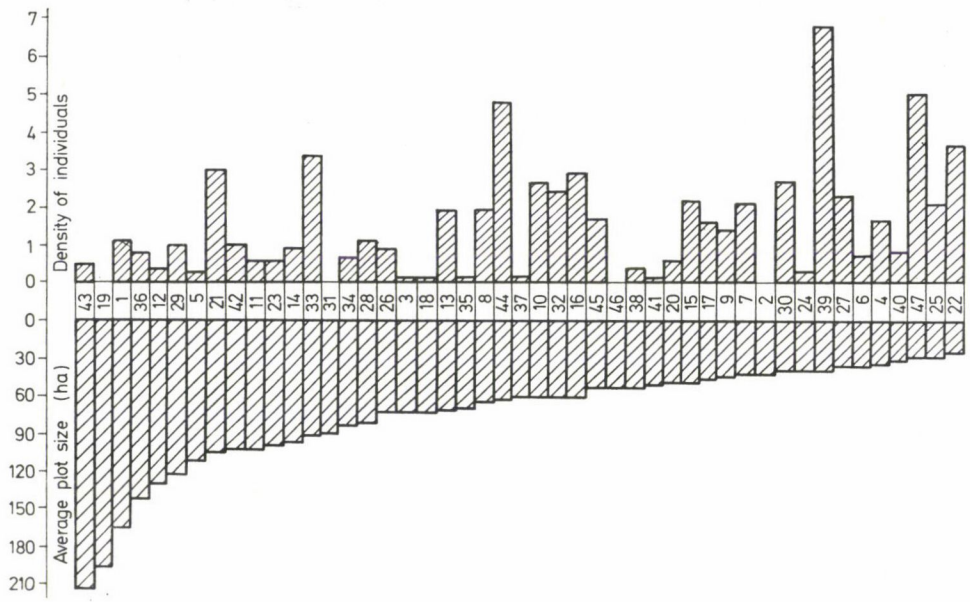

Fig. 4. Relation between density of individuals (individual/m²) and average plot size in the investigated farms

telek, Pálfa, Szarvas) only one species was detectable in each farm, whereas in two farms (Kötegyán) 35 species and (Sárrétudvari) 29 species could be found, as prominently high values.

The average plot sizes were calculated for each farm and the values were compared with the numbers of species (Fig. 3). A negative correlation proved to exist between the average plot size and the actual number of species. According to a list of farms arranged on the basis of decreasing plot sizes, the number of species was higher than the average of 7.4 at only 5 of the first 24 farms of the list; whereas among the next 23 farms, 14 exhibited species numbers exceeding the average value. The average species number (5.66) of the first 24 farms was only half as great as that of the average species number (10.52) of the further 23 farms.

Obviously a high or low number of species is the final result of a great number of factors. However, the effect of the strongest factors, one of which is the plot size, can be detected without any difficulties. Furthermore chemical agents and agrotechniques soil and climatic conditions, the weed coverage of the soil surface the nature of the crop, the arrangement and total surface of the sampling plots, the ground beetles of the adjacent biotopes and human subjective differences the sample collection.

The correlation between the great average size of plots and the small number of species was detectable also in the case of farms where the sample surface was prominently large (Sárospatak). However, here the high sampling value increased the expectable species number only to a small extent. Alternatively, among the farms having a small sampling area generally less species occurred than expected, even in those cases where the average plot size was small.

Besides the samplings carried out by the farms we have in many cases also withdrawn samples. In the course of these soil samplings, it could be observed that on passing through relatively homogeneous large-scale plots from the borders towards the centre, the population of ground beetles per unit surface exhibited a gradually decreasing tendency. From this

observation, quite in accordance with that made concerning the samples withdrawn by the farms, one may conclude that in the centre of the large monocultures (above 50 ha) the life conditions are very unfavourable for the ground beetles. The centre of each plot obtains a population of ground beetles from the verges of the plot, whereas the verges themselves become populated by ground beetles from the surrounding biotopes.

The correlation between the average plot size and the number of species may be related to the immigration of insects from the surrounding territories. The smaller plots have greater contact with the surrounding biotopes with a relatively greater surface, and the smaller plots are formed *a priori* on areas where both the surface and the biotope conditions are more variegated. Here the formation of larger plots is not economically reasonable. In these smaller plots the immigration of ground beetles from the environment richer in both species and individuals occurs on a larger scale.

The above described correlation is also essentially valid in relation to the number of individuals (Fig. 4). On arranging the farms in the order of decreasing average plot sizes, we find that the average population density of ground beetles per unit surface of the first 24 farms is only the half (1.04/m²) of the average of the other 23 farms (1.92/m²). The exceptions are explained by the effect of other factors which have already been mostly mentioned. Thus, in those cases where higher numbers of individuals would have been expected, the actually lower value was due in general to the small size of the sampling area.

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MISCELLANEOUS COMMUNICATIONS

A NEW METHOD FOR THE DETECTION AND QUANTITATIVE DETERMINATION OF PYRIDATE RESIDUES IN PLANTS

In pesticide analysis the employment of TLC as an analytical method is not unusual (ZWEIG 1974). Making the material perceptible (detection) and establishing its quantity generally represent a greater problem than the separation. In most cases separation is preceded by a purification process consisting of several stages. The interesting thing about the present analytical method is that, because of the fairly specific reagent used, separation and quantitative evaluation can be carried out without any previous purification.

Pyridate (O-6-chloro-3-phenyl-4-pyridazinyl-S-n-octyl-thiocarbonate), a herbicide used mainly to control dicotyledonous weeds, is marketed in Hungary by the North Hungarian Chemical Works under the name Lentagran. In order to examine its decomposition, it was necessary to elaborate an analytical method by which the quantity of the active agent could be determined. The producer of the pyridate, Chemie Linz AG, indicates in the description of the active agent that the quantity of the decomposition product (3-phenyl-4-hydroxy-6-chloro-pyridazine) can be measured using a gas chromatography technique. However, with this method it is impossible to differentiate between the active agent and the decomposition product which may appear in the plant.

In the course of earlier investigations, carried out for other purposes, it was found that pyridate added to a chloroplast suspension could be extracted with carbon tetrachloride and easily separated from plant pigments on a silica gel layer. Using 2,6-dichlorquinone chlorimide and Na_2CO_3 solution as reagent at room temperature the pyridate appears in visible spots after 30 minutes or so. This method of detection, though not sufficiently sensitive, called attention to the possibility of elaborating an adequate method of analysis along these lines. An attempt was made to find the optimum conditions for extraction from the plant, for separation, and for quantitative determination. The present paper does not give an account of the process by which the method was elaborated, but is confined to describing certain phases of the analytical technique.

Separation by thin layer chromatography

The material to be examined was applied to a Merck silica gel plate (DC-Fertigplatten Kieselgel 60), and develop with a 100 : 8 mixture of carbon tetrachloride and ethyl acetate in a non-saturated chamber. The R_f value of pyridate varies as a function of the external conditions, particularly of the vapour composition of the solvent, giving a value of about 0.4. When a standard is used in each case, slight changes in the value of R_f are not disturbing.

Detection

2,6-dibromo-quinone-chlorimide proved more suitable than reagent previously used. The 20×20 cm plate is sprayed with a 0.2% solution of 2,6-dibromo-quinone-chlorimide dissolved in ethanol, and immediately afterwards with 10 cm^3 saturated aqueus Na_2CO_3 solution. To accelerate the appearance of the spots, the plate is placed for 10 minutes in a thermostat at 100 °C. The brownish-yellow spots, while hardly visible to the naked eye, are clearly seen to fluoresce when illuminated by ultraviolet light with a wave-length of 350–360 nm. The spots appearing on the plate are stable for several days.

Quantitative evaluation

The best method for the quantitative evaluation of the spots proved to be the measurement of the intensity of luminescent light. To induce this a Hg E/2 (Narva) spectral lamp was used. The focussed light was directed onto the chromatographic layer through a colour screen giving maximum transmission at 355 nm. The beam containing both the reflected and the luminescent light was filtered with a colour screen providing maximum transmission at 526 nm, and directed onto a photocell sensitive to blue. Measurement was carried out with equipment consisting of an MD-100 microdensitometer of Zeiss make and a K-200 recorder. The microdensitometer was necessary only for the even motion of the plate.

In Fig. 1 the fluorescence intensity of varying concentrations of the standard material on the reagent-sprayed dry plate is shown as a relative value when the recorder had a sensitivity of $2 \cdot 10^{-9}$ A (Fig. 1). As can be seen, amounts of pyridate as low as 10 nanomoles can be easily measured. Attempts were made to increase the sensitivity of the quantitative determination, and it was found that certain polar organic solvents increased the visibility of the spots as long as they kept the environment of the spots damp. After they had evaporated both the visibility and the intensity of the fluorescence decreased again. In the environment

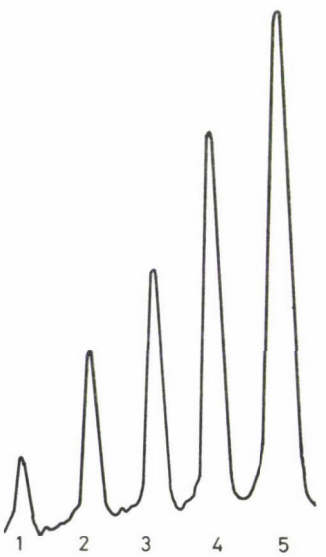

Fig. 1. Relative fluorescence intensity values of pyridate standard measured on a dry layer (1 = 10 nanomoles, 2 = 25 nanomoles, 3 = 50 nanomoles, 4 = 100 nanomoles, 5 = 200 nanomoles; sensitivity: $2 \cdot 10^{-9}$ A)

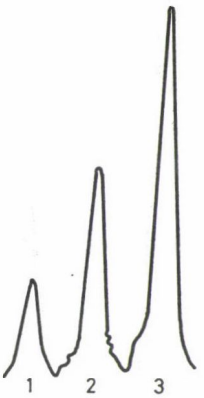

Fig. 2. Relative fluorescence intensity values of pyridate standard measured after spraying with ethanol (1 = 2 nanomoles, 2 = 5 nanomoles, 3 = 10 nanomoles; sensitivity: $0.5 \cdot 10^{-9}$ A)

of the compound to be measured the background becomes darker and the fluorescence of the spots can be seen better. During measurement the "background noise" lessens, so the sensitivity of the recorder can be increased.

In Fig. 2 the effect of spraying with ethanol after the detection of the spots to be measured can be seen (Fig. 2), showing that under such conditions a quantity of pyridate as low as 2 nanomoles can be measured at a recorder sensitivity of $0.5 \cdot 10^{-9}$ A.

Extraction of pyridate from the plant

Sunflower and maize plants were planted in pots 23 cm in diameter. The young plants were sprayed by means of a hair sprayer with a quantity of pyridate 70 EC corresponding to a 2 litre/ha treatment. For the extraction half the plants raised in the pots, i.e. equivalent to a plant-growing area of roughly 200 cm^2, were used. During the days following the spraying the possibilities of extraction were studied. The plants were first homogenized in an aqueous medium, and the herbicide was shaken out of with carbon tetrachloride. The Potter homogenizer gave a better result than homogenization in a blender, but the former is a highly labour-intensive procedure. Among the traditional methods, grinding with quartzsand seems to be the most suitable. Although a considerable quantity of pyridate can also be extracted from leaves dried at 100 °C, the highest value was obtained by grinding with quartzsand.

When grinding with quartzsand a 0.33 M NaCl solution buffered with 0.05 M phosphate was used as the aqueous medium. The thick pulpy substance was washed with this solution into a funnel shaker, then shaken twice with carbon tetrachloride. The carbon tetrachloride phases were united and distilled to dryness in a vacuum. The residue was dissolved in 1 cm^3 ethanol, and 20–25 μl of this solution was dripped onto the silica gel plate. Even a quantity of 50 μl separates relatively well, and though the area of the spot is rather large, the quantitative evaluation can still be carried out.

As seen in Fig. 3, one day after spraying a considerable amount of pyridate can still be measured in the sunflower plant (Fig. 3). On the fifth day following spraying only 20% of the initial value can be demonstrated. Fig. 4 shows the values obtained for the maize plant two and six days after spraying (Fig. 4). It is clear that a decrease in the active agent can be demonstrated in this case, too, though the change is of lesser extent than in the dicotyledonous sunflower.

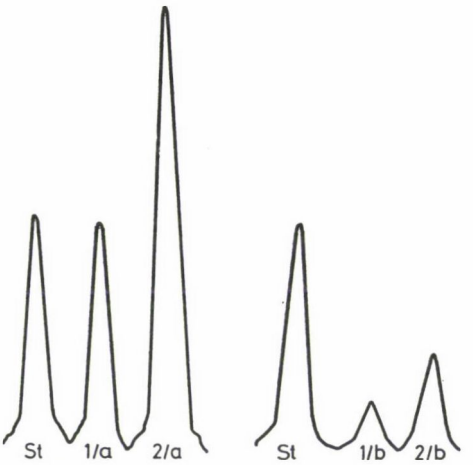

Fig. 3. Changes in the pyridate content of sunflower (St = 10 nanomoles pyridate, 1 = 25 μl experimental material (a = 1 day, b = 5 days after spraying), 2 = 50 μl experimental material; sensitivity: $1 \cdot 10^{-9}$ A)

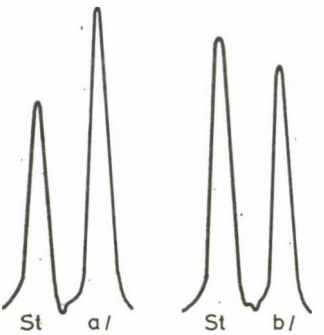

Fig. 4. Changes in the pyridate content of maize (St = 10 nanomoles pyridate, a = 25 μl experimental material 2 days after spraying, b = 25 μl experimental material 6 days after spraying)

In the work reported in the present paper the aim was to elaborate a new, practicable method of analysis rather than to study the decomposition of pyridate. The data obtained with plants serve to demonstrate the usefulness of the method. However, they suggest that the rate of decomposition of pyridate in pesticide-sensitive dicotyledonous plants is not the same as in non-sensitive monocotyledonous plants.

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STUDIES ON INTERRELATIONSHIPS BETWEEN YIELD AND YIELD COMPONENTS IN INTERVARIETAL CROSSES OF LINSEED (*LINUM USITATISSIMUM* L.)

In an autogamous crop like linseed, breeding procedures are restricted to hydridization and subsequent selection for better plant ideotypes. Ideotype breeding promises to elevate the yield potential in new genotypes of crop plants. This approach to crop improvement, suggested by DONALD (1968), is concerned with the structural and developmental sequence of plants which are best suited to a particular environment. An improvement in yield may be possible with ideotype breeding, which involves breeding for yield and yield components. The description of the ideal plant type depends not only upon the interrelationship of the different variables but also on the cause and effect relationship of the variables.

In the present investigation, studies on interrelationship and path coefficient were undertaken in hybrid and segregating populations (F_1 and F_2), along with their parents, to assess the information requiered for ideal plant type.

Ten genetically diverse linseed types were crossed in all possible combinations excluding reciprocals. These ten genotypes included peninsular, Indo-Gangetic and exotic cultures. The peninsular types were S-36 and 46-10, the Indo-Gangetic types were R-17, Neelum, Mukta, T603, T397, NPRR-9 and K2 and the exotic type was EC 1387. The parents, F_1 and F_2 were sown in single and four-row plots, respectively, in a complete randomised block design with three replications. In each plot, rows 3 m in length were spaced 30 cm apart and the plant to plant distance was 15 cm. Five plants from the parents and F_1, and 20 plants from the F_2 were randomly selected for recording observations on the following characters: (1) days to 50% flowering, (2) days to maturity, (3) plant height (cm), (4) tillers/plant, (5) capsules/plant, (6) seeds/capsule, (7) 1000 seed mass (g) and (8) yield/plant (g).

The correlation coefficients and path coefficients were calculated at the genotypic and phenotypic levels for the F_1 and F_2 generations separately according to AL-JIBOURI *et al.* (1958) and DEWEY and LU (1959), respectively.

The phenotypic and genotypic correlation coefficients observed in the F_1 and F_2 generations are presented in Table 1.

In the F_1 generation, grain yield showed a significant and positive correlation with tiller number, capsule number and 1000 seed mass at phenotypic and genotypic levels. However, in the F_2 generation the yield showed a negative association with the number of tillers per plant; this may be due to the low heritability of the character. The magnitude of the estimates of genotypic correlation were higher than the phenotypic correlations in most cases in both the F_1 and F_2 generations. A significant positive correlation of the yield with the number of tillers per plant, capsules per plant and 1000 seed mass was also reported by BADWAL *et al.* (1970), BADWAL *et al.* (1971), YADAWA and DALAL (1972) and VIJAYKUMAR and VASUDEVARAO (1974) in linseed. CHANDRA (1978) reported a positive association of yield with capsule number and 1000 seed mass, but a negative correlation with tiller number. Number of seeds per capsule, days to 50% flowering, days to maturity and height showed a negative association with yield in both the generations. A negative association of yield with plant height is reported by CHARDRA (1978).

In both the F_1 and F_2 generations, capsules per plant and 1000 seed mass showed a positive significant correlation, while the number of seeds per capsule and 1000 seed mass showed a negative association. Similarly, a very weak association between plant height and tiller number was observed in both the generations.

The path coefficient analysis, which measures the direct and indirect effects of one component via another on the yield, was worked out separately for the F_1 and F_2 generations. The results are presented in Tables 2 and 3.

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Table 1

Phenotypic (P) and genotypic (G) correlation coefficients among eight characters in P_1 (upper diagonal) *and* F_2 (lower diagonal)

		Days to 50% flowering	Days to maturity	Plant height (cm)	Tillers/plant	Capsules/plant	Seeds/capsule	1000 seed mass (g)	Yield/plant (g)
Days to 50% flowering	P		0.4993**	0.6691**	0.1429	−0.2282	1.1445	−0.3260*	−0.1834
	G		0.5989**	0.8011**	0.2956*	−0.2160	0.2824*	−0.3771**	−0.1943
Days to maturity	P	0.7480**		0.6992**	0.0423	−0.1722	−0.1334	−0.0125	−0.1022
	G	0.8036**		0.8890**	0.0369	−0.1907	−0.2050	−0.0467	−0.1336
Plant height (cm)	P	0.7182**	0.6584**		0.0497	−0.1645	−0.0605	−0.1100	−0.1296
	G	0.7882**	0.7471**		0.0471	−0.2779*	−0.0823	−0.1287	−0.2535
Tillers/plant	P	0.3794**	0.1977	0.2187		0.5764**	−0.0624	−0.0802	0.3855**
	G	0.5341**	0.2742*	0.2581		0.6976**	−0.1991	−0.1165	0.4412**
Capsules/plant	P	−0.4677**	−0.4646**	−0.2929*	0.2225		−0.1440	0.2584	0.7479**
	G	−0.6245**	−0.6389**	−0.5508**	0.1462		−0.4034**	0.3867**	0.9172**
Seeds/capsule	P	0.2299	0.2434	0.1471	−0.1171	−0.2277		−0.3145*	−0.0777
	G	0.4646**	0.5691**	0.3667**	−0.0592	−0.8326**		−0.5078**	−0.2283
1000 seed mass (g)	P	−0.3220*	−0.2077	−0.2443	−0.0941	0.1544	−0.1686		0.3584**
	G	−0.4115**	−0.2826*	−0.3239*	−0.1601	0.3462**	−0.4175**		0.5485**
Yield/plant (g)	P	−0.4721**	−0.3807**	−0.2532	0.0658	0.7884**	0.1643	0.2448	
	G	−0.6305**	−0.5007**	−0.4521**	−0.0710	0.9403**	−0.5091**	0.5444**	

*, ** Significant at 5 and 1% levels, respectively.

Table 2

Direct and indirect effects of plant characters on grain yield using phenotypic and genotypic correlation coefficients in the F_1 generation

Character		Days to 50% flowering	Days to maturity	Plant height	Number of tillers	Number of capsules	Number of seeds/capsule	1000 seed mass
Days to 50% flowering	P	*0.0472*	0.0228	−0.0297	−0.0026	0.1661	0.0127	−0.0676
	G	*0.4901*	0.2322	−0.4399	−0.1684	−0.2907	0.0551	−0.0728
Days to maturity	P	0.0235	*0.0457*	−0.0310	−0.0007	−0.1253	−0.0117	−0.0026
	G	0.2935	*0.3878*	−0.4881	−0.0210	−0.2567	−0.0400	−0.0090
Plant height	P	0.0315	0.0320	*−0.0444*	−0.0009	−0.1197	−0.0053	−0.0288
	G	0.3927	0.0447	*−0.5491*	−0.0268	−0.3740	−0.0160	−0.0248
Number of tillers	P	0.0067	0.0019	0.0022	*−0.0184*	0.4195	−0.0034	−0.0166
	G	0.1448	−0.0143	−0.0258	*−0.5698*	0.0389	−0.0388	−0.0224
Number of capsules	P	−0.0107	−0.0078	0.0073	−0.0106	*0.7278*	−0.0126	0.0536
	G	−0.1058	−0.0739	0.1526	−0.3975	*1.3459*	−0.0787	0.0746
Number of seeds/capsule	P	0.0068	−0.0061	0.0026	0.0011	−0.1048	*0.0879*	−0.0652
	G	0.1384	−0.0795	0.0451	0.1134	−0.5430	*0.1952*	−0.0980
1000 seed mass	P	−0.0153	−0.0005	0.0048	0.0014	0.1880	−0.0276	*0.2076*
	G	−0.1848	−0.0180	0.0706	0.0663	0.5204	−0.0991	*0.1931*
Residual effect	P	0.4034						
	G	−0.0356						

(Italics values are direct effects)

Table 3

Direct and indirect effects of plant characters on grain yield using phenotypic and genotypic correlation coefficients in the F_2 generation

Character		Days to 50% flowering	Days to maturity	Plant height	Number of tillers	Number of capsules	Number of seeds/capsule	1000 seed mass
Days to 50% flowering	P	*−0.1920*	0.0688	0.0563	−0.0206	−0.3592	0.0072	−0.0326
	G	*1.4633*	−0.3721	0.2232	−0.5650	−1.9554	0.8180	−0.2424
Days to maturity	P	−0.1436	*0.0920*	0.0517	−0.0107	−0.3568	0.0076	−0.0210
	G	1.1759	*−0.4630*	0.2115	−0.2901	−2.0005	1.0020	−0.1665
Plant height	P	−0.1375	0.0606	*0.0786*	−0.0118	−0.2249	0.0046	−0.0227
	G	1.1534	−0.3459	*0.2832*	−0.2730	−1.7246	0.6457	−0.1908
Number of tillers	P	−0.0728	0.0182	0.0171	*−0.0543*	0.1708	−0.0036	−0.0095
	G	0.7815	−0.1269	0.0731	*−1.0579*	0.4577	−0.1042	−0.0943
Number of capsules	P	0.0898	−0.0427	−0.0230	−0.0120	*0.7680*	−0.0071	0.0156
	G	−0.9138	0.2958	−0.1560	−0.1546	*3.1310*	−1.4660	0.2039
Number of seeds/capsule	P	−0.0441	0.0224	0.0115	0.0063	−0.1748	*0.0314*	−0.0170
	G	0.6798	−0.2635	0.1038	0.0626	−2.6067	*1.7609*	−0.2460
1000 seed mass	P	0.0618	−0.0191	−0.0176	0.0051	0.1185	−0.0053	*0.1013*
	G	−0.6021	0.1308	−0.0917	0.1693	1.0838	−0.7351	*0.5892*
Residual effect	P	0.6387						
	G	0.3427						

(Italics values are direct effects)

In both the F_1 and F_2 generations the path coefficient analysis results showed that the direct effects on the yield were positive in the case of number of capsules per plant, number of seeds per capsule and 1000 seed mass at the phenotypic and genotypic levels. Capsule number had the maximum direct positive effect on seed yield in both generations. Its indirect effects were either negative or very low in both the F_1 and F_2. The character 1000 seed mass showed a high positive indirect effect through capsule number.

It is interesting to note that in both generations tiller number showed a negative direct effect, while it showed a positive indirect effect via the number of capsules per plant. The other indirect effects were negative. The number of capsules per plant and 1000 seed mass showed direct positive effects on the yield. They also complemented each other through indirect effects, thus confirming the need for judicious selection for yield components. The results of maturity and plant height were not encouraging, thus indicating their insignificant contribution to yield.

The findings of the present investigation suggest that capsule number and 1000 seed mass are the major factors which directly contribute to seed yield. These characters are therefore important selection criteria for linseed improvement. The importance of these characters in linseed was also reported by BADWAL *et al.* (1970), VIJAYKUMAR and VASUDEVARAO (1974) and CHANDRA (1978).

Both the number of seeds per capsule and the 1000 seed mass had a positive direct effect on seed yield, indicating their importance in breeding programmes. However, these characters are negatively correlated, which has indicated that it may not be possible to increase the number of seeds per capsule without affecting the seed size (PATIL *et al.* 1979.)

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SEASONAL RELATION OF GROWTH AND NITROGEN ASSIMILATION IN MAIZE TO CHANGES IN THE CONDITION OF SOIL

Literature on plant physiology discusses the development phases of maize and the dynamics of nutrient uptake and nutrient transport between the plant organs in the course of development (HAY *et al.* 1953, FÜREDI 1960, ANDREJENKO and KUPERMAN 1961, SIMON and WOLCSÁNSZKY 1963, SZLOVÁK 1968, PÁL 1968, BEAUCHAMP *et al.* 1976, EVANS 1975). However, our knowledge is deficient of how the ecological conditions influence the nutrient uptake and the productivity of maize.

Seasonal changes in the soluble nutrient fractions of the soil have also been described by many authors (TREITZ 1924, KREYBIG 1946, MANNINGER and KERPELY: in KREYBIG 1946, VÁRALLYAY and KERESZTÉNY 1952, STANFORD and HANWAY 1954, FEHÉR 1954, KERESZTÉNY and CSÓK 1960, LOGINOV and KASZUBIAK 1964, NESZTEROVA 1965, PATÓCS 1974, KISSEL and SMITH 1978, MAHMUDOVA 1978, READ and COMERON 1979, STEFANOVITS and TOMKÓ 1980).

However, these authors studied only the nutrient dynamics of the soil, and this again does not give sufficient information about the dynamics of the soil-plant relationship.

The agrochemical literature concentrates above all on the grain yield and the rate of nutrition applied (GYŐRFFY 1966, DEBRECZENI 1974). Data available on the relation of soil and plant are mostly static. Dynamic studies on maize were published by SIGMOND (1900), SIGMOND and FLODERER (1905) and FERENC (1958), but neither were seasonal analyses of soil carried out in these studies. As for the period of initial development, results of model experiments are available (LATKOVICS and MÁTHÉ 1963, PUSZTAI and KÁDÁR 1980). Even such works dealing with the ecology of maize (FEHÉR 1962, ARNON 1974, VERESS 1975, PINTÉR 1979) do not mention investigations under the following conditions:

(1) Samples taken frequently enough to show the fluctuations in the growth- and nutrition processes of plants.

(2) Parallel measuring of the productivity and nutrient incorporation of the plant on the one hand, and of changes in the conditions of the top soil, on the other, under field conditions.

By providing for these two conditions, we intended to acquire a knowledge of the seasonal changes in the conditions of soil and maize plant, and discover their relationship.

The experiments were carried out in the field. This paper gives an account of the results in 1978 and 1979, obtained in a large-plot agrotechnical, fertilization, plant number and variety trial of the Bábolna Maize Production System, laid out on an area of some 750 m² in the fields of the Agárd Agricultural Combinate by Zichyújfalu, in three plots. The hybrid (JX62) was the same in all plots both in 1978 and 1979. Fertilization and plant number treatments per plot from 1977 on are shown in Table 1. In our examinations of seasonal dy-

Table 1

Fertilization and plant number treatments of plots

Plot	N	P_2O_5	K_2O	Total active agent	Plant number, 1000/ha
	kg/ha				
1.	180	120	200	500	60
2.	300	200	300	800	75
3.	300	200	300	800	60

Table 2

Soil, plant and meteorological data

Soil	Unit of measure	Abbreviation	Method	Number of data
1. Soil temperature	°C	s. temp.	field	780
2. Moisture	g/100g $cm^3/100cm^3$ FC %	s. moist.	desiccator	780
3. Plasticity	—		Arany's	780
4. pH	—	pH (KCl)	in nKCl (suspension)	780
5. pH		pH ($CaCl_2$)	in 0.02n $CaCl_2$ (extract)	780
6. Lime	%	$CaCO_3$	Scheibler	780
7. Total salt		salt	Conductometer	780
8. Humus	%	hum.	Tyurin's	780
9. N-hydrolysable	ppm	N hyd.	0.5n H_2SO_4, elementary N	160
10. N-soluble	ppm	N(KCl)	in nKCl, elementary N	780
11. in NO_3-CaCl_2	ppm	NO_3	in 0.02n $CaCl_2$, elem. N	780
12. in NH_4-CaCl_2	ppm	NH_4	in 0.02n $CaCl_2$, elem. N	780
13. P — AL	ppm	P — AL	ammonium lactate, el. P	780
14. in $P-CaCl_2$	ppm	P	in 0.02n $CaCl_2$, elem. P	780
15. K — AL	ppm	K — AL	ammonium lactate, el. K	780
16. in $K-CaCl_2$	ppm	K	0.02n $CaCl_2$, elem. K	
17. Magnesium	ppm	Mg	nKCl	780
18. Manganese	ppm	Mn	0.05n EDTA + 0.1n KCl	780
19. Sodium	ppm	Na	ammonium lactate	780
20. Copper	ppm	Cu	0.05n EDTA + 0.1n KCl	780
21. Zinc	ppm	Zn	0.05n EDTA + 0.1n KCl	780
22. SO_4	ppm	SO_4	nKCl	780
23. Bulk density	g/cm^3	BD	monolit	85
24. Soil water regime	sat %	WP, FC	pF instrument	120
25. Cellulose decomposition	s %	cell.	Unger's test	150
Soil total	—			*16 895*
Climate				
1. Daily min. temperature	°C		min. thermometer	670
2. Daily max. temperature	°C		max. thermometer	670
3. Daily morning temp.	°C		normal thermometer	670
4. Daily precipitation	mm		pluviometer	145
5. Sunshine hours	hour/day		radiometer	670
Climate total				*2 825*
Plant				
1. Growth space	cm^2	g.sp.	plant and row distance	486
2. Leaf area	cm^2	LA	length × width	3 200
3. Fresh weight	g	FW	gravimetry	135
4. Dry matter		Dm		
leaf			gravimetry	270
5. stalk			gravimetry	270
6. grain			gravimetry	150
7. other			gravimetry	180
8. Nitrogen in leaf	%		protein — N	270
9. in stalk	%		protein — N	270
10. in grain	%		protein — N	150
11. in other	%		protein — N	180
12. Phosphorus in leaf	%		elementary P	270
13. in stalk	%		elementary P	270
14. in grain	%		elementary P	150

(Table 2 continued)

	Plant	Unit of measure	Abbreviation	Method	Number of data
15.	in other	%		elementary P	180
16.	Potassium in leaf	%		elementary K	270
17.	in stalk	%		elementary K	270
18.	in grain	%		elementary K	150
19.	in other	%		elementary K	180
20.	Manganese in leaf	%		elementary Mn	270
21.	in stalk	%		elementary Mn	270
22.	in grain	%		elementary Mn	150
23.	in other	%		elementary Mn	180
24.	Zinc in leaf	%		elementary Zn	270
25.	in stalk	%		elementary Zn	270
26.	in grain	%		elementary Zn	150
27.	in other	%		elementary Zn	180
28.	Copper in leaf	%		elementary Cu	270
29.	in stalk	%		elementary Cu	270
30.	in grain	%		elementary Cu	150
31.	in other	%		elementary Cu	180
	Plant total				*9 911*
				Grand total	29 631

namics, these treatments were only regarded as modifying factors rather than the main questions of the experiment. The soil was a lime-coated chernozem.

In the first plot, the fertilizer active agents reflected the average nutrient supply of the farm; while in the other two plots, they represented an increased level. Regarding plant number, the first plot showed again the local practice characteristic of the hybrid in question, as did plot 3. Plot 2 was a treatment of increased plant density and the plant number was rather uneven.

The interaction between soil and plant and the validity of the correlations were examined, with the modifying effects of fertilization and plant number taken into consideration.

During the two years, a total of 26 samples were taken, 18 of them in the vegetation period when soil- and plant samples were collected every two weeks.

We began sampling by removing 5 plants per plot. The plants were regarded as replications of each other. The soil profile was deepened below the removed 5 plants. The frontal walls of the profiles faced the same direction at a distance of some 2 m apart. From each of the three profiles 10 samples were collected by 10 cm layers, down to a depth of 1 m. From the walls of profiles — after they had been cleaned — the samples were cut out with a knife, so that the sample of about 2 kg represented the given layer of the soil.

The list of measurings is given in Table 2. The distance of each plant from its two immediate neighbours and from the next two plants was measured on the spot. The soil temperature was taken with mercury soil thermometers in each layer of the soil profile. Air temperature and precipitation were recorded at the meteorological station set up in the field. The easily soluble nutrients were extracted by shaking with 0.02 n $CaCl_2$ for 5 minutes. The measuring of the wet soil and the necessary amount of solution was corrected by the moisture content of the soil. Besides measuring the moisture content, we also took the soil density and pF of intact samples. The plants were diggested in H_2SO_4 and H_2O_2. We performed parallel analyses of all plant organs.

Table 3

Main component analysis of 23 characteristics of soil condition on the basis of 260 data of each of plots 1, 2 and 3

Measurements abbreviated	Plot 1 main components			Plot 2 main components			Plot 3 main components		
	1	2	3	1	2	3	1	2	3
1. Soil temp.	0.35	0.53	−0.13	0.18	0.51	−0.31	−0.02	−0.31	−0.19
2. S. moist. s%	−0.33	0.12	0.63	−0.28	0.30	0.34	0.42	−0.12	0.39
3. S. moist. wc%	−0.20	0.02	*0.81*	−0.13	−0.02	*0.83*	0.31	−0.07	*0.72*
4. S. moist. sat%	−0.73	−0.06	0.49	−0.80	−0.08	0.32	0.80	−0.00	−0.34
5. Plasticity	*0.96*	0.18	−0.05	*−0.96*	−0.15	−0.06	*0.97*	0.15	0.07
6. pH	−0.29	*−0.89*	−0.21	−0.33	*−0.89*	−0.09	0.38	*0.77*	−0.36
7. Lime	*0.81*	−0.49	−0.12	0.41	*−0.80*	−0.08	−0.43	*0.70*	−0.30
8. Total salt	*0.95*	0.24	0.14	*0.98*	0.15	0.07	*−0.96*	−0.17	0.19
9. Humus	*−0.86*	0.37	0.23	*−0.84*	0.43	0.20	*0.83*	−0.27	0.38
10. N(KCl)	−0.21	−0.42	0.51	−0.39	−0.02	0.56	0.29	0.58	0.57
11. $N(CaCl_2)$	0.60	−0.14	0.57	0.80	0.17	0.42	−0.34	0.46	*0.69*
12. $NO_3(CaCl_2)$	−0.20	−0.26	*0.70*	−0.24	−0.13	*0.64*	0.23	0.61	*0.63*
13. $NH_4(CaCl_2)$	0.74	0.12	0.34	*0.85*	0.18	0.19	*−0.82*	−0.03	0.33
14. P-AL	*0.95*	0.25	0.15	*0.97*	0.15	0.07	*−0.96*	−0.17	0.20
15. $P(CaCl_2)$	*0.95*	0.25	0.13	*0.97*	0.15	0.07	*−0.96*	−0.18	0.19
16. K-AL	−0.64	0.48	−0.22	−0.62	0.35	−0.45	0.68	−0.32	−0.04
17. $K(CaCl_2)$	*0.92*	0.24	0.23	*0.94*	0.12	0.12	*−0.89*	−0.21	0.27
18. Mg	−0.79	0.55	0.02	−0.80	0.49	−0.04	0.75	−0.41	0.10
19. Mn	−0.25	0.63	0.27	−0.18	0.79	0.25	0.22	*−0.73*	0.23
20. Na	*0.98*	0.10	0.04	0.98	−0.02	0.01	*−0.98*	−0.02	0.15
21. Cu	−0.57	*0.71*	0.08	−0.47	0.74	0.09	0.48	*−0.72*	0.18
22. Zn	−0.05	0.10	−0.43	−0.07	0.06	−0.67	0.00	−0.02	−0.50
23. SO_4	−0.27	−0.83	0.17	−0.49	−0.70	0.20	0.41	0.75	0.13
Explained variance	44.6	18.1	13.3	45.5	17.8	12.2	42.6	18.4	13.4
%		75.9			75.5			74.3	

Data processing was carried out by main component analysis and graphic solutions. In the main component analysis processing without rotation was strictly applied. (In the text the word "factor" is also used in the sense of main component.) The most delicate phase of the main component analysis is the interpretation of results, in particular the identification of the main components with a definable phenomenon. It permitted us to produce the new compound variables in an objective way, exclusively on the basis of correlations actually existing between the data.

In consideration of the above, let us examing Table 3. The main component analysis of 23 characteristic conditions of the soil produced three major complex variables. The results of two years' measuring of soil samples were the input data of the analysis. The analysis of variations resulting from 10 depths × 26 dates yielded the most surprising conclusion of a totally similar main component structure in the 3 plots. This increases the reliability of interpretation and likewise means that differences in treatment between the plots did not influence the sequence of natural factors controlling the variability (and reflected in the main components), nor affected their importance (interpreted proportion of variance).

Without going into details, we give here the interpretation of the three main components. The first main component was identified with the temporal and spatial heterogeneity of the layers in the soil profile, that may be called soil composition or physical heterogeneity. The vertical and horizontal distribution of the quantity and quality of colloids explains nearly

Table 4

Main component analysis of soil, meteorological and productivity data

Plot 1

260 measuring data

List of variables	1.	2.	3.	4.	5.
1. S. moist. wc%	0.42	0.53	*−0.62*	0.15	−0.18
2. Plasticity	0.51	0.30	0.03	*−0.53*	−0.41
3. pH (KCl)	*−0.87*	0.19	−0.08	0.14	−0.08
4. Lime	*−0.89*	−0.04	0.15	0.24	−0.02
5. Humus	*0.90*	0.05	−0.24	−0.11	0.09
6. N(KCl)	0.01	*0.80*	0.38	−0.23	−0.05
7. $N(CaCl_2)$	−0.07	*0.82*	0.26	−0.33	0.09
8. $NO_3(CaCl_2)$	−0.02	*0.92*	0.20	−0.20	0.00
9. $NH_4(CaCl_2)$	−0.10	−0.07	*−0.66*	−0.24	0.49
10. P-AL	0.64	0.15	−0.27	0.49	−0.35
11. $P(CaCl_2)$	0.51	0.32	0.27	*0.60*	−0.33
12. K-AL	0.63	−0.23	0.57	−0.02	−0.08
13. $K(CaCl_2)$	0.56	0.56	0.33	0.25	0.07
14. Mg	*0.91*	−0.27	0.08	−0.15	0.04
15. Cu	*0.80*	−0.22	−0.13	−0.17	0.41
16. Zn	−0.03	−0.23	*0.77*	−0.01	0.02
17. SO_3	*−0.69*	0.41	−0.15	0.10	−0.08
18. Temperature	0.24	−0.17	0.32	0.50	*0.62*
19. Precipitation	0.39	0.10	−0.49	0.20	−0.15
20. NAR	0.19	*0.67*	0.11	0.10	*0.50*
21. NNAR	−0.11	*0.72*	−0.20	0.28	0.25
Explained variance	30.4	21.1	13.2	8.3	7.7
%			80.7		

half of the variations. The second complex variable is the chemical solubility or pH factor, while the third is a factor characterizable with the relative water content and available nitrogen content of the soil.

The factor weight matrix shown in Table 4 is much like the former ones (Table 4). It cannot be totally identical with them if only because, in order to avoid too large a number of variables, we omitted 6 soil variables. Besides the soil variables, we included here 2 climatic and 2 productivity factors; the temperature totals and the amount of precipitation between the dates of sampling, and the net assimilation rate (NAR) and net nitrogen assimilation rate (NNAR), respectively. The latter was first introduced in September 1980 (KOVÁCS—MÁTHÉ 1980). For NNAR we used the same method of calculation as for NAR, except that the increase of dry matter was replaced by the increase of assimilated nitrogen. The 2 pro-

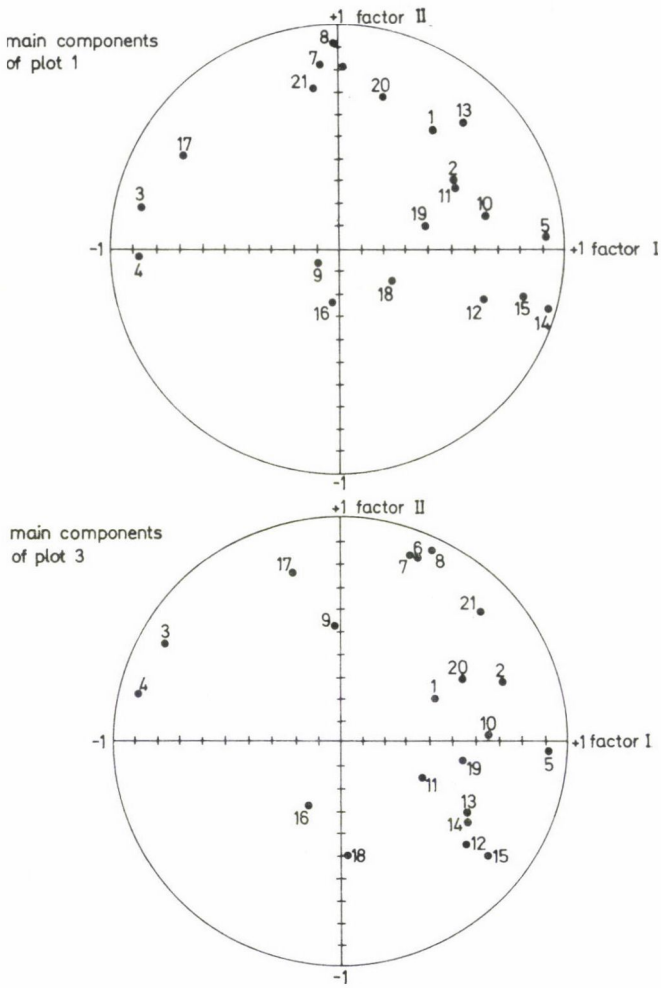

Fig. 1. Main component analysis of soil, meteorological and productivity data: projection of the vectors of the original variables in the plane of the first two main components. Numbers explained in Table 4

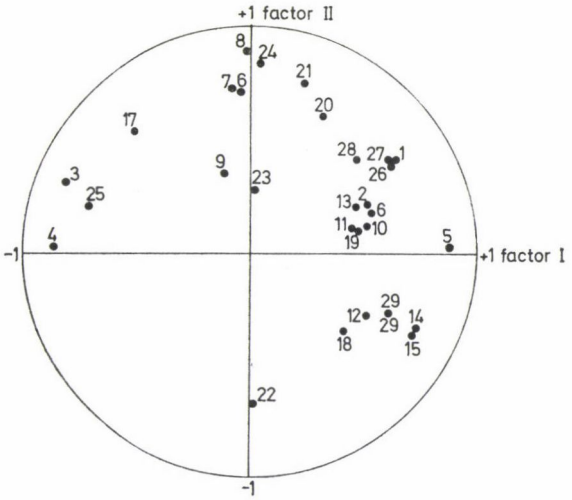

Fig. 2. Joint main component analysis of the three plots. The list of variables up to the 22nd is found in Table 4 and from then on they are: 22 = LAI, 23 = growth space, 24 = total salt, 25 = K-AL, 26 = soil moisture (s%), 27 = soil moisture (sat%), 28 = soil temperature; 29 = Mn

ductivity variables introduced have a greater share in the formation of factors 2 and 5. Factor 5 may be called "temperature factor" which also shows relation to the NAR, but its share in the variation is relatively low (7.7 per cent).

The second factor corresponds to factor 3 in the former main component analysis. The weight of the factors shifted towards the different nitrogen indices. This means that the easily soluble nitrogen content of the soil, and the dry matter and nitrogen increase of maize per unit assimilation surface, provide the second most important factor of the whole range of variables examined. For this reason that factor may be called the nitrogen factor as well. In the first factor the combination of factors 1 and 2 of the former analysis can be observed. It has, however, no ecological importance even in the first two plots, since the factor weights of NAR and NNAR, the indicators of productivity, are 0.1 or so. On the other hand, in the third plot the factor weights of NAR and NNAR are considerable — about 0.5–0.6 — with a practically unchanged structure of factors. It can be assumed, accordingly, that the physico-chemical heterogeneity of the soil had reached a threshold value where the maize plant responded to environmental changes with various rates of assimilation. This change, resulting in the turn of the planar projection of factor fields, is seen in Fig. 1. The vectors of assimilation rates came nearer to the axis of factor 1.

From the joint main component analysis of 30 variables for the three plots, the axial section of main components 1 and 2 are shown in Fig. 2. The number of observation units is 780. The first 5 main components explain 76.5 per cent of the total variance, the first two 47.8 per cent. It can be seen that with all data of the three plots taken into consideration, the variables of the soil nitrogen indices and of the NNAR and NAR are found along the vertical axis, i.e. the nitrogen factor, with a relatively high vector value in the positive range; while the — mostly negative — values of LAI are located similarly along the axis. The NAR, and to a lesser extent the NNAR, can be observed to move towards axis I. The cause was the phenomenon seen in plot 3 in the former analysis. This result confirms the existence of a dynamic relationship between the nitrogen content of soil and the assimilation. The *r*-values

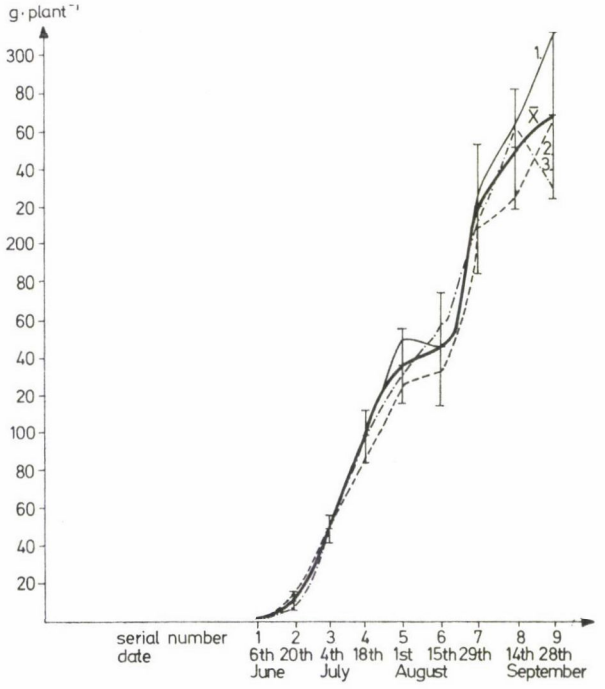

Fig. 3. Dynamics of dry matter accumulation in maize, 1978 (━ average of three plots, — plot 1; - - - - - plot 2; ····· plot 3; I confidence band, P = 5% for the average of the 3 plots)

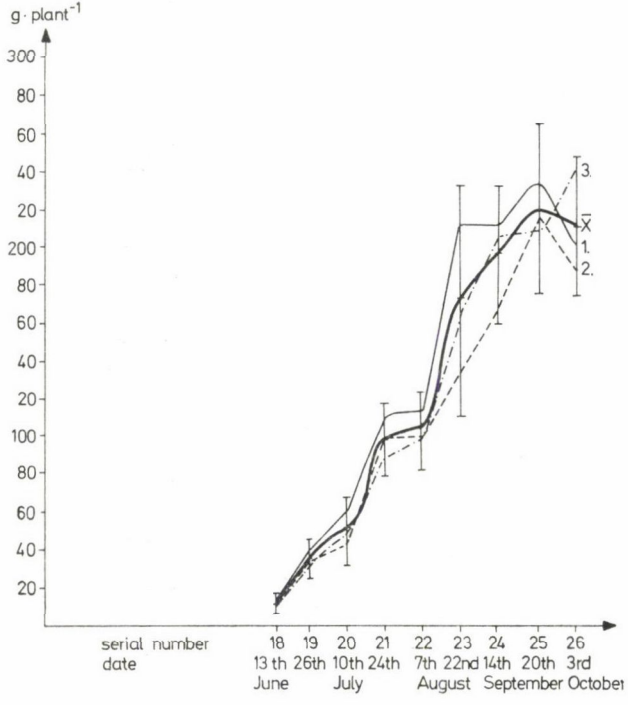

Fig. 4. Dynamics of dry matter accumulation in maize, 1979 (━ average of three plots; — plot 1; - - - - - plot 2; ····· plot 3; I confidence band, P = 5% for the average of the 3 plots)

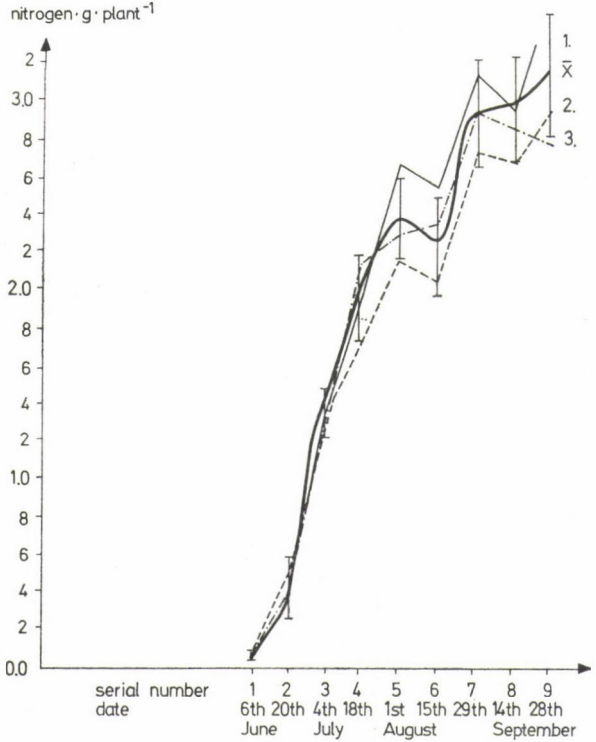

Fig. 5. Dynamics of nitrogen accumulation in maize, 1978 (▬ average of the three plots; — plot 1; - - - - - plot 2; ····· plot 3; I confidence band, P = 5% for the average of the 3 plots)

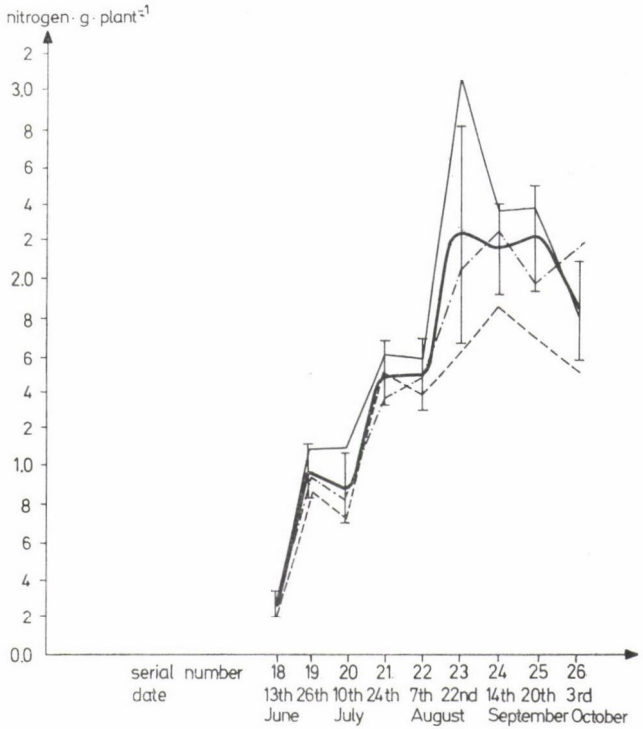

Fig. 6. Dynamics of nitrogen accumulation in maize, 1979 (▬ average of the three plots; — plot 1; - - - - - plot 2; ····· plot 3; I confidence band, P = 5% for the average of the 3 plots)

concerning the relation of various forms of soil nitrogen to N assimilation are one and all significant and positive. The close relation of the latter to the NO_3 content soluble in 0.02 n $CaCl_2$ is particularly remarkable. This supports the statements of LITVINYENKO and LEBENYEV (1978) concerning the relation of nitrogen deficiency to reduced photochemical activity.

The first two factors maintained their factor weight compositions in further calculations — not published here — in all three plots and both years. The other factors were hardly important — if at all — from the point of view of the productivity or the nutrient regime of maize. Therefore we directed our attention to the interpretation of the first two factors and the detailed exploration of the correlations indicated. The second, i.e. the nitrogen factor, seems to be the most important ecological question in the experiment from both a theoretical and a practical point of view. We therefore drew up the dry matter and nitrogen accumulation curves of maize. Figs 3 and 4 show the increase of dry matter, while in Figs 5 and 6 the additive curves of nitrogen assimilation are seen. Each figure represents one year's data for the three plots.

Similarly, as the three plots showed no significant differences in the main component analysis, the curves of dry matter and nitrogen increase, respectively, in the three plots are also very similar. The two-week period beginning at the end of July is remarkable; dry matter accumulation slows down at that time in both years, and nitrogen assimilation does not take place — according to the curves. It is important to know that the annexed summarizing curves are based on the measuring data of the above-ground parts. If we accept the hypothesis of BALDWIN (1975) who states that in the case of nitrogen deficiency the assimilates are transported to the roots and the root system develops vigorously, then we can understand the temporary reduction of nitrogen in the above-ground part, as shown numerically in Table 5, on the average of the three plots (Table 5).

Table 5

Increases in the amount of assimilated nitrogen and the related SD values (aboveground part, g/plant, n = 15)

Intervals	increase of N	$SD_{P=5\%}$
	g	
1978		
6–20 June	0.36	0.11
20 June–4 July	0.94	0.16
4–18 July	0.61	0.25
18 July–1 August	0.42	0.30
1–15 August	−0.14	0.33
15–29 August	5.17	0.37
29 August–14 September	0.04	0.37
14–28 September	0.18	0.42
1979		
13–26 June	0.70	0.15
26 June–10 July	−0.09	0.21
10–24 July	0.62	0.24
24 July–7 August	−0.01	0.25
7–22 August	3.73	0.57
22 August–4 September	−0.08	0.59
4–20 September	0.06	0.37
20 September–3 October	−0.38	0.37

From the results we have drawn several theoretically und practically important conclusions.

(1) Under the given climatic and soil conditions, the two-week period from the end of July was critical for the assimilation of maize.

(2) From the point of view of dry matter increase and nitrogen incorporation in maize, the readily soluble nitrogen content of soil and its seasonal dynamics are of outstanding importance.

(3) The seasonal dynamics of nitrogen assimilation in maize was not practically influenced by fertilization and increased plant number under the conditions of the treatments applied.

(4) The new parameter introduced by us — the Net Nitrogen Assimilation Rate (NNAR) — has proved suitable to describe ecological correlations.

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EFFECT OF FERTILIZATION ON THE WATER CONTENT OF GRAIN IN MAIZE HYBRIDS

Among the grain fodders, maize harvested shelled requires the largest amount of fuel for drying. It would be desirable to reduce the water content of maize grains in a natural way by the time of harvesting. This can be achieved only by growing hybrids with an appropriate vegetation period and a quality of losing excessive water. Considerable energy can be saved with the recently elaborated wet storage methods (maize grains stored hermetically, preserved in silo or prism, as well as maize ground wet, and wet maize grain crushings). However, when producing mixed fodders dry maize cannot be dispensed with, and even the whole grains stored in air-tight elevators are the most favourably stored when the water content of grains is lower.

In Hungary the causes of water evaporation from the grains have only been studied for a few years, and though some correlations are already known, they are not enough to provide reliable comprehensive information (NÉMETH 1980). HADI (1981) obtained the closest correlation with the raw thousand-grain-weight. Factors influencing the evaporation of water are the type of grain (DERIEUX 1975), the thickness of pericarp (PURDY and GRANE 1967, HELM and ZUBER 1969), the number and quality of husk leaves (GRANE *et al.* 1959). NEMÉNYI (1983) pointed out relationships between the evaporating capacity of maize hybrids, and the pericarp structure and chemical composition of maize grains, as well as their ability to lose water. At the same time the cultural practices also influence the evaporation of water (NAGY and ZEKE 1981).

Among the numerous factors affecting the water content of maize grains, the effect of fertilizers is very important. Studying the effect of N-containing fertilizers GOTLIN and PUCORIC (1977) found that, with an increase in the rate of fertilization, the water content of grains decreased. They analysed five maize hybrids for crude protein percentage, yield and water content on harvesting. With increasing rates of N-fertilization, the yield and crude protein content increased while the moisture content of maize grains decreased, in the hybrids. GAGRO (1978) likewise studied the influence exercised by the increasing rates of N-fertilization (0–200 kg/ha N active agent) on the moisture content of maize grains, and found the highest moisture content of grain in the untreated control and the 200 N kg/ha treatment. Factors affecting favourably the development of the maize stand have a positive effect also on the loss of water from the maize grains. Fertilization first of all promotes the better development of cobs and grains, thus making it possible to attain larger yield averages. In addition, fertilization, when carried out properly, somewhat decreases the specific water demand of maize (LÁNG 1976). When in the development period between tasseling and waxen ripeness, optimum quantities of water and nutrients are not available, and a decrease in yield occurs (KREUTZ *et al.* 1977). Irrigation at a low fertilizer level considerably increased the moisture content of

grains in several maize hybrids (NAGY and ZEKE 1982). In response to a favourable nutrient supply, the utilization of water by the plants greatly improves, and the plant production is increased by fertilization to a much higher extent than the water uptake (DEBRECZENI 1976, RUZSÁNYI 1975). A scientifically-founded nutrient replacement is a basic condition for the development of the plant stand and the further increase of yields (BESZLANEEV 1976, TOMUZEI *et al.* 1976, NEL and VERWEY 1977).

To determine the optimum rate of fertilization is a difficult task, if only because it varies with year, and plant variety, and depends also on the water balance and chemical characteristics of the soil. The results of investigations made under different ecological conditions range between different N-optimum intervals. But they all agree in one point, that the size of yield is primarily determined by the rate of N-fertilization, provided that the other elements are not reduced to minimum (BOCZ 1976, GYŐRFFY 1979, SARKADI 1979). According to LEASK and DAYNARD (1976) the dry matter content of maize grains shows an exponential increase in function of the decrease in their moisture content from 36%.

We set up our experiment on the central Field Trial Grounds of the Debrecen University of Agricultural Sciences at Hajdúszoboszló, with the assistance of the KITE. In 1980–1983 we followed the trend of the grain moisture content in a number of maize hybrids at a total of six nutrient levels (Table 1). The soil of the experiment was chernozem with deep humus layer formed on loess, which offered every possibility to obtain maximum yields. The humus content of the soil was 3.2 per cent, its Al-soluble P_2O_5 content in the control plots 40–50 mg, and its K_2O content 190–200 mg/1000 g soil.

The hybrids examined were: Pioneer hybrid 3780 (560) MSC, Szegedi MSC 515, Pioneer hybrid 3901 (390) and Pioneer hybrid 3978 (280).

Ear samples for measuring the moisture content of maize grains were taken from all four replications of the experiment on each occasion. The samples were taken from the three middle rows of the net plots, leaving the first five plants left out. On each occasion of sampling, we collected 3 ears — one per row — from the plots of the four replications, so all of our data are averages of 12 samples. Sampling was carried out continuously on all of the plants. The sample ears were shelled one by one, dried in thermostat at 60 °C to constant weight, then measured back. The method we used made the statistical analysis and the evaluation of grain moisture data possible.

Sampling was carried out at the time of harvesting; in 1980 on 20 October, in 1981 on 3 October, in 1982 on 3 October, and in 1983 on 23 September. In our experiment the forecrop in 1980, 1981 and 1983 was maize, in 1982 wheat. The time of sowing was 29 April in

Table 1

Fertilizer active agent

(kg/ha, 1980–1983)

Rate of NPK fertilization	N	P_2O_5	K_2O	Total
0	—	—	—	—
1	60	45	53	158
2	120	90	106	316
3	180	135	159	474
4	240	180	212	632
5	300	225	265	790

1980, 27 April in 1981, and 22 April both in 1982 and 1983. The rows were spaced at 70 cm. The number of plants was 59 242/ha with Pioneer hybrid 3780 and Szegedi MSC 515, and 75 188/ha at Pioneer hybrid 3901 and Pioneer hybrid 3978.

The weather was very different in the successive years of the experiment. The amounts of natural precipitation from the removal of the precrop to sowing, then from sowing to harvesting were 187 and 434 mm in 1980, 305 and 306 mm in 1981, 287 and 306 mm in 1982, and 163 and 312 mm in 1983, respectively. The seasonal differences are clearly shown by the effective thermal unit calculated for the vegetation period. In comparison to the 50 years' average of the experimental area, the total temperature of the vegetation period was —183.2 °C in 1980, —36.6 °C in 1981, +141.4 °C in 1982 and +198.2 °C in 1983. The major climatic factors influencing the production of maize hybrids on our experimental area are shown in Table 2.

Table 2

Trends of major climatic factors influencing the production of maize
(Hajdúszoboszló, 1980–1983)

	50 years' average	1980	1981	1982	1983
Sunshine hours					
April–September	1451	1305	1499	1623	1532
Mean temperature (°C)					
April–September	17.3	14.2	16.1	17.1	17.3
Precipitation (mm)					
October–March	340	187	305	287	163
April–September	340	434	306	306	312
October–September	680	621	611	593	475
Total temperature (°C)	1356	1172	1319	1497	1554

Table 3

Effect of fertilization on the moisture content of grain in Pioneer hybrid 3901
(Hajdúszoboszló, 1980–1983)

Rate of NPK fertilization	Moisture percentage of grains				Average
	1980 20 October	1981 3 October	1982 3 October	1983 23 September	
Ø	30.9	30.9	23.5	20.4	26.4
1	26.6	29.3	22.0	16.5	23.6
2	27.8	28.7	21.2	17.5	23.8
3	22.1	27.6	20.8	17.9	22.1
4	26.5	32.1	20.4	18.1	24.2
5	27.9	30.6	22.5	17.8	24.7
Average	26.9	29.8	21.7	18.0	24.1
Fertilization $SD_{5\%}$	1.17***	1.01***	0.60***	0.99***	

*** P = 0.1%

The trend of the grain moisture content in the maize hybrid Pioneer hybrid 3901 is shown in Table 3. In response to fertilization, the moisture content of grains considerably decreased in all four years of the experiment. On the average of four years, the lowest moisture content of maize grains was obtained with the threefold dose of fertilizer — 180 kg N, 135 kg

Table 4

Moisture content of grains in Pioneer hybrid 3780 as a function of various nutrient levels
(Hajdúszoboszló, 1980–1982)

Rate of NPK fertilization	Moisture content of grain, %			Average
	1980 20 October	1981 3 October	1982 3 October	
Ø	33.3	32.9	29.8	32.0
1	30.8	27.9	28.9	29.2
2	30.4	30.5	27.9	29.6
3	32.0	31.7	26.4	30.0
4	32.0	32.5	23.2	29.2
5	31.3	30.5	24.1	28.6
Average Fertilization	31.6	32.9	26.7	29.7
$SD_{5\%}$	1.27***	1.10***	0.78***	

*** P = 0.1%

Table 5

Moisture content of maize grains at various nutrient levels
(Hajdúszoboszló, 1980–1981)

Hybrid	Rate of NPK fertilization	Moisture content of grain, %		Average
		1980 20 October	1981 3 October	
Szegedi MSC 515	Ø	34.1	32.1	33.1
	1	30.5	25.2	27.9
	2	32.2	29.1	30.7
	3	32.4	30.1	31.3
	4	30.8	31.8	31.3
	5	32.6	32.1	32.4
Average		32.2	30.0	31.1
Pioneer hybrid 3978	Ø	25.4	22.8	24.1
	1	20.9	21.4	21.2
	2	21.4	22.2	21.8
	3	20.7	20.4	20.6
	4	20.3	22.2	21.3
	5	22.2	21.6	21.9
Average		21.8	21.8	21.8

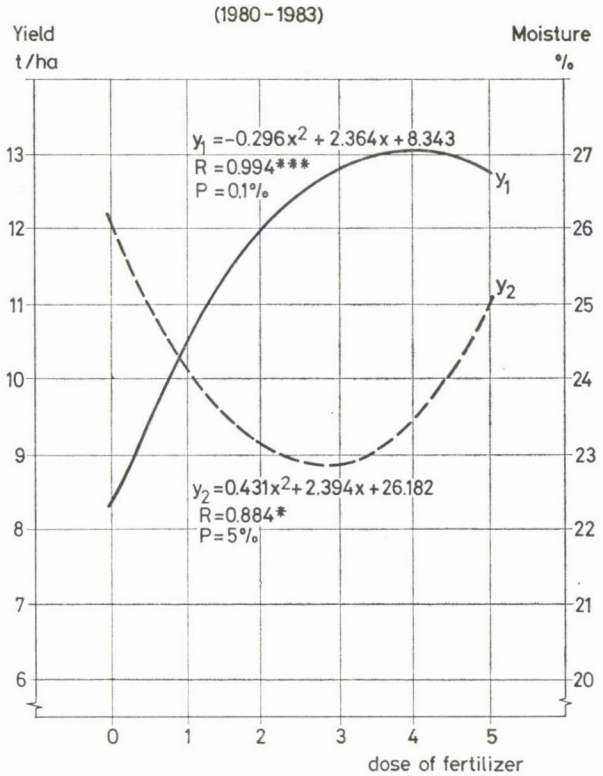

Fig. 1. Relationship between the yield (y_1) and the moisture content of maize grains in Pioneer hybrid 3901 as a function of the quantity of fertilizer active agents (1980–1983)

P_2O_5 and 159 kg K_2O per ha, 4.3% lower than in the untreated control. The differences are significant. The data prove the decisive effect of the season. In 1983, 27 days earlier than in 1980, the moisture content of grain was lower by 8.9% on an average. The moisture content of grain in Pioneer hybrid 3780 also showed a considerable decrease, parallel to the increasing rate of fertilization (Table 4). In 1980 and 1982, the effects of fertilizers were significant at all nutrient levels, compared to the control. The differences ranged between —1.3% and —2.9% in 1980, and between —1.1% and —6.6% in 1982. In each year of the experiment, the moisture content of grains in the fertilizer treatments was lower than in the control plots. In the favourable year of 1982, the moisture content of grains in the maize hybrids Pioneer hybrid 3780 and Pioneer hybrid 3901 was, on the average of the fertilizer treatments, even lower compared to the grain moisture data of 1980 and 1981 (4.2–8.1%). The variation of the fertilizer treatments is not, however, remarkable. In 1980 and 1981, the moisture content of grains in the maize hybrid Szegedi MSC 515 showed a trend similar to those in the treatments of Pioneer hybrid 3780 (Table 5). There was no significant difference between the two hybrids. In 1981 the moisture content of grain in Szegedi MSC 515 was lower by an average of 2.2% than in 1980. The moisture content of grain in Pioneer hybrid 3978 decreased in 1980 compared to the control nearly to the same extent in the different fertilizer treatments (—3.2–5.1%). In 1981 the effect of fertilization was negligible. The relationship between the yield (y_1) of Pioneer hybrid 3901 and the moisture content of its grains, as a function of the quantity of

fertilizer active agent (1980–1983), is shown in Fig. 1. In agreement with other authors (GOTLIN—PUCORIC 1977, GAGRO 1978) we found the moisture content of grain to decrease under the influence of fertilization. On the basis of our investigations we pointed out that the moisture content of grains in Pioneer hybrid 3901 at the time of harvesting was most favourable when the amount of active agents applied was 180 kg N, 135 kg P_2O_5 and 159 kg K_2O per ha. Further increases in the rate of fertilization did not reduce the moisture content of maize grains. We have established that a rate of fertilization favourable for the development of the maize plant has a positive influence on the yield of hybrids and on the moisture content of maize grains.

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LECTURE

AGRONOMIC AND ECOLOGICAL IMPACT OF SOIL AND WATER SALINITY*

The agricultural and industrial activities of mankind have a substantial impact on the environment. Industry, agriculture, forestry, fishery, etc., as well as producing food and raw materials, change the properties of soil, water, air and other components of the biosphere. Regarding alterations caused by production in the environment, agriculture has a particular importance. With world population growth, the results of the development of technics and extension of agricultural land have increasingly influenced nature. During the history of mankind, the human effect has always been not only significant but also of serious consequences in many places of the world. By now this effect has become a world-wide problem which many national and international organizations are confronting.

Irrigation, one of the oldest agricultural methods, also has a long history of different results, both favourable and unfavourable. Among the latter the problem of salinity has been and remains one of the most important. For many thousands of years, irrigation often caused the accumulation of harmful salts, both in soils and waters, and had the deteriorating effect which led to the decline not only of production but also of ancient cultures and civilizations. Nowadays this effect has not been diminished; on the contrary, it is a growing constantly expanding hazard.

Salinity and secondary salinization in agriculture in ancient times

Particularly in arid and semiarid regions, irrigation is as old as agriculture itself. The lack of rainfall made imperative the application of irrigation in many ancient agricultural systems. The problem stemmed from the fact that such systems developed mainly in those arid regions where, according to the landscape geochemistry of deserts and semideserts, this activity promotes salt accumulation. This was an intimate problem for nearly all of the ancient cultures employing irrigation.

The effect of irrigation on salinization, during the whole history of this method in dry countries, has never been fully elaborated in a comprehensive volume, although many books and papers, describing this adverse effect and its consequences, have been published over the years.

It is well-known that, in the valleys of the rivers Tigris and Euphrates in old Mesopotamia, fertile soils supplied abundant quantities of grain and other produce for a long time, feeding large populations in places now covered by bare deserts. It is also well-known that, in ancient China, the Indus Valley and South America, vast territories affected by salinity during irrigation by ancient societies turned into deserts. The problem of secondary salinization runs through the whole history of mankind. Evidently there was neither sufficient knowledge nor technical means to predict, explain and combat salinization for many thousands of years. In consequence, the degradation of the fertility of soils and other adverse effects were recognized too late to do anything against their development. The process forced people to leave the land that had become saline and others to cease production or to shift irrigation to another place which, in many cases, also became salinized. As long as new ter-

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ritories were available, the shifting of irrigated agriculture temporarily solved the problem; but either the growing density of population or the exhaustion of new land led to tragic consequences. More than one such example is known from history.

The main aspects of secondary salinization and alkalization

With the development of science, step by step, the causes and regularities of salt accumulation have been disclosed. Modern soil science and other branches of science explain nearly completely the processes and hazards of salt accumulation in irrigated agriculture. Unfortunately, in spite of comprehensive knowledge in this respect, the processes of salinization and alkalization have not been arrested, nor even substantially diminished. On the contrary, they appear in new territories, causing enormous harm to a growing number of countries even today.

A brief summary necessary of the main aspects on salinization and alkalinization caused by irrigation, and the agricultural as well as environmental consequences.

There are only a few chemical elements and compounds which play a decisive role in the salinization and alkalization of soils and waters. They are as follows:

Cations	*Anions*
Ca^{2+}	Cl^-
Mg^{2+}	SO_4^{2-}
Na^+	HCO_3^-
K^+	SiO_3^{2-}

Here and in this paper generally, the acid sulphate soils, and the problem of some toxic elements occurring in the different saline and alkali soils will not be discussed. Only the dominant elements and compounds regulating the mentioned processes will be interpreted.

The ions and compounds, the migration and accumulation of which lead to the formation of saline and/or alkali soils, behave diversely in the weathering processes taking place on the earth's surface.

It is evident that, in arid and semiarid areas, the weathering processes finally result in water soluble compounds which, due to the lack of precipitation, remain in the place of their formation. Consequently, these final products of weathering are mainly responsible for the salt accumulation in rocks, soils and waters.

In Table 1, according to FERSMAN (1934), the places of the dominant elements in the sequences of extraction are demonstrated. The sequences with growing numbers indicate the decreasing mobility of elements during the weathering processes.

According to FERSMAN (1934), the energy coefficient can be calculated on the basis of known lattice energies in inorganic salts. These values are called "experimental energy coefficients" and considered the most reliable ones. The energy coefficients of FERSMAN (1934) are closely related to the sequence of the extraction of ions from minerals, to the rate of migration of ions, and to their ability to accumulate in sediments and soils.

The weathering of rocks has been the primary source of soluble salts getting into natural waters, sediments and soils.

Table 1

Sequence of ion extraction during weathering

Sequence of extraction	Ion	Energy coefficient	Sequence of extraction	Ion	Energy coefficient	Sequence of extraction	Ion	Energy coefficient
I	Cl^-, Br^-	0.23	II	Na^+	0.45	III	SiO_3^{2-}	2.75
	NO_3^-	0.18		K^+	0.36			
	SO_4^{2-}	0.66		Ca^{2+}	1.75	IV	Fe^{3+}	5.15
	CO_3^{2-}	0.77		Mg^{2+}	2.10		Al^{3+}	4.25

Table 2

Relative mobility and average distribution of some compounds and ions in rocks and waters

Compound	Average content in igneous rocks, %	Average content in mineral residue of river waters, %	Relative mobility, %
SiO_2	59.09	12.80	0.20
Al_2O_3	15.35	0.90	0.02
Fe_2O_3	7.29	0.40	0.04
Ca^{2+}	3.60	14.70	3.00
Mg^{2+}	2.11	4.90	1.30
Na^{+}	2.97	9.50	2.40
K^{+}	2.57	4.40	1.25
Cl^{-}	0.05	6.75	100.00
SO_4^{2-}	0.15	11.60	57.00
CO_3^{2-}	—	36.50	—

The geochemistry of salts in a certain place is determined by the mobility of the compounds formed and by the sequence of the precipitation of weathering products. The mobility of the rock forming elements depends on the following factors:

(a) the stability of the crystalline network

(b) the radius of ions formed during weathering

(c) the charge of the ions formed during weathering.

It is evident that the possibilities of translocation for weathering products depend mainly on their mobility.

From Table 1, it follows that the elements and compounds with a dominant role in salinization and alkalization are mainly in sequences I and II; in other words, they are capable of intensive migration. In spite of this, very diverse values can be measured as to the mobility of the mentioned compounds, also their occurrences in rocks and waters are similarly diverse. In Table 2, the relative mobility and ratio of ten elements and ions respectively are set out according to POLYNOV (1956).

Accumulated salts may be found in many places, in soils and waters of dry areas, and constitute a potential hazard for irrigated agriculture.

The other source of salinization can be the salt contents of surface waters which may be used for irrigation purposes. In this respect the picture is rather multi-coloured in arid and semiarid regions. While in many places, particularly in big rivers, the water is of good quality (i.e. it has a low salt concentration), in others particularly in small tributaries, saline water often exists in lakes, lagoons and swamps. Evidently, if this water is utilized for irrigation, it will sooner or later result in secondary salinization and/or alkalinization. It should be mentioned here that, on sea shores and in related areas, the salt contents of sea water have a definite effect on the salinity of adjoining territories.

Remarkable differences can be found, too, in the chemical compositions of river waters on the different continents (Table 3).

The data in Table 3 show that river waters in South America and Australia are twice as diluted as the global average, and nearly three times more than the waters of Europe. Even larger differences can be observed in the concentration of some cations and anions in the river waters. However, it is also clear from this Table that all the continental river waters constitute good quality irrigation water, as far as their average values are concerned.

Otherwise, sharp differences exist in the chemical compositions of the waters in different rivers. In Table 4, according to KOVDA (1947), the salinity levels of the rivers Volga and Amu Daria are compared. While the latter flows through desert and semidesert regions, the Volga water comes from mainly non-arid land.

Table 4 clearly shows that tremendous amounts of soluble salts can be found in the water of some rivers traversing deserts and semideserts. The water quality problems must be studied individually in such cases, in order to control the chemical composition of irrigation waters.

Table 3

Average chemical content of river waters on the continents

Continent	Dry residual ppm	Ca^{2+}	Mg^{2+}	Na^{2+}	K^{+}	HCO_3^-	SO_4^{2-}	Cl^-
		me/l						
N. America	142	1.05	0.42	0.39	0.04	1.11	0.42	0.02
S. America	69	0.86	0.18	0.17	0.05	0.58	0.10	0.14
Europe	182	1.55	0.47	0.24	0.04	1.56	0.50	0.20
Asia	142	0.92	0.47	0.24	—	1.80	0.18	0.25
Africa	121	0.60	0.32	0.48	—	0.69	0.28	0.39
Australia	59	0.20	0.23	0.13	0.06	0.52	0.05	0.28
Global average	118	0.78	0.34	0.27	0.05	0.96	0.26	0.21

Table 4

Annual salt accumulation in the catchment of two rivers

River	Catchment area, km^2	Airborne salts, t/km^2	Discharge to sea, t/year
Volga	1 401 949	2	8 000 000
Amu Daria	308 804	10	226 000 000

Table 4 also indicates that, in many regions, the quantity of airborne salts should also be taken into consideration. However, when comparing this amount with that of the salts collected and transported by waters, we shall find that, with the exception of some seashore districts, the quantity of airborne salts is negligible.

Among the possible sources of salts, KOVDA (1980) also mentions the biological processes, particularly in arid regions, where the ash of halophytes may contribute to the salinity of soils and waters. However, it is difficult to say whether it is a cause or a consequence when speaking in terms of landscape geochemistry, because halophytes grow as a results of intensive salinity in their environment.

Ground water is the main reservoir of saline water in deserts and semideserts. As a result of the geochemical processes described above, the bulk of water soluble salts causing salinity during irrigation accumulates in the ground water. As long as the ground water table is deep and the moisture cannot rise through capillary flow to the soil profile, even saline ground waters do not involve immediate salinization. As an effect of irrigation, the ground water may rise so high that it can reach the surface layers and cause salinization even in cases of irrigation with good quality water. Unfortunately, this simple rule is often ignored during the planning and exploitation of many recent irrigation systems. The hazard of irrigation raising the ground water table is underestimated because, if this table is at great depths (10–20 metres), before the construction of the irrigation system it can easily be elevated to 1–2 metres depth below the surface, particularly when the drainage system is either imperfect or lacking.

The natural or artificial drainage of irrigated land, or land to be irrigated, is also a substantial factor in the processes of secondary salinization. Referring again to the experiences of ancient agriculture, in the Nile Valley irrigation was practised for thousands of years under a dry climate without secondary salinization. This phenomenon may be explained with the good natural drainage of the land strips along the Nile owing to the suction effect of the river. Recent similar examples can be found in many places, such as Syria, Central Asia, etc. As early as the 19th century, perennial irrigation was introduced in Egypt. Owing to the change in the salt and water regime, the Nile Delta became salinized and the building of an artificial drainage system was the only way to dispose of excess salts.

It can be concluded that, except for somewhat rare places with good natural drainage, in deserts and semideserts the lack of artificial drainage eventually leads, to secondary salinization. It, should be noted here that, in this paper, the term "secondary salinization" will be used in its: conventional meaning, as opposed to primary salinization which develops without human interference. Secondary salinization develops due to human activities, mainly irrigation.

In non-arid areas, where the rainfall and consequently the leaching of substances through soils is remarkable, secondary salinization and alkalization can be avoided, even without artificial drainage.

The development of irrigation as a worldwide method for increasing yields and the consequent extension of secondary salinization and alkalinization

Although irrigation dates back to prehistoric times, its rapid development only began about 200 years ago. Table 5 represents this development.

As is obvious in this Table, the countries listed accounted for two thirds of all the irrigated soils of the world at the beginning of the century. Irrigation was then only practised

Table 5

World development of irrigation

Year	Irrigated land (million ha)
1800	8
1900	48
1949	92
1959	149
1980	200

From Table 5, it can clearly be seen that the acreage of irrigated land grew from 8 million ha in 1800 to 48 million ha in 1900, and more than doubled in the last 50 years. This trend is very remarkable and has resulted not only in increased world production in agriculture but also in a number of technical and environmental problems. In the following, I can only refer to some of them.

(1) At the turn of the century, when they did not exceed 50 million hectares, the irrigated lands of the world were mainly distributed among a few dry countries, as shown in Table 6.

Table 6

Areas under irrigation in some dry countries in 1900

Country	Irrigated area (million ha)
Indian subcontinent	15.49
Russia	3.80
USA	3.01
Japan	2.71
Egypt	2.00
Italy	1.30
Spain	1.00
Chile	0.30
Total:	30.12

in dry regions. The recent extension of irrigation has involved not only arid and semiarid but also many semi-humid regions. The regularities of salt accumulation and secondary salinization differ in arid and semi-humid countries in respect of the chemistry of salt accumulation.

(2) In many countries, irrigation was introduced as a new method in recent decades. Experiences of countries having long-term irrigation practices were not always known and applied in irrigation, so as to fight against secondary salinization in the new irrigation systems.

(3) The extension of irrigation affected, as well as the greater irrigated land, the neighbouring non-irrigated territories while irrigation was occasional in small areas, its environmental effect was evidently much inferior to that of big irrigation systems affecting large surrounding areas.

(4) The tremendously increased irrigation had many effects on the biosphere (besides the irrigated crop), some of them adverse, such as:

— salinization and contamination of drinking water
— water logging and salinity as a breeding ground of parasites and diseases
— toxic effects on soil microorganisms, etc.

The listed phenomena, and others, constitute in many places a barrier not only for the development of agriculture and human civilization but also for maintaining the present level of production.

The increase of irrigated territories throughout different parts of the world is remarkable. In the USA the area under irrigation was doubled between 1949 and 1973 to 21 million hectares. In the USSR every year, 1 million ha. of new irrigated land are brought under cultivation. In Kenya the area of irrigated land was doubled between 1959 and 1969, and further development is envisaged. In Hungary irrigated areas have shown a more than tenfold increase since the Second World War.

In many countries where irrigation was introduced mainly under non-arid conditions in densely populated areas, its side effects were different from those appearing in most of the arid countries. In dry countries the vast desert which surrounds irrigated massives makes possible the disposal of brackish water and offers the possibility of tolerating such adverse consequences of irrigation as secondary salinization in adjoining areas. In countries like Hungary where the utilization of land is over 70%, the above mentioned and similar side effects would be catastrophic.

In some countries, like Egypt, nearly 100% of the agricultural land is irrigated. The corresponding figures are: 90% in the Malgache Republic, 26% in Thailand and 50% in Pakistan. Similar ratios exist in many arid and semiarid countries. In less arid or semi-humid countries the irrigated land often consists of a small percentage only, but this is sharply increasing even in such countries. In 1970 nearly 13% of the total agricultural land was irrigated in France, more than 10% in Spain and nearly 15% in Greece.

In spite of the abundant information available, the figures concerning the lands of the world where irrigation has recently been introduced are very diverse. Widely different accounts and estimates of between 150 and 250 million hectares can be found in various papers and records. The explanation for such diversity of information is probably the fact that it is one thing to register the existing irrigation systems in the world and it is another to keep record of the ones in permanent operation. In all probability, this is the reason for the data of FAO (Food and Agricultural Organization of the United Nations) and ICID (International Council for Irrigation and Drainage) always differing as to the acreage of irrigated land.

It is evident that the neglected or abandoned irrigation systems are rather frequent and account for a very high percentage of all those existing. According to the estimates of FAO and UNESCO (United Nations Educational, Scientific and Cultural Organization), as much as half of all the current irrigation systems of the world are more or less under the influence of secondary salinization, alkalization and water logging. This phenomenon is very common not only in old irrigation systems but also in areas of recently introduced irrigation.

According to the estimates of all of the above mentioned agencies, 10 million hectares of irrigated land are abandoned yearly in consequence of the adverse effects of irrigation, mainly secondary salinization and alkalization.

The harms mentioned and losses are not evenly distributed among the irrigating countries. In some of them, the damage is comparatively low, but in others it can be high enough to constitute a major problem in the agriculture or even in the national economy. We are unfortunately rich in such sad examples. In Pakistan NAZIR AHMAD (1965) carried out statistical analyses of secondary salinized land. His data records that, out of 35 million acres of total irrigated territory, salinized areas account for 5.3 million acres after a few years of irrigation. He indicates, among the causes of secondary salinization in Pakistan, the combined effect of irrigation and fround water. According to G. ZAVALETA (1965), practically all irrigated

alluvial soils in Peru show the features of salinity and alkalinity. It is known from FAO reports and the papers of V. KOVDA (1980) that more than 40% of irrigated soils in Iraq are affected by secondary salinization. A country report on salinity in Syria estimates the adverse effect as follows:

(a) In more than 20,000 ha. salinity developed to a level where these soils had to be taken out of cultivation, and the loss is estimated at a total of 30,000 tons of cotton per year.
(b) In about 30,000 ha the yield decreased by 50%, and the total loss is estimated at 20,000 tons of per year.
(c) In about 60,000 ha the yield decreased by 20%, and the total loss is estimated at 20,000 tons of cotton per year.

No continent is at present free from the very serious occurrences of this phenomenon. In Argentina, 50% of the 40,000 ha of land irrigated in the 19th century are now salinized. In Australia, secondary salinization and alkalization take place in the valley of the River Murray, and in Northern Victoria 80,000 ha. have been affected. The same phenomena can be observed in Alberta, Canada. Similar processes have been recorded in the northern states of the USA, where irrigation was introduced much later than in the dry west. It should be noted that the last four, and many other irrigated regions, are far from being arid and the majority of salts accumulating are associated with the sodium salts capable of alkaline hydrolysis, not with the neutral sodium salts that are familiar to desert and semidesert areas.

A great number of available sources refer to the different problems of secondary salinization and alkalization and describe their adverse effects in many regions. Based on this literature, the following countries can be mentioned where the salinization and/or alkalization of irrigated soils either represented a serious problem in the past of poses such a problem at present. *In Europe:* Austria, Bulgaria, Czechoslovakia, France, Greece, Hungary, Italy, Portugal, Roumania, Spain, the USSR and Yugoslavia (SZABOLCS 1974); *in North America:* Canada and the USA; *in Mexico* and *Central America:* Cuba and Mexico; *in South America:* Argentina, Brazil, Chile, Columbia, Peru and Venezuela, *in Africa:* Algeria, Angola, Chad, the Cameroons, Egypt, Ethiopia, Ghana, Kenya, Libya, Morocco, Niger, Nigeria, Rhodesia, Somalia, South West Africa, Sudan, Tanzania, Tunisia and Zambia; *in South Asia:* Afghanistan, Burma, India, Iran, Iraq, Israel, Jordan, Kuwait, Pakistan, Saudi-Arabia, Syria, the Trucial States and Turkey; *in North and Central Asia:* China, Mongolia and the USSR; *in South East Asia:* Indonesia, Malaysia, Thailand and Vietnam; and *in Australasia:* Australia. According to the knowledge of, and the data available for, the author secondary salinization not only occurs in these countries, but represents practical problems. The absence from the list of several countries where the phenomenon may also occur is due to missing records or the lack of information available to the author of this paper (SZABOLCS 1979).

On the basis of the available data, we can conclude that, parallel with the accelerating increase of irrigation in many parts of the world, the processes of secondary salinization and

Table 7

Salt affected soils on continents and subcontinents

	Thousand ha
North America	15 755
Mexico and Central America	1 965
South America	129 163
Africa	80 608
South Asia	87 608
North and Central Asia	211 686
South East Asia	19 983
Australasia	357 330
Europe	50 804
Total:	954 832

alkalization also accelerate. We have reliable, if not fully exact, data on the extension of existing salt-affected soils of our globe, as is shown in Table 7.

The total figure indicates that nearly a tenth part of the all the contiments is touched with soil salinity and/or alkalinity. A certain fraction of this territory is under irrigation, but the greater part of irrigated areas consists of soils which are non-saline and non-alkali — at least for the moment. Such land can be potentially saline or potantially alkaline. Potential salinity or alkalinity means that a soil, which is neither saline nor alkaline at the moment, can be turned into either by applying improper methods or irrigation. Most of the present secondary salt affected soils have gone through this process (SZABOLCS 1979).

While we have reliable records on the extension of salt-affected soils in our globe, we are still unfortunately lacking proper data on the world extension of secondary salinized or alkalized soils; we must make our own estimates. The above cited UNESCO/FAO data on 50% salinization and alkalization of irrigated areas provide some guidance for such calculation. Based on these and other figures, we may conclude that the territory of secondary salinized and alkalized soils, which once were fertile, have been turned into bare deserts, as a side effect of improper irrigation. This area is of the same order of magnitude as those recently existing salt-affected soils which have never been irrigated. Such estimates are essential if we want to forecast the future.

Neither do we have proper data and records on the extension of potentially salt-affected soils. It is necessary first of all to clarify this term. As mentioned above, potential salt affected soils are those which are non-saline or alkaline on the top layers at the moment, but may be salinized due to irrigation. Evidently, such a definition is relative because any soil can be salinized, e.g. when irrigated with saline water or lacking any drainage. That is why the definition of secondary salinization and alkalization should always be examined against the background of the methods of irrigation, soil and water properties, farming pattern, natural or artificial drainage, etc. This is the reason that diagnosing secondary salt-affected soil based on a simple soil survey is always difficult and often omitted even during the planning stage of irrigation. This omission has caused much unexpected harm in the first years or in later periods of exploitation of irrigation systems in many countries. Evidently, under different climatic conditions, secondary salinization has different interpretations. Closely related to the biogeochemical processes of salt accumulation, the evident hazard of secondary salinization is bigger in desert areas than in humid regions where natural leaching processes remove soluble salts. In many arid and semiarid areas, practically all the soils, or most part of the soils, can be considered potentially saline. The determination, grouping, characterization and mapping of secondary salt-affected soils, in consequence of the above described regularities, must be performed in the context of the local environmental and economic conditions.

Apart from environmental conditions, economic aspects must also be taken into consideration because, although the war against secondary salinization is theoretically possible in many developing countries, in most cases the construction of expensive drainage systems can make doubtful the economic expediency of the introduction of irrigation.

Whether saline irrigation water and/or saline ground water or both, trigger adverse processes on a global scale it is worthwhile to list also the other forms of secondary salinization or alkalization after KOVDA (1980) due to the importance of the phenomenon.

I. *When non-irrigated land is utilized:*

(1) The formation of secondary alkaline or saline soils as a result of overgrazing and compactness of sod meadow land;
   (a) along the contact belt of mountainous foothills and plains
   (b) on low terraces of valleys after flooding by rivers was excluded by barrage construction.

(2) The formation of secondary saline soils as a result of disposal of brackish water pumped from:
   (a) petroleum wells,
   (b) coal mines,
   (c) industrial plants.

(3) Salinization of soils after sea water invasion under the influence of land subsidence, or after heavy tsunami or storms and earthquakes.

(4) Accelerated formation of saline alluvial soils on deltaic and tidal wave territories, after periodic floodings have stopped, as a result of dam construction in the middle and upper reaches of the river valley.

II. *When irrigated land is utilized:*

(1) The formation of water-logged and saline soils along nonlined canals as a result of water seepage, ground water elevation and evaporation.
(2) The formation of spotty saline fields, then totally saline fields after several (5–10–15) years of irrigation without appropriate drainage installations for the evacuation of saline subsoil water.
(3) Wrong application for watering soils of brackish (or alkaline) irrigation water taken from:
   (a) saline rivers,
   (b) tube wells installed into saline ground water or after overpumping good subsoil water,
   (c) sea or gulf sources.
(4) Appearance of saline soils on valley terraces above and after the construction of a dam (as a result of the submerging of subsoil water following reservoir formation).

Based on this, we have to agree that man-made salinization is a way to the destruction of the global biosperic mechanism, with an influence not only directly on the soil but also indirectly, on several processes from photosynthesis to the cycling of bio-elements (C, O, N), etc. Such influences must also be taken into account in respect of the organic soil matter, energy resources and soil bioprocesses, etc. The negative consequences of soil salinization are not only social and economic, they are globally destructive for the biospere of our planet.

Some recent studies describe the adverse effects of salinity not only on plants but on animals, too. The increased electrolyte contents of the environment, particularly of waters and soils, result in excessive salt intake of animals, disturbing the metabolism of their life functions. In Australia, for instance, sheep and other livestock die from time to time after drinking salty water in hot regions. Kidney and other organs suffer from saline and sodic water; the total body water increases and there is an expansion of extracellular volume. Other disorders also occur following the salinization of soil and water, particularly in dry areas.

Combat against secondary salinization and alkalization; methods and recommendations

The extension of irrigation is and remains a major prospect for increasing yields and for nourishing the world's population. Not only if the exploitation of irrigation systems is done carefully but also if, during the planning and construction phases of irrigation systems, the necessary preliminary surveys and precautions are carried out and taken into consideration, respectively, then the production of food and raw materials can be multiplied worldwide in the future.

Many prognoses are available in respect of the development of irrigation for the turn of the millenium and the next century. Part of them are local or country reports, but some of them are on a global scale, like the well-known Report for the President ICID, prognoses, etc. It is evident that, in different sources, different figures can be found, but on the average about 400 million ha. of irrigated land are predicted for the first part of the 21st century. Unfortunately, no reliable predictions are available on the hazard of the development of secondary salinization resulting from such a sharp increase of the territory of irrigated land in the near future. Based on experiences, we have to agree that in general the increase of the hazard of secondary salinization and alkalization is not in linear proportion with the increase of the acreage of irrigated land. The correlation is closer to logarithmic. We still lack the exact analysis of the rate of the possible hazard of recent and predicted extension of irrigation in different countries. Evidently, it must be very diverse in the different areas, regions and districts; but if secondary salinization increases in space and time as a world wide process, it is more than probable that its global importance will sharply increase in the future.

It is imperative to encourage, to develop and, whenever possible, to adopt different studies and their results in the local, national and even international planning of new irrigation systems as soon as possible. It is also necessary to extend such studies to the predictable joint effect of existing and future irrigation systems on the environment.

In case of future development of irrigation not only the pedological but also the general environmental influence of irrigation will assume new dimensions. For instance, the concentration of CO_2 in the atmosphere, brought about by human activities, is a widely discussed problem of our days. A great number of books, reports and prognoses are available on this subject, some of them threatening consequences which would be tragic for mankind. If the area of irrigated land doubles or trebles, the irrigated plants will be able to consume,

through photosynthesis and the formation of biomass and harvest, as much as 30–40 billion tons of CO_2 annually, instead of the recent 15–20 billion tons.

But let's not be carried away by the many possible similar considerations. The above example is enough to show that irrigation, its prospects and successes, are interrelated with numerous vital problems of our globe. As it is clear from the mentioned example, the aim of irrigation development is to improve the food situation as well as the environment. It is also evident that the hazard of secondary salinization and alkalization will be one of the major obstacles to this development, if we do not intensify the study of this risk and apply the methods for its prediction and prevention.

It is urgent to intensify both the theoretical and technical activities relating to the hazard of secondary salinization and alkalization. Up to now, the influence of the geochemical and hydrogeochemical processes have been underestimated in many places which eventually results in salt accumulation by irrigation in the given territory. While an abundance of studies and quality requirements for irrigation water are available, the effect of ground water on soil salinity is often left out of consideration. That is why a comprehensive preliminary study is necessary before planning new irrigation systems and extending existing ones, not only of soils and surface waters, but also of underground waters and layers (DARAB and FERENCZ 1969).

In relation to the influence of ground water on salt accumulation, first the so-called critical depth of ground water table should be determined. This level is the depth below which, owing to natural or irrigated conditions, leaching prevails while above this level salt accumulation takes place in the soil profile. In other words, the salt regime of the given territory is in equilibrium.

The salt regime of soils denotes the accumulation and the leaching of the soluble salts, that is, the periodical changes of these processes in the soil. The examination of the salt regime, the periodical changes in the quantity and quality of salts, reveals the prevailing direction of their movements, whether the accumulation or the leaching of salts takes place under the given conditions.

Salt balance

Although the study of the salt regime supplies important data on the dynamics of a salt-affected soil, it does not present in itself any further information. Therefore, the next step is to compare the salt contents of the soil measured at given times and to express them in salt balances. Salt balances reveal the effects, either existing or expected, of amelioration or agrotechnical measures on the changes in the degree of salinity and alkalinity of the soil, as well as those of irrigation on its soluble salt contents. The establishment of salt balances requires an exact knowledge of the cause, speed and degree of accumulation or leaching.

The following data are needed for the establishment of the salt balance, regardless of the extent of the area concerned:

(a) Total amount of soluble salts at the beginning and the end of the observation.
(b) The increase of soluble salt contents during the observation.
(c) The decrease of soluble salt contents during the observation.

Three types of salt balances may be distinguished:

(a) Stable salt balance.
(b) Balance of salt accumulation.
(c) Balance of leaching.

The salt balance of soils may be established for both larger (e.g. a drainage basin) and smaller territorial units.

A salt balance may be established either for the whole soil profile or for given genetic horizons.

The tendency of the salt balance of a soil depends on the joint effect of numerous factors. From among these factors, the following must be specifically mentioned:

The depth and the chemical composition of the ground water. When examining the water table, we must take into account the fact that it fluctuates periodically. The depth of the water table is influenced by local factors (e.g. the amount of precipitation in the given place, the micro- and meso-relief of the area). It is also affected by the amount of water coming into the catchment area from various sources, supplying the ground water and, by the time its effect manifests itself, in the place examined. The depth of the ground water also changes when the natural conditions are artificially altered due to the effect of drainage or irrigation.

The analysis of the chemical composition of the ground water must be carried out simultaneously with the determination of the depth of the water table.

The following qualitative data of the ground water must be given:

(a) The total salt contents of the ground water in mg/l.
(b) The relative amount of sodium salts in the ground water.
(c) The relative proportion of magnesium salts within the alkali earth metal salts.
(d) The distribution of soluble salts in the ground water according to the anions.

The physical and water regime properties of a soil also affect its salt regime to a considerable extent. Of these, two should be specifically mentioned; the water conductivity of the soil profile and, if present, the depth of the accumulation horizon of heavier mechanical composition or of disadvantageous water regime properties.

The relief of a given area influences the salt regime of soils by determining (1) the infiltration of rainfall or irrigation water into the soils of different relative height; (2) the wetting of the soil profile and (3) when the downward movement of rainfall or irrigation water is followed by the upward movement of ground water or the moisture content of deeper layers.

The technics of irrigation

Under irrigated conditions the salt regime of the soils also depends on the methods and the technical level or irrigation.

In the case of surface irrigation, as a function of the amount of the applied irrigation water, leaching on a larger scale may take place. We must, however, take into account that part of the applied irrigation water gets into the ground water and this may result in a rising of the water table, decreasing the possibilities for the leaching of soluble salts or even in shifting the salt balance of the soils toward to positive side, if the drainage conditions of the irrigated area are unsatisfactory.

The calculation of salt balance

Given the knowledge of the factors influencing the increase and decrease of the salt contents of soils, the salt balance may be established on the basis of the following equation:

$$b = a + \left(d + \frac{cv}{M\,t_{fs}} \cdot 10^{-5}\right)$$

Where:

b = soluble salt contents of the soil at the end of the observation in mg/100 g soil
a = soluble salt contents of the soil at the beginning of the observation in mg/100 g of soil
c = the salt concentration of the irrigation water in g/l
v = the quantity of the irrigation water applied during the observation period in m^3/ha.
M = the thickness of the soil layer for which the salt balance was established, in m
t_{fs} = the bulk density of the soil
d = the salt regime coefficient of the soil in g/100 g of soil

The change that has occurred in the salt contents of a soil during the observation period is expressed in the salt regime coefficient. It gives the difference between the amount of the salts leached from the soil and that of the salts which came into the soil from sources other than the irrigation water.

As it is rather difficult to calculate the value of "d", we had better determine the change in the salt content of the soil and calculate the salt regime coefficient on basis of the following correlation:

$$d = b - \left(a + \frac{cv}{M\,t_{fs}} \cdot 10^{-5}\right)$$

Having completed the calculations for several irrigated soils, we can distinguish the following characteristical cases:

(a) The salt regime constant is of a negative value.

(b) The salt regime constant is of a negative value but the salt content of the soil increased during the observation period. This means that although leaching took place to a certain extent, more salt was introduced with the irrigation water than could be leached out.

(c) The salt regime constant is of a positive value, and the soluble salt contents of the soil increased during the observation period. This indicates that more salt got into the soil, not only from the irrigation water but also from the ground water and perhaps from other sources, than could be leached out.

(d) The salt regime coefficient of the soil may be zero. In this case the salt balance of the soil is stable and the current depth of the ground water table is practically tantamount to the critical depth.

To calculate the salt regime coefficient with the above simple equation requires the regular determination of salt movements in the given territory.

Where even such determinations are difficult, KOVDA (1980) recommends a simple empirical estimate of the critical depth of the ground water:

$$L = 170 + 8t \pm 15$$

Where:

L = the critical depth in cm
t = the mean annual temperature in centigrades

Clearly, this equation has only a very general validity, because the single variable is the mean annual temperature of the region.

Salinity hazard

For the control of the possible hazard of salinization and/or alkalization in irrigated areas, or areas to be irrigated, the following factors should be studied and determined:

(1) Climatic factors, such as temperature, rainfall, humidity, vapour pressure, evaporation and their fluctuations and dynamics;

(2) Geological, geomorphological, geochemical, hydrological, hydro-geological and hydrochemical factors, such as natural drainage, the depth and fluctuation of the water table, the direction and velocity of horizontal ground water flow, the salt contents and composition of the ground water, etc.

(3) Soil factors, such as soil profile, texture, structure, saturated and unsaturated water conductivity, soluble salt contents, salt composition and salt profiles, exchangeable cations, pH, etc.

(4) Agrotechnical factors, such asland use, crops, cultivation methods, etc.

(5) Irrigation practices, such as, the amount of irrigation water, the method, frequency and intensity of irrigation, salt contents and composition of irrigation water, natural and artificial drainage, etc.

The above mentioned factors determine the aims and methods of the preliminary survey of soils, made in order to define the degree or the existence of potential salinity and/or alkalinity.

Evidently, the environmental conditions on the one hand, and the methods of the utilization of the territory in question on the other hand, should be taken into consideration when an area is evaluated in this respect. Due to this fact, different limit values and different methods — based on uniform principles — should be selected in the course of this procedure.

In Table 8 a scheme of methods, recommended for the control of salinity and alkalinity in irrigated areas is given.

This Table shows that the prediction of secondary salinization and alkalinization of the soils to be irrigated should be based on a preliminary survey of the landscape and soils before the construction of the irrigation system. In this way, it is possible to take the necessary steps for the prevention of adverse processes.

During irrigation, a well-organized monitoring of the soil and water properties is to be conducted in order to record changes, if any, and to support taking precautions, if necessary. Monitoring methods, as well as the timing and location of sampling, depend upon local conditions.

In the course of making the survey and monitoring, in order to develop a reliable method for the prediction of salinization and alkalinization, the following problems must be solved:

Table 8

Scheme of methods recommended for the control of salinity and alkalinity in irrigated areas

A) Before construction of irrigation system	*Preliminary survey*	
	Landscape	*Planned irrigation*
	climate	available irrigation water quantity and quality
	hydrology	
	hydrogeology	ground water depth and quality
	geomorphology	
		technology of irrigation
		cropping pattern tolerance
B) During irrigation	*Monitoring*	
	salinity and alkalinity of soil and ground water table	
	chemical composition of ground water	
	chemical composition of irrigation water filtration	
	physical soil properties	
	toxic elements, if any, in soil and water	

(1) The main sources of water soluble salts (irrigation water, ground water, surface waters, salty deep soil layers, etc.) must be identified.

(2) The main features of the salt regime must be characterized (salt balance); and the whole range of natural factors influencing the salt regime must be analysed.

(3) The effect of irrigation on the water and salt regimes of the soil must be determined.

Consequently, an exact salinity and/or alkalinity prognosis must be based on the evaluation of many natural and human factors and a thorough knowledge of the existing soil processes.

Numerous handbooks and recommendations are available on quality requirements for both soils and waters as the subject and means, respectively, of irrigation. We have to note that any of these must be adjusted to local conditions (SZABOLCS—DARAB 1982). It is beyond the aims of this paper to compare and evaluate the different irrigation water quality systems of the different countries and regions. As a general rule, however, the following properties can be listed as the subject of determination for all systems:

(1) Total salt contents of irrigation water
(2) Sodicity (Na^+) of irrigation water
(3) Alkalinity of irrigation water
(4) Mg contents of irrigation water
(5) Boron contents of irrigation water

The mapping of the results of preliminary and subsequent surveys constitutes not only a good display of soil and environmental conditions of the areas, either under irrigation or to be irrigated, but also guide-lines for proper irrigation and land protection. Such systems elaborated by various authors, including the author of this paper, for different places and conditions are also available in technical literature (SZABOLCS *et al.* 1969).

The monitoring system of irrigated areas must be elaborated and/or also adapted to closely related local circumstances. Soils, irrigation water, and ground water must be studied regularly and, whenever discrepancies occur with the predicted salt regime, the necessary measures should be taken, either by diminishing the acreage or the intensity of irrigation or by improving the drainage of the land.

In this chapter only a few, rather random examples are furnished of the methods of studies aiming at the prediction and prevention of secondary salinization and alkalinization of irrigated soils. Our weakness is not the lack of such studies but rather the lack of sufficient knowledge of how to adopt properly the proper methods. One of the main tasks for the future

is to intensify the study of the possible hazards of increasing irrigation on soil and environment, and to elaborate up-to-date and economical methods to overcome the growing danger of the development of harmful processes.

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BOOK REVIEWS

P. FEYÉR: *A szőlő- és bortermelés Magyarországon* (1848-ig) [*Grapes and wine production in Hungary* (up to 1848)]. Akadémiai Kiadó, Budapest, 1981.

The year in brackets does not imply that the authoress had nothing to say about the development of viti- and viniculture in Hungary after 1848. In her book on its historical background, published in 1970, the years following 1848 were treated in greater length. She apparently studied at that time most of the sources used for her present work, and gave notice of their wider utilization: "The collecting, systemization and processing of further data will be carried out in years to come. Many interesting data on Hungarian vine growing and wine making from ancient times are just waiting to be published".

P. Feyér's recent book contains many interesting data indeed, giving evidence of her respect for sources reflecting the past of viti- and viniculture in Hungary, and testifying to her zeal in making the best of them. Beyond the presentation of scattered documents, she deals with vine growing in certain regions (Hegyalja region of Tokaj, Sopron and Pozsony, Tata, Pécs) and localities (Buda, Kecskemét, Miskolc) profoundly on the basis of detailed research. She places her subject in the process of a general historical development. As for the actual work of vine growing and wine making, she relies mostly on retrospective publications of periodicals on viniculture, and on general treatments of viti- and viniculture in recent times.

This endeavour of the authoress to establish her treatment well justifies us in calling her attention to further important works, first of all to sources supplying material directly utilizable in a prospective new edition of her book. The wine district of Hegyalja was described in 1790 by F. J. Fuker (Versuch einer Beschreibung . . .), in 1828 by J. Mohl and A. G. Laszgallner (Das Tokayer Weingebirge . . .); vine growing in that region was discussed by J. Matolai (Disquisitio physico-medica, 1744), the Tokay wine by S. Dombi (Dissertatio inauguralis, 1758); in a work published in 1820 [A tokaji vagyis hegyallyai (The Tokay or Hegyalja wine)] the same A. Szirmay as cited by the authoress dealt with vine plantation and cultivation, wine making and handling at Hegyalja. As to Sopron J. Matolai's study published in M. Bél's "Prodromus" (1723) it is a more important work than J. P. Komáromy's "Dissertatio physico medica" (1715, Basel). Grape-vine cultivation in the district of Pozsony was described by Bél himself (Historia vinearum, 1722). As regards vine growing at Buda, it is worth noting F. Pethe's anonymous publication: "Budai szőllőm ültetése módja" (Plantation method of my Buda vineyard, 1827). The Transylvanian vine cultivation is discussed in two remarkable works: "Erdéllyi bor-gazda" (Transylvanian wine-maker) (year of publication unknown) and "Der siebenbürgische Weinbau", 1833. Grape-vines of Hungary are discussed in general by P. Jänich and P. Keller (Dissertatio de vineis, and Beschreibung, respectively, 1726); the Hungarian wine is treated by J. Welsch (Dissertatio . . ., 1721) in which a German author writes about the excellent quality of Hungarian wine, and by three Vienna editions of "Abhandlung von der vortrefflichen Natur, Eigenschaft und Wirkung des Ungarischen Weins" (1789, 1793, 1802). P. Prónay's work comprising viti- and viniculture alike: "A szőllőknek plántálásáról . . ." (Vine plantation . . .) was edited twice (1780, 1786). J. A. Chaptal and his collaborators' work on the methods of the developed French viti- and viniculture made a deep impression at the beginning of the 19th century. J. Fábián was the first to translate it into Hungarian, completing it with a description of the wine of Somló (1805, 1813–1814); then J. Voltiggi, commissioned by count J. Erdődy, translated it into Latin with comments by L. Mitterpacher (1808) who also later made brief summaries of it in Latin and German. Chaptal's work was

translated into Hungarian by J. Pósfai too (1813, 1814, 1815, 1818). It was also Chaptal's and his collaborators' activity that the six German and one Hungarian editions of K. A. Hellenthal's work (Hülfsbuch für Weinbesitzer, 1815–1836), published then by J. K. Lübeck and by H. Wiese, were based on. Similarly, it was with wine-making and -improvement that the following works dealt: "Handbuch für Weinhändler" (1822), "Ueber die Verbesserung und Mischung der Weine" (1830), "A tapasztalt borosgazda" (The experienced winemaker) (1833), J. Némethy: "A szüret" (The vintage) (1838), M. Borsos: "A borjavításnak . . . titkai" (The secrets of . . . improving wines) (1846).

The authoress seems to have been less expert in systematizing than in collecting the data. Even the fact that the volume closes with the year 1848 may be disputed. Vineyards were mostly possessed by the peasantry. The writer herself is obliged to establish that "according to the law of April 1848 it was the very vineyard that the serfs could not make their civic property, although they had for centuries felt it to be theirs more anything" (p. 377). But even after 1848–49 changes occurred in the field of sales and not in respect of viti- and viniculture; and the eras of grapes and wine production are determined by the major changes taking place in them rather than by the political turning points of history. For this very reason, the division of the book by centuries does not in itself say much, the less so because the limits are blurred by frequent retrospects and anticipations as well as by sub-chapters that often encompass several centuries.

Of course, the abundance of the data available also plays some role in the inconsistency shown in the structure of the chapters; the logical succession of production factors (even the area and proprietorship included) — vine plantation — implements — methods of cultivation — yield — utilization — trade is missing. The reader hardly encounters a similar grouping, not even according to wine regions. The authoress is apparently confused by the richness of the material, especially from the beginning of the 17th century. The reader sometimes learns first about the consequences and only much later about the preliminaries. Contradictions, and erroneous statements originating from an insufficient critical consideration of the sources, are also present. [To give a few examples: in the discussion of replantation in the 18th century the role of Hungarians is not emphasized; it is going too far that "the landlord disposed of his serfs' labour freely or even with a high hand in spite of the regulations", it is similarly not exact that there were no decrees concerning the Transylvanian serfs, and that, "the private wine sales were only permitted at fairs"; the landlord was allowed to sell wine all the year round when he established a hostelry and not a tavern; Act 11 (correctly 41) 1498 does not speak of lease; no legislation took place in 1779, etc.]

The above objections do not change the fact that P. Fejér's work gives the reader such a rich and many-sided knowledge as found nowhere else in the historical treatments of any branch of Hungarian agriculture. For this very reason it is a pity that, in the insufficiently arranged mass of data, the main point often gets lost in spite of the writer's clear though not always logical way of discussion. She even presents statistical data (considered, naturally, approximations) on the area and yield of vine plantations, and informs the reader about the units of measure used (but urn concerning wines means akó* and not bucket). On the other hand, a map of the major wine districts and vine growing regions, and, considering the diversity of data, an index of subjects would have come in handy. Also, limits of periods adjusted to changes in viti- and viniculture would have made the material easier to survey: after the Hungarian conquest, then the organization of the Church with the tithe, the introduction of the ninth part of the peasant wine harvest owing the landlord in 1351; the middle of the 16th century with the serfs' life conditions changing for the worse and with establishing the manorial retail of wine the best-known wine region of Syrmia falling into Turkish hands and Hegyalja coming into prominence; the first third of the 18th century when in the because of Turkish rule destroyed part of the country vine was replanted too, registration and description of the major vine areas began, and with J. Matolai a scientific viticulture developed beside the traditional vine growing practice; the beginning of the 19th century when in connection with an increasing demand for wine, beyond vine cultivation an increasing attention was paid at last to the viniculture — as shown by the multiplication of works on this subject; and finally — after 1848 — the period of phylloxera. All this could be accentuated with the literature of the neighbouring (first of all Austrian) viti- and viniculture, and in general by using the international literature on wine, as well as taking into consideration in Hungary e.g. the activity of R. Rapaics ["A magyar gyümölcs" (The Hungarian fruit), etc.].

Feyér's book mostly contains the data required to acquaint the reader with the

* An old measure, about 12 gallons.

history of viti- and viniculture in Hungary in the feudal regime, nor are the components and important momentums of its development missing either; but the discussion of market and exports pushes in many cases the description of the process and methods of vine cultivation into the background. On the other hand, owing to the deficiencies of systemization, often the essential things are not sufficiently stressed. The subsequent remarks, addenda and corrections are intended to give due emphasis to some significant points.

Among other points, the author does not leave it unmentioned that the peasant vineyard did not belong to the land held in villeinage strictly speaking. As a matter of fact, outside the inner plot the latter consisted of nothing else than arable land and meadow, as a direct consequence of the fact that the everyday food was provided by crop growing and animal husbandry. The scattered arable and grasslands of each serf were inserted between other serfs' lands, work on them was synchronized in accordance with the prescription of the village community. If only for this reason, but mainly because it required a greater effort only at the time of ploughing, sowing, harvesting and thrashing, respectively when cutting the grass, the cultivation of serfs' lands did not involve much labour. Vine growing, on the other hand, demanded hard work and skill almost throughout the year. And in the feudal system everybody had right to the land to the extent that he put work into it, much more right to the clearing than to the arable- and grassland, and through the continual zealous and skilful work still more to the vineyard, created frequently by clearing, too. It was not a matter of lease, the vineyard was a kind of property comparable to the emphyteusis, but had much more advantage than this as the compensation paid to the landlord amounted to a mere ninth of the harvest or a similar but steady quantity of wine. Only those were charged to pay terragium in acknowledgement of the landlord's proprietorship who were not his serfs and lived elsewhere, still had a piece of land in the vineyard of the village belonging to him; beyond this they paid only the ecclesiastical tithe and the seigniorial ninth or a fixed amount of wine just as did the landlord's serfs. So the latter were not obliged to deliver any other produce, the less they owed the landlord socage or money rent after their vine areas. At the same time, it was the very wine yield that gave the peasant opportunity to fulfil his pecuniary obligations, since besides live animals wine was the easiest to sell, and that on the spot, in the series of houses or in the village inn, from Michaelmas (29 September) to St. George's day (24 April), if there were no vineyards belonging to the village until Christmas.

These advantages were enough to urge the serf to try to acquire a vine area. And even the cotters strived for possessing vine areas, as vine cultivation required draught power for manure transport and wine conveyance at the most. But a still greater attraction was exercised by the possessory right which was close to the proprietorship. With the correct interpretation of Werbőczy's very respected codification of the Hungarian customary law (1514), the landlord could not lay hands on the vineyard at any time, only on its cessing, and had the right of expropriating the new owner of the vineyard merely with the full value paid for compensation, as determined by the serfs of the village if the local tradition so demanded and not by the district administrator, but could not do the same to a peasant who had possessed the vine area continuously for some time. True, though, that many a landlord disregarded these rules, yet, expropriation of peasant vineyards was restricted by the tenfold amount of the common assessed value it involved, and the high costs of subsequent cultivation. Namely, if they wanted to achieve results he had to employ day-workers or farmhands, in larger vineyards even a vine-dresser, because delicate operations requiring skill such as pruning and hoening, when performed as socage service resulted in damage rather than in profit. That was partly the reason why it was in the most intensive branch of agriculture that peasant possession and production exceeded most the results of seigniorial domestic economy, that is to say in the quantity and not in the quality of wine, because the serf could not pay much attention to handling the wine, as he had to sell it soon in order to get money and fulfil his pecuniary obligations.

As a matter of fact vine-growing in his own management was profitable for the landlord on hillsides producing excellent quality wine. In such places not only the landlord, but outsiders too — noblemen, priests, commoners — tried to acquire land amongst the serfs' vine-lands. All of them equally belonged to the vine-growing community which was independent from the village community. At the general meeting convened at least once a year the governing body was elected on equal terms, generally independently from the landlord (not only at Hegyalja). Nobleman (or his substitute) and peasant were equally bound by the "vineyard law" based upon traditional custom, which authorized the governing body to look after the work, punish offences, authenticate buying and selling of vine-lands, make decision in inher-

itance proceedings, employ full-time field-guards and hire special guards for the period of grape ripening. Strangers could not lay claim to anything there, could not distrain for debts there without the approval of the leader of the governing body, and could not even enter the area of the vineyard unless they previously "called out" to the guards three times. The jointly maintained hedge surrounding the vineyard and separating it from the outside world united the representatives of different social classes in a close community unique in the feudal system. There the otherwise despised serf and cotter felt the burden of feudal exploitation much less. They had not an almost full right of possession against efforts to expropriation; it meant a special attraction for them that where they spent labour and skill on the most developed agricultural work they also were released to some extent from the pressure of seigniory. The rich material of P. Feyér's book contributes to the recognition of this component of the peasant lot, too.

I. WELLMANN

Agricultural Literature of Czechoslovakia, Nos 3–4, 1981, Prague

The Agricultural Literature of Czechoslovakia is published by the Institute for Scientific and Technical Information for Agriculture, Prague. The publication, which appears regularly, contains abstracts of articles written by Czechoslovakian authors on agricultural subjects and published in the Czechoslovakian Socialist Republic, with exact data on the original habitat.

The nine main subject areas indicated by the list of contents are: Agricultural Economics; Agricultural Engineering; Pedology, Hydrology, Bioclimatology; Plant Production; Livestock Production; Veterinary Medicine; Forestry; Applied Sciences, Life Environment Protection.

The publication is completed by an Author Index, a Subject Index and a Survey of Study Information for 1981.

English summaries of 453 papers published in Bohemian or Slovakian languages are found in this volume, 16 of them on agricultural economics, 20 on agricultural engineering, 16 on pedology, hydrology and bioclimatology, respectively, 191 on plant production, 116 on livestock production, 50 on veterinary medicine, 10 on forestry, 20 on applied sciences, 14 on life environment protection.

Reading through the volume the reader may acquire a wide knowledge of those questions that concern the agriculture of Czechoslovakia, and of the search for solutions. Such a journal of reference also provides possibilities for the researchers and experts working in the same field to get information on the relevant results.

An important requirement of such a journal of reference is that it should offer information on recently published articles and papers in the shortest possible time. In this regard it can be established that the papers published in this volume 3–4 of the Agricultural Literature of Czechoslovakia appeared originally at the end of 1980 and beginning of 1981.

It is a pity that the title page is so laconical, showing only the following brief text: "Agricultural Literature of Czechoslovakia, Prague, 1981. Nos 3–4". This does not inform the reader how many years the journal has been published nor how frequently it appears. Also, there is no information as to how, where and at what price one may subscribe for it.

The full titles of the original sources (possibly also translated into English) would be worth an additional page to the volume. Apart from the Czechoslovakian readers, who probably read the studies in their original publications, few are able to find out what kind of journal is referred to by mere abbreviation.

It would be easier to introduce the papers published in this journal for international scientific circulation if computer processing were facilitated by key words given after each abstract. At the same time, this may result in a more careful compilation of the Subject Index. For example it could not then happen that the reader would try in vain to find the words corn, maize, Zea mays, or Fusarium, because these are not included in the Subject Index. However, within the subject of plant protection alone, seven articles deal with maize and two with Fusarium.

Except for these deficiencies the Agricultural Literature of Czechoslovakia would be a highly valuable and useful publication. In particular, for those engaged in agricultural research in the surrounding socialist countries, it could assist greatly in the search for solutions to similar problems.

It would also be worth considering the elaboration of a uniform system for similar publications from other socialist countries, thus enabling the mechanical processing and facilitating the study and selection of the almost unbearable mass of publications.

Despite all the above objections, the numbers of the Agricultural Literature of Czechoslovakia are worthwhile being read through.

L. KIZMUS

NURI N. MOHSENIN: *Thermal Properties of Foods and Agricultural Materials.* Gordon and Breach, London—New York—Paris

It is needless to say what an important role food plays in the world today. There is a countless number of evidence to prove how right some scientists were when they said years ago that food may one day become the most important strategic weapon. There are millions and millions of people who are suffering from malnutrition or are even at the verge of starving, which makes it our bound duty to keep the nutritive value of the agricultural products as far as possible during processing, storage and distribution. On the other hand the "energy crisis", this over all and threatening phenomenon forces us to save as much as possible of our scarce energy supplies in food processing.

For the sake of keeping the nutritive value of the agricultural products at a minimal "expence of energy" we have to learn some more about the thermal properties of foods and agricultural materials. In this respect Professor Nuri N. Mohsenin's book on the subject is of vital importance.

The book of 406 pages is divided into 6 chapters and one appendix which itself could stand as an individual manual of great value.

The first two chapters deal with some basic concepts of heat transfer, as related to thermal processing and techniques for determination of available data on specific heat of raw and processed food and feed products, soil and wood. A number of illustrated examples are included to demonstrate the use of a given technique or principle.

This is followed by two more chapters which contain methods for determination of data on thermal conductivity, thermal diffusivity, unit surface conductance or the heat transfer coefficient of foods and agricultural materials.

In the last two chapters the applications of thermal properties in relation to cooling, freezing, drying, heat treatment, heat of respiration, and thermal expansion are covered.

Thus the book gives a good example of how the basic concepts, methodology and application can be summarized and at the same time give clear easy to handle, a most educative, scientific publication.

Going into detail, I should call the *first chapter* (Some basic concepts of heat transfer) an introduction as it gives a brief survey of the different forms of heat transfer, related physical properties, the laws of heating and cooling and discusses criterion for the choice of the method of solution of the heat transfer problems.

Among the mentioned physical properties specific heat as the most important one is separately dealt with in the *second chapter*. The different methods for the measurement and calculation of specific heat is given with a lot of practical data on the specific heat of foods and agricultural materials such as: grains and seeds, forage products, fruits, vegetables, and nuts, tobacco, wood and treebark, soils, as well as the specific heat of processed food materials such as: baked products, frozen foods, dehydrated foods, oils and butter, and fluid foods.

In the *third chapter* thermal conductivity, thermal diffusivity, and surface conductance — three more significant physical properties — are dealt with in detail. Beside giving a survey of the methods for measuring the three aforementioned physical properties emphasis is also laid on the disturbing effects of temperature and moisture.

In thermal processing of a mass of solid materials such as soil, fertilizers, seeds and grains, forage and silage, fruits and vegetables, cotton, tobacco, sugar beets as well as fluid materials such a liquid food and feed and slurries we are concerned with either heat transfer within a single solid particle condition or a multiple particle condition of a mass of the material. In either case the single particle situation is the starting point for describing the multiple condition case. If the particle does not move with respect to its surrounding fluid, heat transfer between it and the fluid must take place predominantly by simple conduction. When there is motion between the particle and the fluid, heat transfer by convection is also added. At elevated temperatures, radiation predominates the heat exchange and thermal emmissivity of the material.

By applying these methods on foods and agricultural materials the *fourth chapter* reviews the thermal conductivity, thermal diffusivity, and unit surface conductance of seed and grains, forage materials, fruits, vegetables, and nuts, sugarbeets, tobacco, woods, soils, as well as red meat, poultry and fish product and soy-bean meal.

The methods of measurement discussed earlier in the third chapter have been developed for, and are generally applicable to, solid or liquid materials, homogeneous and isotropic with heat transferring equally well in all directions. Application of these principles to single units or particles of food and agricultural materials, with modifications to account for the geometry and other assumptions, can be the first step in understanding the heat and mass transfer phenomenon in these biological materials. However, such application to loose and granular materials in packed beds would at best produce a measure of bulk or effective thermal con-

ductivity but not the particle conductivity. These problems are discussed in this chapter.

In the *fifth chapter* the significance of cooling and freezing of foods and agricultural materials is emphasised and after it the applications of thermal properties in these processes is discussed.

The *sixth chapter* goes into detail as regards heating and heat treatment of foods and agricultural materials. The application of thermal properties in these processes (like heated air-drying, freeze-drying, etc.) is written about.

In the *appendix* we can find almost forty pages of most valuable tables concerning the different thermal properties of a very long list of foods and agricultural materials as well as a great number of materials used or being in some relationship with agriculture and related industries. Another thirty pages of plotted graphs contribute to the fuller value of the book. These figures graphically illustrate relationship between thermal properties and certain disturbing parameters for almost all of the foods and agricultural materials mentioned in the book.

In the appendix we can also find—beside the usual subject and name indices — a most useful table on selected conversion factors between S.I. and traditional system of units.

Even this brief survey of the contents of the chapters and appendix is sufficient to show that the highly complex material dealt with in the book is rationally compiled and well arranged, and that the problems arising in the field of theory and practice are discussed with great competence. The course of the discussion, as well as the weighing and critical evaluation of the material, are excellent and make the book suitable for use not only at universities and research institutes, but also by design and construction engineers, particularly by those engaged in agricultural engineering and food processing.

Attention should be called to the great pedagogical sense shown by the authors in writing the book: he always leads the reader through simpler cases to the most complex questions with clear and convincing reasoning.

The text is illustrated with examples taken from practice and carefully designed and highly instructive figures.

K. J. KAFFKA

Á. HARASZTY, L. FRIDVALSZKY and P. GRACZA: *Microscopic Plant Anatomy*. Tankönyvkiadó, Budapest, 1982. (256 pages, with 328 black and white figures, 72 coloured photomicrographs respectively)

This university and college handbook, prepared in the form of a picture atlas, contains a wealth of knowledge on plant anatomy. With its carefully chosen light microscope, transmission and scanning electron microscope photographs and brief explanatory texts, which greatly help in acquiring a thorough knowledge of the subject, the book meets a long felt need in Hungarian publications at higher educational level. In this sense it serves a purpose similar to that of Verzár-Petri's microscopic "Drug atlas" published by Medicina in 1979.

Apart from the Preface and the Subject index the book is divided into eight chapters giving examples from all the main categories in the plant kingdom.

Chapter 1, which bears the superscription "*Thallophyta*", shows the organization of representatives of the algae, fungi and mosses, and the ultrastructure of their components. These include the micellar stroma of the chloroplasts of Euglena, a detailed illustration of the Golgi apparatus with the numerous Golgi vesicles, several diatoms of various structure and characteristic shape, and the pyrenoid-containing, thread-like chloroplasts of Spirogyra; there are a number of photographs slowing the body organization in stonewort, ergot and champignon. Some excellent photographs present details of the organization process of scale-moss and several musci.

Photographs 15 to 72, presented in *Chapter 2*, serve to illustrate the *plant cell* in general, and its structural elements in particular. First the structure and development of the meristemic cell are shown, then the cytoplasm and some major components of the cell, followed by information on the vacuoles and inclusions of the cytoplasm. Highly demonstrative photographs reveal the thylakoid — granum ultrastructure of the chloroplasts, the process by which they are transformed into chromoplasts, the structure of starch, the nucleus and its division, and finally the structural diversity of the cell-wall. The particularly informative scanning and transmission electron microscope photographs deserve special attention.

The figures in *Chapter 3* (Nos 73–122) show the light microscope structure of the most important permanent *plant tissues*. These not only give an accurate demonstration of the characteristic features of the parenchyma, prosenchyma, assimilating ground tissue, aerenchyma, storage tissue, various mechanical tissues, secretory tissue and other ground tissues, but also give a clear idea of the major types of epidermal stomata, hairs and con-

ducting tissue systems, such as collateral closed and open vascular bundles, bicollateral, concentric and lamellar bundlex and their structural elements, showing them in cross-section and in some cases in longitudinal sections.

The light microscope photos (Nos 123–190) in *Chapter 4* deal with the inner organization of the vegetative "*shoot*": they are not only fine to look at but also adequately informative and well chosen, giving the reader an insight into the diversity of the inner structure. The first picture shows the complete tissue structure of the maize germ. In several further photos the growing tips of vegetative shoots in mono- and dicotyledonous plants are seen in longitudinal section without, however, any reference to the meristems (Nos 123, 124a, b, 125 and 128). The following five pictures show the peculiarities of tissues, first in a young and then in an older dicotyledonous liane stem the cambial growth, the secondary phloem and xylem, the medullary parenchyma and the other tissue zones of the stem in cross-section. These are in many ways complemented by the cross-section photos in which the most frequent types of vascular bundles (collateral open and closed, concentric) can be studied, as well as fine examples of originally interconnected vascular systems and of initially fasciated then secondarily interconnected conductive tissue systems; at the same time, the tissue zones of the best known stem structures, their position and ratio to each other are also clearly seen in the photos. These are followed by a large number of expressive photographs (32 in all) on the anatomical diversity of the young shoots and older xylem, phloem and trunk of gymnospermous and angiospermous arboraceous plants, with special regard to the characteristic types of cell-wall thickening in secondary xylem elements. The tissue structure of the leaf, i.e. of the foliage leaf, a basic organ of the vegetative shoot, is shown in cross section in an adequate number of photos (16). Besides the bifacial and unifacial leaf-blade structures of mono- and dicotyledonous plants, cross sectional photos and occasionally rough sketches of the petiole, with its highly varied inner differentiation, and of leaf-sheats types are also to be found. The anatomy of the pine-needles of a number of representatives of the Gymnospermae (Scotch fir, fir and spruce) is also included.

The photos and the complementary sketches (Nos 191–218) in *Chapter 5*, "*The tissue structure of the root*", acquain the reader with the roots of shield-fern and spruce, the radicle of the monocotyledonous germ, the younger and older roots of mono- and dicotyledons, and with the inner organization of the lateral root. The illustrations include cross-sections of diarch, triarch, tetrarch and polyarch types of root structures, as well as older roots with continuous vascular tissue systems. There are tissue structure photos of the prop root of maize, the haustoria of the semiparasitic mistletoe and parasitic dodder, the storing root of sugar-beet, the aerial root of philodendron, the lateral root of reed and the lateral root primordium of French beans.

Chapter 6, starting with "*The ferns*", gives illustrated information not only on the organization of the vegetative plant parts, but more importantly on the structural peculiarities of the reproductive organs (sporophyll, sporangium, spore), using horsetail, shield-fern and ruca öröm as the examples.

A separate group is represented in *Chapter 7*, in which 12 histological photos demonstrate the major features of structural properties appearing in the vegetative and reproductive organization (growing point of shoot, foliage leaf, dwarf shoot, stamen, anther, pollen, seed primordium and seed) of *gymnosperms*, discussing not only the spruce, but also the ginkgo and Scotch fir.

Finally, *Chapter 8*, under the superscription "*The flower*", offers a large number of photographs (Nos 249–328) on the tissue structure, and varied differentiation not only of the angiospermous flower in the strict sense of the word, but also of the fruit and seed that develop from it. A particularly large number of photos (50) were taken of the flower and seed organization in poppy *(Papaver somniferum)*, from the reproductive growing point through the primordial perianth, androecium and gynoecium to the anther and the locular ovary. In the highly impressive pictures the microsporogenesis that precedes microgametogenesis can be seen, together with the seed primordia, including megasporogenesis and megagametogenesis, and the organization of the developed female gametophyte (embryo sac). Information is also supplied on the major processes of seed formation after fructification, on the histogenic aspects of the young sporophyte (embryo), on the inner nutritive tissue, the seed-coat and the fruit-wall. The histology of the flower, seed and fruit are presented not only far but also for other plants such as sunflower, syringa, etc.

Attention should be called to the coloured photomicrographs inserted after page 240 as a supplement. These are printed on higher quality paper and numbered 1 to 72. They were taken either of singly or multiply stained

preparations or using special microscopes, e.g. interference contrast and polarization microscopes. It can safely be said that any one of them could compete favourably with coloured photos of a similar character in the highest quality text-books, handbooks and phytohistological atlases, not only in Hungary, but elsewhere in the world. They excel both in colour, clarity, didactical value and attractiveness, proving the authors' great competence and micro- and phototechnical skill.

In spite of its great value the book has some shortcomings, but they are mostly typographical deficiencies easy to eliminate in the future. For example, the microphotogram No. 176 on page 142 seems to have been placed with the lower epidermis upwards; on page 219 the term "pollen mother cells" in the caption for Fig. 281 should be replaced by the expression "microspore mother cells"; in the pictures on pages 230–240 the letter referred to in the text are generally missing, and in many cases letters indispensable if full information is to be given have been left out both in the text and in the picture; in the explanatory text to picture No. 304 on page 234, the word "embryo" should be replaced by the term "embryo primordium", since this is what the picture shows. Another objection is that for most of the photos the scale of enlargement is not given; it is therefore difficult to determine the original size of the picture or of the details seen in it. Finally, it cannot be concealed that the order in which the black-and-white photos are published is not always logical, and some of them are not sufficiently clear-cut (e.g. 121a, 158, 173, 207, 218, 248, 266, 267, 308). However, these photos can be replaced in the next edition. The above observations and suggestions do not detract to any extent from the value and usefulness of this much-needed work.

In closing it should be emphasized that the plant anatomy atlas, with its rich illustrations and handsome design, will be of good service not only to students and teachers of biology, but to all those who are interested in the diversity of the inner structure of plants and who wish to widen their knowledge on this special field.

S. SÁRKÁNY

F. NYUJTÓ and D. SURÁNYI: *Apricot.* Mezőgazdasági Kiadó, Budapest, 1981 (468 pages with 90 figures of which 53 are photos, 21 drawings, 16 graphs, and 66 tables of various kinds)

As can be read in the introduction commemorative of Gy. Magyar, apricot was widely grown in Hungary in the second half of the past- and at the beginning of this century, its fruit was much liked and consumed in large quantities. Then in the second half of this century, with the introduction of commercial production, the cultivation of apricot in Hungary, as in some foreign countries, gradually decreased, and its place was increasingly occupied by peach plantations (partly in dwarf form). It was probably to counterbalance this process that a work by F. Nyujtó—P. Tomcsányi "Apricot and its cultivation" was published in 1959, in which the theoretical and practical knowledge of those days were summed up, thereby encouraging a resumed occupation with apricot. In spite of this, the interest in this highly valuable fruit did not increase; on the contrary, the situation turned from bad to worse. However, in the field of research, in studying and partly solving the arising problems, an ever more intensive, enthusiastic and successful work was carried on, as proved by the establishment of the "Apricot Work Committee" several years ago. The members of this Committee have been taking part in analysing, studying and solving—partially or fully—many open questions concerning apricot; e.g. apoplexy, frost damage, pruning, crown training. It was mainly with the cooperation of this work committee and by making use of their own experiences that the two authors have written this book. Their purpose was on the one hand to inform the reader on the prograss of apricot research in Hungary and abroad, and on the other hand to arouse the interest—first of all of the owners of small gardens and week-end orchards—in apricot cultivation, by providing advice and new theoretical and empirical data.

As to the thematic division, the book consists of 28 units logically built on each other. Besides the two authors, the following experts took part in writing the different chapters: J. Főző, I. Gergely, J. Harsányi, G. Jenser, Mrs. T. Kállay, Z. Klement, E. Koháry, G. Kovács, R. Mády, L. Molnár, Zs. Rozsnyai, K. Véghelyi. The text is completed with well chosen, highly expressive photos, graphic illustrations, diagrams and tables. An outline of the chapters follows.

Chapter 1 written by F. Nyujtó deals with the cultivation and economic importance of apricot. In this framework a survey is given of the characteristics of consumption, the chemical composition, vitamin and mineral content of the fruit, of the commercial and industrial demands, of the situation of apricot cultivation is Hungary. Further, mention is made of the demands of development, and of apricot production and -trade on a world scale.

In *Chapter 2* "The taxonomy of apricot and the botanical characterization of the species" D. Surányi gives the taxonomic place of the species group, characterizes the species group of Armeniaca (apricot), touches upon its taxonomic key, phytogeography, as well as the identification of the varieties on the basis of the foliage leaf, also with a taxonomic key.

Chapter 3, the culture history of apricot, was compiled by the two chief authors: F. Nyujtó and D. Surányi. Referring to earlier and recent literary works they discuss the origin of apricot several thousands of years ago, and there is a possibility of its Chinese origin. The stone remnants found, on the other hand suggest Üzbek, Tadzhik and Armenian areas as the original land. In any case the fruit of fine colour and taste was known and consumed in those regions. The authors even show Chinese ideographs which suggest a Chinese origin. The authors then speak of a later appearance of apricot in Europe, its introduction into Hungary in the 14th century, and subsequently its gradual spreading during the 19th century. In a separate subchapter, referring to Priszter's paper, the authors analyse the various names of apricot and compare them with the names of peach. Finally, the names of apricot in other languages are listed.

Chapter 4 on the apricot varieties (F. Nyujtó) informs the reader about the origin of the species and evaluates them, mentioning the standard qualities, the indices of production value and the morphological characteristics. The author deals with the systemization of the varieties and emphasizes the difficulties encountered in this field.

Chapter 5 contains fundamental information on the major apricot varieties irrespective of whether they are species licensed for sale, or provisionally certified or state registered varieties. The varieties listed by J. Harsányi are: "Korai piros 83", "Ceglédi óriás 84", "Szegedi mammut 85", "Ceglédi bíborkajszi 86", "Magyar kajszi 86", "Ligeti óriás 92", "C 325 94", "Rakovszky kajszi 94", "Mandula kajszi C 712 95", "Ceglédi hajnalpír 96", "Budapest 97", "Kécskei rózsa 99", "Borsi-féle kései rózsa 100". As a completion, brief characterization is given of 6 Hungarian prospective varieties, as well as of varieties grown in the Soviet Union, in Eastern and Central Europe, in the Mediterranean countries and in the United States of America.

In *Chapter 6* F. Nyujtó gives an account of the situation and problems of apricot breeding in Hungary. The major biological, cultivation and marketing qualities of the Hungarian varieties, in other words their favourable properties to be improved and unfavourable ones to be eliminated, are presented in a tabulated form. Apricot breeding by selection is an old popular practice; however, systematic selection experiments in Hungary were only started in the thirties of this century. Valuable clones were propagated, then a methodical variety- and rootstock breeding began according to the programme and guidance of Gy. Magyar. In the second half of this century, gross-breeding was also introduced. From a stock of several thousand young hybrid trees "many frost resistant, early and high yielding plants with good quality parameters were selected". Beside an extensive resistance breeding, the advantages of the method of inbreeding as well as the possibilities offered by the introduction of varieties of foreign origin must also be exploited. The most important thing is to produce or introduce such new varieties whose cultivation is safe, and whose quality meets the market demands and the domestic and foreign trade as well as the industrial requirements.

Chapter 7 deals with the natural conditions of plantation including the climatic and soil demands of apricot, the situation of the growing site, along with the economic and management aspects. The chapter ends with a proposal on plantation.

Chapter 8 discusses the root-stocks of apricot completed with a tabulated evaluation of various stock actions and numerous literary references.

Chapter 9 under the heading "Plantation" acquaints the reader with the informatory work before planting, the prescriptions and examinations, the concept of soil sickness, and describes the planting operations, namely: soil preparation, laying out, planting in due time, tending of young trees, replacement and renewal.

Chapter 10 "Biology of the apricot tree" the authors (D. Surányi and L. Molnár) supply highly valuable, richly illustrated information relying partly on their own results of examination, observation, measuring and chemical analysis, partly on a wide range of literary data. Emphasis is laid on the life cycles important from the standpoint of ontogeny and practice; growth period of the bearing surface; bearing age (production balance, thinning, renewal of the bearing surface); age of decreasing yields; phenophases of shoots (shoot development, increase

of trunk diameter, defoliation); biology of lower-bud formation and flower organization (periodicity and vegetative performance of the tree, flower-bud organization, correlation of the generative organs, winter, deep and forced dormancy, frost resistance). In the section "Phenophases of the generative organs" we learn about bud swelling, flower-bud bursting, calyx setting. The latter may be influenced to a greater or lesser extent by meteorological and other factors beside the genetic and health conditions of the plant. After setting the fruit begins to develop and grow through three characteristic phases; cell division, stone hardening — embryo growth, and ripening. The chapter also deals with natural thinning, fruit dropping, and other factors influencing the size of the fruit.

In *Chapters 11*, *12* and *13* we are informed about the training systems of apricot plantations (L. Molnár), about the planting systems themselves (wide-spaced, broad hedge, hedge) and the crown shapes of apricot-trees, those of the unpruned, wide-spaced, broad hedge and hedge systems.

Chapter 14 discusses the work of pruning in detail; the crown pruning, the pruning of bearing trees, the controlling pruning, as well as the purpose, way and extent of the atter, the rejuvenating pruning, the so-called spring, early summer and late summer pruning, in addition to the techniques of pruning and mechanical pruning. In this chapter too we are given much useful advice, and are informed about valuable experiences, experiment results, particularly concerning the causes of apoplexy and the control of this disease.

Chapter 15 deals with some details of the extremely important question of nutrient replacement (F. Nyujtó). Citing foreign date, he gives approximative answers to the questions of how much nutrient the apricot-tree extracts from the soil on the one hand, and what the nutrient balance of the plant is like, on the other, also mention is made of the theory and practice of nutrient replacement as well as of the determination of the nutrient requirement, and finally of the nutrition of apricot plantations and young orchards.

Chapter 16 discusses the soil cultivation and weed killing (F. Nyujtó—E. Koháry);

Chapter 17 the green manure application; while

Chapter 18 deals with the chemical control of weeds, referring to the experiment results of many Hungarian and foreign researchers, and to experiences and achievements related to the herbicides studied and listed, with their various action mechanisms.

Chapter 19 analyses a similarly important and long since disputed problem, the apoplexy, a dangerous disease of the apricot-tree. The authors' collective (Z. Klement, D. Zs. Rozsnyai, D. Surányi, G. Kovács) relying on the most recent experiment results points out the different possible causes of apoplexy, among others the bacterial, cytosporic, eutypic cancer and necrosis, further the possibilities of control and the physiopathological aspects of transpiration in apricot.

The subject of *Chapter 20* is plant protection for the apricot in general, including the soil analysis of the orchard to be planted with a view to plant protection. The authors (G. Jenser and K. Véghelyi) speak of the plant protection of young plantations and bearing orchards, of chemical treatments against infections and insect damage of the method and time of spraying.

In *Chapter 21* (I. Gergely) we can read of the mechanical control of late spring frosts, of stirring the air, of the combined application of stirring the air and heating, and of heating the air. We learn about protection against frost and retardation of flowering by irrigation and other methods used for frost control, as supported by valuable experimental results.

Chapter 22 sums up all that is to be known about the irrigation of apricot, and mentions the effect of irrigation on the yield as well as the determination of the time of irrigation and quantity of irrigation water.

Chapter 23 discusses the regulation of yield; then, on the basis of experiment results and experiences obtained by the author (D. Surányi) and other well known Hungarian and foreign researchers in the last 12 years (from 1970), deals with several interesting subjects such as: regulation of flower formation, root-stock and graft management, stimulation and inhibition of flower formation; also mechanical and chemical fruit thinning, two almost simultaneously introduces methods; regulation of fruit dropping, acceleration of ripening, increased efficiency of mechanical harvesting, and chemicals used is temporary storage.

Chapter 24, compiled by R. Mády, discusses the apricot harvest. After the most important technological aspects of hand pick-

ing, we are informed about the various machines used for mechanical harvesting, and finally the arising problems are outlined.

Chapter 25 bears the heading "Apricot as a commodity" and describes sorting, grading, packing, handling the empty and filled integuments, and finally tells about the machine lines used to prepare the apricot for marketing.

In *Chapter 26* the author (J. Harsányi) sums up the industrial processing and refrigeration of apricot and its utilization by the distilling industry.

Chapter 27 discusses another important practical question, namely the profitability of apricot growing (Mrs. T. Kállay). Mention is made of the situation of apricot cultivation in Hungary, the technological problems of harvesting, and the economic efficiency of apricot growing as shown by three separate models.

In *Chapter 28* we can read of the apricot production systems (J. Főző). Information is given on the essential features and importance of the system activity on the one hand, and on the special requirements of apricot production on the other.

The last larger unit of the book is the rich 14 page bibliography compiled by D. Surányi. It contains more than 280 literary references, mostly published in the seventies up to and including 1980.

After the bibliography, a detailed list of contents is found which offers quick orientation in the extremely rich, manifold and up-to-date material.

In conclusion we emphasize that the book, written in good Hungarian, with in excellent style and completed with many illustrations in accordance with the demands of our time makes use of innumerable theoretical and practical results, Hungarian and foreign data and the authors' own experiences deserve full recognition. As a very useful technical book and at the same time a thorough guide in theory and practice, it is equally worthy of the attention of workers of large farms and homeplots and owners of private gardens.

S. SÁRKÁNY

Scientia Agriculturea Bohemoslovaca

The "Scientia Agriculturea Bohemoslovaca" is a journal of the Institute for Scientific and Technical Information for Agriculture (UVTIZ) of the Czechoslovak Academy of Agriculture (ČSAZ). It is published four times a year. Address of administration: Praha 2, Slezská 7. The exchange of the journal for publications is mediated by the Central Agricultural Library of the UVTIZ. Publications from all countries and nations are appreciated, and accepted both in English and Russian languages, but it gives brief English, Russian, German and Czech abstracts of each paper in its synopsis. Papers published in this journal treat the results of all subjects connected with research work carried out in agricultural fields. Thus, we might get information on experimental results of plant physiology, plant ecology, plant breeding, agrotechnique, animal breeding, animal nutrition, forestry etc. There are even data on agricultural economic work in member countries of the Council for Mutual Economic Assistance.

The present journal is the third volume for the year 1982. It contains eight articles, and this brief summary of each paper will indicate the range of subjects.

(1) M. KRÁLOVÁ, K. RAŽDÁK and J. KUBÁT: "*Behaviour of* $^{15}KNO_3$ *and* $(^{15}NH_4)_2SO_4$ *During Incubation with Soil Suspension and Two Clay Minerals in a Quartz Medium*".

The aim of the authors's experiment was to study nitrogen compound produced at various steps of transformation processes, the mutual effect of these compounds and soil constituents under different physical, chemical and biological conditions. Labelled ammonium and nitrate nitrogen were used as nitrogen sources. Experiments were carried out within four days of the incubation at 28 °C in the presence of glucose, different types of clay minerals (montmorillonite and kaolinite) and soil suspension in a quartz medium. It has been found that the application of ammonia doubled the mineralization of the organic matter, in comparison with nitrate nitrogen. The immobilization rate of nitrogen, and distribution of inorganic nitrogen into several forms, depended upon the form of nitrogen applied and the type of clay mineral. Nitrification rate was influenced by the type of clay mineral and its particle size.

(2) V. MALY: "*Negative Effects of* SO_2 *on Farm Crops in Model Glasshouse Experiments*".

This paper is written in Russian Language. The well-known harmful effect of atmospherical pollution produced by chemical and industrial industries creates an almost unsolvable worldwide problem. Many research workers try to find solution for this. In the present paper written in Russian, the author studies the influence of SO_2, at different concentration, on the damage to farm crops,

crop yields, crop quality and the S content in wheat, rye, barley, oats, trefoil, alfalfa, maize, beetroot and potato plant cultures in greenhouses. The results presented here prove that the long-term effects of high SO_2 concentration are harmful to farm crops and reduce yields. By chemical analyses of farm crops, an increased content of sulphur and lower N content were found at a concentration of 0.90 mg/m³. No large differences were observed in per cent dry matter, ash, digestible N-compounds, K, Ca, Mg, P and Na content, and fiber in farm crops exposed to SO_2, in comparison with control crops.

(3) K. KNOP and L. ZENIŠČEVA: "*The effect of Nitrogen Fertilization on the Length of Growing Season and Yield of Spring Barley*".

It has been proved that the level of grain yield of cereals is determined by the photosynthetic activity of the green parts of plants, the rate of assimilate translocation and the storage capacity of plants. The storage capacity is the result of the number of fertile tillers per unit area, the number of grains per ear, 1000-grain-weight, and the intensity of tiller reduction. Altogether, these are influenced by ecological factors and nutrition.

The authors investigated the effect of such nitrogen forms as ammonium sulphate and slow-acting ureaformaldehyde fertilizers upon the onset of Feekes growth stages, the number of fertile and infertile tillers, yield components of the growing season, and grain and straw yields of three genotypes of spring barley; half-dwarf, short-stalked and long-stalked types. The applied nitrogen rates were low, medium and high of ammonium sulphate, and high of ureaformaldehyde.

The yield levels of grain and straw were influenced by genotypic properties and by the applied nitrogenous fertilizers, including the nitrogen doses. This was due to the differences in the number of fertile tillers, in the number of grains per plant and per ear, and in the 1000-grain-weight. The highest grain yield (especially in the halfdwarf genotype) was obtained in the case of slow-acting nitrogen form application.

(4) Z. STEHNO and M. APLTANEROVÁ: "*Pollen Fertility Restoration in the Alloplasmatic Lines of Wheat with the cytoplasm sp.*".

A high degree of pollen fertility restoration in the F_1 generation is a preliminary condition for the practical use of the systems of cytoplasmatic male sterility (CMS) in the course of production of hybrid seed. In the case of wheat, which is the most important of commercial crops, the CMS system is throughly studied on the basis of the cytoplasm of *Triticum timopheevi* Zhuk. The fertility restoration genes (Rf genes) originate from *Triticum timopheevi*, as cytoplasm donor. However, they occur in other species of the genus *Triticum* L., as has often been proven.

The recent paper describes the experiments carried out on the pollen fertility restoration in CMS lines derived from the cytoplasm of selected species of the genus *Aegilops* L. The seeds used for the trials were obtained by crossing the male steriles of wheat cultivars with fertility restorers of different origin.

The set of male steriles and fertile wheat (*Triticum aestivum* L.) cultivars included:

(T. timopheevi)	Pitic 62
(Ae. aucheri)	Pitic 62
(Ae. biuncialis)	Pitic 62
(Ae. macrochaeta)	Pitic 62
(Ae. columnaris)	Pitic 62
(Ae. recta)	Pitic 62
(Ae triaristata)	Pitic 62
(T. timopheevi)	Penjamo 62
(Ae. heldreichi)	Penjamo 62
(Ae. comosa)	Penjamo 62
(T. diccocoides var. *spontaneovillosum)*	Penjamo 62
Pitic 62	
Penjamo 62	

The set of fertility restorers included:

Wilson — restorer of spring nature; Rf genes come from *T. timopheevi*

PMH 1 — restorer of spring nature; Rf genes probably come from *T. timopheevi*

Prof. Marchal — winter cultivar; Rf genes come from *T. aestivum*

Primepi — winter cultivar; Rf genes come from *T. aestivum*

Each combination was observed over a two-year period. The results suggest that the Rf genes coming from *T. aestivum* varieties were more effective, compared with those coming from *T. timopheevi*. Restorers in the cytoplasm of *Ae. columnaris*, *Ae. comosa* and *Ae. heldreichii* were completely ineffective. The relatively highest fertility restoration was observed in the cytoplasm of *Ae. aucheri* and *T. diccocoides* var. *spontaneovillosum*.

(5) J. PYTLOUN, F. ZAJIČEK and J. MILER: "*Frequency of Mutual Sucking in Heifers in Relation to the Origin after a Sire*".

In the period of vegetative nutrition, rather a high occurrence of the active manifestation of undesirable sucking (in 70% out of 170 evaluated animals) was observed in heifers of Bohemian Spotted breed, at the age of 3–6 months. Large differences were found between daughters of five sires eval-

uated, even though the minimum occurrence of the frequency of undesirable sucking in daughters of the sire HAJ-19 (52.28c) is considerably high. On the contrary, in daughters of the DR-340 sire the active sucking was observed in almost 90% of the heifers.

(6) V. MOSKAL and M. POUR: "*Relationship between Carcass Value and Pork Quality in Purebred Pigs and Hybrids*".

In pig breeding the efficiency parameters of economic and zootechnical importance can be divided into partial complexes of traits: complexes of traits of reproduction, fattening performance and carcass value; physical traits as pH, colour, content of bound water; chemical composition of meat as content of protein, fat etc. Between these complexes exist physiologically conditioned relationships.

This study deals with the determination of the level of relationship between the traits of carcass value, and the physical and chemical traits of pork muscle, in purebred pigs and hybrids. The pig breeds were marked with the following abbreviations: LW = Large white, PB = Prestitzer Black-Pied, L = Landrace, Bl = Belgian Landrace.

Phenotypic correlations between the complexes of production traits in two groups of prebred pigs and one group of hybrids were calculated. In PB breed, close and significant correlations were found between the meat production characters and $pH_{4.5}$ values (musc. long. dorsi and musc. semimemb.) and between the meat colour values (spekol). Mostly low and minute correlations were found among physical, chemical and nutritive value traits. In PB breed and in hybrids $(LW \times PB) \times BL$ significant correlations were found between the carcass value traits and meat nutritive value traits.

(7) J. KRAUS: "*International Division of Work in Agro-Industrial Complexes of the Member Countries of the Council for Mutual Economic Assistance*".

Problems of international specialization of the C.M.E.A. member countries in the field of agricultural and food products are discussed. It deals with the specific features of international specialization in the sphere of agricultural primary production and the food industry, as well as factors limiting its effects in a given national-economy complex. Foreign trade is conceived as a realization output of the trend specialization. Possibilities of cooperation with the third countries, mainly developing countries, are analyzed. The current state of international specialization of the C.M.E.A. member countries is described as it exists within the Agricultural and Food Production Complex, and prospects of its further development are discussed.

(8) M. VYSKOT: "*International Experimental Plot of the IUFRO Forest District Mrákotin*".

This international experimental area, founded in 1971, is located in the region of forest enterprise Telč, forest district Mrákotin, altitude 730–740 m. The experimental area consist of 5 obligatory and 6 facultative areas of the total area 5775 ha. In 1971, the average tree age was 23 years. The obligatory areas were subjected to thinning and to tree number reduction according to the IUFRO methodology. The facultative area consist of the control A_1 area, without any tree number reduction, whereas the remaining areas are experimentally utilised for low thinning, B degree—slight, C degree—strong, thinning by Borggreve—Voropanov method and thinning by positive selection, for seeking the promising trees and tending them. As documented by the recent results, the trees respond to more extensive density reduction by a larger diameter increment.

I. KOVÁCS

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Results of the "Síkfőkút" Project

Vol. I. Structure, Primary Production and Mineral Cycling

Series: Ecology of an Oak Forest in Hungary

In English. 1985. 545 pages. 16 photoplates,125 figures 205 tables, 17×25 cm. Hardcover
$49.00/DM 124,—/£34,25 ISBN 963 05 3371 5

The ecological investigations of climax oak-forests in Hungary are conducted as a part of the temperate-forest studies of the "Man and Biosphere" programme organized by UNESCO. Ecologists of 22 institutes have been cooperating since 1972 in studying a fairly undisturbed forest community (Quercetum petraeae-cerris) composed by Quercus petraea and Quercus cerris tree-species in the northern mountain region of Hungary. Similar forests, being characteristic of the Pannonicum region, once covered about a quarter of the country's territory. The synthetic ecological studies, carried out in a forest of 16 hectares equipped for permanent field-studies, are planned to continue until 1990. The first results of these investigations are included in this book.

Chapters I—III outline the main objectives and organization of the whole ecological research, and also the topics of investigations that have been carried out. Geomorphological, pedological and climatic data on the wider geographical surroundings are also included, followed by a phytosociological and pedological description of the sample area, together with the meteorological trends in the sample period.

The following part include only the results of studies on autotrophic levels until 1977. The material from investigations since 1977 and from the studies on heterotrophic levels will be published in the volume of "*Results of the "Síkfőkút" Project II.*"

Chapter IV gives the structural parameters of the forest, Chapter V deals with phytomass and primary production of organic matter, Chapter VI includes the results of growth- and pigment-studies on assimilatory organs, Chapter VII deals with energy-relationship of the autotrophic level and efficiency, Chapter VIII with the element content of higher plants and mosses and Chapter IX contains the results of element-circulation and litter-decomposition studies. The above mentioned main chapters are divided into numerous smaller units. The text and tables always contain results of investigations repeated at last over three years.

The book is the first basic work of its kind in Hungary in a field of terrestrial ecology, whose literature is also rather scarce world-wide. Its final chapter calls attention to trends of global environmental changes (atmospheric CO_2 accumulation, soil-acidification, break-down of element-cycles) based on the data given in the book.

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PHYTOPRODUCTION STUDIES ON UNIRRIGATED SINGLE-SPECIES GRASSES

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(Received: May 1983)

Our single-species grass plots experiments, involving seven species, were carried out without artificial watering in 1978 and 1982 at the Experimental Research Area of the Department of Water Management and Amelioration in the Agricultural University at Gödöllő. The plots were fertilized one time with N, K and P. The coenological structure, the ratio of weeds, the grass yield after repeated moving, the changes of the root mass in 0–50 cm soil layer, and the changes of the composition values of the yield in correlation with the soil parameters, were investigated. In our experiments the yield of the grass plots exceeds the national average value of grass production, cultivated without irrigation in every case, which can be interpreted mainly, due to the favourable soil conditions and the required artificial fertilization.

Introduction

The establishment of a fodder basis for large-scale specialized livestock management, for cattle and sheep farming based on grazing, requires a many-sided study of both natural and planted grasses, also of ecological, cenological, soil- and water management experiments carried out under different soil- and climatic conditions, in addition to the well-known methods of grass management.

Owing to the problem of water supply and the high costs of water consumption, as well as for technical reasons, the large-scale irrigation of high productivity mesofrequent grasses is restricted in the 6th Five-Year Plan period. In this period grass areas managed under dry conditions (with fertilization) are of special importance. The utility of expertly supplied optimum quantities of fertilizer is, under such conditions, mainly a function of the natural precipitation, apart from the local ecological factors.

In our experiment carried out for four years in the environs of Gödöllő, we studied the phytocenological aspects, grass yield, its components and the trend of root weight at the time of cutting the successive growths, for single-species grass stand of seven perennial species of high feed value and medium water demand, sown on a rust-brown forest soil and used as hayfield, without irrigation. Another objective was to obtain data suitable to compare the species sown with those grown on a solonecz meadow soil in the neighbourhood

of Szarvas under irrigated and fertilized conditions between 1973 and 1980 (KOVÁCS and CINKÓCZKY 1974, KOVÁCS 1979, 1982a, b, 1983). With the data thus obtained, the border lines of optimum cultivation can be still more exactly drawn for these species. Our work is connected with the research programme of meat and milk production based on mass fodders and by-products (OKKFT-A)10.

Material and methods

Our unirrigated (fertilized) single-species grass experiments planned for four years (1978–1981) were set up on the Szárítópuszta trial ground of the Department of Water Management and Amelioration of the Gödöllő University of Agricultural Sciences, in plots of 25 m^2 each, on 16 March 1978 with five grass species: *Typhoides arundinacea* (L.) Dum. Szarvasi-72 prospective variety; *Bromus inermis* Leyss. "G" state registered in 1959; *Festuca arundinacea* Schreb. "G" state registered in 1975; *Festuca pratensis* Huds. "G" state registered in 1964: *Dactylis glomerata* L. Szarvasi-51 state registered in 1978 and two papilionaceous species. *Trifolium repens* L. f. *giganteum* Lagr. Szarvasi-4 state registered in 1967; *Lotus corniculatus* L. "G" Keskenylevelű state registered in 1969, in the place of a four-year grass experiment ploughed out in the autumn of 1977 (KOVÁCS and ANGELI 1981). The grass stands were supplied every year in March with fertilizer corresponding to NPK = 240 : 100 : 100 kg/ha active agent.

The trial ground is situated in the outskirts of Gödöllő, south of the Gödöllő-Valkó highway, at a height of 215–238 m above sea level. The ground-water level is more than 4–6 m below the surface.

Table 1

The important soil characteristics of the grass stands in the year 1981

Grass stand	Depth of soil	pH		Humus, %	Total N %	P_2O_5	K_2O	Pervious to water capacity, mm/h	H_y	$V_{c\,max}$ (tf %)	Total porosity
		H_2O	KCl			mg/100 g					
Trifolium repens f. *giganteum*	0–10	6.41	5.91	1.2	0.018	14.4	19.6				
	10–20	7.19	6.42	1.1	0.015	11.6	14.4	102	7.2	39.7	39.2
	20–35	7.42	6.82	1.1	0.019	4.4	14.3				
Typhoides arundinacea	0–10	6.02	5.12	1.7	0.019	7.8	17.8				
	10–20	7.13	6.56	1.5	0.017	5.6	13.6	44	6.55	36.3	37.5
	20–35	7.25	6.62	1.4	0.021	5.4	13.8				
Lotus corniculatus	0–10	5.18	4.12	1.8	0.019	7.2	30.0				
	10–20	6.84	6.02	1.7	0.023	4.6	14.4	116	6.5	42.7	42.1
	20–35	7.12	6.79	1.5	0.021	5.8	13.6				
Bromus inermis	0–10	6.92	6.39	1.8	0.018	8.0	15.8				
	10–20	7.48	6.95	1.3	0.013	7.6	13.4	32	6.0	38.5	38.5
	20–35	7.62	7.15	1.3	0.014	7.8	13.6				
Festuca arundinacea	0–10	6.72	6.39	1.5	0.025	12.8	18.6				
	10–20	7.35	6.75	1.4	0.018	10.6	13.4	30	7.8	41.3	41.9
	20–35	7.42	6.82	1.3	0.017	14.6	13.0				
Dactylis glomerata	0–10	5.86	4.75	1.5	0.020	10.4	19.2				
	10–20	7.48	6.60	1.4	0.016	9.0	14.2	68	7.6	41.8	43.3
	20–35	7.60	6.87	1.3	0.017	8.0	13.2				
Festuca pratensis	0–10	6.82	6.13	1.5	0.022	9.0	20.8				
	10–20	7.90	6.98	1.4	0.020	6.8	13.6	64	7.2	43.1	43.6
	20–35	7.96	6.88	1.4	0.017	6.8	13.2				

Table 2

Characteristic meteorological data (Szárítópuszta, Gödöllő)

	Months													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly average	III–IX
							1978							
Mean temperature (°C)	−0.7	−1	6.3	9.6	13.5	18.3	18.9	18.4	14.8	11.2	1.4	0.1	9.2	14.3
Number of sunshine hours	66	63	166	165	187	273	299	287	213	187	21	32	1959	1590
Precipitation (mm)	34	34	30	45	127	96	74	41	38	19	19	31	588	451
Air humidity (%)	83	87	76	76	79	71	73	72	76	82	95	93	80	75
							1979							
Mean temperature (°C)	−3.5	1	6.8	9.8	17.7	21.9	18.9	19.7	17.2	1.8	4.8	3	9.9	16
Number of sunshine hours	52	95	167	227	329	268	258	274	229	193	39	50	2181	1752
Precipitation (mm)	82	41	63	53	10	118	42	50	16	25	85	50	635	352
Air humidity (%)	90	83	80	71	65	73	72	72	75	73	93	88	80	73
							1980							
Mean temperature (°C)	−4.3	0.7	−0.9	8.4	13.4	18.3	19.2	19.8	15	10.1	2.6	−0.2	8.5	13.3
Number of sunshine hours	59	83	108	145	244	262	259	269	191	150	74	66	1910	1478
Precipitation (mm)	48	22	35	66	47	54	36	34	27	59	130	35	593	299
Air humidity (%)	77	72	76	65	66	68	67	69	78	78	79	88	74	70
							1981							
Mean temperature (°C)	−2.9	0.8	8.3	10.5	16	20.3	20.4	20.2	16.8	11.2	4.2	−1.6	10.35	16.1
Number of sunshine hours	114	125	167	205	231	234	276	280	183	143	83	21	2062	1576
Precipitation (mm)	28	7	28	13	97	96	30	43	49	29	21	97	538	356
Air humidity (%)	84	82	77	72	66	67	71	67	77	79	86	84	76	71
							50-year average							
Mean temperature (°C)	−2.4	−0.9	4.3	9.5	14.9	17.8	19.9	19	14.8	9.3	3.3	−0.4	9.1	14.3
Number of sunshine hours	66	83	141	178	245	259	291	164	194	132	60	47	1960	1572
Precipitation (mm)	32	32	37	45	63	61	50	50	44	50	56	47	564	350
Air humidity (%)	83	80	73	67	67	65	65	67	73	79	85	87	74	68

Table 3

Harvest results of the single-species

	Naming	*Trifolium repens* f. *giganteum*		*Typhoides arundinacea*		*Lotus corniculatus*	
		fresh	dry	fresh	dry	fresh	dry
		weight		weight		weight	
1978	I. harvest	26.0	4.526	7.6	2.137	11.2	2.775
	II. harvest	9.56	2.519	4.3	1.331	5.64	1.556
	Total	35.56	7.045	11.9	3.468	16.84	4.331
1979	I. harvest	13.6	2.361	26.6	5.350	15.4	2.866
	II. harvest	4.38	1.881	8.0	2.738	7.16	3.125
	Total	17.98	4.242	34.6	8.088	22.56	5.991
1980	I. harvest	16.0	2.844	29.48	4.932	23.08	4.272
	II. harvest	9.6	3.081	16.4	5.133	11.6	4.108
	Total	25.6	5.925	45.88	10.065	34.68	8.380
1981	I. harvest	11.8	2.09	17.6	2.94	13.6	2.53
	II. harvest	5.2	2.87	6.4	4.38	6.08	2.83
	Total	17.0	4.96	24.0	7.32	19.68	5.38

The soil type of the experiment area is a moderately eroded recalcified rust-brown forest soil formed on coarse grained river sand. The physical and chemical analyses of soils in the experiment plots were performed with samples taken from the AB (0–35 cm) level. The soil samples were taken in September 1981, from the 0–10, 10–20 and 20–35 cm layers and the characteristic data are contained in Table 1. The pH value was determined by electrometry, the humus and total N content with *Tyurin*'s methods; while, for the determination of water permeability and maximum water capacity, the *Klimes-Szmik*'s method was used. The wilting point (H_v) was read at 4.2 pF on an *EIJKAMP Sand Box Apparatus*, and total porosity was calculated on the basis of the pF curve.

As seen from the data of Table 1 the pH values of the soils of the seven planted grass stands differed to the greatest extent in the 0–10 cm layer, ranging from acid (5.18) to slightly acid and neutral (6.92). In the deeper 10–35 soil layer the pH changed from neutral to slightly alkaline. Acidification in the upper 10 cm soil layer can be attributed to the yearly supplied fertilizer and the low buffer capacity of the soil.

The soil of the grass stands was slightly humus. In comparison to the unsown fallow, its humus content rose from 1.2 to 1.43% on an average. The higher, 1.2–1.8% humus content, in the 0–10 cm layer of the soil was due to the large volume of roots concentrated there and partly humified.

The total N content — in conformity with the moderately eroded forest soil — was characteristically very low. Only in the plot of bird's-foot trefoil of all stands was the total N content of the soil high, due to its specific character. The soluble (AL) phosphours and potassium status of the grass soils was considered medium.

The water permeability of the soils in the papilionaceous stand was multiple compared to the grass stands, i.e. very good and good, respectively. The H_v rose from the original 4.7 (tf %) to 6–7.8, the maximum water capacity ($V_{c\max}$) decreased (from the initial 46.6 to 43.1), and so did the total porosity (from 48.1 to 43.6–37.5%) (KOVÁCS and ANGELI 1981).

In general, meteorological conditions greatly influence the yield of grasses (according to SZABÓ 1977 by ±12%). In *Bacsó*'s regional classification, the experiment area belongs to the Gödöllő hill-country with its moderately cool and moderately dry climatic conditions. The annual mean temperature is 9.1 °C, the number of sunshine hours 1960, the temperature total of the vegetation period 3100–3200 °C, and the annual amount of rainfall 564 mm. The meteorological data in Table 2 show that for 1978 the values of annual mean temperature and rainfall were about the average; the year 1979 was rainier and 0.8 °C warmer

grasses in the years 1978–1981 (t/ha)

Bromus inermis		*Festuca arundinacea*		*Dactylis glomerata*		*Festuca pratensis*	
fresh	dry	fresh	dry	fresh	dry	fresh	dry
weight		weight		weight		weight	
8.0	2.628	10.0	2.684	9.2	1.980	8.8	2.319
2.6	0.854	2.6	0.762	3.24	0.979	2.34	0.739
10.6	3.482	12.6	3.446	12.44	2.959	11.14	3.058
23.4	5.617	21.2	5.120	22.6	4.947	21.5	4.327
6.4	2.285	7.68	2.583	6.8	2.599	6.4	2.164
29.8	7.902	28.88	7.703	29.4	7.546	27.9	6.491
26.6	5.065	29.4	5.977	22.0	3.621	21.16	4.377
10.0	3.857	14.2	4.616	12.2	4.200	11.6	4.273
36.6	8.922	43.6	10.593	34.2	7.821	32.76	8.650
14.8	2.82	12.8	2.60	9.6	1.58	8.4	1.74
4.12	2.38	2.92	1.18	4.6	2.32	3.8	1.98
18.92	5.20	15.72	3.78	14.2	3.90	12.2	3.72

than average; in 1980 the amount of precipitation was average, the mean temperature 0.6 °C below the average; and the year 1981 was droughty, with a 1.2 °C higher temperature mean and 60 mm less rainfall, compared to the 50-year average.

Grass and root samples were taken simultaneously on two occasions in each vegetation period. The first sampling took place when the grasses were in full flower (in May), the second when the lower stem leaves began to turn yellow (from at the end of August — till beginning of September). The fresh grass yield was determined by weighing the total amount of grass cut, while the dry matter yield by drying (at 80 °C) four samples taken at random from the fresh crop to constant weight, then weighing them. The root weight was determined at the time of cutting by the soil monolith method, a technique elaborated by us (KOVÁCS and GÁSPÁR 1975, 1976–1977), to a depth of 50 cm from the ground surfaces. This present study is based on the processing of 448 fresh and dry grass and 2240 root samples. The soil analyses were carried out in the Department of Soil Science at the Gödöllő University of Agricultural Sciences. The components were analysed in the laboratory of the Petőfi Cooperative Farm, Dunavarsány. The phytocenological survey of the grass stands was made separately for each successive growth (on plots of 25 m²) with the method and scale of BRAUN-BLANQUET.

Results

(1) *White clover (Trifolium repens* f. *giganteum) stand*

In the first and second year following sowing, the species covered 70–90% of the area. Owing to the severe winter of 1979–1980, this value fell to 2.5% by the autumn of 1980 and to 0.1% by the spring of 1981; that is, the sown species practically died out. The individual numbers of rye-grass *(Lolium perenne)* and wheat-grass *(Agropyron repens)* which took its place gradually increased, and by the end of 1981 the total cover of the two species reached 90%.

Table 4

Trend of changes in

Species	Sampling date	Depth of soil: 0–10		10–20	
		Weight of roots in fresh			
		fresh	dry	fresh	dry
Trifolium repens f. giganteum	19. 7. 1978	15.25	3.29	3.12	0.59
	5. 9. 1978	18.34	4.35	3.28	0.78
	17. 5. 1979	19.34	4.17	5.51	1.04
	16. 8. 1979	21.64	5.13	3.46	0.82
	14. 5. 1980	15.72	2.35	8.32	0.93
	17. 9. 1980	51.71	14.78	2.77	0.63
	23. 5. 1981	21.41	4.95	8.00	0.73
	28. 8. 1981	16.24	5.08	3.72	1.18
Typhoides arundinacea	19. 7. 1978	32.26	7.80	3.29	0.71
	5. 9. 1978	43.19	8.99	4.37	1.19
	17. 5. 1979	43.32	10.48	4.79	1.04
	16. 8. 1979	41.42	8.62	8.38	2.28
	14. 5. 1980	69.46	15.56	12.24	1.66
	17. 9. 1980	73.43	17.30	4.30	0.93
	23. 5. 1981	94.23	25.02	9.08	2.03
	28. 8. 1981	64.69	28.33	4.98	1.34
Lotus corniculatus	19. 7. 1978	14.37	2.90	2.12	0.41
	5. 9. 1978	19.59	4.93	3.07	0.70
	17. 5. 1979	28.45	5.74	3.11	0.60
	16. 8. 1979	19.86	5.00	5.15	1.17
	14. 5. 1980	59.90	9.83	12.28	1.86
	17. 9. 1980	35.93	8.93	9.05	1.77
	23. 5. 1981	32.66	5.92	13.23	2.55
	28. 8. 1981	50.29	15.88	11.55	2.91
Bromus inermis	19. 7. 1978	34.57	6.94	4.69	0.91
	5. 9. 1978	40.89	8.73	5.30	1.24
	17. 5. 1979	45.06	9.04	6.89	1.33
	16. 8. 1979	38.85	8.30	6.00	1.40
	14. 5. 1980	96.51	15.31	11.32	1.26
	17. 9. 1980	81.77	17.30	7.86	1.65
	23. 5. 1981	28.52	6.10	6.65	1.71
	28. 8. 1981	25.97	5.07	4.07	0.92
Festuca arundinacea	19. 7. 1978	67.49	14.42	7.54	1.97
	5. 9. 1978	71.15	19.79	7.91	1.88
	17. 5. 1979	72.89	15.58	10.93	2.57
	16. 8. 1979	84.91	23.62	7.89	1.88
	14. 5. 1980	106.99	28.97	13.93	1.71
	17. 9. 1980	42.43	7.98	7.32	1.95
	23. 5. 1981	103.28	25.93	7.75	1.85
	28. 8. 1981	94.65	44.60	13.26	2.52
Dactylis glomerata	19. 7. 1978	61.17	13.54	4.12	1.15
	5. 9. 1978	68.00	25.53	4.80	1.65
	17. 5. 1979	74.46	16.48	5.58	1.51
	16. 8. 1979	137.62	51.67	6.39	2.20
	14. 5. 1980	78.67	18.16	8.71	1.47
	17. 9. 1980	64.38	16.05	6.52	1.38
	23. 5. 1981	72.43	22.20	3.84	0.90
	28. 8. 1981	64.73	18.03	3.22	0.76
Festuca pratensis	19. 7. 1978	42.51	10.70	3.32	0.96
	5. 9. 1978	47.79	14.24	4.54	1.10
	17. 5. 1979	56.70	13.13	5.51	1.60
	16. 8. 1979	42.70	12.72	3.93	0.95
	14. 5. 1980	69.22	10.60	13.01	2.48
	17. 9. 1980	87.29	19.13	6.49	0.98
	23. 5. 1981	49.62	12.58	4.75	1.72
	28. 8. 1981	25.79	10.44	5.76	1.62

the mass roots (t/ha)

in cm							
20–30		30–40		40–50		Total	
and dry matter, t/ha							
fresh	dry	fresh	dry	fresh	dry	fresh	dry
1.85	0.40	0.52	0.14	0.11	0.02	20.85	4.44
2.05	0.47	0.67	0.14	0.32	0.09	24.66	5.83
2.96	0.65	0.94	0.25	0.53	0.08	29.28	6.19
1.31	0.30	0.87	0.18	0.41	0.12	27.69	6.55
1.76	0.18	1.16	0.12	0.46	0.09	27.42	3.67
1.68	0.47	1.17	0.23	0.68	0.15	58.02	16.26
4.43	3.02	1.45	0.33	1.49	0.31	36.78	9.34
2.52	0.62	1.95	0.45	0.84	0.26	25.27	7.59
2.10	0.37	1.12	0.26	0.26	0.04	39.03	9.18
2.59	0.55	1.67	0.41	0.32	0.06	52.14	11.20
2.57	0.45	1.87	0.44	0.97	0.16	53.52	12.57
3.40	1.12	1.48	0.37	1.35	0.30	56.23	12.69
7.84	0.99	5.56	0.69	1.03	0.09	96.13	18.99
2.42	0.50	1.27	0.33	0.79	0.15	82.21	20.21
5.58	1.37	2.85	0.43	3.03	0.48	114.77	54.35
3.12	1.19	1.86	0.34	1.56	0.21	76.21	31.41
0.98	0.22	0.61	0.15	0.12	0.03	18.20	3.71
1.56	0.32	1.05	0.22	0.62	0.11	25.89	6.28
1.07	0.24	0.95	0.24	0.74	0.17	34.32	6.67
3.20	0.65	2.21	0.47	1.55	0.27	31.97	7.56
7.97	1.06	1.99	0.22	0.77	0.11	82.91	13.08
1.00	0.40	0.89	0.33	0.81	0.20	47.68	11.63
6.32	1.27	4.86	0.90	3.35	0.71	61.04	11.35
4.50	1.36	3.23	0.79	3.22	0.83	72.79	21.77
3.15	0.71	1.05	0.24	0.50	0.11	43.96	8.91
4.19	0.83	1.40	0.39	0.62	0.17	52.40	11.36
7.07	1.60	1.29	0.30	0.87	0.19	61.18	12.46
2.43	0.48	1.87	0.53	1.37	0.38	50.52	11.09
5.65	0.65	2.45	0.19	1.11	0.14	117.05	17.55
4.51	0.98	2.36	0.55	0.85	0.23	97.35	20.71
4.46	0.87	3.00	0.62	3.22	0.63	45.85	9.94
1.54	0.32	1.44	0.42	1.32	0.45	34.34	7.18
1.85	0.49	0.97	0.26	0.49	0.16	78.34	17.30
2.63	0.74	1.40	0.41	0.65	0.14	83.74	22.96
2.11	0.51	1.17	0.28	0.55	0.18	87.65	19.12
2.43	0.68	2.49	0.73	2.29	0.51	100.01	27.42
4.90	0.82	3.11	0.49	2.02	0.26	130.95	32.25
5.53	1.02	2.63	0.50	2.15	0.45	60.06	11.90
6.30	1.35	5.81	1.08	2.90	1.02	126.04	31.23
5.47	1.57	2.33	0.52	1.26	0.25	116.97	49.46
1.85	0.49	0.75	0.19	0.42	0.07	68.31	15.44
2.53	0.44	1.17	0.33	0.87	0.31	77.37	28.28
2.21	0.57	0.90	0.23	0.63	0.10	83.78	18.89
2.31	0.40	1.05	0.40	0.49	0.21	147.86	54.88
2.54	0.48	1.85	0.22	0.59	0.04	92.36	20.37
2.17	0.65	1.33	0.30	0.27	0.07	74.67	18.45
2.30	0.42	0.87	0.25	0.93	0.15	80.37	23.92
1.17	0.26	0.92	0.43	0.20	0.06	69.98	19.54
1.12	0.18	1.05	0.21	0.43	0.09	48.43	12.14
2.19	0.61	1.45	0.41	0.87	0.29	56.84	16.65
1.61	0.33	1.53	0.25	0.87	0.19	66.22	15.50
1.60	0.45	0.88	0.25	0.81	0.27	49.92	14.64
6.29	0.49	1.69	0.21	0.99	0.07	91.20	13.85
4.39	0.87	2.87	0.55	1.20	0.37	102.14	21.90
2.63	0.64	1.64	0.28	0.77	0.14	59.41	15.36
1.23	0.26	0.91	0.20	0.54	0.13	34.23	12.65

Parallel to the thinning of *Trifolium repens* f. *giganteum*, the species number of the stand rose from nine in 1978 to twenty-seven by 1981. Thus, in the autumn of 1981, twelve grass-, two papilionaceous species, and fourteen species, mainly weeds, were registered belonging to other families (*Jaccard*'s similarity index: 0.28, *Sorensen*'s: 0.44). The constant species of the stand were: *Medicago sativa*, *Lolium perenne*, *Festuca arundinacea*, *Agropyron repens*, *Capsella bursa-pastoris*, *Reseda lutea*, *Taraxacum officinale*, its subconstant species: *Bromus sterilis*, *Poa pratensis angustifolia*, *Cirsium arvense*, *Erigeron canadensis*, *Polygonum aviculare*, which either came from the adjacent plots or developed from the weed seed reserves of the soil, together with the other accidental species.

The green yield of the stand was the largest in the year of sowing. The gradual thinning of the sown species and the invasion of masses of other, mainly grass, species were determinative of the yield. The four year average of grass was 24 t/ha of fresh crop and 5.5 t/ha of dry matter (Table 3).

In the first two years of the experiment, the stand continually increased the volume and depth of roots. Under the influence of low temperatures at the end of 1979 and beginning of 1980, the dry weight of roots decreased to 40%. In the more favourable year of 1980, on the other hand, the root weight increased fourfold. In 1981, in response to a more favourable water supply after the spring drought, the root weight of the second growth was 20% lower than that of the first growth. The roots penetrated ever deeper into the soil, but in drought periods those near the soil surface showed a sudden increase (Table 4).

The weight ratio of surface-soil to underground phytomass always reflected the meteorological conditions of the vegetation period. In the case of favourable nutrient and water supply this ratio (1 : 2, 1 : 3) was characteristic of mesofrequent site conditions and flora; in drought periods it reflected xero-mesofrequent (1 : 6) conditions, with a characteristic seasonal dynamic. This weight ratio was the lowest with the first growth and in rainier periods, and the highest at the end of summer and in droughty periods.

As to its components, the grass crop, with 91.89 and 91.54% dry matter taken respectively into account, was characterized by 10.98–8.88% crude protein, 36.37–27.89% raw fibre, 15.76–9.57% ash and 1.8–0.45% CaO from the first and second growth of 1981. However, this was due not to the sown species of *Trifolium repens* f. *giganteum* but to the 98% cover of other, mainly grass species; even then these figures differ from the literature data (SZABÓ 1977).

(2) *Green canary-grass (Typhoides arundinacea) stand*

In the first two years after sowing, the cover of green canary-grass was 90%, and from the third year on 95%. In the first growth of 1978 the number of associated species was two, while in the last growth of 1981 seventeen, of

which ten were papilionaceous species, ten grass species, and six were mostly weed species belonging to various other families. Constant species were: *Festuca arundinacea*, *Lotus corniculatus* (62.5%), *Cirsium arvense*, *Reseda lutea*, *Taraxacum officinale;* subconstant species were: *Dactylis glomerata*, *Agropyron repens.* The number of accidental species was five, their cover hardly reaching 2%. A comparison of the lists of species registered in the first growth of 1978 and last growth of 1981, on the basis of *Jaccard*'s (0.16) and *Sorensen*'s similarity indices, reveals that a number of species, mainly the annual weeds, continually grew; but their total cover hardly reached 2–3%. Consequently, in a year the green canary-grass with a dominant character and a cover of 95%, formed a grass stand of lasing structure.

The grass stand already attained in the second year the grass yield of fertilized sown grasses (34.6 t/ha fresh crop, 8.3 t/ha dry matter), to reach a maximum of (46 t/ha fresh crop and 10 t/ha dry matter) in 1980. The spring drought in 1981 reduced the grass yield to half of that in the previous year. The average yield over four years was 30 t/ha fresh crop, and 7 t/ha dry matter. In the first three years of the experiment, the grass yield of the first growth was always larger than that of the second growth; while in 1981, owing to drought at the beginning of the vegetation period, the reverse was true (Table 3).

The grass stand steadily increased its root volume from an average 10 t/ha dry matter in 1978 to a 42 t/ha average in 1981. A particularly intensive root growth was observed with the first growth of the year 1981 (54 t/ha dry matter); the grass stand responded to the lasting nutrient and water deficiency with increased root growth. A large proportion (72–85%) of the roots was concentrated in the uppermost 10 cm layer of the soil, with a characteristic seasonal and yearly fluctuation depending on the weather conditions.

The weight ratio of the aboveground and underground phytomasses mainly reflected the nutrient and water supply in the vegetation period. It was characteristic of mesofrequent and xero-mesofrequent site conditions, respectively, being 1 : 5 under favourable conditions, and 1 : 8, 1 : 11 at the end of summer or in droughty periods.

As to its components, the grass yield, with 91.51–91.69% dry matter per growth taken into account, was characterized by 9.66–9.07% crude protein, 36.9–27.4% raw fibre, 9.38–6.98% ash and 11.6–0.65% CaO (1981 data), though these figures differ from the literature data (SZABÓ 1977).

(3) *Bird's-foot trefoil (Lotus corniculatus) stand*

Bird's-foot trefoil had a40% cover for three and a half years after sowing. In the second growth of 1981 its cover was reduced to 25%. The total cover of Hungarian brom grass *(Bromus inermis)*, blue grass *(Poa pratensis)*, green canary-grass *(Typhoiedes arundinacea)*, tall fescue *(Festuca arundina-*

cea), which from the second year settled in the stand beside the sown species, reached 50–60%. Among these species the Hungarian brome grass showed the most vigorous development: by the end of 1981 its cover reached 40%. In 1978 the number of associated species in the first growth was five; this number rose to twenty-seven in the second growth of 1981 (similarity index: 1.22 by JACCARD and 0.36 by SORENSEN), of which thirteen were grass, two papilionaceous species, and twelve species belonged to various other families. Constant species were: *Trifolium repens*, *Lolium perenne*, *Festuca arundinacea*, *Dactylis glomerata*, *Reseda lutea;* subconstant species were: *Bromus inermis*, *Typhoides arundinacea*, *Poa pratensis*, *Bromus sterilis*, *Agropyron repens*, *Festuca pratensis*, *Amaranthus retroflexus*, *Capsella bursa-pastoris*, *Taraxacum officinale*. The total cover of accidental species hardly reached 3–5%. To sum it up, the bird's-foot trefoil maintained its individual number over four years; but, with the large number of perennial grass species settled beside the sown species, the stand became similar to one sown with a multi-component grass mixture, which essentially influenced the quantity and quality of yield.

Even in the first year, the grass yield exceeded the average yield of fertilized bird's-foot trefoil stands (4.3 t/ha dry matter), and increased from year to year to reach 8.4 t/ha dry matter in 1980. However, in 1981, it decreased by 40% compared to the previous year's yield, owing to the lasting drought in spring. The average yield of the four years was 23.44 t/ha fresh crop and 6 t/ha dry matter, some 60% of which come from species, mostly grasses, settled in the stand (Table 3).

The root volume of the stand showed a steady annual average increase over four years. The trend of water supply in 1980 and 1981 was reflected not only in the ratio of fresh to dry root weight, but also in the vertical distribution of the root-system. The root weight was the largest at the end of summer or in droughty periods, and it was also then that the distribution of the root-system in deeper soil layers was more expressed. The trend of the root weight was determined to 60–70% by the roots of the adventitious perennial grass species: that is, it mostly reflected the seasonal dynamics characteristic of the root weight of grasses (Table 4).

The weight ratio of surface-soil to underground phytomasses (on dry matter basis) reflected mesofrequent (1 : 2, 1 : 3) site conditions in the case of a favourable nutrient and water supply, while in drought periods it was characteristic of xero-mesofrequent site conditions (1 : 5, 1 : 8), with typical seasonal dynamics. In the last two years of the experiment, this weight ratio was modified by the grass species settled in the stand, and became similar to that of grasslands sown with grass mixtures.

In the first and second growth of 1981, the values of components were determined by the bird's-foot trefoil with its 25% and by the grass species

with their 70% cover. With the 91.51–91.69% dry matter taken for basis, crude protein was 8.59–16.52%, raw fibre 43.45–31.47%, ash 7.20–7.23% and CaO 0.73–0.91% compared to 12.26% crude protein, 27.17% raw fibre, 9.34% ash and 1.16% CaO in the second growth of 1978. A comparison of the two data series also proves the floristical transformation of the stand, and the negative effect of the drought year.

(4) *Hungarian brome grass (Bromus inermis) stand*

In the first two years after sowing, the Hungarian brome grass showed a 75% cover, and subsequently formed an almost pure weedless stand with a cover of 90–100%, in which the proportion of species settled in hardly reached 2–3%. Beside the Hungarian brome grass which maintained its dominant character throughout the experiment, twenty-seven other species settled in the stand; seven of them were grasses, three papilionaceous plants and twelve were species belonging to various other families. In the first growth of 1978 five, in the second growth of 1981 twenty-two alien species were found, though in very low individual numbers (similarity index: 0.26 by JACCARD and 0.41 by SORENSEN). Constant species were: *Agropyron repens*, *Lolium perenne*, *Trifolium repens*, *Taraxacum officinale*, *Reseda lutea*, *Achillea collina*, *Sonchus arvensis;* subconstant ones: *Bromus sterilis*, *Poa pratensis*, *Artemisia vulgaris*, *Convolvulus arvensis*. Most of the accidental species were segetary weeds. To summarize, in two years the Hungarian brome grass developed a permanent closed stand in which the large number of species settled in only survived in very low individual numbers.

The grass yield, which exceeded the average grass yield of fertilized sown grasses already in the second year, increased for three years. The maximum yield was 36.6 t/ha of fresh crop and 9 t/ha of dry matter in 1980. The average yield over four years was 24 t/ha fresh crop and 6.37 t/ha dry matter (Table 3).

In the first three years, the volume of roots steadily grew and showed seasonal dynamics characteristic of the root weight of grasses; namely, under the influence of a favourable nutrient and water supply the root weight is the largest at the time of flowering and decreases afterwards (RABOTNOV 1970, 1974, DEMIN 1966, 1970). A change in the above phenomenon was caused by the insufficient precipitation at the end of summer in 1980 and in the spring of 1981. The grass stand responded to the nutrient and water deficiencies with an increase in the volume of the root-system and with its penetration in to deeper layers (Table 4).

The weight ratio of surface soil to underground phytomasses was characteristic of mesofrequent site conditions and flora (1 : 3) in the case of favourable nutrient and water supply, generally in the first growths, and reflected xero-mesofrequent (1 : 5. 1 : 13) conditions at the end of summer or in drought

periods. The year 1981, when this ratio for the two growths was inverse, being higher in the first and lower in the second growth, was exceptional.

The components of the first and second growths in 1981 also followed the same trend. With a dry matter content of 91.48–91.38%, the crude protein content was 8.62–10.77%, the raw fibre 43.54–30.54%, the ash content 7.16–8.11% and the CaO 0.42–0.91%. Thus, as a result of unfavourable nutrient and water supplies, the amounts of crude protein, ash and CaO were smaller and the raw fibre content higher in the first growth, though these values too differ from the literature data (SZABÓ 1977).

(5) *Tall fescue (Festuca arundinacea) grass stand*

During the four years of the experiment the cover of tall fescue ranged from 90 to 100%. The species rapidly developed a closed stand: therefore, the number of species settled in the stand was substantially smaller than in the other stands. The cover of plants of these species hardly reached 1–2%. Beside the tall fescue, which maintained its dominance throughout the experiment, in the first growth of 1978 seven, and in the second growth of 1981 eighteen alien species were found (similarity index: 0.35 by JACCARD and 0.52 by SORENSEN), of which ten were grasses, one was a papilionaceous plant and seven were species belonging to various other families. The constant species of the grass stand were: *Poa pratensis*, *Lolium perenne*, *Agropyron repens*, *Festuca sulcata*, *Achillea collina*, *Amaranthus retroflexus*, *Reseda lutea*, *Convolvulus arvensis;* subconstant species was the *Arrhenatherum elatius*. The accidental species, like the other species settled in, came from the neighbouring plots or from weed associations. To sum it up, owing to its "aggressive" character, the tall fescue formed a grass stand of stable population composition as early as in the year of sowing and the associated species mostly were grasses representing a proportion of 1–2%.

The grass yield of the stand attained the yield level of fertilized, unirrigated sown grasses in the second year, and reached its maximum in 1980 (10.6 t/ha dry matter). In consequence of drought weather in 1981 the grass yield fell to 36% of that in the previous year. The average grass yield oven four years was 25.2 t/ha fresh crop and 6.38 t/ha dry matter (Table 3).

The volume of roots in the grass stand increased steadily in the four years, and gave quick response to temporary nutrient and water deficiencies. It fell to its minimum (11.9 t/ha dry matter) in the rainy summer of 1980 and reached its maximum (49.46 t/ha dry matter) in the drought period of 1981. In this case again, the nutrient and water deficiency determined the vertical growth of the root-system (Table 4).

The weight ratio of surfarce soil to underground phytomasses reflected the seasonal changes and effect of nutrient and water supply most clearly in this grass stand. This ratio was 1 : 3, 1 : 4 in rainy periods, and 1 : 30, 1 : 40

in dry weather at the end of summer or at the time of drought, due to the dominant adaptive character of this mesophilous species. It was the only species sown in our experiment which, in the rainier weather of late summer, further increased its large volume of root developed at the time of the spring drought by nearly 18 t/ha on dry matter basis (Table 4).

The components of the two growths in 1981, as referred to 91.48–91.38% dry matter, were 8.62–10.77% crude protein, 43.54–30.54% raw fibre, 7.16–8.11% ash and 0.42–0.91% CaO. That is, the deficiency of water caused, as is commonly known, a decrease in the crude protein, ash and CaO content and an increase in the amount of raw fibre. These values again are different from the literature data (SZABÓ 1977).

(6) *Dactylis (Dactylis glomerata) grass stand*

Dactylis formed a closed stand of 90% cover in the early years of sowing. In the third and fourth year of the experiment this cover grew to 98%. Other plants settled in the stand reached a total cover of merely 1–2%, in spite of their large species number. In the first growth of 1978, one alien species was found. In the last growth of 1981 there were twenty, of which ten were grass species, one was a papilionaceous plant, and nine were species belonging to other families (similarity index: 0.09 by JACCARD and 0.17 by SORENSEN). Constant species of the stand were: *Taraxacum officinale, Reseda lutea;* subconstant species were: *Echinochloa crus-galli, Capsella bursa-pastoris, Daucus carota, Erigeron canadensis.* To summarize, fertilization resulted in a closed, quickly regenerating stand of *Dactylis*, in which other, mainly annual weed species could only settle in very small individual numbers.

The grass yield steadily increased for three years to reach its maximum (7.8 t/ha dry matter) in the third year after sowing. In the droughty year of 1981, the grass yield decreased to nearly half of that in the previous year, which partly can be explained by the ecological character of this species of high nutrient and medium water demand. The average grass yield over four years was 22.56 t/ha fresh crop and 5.56 t/ha dry matter, attaining the yield level of unirrigated sown grasses (Table 3).

The root volume of this typically mesofrequent species with its highly varied numerical values truly reflected the seasonal changes in the nutrient and water supply. Maximum root weight was measured at the end of summer, in the second growth, and in the drought period; it was the highest among the species studied, due partly to the specific ecological character of the species (Table 4).

The weight ratio of surface soil to underground phytomasses similarly showed the seasonal fluctuation of nutrient and water supply. Under favourable conditions, generally in the first growths, this ratio was 1 : 4, 1 : 5, while under unfavourable conditions it was 1 : 15, 1 : 29. That is, this typical meso-

philous species counterbalanced the temporary nutrient and water deficiencies by developing a larger volume of roots.

In 1981 the components of the two growths, with a dry matter content of 92.08–91.57%, were: 8.5 and 10.95% crude protein, 44.6 and 30.12% raw fibre, 7.12 and 8.42% ash and 0.39 and 0.99% CaO, respectively, though these values again are different from the literature data (SZABÓ 1977).

(7) *Meadow fescue (Festuca pratensis) grass stand*

The meadow fescue only formed a closed stand in the third year after sowing. Its cover was 80% in the first two years; and, after reaching a 95% cover in the third year, it began to thin out. Of the species settling beside and in the place of the sown species, *Poa pratensis angustifolia* continuously increased its individual number from the second year on, attaining a cover of 15% in the fourth year. In the first growth of 1978 two, in the last growth of 1981 twenty-two adventive species were found (similarity index: 0.13 by JACCARD and 0.23 by SORENSEN), of which ten were grasses, one was a papilionaceous plant, and eleven were species belonging to other families; their total cover was 20%. Constant species of the grass stand were: *Echinochloa crus-galli*, *Achillea collina*, *Cichorium intybus*, *Reseda lutea*; subconstant species were: *Poa pratensis angustifolia*, *Bromus inermis*, *Festuca sulcata*, *Poa pratensis latifolia*, *Lolium perenne*, *Setaria lutescens*. A large proportion of the accidental species were weeds and their total cover hardly reached 1%. To sum up, mostly perennial grasses of high feed value settled after three years beside the thinned meadow fescue, while the share of weeds in the strict sense of the word was negligible.

The grass yield of the stand steadily increased for three years and reached its maximum (8.6 t/ha dry matter) in the third year after sowing. In the drought year of 1981 it was nearly equal to that obtained in the year of sowing (3–3.7 t/ha dry matter). The average grass yield over four years was 21 t/ha fresh crop and 5.48 t/ha dry matter, attaining the yield level of fertilized sown grasses (Table 3).

The volume of roots continuously increased through three years, from 12 to 22 t/ha (on matter basis). Then, in the drought year of 1981, this typically mesophilous species produced an essentially lower root volume than did the other species, owing to the deficient nutrient and water supply, with seasonal and vertical dynamics similar to that of the other species (Table 4).

The weight ratio of aboveground to underground phytomasses was characteristic of mesofrequent site conditions and flora (1 : 2, 1 : 4) when the nutrient and water supply was favourable and particularly in the first growths. In the late summer growths and in drought periods it reflected xero-mesofrequent conditions (1 : 7. 1 : 9). Numerically the weight ratio here was more balanced than in the other stands.

The values of components in the growths of 1981 were 8–12 and 10.27% crude protein, 42.59 and 30.17% raw fibre, 8.08 and 8.10% ash and 0.38 and 0.89% CaO, with 91.39 and 91.32% dry matter contents, respectively.

Summary

As for the cenological trends of the sown grasses, it can be established that with the given soil and climatic conditions and fertilizer doses *Festuca arundinacea*, *Dactylis glomerata*, *Typhoides arundinacea* and *Bromus inermis* in one to two years formed stable, closed stands in which the sown species had a 90–100% cover. The extent of weediness was the lowest in these stands due not only to the site conditions but also to the aggressive nature of these species. Under similar ecological and cultivation conditions these four species can be profitably grown on a large scale. *Festuca pratensis*, while increasing its cover from 80 to 95% in three years, began thinning in the drought year of 1981, and its cover fellback to 80%, with a parallel increase in the extent of weed growth. *Lotus corniculatus* was unable to form a pure closed stand; its 40% cover, maintained over three years, decreased to 25% in the drought 1981 year. Under similar ecological and cultivation conditions, one may suggest that it be sown as a component of grass mixtures, so that its high associative and adaptive qualities will be fully displayed. The *Trifolium repens* f. *giganteum* was able to maintain its stand for only two years. In our case, it died out of frost damage. It is not reasonably grown by itself without irrigation. Under irrigated and fertilized conditions, without severe frosts, it even lasted for seven years, preserving its weedless stand in a grass experiment in the neighbourhood of Szarvas (Kovács 1983).

Under the given soil- and climatic conditions and with the given treatments (NPK = 240 : 100 : 100 kg/ha active ingredient) the largest grass yield (30 t/ha fresh crop, 7 t/ha dry matter) was obtained with the *Typhoides arundinacea* stand, an average equal to other results recorded in Hungary. As to the other species, the surplus grass yield compared to other results in Hungary was 100% with *Trifolium repens* f. *giganteum*, 230% with *Lotus corniculatus*, 157% with *Festuca arundinacea*, 150% with *Bromus inermis*, 125% with *Dactylis glomerata* and 116% with *Festuca pratensis* (Szabó 1977). The surplus yield was determined by the given ecotype, the fertilization and the agroecological potential of the sown species. In the case of *Lotus corniculatus* and *Trifolium repens* f. *giganteum*, the grass yield came from the species, mainly perennial grasses, that settled beside or in the place of the sown species, rather than from the sown species itself. Of the growths, the first one always produced the largest grass yield, except in the drought year of 1981 when it was the reverse occurred, in accordance with the two occasions of cutting a year, the time of cutting, and the biological character and regenerative ability of the sown species. In comparison to the optimum year of 1980, the loss of yield vaused by the drought in 1981 was 83% with *Trifolium repens* f. *giganteum*, 73% with *Typhoides arundinacea*, 64% with *Lotus corniculatus*, 58% with *Bromus inermis*, 50% with *Dactylis glomerata*, 43% with *Festuca pratensis* and 26% with *Festuca arundinacea* on a dry matter basis; but here, the age and floristic stability or degradation of the stands, and the different drought tolerance of the species, must also be taken into consideration.

For the increase of grass yield in response to fertilization it was found that under the given soil- and climatic conditions the NPK dose applied resulted in a surplus grass crop of 26 t/ha with *Trifolium repens* f. *giganteum*, 18 t/ha with *Typhoides arundinacea*, 26.6 t/ha with *Lotus corniculatus*, 17 t/ha with *Bromus inermis*, 25 t/ha with *Festuca arundinacea*, 1974, 1977, Nagy 1977), which more or less agrees with the statement that 1 kg N active ingredient yields 100 kg surplus green crop (Barcsák and Kertész 1980).

Among the grass stands studied the highest average annual root weight (on dry matter basis) was measured in *Festuca arundinacea* (26.45 t/ha), *Dactylis glomerata* (24.94 t/ha), *Typhoides arundinacea* (21.32 t/ha); and the lowest one in *Trifolium repens* f. *giganteum* (7.48 t/ha), *Lotus corniculatus* (10.26 t/ha), *Bromus inermis* (12.4 t/ha) and *Festuca pratensis* (15.33 t/ha). According to some authors, the NPK considerably increases the root weight and decreases its seasonal dynamics (Demin 1972), while others are of the opinion that it reduces the weight of roots (Spiedel 1976). We found that the grasses produced almost in every case the largest volume of roots at the time of flowering, as well as at the end of summer and in the drought periods; while, with a better nutrient and water supply, the root weight always decreased as a function of the plant parts both above and underground (Kovács 1979, 1982a, b, 1983).

As for the dry matter content of roots, on the four year average it was 30% for *Typhoides arundinacea*, *Festuca pratensis* and *Dactylis glomerata*, 27% for *Festuca arundinacea*, 20% for *Bromus inermis*, 24% for *Trifolium repens* f. *giganteum*, and 22% for *Lotus corniculatus*. This ratio of dry matter to water was higher in the first and lower in the second growth.

As to the vertical distribution of the root system, we found that the mass of roots (82–92%) in *Bromus inermis*, *Festuca pratensis* and *Dactylis glomerata* was permanently concentrated in the 0–10 cm layer of the soil, while that of *Typhoides arundinacea* remained on the average unchanged (74%). The roots of the two papilionaceous stands, with the floristic transformation of the stand, showed a seasonal dynamics and vertical distribution characteristic of the root systems of grass species. The vertical distribution and dynamics of the root-system is, besides the specific character, greatly influenced by the nutrient and water supply. With a deficient water supply, the root system in each case increased its spreading to deeper layers parallel to its concentration in the upper 0–10 cm soil layer, where the lack of water was to some extent counterbalanced by the nutrients (mineralized root + fertilizer), as proved by the relevant results of several authors (PLEWECZYNSKA-KURAS 1976, BELKIN 1977).

The total phytomass (surface soil plant parts) of the four years showed the following trend in fresh and dry weight: *Festuca arundinacea* 123 — 33 t/ha, *Dactylis glomerata* 109 — 30.5 t/ha, *Typhoides arundinacea* 101 — 28.3 t/ha, *Bromus inermis* 87 — 19 t/ha, *Festuca pratensis* 84.5 — 21 t/ha, *Lotus corniculatus* 70 — 16 t/ha, *Trifolium repens* f. *giganteum* 55 — 13 t/ha; the above order of succession at the given site expresses on the whole the water demand and drought tolerance of the individual sown species and grass stands.

The ratio of surface soil to underground phytomasses was determined, besides the specific character, by the NPK dose, the soil conditions and the water supply. NPK fertilization generally decreased the ratio of the two (SPIEDEL 1976, DEMIN 1970, PAWLAT 1977, TOLWINSKA 1977). In the case of favourable nutrient and water supply this weight ratio indicated mesofrequent site conditions (1 : 2, 1 : 5), generally with the first growth, while at the end of summer or in drought periods reflected xero-mesofrequent conditions (1 : 8, 1 : 30) in the second growth.

The values of components in the growths of the examined grass stands differ from the data known from the literature. The above data are characteristic of drought cropyeass, when the crude protein content decreases and the amount of raw fibre increases, mainly because of changes in the biological development of the plants.

The results of our grass experiment may be useful first of all for large-scale grassland management and livestock farming systems when planning and establishing grasses, sown with a single species in grass mixture, in hill countries. On alkali and sandy soils of lowlands, these sown grasses can produce similar crop results only under irrigated conditions and with adequate amelioration. With a knowledge of the volume of roots and their components, optimum nutrient balance can be prepared concerning the fertilization and nutrient replacement of the grass stands. The large root volume, which develops relatively fast and becomes continuously humified and mineralized in the soil, can be successfully used for improving low productivity soils, and is excellently utilizable in rotation systems of grass and cereal.

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FLOWER-BUD ORGANIZATION IN APPLE VARIETIES

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The periodical fruiting of apple orchards makes it difficult to fulfil production tasks; in years with large yields the smooth marketing of the fruit produced causes problems.

A knowledge of flower-bud formation in fruit trees is a basic factor in up-to-date yield control and is thus important for growers.

The date of formation and the course of development of flower-buds, the quantity of buds and the factors affecting them must be known if various cultural practices are to be carried out in time to ensure uniform and regular yields from year to year.

Introduction

Studies on the factors affecting flower-bud formation in fruit trees have been carried out for more than a hundred years. Important works on the subject have been published by several foreign authors, e.g. RO (1929), KOBEL (1954), KARPOV (1955), KOLOMIEC (1976), VASILCOVA (1959), ZELLER (1955–1961), NEUMANN (1962), FEUCHT (1968), LUCKWILL (1974), BLASSE (1980) and FERRARI (1982).

In Hungary GYURÓ (1959) put the date of flower-bud differentiation in apple trees between 15 and 25 July for the most widely grown varieties.

BUBÁN (1976) studied the flower-bud differentiation of apple varieties with histological, histochemical and biochemical methods over several years. He suggests two methods for increasing the bearing organs of apples: either by reducing the number of fruit primordia in years with a high fruit setting rate or by counterbalancing the inhibitory effect on flower formation of growth substances produced by the seed primordia.

LALATTA, MARRO and SANSAVINI (1978) attempted to discover what factors influenced the formation of flower-buds besides genetic properties.

BLASSE (1980) pointed out that the central flowers within the inflorescence are in a physiologically favourable position and therefore give a higher proportion of fruit setting than the lateral flowers, which are in a physiologically disadvantageous position.

According to BLASSE (1978) *Malus floribunda* types are suitable pollen donors for cultivated apple varieties since they begin blossoming simulta-

neously with the most important apple varieties, and blossom over a relatively long period.

FERRARI (1982) is of the opinion that the microscopic examination of flower-buds will become just as integral a part of fruit production as leaf and soil analyses.

The use of *Malus* species as pollen donors has been studied for 15 years. *Malus floribunda* was first recommended as a pollen donor in England in 1964, for the varieties Scarlet Pimper and Cox orange renet. Similar investigations have been made in Holland since 1971, in France since 1976 and in the German Democratic Republic since 1977.

In Hungary the elaboration of a *Malus* pollination system started in 1977; related studies on flower-bud differentiation have been carried out since 1980.

A major objective of the research was to determine the date of formation and course of development of flower-buds with morphological methods for the apple varieties grown on farms, in the hope of providing useful information for apple growers.

Material and methods

The examination of the buds was started in 1960 on Jonathan trees with medium high trunks and so-called "branch-group" crowns grafted on to wild stocks. After the introduction of intensive crown forms, the examinations continued on Jonathan, Starking 'Golden Delicious and Starkrimson Delicious varieties on various rootstooks (M9, M4, wild stock and own-rooted).

In 1980 flower-bud studies were begun on various *Malus* species, similar to those performed on the cultivated varieties. Of the factors influencing the development of flower-buds, attention was paid to the root-stock, growing site, yield, irrigation and meteorological factors, and a relationship was sought between the major phenophases (bud-bursting, blossoming, fruit drop, fruit ripening) and the organization of the flower-buds.

From each of the designated trees 15 short bearing parts were collected every week from June to October, and very two or three weeks from October to the end of December. In the course of microscopic examinations every bud was qualified according to its stage of development, then described and microphotographed.

Results

Taking into consideration the development of the individual flower organs, eight development phases can be distinguished in apple.

Phases of flower-bud organization in apple

Phase 0. The vegetative growth tip is flat and spreading (Fig. 1).

Phase 1. The base of the bud widens; the vegetative tip rises above the level of leaf primordia. This protrusion is the first flower primordium (Fig. 2).

Phase 2. In the course of flower-bud differentiation the central part continues to rise; this is the medium flower primordium (Fig. 3).

Phase 3. After the appearance of the flower primordium the five sepal primordia become visible (Fig. 4).

Phase 4. The protuberances of the lateral flowers appear, the flowers separate (Fig. 5).

Phase 5. The primordia of the petals appear (Fig. 6).

Phase 6. Differentiation of the outer circle of stamina; in the outermost circle 10 stamina develop (Fig. 7).

Phase 7. The stamina appear in three circles. Opposite to each petal 5 stamina develop in each of the two outer circles in a chess-board pattern (Fig. 8).

Phase 8. Differentiation of carpel primordia (Fig. 9).

Flower primordia formed in the above order of succession enter deep dormancy somewhere around the end of October depending on the weather. In spring development is resumed.

For apple flower-buds the sequence of development within the inflorescence is as follow: first the organs of the central flower primordium develop followed by the lateral flower primordia.

The morphological bud differentiation in apple varieties starts between the beginning of July and the first ten days of August depending on the ecological factors and on the cultural practices applied.

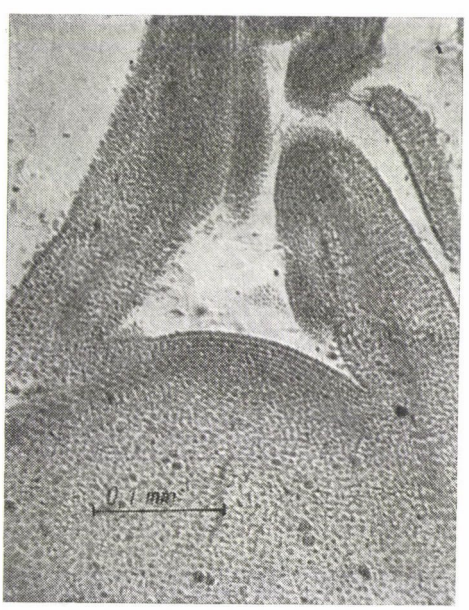

Fig. 1. Vertical section of the vegetative bud

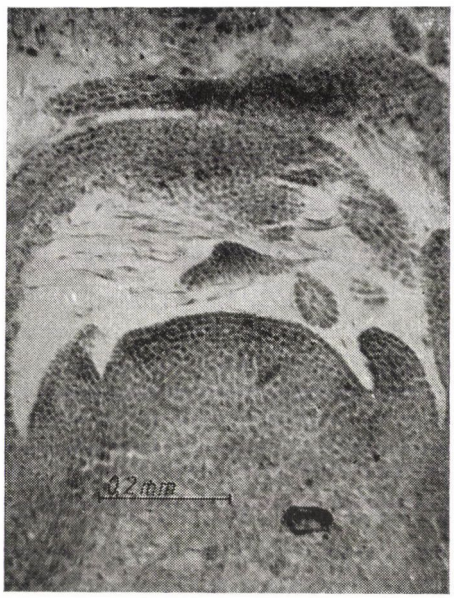

Fig. 2. Appearance of flower primordium

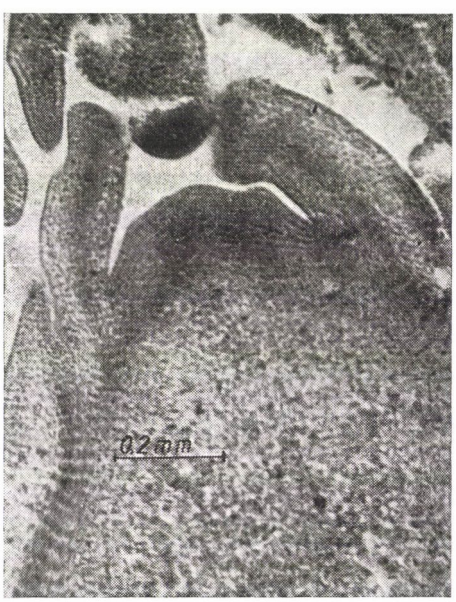

Fig. 3. The first (middle) flower primordium

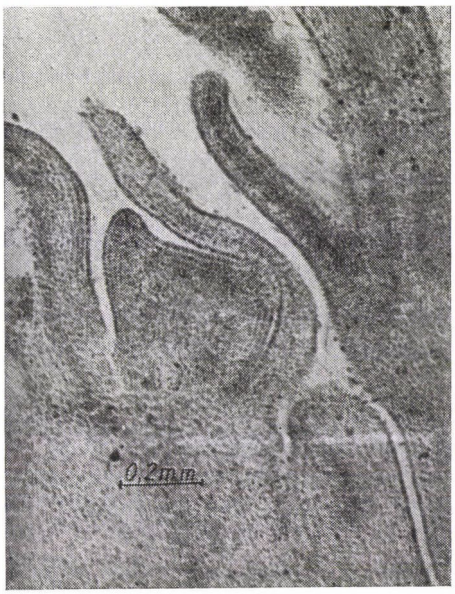

Fig. 4. Differentiation of the sepal primordia

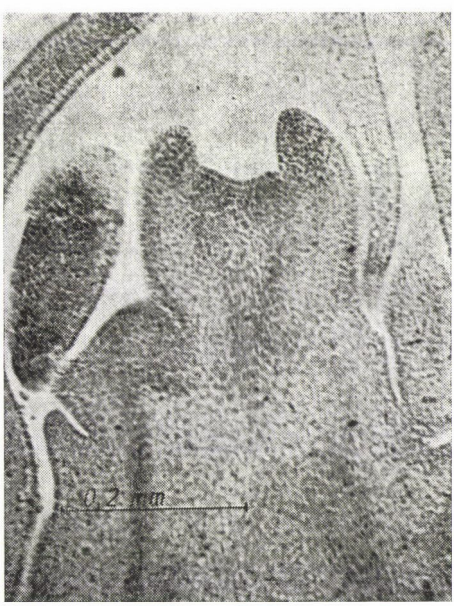

Fig. 5. The protuberances of the lateral flowers appear

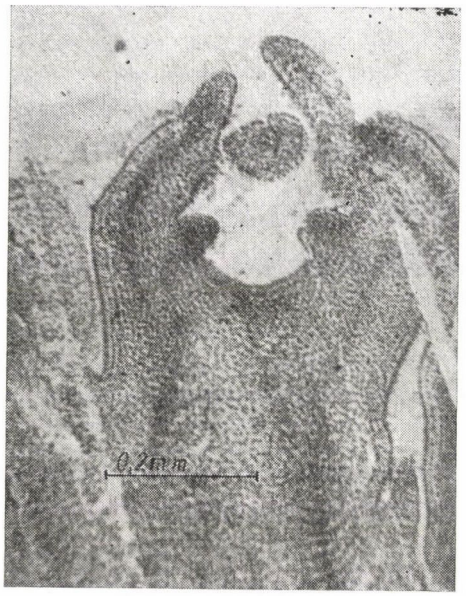

Fig. 6. Appearance of the five sepal primordia

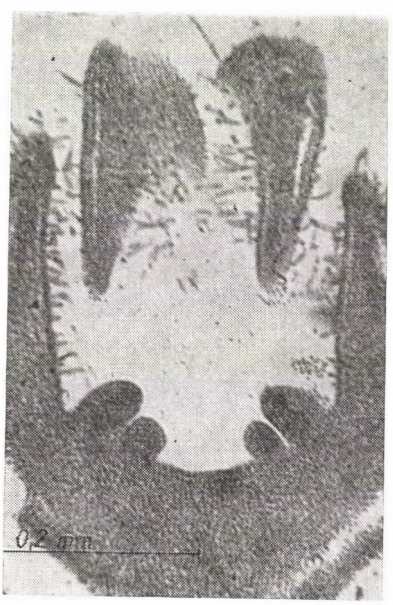

Fig. 7. Differentiation of the outer circle of stamina

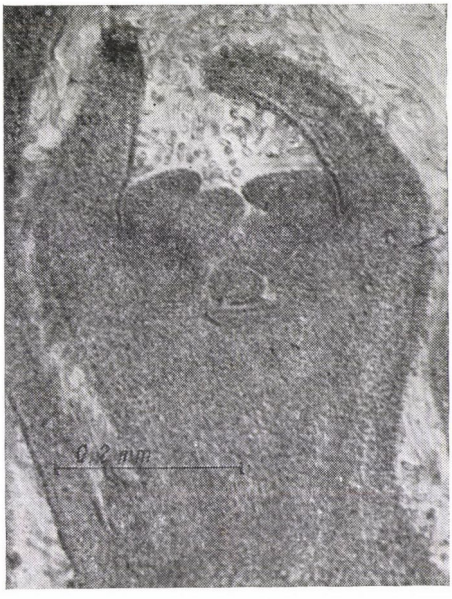

Fig. 8. The stamina appear in three circles

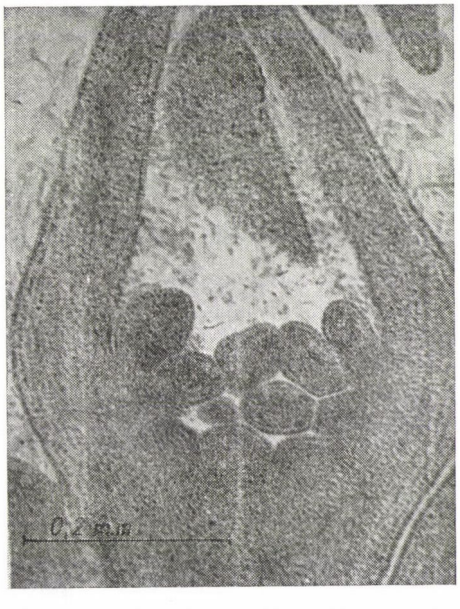

Fig. 9. Differentiation of carpel primordia

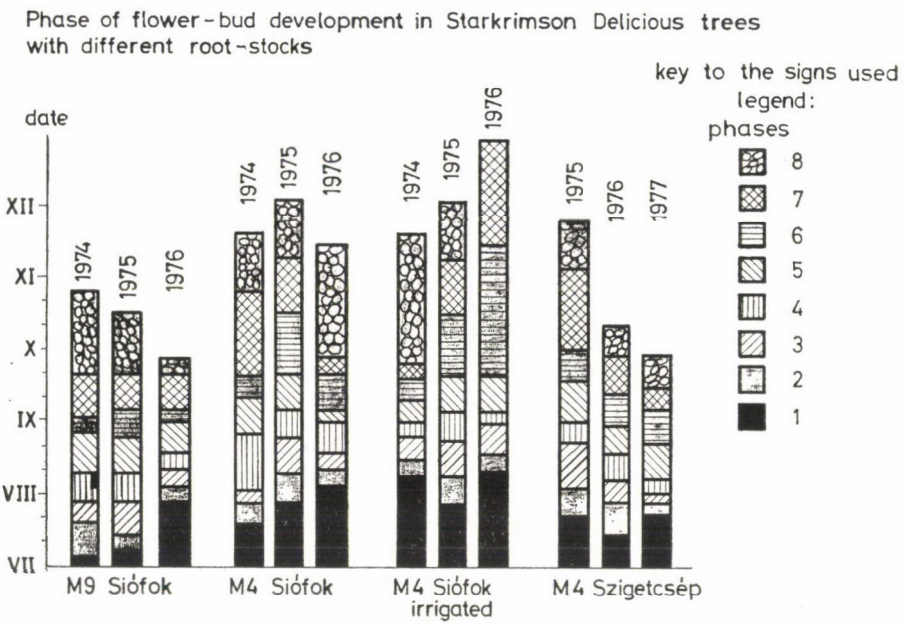

Fig. 10. Phase of flower bud development in Starkrimson Delicious trees on different root-stockes

Histological analysis is able to demonstrate flower-bud primordia 10–14 days earlier than morphological examinations. The beginning of differentiation usually coincides with the natural fruit drop, then by the time ripening begins the different flower organs also take shape.

On the short bearing parts differentiation starts about 3 weeks earlier than in buds developing on one-year old shoots. In buds from short bearing parts even the pistil primordia appear during the first ten days of October and become fully developed by the middle of December. In buds from one-year-old shoots only a part of the stamina are formed before the dormancy period. This is of great importance from the point of view of production, because in the case of unfavourable weather the buds are not uniformly damaged. In trees with root-stock of poor growth, the growth of the shoots is completed earlier; therefore the differentiation of the buds also begins earlier; e.g. in the orchard of the Siófok State Farm the first phase of differentiation in the variety Starkrimson Delicious was observed in the 1974–1975 season 19 days earlier on M9 root-stocks than when the root-stock was M4. In the case of the same root-stocks there was no essential difference between the Szigetcsép and Siófok sites as regards the beginning of differentiation. In the development of the flower organs (the length of the phases) the difference was substantial (Fig. 10).

The volume of yield has an effect on the development of flower-buds. When there are a large number of apples on the trees the differentiation of the flower buds is delayed, and the development of the individual flower organs is protracted.

Under the influence of irrigation in dry weather differentiation begins later, and the rate of development is slower than without irrigation. However, the flower primordia in the flower-buds showed uniform development and flowers of full value were formed.

The *Malus* species (types) were examined for morphological differences in the development of the generative organs. For the evolution of the flower-buds 8 development phases were observed similar to those in the cultivated varieties. Wide variation was found in the date of flower-bud formation.

Even the rate of development of the different flower parts varies. There are *Malus* types, e.g. M-8-SBK-TA, *Malus baccata*, in which either the central or a lateral flower primordium was more developed than the others. In the very small spurs 6–7 flower primordia were found.

In the course of the examinations alternation was found to appear in some *Malus* species, e.g. M-1014-SBT-TA-*Malus dasyphyllapumila*. Such types are not suitable for pollinating the cultivated varieties.

Summary

The formation and course of development of the flower-buds at cultivated apple varieties grown in commercial orchards were studied using morphological methods.

Since 1980 various *Malus* species have also been examined for flower-bud organization, in the same way as for the cultivated varieties.

In the course of microscopic examinations every bud was qualified according to its stage of development.

Considering the development of the different flower organs eight development phases were distinguished.

The sequence of flower-bud formation within the apple inflorescence is as follows: first the organs of the central flower primordium develop, followed by the lateral flower primordia. The morphological bud differentiation in apple varieties starts between the beginning of July and the first ten days of August depending on the ecological factors and the cultural practices applied. It generally coincides with the natural fruit drop, then by the time ripening begins the flower organs also take shape.

On short bearing parts flower buds are formed earlier than on one-year-old shoots. This is of great importance from the point of view of production because in the case of unfavourable weather conditions the buds are not uniformly damaged.

The date of flower-bud differentiation is influenced by the root-stock; in trees with root-stocks of poor growth the growth of the shoots stops earlier.

The date of formation and course of development of flower-buds are influenced by the growing site, though not to the same extent as by meteorological factors. The volume of yield affects flower-bud organization. If there are too many fruits on the tree the differentiation of the flower-buds is delayed and their development is protracted. In response to irrigation a larger number of flowers of full value develop.

For the *Malus* species (types) it can be established that they show variation concerning the development of the bud. Some of them display a tendency to periodicity and are therefore unsuitable as pollen donors in purebred plantations.

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VEGETATIVE CHARACTERS IN TOMATO

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A diallel experiment composed of 11 parental lines and a set of their F_1 was carried out. The resultant families were grown in three randomized blocks in the field and under a non-heated polyethylene plastic cover. The characters studied were: internode length, number of leaves between 2nd and 3rd clusters, number of leaves between 3rd and 4th clusters, and length between clusters. *Griffing*'s analysis detected significant differences for all the characters, both among parental lines and between general and specific combining abilities. Partial dominance was found for all the characters, although the importance of such dominance varied with each of the characters. The number of leaves between the 2nd and 3rd clusters and between the 3rd and 4th ones, seems to be ruled by the same genetic system, but does not show common environmental influences. The length between clusters was correlated to the number of leaves between clusters rather than to the internode length, the latter being highly influenced by the environment. The internode length was independent of the number of leaves between clusters. The determinate growth habit has shown association neither with the internode length nor with the number of leaves between clusters. These vegetative characters present little or no correlation with production, earliness, number of fruits, fruit weight and fruit cracking.

Introduction

Vegetative characters of tomato have been studied much less than production factors due to their less direct economical implication. Nevertheless, the requirements of modern cultivation methods, compel us to becoming acquainted with the genetic systems that rule plant height or the characters into which it can be broken down. Plant height has been studied by KHANNA and CHAUDHARY (1974), internode length by LAPUSHNER et al. (1973), and number of leaves between clusters by DASKALOFF et al. (1975), among others. In this work, the interrelated characters such as internode length, number of leaves between clusters and length between clusters have been studied, with some aspects related to production.

The possible environmental influence and the genotype-environment interaction were established by measuring the internode length under the conditions of both field and polyethylene plastic-house cultivation.

Material and methods

A diallel cross without reciprocals was made with 11 lines obtained by self-fertilizaton from 11 cultivars (Table 1). This cross type, instead of a complete diallel, was used, as in the bibliography (KHANNA and CHAUDHARY 1974, CUARTERO 1976) there do not appear important reciprocal effects, and this procedure permitted investigation of almost the double of parentals for the same number of studied genotypes. The hybrids and parents were grown in three

Table 1

Cultivars, origin and characteristics

No	Cultivar	Origin	Growth habit	Generations of selfing
1	Valenciana	Spain	indeterminate	5
2	Piervil	France	indeterminate	2
3	Ace	USA	determinate	2
4	Marglobe	USA	indeterminate	3
5	Manalucie	USA	indeterminate	3
6	Early pak	USA	determinate high	4
7	Muchamiel	Spain	indeterminate	4
8	Supersonic	USA	indeterminate	2
9	Floradel	USA	indeterminate	2
10	Harold 12088	USA	indeterminate	5
11	Red top	USA	determinate	2

randomized blocks, both in the field and under a non-heated polyethylene plastic cover. Under the plastic cover, the ground was gravelled and drip irrigation employed to distribute the fertilizer. In the field, cultivation took place on a ground with furrow irrigation. Data were taken for 8 plants for each genotype block and environment.

Two of the lines, 11 and 3, have the *sp* gene, but neither of them carries the *j* gene that could cause distortion of the characters discussed here (PHILOUZE 1978).

The characters measured were internode length (distance in cm between the 2nd and 4th clusters of each plant, divided by the number of internodes), number of leaves between the 2nd and 3rd clusters, number of leaves between the 3rd and 4th clusters and length between clusters (average internode length in cm between the 1st and 4th clusters under plastic cover and between the 2nd and 4th ones in the field). The reason for not measuring the same internodes in either case is that, under the plastic cover there is no soil cultivation after planting, while in the field, ridges are built along the plant rows which may cause a loss of leaves on the lower part of the plant (CUARTERO 1976). For the same reason, the number of leaves between the 1st and 2nd clusters was not studied. The first three characters were measured only for field conditions.

Data have been analysed following *Griffing*'s method (GRIFFING 1956). Genotypic and environmental correlations with other characters related to production were investigated

Results and discussion

Internode length

Differences among lines are highly significant, $F_{61.1078} = 5.04$. There is also an interaction of line $\times$ block, but no significance for block effects. Although the component for lines is remarkably superior to the interaction line $\times$ block,

Table 2

Variance analysis for combining ability (Griffing's method)

Source	DF	*il*[a]		1 2–3		1 3–4		*lc* (F)		*lc* (PH)	
		MS	K^2[b]	MS	K^2	MS	K^2	MS	K^2	MS	K^2
G.c.a.	10	0.491***	0.035	0.273***	0.020	0.633***	0.047	12.735***	0.904	19.250***	1.469
S.c.a.	55	0.074***	0.043	0.043***	0.034	0.097***	0.078	2.490***	1.502	2.883***	2.723
Error	122[c]	0.030		0.010		0.019		0.988		0.200	

[a] *il* = internode length; 1 2–3 and 1 3–4 = leaves between 2–3 and 3–4 clusters; *lc* (F) and *lc* (PH) = length between clusters in the field and in the plastic-house.
[b] Variance components.
[c] For *il* and *lc* (PH) the degrees of freedom of error are 1078 and 865 respectively.
*** $P < 0.001$.

Table 3

G.c.a. values estimated according to Griffing

Lines	*il*[a]	Lines	1 2–3	Lines	1 3–4	Lines	*lc* (F)	Lines	*lc* (PH)
6	0.203	4	0.133	7	0.198	2	0.914	7	1.600
3	0.171	7	0.131	4	0.194	9	0.867	1	1.472
9	0.145	1	0.120	2	0.190	5	0.590	9	0.527
10	0.117	5	0.109	1	0.170	4	0.545	2	0.293
2	0.097	2	0.083	5	0.145	1	0.467	5	0.248
5	—0.005	8	0.072	9	0.054	7	0.229	6	0.179
1	—0.011	9	0.029	8	0.046	10	0.205	8	0.001
4	—0.052	10	—0.052	10	—0.028	8	—0.101	10	—0.003
7	—0.071	3	—0.165	11	—0.275	3	—0.480	4	—0.073
8	—0.099	11	—0.218	3	—0.304	6	—0.676	3	—1.566
11	—0.495	6	—0.241	6	—0.388	11	—2.560	11	—2.678
$D(g_i)$	0.046		0.026		0.036		0.263		0.106
$D(g_i - g_j)$[b]	0.068		0.038		0.054		0.390		0.157

[a] *il* = internode length; 1 2–3 and 1 3–4 = leaves between 2nd–3rd and 3rd–4th cluster; *lc* (F) and *lc* (PH) = length between clusters in the field and in the plastic-house.
[b] Variances of g.c.a. and of differences between g.c.a. estimations.

Table 4

S.c.a. estimations for length

Lines	1	2	3	4	5
1	−0.050	−0.018	−0.162	−0.230	−0.277
2		−0.285	−0.265	—	−0.126
3			−0.226	−0.115	0.264
4				−0.032	−0.063
5					−0.259
6					
7					
8					
9					
10					
11					

$D(\hat{s}_{ii})^a = 0.147$ $D(\hat{s}_{ii} - \hat{s}_{jj}) = 0.205$ $D(\hat{s}_{ij} - \hat{s}_{K1}) = 0.227$

$D(\hat{s}_{ij}) = 0.162$ $D(\hat{s}_{ij} - \hat{s}_{IK}) = 0.237$

[a] Variances of SCA and of differences between s.c.a. estimations.

9 of the 11 parental lines show similar lengths, between 4.03 cm (line 5) and 4.47 cm (line 8); only lines 7 (3.69 cm) and 11 (2.92 cm), have shorter internode lengths. The genotypic variability for internode length is only 15.7% of the total phenotypic variability.

One remarkable fact is the lack of association between self-pruning habit and internode length: line 3, with self-pruning habit, had longer internodes than line 7 which does not have the *sp* gene. These results coincide with those of DASKALOFF et al. (1975), suggesting independence between *sp* and internode length.

Comparative analysis of parental lines with their hybrids, offers a result of 25 cases of heterosis towards a greater length (H^+), 9 with dominance in the same sense (D^+), 8 with intermediate inheritance (A) and 6 and 3 with dominance (D^-) and heterosis (H^-) for smaller length, respectively. DASKALOFF et al. (1975) found partial dominance. KHANNA and CHAUDHARY also detect dominance for indeterminate growth habit. LAPUSHNER et al. (1973) detected heterosis in crosses with low value parents, but not in those with parents having a great internode length. According to our experience, there is a clear preponderance of situations with heterosis or positive dominance, independent from the internode length in the parental lines. Only line 8 has showed anomalous behaviour, its ten hybrids being $2H^-$, $5D^-$, and $3A$.

Griffing's analysis of combining ability (Table 2) detects high significance both for general and specific combining ability (g.c.a. and s.c.a.). Moreover, both components are of similar quantity, which implies a great importance of the dominant variance in the variation structure. KALLOO et al. (1974) and SVANOSIO and VANDONI (1974) also stressed the importance of s.c.a. for the plant height. Nevertheless, the importance of additive variability should

between clusters (field)

6	7	8	9	10	11
—0.004	0.128	0.151	0.400	0.273	—0.162
0.290	0.425	—0.064	0.186	—0.084	0.147
0.471	—0.060	—0.151	0.051	—	—
0.196	0.338	—0.009	—0.083	—0.011	—0.037
0.262	—0.275	—0.010	0.023	0.201	—
—0.652	0.062	—0.078	—0.415	0.290	0.230
	—0.474	—0.094	0.287	0.246	—0.109
		0.363	—0.020	—0.256	—0.195
			—0.299	0.179	—0.008
				—0.313	—0.118
					—0.392

not be underestimated. The mean regression coefficient of the F_1 hybrids, in relationship to the average values for their parents, detects the relative importance of additive variability with regard to genotypic variability; in this case the value b = 0.68 ($t_{\alpha=5\%} = 4.25$; df = 49).

The attainment of genotypes with short internodes might be of economical interest owing to their better adaptation to mechanical recollection, as well as their achievement of a greater fructification density. In view of the obtained results, it seems difficult to get hybrids with short internodes, as there is dominance for greater length.

G.c.a. estimations are reported in Table 3. The high values of lines 6 and 3 stand out, while the lowest values were for lines 11 and 8. As lines 3 and 11 have the *sp* gene, while lines 6 and 8 contain the wild sp^+ allele, the genetic independence between self-pruning habit and growth habit, of which the internode length is a component, occurs once again.

The correlation between the average phenotypic values of the parental lines and their g.c.a. estimations was 0.80 $\pm$ 0.12. Although the correlation is high, it does not allow a precise enough estimation of the g.c.a. based on the average phenotypic values. KHANNA and CHAUDHARY (1974) found high values for this correlation with regard to plant height ($r = 0.94 \pm 0.13$).

The highest s.c.a. values belong to heterotic hybrids (Table 4). The lowest s.c.a. values belong to some of the parental lines; all the parental lines show negative values, except for line 8. Hybrids with low s.c.a. values do not necessarily correspond to H^- or D^- situations, and D^+ and A cases are also produced. The correlation between the lines and hybrids average phenotypic values and s.c.a. values was $r = 0.71 \pm 0.06$.

Number of leaves between clusters

There are highly significant differences among lines, both for the number of leaves between the 2nd and 3rd clusters (1 2–3), $F_{(61.122)} = 8.66$, and for the number of leaves between the 3rd and 4th clusters (1 3–4), $F_{(61.122)} = = 10.01$. No statistical significance existed for blocks. The parental lines variation rank for 1 2–3, varies between 1.98 for line 11 and 3.08 for line 7; for 1 3–4 varies between 1.58 for line 11 and 3.21 for line 1. For parental and hybrid lines as a whole, 1 3–4 is, in general, lower than or equal to 1 2–3.

The fraction of phenotypic variability due to variety differences was 0.72 for 1 2–3 and 0.75 for 1 3–4, suggesting a small environmental influence upon the character. CUARTERO (1976) found lower values, due to the different parental lines used. Within parental lines, two groups can be established: the one with few leaves between clusters, made up of lines 3, 6 and 11, and the other with a number of leaves around three, made up by the rest of the lines. Line 3 and 11 are *sp*/*sp* while 6, in spite of being of sp^+/sp^+ genotype, has a low number of leaves between clusters, suggesting independence between the two characters (DASKALOFF et al. 1975).

The comparison of F_1 hybrids with their parents results in a majority of cases with partial dominance towards a greater number of leaves. This condition appears more marked for 1 2–3 for 1 3–4. DASKALOFF et al. (1975) remarked total dominance in both cases, working with the same characters as in this study.

There are highly significant differences both for g.c.a. and s.c.a. (Table 2). The variance component for s.c.a. is 50% higher than for g.c.a., both for 1 2–3 and for 1 3–4. G.c.a. values (Table 3) lead to similar parental orders for 1 2–3 and 1 3–4, their amount being slightly higher for 1 3–4 than for 1 2–3. Three groups can be established: lines 7, 4, 2, 1 and 5 show the highest g.c.a.; lines 9, 8 and 10 exhibit values near zero; and lines 11, 3 and 6 present the lowest values.

Correlations between g.c.a. values and the parental lines phenotypic averages are 0.97 ± 0.02 for 1 2–3 and 0.98 ± 0.02 for 1 3–4. The high value of these correlations allows estimating g.c.a. of a line on the basis of its average phenotypic value. Despite the relatively great importance of s.c.a. with regard to g.c.a., there is a high correlation between the genotypic value and the g.c.a., as a consequence of the existence of a high correlation between lines g.c.a. and s.c.a. ($r = 0.80 \pm 0.11$).

All of the parental lines show medium or low s.c.a. values (Table 5). Lines 11, 3 and 6 stand out particularly. Hybrids showing extreme values for both character are 3×2, 3×5, and 7×11 for high values; 6×3, 6×11, and 11×10 for low values. It is surprising that lines 3 and 11 produce hybrids with very high s.c.a. values.

Correlations between s.c.a. and the average phenotypic value are 0.72 ± ± 0.06 (1 2–3) and 0.71 ± 0.06 (1 3–4), remarkably similar and of important magnitude.

Length between clusters

Analysis of variance at average level detected highly significant difference among lines, both in the field and under the polyethylene plastic cover conditions. Regarding the latter, the high significance among blocks is noteworthy; but this effect was not significant in the field conditions. The analysis of variance carried out at plant level donfirms the above-mentioned results, and a highly significant interaction line × block appears under the plastic cover ($F_{(120\cdot865)} = 3.06$).

Parental extreme values under plastic cover (7.69 for line 11 and 20.72 for line 1), show a greater rank than in the open-air (8.3 for line 11 and 16.9 for line 9). Under plastic cover, no hybrid surpassed line 1; nevertheless, in the field, the longest line 9 was surpassed by 23 of the 51 hybrids. The high values of hybrids derived from lines 6 or 7 and the low values of hybrids descending from line 11 are remarkable.

The genotypic correlation of the character between both cultivation systems, is of 0.70 ± 0.07, significantly different from 1, which shows the existence of a clear interaction genotype × environment. Consequently, from the breeder's point of view, the length between clusters measured on plants cultivated in the field must be considered as a different character than the mentioned length on plants cultivated in a polyethylene plastic-house. The fraction of phenotypic variability due to differences among lines is 0.57 under plastic cover and 0.53 in the field. Low heritability or the plant height until the 3rd cluster has been found (Baronce et al. 1972).

The inheritance estimate obtained by comparing the parents' values with their progeny is similar in both environments: partial dominance for greater length between clusters; nevertheless, this tendency is more marked in the field. Both in the field and the plastic cover, line 4 stands out for its tendency towards giving negative heterotic hybrids (shorter than the shortest parental). It is possible that this mode of inheritance is fundamentally the same as the one we found for internode length, which is described in the literature regarding plant height (Lapushner et al. 1973, Khanna and Chaudhary 1974, Daskaloff et al. 1975).

G.c.a. and s.c.a. are highly significant (Table 2) and in the plastic-house, there were much greater variations than in the field. The variance component for s.c.a. is 70% higher than the one corresponding to g.c.a. Perhaps these results agree still more with the literature about plant height (Kalloo et al. 1974, Svanosio and Vandoni 1974) than the variation structure for combining ability, already mentioned for internode length.

Table 5

S.c.a. estimations for number of leaves between clusters in the field

Lines	Number of leaves between the second and third clusters										
	1	2	3	4	5	6	7	8	9	10	11
1	−0.041	−0.224	0.191	−0.107	−0.125	0.183	−0.106	−0.005	−0.003	0.077	0.202
2	0.112	−0.061	0.270	—	−0.179	0.167	−0.164	−0.009	0.034	0.073	0.281
3	−0.114	−0.133	−0.389	0.178	0.298	−0.305	0.049	−0.094	−0.148	—	—
4	−0.255	0.402	−0.425	−0.120	−0.137	0.254	−0.083	−0.059	−0.016	0.065	0.273
5	−0.290	—	0.273	−0.058	−0.127	0.195	−0.005	−0.118	0.008	0.089	—
6	−0.221	−0.160	0.358	−0.218	−0.099	−0.384	0.256	0.190	−0.011	0.139	−0.300
7	0.298	0.439	−0.627	0.440	0.448	−0.239	−0.035	−0.105	−0.153	0.066	0.316
8	−0.164	−0.463	0.352	−0.146	−0.144	0.353	0.008	−0.088	0.128	0.042	0.208
9	−0.011	0.058	−0.329	−0.077	−0.236	0.102	−0.046	−0.114	0.088	−0.016	0.002
10	−0.109	−0.045	−0.212	−0.133	0.042	−0.056	−0.192	0.146	0.055	−0.013	−0.595
11	−0.134	0.084	—	0.122	0.046	0.037	0.028	0.228	0.125	−0.126	−0.435
	0.268	0.248	—	0.327	—	−0.954	0.406	0.392	0.324	−0.351	−0.629

	Number of leaves between the third and fourth clusters	
	1 2-3[b]	1 3-4[b]
$D\ (\hat{s}_{ii})$[a]	0.082	0.115
$D\ (\hat{s}_{ij})$	0.091	0.127
$D\ (\hat{s}_{ii} - \hat{s}_{jj})$	0.115	0.161
$D\ (\hat{s}_{ij} - \hat{s}_{ik})$	0.133	0.186
$D\ (\hat{s}_{ij} - \hat{s}_{k1})$	0.127	0.178

[a] Variances of s.c.a. and of differences between s.c.a. estimations.
[b] 1 2-3 = number of leaves between 2nd–3rd clusters; 1 3-4 = number of leaves between 3rd–4th clusters.

Table 6

S.c.a. estimations for length between clusters (plastic-house and field)

Lines	Plastic-house										
	1	2	3	4	5	6	7	8	9	10	11
1	1.847	−1.152	0.029	−0.592	−1.307	2.828	0.246	−0.660	−1.186	−1.978	0.080
	−0.625										
2		−0.229	1.469	—	−0.279	2.263	−1.714	−0.731	0.657	0.907	0.259
	0.777	−1.394									
3			−2.512	1.207	1.342	−4.212	0.645	0.811	0.596	—	—
	0.484	0.708	−3.051								
4				1.803	−1.679	1.685	−2.054	−1.021	−1.186	0.550	−0.609
	−1.609	—	0.885	−0.754							
5					−0.309	1.548	−2.802	1.231	−0.825	0.685	—
	−1.661	−0.870	3.088	−0.661	−1.654						
6						−2.713	1.255	0.049	0.935	1.242	−2.166
	1.242	2.296	−1.231	2.456	2.557	−3.454					
7							−1.046	0.817	1.542	1.384	—
	−0.263	0.658	0.623	0.785	−1.077	2.003	−3.047				
8								−2.078	2.180	0.212	1.268
	0.845	0.153	−1.052	−0.438	−0.990	0.135	−0.788	0.725			
9									−0.590	0.221	−0.439
	1.584	0.156	−0.313	−0.648	0.113	−1.296	0.929	0.213	−0.971		
10										1.220	−1.013
	1.133	−0.165	—	0.326	0.098	0.546	2.324	0.020	1.059	−1.756	
11											−2.883
	0.274	1.049	—	0.830	—	−1.800	0.900	0.451	0.145	−1.902	−2.747

	Field	
	Plastic-house	Field
$D(\hat{s}_{ii})$[a]	0.336	0.835
$D(\hat{s}_{ij})$	0.371	0.921
$D(\hat{s}_{ij} - \hat{s}_{jj})$	0.471	0.170
$D(\hat{s}_{ij} - \hat{s}_{ik})$	0.544	1.351
$D(\hat{s}_{ij} - \hat{s}_{ke})$	0.521	1.293

[a] Variances of s.c.a. and of differences between s.c.a. estimations.

The estimated g.c.a. values are given in Table 3. Some lines show similar values under both cultivations; therewith, line 9 has a high g.c.a. and line 10 a near-zero g.c.a., and values for line 3 and 11 are strongly negative. On the contrary, the rest of the lines suffer more or less important order alterations, particularly lines 7, 6 and 4. These alterations are a consequence of the above-mentioned interaction of genotype × environment. The correlation of the g.c.a. values between environments was 0.78 ± 0.12.

The correlation between g.c.a. and average phenotypic values of the parental lines are 0.93 ± 0.04 (plastic-house) and 0.92 ± 0.05 (field). The remarkable accordance between both values and their considerably high magnitude allow using the average phenotypic value of a line to estimate its g.c.a.

Regarding s.c.a. (Table 6), the low values of parental lines 6, 11 and 3; high hybrids values of line 6 with 2, 4 and 5 stand out. The correlation among s.c.a. values for both environments is 0.54 ± 0.09, significantly different from the unit. Correlations of s.c.a. with the average phenotypic values are 0.73 ± 0.06 (plastic-house) and 0.76 ± 0.05 (field).

Relationships among vegetative characters

Table 7 points out that the number of leaves between the 2nd and 3rd clusters, and between the 3rd and 4th, have such a high genotypic correlation that this suggests an underlying common genetic system; moreover, the environmental influences, which were reduced as previously seen, have scarcely any common influence on this phenomenon.

The internode length and the number of leaves between clusters are uncorrelated.

Table 7

Phenotypic (r_P), environmental (r_E) and genotypic (r_G) correlations in the field

	1 2–3, 1 3–4[a]	*il*, 1 2–3	*il*, 1 3–4
r_P	0.812	0.091	0.024
r_E	0.298	0.054	0.046
r_G	0.998 ± 0.019	0.138 ± 0.172	0.010 ± 0.173
	1 2–3, *lc*	1 3–4, *lc*	*il*, *lc*
r_P	0.656	0.623	0.729
r_E	0.371	0.358	0.851
r_G	0.844 ± 0.059	0.793 ± 0.069	0.602 ± 0.113

[a] 1 2–3, 1 3–4 = leaves between 2–3 and 3–4 clusters; *il* = internode length; *lc* = length between clusters

The length between clusters is genetically related both to the number of leaves between clusters and to the internode length, although the influence on the number of leaves is slightly higher. The regression equation for typified values is:

$lc = 0.699\, l + 0.627\, il$, $R^2 = 0.988$, where
lc = length between clusters
l = (1 2–3 + 1 3–4)2
il = internode length

Nevertheless, environmental influences are clearly different; although the environmental influences common to the number of leaves between clusters and length between clusters are small, thos between internode length and length between clusters are very marked. As environmental factors that influence internode length do not alter the number of leaves, the distance between clusters increases.

Relationship with other characters

The number of leaves between clusters is genotypically uncorrelated with fruit weight, number of fruit, earliness and number of cracked fruits; its correlation with total production is also very reduced ($r_G = 0.20 \pm 0.12$). Internode length had a genotypic correlation of 0.61 ± 0.08 with the total production and of 0.51 ± 0.09 with the commercial earliness, whereas correlation with fruit number and fruit weight is negligable.

The length between clusters presents relationships similar to the ones pointed out for length between nodes, although to a slightly less extent. No important differences in these relationships occurred between the field and the polyethylene plastic-house conditions.

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GENETIC ADVANCE IN WHEAT BREEDING AND ITS CONTRIBUTION TO YIELD GAINS

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The genetic advance in wheat breeding was investigated and the role it plays in increasing yield averages determined. A six-year experimental series showed that from 1961, when Bánkúti 1201 was replaced, the genetic gain in grain production was 48% over an average of the three new varieties. This increase in genetic yielding ability is the result of an increase in two factors, the biological yield (20–23%) and the harvest index (20–30%). 54.4% of the 2.4 ton increase in national yield averages (135 kg/year from 1961 to 1983) can be attributed to the development in crop production methods and 45.6% to genetic advance.

Introduction

In Hungary during the first three decades of the century varieties selected from the local varieties Tiszavidéki and Bánáti were grown. These were replaced in the late thirties and forties by Bánkúti 1201, registered in 1931, and Fleischman 481, registered in 1939. Bánkúti 1201 was grown on most of the wheat area until 1961 when a spectacular series of variety replacements was begun, partly to develop large-scale production, including the creation of better conditions for fertilizer supply and mechanization, and partly as a result of the appearance of a new type of varieties, known as intensive varieties.

Bánkúti 1201 and Fleischman 481 were replaced by Fertődi 293, registered in 1957, and the Soviet variety Bezostaya 1, introduced in 1961. Fertődi 293 was sown on a large area for ten years and on 25–30% of the wheat area for many years, whereas Bezostaya 1 occupied a large area for 15 years, including the greater half of the wheat area from 1963–1973.

There were still no competitive Hungarian intensive wheat varieties in the early 1970s, so varieties introduced from abroad were mainly registered and produced. Bezostaya 1 was ousted and later replaced by the Italian variety Libellula and the Soviet varieties Yubileinaya 50, Avrora and Kavkaz. Libellula was sown from 1972–1979 and Avrora and Kavkaz from 1972–1976 on more than 10% of the wheat area. Yubileinaya 50 is still in production.

There was a further change in varieties in the late 1970s. Martonvásári 4, registered in 1974, and Sava, NS Rana 1 and NS Rana 2, introduced from

Yugoslavia, became widespread. Four years later the Yugoslavian varieties were ousted by new Hungarian varieties, mainly from Martonvásár (Martonvásári 4, Martonvásári 8, Martonvásári 9), which occupy 55% of the wheat area at present. Although the crop area of Yubileinaya 50 is decreasing, it is still substantial (about 10%). The new Szeged (GK Ságvári, GK Boglár), Martonvásár (Mv 11, Mv 12, Mv 13) and recently registered Yugoslavian varieties (Baranjka, Zagrepcsanka) are gaining ground. About 80% of the wheat area is occupied by Martonvásári 8, Yubileinaya 50, Martonvásári 4, Martonvásári 9 and Baranjka.

It is characteristic of the accelerated variety replacement that the average age of a wheat variety is about five years, of the 23 varieties registered at the moment only two are older than 10 years (Yubileinaya 50, Martonvásári 4).

Material and methods

Genetic advance was studied using two methods. The first method was applied to investigate the yielding abilities of Bezostaya 1 and the varieties with the highest yields in the state variety trials in the years 1961, 1962 and 1963 as well as 1977, 1978 and 1979. The crop production practices and fertilizer rates were equal to the national average in both periods. On the basis of the results obtained the advance due to development in crop production practices was determined based on the grain yield of Bezostaya 1, and genetic advance based on the increase in yields of the highest yielding varieties. In a knowledge of the yield differences for the highest yielding varieties and the yield increase due to crop production factors, genetic advance was calculated in the following way:

$$\text{Genetic advance} = \frac{(Y_2 - Y_1) - (B_2 - B_1)}{Y_2 - Y_1} \times 100$$

where Y_1 is the average yield of the top yielder in 1961–63
Y_2 is the average yield of the top yielder in 1977–79
B_1 is the average yield of Bezostaya 1 in 1961–63
B_2 is the average yield of Bezostaya 1 in 1977–79.

Using the second method the most important standard varieties of the past two decades were included in a trial on well fertilized (500 kg NPK fertilizer at a ratio of 1 : 1 : 1) heavy grassland soil and their yields were compared with those of the most recent varieties. The trial was continued for six years in a random block design, with five replications, on 20 m² plots per replication, between 1977 and 1983.

Samples were taken from the trials from 0.5 m² in four replications, and the above) ground biological yield and the harvest index were determined and plant height was measured.

Results and discussion

(1) *Genetic advance and increase in yields*

In Hungary the wheat area is stable at around 1.3 million hectares. On this area 1.22 t/ha were produced in the first half of the century 1.86 t/ha between 1961 and 1965 and 4.27 t/ha between 1981 and 1983. During the

past 23 years the national yield average has increased by 135 kg/ha per year (Fig. 1) and the average yield in the national variety trials, set up at 15 locations, showed an even higher increase of 162 kg per year.

It is difficult to express in figures how much of the yield increase can be attributed to genetic advance and how much to fertilizer application, herbi-

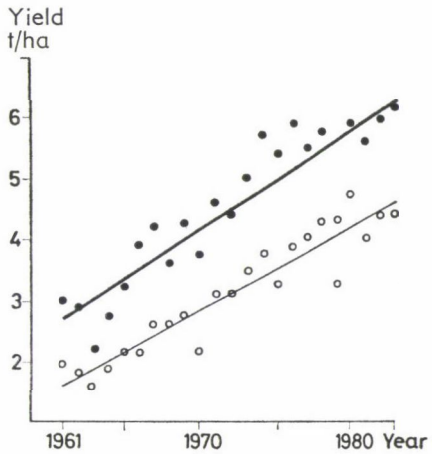

Fig. 1. National yield average (○) and the average yield of the national variety trials (●)

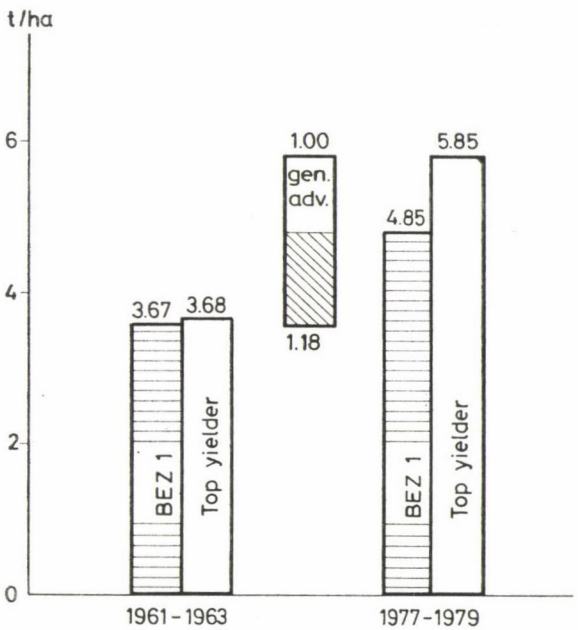

Fig. 2. The yields of Bezostaya 1 and the highest yielding variety in the state variety trial

Table 1

Increase in biological and grain yield
(Martonvásár, 1978–1983)

Variety	Plant height, cm	Biological yield, t/ha	%	Grain yield, t/ha	As a % of Bánkúti 1201	Harvest index, %	%
Bánkúti 1201	125	13.6	100.0	4.94	100	36.4	100.0
Bezostaya 1	103	14.3	105.1	6.03	122	42.7	117.3
Yubileinaya 50	107	15.9	116.9	6.57	133	42.2	115.9
Martonvásári 4	105	15.1	111.0	6.63	134	43.9	120.6
Martonvásári 8	96	16.8	123.5	7.01	142	44.2	121.4
Martonvásári 9	89	16.3	119.9	7.38	149	43.6	119.8
Martonvásári 10	83	16.0	117.6	7.53	153	47.2	129.7
LSD (0.05%)	3	1.4	10.4	0.56	11	2.5	6.9

cides, development in mechanization, up-to-date plant protection and more advanced professional knowledge. It is a fact that yield increases can be achieved by the harmonic development of all these factors. As AUSTIN (1978) established, the roles of the various factors differ according to the standard of production and the yield levels.

The role of varieties in yield increase has been analysed by several authors. In the United Kingdom 62.3% of the yield increase can be attributed to genetic advance according to ELLIOT (1962), 60% according to AUSTIN (1978) and 50% according to LUPTON (1982). In Czechoslovakia SCHMIDT (1975) attributes 33.8% of the yield increase to the new varieties, while the corresponding figure for the USA (SCHMIDT 1984) is 50% and for Hungary 30–40%, BOCZ (1973) 30%, KAPÁS (1978).

In order to determine the role of genetic advance and crop production, the yields of Bezostaya 1 and the highest yielding variety in the state trials were investigated (Fig. 2). Bezostaya 1 yielded 3.67 tons per hectare during the three years following its introduction (1961, 1962, 1963) and 4.85 t/ha in the last three years of its "career" (1977, 1978, 1979). In the first period of the studies there was no variety with yields significantly higher than Bezostaya 1. In the last period of the studies 14 varieties outyielded Bezostaya 1 the best of them by 1000 kg/ha.

During the period between the investigations the yield increase was 2180 kg/ha. 1180 kg (54.1%) of this was due to progress in crop production and 1000 kg (45.9%) to genetic advance.

The data for the more important standard varieties of the past two decades and for the new Martonvásár varieties are presented in Table 1.

The old variety, Bánkúti 1201, yielded 4.94 t/ha over a six year average at the present level of crop production. The standard variety of the next period Bezostaya 1 yielded 6.03 t/ha, 22% more than Bánkúti 1201. The two

standard varieties following the Bezostaya 1 era. Yubileinaya 50 and Martonvásári 4, yielded 6.57 and 6.63 t/ha, respectively, 33 and 34% more than Bánkúti 1201. Martonvásári 4 and Yubileinaya 50 are still in commercial production. Their sowing area still exceeds 25%.

The highest yielding varieties at present are Martonvásári 8, Martonvásári 9 and Martonvásári 10. Their yields under ecological conditions identical to those for the previous varieties were 7.01, 7.38 and 7.53 t per hectare. These three varieties outyielded Bánkúti 1201 by 42, 49 and 53% respectively. The genetic advance on the average of these varieties was 48%. This means a yearly average of 2.3%. Thus 62.1 kg of the annual national yield increase of 135 kg can be attributed to genetic advance, which in Hungary is equal to 80 730 t grain yield on 1.3 million hectares.

(2) *Components of yield increase*

The increase in yielding ability is basically the result of changes in two factors, the biological yield and the harvest index. Although Bánkúti 1201 was a tall variety (125 cm) its aboveground biological yield was small (13.6 t/ha). The biological yields of the more recent varieties have been gradually increasing, whereas their plant heights have decreased. The heights of the most recent varieties, associated with a 7 ton grain yield, have been reduced to 80–90 cm, which can be considered optimal at the moment, whereas their biological yields are 3.0–3.9 t/ha, 17–23% higher than that of Bánkúti 1201.

The 36.4% harvest index of Bánkúti 1201 was surpassed by Bezostaya 1 by 6.3%. Among the most recent varieties the harvest index of Martonvásári 10 is 10.8% higher than that of Bánkúti 1201 and approaches, and in certain years attains 50% which is equal to a 1 : 1 grain-straw ratio.

The genetic advance achieved in the grain yield is therefore the result of changes in two factors: an increase in biological yield and a decrease in the grain-straw ratio (i.e. an increase in the harvest index), while the plant height decreased to 80–90 cm.

On the basis of the data of six-year comparative trial the correlations between the aboveground biological yield and the grain yield, harvest index and plant height, between the grain yield and the harvest index and plant height and between the harvest index and the plant height were calculated (Table 2). There was a close, positive correlation between biological yield and grain yield (0.89), biological yield and harvest index (0.72) and grain yield and harvest index (0.92). A close but negative correlation was found between grain yield and plant height (—0.95), harvest index and plant height (—0.92) and biological yield and plant height (—0.77). These correlations prove that in wheat breeding genetic advance takes place through the selection and use of correlation-breaking forms (BALLA 1973).

Table 2

Correlation between certain characteristics of wheat varieties
(Martonvásár, 1978–1983)

Biological yield — grain yield:	$r = 0.89^{**}$
Biological yield — harvest index:	$r = 0.72^{*}$
Biological yield — plant height:	$r = -0.77^{*}$
Grain yield — harvest index:	$r = 0.92^{**}$
Grain yield — plant height:	$r = -0.95^{***}$
Harvest index — plant height:	$r = -0.92^{***}$

Note: * LSD (0.05%)
** LSD (0.01%)
*** LSD (0.001%)

On the basis of the negative correlations between biological yield and plant height and between harvest index and plant height, it can be established that wheat populations have changed. The biological yield has increased despite the decrease in straw height, which is the result of a more dense population, thicker straw and larger leaf area duration.

Summary

During the past 23 years the yield average in Hungary has increased by 135 kg/ha per year. The yields of Bezostaya 1 and the highest yielding varieties in the state trials were investigated. According to these results 54.4% of the yield increase was due to progress in crop production and 45.6% to genetic advance.

In a six-year trial the most important standard varieties of the past two decades were investigated. The newest varieties outyielded the old Bánkúti 1201 by 42–53%. The genetic advance over the average of these varieties was 48%. This represents a yearly average of 2.3%.

The increase in yielding ability is basically the result of changes in the biological yield and the harvest index. The height of recent varieties has been reduced to 80–90 cm, whereas their biological yields are 17–23% higher than that of Bánkúti 1201.

Among recent varieties the harvest index of Martonvásár 10 is 10.8% higher than that of Bánkúti 1201, and approaches and in certain years attains 50%, which is equal to 1 : 1 grain-straw ratio.

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GENETIC ANALYSIS OF THE FROST RESISTANCE AND WINTER HARDINESS OF WHEAT UNDER NATURAL AND ARTIFICIAL CONDITIONS

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The inheritance of frost resistance and winter hardiness was studied under nursery and phytotronic conditions. The artificial and natural tests were carried out on varieties, and on the F_1 hybrids of a 10-parental diallel cross.

It was found that under controlled conditions the frost resistance of wheat varieties and the differences between the varieties can be determined more precisely than under natural conditions. At variety and F_1 hybrid level a close positive correlation was found between frost resistance and winter hardiness. Both environments are suitable for an analysis of combining ability, though the additive-dominance model was only adequate for phytotronic testing. Thus, the direction of dominance, the distribution of dominant and recessive alleles and the genetic parameters of variance could not be estimated for winter hardiness.

Introduction

Under Hungarian conditions the wheat yield is influenced not only by the yield potential and disease resistance of the varieties, but also to a great extent by their winter hardiness. The winter exposes young wheat seedlings to many kinds of stress: direct frost effect, cold winds, snow cover, intense freezing and glaciation of the soil, the consequent lack of water and nutrients, frost lifting in spring and, last but not least, various diseases which thrive in or can withstand the cold (LELLEY and RAJHÁTHY 1955).

Frost resistance is one component of winter hardiness. If seedlings are frost resistant, it means that they can survive the frost effect without any considerable damage. The vast majority of the active components are related to freezing or to the freezing temperature. Wheats which are frost resistant generally survive the winter well, which means that a study of frost resistance gives a good indication of the winter hardiness (RAJKI 1980).

Under continental climatic conditions a genetic analysis of winter hardiness is only possible in the nursery every five to ten years. In mild winters it may prove impossible to detect any difference between the wheat varieties, while in severe winters the whole experiment may be destroyed (FOWLER et al. 1977). It is practically inconceivable for climatic factors to be reproduced year by year in the nursery. It was obviously the recognition of this fact that led

to the development of various methods for artificially testing frost resistance, where phytotronic climatic chambers are used for the whole or part of the test (DEXTER 1956, TSENOV 1972, BARASHKOVA 1975, POMEROY et al. 1975, GULLORD et al. 1975).

Attempts were made as early as the 1930s to use frost resistance to predict winter hardiness, since a relatively good positive correlation was found between the two characters (ANDERSON and KISSELBACH 1934, WORZELLA 1935). However, the methods applied at that time gave little success in predicting winter hardiness and in the selection of winter hardy genotypes. Although they were able to distinguish between varieties with widely different frost and winter hardiness (WORZELLA and CUTLER 1941, POMEROY and FOWLER 1973, GULLORD et al. 1975), only limited success was achieved in tracing the inheritance of the characters. The selection of the required genotypes from a segregating hybrid population was very unreliable (ROBERTS and GRANT 1968, FOWLER and GUSTA 1977).

Nowadays a wide range of methods for testing frost resistance and winter hardiness are used in genetic analysis (GULLORD 1975, STEPONKUS 1978, RAJKI 1980, MARSHALL et al. 1981, SUTKA 1981, PARODI et al. 1983). The differences in the results achieved by various research groups when testing frost and winter hardiness are presumably due to the application of different methods: it is difficult to draw general conclusions.

The present paper gives an account of the correlations found between frost and winter hardiness under nursery and phytotron conditions at the levels of wheat varieties and F_1 hybrids.

Material and methods

Winter hardiness was tested in the nursery, and frost resistance in the phytotron. The experiments were carried out on various wheat varieties and F_1 hybrids, but the experimental conditions were not completely identical. On the basis of the genetic material studied and the experimental and testing conditions, two group can be distinguished.

In the first experiment the wheat varieties studied (Yubileinaya 50, Mv 4, Mv 8, Mv 10, B 1201, GK Szeged) represent a wide range of frost and winter hardiness and also play an important role in Hungarian wheat production.

The wheat grains were germinated on moist filter paper in petri dishes and planted out into wooden boxes with inner dimensions of $39 \times 27 \times 11$ cm. The raising medium was a 3 : 1 mixture of garden soil and sand. Nine rows each consisting of 20 germinating seeds were sown in each box. The experiment was carried out in four replications. Some of the boxes were placed in a PGV chamber in the phytotron while the remainder were put into the soil in the internal nursery, where they were left until spring to ensure natural field conditions.

Frost resistance testing in the phytotron can be divided into three phases: 1. raising and hardening, 2. freezing, 3. regrowth and evaluation (RAJKI 1980).

The raising period lasted 6 weeks, during which time the temperature, light intensity and illumination period gradually decreased, due to weekly changes in the programme, in a manner similar to the natural weather conditions in November and December. For a week at a time the plants were raised with identical daily temperature fluctuations, light intensity and daylength. The daily temperature fluctuation corresponded to the temperature changes found in nature. During the 7th week hardening was carried out at temperatures between -3 °C and $+3$ °C, with a 21-hour day and an illumination of 15 000 lux. After the one-week

hardening period the boxes were placed in a frost testing chamber where the plants were further hardened for 4 days at −4 °C without illumination. Following this the temperature was gradually lowered to −15 °C. The frost treatment lasted for 24 hours. After freezing the experimental material was left to thaw out in the frost testing chamber for another 2 days at 0.5 °C. After thawing the boxes were transferred to a GB chamber for recovery at a night temperature of 15 °C and a day temperature of 16 °C, with a 14-hour day and a light intensity of 10 000 lux for 3 weeks. At the time of transfer the leaves were cut back to 1–2 cm above the soil, so as to facilitate the evaluation of new growth and to eliminate the danger of fungal infection. During the raising and regrowth periods the plants were irrigated with tap water. No irrigation was carried out during hardening and freezing. At the end of the third week plants which had survived freezing and begun to develop could be easily distinguished from those which had been destroyed. When evaluating the results, the number of plants which had survived freezing was expressed as a percentage of the number of germinating wheat grains planted.

The experiment with boxes dug into the soil in the nursery was carried out in two years (1982/83 and 1983/84). Overwintering was scored in March. Winter hardiness, too, was expressed in terms of the percentage of germinating wheat grains planted.

The aim of the second experiment was to compare the results of the phytotron frost testing method elaborated for the genetic analysis of frost resistance with the results of winter hardiness testing carried out in boxes in the field.

The experimental material consisted of wheat varieties and lines representing various levels of frost resistance (1. Mv 8, 2. Mv 4, 3. Gödöllői 1, 4. GK Apolló, 5. GK Szeged, 6. Mv 5, 7. Mv 103/w336, 8. Mv 5400/5052, 9. Gödöllői 2, 10. Mironovskaya 808), and the diallel F_1 hybrids of these.

The F_1 generation of a 10-parental diallel cross set up in 1981 was tested partly under phytotronic conditions at −14 °C (SUTKA 1984) for the preparation of a semi-diallel table, and partly in the nursery in boxes placed on the surface of the soil on October 21st 1981. On March 5th 1982 the boxes were transferred to a GB chamber for regrowth, where the same temperature and light conditions were programmed as were used for boxes removed from the frost testing chamber.

In contrast to the 1st experiment, in experiment II five germinating grains of each of 30 F_1 hybrids and/or varieties were planted in each box. For each variety and F_1 hybrid 100 data were available for evaluation. The frost and winter hardiness of the individual plants was recorded using a 0 (destroyed) to 5 (no damage) scale, which is more convenient for diallel analysis than a percentage survival figure.

The evaluation of frost and winter hardiness in terms of general (g.c.a.) and specific (s.c.a.) combining ability was carried out using the methods described by GRIFFING (1956) and KEULS and GARRETSEN (1977). The method elaborated by JINKS (1954) was used for the graphic analysis of covariance/variance.

Results and discussion

In order to be able to evaluate the nursery data it is necessary to describe the temperatures and the quantity of precipitation in the seasons 1981/82, 1982/83 and 1983/84. In the 1981/82 season the air temperature dropped to —5 °C in mid-December, followed by a slightly warmer period in late December and early January. In mid-January the mean temperature was extremely low. The 1982/83 winter was very mild, particularly in January, with a mean temperature of 5.1 °C, 6 °C higher than the average over many years. The ten-day mean of air temperature did not drop below zero until February. In the winter of 1983/84 the minimum temperature had dropped to below —10 °C by November. There was a somewhat milder period at the end of the month, but by mid-December the minimum temperature had again dropped to below —10 °C, and the mean temperature was also relatively low. There

was another cold spell at the end of January. With respect to the years in question, the lowest quantity of precipitation fell in the winter of 1983/84.

In the first experiment, in which boxes were dug into the soil, no significant difference was found between the varieties tested in any of the years (Table 1), due no doubt to the relative mildness of the winters. The only exception was the behaviour of GK Szeged in 1983/84, when the overwintering percentage was only 51%. In 1982/83 B. 1201 and GK Szeged proved to be somewhat less hardy. When frozen at —15 °C in an artificial environment, however, considerable differences were found in percentage survival. The results obtained for Yubileinaya 50 and Mv 8 seem to be somewhat contradictory, since the former gave a low survival percentage and the latter a rather high figure compared with the standard Mv 4, but in this experiment the differences were not significant ($LSD_{5\%} = 15$). It can be concluded from the results that the phytotron frost test is a better indication of differences in frost resistance between the varieties than the nursery experiment. In a controlled environment the raising and hardening of the plants, and the supply of water and nutrients can be carried out in a reproducible manner and optimised for the purpose. Since a close correlation ($r = 0.83$ and $r = 0.75$) was found between winter hardiness in the nursery and survival after artificial freezing, the phytotron frost testing method described here definitely appears to be suitable for distinguishing between wheat varieties and experimental lines when the differences are great enough to be significant from the point of view of wheat production.

In the second experiment the climatic programme was somewhat simpler than in experiment I, though here again the testing is divided into three distinct periods (SUTKA 1981). Due to the large number of randomly arranged replications, the setting up of the experiment is more complicated, and the individual scoring of all the surviving plants on a 0–5 scale in also more laborious, requiring skill and objectivity. Using single factor analysis of variance the differences between the genotypes are significant.

Table 1

Percentage survival of wheat varieties frozen at —15 °C in the phytotron and in boxes dug into the soil in the nursery

Varieties	Phytotronic freezing	Nursery	
		1982/83	1983/84
Jub. 50	80	94	92
Mv 4	85	97	92
Mv 8	79	87	94
Mv 10	50	86	92
B. 1201	39	74	100
GK Szeged	0	77	51

Table 2

Mean values of frost and winter hardiness for parents and F_1 hybrids under phytotronic (P) and nursery (N) conditions

Parents	1	2	3	4	5	6	7	8	9	10	Environment
1	1.77	2.50	1.90	0.92	0.59	2.49	1.10	0.69	1.51	2.77	P
	3.35	2.70	2.63	1.67	0.68	1.89	1.73	1.50	1.95	3.40	N
2		2.37	2.48	1.46	1.18	3.14	2.24	1.37	2.50	3.65	P
		3.49	3.10	1.68	1.20	3.35	1.85	1.23	2.23	3.95	N
3			2.62	1.11	0.64	2.37	1.77	0.73	2.07	3.07	P
			4.05	1.92	1.15	3.58	2.03	1.63	2.30	2.93	N
4				0.09	0.00	1.96	0.92	0.18	0.76	1.90	P
				2.15	0.10	1.58	1.33	0.15	1.85	2.33	N
5					0.00	1.00	0.21	0.01	0.17	1.28	P
					0.00	2.70	0.68	0.05	1.00	3.50	N
6						1.92	1.81	1.29	2.22	3.62	P
						3.43	1.10	2.48	2.73	4.40	N
7							1.15	0.23	1.17	2.06	P
							1.73	0.70	1.80	2.63	N
8								0.14	0.43	1.42	P
								0.80	1.48	2.08	N
9									0.75	2.23	P
									1.47	3.00	N
10										2.85	P
										4.00	N

For names of wheat varieties see "Materials and methods" section

The mean values of frost resistance for the parents and F_1 hybrids of the 10-parental semi-diallel cross are shown in Table 2. With one or two exceptions the mean values of plants raised in boxes on the surface of the soil in the nursery, then hardened and frozen, and regrown in a GB chamber, are higher than those of plants tested in an artificial environment. Since the boxes

Table 3

Analysis of variance for combining ability under phytotronic (P) and nursery (N) conditions

Source of variance	Environment	df	SS	MS	F
General (g.c.a.)	P	9	86.3	9.59	103.15***
	N	9	88.6	9.84	79.67***
Specific (s.c.a.)	P	45	6.3	0.14	1.50*
	N	45	21.8	0.49	3.93***
Error	P	54	4.86	0.09	
	N	54	6.7	0.12	

*, *** P = 0.05, P = 0.001, respectively

were placed on the surface of the soil, the frost effect was more intense than in the soil, so the field conditions caused significant differences in winter hardiness between the genotypes. The variety GK Szeged was completely destroyed, while Mironovskaya 808 and Gödöllői 1 gave mean values of 4.00 and 4.05. There was a very close correlation between the values obtained in the artificial and natural tests ($r = 0.83$).

The variance analysis of combining ability showed that under both phytotronic and nursery conditions the variance of both general (g.c.a.) and specific (s.c.a.) combining ability was significant (Table 3). It follows from this that additive and non-additive gene effects are both important. On the basis of the g.c.a. : s.c.a. ratio, the additive genetic variance is considerably greater than the non-additive genetic variance, i.e. than dominance and epistasis. The effects of general combining ability (g.c.a.) had a similar tendency under both phytotronic and nursery conditions (Table 4). In bot hcases, for example, the best general combining ability was exhibited by Mironovskaya 808 and the poorest by GK Szeged. Mv 4, however, acts slightly differently. In the nursery it was found to have poorer general combining ability than in the phytotron. It is interesting to note that Gödöllői 2 had better general combining ability under both artificial and natural conditions than was to be expected from the mean values of frost and winter hardiness.

The covariance/variance regressional analysis demonstrated that the additive-dominance model is only adequate in the case of phytotronic frost testing (SUTKA 1981, 1983), and not under field conditions. In the latter case, non-additive genetic variance does not consist only of dominance. The various environmental factors active in the nursery produce interactions which make

Table 4

Effect of general combining ability (g.c.a.) on frost and winter hardiness under phytotronic (P) and nursery (N) conditions

Parents	Environment	
	P	N
1	0.11	0.10
2	0.77	0.43
3	0.36	0.49
4	−0.59	−0.55
5	−1.01	−0.94
6	0.66	0.70
7	−0.25	−0.49
8	−0.87	−0.84
9	−0.14	−0.07
10	0.97	1.17
SE for g.c.a.	±0.065	±0.075

it impossible to determine the direction of dominance and the distribution of dominant and recessive alleles. Consequently, the genetic components of variance cannot be estimated. It is thus obvious that the inheritance of winter hardiness is more complicated than that of frost resistance. Although frost resistance plays the most important role in the development of winter hardiness, under field conditions the operation and expression of the genes responsible for frost resistance may be considerably modified by complicated, constantly changing environmental factors. Therefore, the genetic analysis of frost resistance, itself not a simple character, is only rational in a controlled environment.

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GENETIC DIVERGENCE IN SPECIES OF GENUS *LINUM*

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Twelve species of genus *Linum* and their thirteen crosses were grown in a randomized block design with two replications. Obervations were recorded on eights characters namely, capsule size, seeds per capsule, capsule per plant, yield per plant, days to flowering, plant height, tiller number and pollen diameter. Analysis of variance revealed highly significant differences among populations for all the characters studied indicating that there existed a high degree of variability for different characters. Wilk's criterion also revealed significant differences among genotypes based on all characters taken together. Mahalanobis' D^2 statistics was used to assess the diversity among these genotypes. Yield per plant, plant height and pollen diameter collectively contributed 87 + towards divergence. On the basis of multivariate analysis, these genotypes were grouped into five clusters. Species that seem to be promising for hybridization have been identified (Fig. 1.).

Introduction

A plant breeder is constantly engaged in making an effective choice of desirable genotypes for a successful hybridization programme. In this context, genetic diversity among selected genotypes in greatly emphasized. In order to study divergence, statistical distance has been successfully used in discriminating populations in anthropometry, psychometry (RAO 1952) and biology, using multivariate analysis. D^2 statistics, as developed by Mahalanobis, have been used in this paper for obtaining information about genetic diversity among a group of *Linum* species. From the literature survey, it appears that no information on divergence as reflected by use of statistics like D^2 seems to be available, as far as species of a genus in general and *Linum* in particular are concerned. This study was, therefore, undertaken to examine the genetic diversity among different species of genus *Linum* with respect to seed yield and its components, including morphological and developmental traits.

Material and methods

Twelve species of *Linum (Linum usitatissimum, L. anqustifolium, L. catharticum, L. crepetans, L. floccosum, L. gallicum, L. hirsutum, L. lewissi, L. pallescence, L. perenne, L. strictum* and *L. tenue)* and their thirteen crosses (eleven with *L. usitatissimum* and other two as *L. catharticum* × *L. hirsutum* and *L. strictum* × *L. lewissi*) were sown in a randomized

block design with two replications. Data were recorded for 10 competitive plants on eight characters, namely: capsule size, seeds per capsule, capsules per plant, yield per plant, days to flowering, plant height, tillers per plant and pollen diameter. After carrying out the conventional RBD analysis, the data were subjected to multivariate analysis.

Wilk's criterion (RAO 1952) was used to test the significance of pooled differences in the mean values of the characters studied. The original mean values for different characters (X_1 to X_8) were transformed to uncorrelated variables (Y_1 to Y_8) by the pivotal condensation method for 8×8 common dispersion matrix. D^2 values, calculated as the sum of differences of the genotypes over all the transformed variables, were utilized to classify these genotypes with similar D^2 values in each cluster.

Results and discussion

The species studied in the present investigation probably had the same genomic constitution as revealed by highly fertile hybrids among tem (KUMARI 1974). Therefore, it appeared desirable to classify these species into tomogenous groups so that only a few of these could be identified for use in hybridization.

Analysis of variance, based on plot means, revealed highly significant differences among the populations for all the characters studied. Again, these differences were found to be highly significant when the aggregate effect of all the twelve characters, as one combination, was tested by Wilk's criterion.

Table 1

Contribution of various traits to divergence

Character	Capsule size	Seeds per capsule	Capsule per plant	Plant yield	Days to flowering	Plant height	Tillers number	Pollen diameter
Rank totals	4	9	2	88	9	64	14	110
Contribution, %	1.3	3.0	0.7	29.3	3.0	21.3	4.7	36.7

Table 2

Clustering pattern of 12 species and 13 hybrids in genus Linum

Cluster		Populations
No.	Size	
1	10	*L. usitatissimum*, *L. catharticum*, *L. lewissi*, *L. angustifolium* × *L. usitatissimum*, *L. catharticum* × *L. usitatissimum*, *L. hirsutum* × *L. usitatissimum*, *L. lewissi* × × *L. usitatissimum*, *L. pallescence* × *L. usitatissimum*, *L. perenne* × *L. usitatissimum*, and *L. tenue* × *L. usitatissimum*
2	7	*L. crepetans*, *L. floccosum*, *L. strictum*, *L. tenue*, *L. crepetans* × *L. usitatissimum*, *L. floccosum* × *L. usitatissimum* and *L. strictum* × *L. lewissi*
3	5	*L. angustifolium*, *L. hirsutum*, *L. pallescence*, *L. perenne*, and *L. gallicum* × × *L. usitatissimum*
4	2	*L. strictum* × *L. usitatissimum* and *L. catharticum* × *L. hirsutum*
5	1	*L. gallicum*

Table 3

Intra- (diagonal) and intercluster genetic distances $(D^2)^{1/2}$

Clusters	1	2	3	4	5
1	4.57	13.69	10.85	10.35	12.00
2		4.79	22.81	9.84	23.21
3			6.58	19.01	10.08
4				6.16	19.99
5					0.00

The relative contribution of each character to divergence was estimated and D^2 values were computed. It can be seen from Table 1 that 87% of the total diversity was due to characters, yield per plant, plant height and pollen diameter. This result indicated that these three characters are sufficient to classify all 12 species and their 13 hybrids into different groups.

Based on the estimates of D^2 values, these species and hybrids could be grouped into five clusters (Table 2). Group 1 consisted of 3 species and 7 hybrids. However, the hybrids included in this group were among these species, this showing affinity of the hybrids to the parental species. Group 2 was formed of 4 species and only 3 hybrids. Similarly, group 3 had 4 species and 1 hybrid. Group 4 had only 2 hybrids. Contrarily, group 5 had only one species, i.e., *L. gallicum*.

Intra- and intercluster genetic distances are presented in Table 3. Maximum intercluster distance was among group II and V (23.2), followed by that between II and III (22.8). It is therefore logical to attempt crosses among the species belonging to thsse groups. *L. gallicum* belonging to group V was uniquely divergent from all other populations. This species was characterized by high capsule size and number, seed yield and seeds per capsula

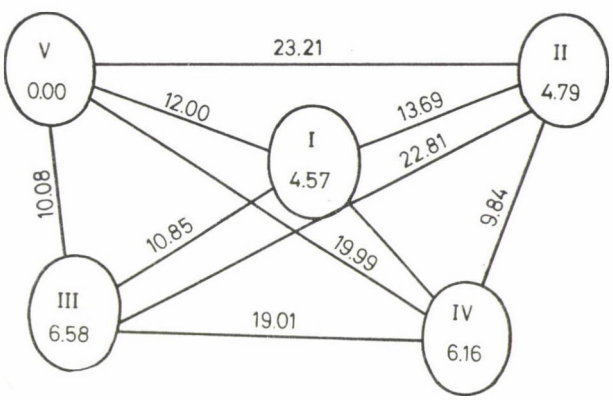

Fig. 1 The five clusters of genotypes on the basis of multivariate analysis

(KUMARI 1974). Among the species in cluster II and III, *L. tenue*, *L. hirsutum* and *L. pallescence* were promosing for the important economic characters like capsule number and size, plant yield and seeds per capsule. Further, these species were early in flowering and height. These species should therefore be exploited through hybridization and subsequent selection in their segregating generations. Selection of parents for hybridization, based on genetic distance, has been found much superior to other methods as reported by BHATT (1973). Attempting diallel mating among these identified species seems to be the best was to exploit all of them simultaneously.

Similarly, species *L. usitatissimum* from cluster I appeared promosing from this viewpoint.

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THE EFFECT OF NITROGEN DOSES AND DIFFERENT WATER SUPPLY UPON NITROGEN UTILIZATION OF MAIZE

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A culture pot experiment was carried out in a growth-house to examine the nitrogen utilization of maize plants at different nitrogen doses and two soil moisture levels.

The amount of applied nitrogen significantly determined the development, the dry matter yield, the nitrogen uptake and nitrogen utilization of the whole maize plant as well as of its most important product, the grain. The effect of nitrogen doses significantly depended upon the water supply of plants. By comparing the nitrogen utilization of plants in the same treatment, but at different water supply, it is clear that the better water supply ensures a higher nitrogen utilization.

Introduction

According to our experimental results (SZLOVÁK 1983) nitrogen doses significantly influence the dry matter yield, transpiration and water utilization of maize plants. Nitrogen utilization is also greatly influenced by nitrogen doses. But the effect of nitrogen doses upon nitrogen utilization varies in different experiments. According to the data of BARTHOLOMEV and HILTBOLD (1952) and of HAMID (1972) the increased nitrogen doses improve the nitrogen utilization while MCNEAL et al. (1971), furthermore STANFORD and HUNTER (1973), obtained opposite results. The contradictory results are due very likely to the different conditions in which the experiments were carried out.

Since the nutrient uptake is highly dependent upon water supply, the nitrogen utilization was examined at two soil moisture levels.

Material and method

On 5 May 1977 maize seeds were planted in pots in a growth-house. During the day the plants were exposed to environmental factors nearly identical with those in the field since the culture pots containing the maize plants were placed on carts running on tracks and moved every morning into a space enclosed by a wire net (Fig. 1). During the night, and whenever it rained, the carts were pushed under a glass roof.

In the 20×25 cm white enamel painted pots for 6 kg absolute dry soil, air dry alluvial-meadow surface soil (Szarvas-Bikazug) was placed. The maximum waterholding capacity of the soil was determined in laboratory and a value of 49.90% was obtained (expressed in

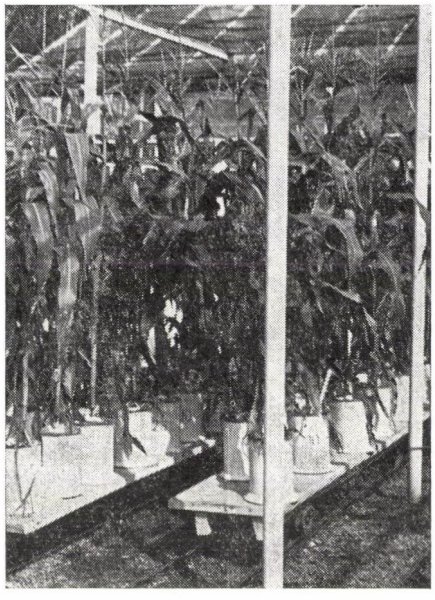

Fig. 1. Maize plants on movable carts in the growth-house

weight % of absolute dry soil). Other main characteristics of the soil used in the experiment: pH (H_2O): 6.73, pH (KCl): 5.69, total salt %: 0.06, humus %: 2.06, total N %: 0.14.

P_2O_5 Al—P } method	mg/100 g soil	6.47
K_2O Al—K } method	mg/100 g soil	18.20
K_A (soil plasticity index)		44.57

The soil on which the hybrid Mv-580 maize plants developed was filled with water to 50- and 70% of its maximum waterholding capacity at daily waterings.

The active ingredients of fertilizers per pot were as follows: N: 2.4 g (ammonium nitrate), P_2O_5: 1.2 g (superphosphate), K_2O: 1.2 g (potash, KCl). The lowest nitrogen dose was 1.2 g and the highest 7.2 g per pot. The increment of the nitrogen doses was 1.2 g. All nitrogen treatments received the same amount of phosphorus and potash.

Five seeds were sown in each pot. After emergence the plants were thinned to one in each pot. There were ten replicates for all treatments. For transpiration measurements the pot soil was covered with PVC film; thus the water loss from the pot was due solely to the transpiration by plants. The amount of transpired water was restored by daily waterings. The plants were harvested on 15 September 1977. At harvest the roots were washed out of the pot soil. After separation, the plant parts were dried at an oven temperature of 60 °C. The drying continued until there was no more change in the subsequent weight measurements. Kjeldahl method was used for the total nitrogen determination.

Results and discussion

In our culture pot experiment a great portion of the inorganic nitrogen mixed with the soil, because of the dense root formation, was available for the plants. This nitrogen uptake was promoted by the diffusion formed along the concentration gradient, which was brought about by the relatively low

nitrogen concentration on the root surface, the water movement caused by transpiration, and also by the growth of roots to new soil regions where the nitrogen concentration was still high.

The nitrogen content of maize in per cent and total was examined per plant parts as well as for the whole plant.

Root

The nitrogen concentration in roots, with one-one exception at both soil moistures, increased with raising nitrogen doses. At low soil moisture, with the exception of plants in the $N_{1.5}$PK-treatment, the nitrogen concentration was higher than at optimum water supply (Table 1). But this deviation was only slight and not significant. The total nitrogen content in roots increased to $N_{1.0}$PK-treatment at low soil moisture and to $N_{1.5}$PK-treatment at optimum water supply; then with increasing nitrogen doses it decreased. Thus, though the nitrogen concentration maximum was observed in plants grown at the highest nitrogen dose, the total nitrogen content, because of decreasing root weight, declined at higher nitrogen doses. While at low soil moisture the nitrogen concentration of roots increased with one expection, the total nitrogen with the exception in PK-treatment, as a result of better developed plants, showed higher total nitrogen values at optimum water supply. The obtained data clearly indicate that the greatest difference in total nitrogen content of roots, developed at 2 soil moistures, was at the highest nitrogen dose. In this treatment the total nitrogen content of roots developed at optimum water supply was 1.99-fold, compared to that at low soil moisture level.

Stem

The nitrogen content of stem, leaf-sheat, shank and tassel was analyzed together, and henceforth we consider all these as stem. As at roots, the nitrogen concentration of stem at optimum water supply in the control and PK-treated plants was higher than at the lowest nitrogen dose ($N_{0.5}$PK). At low soil moisture in the case of stem, this could be observed only in the control plants. As at roots, in the nitrogen containing treatments, the nitrogen concentration was higher at low soil moisture; and at both soil moisture levels, in accordance with the raising nitrogen rates, it increased. The total nitrogen content also rose with increasing nitrogen rates, except at the highest nitrogen dose at low soil moisture, where a slight decrease could be observed. In the $N_{0.5}$PK-treatment at optimum water supply the total nitrogen content of stem is higher than at low soil moisture, but with increasing nitrogen rates (with the exception of the highest) the total nitrogen content is higher in stems of low soil moisture. This is very likely due to the fact that at optimum water

Table 1

The effect of increasing N doses upon the N concentration

Treatment	Plant								
	Root						Stem		
	Soil moisture in per cent								
	50			70			50		
	Dry matter, g	Nitrogen		Dry matter, g	Nitrogen		Dry matter, g	Nitrogen	
		%	g		%	g		%	g
Control	6.85	0.959	0.064	8.43	0.923	0.086	23.64	0.295	0.070
PK	9.47	0.849	0.081	8.52	0.792	0.067	25.77	0.219	0.057
$N_{0.5}PK$	16.02	1.102	0.177	28.71	0.749	0.231	33.40	0.241	0.082
$N_{1.0}PK$	18.00	1.501	0.270	27.39	1.051	0.308	34.95	0.537	0.192
$N_{1.5}PK$	15.29	1.467	0.230	27.67	1.494	0.423	34.30	1.376	0.473
$N_{2.0}PK$	11.65	1.817	0.213	27.09	1.476	0.401	33.67	1.912	0.711
$N_{2.5}PK$	11.57	1.883	0.199	20.44	1.808	0.376	34.17	2.351	0.794
$N_{3.0}PK$	8.09	2.262	0.186	17.39	2.084	0.371	24.56	3.135	0.748
LSD 0.1%	6.61	0.252	0.108	6.61	0.252	0.108	12.91	0.378	0.243
1.0%	5.14	0.196	0.084	5.14	0.196	0.084	10.03	0.293	0.189
5.0%	3.90	0.149	0.064	3.90	0.149	0.064	7.62	0.222	0.143

Significant difference between the same fertilizer

	Dry matter, g	Nitrogen		Dry matter, g
		%	g	
LSD 0.1%	6.37	0.25	0.104	13.18
1.0%	4.95	0.20	0.081	10.24
5.0%	3.76	0.15	0.062	7.78

supply, with the exception at the lowest nitrogen dose, more nitrogen was translocated from stem to the grain than at low soil moisture. This seems to be supported also by the data of total grain nitrogen content at the two soil moistures in Table 2. It can be seen that, in the $N_{1.0}PK$-treatment, the grain of plants developed at optimum water supply contained 1.53 times as much total nitrogen as the grain in the same treatment at low soil moisture. With increasing nitrogen doses the differences increased, with the exception of the highest nitrogen dose.

Leaf-blade

In the nitrogen metabolism the leaves are the most important plant parts since they are the main site of amino acid synthesis, and also they play a significant role in the storage of nitrogen.

The nitrogen concentration of leaf-blades at both soil moisture levels

and total N content of roots, stems and leaf-blades of maize

parts								
			Leaf-blade					
of its maximum waterholding capacity								
70			50			70		
Dry matter, g	Nitrogen		Dry matter, g	Nitrogen		Dry matter, g	Nitrogen	
	%	g		%	g		%	g
34.43	0.286	0.093	8.73	0.508	0.045	11.33	0.516	0.057
36.06	0.262	0.098	11.64	0.467	0.052	11.94	0.514	0.062
53.17	0.207	0.122	18.65	0.651	0.122	22.44	0.553	0.122
55.56	0.298	0.169	16.90	1.023	0.171	27.30	0.774	0.218
52.51	0.545	0.300	16.80	1.190	0.217	24.50	1.192	0.289
51.49	0.857	0.466	16.28	1.509	0.247	24.91	1.228	0.315
45.06	1.449	0.649	15.18	1.704	0.250	24.19	1.424	0.343
47.66	2.212	1.090	14.03	1.920	0.267	21.78	1.607	0.363
12.91	0.378	0.243	4.31	0.195	0.047	4.31	0.195	0.047
10.03	0.293	0.189	3.35	0.151	0.037	3.35	0.151	0.037
7.62	0.222	0.143	2.55	0.115	0.028	2.55	0.115	0.028

treatments of the two soil moisture groups

Nitrogen		Dry matter, g	Nitrogen	
%	g		%	g
0.363	0.243	4.31	0.195	0.047
0.282	0.189	3.35	0.151	0.037
0.214	0.143	2.55	0.115	0.027

increases with rising nitrogen doses. While the nitrogen concentration of leaf-blades of the control and PK-treated plants is higher at optimum water supply, in the nitrogen containing treatments, with the exception of $N_{1.5}PK$-treated plants, where the deviation is very small, the nitrogen concentration of leaf-blades is higher at the low soil moisture. It is noteworthy that at optimum water supply, in the lowest nitrogen dose treatment, the nitrogen concentration of leaf-blades is only 0.04% higher than in control and PK-treated plants; nevertheless this slight nitrogen concentration difference doubled the total nitrogen content of leaf-blades. It seems that there is a threshold value here since a minute change in nitrogen concentration was accompanied by a great change in the total nitrogen content of leaf-blades. The minimum nitrogen concentration rise in leaf-blades greatly increased the grain yield and total nitrogen content. Certainly it should be taken into account also, that the high total nitrogen content of leaf-blades in the $N_{0.5}PK$-treatment is a result of a nearly twofold dry leaf-blade weight. The nitrogen

Table 2

The effect of increasing N doses upon the N concentration

Treatment	Plant								
	Husks						Cob		
	Soil moisture in per cent								
	50			70			50		
	Dry matter, g	Nitrogen		Dry matter, g	Nitrogen		Dry matter, g	Nitrogen	
		%	g		%	g		%	g
$N_{0.5}PK$	6.68	0.393	0.026	12.09	0.357	0.036	11.65	0.373	0.043
$N_{1.0}PK$	7.54	0.593	0.047	15.67	0.457	0.070	12.71	0.384	0.045
$N_{1.5}PK$	7.20	0.818	0.052	14.58	0.586	0.085	10.55	0.486	0.051
$N_{2.0}PK$	8.52	1.003	0.077	15.34	0.666	0.096	8.36	0.724	0.058
$N_{2.5}PK$	8.82	1.173	0.105	12.45	0.905	0.108	8.65	0.767	0.067
$N_{3.0}PK$	6.23	1.596	0.099	12.89	0.984	0.149	5.83	0.895	0.056
LSD 0.1%	4.79	0.290	0.047	4.79	0.290	0.047	3.37	0.152	0.027
1.0%	3.72	0.225	0.037	3.72	0.225	0.037	2.62	0.118	0.021
5.0%	2.83	0.171	0.027	2.83	0.171	0.027	1.99	0.090	0.016

Significant difference between the same fertilizer

	Dry matter, g	Nitrogen		Dry matter, g
		%	g	
LSD 0.1%	20.29	0.178	0.391	3.37
1.0%	15.77	0.138	0.304	2.62
5.0%	11.98	0.105	0.231	1.99

rate increase raises the total nitrogen content of leaf-blades and, contrary to the stem at optimum soil moisture in the treatments of $N_{1.0}PK$, $N_{1.5}PK$, $N_{2.0}PK$ and $N_{2.5}PK$, the total nitrogen content does not decrease, compared to the plants at low soil moisture.

The leaf-blade quality of maize differs at various nitrogen and water supplies and this may greatly affect the grain yield. Experimental results of SZLOVÁK (1981) indicate that the nitrogen doses and also the water supply significantly affects the grain yield calculated per unit weight of dry leaf-blade. At optimum nitrogen dose and soil moisture, 4.03 g grain were produced per 1 g dry leaf-blade. The applied lower nitrogen dose as well as the higher nitrogen doses decreased the grain yield calculated per unit of leaf-blade weight. At suboptimum water supply by the same nitrogen dose, instead of 4.03, only 2.85 g grain yield was ensured per 1 g dry leaf-blade.

Since there was no proper grain development at control and PK-treated plants, the nitrogen concentration and the total nitrogen content of husks, grain and cob were examined only in the nitrogen treatments.

and total N content of husks, cob and grain of maize

parts								
			Grain					
of its maximum waterholding capacity								
70			50			70		
Dry matter, g	Nitrogen		Dry matter, g	Nitrogen		Dry matter, g	Nitrogen	
	%	g		%	g		%	g
17.90	0.424	0.066	51.57	1.394	0.710	69.36	0.972	0.673
24.58	0.367	0.089	48.47	2.003	0.972	106.84	1.410	1.486
22.71	0.441	0.100	41.87	2.160	0.965	97.38	1.864	1.808
21.94	0.434	0.095	34.05	2.351	0.892	93.23	2.042	1.879
19.18	0.534	0.094	23.88	2.372	0.567	80.64	2.094	1.737
16.07	0.584	0.088	19.54	2.471	0.557	56.22	2.319	1.392
3.37	0.152	0.027	23.30	0.178	0.460	23.30	0.178	0.460
2.62	0.118	0.021	16.19	0.138	0.320	16.19	0.138	0.320
1.99	0.090	0.016	12.30	0.105	0.243	12.30	0.105	0.243

treatments of the two soil moisture groups

Nitrogen		Dry matter, g	Nitrogen	
%	g		%	g
0.142	0.027	5.36	0.276	0.047
0.095	0.021	4.17	0.215	0.037
0.084	0.016	3.16	0.163	0.027

Husks

The nitrogen concentration and the total nitrogen content of husks at both soil moistures, with one exception, rose in accordance with the increasing nitrogen doses. The nitrogen concentration of husks in all treatments was higher at the low soil moisture. There was a higher total nitrogen content at optimum water supply (Table 2).

Cob

At low soil moisture the nitrogen effect upon nitrogen concentration of cobs was similar to that of husks. Also as at husks, in the highest nitrogen dose treatment, because of smaller cobs, the total nitrogen content of cobs decreased. At optimum water supply, the nitrogen concentration did not rise according to the increasing nitrogen doses and the total nitrogen content of cobs beginning with $N_{2.0}$PK-treatment decreased. In all treatments, the total nitrogen content of cobs was higher at optimum soil moisture.

Grain

Grain is the most important plant part that is always carried away from the field. This brings about the loss of nitrogen in the soil. As our experimental results indicate, most of the nitrogen taken up by plants is stored in grain. In the treatment securing the highest grain yield ($N_{1.0}PK$, optimum soil moisture) the total nitrogen ratio of grain and the whole plant (including the roots) is 63.50%. If this ratio is calculated only to the above ground plant, excluding the roots, then a value of 73.13% is obtained. ELEK (1981) examined this ratio in large scale field experiments and concluded that 67.8% of the nitrogen taken up by maize is in the grain. The nitrogen content of grain is important because it determines its protein content which plays a significant role in nutrition.

At both soil moistures the nitrogen concentration of grain increased in accordance with the nitrogen rate rise. In the field experiments LATKOVICS (1975) also observed a rise in nitrogen concentration of grain as the nitrogen doses increased. In our experiment at low soil moisture in all treatments the nitrogen concentration was higher. With the exception of the lowest nitrogen dose treatment at optimum soil moisture the total nitrogen content of grain was above that at low water supply. Most nitrogen in grain was in the $N_{1.0}PK$-treatment at suboptimum soil moisture and in the $N_{2.0}PK$-treatment at optimum water supply. After reaching the maximum, at both soil moistures, the grain nitrogen content decreased as the nitrogen rates increased.

At optimum soil moisture most grain and highest total dry matter yield was obtained when the nitrogen concentration of leaf-blades was 0.77% and that of whole plants 0.91% (Tables 1, 2 and 3). According to STANFORD and HUNTER (1973) the highest grain yield was obtained when the nitrogen concentration of ripe wheat biomass was 1.4%. In our experiment at suboptimum soil moisture, a lower nitrogen concentration of leaf-blades (0.65%) and of the whole plant (0.85%) was required to ensure the maximum grain yield. The highest dry matter yield of the whole plant was obtained when the nitrogen concentration of leaf-blade was 1.02% and that of the whole plant 1.24%. Though it should be remarked here that the maximum dry matter yield of the whole plant in the $N_{1.0}PK$-treatment differed only slightly and not significantly from the dry matter weight of plants in the $N_{0.5}PK$-treatment, where the nitrogen concentration of both, leaf-blades and the whole plants was lower.

THOMPSON et al. (1975) studied the nitrogen effect upon wheat grain yield under irrigated conditions and found that the semi-dwarf wheat varieties gave the highest yield when the nitrogen concentration of grain was 2.3%. In our experiment at low soil moisture, highest grain yield (51.57 g) was obtained when the nitrogen concentration of grain was 1.39% and at optimum

Table 3

Dry matter weight and nitrogen content (in per cent and g) of the whole maize plant

Treatment	Soil moisture in per cent of its maximum waterholding capacity											
	50						70					
	Whole plant		N content		N content		Whole plant		N content		N content	
	g	in % of $N_{1.0}PK$	%	in % of $N_{1.0}PK$	g	in % of $N_{1.0}PK$	g	in % of $N_{1.0}PK$	%	in % of $N_{1.0}PK$	g	in % of $N_{1.0}PK$
Control	39.22	28.33	0.465	37.59	0.178	10.48	55.81	21.62	0.429	47.14	0.235	10.04
PK	46.88	33.87	0.406	32.82	0.190	11.90	56.68	21.96	0.402	44.18	0.227	9.70
$N_{0.5}PK$	137.96	99.67	0.849	68.63	1.160	68.32	205.03	79.44	0.611	67.14	1.251	53.46
$N_{1.0}PK$	138.42	100.00	1.237	100.00	1.698	100.00	258.09	100.00	0.910	100.00	2.340	100.00
$N_{1.5}PK$	127.27	91.94	1.562	126.27	1.988	117.08	239.36	92.74	1.256	138.02	3.005	128.42
$N_{2.0}PK$	111.32	80.42	1.890	152.79	2.199	129.51	241.99	93.76	1.348	148.13	3.252	138.97
$N_{2.5}PK$	102.20	73.83	1.948	157.48	1.982	116.73	205.94	79.79	1.611	177.03	3.308	141.37
$N_{3.0}PK$	78.80	56.93	2.441	197.33	1.913	112.66	177.84	68.91	1.923	211.32	3.443	147.14
LSD 0.1%	23.69	17.11	0.243	19.64	0.408	24.03	23.69	9.18	0.243	26.70	0.408	17.44
1.0%	18.42	13.31	0.189	15.28	0.317	18.67	18.42	7.14	0.189	20.77	0.317	13.55
5.0%	13.99	10.11	0.143	11.56	0.241	14.19	13.99	5.42	0.143	15.71	0.241	10.30

Significant difference between the same fertilizer treatments of the two soil moisture groups

LSD 0.1%	22.61	0.239	0.384	22.61	0.239	0.384
1.0%	17.58	0.186	0.299	17.58	0.186	0.299
5.0%	13.35	0.141	0.227	13.35	0.141	0.227

water supply when it was 1.41% (106.84 g). As the data indicate, the nitrogen concentration of grain at highest yields of the two soil moistures differed only very slightly. At the same time the grain yield of plants developed at optimum soil moisture was 2.07 times higher than at suboptimal water supply. It can be definitely stated that the relation between the nitrogen concentration of grain and grain yield is largely influenced by water supply.

Whole plant

At both soil moistures, most dry matter was produced in the $N_{1.0}PK$-treatment. Then the rising nitrogen doses negatively affected the dry matter yield (Figs 2 and 3). Though in the $N_{0.5}PK$-treatment at both soil moistures the nitrogen uptake by plants was almost the same (1.16 g at low and 1.25 g at optimum soil moisture), the dry weight of plants developed at suboptimum water supply was only 67.29% of those grown at optimum soil moisture. The nitrogen uptake of plants grown at optimum soil moisture in the $N_{1.0}PK$-treatment was already significantly higher (2.34 g) than at low soil moisture (1.70 g). The higher nitrogen uptake was due to the better developed plants. In this treatment ($N_{1.0}PK$) the dry matter yield further decreased at low soil moisture related to the optimum water supply (53.63%). As the data indicate, the proper water supply plays a very important role in the dry matter production. While at optimum water supply most nitrogen was taken up in the $N_{3.0}PK$-treatment, the highest nitrogen dose, at suboptimum soil moisture occurred in the $N_{2.0}PK$-treatment; then, as nitrogen rates increased a decrease in nitrogen uptake took place. The total nitrogen taken up by plants in the $N_{2.0}PK$-treatment at suboptimum soil moisture was lower than in the $N_{1.0}PK$-treatment at optimum water supply.

Though the total nitrogen content of plants developed at suboptimum water supply was lower than at optimum soil moisture, the absence of better growth and higher dry matter yield was not due to the limited nitrogen but to the deficient water supply and the lower hydratation of plant cells, since the nitrogen concentration of plants was higher at low than at optimum soil moisture.

At both soil moistures, the high nitrogen rates hindered the plant growth and the nitrogen concentration of these plants was above those whose dry matter yield was higher. This can partly be explained by the fact that the ion uptake is an energy consuming process, thus less energy is available for plant growth. When VEEN (1980) increased the ion concentration of nutrient solution, an increased ion uptake and higher respiration rate of maize was observed. He showed that when more energy was used for ion uptake, less remained for plant growth. In our experiment, besides the energy consuming high rate ion uptake, the plant growth was largely restricted by the increasing nitrogen

Fig. 2. The effect of nitrogen doses upon maize development at two soil moisture levels 8 July

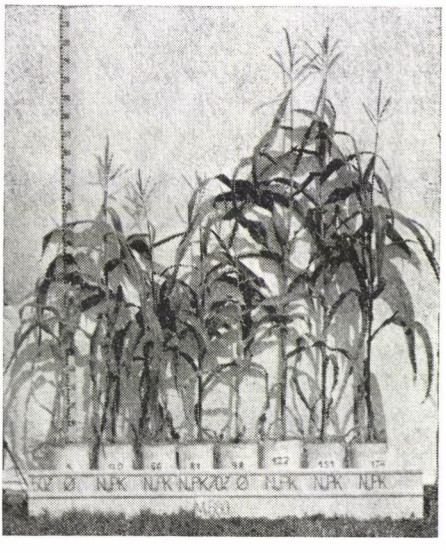

Fig. 3. The effect of nitrogen doses upon maize development at two soil moisture levels 17 August

rates by which the high nitrogen concentration of soil hindered the proper water supply required for normal plant development.

The nitrogen concentration and the total nitrogen content of plants (including the roots) at both soil moisture levels followed the principle observed at plant parts. While the nitrogen concentration was higher at plants developed

at suboptimum soil moisture in all treatments, the total nitrogen content of plants was higher at optimum water supply because the plants grown at optimum soil moisture were better developed.

Nitrogen efficiency

BRUETSCH and ESTES (1976) examining 12 maize genotypes showed that the nitrogen efficiency is genotype dependent. Depending upon genotype, 59–82 kg dry matter was produced per 1 kg absorbed nitrogen. It can be seen in Table 4 that the nitrogen doses as wel as the soil moisture levels in the nitrogen treatments significantly influence the dry matter yield calculated per a unit weight of absorbed nitrogen. A better water supply ensures a higher dry matter yield per unit weight of nitrogen taken up by plants. At both soil moisture levels, most dry matter per unit weight of absorbed nitrogen was produced at the PK-treated — and control plants. It is noteworthy that the difference in water supply in the PK-treatment practically did not effect the dry matter yield per unit weight of absorbed nitrogen.

The lowest dry matter yield calculated per 1 g of absorbed nitrogen in the nitrogen treatments is only 35.10% of the highest dry matter yield per 1 g

Table 4

Dry matter yield of the whole maize plant calculated per 1 g N taken up by plant and per 1 g N applied

Treatment	Whole plant, g		Total N taken up by whole plant, g		Dry matter yield calculated per 1 g N taken up by plant, g		Applied N doses, g		Dry matter yield calculated per 1 g N applied, g	
	Soil moisture in per cent of its maximum waterholding capacity									
	50	70	50	70	50	70	50	70	50	70
Control	39.22	55.81	0.178	0.235	224.83	237.61				
PK	46.88	56.68	0.190	0.227	247.44	249.99				
$N_{0.5}PK$	137.96	205.03	1.160	1.251	118.74	166.54	1.2	1.2	114.97	170.85
$N_{1.0}PK$	138.42	258.09	1.698	2.340	80.70	110.55	2.4	2.4	57.67	107.54
$N_{1.5}PK$	127.27	239.36	1.988	3.005	64.92	80.01	3.6	3.6	35.35	66.49
$N_{2.0}PK$	111.32	241.99	2.199	3.252	58.05	74.67	4.8	4.8	23.92	50.42
$N_{2.5}PK$	102.20	205.94	1.982	3.308	51.50	62.90	6.0	6.0	18.23	34.32
$N_{3.0}PK$	78.80	177.84	1.913	3.443	41.68	52.27	7.2	7.2	11.91	24.70
LSD 0.1%	23.69		0.408		31.50				11.19	
1.0%	18.42		0.317		24.49				8.65	
5.0%	13.99		0.241		18.60				6.55	
Significant difference between the same fertilizer treatments of the two soil moisture groups										
LSD 0.1%	22.61		0.384		30.81				10.95	
1.0%	17.58		0.299		23.95				8.47	
5.0%	13.35		0.227		18.19				6.41	

Table 5

The physiological and agronomic efficiency of N as a function of N doses and two soil moistures

Treatment	Grain weight, g		Total N taken up by whole plant, g		Grain yield calculated per 1 g N taken up by plant, g		Applied N doses, g		Grain yield calculated per 1 g N applied, g	
	Soil moisture in per cent of its maximum waterholding capacity									
	50	70	50	70	50	70	50	70	50	70
$N_{0.5}PK$	51.57	69.36	1.160	1.243	44.35	55.85	1.2	1.2	42.98	57.80
$N_{1.0}PK$	48.47	106.84	1.698	2.340	28.44	45.78	2.4	2.4	20.20	44.52
$N_{1.5}PK$	41.87	97.38	1.988	3.005	21.89	32.15	3.6	3.6	11.63	27.05
$N_{2.0}PK$	34.05	93.23	2.199	3.252	15.67	28.64	4.8	4.8	7.10	19.42
$N_{2.5}PK$	23.88	80.64	1.982	3.308	11.75	24.24	6.0	6.0	3.98	13.44
$N_{3.0}PK$	19.54	60.00	1.913	3.443	10.38	17.48	7.2	7.2	2.71	8.33
LSD 0.1%	23.30		0.479		7.44				9.45	
1.0%	16.19		0.371		5.75				7.31	
5.0%	12.30		0.281		4.35				5.53	
Significant difference between the same fertilizer treatments of the two soil moisture groups										
LSD 0.1%	20.99		0.449		7.61				9.14	
1.0%	15.77		0.347		5.88				7.07	
5.0%	11.98		0.263		4.45				5.35	

nitrogen taken up by plants at suboptimum soil moisture. This ratio decreases only slightly (31.39%) at optimum water supply.

Dry matter yield calculated per 1 g nitrogen applied, at both soil moisture levels decreased to a greater extent, as the nitrogen doses increased, than when dry matter yield was calculated per unit weight of nitrogen absorbed by plants.

It is obvious that the nitrogen and water supply plays an important role in the dry matter production of the whole maize plant; but it is even more important to see what effect has the amount of absorbed and supplied nitrogen as well as the available water upon the yield of the most important plant part, the grain. As indicated in Table 5 the physiological efficiency of nitrogen, that is the grain yield calculated per unit weight of absorbed nitrogen, at both soil moisture levels decreased as the nitrogen rates increased. In all nitrogen treatments the physiological efficiency of nitrogen was significantly ($P < 0.01$) higher at optimum water supply than at low soil moisture. The data obtained by PINO (1979) also indicate that there is a decrease of nitrogen efficiency in biomass and grain production of wheat as the nitrogen doses rise.

The agronomic efficiency of nitrogen, that is the grain yield calculated per unit weight of applied nitrogen, declined to a greater degree than the physiological efficiency of nitrogen as the nitrogen rates increased. At the

smallest nitrogen dose there was only a slight difference between the physiological and agronomic efficiency of nitrogen at the same soil moisture level, but in the $N_{3.0}PK$-treatment at low water supply the physiological efficiency of nitrogen was 3.83-fold of the agronomic efficiency of nitrogen. This ratio at optimum soil moisture is 2.10-fold.

The ratio of the applied — and of the total nitrogen absorbed by the whole plant is presented in Table 6. The nitrogen utilization was calculated by the use of difference method; that is, from the total nitrogen uptake of plants in different treatments, was subtracted the total nitrogen uptake by control plants. According to the data of DOMBOVÁRI (1977, 1980) the nitrogen utilization of soybean, depending upon the treatments varies between 42–85%.

In our experiment at suboptimum soil moisture the best nitrogen utilization (81.79%) was calculated in the $N_{0.5}PK$-treatment. At optimum water supply the highest nitrogen utilization (87.68%) was observed in the $N_{1.0}PK$-treatment. The high nitrogen utilization is due mainly to the development of dense root system in the culture pots and also to the exclusion of leaching which is common under field conditions. At both soil moistures, above the best nitrogen utilization, the increasing nitrogen rates decreased the nitrogen utilization. By comparing the nitrogen utilization of the same nitrogen treat-

Table 6

Nitrogen utilization as a function of N doses and two soil moistures

Treatment	Dry weight of the whole plant, g		Total N taken up by whole plant, g		Total N content difference between control and other N treatments, g		N dose per culture pot, g		N utilization per cent calculated for the whole plant, g	
	Soil moisture in per cent of its maximum waterholding capacity									
	50	70	50	70	50	70	50	70	50	70
Control	39.22	55.81	0.178	0.235						
$N_{0.5}PK$	137.96	205.03	1.160	1.243	0.982	1.016	1.2	1.2	81.79	84.64
$N_{1.0}PK$	138.42	258.09	1.698	2.340	1.519	2.104	2.4	2.4	63.31	87.68
$N_{1.5}PK$	127.27	239.36	1.988	3.005	1.809	2.770	3.6	3.6	50.26	76.95
$N_{2.0}PK$	111.32	241.99	2.199	3.252	2.020	3.016	4.8	4.8	42.09	62.84
$N_{2.5}PK$	102.20	205.94	1.982	3.308	1.804	3.073	6.0	6.0	30.06	51.21
$N_{3.0}PK$	78.80	177.84	1.913	3.443	1.734	3.207	7.2	7.2	24.09	44.55
LSD 0.1%	25.30		0.438		0.479				10.61	
1.0%	19.67		0.341		0.371				8.21	
5.0%	14.86		0.257		0.281				6.21	
Significant difference between the same fertilizer treatments of the two soil moisture groups										
LSD 0.1%	24.53		0.411		0.445				10.06	
1.0%	19.07		0.319		0.345				7.78	
5.0%	14.41		0.275		0.261				5.89	

Table 7

The amount of water (kg) transpired per 1 g of N taken up by maize plant

Treatment	Transpired water, kg		Total N taken up by the whole plant, g		Transpired water per 1 g N taken up by the whole plant, kg		Total N content of the above ground plant part, g		Transpired water per 1 g N contained in the above ground plant part, kg		Total N content of grain, g		Transpired water per 1 g N contained in grain, kg	
	Soil moisture in per cent of its maximum waterholding capacity													
	50	70	50	70	50	70	50	70	50	70	50	70	50	70
Control	7.48	10.80	0.178	0.235	42.60	46.18	0.114	0.150	68.29	78.21				
PK	8.29	10.65	0.190	0.227	43.88	47.12	0.108	0.160	77.65	67.09				
$N_{5.0}PK$	19.50	31.57	1.160	1.251	16.98	25.48	0.983	1.020	20.59	31.07	0.710	0.673	28.09	47.09
$N_{1.0}PK$	18.07	34.22	1.698	2.340	10.68	14.65	1.428	2.032	12.71	16.92	0.972	1.486	18.81	23.36
$N_{1.5}PK$	17.91	35.53	1.988	3.005	9.14	11.96	1.758	2.582	10.39	13.95	0.965	1.808	19.36	20.97
$N_{2.0}PK$	15.49	32.55	2.199	3.252	7.15	10.05	1.986	2.851	7.95	11.51	0.892	1.879	18.69	17.50
$N_{2.5}PK$	14.00	27.37	1.982	3.308	7.20	8.42	1.783	2.932	8.01	9.55	0.567	1.737	31.16	17.11
$N_{3.0}PK$	10.04	23.70	1.913	3.443	5.36	7.04	1.727	3.072	5.92	7.95	0.557	1.392	19.08	18.36
LSD 0.1%	3.03		0.408		5.16		0.394		12.10		0.460		11.02	
1.0%	2.36		0.317		4.01		0.306		9.41		0.320		8.57	
5.0%	1.79		0.241		3.03		0.232		7.14		0.243		6.47	
Significant difference between the same fertilizer treatments of the two soil moisture groups														
LSD 0.1%	3.00		0.384		5.43		0.374		12.20		0.391		11.32	
1.0%	2.33		0.299		4.22		0.290		9.48		0.304		8.80	
5.0%	1.77		0.227		3.19		0.220		7.20		0.231		6.65	

ments at the two soil moisture levels, it is clear that the favourable water supply ensures a better utilization of nitrogen. The plants developed at optimum water supply, with the exception in the lowest nitrogen dose treatment, significantly ($P < 0.001$) utilized the nitrogen better than those grown at suboptimum soil moisture. The greatest difference in the nitrogen utilization of plants grown at two soil moisture levels was observed in the $N_{1.5}PK$-treatment.

Transpiration calculated per unit weight of absorbed nitrogen

The amount of transpired water per unit weight of nitrogen in the whole plant, the above ground plant part and grain is presented in Table 7. At both soil moisture levels the transpiration rate per 1 g of absorbed nitrogen by the whole plant was significantly higher at control and PK-treatment than at nitrogen treatments. The rising nitrogen rates decreased the transpiration per a unit weight of absorbed nitrogen. In all treatments the plants grown at optimum soil moisture transpired more per unit weight of nitrogen absorbed. The relation between the nitrogen content of above ground plant part and transpiration, with the exception in the PK-treatment, at the two soil moistures is similar to the case of whole plants. The above findings do not apply to the grain, since at the three high nitrogen doses, the plants transpired more water per unit weight of grain nitrogen content at low than at optimum soil moisture level.

In all treatments the plants well supplied with water absorbed less nitrogen per 1 kg transpired water, than those developed at suboptimum soil moisture. At low soil moisture in the $N_{0.5}PK$-treatment the plants absorbed 59.49 and in the $N_{3.0}PK$-treatment 190.54 mg nitrogen per 1 kg transpired water. At optimum soil moisture level these values are lower; 39.63 and 145.27 mg.

In culture pot experiment of K. Debreczeni (DEBRECZENI 1970) at optimum water and nutrient supply the maize plants absorbed 47.9 mg nitrogen per 1 kg transpired water. In our weighing lysimeter experiment in a plant stand, the nitrogen uptake by maize was 56.07 mg per 1 kg evapotranspired water (SZLOVÁK 1974).

In conclusion, it can be inferred from the results of this investigation that the nitrogen doses and water supply significantly effect the dry matter weight, the nitrogen concentration and the total nitrogen content of the maize plant parts, as well as the nitrogen utilization of the whole plant.

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EFFECT OF PLANT POPULATION ON FOUR ISOGENIC LINES OF BARLEY (*HORDEUM VULGARE* L.)

I. Yields and yield components

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Studies on the effects of four population levels as obtained by using hill spacing of 15, 22.5, 30 and 45 cm on the yield and yield components of 4 isogenic lines of barley, differing in leaf width, showed that the highest grain yield, number of heads per metre-square and total dry weight were obtained from the 15 cm hill spacing (i.e. a population of 222.2 plant/m^2). Number of kernels per head, 1000-kernel weight, weight of kernels per head and harvest index were all highest at the widest hill spacing (45 cm), and the values of the above-mentioned characters were reduced significantly as the spacing between the hills decreased from 45 cm.

The over-all mean of the four isogenic line showed that the grain yield/ha of the wide leaf type isogenic line was substantially lower than the yield of the other three lines. The highest grain yield/ha was given by the narrow leaf type line, which had a yield nearly similar to those of double recessive normal and double dominant normal leaf type isogenic lines.

Introduction

The productivity of a genotype depends upon its morpho-physiological characteristics. However, the realization of the complete yield potential depends upon the availability of suitable environment conditions. The number of plants per unit is an important component of yield per unit area. However, the number of plants that could optimize the production will depend upon the plant morphology.

GARDENER (1966) compared 3 barley varieties known to be high-yielding with 3 known to be low-yielding. He found that narrow leaves were characteristic of high-yielding varieties. According to TANNER (1966), the yields of barley and wheat varieties used in his studies related to the width and angle of leaves.

This research was designed to compare the response of 4 isogenic lines of barley, differing in their leaf width, to four different plant populations (seeds planted in four equidistant hill spacings).

Material and methods

Two of the 4 isogenic lines used in this study were radiation-induced mutants of cv. Hunchen, having narrow or wide leaves. When both mutants were crossed, they produced an F_2 ratio of 10 normal plants to 3 plants with narrow and 3 plants with wide leaves (RAMAGE and DAY 1961). This ratio was explained on the assumption that both the double dominant and double recessive genetypes produced normal phenotypes. Both mutants are controlled by a single recessive pair of genes. The phenotypes and genotypes of these isogenic lines are as follows:

Isogenic line phenotype	*Isogenic line genotype*
Normal (double dominant)	
Leaf width	Nlh nlh Wlh Wlh
Narrow leaf	nlh nlh Wlh Wlh
Wide leaf	Nlh Nlh wlh wlh
Normal (double recessive)	
Leaf width	nlh nlh wlh wlh

The isogenic lines were planted in early December, in a moist seed bed in a grabe leam soil. The seeds were treated with Vitravax, for the control of loose smut [*Usiilago nuda* (Jens) Rostr.]. A stand for each isogenic line was established by hand thinning, after 4 weeks from planting, at 5 plants per hill, at spacing of 15, 22.5, 30 and 45 cm. These hill spacings gave 4 plant population treatments of 222.2, 98.7, 55.5 and 24.7 plants per m^2 respectively. The experimental design was a complete randomized block with 8 replicates. Plot size at sowing was the same for all the treatments. The plots consisted of 144, 64, 36 and 16 hills, respectively for 15, 22.5, 30 and 45 cm hill to hill distance treatments. Yield date were taken from 0.81 m_1 area which consisted of 36, 16, 9 and 4 hills for the above-mentioned 4 treatments, respectively.

Results

Grain yield per ha was significantly affected by plant population and isogenic lines. The highest grain yields of 8325 kg/ha were obtained from plant population of 222.2 plant/m^2 which surpassed the yields of 98.7, 55.5 and 24.7 plants/m^2 population by 24.6%, 39.8% and 42.0%, respectively (Table 1). The yield of 98.7 plants/m^2 treatment was 20.2% and 23.1% higher

Table 1

Effect of hill spacings on grain yield (kg/ha) of 4 isogenic lines of barley

Isogenic line genotype	Hill spacing (cm)				Isogenic line mean
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	8497 a*	6895 b	4213 d	5070 c	6169 a
nlh nlh Wlh Wlh	8632 a	6365 b	5732 b	4803 c	6383 a
Nlh Nlh wlh wlh	7911 a	5300 b	4535 c	4543 c	5572 b
nlh nlh wlh wlh	8259 a	6561 f	5568 c	4912 d	6325 a
Hill spacing mean	8325 a	6280 b	5012 c	4832 c	6612

* Means in rows within the table and isogenic line and hill spacing means followed by the same letter are not significantly different at the 0.05 level according to Student—New man—Keul's Multiple Vange Test.

Table 2

Effect of hill spacings on dry matter yields (metric tons/ha) of 4 isogenic lines of barley

Isogenic line genotype	Hill spacings (cm)				Isogenic line mean
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	37.3 a*	27.6 b	15.7 c	14.3 c	23.7 ab
nlh nlh Wlh Wlh	33.9 a	22.4 b	22.7 b	16.1 c	23.8 ab
Nlh Nlh wlh wlh	32.8 a	24.1 b	19.6 d	14.8 d	22.8 b
nlh nlh wlh wlh	35.0 a	32.2 a	18.5 c	13.7 c	24.9 a
Hill spacing mean	34.8 a	26.6 b	19.1 c	14.7 d	23.8

* Means in rows within the table and isogenic line and hill spacing means followed by the same letter(s) are not significantly different at the 0.05 level according to Student—New man—Keul's Multiple Range Test.

than that for 55.5 and 24.7 plants/m^2 treatment, respectively. No significant differences in grain yields were observed between the last 2 population treatments.

The double dominant normal leaf, narrow leaf and the double recessive normal leaf type isogenic line, had similar yields and their average yield (6292 kg/ha) was significantly higher than that of wide leaf type isogenic line by 11.4% (Table 1).

The significance of the interaction of isogenic line×plant populations indicated that morphological type had an effect on the response to population. All the isogenic lines responded differently to the increase in plant population per ha. Although the maximum grain yields were obtained for all the isogenic lines at 222.2 plants/m^2 population. Results also indicated that the evaluation of these genotypes needs to be made in a hill spacing narrower than that used in this investigation.

The total dry weight significantly increased with the increase in plant population. The highest weight was produced at 222.2 plants/m^2 population, which out-yielded these of 98.7, 55.5 and 24.7 plant/m^2 treatment by 23.6%, 45.1% and 57.8%, respectively (Table 2).

Differences among the isogenic lines in total dry matter weight/ha were significant. The double recessive normal leaf type isogenic line produced 8.4% higher yield than the wide leaf type isogenic line.

BRINKMAN et al. (1979) found that the increased grain and straw yields in narrower rows (7.5 and 15 cm) were attributed to greater number of heads per unit area: while BALDWIN (1963) determined the increase in head size, rather than head number, as the primary factor contributing to grain yield improvements, when small grains were grown in narrow rows. These contrasting responses agree with HOLLIDAY's (1963) conclusion that yield improvements with narrow spacing were attributed to increases in either head number

or head size, or to complementary increases in both. Although root development was not measured in this experiment, FOTH et al. (1964) reported that root growth in narrower rows increased concomitantly with improved grain and straw production. These authors, and HOLLIDAY (1963) have concluded that the efficiency of nutrient uptake by roots is not greater in narrower rows, and have suggested that increased plant productivity in narrower rows is probably due to a more efficient use of light in photosynthesis. Because small grains needed in narrower rows have a better spatial arrangement, they intercept more light earlier in the growing season. This increases both total photosynthesis per unit area and plant productivity.

Number of heads per m^2 was affected significantly by population and isogenic line (Table 3). Number of heads per m^2 decreased sharply and significantly with decreasing plant population from 222.2 plants/m^2 to 24.7 plant/m^2. Number of heads per m^2, developed from the highest plant population, exceeded those from 98.7, 55.5 and 24.7 plants/m^2 population treatment by 30.7%, 45.2% and 55.2% respectively. Population of 98.7 plants/m^2 produced an extra 20.9% and 44.7% heads per m^2 over those of 55.5 and 24.7 plants/m^2 treatments, respectively. The 55.5 plants per m^2 had 18.2% more heads per metresquare than the treatment with 24.7 plants/m^2 (Table 3).

The narrow leaf type isogenic line had significantly more heads per m^2 than those obtained from the double recessive normal leaf, the double dominant normal leaf and wide leaf type isogenic lines by 11.2%, 31.5% and 37.0% respectively.

The interaction between population and isogenic lines was significant for the number of heads per unit area.

The number of kernels per head had a reverse trend to that of the grain yield and number of heads per unit area. With each additional increase in plant population there was a parallel decrease in number of kernels per head (Table 4).

Table 3

Effect of hill spacings on number of heads per szuare metre of 4 isogenic lines of barley

Isogenic line genotype	Hill spacing (cm)				Genotype line mean
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	1056.0 a*	737.5 b	492.9 c	466.4 c	688.2 c
nlh nlh Wlh Wlh	1450.7 a	1035.6 b	870.4 c	664.9 d	1005.4 a
Nlh Nlh wlh wlh	998.9 a	601.1 b	845.7 bc	446.9 c	633.1 c
nlh nlh wlh wlh	1285.9 a	944.2 b	774.7 c	566.6 d	892.8 b
Hill spacing mean	1197.9 a	829.6 b	743.9 c	536.2 d	804.9

* Means in rows within the table and isogenic line and hill spacing means followed by the same letter are not significantly different at the 0.05 level according to the Student—New man—Keul's Multiple Range Test.

Table 4

Effect of hill spacings on number of kernel per head of 4 isogenic lines of barley

Isogenic line genotype	Hill spacings (cm)				Isogenic line means
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	22.2 a*	24.7 a	24.8 a	26.8 a	24.6 a
nlh nlh Wlh Wlh	19.9 a	20.8 a	20.8 a	22.1 a	20.9 c
Nlh Nlh wlh wlh	23.4 a	25.6 a	25.6 a	26.5 a	25.3 a
nlh nlh wlh wlh	20.6 a	21.8 a	21.9 a	24.0 a	22.1 b
Hill spacing mean	21.5 d	23.2 c	23.3 b	24.8 a	23.2

* Means in rows within the table and isogenic line and hill spacings mean followed by the same letter are not significantly different at the 0.05 level according to the Student—New man—Keul's Multiple Range Test.

The isogenic lines with double dominant normal leaf type and wide leaf type had significantly higher number of kernels per head than the narrow leaf and double recessive normal leaf type isogenic lines. The double recessive normal leaf type isogenic line had a significantly higher number of kernels per head than the narrow leaf type isogenic line. All the isogenic lines had the greatest number of seeds per head at a plant population of 24.7 plant/m^2 (Table 4).

The highest 1000-kernel weight was obtained from a population density of 24.7 plant per m^2. Although the weight was reduced significantly as plant population was increased from 24.7 to 222.2 plants per m^2, the changes in 1000-kernel weight did not have a distinguishable pattern of response (Table 5).

The differences among the line, for 1000-kernel weights, were significant. The double dominant normal leaf type isogenic line had the highest weight. The lowest weight came from the narrow leaf type isogenic line, which was less affected by the decrease in plant population per ha. Weight of kernels

Table 5

Effect of hill spacings on weight of 1000-kernel (g) of 4 isogenic lines of barley

Isogenic line genotype	Hill spacings (cm)				Isogenic line mean
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	37.8 a*	38.2 a	38.6 a	41.9 a	39.1 a
nlh nlh wlh wlh	29.8 a	29.5 a	30.5 a	31.9 a	30.4 d
Nlh Nlh wlh wlh	34.6 a	34.4 a	36.4 a	38.1 a	35.9 b
nlh nlh wlh wlh	31.0 a	32.0 a	33.4 a	35.2 a	39.2 c
Hill spacing mean	33.2 c	33.5 c	34.7 b	36.8 a	34.6

* Means in rows within the table and isogenic line and hill spacing means followed by the same letter are not significantly different at the 0.05 level according to Student—New man—Keul's Multiple Range Test.

per head was significantly affected by the hill spacing and isogenic lines. The highest weight was obtained from the lowest population and the weight was reduced significantly as the population increased (Table 6). Among the isogenic, the double dominant normal leaf type line had the highest seed weight per head and its weight averaged 6.2%, 24.3% and 34.8% higher than that of the wide leaf, double recessive normal leaf and narrow leaf type isogenic lines, respectively.

All the isogenic lines showed an increase in the head weight with a decrease in plant population. Both the double recessive dominant normal leaf and wide leaf type isogenic lines had higher seed weight per head, at all the four plant populations, in comparison with the other 2 isogenic lines. The lowest population averaged 17.7% higher in kernel weight per head than the highest population level for the wide leaf and normal double dominant leaf type isogenic line, respectively (Table 6).

Table 6

Effect of hill spacings on weight of kernel per head (8) of 4 isogenic lines of barley

Isogenic line genotype	Hill spacing (cm)				Isogenic line mean
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	0.87 a*	0.94 a	0.96 a	1.12 a	0.97 a
nlh nlh Wlh Wlh	0.59 a	0.61 a	0.63 a	0.70 a	0.63 d
Nlh Nlh wlh wlh	0.83 a	0.88 a	0.93 a	1.01 a	0.91 b
nlh nlh wlh wlh	0.68 a	0.70 a	0.73 a	0.84 a	0.74 c
Hill spacing mean	0.74 c	0.78 b	0.81 b	0.92 a	0.81

* Means in rows within the table and isogenic line and hill spacing means followed by the same letter are not significantly different at the 0.05 level according to Student—New man—Keul's Multiple Range Test.

Table 7

Effect of hill spacings on harvest index of 4 isogenic lines of barley

Isogenic line genotype	Hill spacing (cm)				Isogenic line mean
	15	22.5	30	45	
Nlh Nlh Wlh Wlh	0.23 c*	0.25 bc	0.27 b	0.35 a	0.28 a
nlh nlh Wlh Wlh	0.25 b	0.28 ab	0.25 b	0.30 a	0.27 a
Nlh Nlh wlh wlh	0.24 b	0.22 b	0.24 b	0.31 a	0.25 b
nlh nlh wlh wlh	0.23 c	0.20 c	0.30 b	0.36 a	0.27 a
Hill spacing mean	0.24 c	0.24 c	0.27 b	0.33 a	0.27

* Means in rows within the table and isogenic line and hill spacing means followed by the same letter(s) are not significantly different at the 0.05 level according to Student—New man—Keul's Multiple Range Test.

The harvest index increased significantly with the decrease in population. This response was the reverse of the response in grain yield and total dry matter. The lowest harvest index value came from the wide leaf type isogenic line, and the highest from the normal double dominant leaf isogenic line (Table 7). Generally, all the isogenic lines had their highest harvest index value at the 45 cm hill spacing, or at the lowest plant population per ha.

Discussion

RASMUSSON and CANNEL (1970), conducted a study with barley to find which component was most important in selection for yield. They concluded that selection for number of heads per hill was similar to selection for yield. Selection for kernel weight was similar to selection for yield in one population, but not in the other. Yield was reduced in one population when selected for number of seeds per hill.

When barley was planted at high population, the number of kernels per head, kernel yield per head and harvest index were reduced, due to severe competition (Tables 4, 6 and 7). The total dry matter per ha, number of heads per unit area and grain yield per ha were all increased with population increase (Tables 2, 3 and 1).

The effect of selecting for a component to increase yield will therefore depend on the extend of compensatory effects in the other components, determined by the environment and by the genetic history of the population, which would dictate the linkage relationships of the genes controlling the components (RASMUSSON and CANNEL 1970).

In this study, the narrow leaf type isogene had the highest number of headst per unit area, the smallest head and kernel size, low 1000-kernel weight and low grain yield per head. In the case of the wide leaf type isogenic line, the reverse was true.

Increases in number of shoots per unit area would affect the source by increasing the leaf area, and any photosynthesizing parts of the plant and the sink, by providing more heads per unit area. High genetic ceilings for number of heads and kernels per head could result in a large early demand on nutrients and water which could then become limiting at later more critical stages of growth (RASMUSSON and CANNEL 1970).

In breeding for cereal crops, the primary objective is to create new cultivars, which give more yield per unit area than do existing cultivars. Since grain yield is the end product of the plant life cycle and is greatly affected by the dynamic environmental factors during growth, it is thought that selection for its components might indirectly increase this yield. Thus it seems that there is a balancing mechanism among the number of heads per unit area,

1000-kernel weight and the number of kernels per head, which is a biological characteristic of small grain plants. Selection for an increase in one component can cause a reduction in one or both of the other components, and so the yield is not increased.

The present study showed that the narrow leaf isogenic line had the largest number of heads per unit area, but simultaneously it had the lowest number of kernels per head and the lowest 1000-kernel weight. The wide leaf type isogenic line was characterised by the number of heads per unit area, higher number of kernels per head and larger 1000-kernel weight.

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COMBINING ABILITY FOR YIELD AND FORAGE COMPONENTS IN DIALLEL CROSSES OF SOME MALE-STERILE AND MAINTAINER LINES OF SORGHUM

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For substantial yield and quality improvement, a thorough understanding of the genetics of forage quality and yield components are required. Attempts were made to study the magnitude of heterosis, nature of gene action for substantial yield and quality improvement in sorghum. The diallel analysis of heterosis and combining ability, involving five male-sterile lines and its maintainers was performed for height of plant, leaf length, leaf breadth, leaf surface, number of leaf/tillers, leaf weight, stem weight, grain weight, green fodder yield. The study revealed that the heterosis was limited to the characteristics of height of plant, leaf length, leaf breadth. These results suggest a deficiency of genetic diversity among the male-sterile lines. However, considerable additive gene action was indicated for all the characteristics studied. Investigation on the nature of combining ability in citoplasmatic male-sterile lines showed the importance of general combining ability.

Introduction

The concept of combining ability is increasingly important in plant breeding. It is especially useful in connection with hybridization in which it is desired to study and compare the performances of lines in hybrid combination. For substantial yield and quality improvement, thorough understanding of the genetics of forage quality and forage yield components are required. Attempts were made to study the magnitude of heterosis, the general and specific combining ability in relation to diallel crossing systems. Combining ability analysis, as proposed by GRIFFING (1956) has widely been used in crop plants for testing the performance of genotypes in hybrid combinations and the gene action involved in controlling a quantitative trait SAINI and PARODA (1977).

Most of these studies in sorghum genes were performed on grain sorghum and hardly any information is available on combining ability of forage genotypes (GOVIL and MURTY 1964, 1973, CROOK and CASADY 1974). In view of this, it is necessary to study the extent of heterosis and the nature of combining ability in some crosses involving cytoplasmatic male sterile, and maintainer lines of forage sorghum.

NIEHAUS and PICKETT (1966) emphasized the greater importance of general combining ability over specific combining ability of *Sorghum vulgare*. Such data are not available in crosses involving male-sterile and maintainer lines.

This study with five cytoplasmatic male-sterile lines of divers origin and with its maintainer lines intended to provide data in this area of interest.

Material and methods

The five male-sterile lines involved in the set of diallel crosses, including reciprocals are AK-1, AK-2, AK-3, AK-4 and AK-5; maintainer lines are BK-1, BK-2, BK-3, BK-4 and BK-5 respectively.

The ten possible F_1's and their reciprocals together with the male-sterile lines were grown during 1981 in a randomized block design in five replications. The material was sown in a plot of four rows of five meters, with a spacing of 60×10 cm between and within the rows. Individual plant observations were recorded on thirty plants, excluding border plants. 102 kg N per hectare as ammonium nitrate and 90 kg P_2O_5 per hectare as super-phosphate were applied as a basal dressing.

The characteristics studied were height of plant leaf length, leaf breadth, leaf surface, number of leaves per plant, leaf weight, stem weight and green fodder yield.

Combining ability effects and variances were calculated according to the method I (and model I) of GRIFFING (1956) where the parents, F_1's and reciprocals are included. In order to study grain yield and to produce single and three-way cross sorghum $\times$ sudangrass hybrids, sorghum sudanense was applied as pollinisator.

Table 1

Performance of male-sterile lines and hybrids for the characteristics studied

Male-sterile line/hybrid	Height of plant	Leaf length	Leaf breadth	Leaf surface (cm^2)	Number of leaves/ tillers	Leaf weight	Stem weight	Grain weight	Green fodder yield
	cm					kg/12 m^2			
AK-1	87.6	45.4	6.3	886.9	6.2	2.86	16.77	2.15	21.78
AK-2	122.8	47.8	5.8	1022.5	7.4	2.76	23.71	2.17	28.64
AK-3	156.6	52.8	8.6	2022.1	8.8	4.58	58.52	3.94	67.04
AK-4	132.8	58.4	8.1	1787.8	7.6	4.71	31.14	3.11	38.96
AK-5	119.6	55.4	6.9	1278.2	6.7	3.84	34.81	4.07	42.72
Mean (AK)	123.9	51.9	7.1	1399.5	7.3	3.75	32.99	3.09	39.83
AK-1 $\times$ BK-2	118.6	51.2	7.1	1230.4	6.7	3.66	24.34	2.87	30.87
AK-1 $\times$ BK-3	139.5	53.0	7.2	1492.2	8.2	3.82	46.88	4.26	54.96
AK-1 $\times$ BK-4	104.1	57.6	8.2	1949.1	7.3	4.75	30.51	3.55	38.81
AK-1 $\times$ BK-5	110.2	58.6	7.3	1554.9	7.1	4.36	26.23	3.28	33.87
AK-2 $\times$ BK-3	141.6	51.9	7.6	1683.9	8.5	3.94	56.03	4.63	64.60
AK-2 $\times$ BK-4	121.8	55.5	8.2	1698.4	7.5	4.53	38.04	3.74	46.31
AK-2 $\times$ BK-5	128.3	60.5	7.8	1809.7	7.6	4.76	37.76	4.09	46.61
AK-3 $\times$ BK-4	155.3	56.7	9.0	2087.0	8.3	5.06	59.06	4.85	68.97
AK-3 $\times$ BK-5	161.5	63.0	9.3	2589.0	8.8	5.89	67.21	5.20	78.30
AK-4 $\times$ BK-5	135.7	66.2	7.0	2062.7	8.0	4.65	37.10	3.99	45.74
Mean (SC)	131.7	57.4	7.9	1815.7	7.8	4.54	42.32	4.05	50.91
$LSD_{0.05\%}$	4.54	2.67	0.39	38.79	0.98	0.35	1.19	0.12	1.98

Table 2

Analysis of variance for the characteristics studied (Mean squares)

Source	Height of plant	Leaf length	Leaf breadth	Leaf survace (cm^2)	Number of leaves/tillers	Leaf weight	Stem weight	Grain weight	Green fodder yield
	cm					kg/12 m^2			
General combining ability	1933.81***	113.56***	237.80***	660 092.97***	26.59*	1.881***	1115.19***	2.80***	1029.07***
Specific combining ability	95.12*	20.34*	103.85*	160 457.98*	2.34	0.61*	68.72*	0.52*	832.41***
Reciprocal effects	45.42*	13.76	19.95	21 752.08	0.94	0.10	10.96	0.22	45.85*

* Significant at the 0.05 probability level
*** Significant at the 0.001 probability level

Table 3

General combining ability effects for characteristics studied

Male-sterile lines	Height of plant	Leaf length	Leaf breadth	Leaf surface (cm^2)	Number of leaves/tillers	Leaf weight	Stem weight	Grain weight	Green fodder yield
	cm					kg/12 m^2			
AK-1	−18.08	−3.17	−5.00	−309.8	−0.61	−0.49	−11.51	−0.63	−12.66
AK-2	− 3.50	−2.95	−4.36	−243.5	−0.16	−0.45	− 4.47	−0.35	− 5.31
AK-3	20.82	−0.85	6.10	242.3	0.82	0.27	17.09	0.72	18.15
AK-4	− 0.18	2.55	3.70	184.5	0.03	0.36	− 1.28	−0.01	− 0.94
AK-5	0.94	4.41	−0.46	126.4	−0.08	0.31	0.17	0.27	0.75

Results

The data on the performance of the male-sterile lines and hybrids are given in Table 1. The cross combination AK-2 × BK-3 exhibited maximum heterosis for grain weight with an increase of 51.6% over the mean of both lines. The cross combination AK-3 × BK-5 represented maximum heterosis for stem weight and AK-2 × BK-5 for leaf weight with an increase of 44.0% and 44.2% respectively over the mean of the parents. Negative heterosis was noticed in the cross combination AK-1 × BK-4 for height of plant and in the cross combination AK-1 × BK-3 for leaf breadth. The cross combination AK-3 × BK-5 showed maximum heterosis for leaf breadth and leaf length, with an increase of 19.9% and 16.4% respectively over the mean of the parents.

Combining ability analysis revealed significant general combining ability effects for all characteristics studied.

Specific combining ability was found to be important for height of plants, leaf breadth, leaf length, leaf surface, leaf weight, stem weight, grain weight and green fodder yield. Reciprocal effects were also significant for all characteristics except for number of tillers and number of leares (Table 2).

The male-sterile line AK-3 was found to be a good general combiner for most of the characters except leaf length and number of tillers. Their exploitation in a forage sorghum breeding programme would be advantageous. Male-sterile lines AK-4 and AK-5 were found to be a good general combiner for leaf weight and leaf length (Table 3).

The cross combination AK-3 × BK-5 showed good specific combining ability for most of the characters studied while AK-1 × BK-3 for plant height, AK-1 × BK-4 for leaf breadth and leaf surface. The cross combination AK-3 × × BK-5 was found to be a good specific combiner for leaf length and number of leaf/tillers. The cross combination AK-2 × BK-3 exhibited high specific combining ability for grain weight (Table 4).

Table 4

Specific combining ability effects for characteristics studied

Hybrids	Height of plant	Leaf length	Leaf breadth	Leaf surface (cm^2)	Number of leaves/ tillers	Leaf weight	Stem weight	Grain weight	Green fodder yield
	cm^2					kg/12 m^2			
AK-1 × BK-2	10.06	0.99	3.28	51.2	−0.23	0.22	−0.13	0.01	0.05
AK-1 × BK-3	6.64	0.69	− 6.68	−172.8	0.26	−0.35	0.84	0.31	0.77
AK-1 × BK-4	−7.76	1.89	6.62	341.9	0.19	0.50	2.84	0.34	3.71
AK-1 × BK-5	−2.78	1.03	1.18	5.8	0.08	0.16	−2.89	−0.71	−2.72
AK-2 × BK-3	−5.84	−0.63	− 3.42	− 47.4	0.17	−0.26	2.97	0.41	3.06
AK-2 × BK-4	−4.64	−0.43	5.08	24.9	0.09	0.25	3.34	0.25	3.86
AK-2 × BK-5	0.74	2.71	5.94	194.3	0.14	0.51	1.62	0.32	2.47
AK-3 × BK-4	4.54	−1.33	2.62	− 72.4	−0.26	0.05	2.80	0.28	3.06
AK-3 × BK-5	9.62	3.11	10.38	487.7	0.33	0.92	9.49	0.35	10.70
AK-4 × BK-5	4.82	2.91	−11.14	19.3	0.34	−0.41	−2.24	−0.13	−2.77

Discussion

In a systematic breeding programme, the combining ability analysis is increasingly important to study the male-sterile lines with desirable characteristics and good general combining ability for yield as well as yield components.

Crosses between high-yielding male sterile and maintainer lines produced the highest yielding hybrid, but not the highest per cent of heterosis based on the means of the parents. Per cent of heterosis can be misleading as an indicator of combining ability, since a poor hybrid can show a high per cent of heterosis as in the case of the cross combination AK-1 × BK-3. Among the 10 F_1 hybrids only AK-3 × BK-5 yielded significantly more than the best line for all the characteristics except number of leaf/tiller.

Although the amount of the heterosis observed was not impressive for the green matter yield and for its components, in no case F_1-s yielded significantly more then the mean of the corresponding two lines. In addition F_1 hybrids were uniform in germination and they showed rapid early growth. This was also observed by RAO and VENKATESWARLU (1971). The small amount of heterosis suggested a deficiency of genetic diversity among male-sterile lines; since all citoplasmic male-sterile lines were derived from milo and kafir.

General combining ability is primarily due to additive gene action and additive × additive interaction, while specific combining ability is primary due to non-allelic interaction and over-dominance. In analysis of combining ability, g.c.a. and s.c.a. effects were found to be significant for all characteristics studied. Additive gene action appears to be the predominant type of gene action for all characteristics except leaf surface. However, non-additive gene action and reciprocal effects also seem to influence the inheritance of the characteristics; leaf breadth, leaf weight, stem weight, grain weight. Similar results were also reported by SAINI and PARODA (1977). An examination of general combining ability effects revealed that the male-sterile line AK-3 exhibited a good general combining ability for all the characteristics studied. It was the best combiner with BK-5 with respect to height of plant, leaf length, leaf breadth, number of leaf/tillers and leaf surface. The cross combination AK-3 × BK-5 showed good specific combining ability for leaf weight, stem weight, grain weight and green matter yield.

Negative values for general and specific combining ability effects also were obtained for each of the male-sterile lines and each of the cross combinations for more or less characteristics. In spite of the good general combining ability effects of the male-sterile line AK-3, several crosses were not high yielding in the experiment, which suggests epistatic interactions.

The preponderance of variance due to general combining ability for all the characteristics suggests that there is considerable scope for line improve-

ment; further increase in yield may be obtained through the exploitation of additive and additive × additive gene action. The fairly high magnitude of heterosis for forage yield and yield components and the mean squares for specific combining ability for forage yield suggests the possibility of exploiting heterosis in hybrids.

Summary

Attempts were made to study the magnitude of heterosis, nature of gene action for substantial yield and quality improvement in sorghum. The diallel analysis of heterosis and combining ability, involving five male-sterile lines and their maintainers was performed for height of plant, leaf length, leaf breadth, leaf surface, number of leaf/tillers, leaf weight, stem weight, grain weight, green fodder yield. The study revealed that the heterosis was limited for the characteristics of height of plant, leaf length, leaf breadth. These results suggested a deficiency of genetic diversity among the male sterile lines. However, considerable additive gene action was indicated for all the characteristics studied. Investigations on the nature of combining ability in citoplasmic male-sterile lines showed the importance of general combining ability.

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DIALLEL ANALYSIS FOR SEED REACTION OF FOUR INBRED LINES OF MAIZE TO *FUSARIUM* "DAMPING-OFF" DISEASE

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Seeds of 4 maize inbreds and 1 set of 6 F_1's diallel crosses were tested and evaluated under conditions of artificial inoculation by *Fusarium culmorum* and *F. graminearum*, in 4 treatments. Germination percentage, disease rating, shoot height and dry weight were measured and studied, as indicators in determining the reaction of *Fusarium* damping-off for both pre- and post-emergence. Data showed that effect of pathogen treatments and maize entries were highly significant, although the reaction was mainly due to the inoculation of *Fusarium* and partly due to generic differences. The infection severity of *F. graminearum* was significantly higher than of *F. culmorum*. No combining ability was significant, but the magnitude for g.c.a. was much larger than for s.c.a. This indicates an importance of additive gene effects in inheritance of host reaction. However, line MR_{18} had the most resistance, while line B_{14} was the highest susceptibility based on the measurement of mentioned characters. Generally, it seemed that the disease was a stress condition in relation to the host, which curtailed or limited the genetic variability (g.c.a. and s.c.a.). Therefore selection for resistance through genetic mechanisms and use of effective seed treatment fungicides are essential for maize protection against such a disease.

Introduction

Many of soil- or seed-borne fungi may infect germinating maize kernels, causing seed rots and diseases of the seedling, often refered to as damping-off. The terms "pre- and post-emergence damping-off" are used, depending on whether the damage occurs before or after seedling emergence. The pathogens reduce seedling and weaken surviving plants. These diseases are prevalent in poorly drained, cold (less than 10 to 13 °C) and wet soils. Disease severity is affected by planting depth, soil type, age quality of seed, mechanical injury to the pericarp and genetic resistance to infection. Severe infection may kill the embryo before germination (seed rot). Symptoms in post-emergence damping-off include wilting and chlorosis of the levels, and/or rotting of the stem tissue around the soil line (SHURTLEFF et al. 1973 and CASSINI and COTTI 1979). Infection of maize seed by the field fungi, of which *Fusarium* spp., are among the most dangerous, represents a serious problem in all countries which are large producers of this crop (BRODNIK et al. 1978). *Fusarium graminearum (Gibberella zeae)* found in the cooler corn-growing areas, can cause severe seed rot and seedling blight in cold soil. Other fungi such as *F. moniliforme* sometimes are associated with blighted seedling (JUGENHEIMER 1976).

The disease reaction of the tested genotypes is usually examined under artificial inoculation conditions were the rate of infection is high. The artificial inoculation environment is a non-stress environment with respect to disease reaction, while it is a stress environment with respect to the inoculated plants. FREY (1964) defined the stress environment as that in which mean performance for a certain attribute is low. WALKER (1966) reviewed the various techniques used by plant pathologist to identify the best environment for differentiation. All the cited examples could be considered as optimum environments for pathogens. ROY and MURTY (1970) stated that the total genetic variance was higher under optimum than under stress conditions.

The previous work has reported that the genetic nature of inheritance seems rather complex and many genes may be involved. The reaction of single-cross embryos is closely correlated with the average reaction of the parents. Several investigators have concluded that the inheritance of resistance to *Fusarium roseum* f. sp. *cerealis* in the seedling stage is quantitative and conditioned by multiple factors. Four inbred lines and a diallel set of 12 single crosses were tested for seedling reaction to *Fusarium moniliforme*. General combining ability and maternal variances were highly significant, and additive gene action was more important than dominant gene action (HOOKER 1978). This study was initiated in 1983 to obtain data that would add information for the inheritance of reaction of maize to seed rot and seedling disease caused by both *F. culmorum* and *F. graminearum*.

Material and methods

The experimental seeds consisted of 4 maize inbreds viz, MR_4 MR_{18}, B_{14}, and F_{564} and 1 set of 6 F_1 diallel crosses (i.e. P/P + 1/2 entries). In 1983, all entries were grown in a randomized complete block arrangement with two replications at the laboratory (in a growth chamber) of the Institute for Plant Production and Qualification, Budapest. This experiment was conducted under artificial inoculation conditions with the isolates of *Fusarium culmorum* and *F. graminearum* and combinations of them as an soil-borne fungi, in 4 treatments, as follows: (1) control (noninoculated soil), (2) inoculated soil with *F. culmorum*, (3) inoculated soil with *F. graminearum*, (4) inoculated soil by an equal combination of both. The seeds were first disinfected and rinsed in sterile distilled water. Plastic trays measuring $50 \times 40 \times 15$ cm length, width and depth, respectively (with no drain holes) were filled (to 2/3 the tray dimension) with sterile corn field soil.

The inoculation was made by mixing 250 ml of a spore suspension (10^5 spores/ml) of *Fusarium* treatment with the soil in each tray, which contained four plots (rows), and 12 seeds were spaced about 5 cm apart under the soil surface in each row to produce a uniform planting depth of 2.5 cm. Additional water was added to bring the topsoil to field capacity. Then the containers were incubated on a champer bench. Later, the plates received simulated rainfall through a sprinkler, as needed for seedling growth, as carried out by ODIEMAH et al. (1984).

Records were taken after 20 days from planting for germination percentage (G%), disease ratings (DR), shoot height of seedling in cm (SH) and dry weight of seedlings per plot in mg (DW). Seeds whose plumules and radicles had emerged were considered as having germinated. Each hill of plot was rated for disease reaction, using a 1–9 scale based on the degree of infection. On this scale, 1 designated no infection (healthy) and 9, infection primary (seed not germinated and covered with *Fusarium* mycelium or pre-damping off, the whole seedling wilted, or most portions infected), as reported by ODIEMAH et al. (1984).

Data obtained were subjected to factorial analysis on a plot mean basis. However, the method outlined by GRIFFING (1956) was used because of its simplicity. The variation among the entries was partitioned to among parental lines, parents vs crosses (heterosis), among F_k crosses and the remainder. The variation among F_1 crosses was partitioned into general and specific combining ability variances according to the procedure of *Griffing*'s method 4, model 1 (fixed model-selected parent lines). LSD (0.05) was used for comparison between means. Simple correlations among the measured characters were also computed.

Results and discussion

The association among the means of seed traits of parental imbreds, F_1 hybrids and F_2 hybrids were highly correlated, where $r = -0.81$ $P < 0.001$, -0.64 $P < 0.01$ and 0.54 $P < 0.05$ between (G% and DR), (DR and DW) and (SH and DW) respectively. Disease ratings showed highly significant negative correlations with the other traits. Therefore, these characteristics were quite reliable as a measurement indicator for determining the reaction of *Fusarium* damping-off disease in both pre- and post-emergence.

The analysis of variance for the treatments of *Fusarium* sp. and maize entries, concerning the studied characters, is presented in Table 1. Mean square for treatments and entries are highly significant, but the magnitude of treatments is much greater than of entries. It means that the disease reaction is mainly due to the effect of inoculation by *Fusarium* pathogen and partly due to genetic differences among maize entries. The genetic variations are highly significant, with no consistent trend. This leads to the interaction (T×E) which is significant at all cases with the exception of (SH). This indicated that the genotypes respond differently to the change in suscepti-

Table 1

Pertinent sources of the mean squares for four seed characteristics from a four-parent diallel cross of maize, as affected by Fusarium inoculations

S.O.V.	d.f.	G %	SH (cm)	DR 1–9	DW (mg)
Treatments (T)	3	2829.17***	88.60***	79.29***	527 893**
Entries (E)	9	1120.94***	19.59***	17.04***	40 039***
T×E	27	237.73*	4.36 NS	5.73***	13 618***
Parents vs. crosses	1	787.97**	107.36**	2.49 NS	8 291+
Parents	3	440.36 NS	9.22+	32.99***	17 869***
$F_{1,s}$ crosses	5	857.08***	8.27*	10.37***	6 462*
G.c.a.	3	150.81 NS	1.61 NS	1.71 NS	1 124 NS
S.c.a.	2	126.45 NS	0.25 NS	0.71 NS	326 NS
Error	39	122.15	3.35	1.24	2 438
C.V. %		13	15.9	23.1	9.2

+, *, **, ***: indicate significance at the 0.10, 0.05, 0.01 and 0.001 levels of probability, respectively.
NS: indicates non-significance.

bility level of *Fusarium* treatments. It may be due to the stress condition (disease) which curtailed or expanded the variation among used genotypes.

Parents vs crosses was significant at $P < 0.01$ for (G%) and (SH), only. In this case, the difference between the average of single crosses and of the parental lines is an indication of heterosis. However, the variation of crosses apparently gave a better estimate of response to disease reaction than parental lines, where significant differences existed among F_1's crosses with respect to all traits. The variation due to general and specific combining abilities was not significant: though mean squares for g.c.a. were much larger than those for s.c.a. or standard error, indicating a preponderance of additive gene effects. This along with low s.c.a. indicated that dominance was not important

Table 2

Inbred means (on diagonal), F_1's cross means and array means for germination percentage (above diagonal) and disease ratings (below diagonal), as affected by Fusarium treatments in maize

Treatment	Inbred line	MR_4	MR_{18}	B_{14}	F_{564}	Array means
1		6.1 95.0	100.0	80.0	100.0	93.3
2		7.4 95.0	100.0	82.5	92.5	91.7
3	MR_4	7.9 62.5	95.0	40.0	97.5	77.5
4		8.8 65.0	72.5	80.0	85.0	79.2
Mean		7.6 79.4	91.9	70.6	93.8	85.4
1		1.0	1.0 100.0	100.0	100.0	100.0
2		2.7	2.5 100.0	92.5	95.0	95.8
3	MR_{18}	6.9	7.2 92.5	80.0	60.0	78.3
4		6.8	2.7 97.5	82.5	77.5	77.5
Mean		4.4	3.4 97.5	88.8	83.1	87.9
1		6.1	1.0	2.1 95.0	95.0	91.7
2		5.8	6.5	4.5 100.0	72.5	82.5
3	B_{14}	7.9	6.5	7.2 75.0	47.5	55.8
4		6.1	3.3	3.5 87.5	45.0	69.2
Mean		6.5	4.3	4.3 89.4	65.0	74.8
1		1.0	1.0	4.3	1.0 100.0	98.3
2		4.0	2.8	5.2	3.2 100.0	86.7
3	F_{564}	6.0	6.2	7.3	6.3 57.5	68.3
4		6.3	5.9	8.7	2.2 95.0	69.2
Mean		4.3	4.0	6.4	3.2 88.1	80.6
1		2.7	1.0	3.8	2.1	2.4 95.8
2	Mean of	4.2	4.0	5.8	4.0	4.5 89.2
3	crosses/parent	6.9	6.5	7.2	6.5	6.8 70.0
4		6.4	5.3	6.0	7.0	6.2 73.8
Array means		5.1	4.2	5.7	4.9	5.0 82.2

LSD (0.05%)	(G%)	(DR)
Between F. treatment means	= 7.1	0.7
Between entries means	= 11.2	1.1
Between array means	= 4.3	0.6

Table 3

Inbred means (on diagonal), F_1's cross means and array means for shoot height of seedling (above diagonal) and dry weight of seedling (below diagonal), as affected by Fusarium treatments in maize

Treatment	Inbred line	MR_4	MR_{18}	B_{14}	F_{564}	Array means
1		691 11.9	17.6	13.1	14.7	15.1
2		372 11.3	16.6	13.8	12.8	14.4
3	MR_4	348 6.6	13.8	9.1	8.9	10.6
4		255 4.6	8.9	12.4	12.5	11.3
Mean		416 8.6	14.2	12.1	12.1	12.8
1		740	688 12.9	15.6	14.3	15.8
2		698	619 11.7	15.6	13.1	15.1
3	MR_{18}	375	293 8.2	8.8	10.0	10.9
4		559	582 11.0	12.1	10.8	10.5
Mean		543	545 10.8	13.0	12.0	13.1
1		783	709	754 11.8	12.8	13.8
2		683	487	648 11.7	12.7	14.0
3	B_{14}	379	316	299 8.6	10.1	9.3
4		394	567	534 11.3	9.4	11.3
Mean		559	520	559 10.8	11.2	12.1
1		750	734	788	728 11.4	13.9
2		640	540	563	637 10.8	12.9
3	F_{564}	521	364	389	348 8.5	9.7
4		453	469	328	554 9.3	10.8
Mean		591	527	517	567 10.0	11.8
1		758	728	760	757	750.8 14.7
2	Mean of	674	575	578	581	602.0 14.1
3	crosses/parent	425	352	361	425	390.8 10.1
4		469	532	430	417	462.0 11.0
Array means		564	530	532	545	542.8 12.5

LSD (0.05%)	(SH)	(DW)
Between F. treatment means	= 1.2	32
Between entries means	= 1.8	50
Between array means	= 0.9	26

in the inheritance of host reaction to *Fusarium* inoculation. Nevertheless, the combining ability analysis is frequently employed to study the nature of genetic variation and to identify the desirable parents. In this concern, HOOKER (1978) cited several investigators as have concluded that the inheritance of maize seedling reaction to *Fusarium* sp. is quantitative and conditioned by multiple factors. In some crosses resistance seemed to be dominant but in other crosses this was not consistent. Generally, additive gene action was more important than dominant gene action.

Treatment means, entries means and array means are shown in Table 2 for (G% and DR), and in Table 3 for (SH and DW). Data of artificial inoculation assured that all plants of entries were differently infected, in comparison

with non-inoculated treatment (control). Hence, the differences among treatments were significant at $P < 0.05$ in most or all cases. Also, all entries exhibited different susceptibility and tolerance to the changing treatments. By all means, the infection severity of *F. graminearum* was significantly higher than of *F. culmorum*. The ranking based on means of inbred lines per se were not the same of single crosses. This suggests that inbred reaction per se is a poor indication of its performance in hybrids. Although entries showed a different response to treatments they seemed to maintain similar order for all characters. By another meaning, the relative order of treatments within each entry was approximately. The differences and fluctuation between some crosses are due to the interaction (T×E). On the other hand, parental lines consistently gave response to different treatment. Certainly, line MR_{18} had the highest mean for (G%) and the lowest rate for (DR and DW), whereas line B_{14} showed the lowest mean for (G%) and the largest with respect to (DR) Line F_{564} was the shortest in (SH), while line MR_4 had the biggest value for (DW). It means that line MR_{18} had general combiner for resistance or tolerance, while line B_{14} showed general combiner for susceptibility to *Fusarium* damping-off in both pre- and post-emergence.

Furthermore, it can be suggested that the optimal treatment for disease severity was the inoculation method by *F. graminearum*, followed by the combination method of both species, whichever were considered a non-stress condition in relation to the disease and stress environment with respect to the host. Therefore, it may be concluded that the stress condition curtailed or limited the genetic differences among F_1 crosses, especially due to g.c.a. and s.c.a. In general, FREY (1964), ROY and MURTY (1970), ODIEMAH and EL-ROUBY (1973) and ODIEMAH and MANNINGER (1982) reported that the maximum expression of genetic variability was attained in a non-stress environment. Based on the present study, it may be concluded that maize tolerance to soil-borne infection was highly affected by the different species of *Fusarium* much more than by genetic differences. Therefore, it can be suggested that losses from seed rots and seedling disease (*Fusarium* damping-off) have been quite low by selection for resistance through inbreds improvement and hybrids development, planting good quality seed in warm soil and use of effective seed-treatment fungicides.

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EFFECT OF ROUGH DETASSELLING ON SOME AGRONOMIC TRAITS OF MAIZE (*ZEA MAYS* L.) PROGENIES

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It is well known that drastic tassel removal involving a decrease in leaf area causes a reduction in grain yield. But little is known on whether or not rough detasseling modifies the agronomic properties of the progeny. A detasselling experiment was carried out with eight genotypes. The cms analogues of three genotypes were also studied. The seed of four genotypes, whose reduction in yield was different, was produced by the following treatments: normal tassel removal (T), tassel and two leaves removed (T + 2), and tassel and four leaves removed (T + 4). The male partner was common. The seed was tested in a cold test and a sowing time experiment.

The tassel removal trial and the study of *cms* analogues yielded the following results. The grain yield of *cms* analogues, which tend to produce double ears and have a large tassel, increased significantly as compared to normal tassel removal. Rough detasselling decreased the 1000-kernel-weight and the value of the cold test for the progeny, but it proved to have no effect on emergence in the field experiment. Also, the yield of progeny and the yield stability did not change due to the effect of leaf area reduction caused by drastic tassel removal.

Introduction

Seed carries the potential value of a recently bred variety. Therefore, the commercial spread of a new variety is basically determined by how economically the seed can be produced. During the seed production of maize, the detasselling of female rows is an operation which needs great attention and involves many risks. On the one hand, farmers endeavour to detassel safely, but on the other hand, they try to diminish the work involved in detasselling. Therefore, they sometimes carry out this important work earlier than the optimum date or decrease the leaf area significantly.

The yield of basic single crosses may even increase in the case of ideal detasselling (without leaf area reduction) (DUNGAN and WOODWORTH 1939, BERZSENYI 1955, GROGAN 1956, CHINWUBA et al. 1961, HUNTER et al. 1969). But if the leaf area is decreased at detasselling, the yield is reduced depending on the number of leaves removed (DUNGAN and WOODWORTH 1939, BORGESON 1943, KIESSELBACH 1945, HUNTER et al. 1969). HUNTER (1973) tested 10 inbred lines. If only the tassel was removed, the yield increased by 6.9%. If one, two, or three leaves were removed, it caused a 1.5, 4.9 or 13.5% yield reduction, respectively. KIESSELBACH (1945) tested basic single crosses and obtained

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similar results. He found 4.3, 9.3 and 16.4% reductions in yield when removing one, two and three leaves. HUNTER (1973) demonstrated that the degree of yield reduction depended considerably on the genotype.

Insufficient knowledge is available on whether or not rough detasselling has any effect on the agronomic traits of the progeny. The present trials were aimed at answering this question.

Material and methods

The conclusions were based on the results of a 4 year (1978–1981) programme, which included detasselling, sowing time and greenhouse experiments.

Detasselling experiment

Both in this and other experiments the female parents of varieties produced at the Cereal Research Institute were used as the experimental material (Table 2). The experimental material included inbred lines (numbers 5 and 6), sister-line crosses (numbers 1 and 7) and single crosses (numbers 2, 3, 4 and 8).

The experiments were carried out in four replications in a split plot design in the SÁGVÁRI breeding nursery of the institute in 1978, 1979 and 1980. The material was sown with a plant density of 6 plants/m², with a row spacing of 70 cm, on 5 m² plots, using hand guns. After tasselling and before pollen shed the following treatments were conducted: (1) control (not detasselled, fertile), (2) the cytoplasmic male-sterile analogue of the control (not Texas *cms*), (3) only tassel removed (T), (4) tassel and two leaves removed (T + 2),

Table 1

Effect of rough detasselling on grain yield

Genotype	Year	Grain yield of control, kg/m²	Cms analogues	T	T + 2	T + 4	$LSD_{5\%}$
				leaves			
			Percentage increase, +, or decrease, —, compared to control				
GK21 × W153R	1978	0.432		+2.5	— 6.1	—32.6	6.9
	1979	0.422		+2.2	— 4.9	—30.4	7.8
W64A × A632	1978	1.252		—1.2	— 3.0	—15.6	5.3
	1979	1.130		+1.0	0.0	—11.3	7.6
W153R/H × W117	1978	1.217		—0.7	— 6.2	—28.6	8.1
	1979	1.004		+0.2	0.0	—28.7	11.2
GK3 × W153R	1978	1.062		+2.9	+ 0.3	—19.2	7.2
	1979	1.018		+1.8	— 4.0	—26.1	8.3
A632	1979	0.382		—1.6	— 7.4	— 5.3	ns*
	1980	0.357		+3.0	— 2.7	— 6.1	6.5
W64A	1979	0.510	+ 9.1	+3.3	—11.5	—25.7	7.5
	1980	0.506	+10.2	+1.0	—18.8	—31.7	9.3
A632 × A635	1979	0.460	+14.6	+5.7	+10.9	— 4.9	11.5
	1980	0.494	+19.8	+6.2	+ 3.7	— 1.7	8.7
GK71 × GK72	1979	0.640	+ 1.2	—3.4	— 4.6	—27.7	6.3
	1980	0.625	— 0.3	—2.3	— 7.8	—30.7	8.9

* ns = no significant difference

Table 2

Meteorological data for the sowing time experiment (1981)

Parameters studied		Sowing time							
		1 (April 2)		2 (April 12)		3 (April 22)		4 (April 30)	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
No. of days from sowing to emergence		14		18		17		14	
Average soil temperature (a)				2 cm soil depth					
	a	12.02	1.51	11.21	1.61	12.03	1.51	13.86	1.84
No. of days when temperature was lower than 10 °C (b)	b	2	—	6	—	3	—	1	—
from sowing to emergence				5 cm soil depth					
	a	12.51	1.47	11.50	1.60	11.98	1.51	13.67	1.84
	b	2	—	5	—	2	—	1	—
				10 cm soil depth					
	a	12.43	1.43	11.44	1.57	11.88	1.43	13.51	1.77
	b	2	—	5	—	2	—	0	—
Quantity of precipitation 10 days before sowing and from sowing to emergence (mm)		0.5	—	17.80	—	27.50	—	25.60	—
During the 40-day period counted from emergence									
Average air temperature (°C)		13.01	2.06	17.46	2.05	19.22	1.82	19.45	1.79
Precipitation (mm)		31.60	—	44.30	—	74.20	—	81.20	—
No. of sunny hours		254.6	—	290.5	—	317.1	—	312.7	—

Remarks: 1. On 20th April there was a surface frost, so the plants of the first sowing were frostbitten, but later they shooted again.
2. The precipitation supply for the 3rd and 4th sowing times gives similar average values; however, the distribution of precipitation for the 4th sowing time was considerably worse. The soil was dry at emergence, after which it did not rain for 15 days.

tassel and four leaves removed (T + 4). Fertile plants were sown between the plots in order to promote complete fertilization.

Detasselling and sowing time experiments were sown on approximately the same area every year. The soil was well supplied with nutrients. Each year 400 kg/ha active agent was added at a rate of 2 : 1 : 1, N : P_2O_5 : K_2O. One of the most important ecological factors in Hungarian maize production is the quantity of precipitation. In 1978 it rained more than average, while in 1979 and 1980 it rained less than average.

Four genotypes were chosen based on the data of the year 1978 (Table 2). The seed of these genotypes was produced by means of open pollination using GK Exp 1 as the male partner. The following detasselling degrees were applied: T, T + 2, T + 4. The silks were hand-pollinated in order to achieve 100% fertilization. This seed was tested in the greenhouse and in sowing time experiments.

The genotypes for the female partner were chosen with respect to two traits. First, there had to be inbred lines (W64A), sisterline crosses (A632 × A635 and GK21 × W153R) and basic single crosses (W64A × A632) among them. Secondly, they had to respond to different degrees of detasselling with different reductions in yield.

Greenhouse experiment

In the greenhouse experiment the effect of cold treatment on emergence was studied.

Before carrying out the experiment the seeds were steeped in a 1% neomagnole solution for 20 minutes. 300 g screened, airdry soil samples taken from the upper 10 cm layer of a monocultured maize growing are were placed in plastic pots in 4.5–5 cm wide layers. 40 seeds

were sown in each pot and irrigated with 20 ml water. Then the pots were put into a thermostat for 0, 5, 10 or 15 days, with a temperature of 10 °C and a relative humidity of 80%. The control (0 day) treatment was sown 3 days before the pots were taken out of the thermostat and kept in a greenhouse at an air temperature of 20 °C. The cold-treated pots were also kept in the greenhouse. The moisture content of the soil was observed both during cold treatment and germination in the greenhouse and the water loss was replaced if necessary. Emergence was observed for cold-treated plants for 12 days and for control plants for 15 days.

Sowing time experiment

This was carried out in 1980 and 1981 in order to study whether the percentage of field emergence and the agronomic traits of plants sown at different times changed. Plants were sown at intervals of 10 days starting on 2nd April. The data of both years correlate well. The correlation was $r = 0.79^{***}$ (n = 16) for grain yield/m^2. Therefore, only the 1981 data were evaluated.

It was decided to study the 1981 data because that year the weather was worse and more typical of Hungarian conditions than in the previous year. The seedlings of the first sowing time were destroyed at the 2–3 leaf stage by surface frost on 20th April. There was considerable drought during the emergence of the plants sown in the four sowing times because of the bad distribution of precipitation (Table 1).

The experiment was sown with a plant density of 12 plants/m^2, a row spacing of 70 cm and one seed per hill in 5 m^2 plots with 2 rows per plot, randomized, in four replications, using a hand gun. The beginning of plant emergence was carefully observed. 40 days after emergence the plants were thinned to a plant density of 6 plants per m^2. The plants removed were used for the determination of the 40-day dry plant weight.

At 50% silking the blades of the leaves below the ear were removed for plants in the left row of the plot using scissors. The difference in yield between the control row and the defoliated row is a good basis for yield stability estimation (PINTÉR and KÁLMÁN 1981).

As previously mentioned, the quantity of precipitation in 1980 was similar to the average over many years. In 1981 there was a medium quantity of precipitation, in spite of the fact that in the first half of the growing season there was a considerable lack of precipitation.

Results and discussion

Ideal detasselling did not increase the yield significantly (1.3%). A more significant yield increase (9.1%) could be observed for male-sterile *(cms)* analogues (Fig. 1). When the tassel and 2 leaves were removed, it caused a non-significant yield reduction (3.9%). After removal of the tassel and four leaves a significant reduction in yield was observed (21.4%). Both these results and the conclusions drawn from Table 2 (reduction in yield for different genotypes is significantly different) are in agreement with the published data.

The connection between sink and source may be the reason for the different reductions in yield per genotype. According to TOLLENAAR (1977), if a genotype is sink limited, even a reduced leaf area produces enough assimilates for undisturbed seed development. A sink limit may be due not only to genetic but also to production technological reasons. Therefore, if fertilization is defective, there is no need to take into consideration the yield-decreasing effect of rough detasselling.

If detasselling is perfect, especially for male-sterile analogues, the yield increase is significant compared to the control (Fig. 1). The results obtained

*** Reliable at the $P_{0.1\%}$ level.

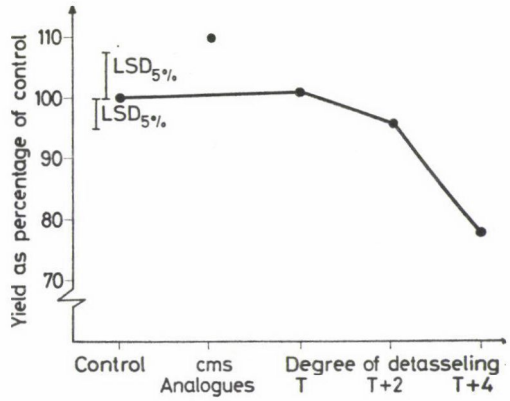

Fig. 1. Changes in quantity of grain yield due to the effect of rough detasselling over the average of the genotypes

by BERZSENYI (1955), GROGAN (1956), DUVICK (1958), CHINWUBA et al. (1961) and GRISWELL et al. (1974) were similar. These authors explained the phenomenon by the fact that maize needs a lot of energy during microsporogenesis. If this process is hindered totally or in a certain phase, the energy can be utilized in the grain yield.

On analysing the yield of the three male-sterile genotypes the question arises why the yield was increased significantly only for two genotypes. This fact may be due on the one hand to the number of ears per plant, and on the other hand to tassel size. The number of ears for W64A was 1.13 in 1979 and 1.15 in 1980; for A632 × A635 these figures were 1.22 and 1.29 and for GK71 × × GK72 1.04 and 1.00, respectively. The tassel of GK71 × GK72 is significanty smaller than that of the other two genotypes. For genotypes which tend to produce double ears there is more chance of incorporating the energy released during microsporogenesis (its quantity is presumably in direct proportion to tassel size). This causes an increase in yield. The same reasons lead to a yield increase for detaselling without leaf area reduction compared to the control plants.

1000-grain-weight decreased for all four hybrids due to the effect of rought detasselling (Table 3). Cold test values (determined in the greenhouse) only decreased significantly for two hybrids. The same treatments had no effect on field emergence, although the date was fixed for plants from the first sowing time when they were 40 days old and after the frost on 20th April. Both the number of days when the soil temperature was lower than optimum and the precipitation supply were significantly different (Table 1) during this season, depending on sowing time. The effect of these factors is shown on the one hand by the number of days between sowing and emergence (Table 1), and on the other hand by the dry weight of 40-day plants (Table 3).

Table 3

Average values of control treatment (1) and significance of differences due to the effect of rough detasselling (2)

Agronomic traits	W64 A-GK Exp 1		(GK21 × W153R)-GK Exp 1		(A632 × A635)-GK Exp 1		W64A × A632 GK Exp 1	
	1	2	1	2	1	2	1	2
1000-grain-weight	297.5	*	361.3	*	323.8	*	367.5	*
Change in greenhouse emergence due to the effect of 10 °C cold treatment								
(a) 0 day	95.8	ns	99.2	**	100.0	ns	94.2	ns
(b) 5 days	95.0	*	90.0	**	100.0	ns	80.0	ns
(c) 10 days	79.2	**	41.7	**	87.5	*	62.7	ns
(d) 15 days	45.0	**	2.5	ns	60.8	ns	30.3	*
Field emergence percentage								
(a) April 2	91.9	ns	95.6	ns	91.1	ns	88.8	ns
(b) April 12	90.7	ns	89.2	ns	88.1	ns	92.5	ns
(c) April 22	94.6	ns	95.8	ns	94.2	ns	94.6	ns
(d) April 30	88.2	ns	79.6	ns	92.1	ns	89.2	ns
Absolute dry weight of 40-day plants (g)								
(a) April 2	2.82	ns	3.55	ns	3.01	ns	2.94	ns
(b) April 12	11.75	ns	13.12	ns	12.03	ns	9.73	ns
(c) April 22	27.11	ns	26.38	ns	27.42	ns	24.81	ns
(d) April 30	23.66	ns	21.39	ns	24.47	ns	23.76	ns
Grain yield (kg/m²)								
(a) April 2	1.221	ns	1.085	ns	1.144	ns	1.115	ns
(b) April 12	1.185	ns	1.104	ns	1.089	ns	1.170	ns
(c) April 22	1.034	ns	0.983	ns	0.970	ns	1.015	ns
(d) April 30	0.902	ns	0.832	ns	0.903	ns	0.810	ns
Yield stability % (Yield reduction due to removing the leaves below the ear at 50% silking)								
(a) April 2	22.6	ns	25.4	ns	21.3	ns	24.9	ns
(b) April 12	25.0	ns	31.2	ns	19.9	ns	27.8	ns
(c) April 22	27.4	ns	30.2	ns	21.5	ns	26.6	ns
(d) April 30	21.5	ns	20.3	ns	26.5	ns	19.1	ns

ns = No significant difference
*, ** = Differences significant at 0.05 and 0.01 levels

(The 40-day plant weights of the fourth sowing time were lower than those of the third. This fact is due to the poor precipitation supply during emergence and the following 15 days.)

Field emergence results and greenhouse cold test results were different because, in spite of the fact that in several cases the soil temperature was lower than 10 °C, during parts of the day or for several days it was higher than that. This fact is demonstrated by the soil temperature data (Table 1).

As the soil temperature is significantly more variable than the temperature during the cold test, cold test values are regarded as important data but only of informative character.

Rough detasselling does not influence either the yielding ability of the progeny or the stability of yield (Table 3). Consequently, detasselling with leaf area reduction afflicts only the seed-producing farms.

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SEVENTEEN YEARS OF EXPERIMENTAL IRRIGATION WITH NITROGEN-CONTAINING SEWAGE

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In irrigation experimentes carried out for 17 years attempts were made to utilize large amounts of sewage containing nitrogen in agriculture as efficiently as possible without causing environmental pollution. To avoid polluting the groundwater the return flow of drain pipes and lysimeteres was thoroughly analysed. Under the given conditions lysimeteres and driven wells were found to be more suitable for environmental protection studies than drain pipes. Irrigation using sewage with a N concentration of 300 mg/l caused no scorching, and if the pH was made acidic this concentration could be increased to as much as 1500 mg/l. For the soil in question a dose of 60 mm supplied at an intensity of 9–10 mm/h was found to be practicable. Irrigation according to a nitrogen/water balance was found to be the best. Large yields may extract as much as 500 kg nitrogen from the soil a year. At present irrigation is concentrated on grasslands and on crops which can be marketed at higher prices. Instead of removing the grass fresh from the field (although this is undoubtedly the was to obtain the largest yield), wilting, removal in the form of hay, and grazing are recommended. The components of fodder crops (crude protein, crude fat, digestible protein, starch equivalent, etc.) were also examined. According to the results of amino acid determinations the composition of fodder crops irrigated with phenolic sewage showed no deterioration. (Total phenol 300 mg/l, monophenol 25 mg/l.) The dry matter content of fodders can be reduced by some 2% with irrigation, while the crude protein content may as much as 2% higher than in the case of a poorer nitrogen supply. Large yields were obtained with both aggressive grass species, and with native grass. Sugarbeet grown as fodder maked good use of sewage; in the best crop years it gave a starch equivalent of 11 t/ha, containing as much as 5.9 t/ha digestible protein, when irrigated with industrial sewage. For some years it has been found profitable to irrigate single-cross maize, soya varieties and beans, though they utilize less nitrogen. The experiments were commissioned from the Plant Production Department of Keszthely University of Agricultural Sciences (and originally from its legal predecessor) by the Central Transdanubian Water Management Directorate, the Várpalota Coal Mines, the Leninváros Chemical Combine, the Research Institute of the Organic Chemistry Industry and the Pét Nitrogen Works. The investigations were carried out with the participation of the Department of Animal Physiology, the Department of Animal Breeding. The Department of Soil Science, the Central Transdanubian Water Management Directorate, the Leninváros Tisza Chemical Combine, the Pét Nitrogen Works and the Várpalota "Jószerencsét" Co-operative Farm.

Introduction

Experiments were carried out for 17 years on the agricultural utilization of industrial sewage rich in nitrogen. The primary task was to avoid environmental pollution. In addition, an attempt was made to find the most economical solution. The aim was to increase economic efficiency by irrigating

the area closest to the source of the sewage and by cultivating crops expected to be more profitable.

After a rise in energy prices more concentrated sewage was used, and crops marketable at higher prices and consuming relatively large amounts of nitrogen were primarily grown. The paper is designed to give information about the experiments, with references to publications having appeared in the meantime.

On of the important tasks of environmental protection nowadays is to avoid, or at least reduce, nitrogen contamination (NH_4, NO_3, NO_2). Attention has been called to the serious problems expected by many authors (SCHÄPERKLAUS 1961, KRÜGER 1966, DROBEK 1968, KICK and KRETSCHMAR 1968, PARR 1972, OLSON 1972, HRIVNÁK 1973, GORIZONTOV 1978, etc.).

The nitrogen pollution of ground-water, lakes, and rivers is increasing. Living waters are not able to decompose the large amounts of NH_4, NO_3 and NO_2, nor can they tolerate them (GAJEWSKI and NŐTLICH 1968). The nitrogen eutrophization is increased not only by industrial, but also by communal sewage, and sewage of animal origin.

The increasing nitrate content of drinking water causes serious damage to health. Apart from methaemoglobinaemia in infants, NO_3 above 10 mg/dm^3 was found to cause vitamin A deficiency and diseases of the thyroid gland in domestic animals; losses of milk production, abortion and other consequences can also be expected (KORZENIOWSKI et al. 1980). Several authors have dealt with the carcinogenic effect of NO_3 (KEMP et al. 1976, 1977, GERRINK 1979, MALESTEIN 1979, In: KORZENIOWSKI et al. 1980).

Sewage can only be purified of nitrogen by the removal of NH_4, NO_3 and NO_2, or through biological denitrification. With a microflora changed by mutation, UJJ-MÉSZÁROS (1981a) achieved much faster decomposition than with wild microflora. DOMKA et al. (1980) report in a summarizing report on various kinds of systems operated with high efficiency.

The elimination of nitrogen is an expensive process. The decision as to whether to destroy the nitrogen or to make use of it in agriculture can only be made in a knowledge of the given economic conditions. The task facing the authors was to elaborate a means of agricultural utilization with the best possible co-ordination of industrial and agricultural interests. If the investments required are equal in value to the cost of destruction, irrigation is still the better solution for the national economy as a whole, because it yields a profit in agriculture.

The size of the profit from irrigation and the efficiency of environmental protection are naturally influences by the amount and composition of the water used, the method of irrigation, the species of crop irrigated, etc. In the case of a large quantity of sewage with a relatively low concentration, crops with high evaporation utilizing as much nitrogen as possible should be irrigated

(NYÉKI and UJJ-MÉSZÁROS 1969). Good N-utilizers are the high-yielding grasses (VERMES and DUMKA 1973, VINCZEFFY 1976, BEATY et al. 1978, FRIBOURGH and OVERTON 1979, SCHMIDT and CALVERT 1979, UJJ-MÉSZÁROS 1981c, d).

How great a nitrogen stress, and how high a N-concentration is permissible: Some authors concerned with the protection of the environment, consider a low, limited amount of nitrogen (60–180 kg) to be most suitable (OLSON 1972, PARR 1972). Others (FALKE and MARTIN 1966, BERG and THIMM 1961, ROTH 1967) suggest using about 480–500 kg/ha. The situation is similar for the N-concentration: BRÜHNE, In: KRÜGER (1963) considers even a concentration of 100 mg/l as too high, although KRÜGER himself used a multiple of this concentration for irrigation (with sewage containing phenol). Sewage containing 600 kg/ha nitrogen at a concentration of 300 mg/l was applied efficiently by NYÉKI and UJJ-MÉSZÁROS (1969) between 1966 and 1968. At Leninváros the same authors used as much as 1040 kg/ha nitrogen (NYÉKI and UJJ-MÉSZÁROS 1971), though favourable effects were only obtained up to 560 kg/ha.

The waste from a nitrogen fertilizer factory, used for irrigation from 1972 on words at Õsi, contained 500–600 kg/ha N. The irrigated crops were examined for components and yield in order to discover which crops utilized the sewage with the highest efficiency.

The present paper gives brief information on he experimence gained in these investigations (NYÉKI and UJJ-MÉSZÁROS 1969, UJJ-MÉSZÁROS 1978, 1979, 1981a, 1981b, 1981c).

Material and methods

In the course of 17 years irrigation experiments were carried out at three experimental sites. The soil analysis data presented refer to the 0–20 cm layer.

(1) The soil of an experimental field irrigated with gas works sewage from the Pét Nitrogen Works at Várpalota (1965–1968) contained about 7–8% humus. Other characteristics of the soil were: pH 8, total N 288 (223–304), P_2O_5 7.2 (2.2–12.8), K_2O 36.25 (18–42) mg/100 g. The quantity of precipitation averaged over many years was 582 mm; the mean temperature was 10.4 °C. The sewage used for irrigation contained 350 mg/l N on average (308–387), 2250 mg/l total salt (mostly sulphates, chlorides), 300 mg/l total phenol, 25 mg/l monohydric phenol, and no heavy metals. On a calcareous soil with good water conductivity SO_4^- and Cl^- were unlikely to cause any damage.

Main treatments:

A_1 irrigation with approx. 300 mm fresh water
300 kg/ha P_2O_5 from fertilizer
350 kg/ha K_2O from fertilizer
600 kg/ha N from fertilizer

A_2 irrigation with approx. 300 mm sewage
300 kg/ha P_2O_5 from fertilizer
350 kg/ha K_2O from fertilizer
600 kg/ha N from gas works sewage

A_3 300 mm irrigation water, half gas works sewage, half fresh water
150 kg/ha P_2O_5 from fertilizer
175 kg/ha K_2O from fertilizer
300 kg/ha N from gas works sewage

A_4 non-irrigated
150 kg/ha P_2O_5 from fertilizer
175 kg/ha K_2O from fertilizer
300 kg/ha N from fertilizer

Plot size: 176 m²

B factors:

B_1 clover with grass
B_2 white clover
B_3 lucerne
B_4 fodder sugar-beet
B_5 maize
B_6 soya

The "B" factors were changed from time to time, and included sunflower, and fodder cabbage; sometimes various hybrids of maize were included as "C" factors, as were different bean, beet and soya varieties. Besides the yields, the dry matter, crude fat, crude protein, etc. contents of the crops were determined. Evaluation was also made on the basis of starch equivalent and digestible protein.

The fodder crops were also examined for amino acid content, essential amino acid index and biological value. Changes in the nutrient content of the soil were also followed with attention.

(2) In the experiments at Leninváros the industrial waste of the Tisza Chemical Combine was used for irrigation. The major data of the prairie soil adjoining the factory, a soil which is inclined to become alkaline, are: 1–1.5% humus; 240 mg (193–294) total N, 15 mg K_2O and 1–6 mg P_2O_5 per 100 g. The quantity of precipitation at the site averaged over many years, was 525 mm; the mean temperature was 9.15 °C. The sewage was diluted to a concentration of 300 mg N/l. (The original total nitrogen was 320–980 mg/l.) The total salt content (mainly SO_4 and Cl) was 50 mg/l. The experiments were carried out from 1969–71.

Main treatments:

A_1 348 kg/ha N
A_2 348 kg/ha N + 87 kg/ha P_2O_5 + 87 kg/ha K_2O
A_3 696 kg/ha N
A_4 696 kg/ha N + 174 kg/ha P_2O_5 + 174 kg/ha K_2O
A_5 1044 kg/ha N
A_6 1044 kg/ha N + 261 kg/ha P_2O_5 + 261 kg/ha K_2O
A_7 non-irrigated
A_8 348 kg/ha P_2O_5 + 348 kg/ha K_2O

Plot size: 207 m²

As "B" factors *Dactylis*, lucerne combined with grass, fodder sugar-beet and maize were used. In another 4 similar experiment hemp was sown. In order to avoid nitrogen contamination, crops supplying high yields and consuming large quantities of nitrogen were again grown. By determining the ratio of N introduced into the soil to that extracted by the plants a N-balance was set up. The nitrogen fixing capacity of the soil was followed with attention and checked by soil analyses.

Attempts were also made to trace the movement of N which had entered the ground-water. One reason for this was that the amount of nitrogen in drinking water wells at a distance of 1 km from the site was found to have risen by some 0.5–1.5%. In order to find out whether it was fertilization or irrigation that had caused the pollution a salting experiment was set up. Close to the site at a depth of 2.5 m (the level of the ground-water) 1500 kg NaCl was washed into the soil. In 4 inspection wells, each driven at a distance of 100 mm from the plant, as well as in the drinking water wells, the appearance of Cl ions, the pH and the conductivity (in mili S) were traced with attention.

The amount and N-concentration of the irrigation water were measured, then compared with the amount and N-concentration of water caught after irrigation in pluviometers placed at different distances from the sprinklers. From this conclusions were drawn on the amount of evaporation.

(3) A trial ground was available at Ősi, on land belonging to the Várpalota "Jószerencsét" Cooperative Farm, from 1972 to 1981. The characteristics of the soil were: humus content 7–8%, K_2O 23–24 mg, P_2O_5 7–17 mg, total N 400 mg per 100 g. The soil, similarly to that at Várpalota, was of marshy origin. The meteorological data agree with those at Várpalota. In order to increase the concentration of N the pH of the sewage was adjusted to a slightly acidic value.

The treatments used in the small-plot experiment were as follows:

Main factors:

A_1 non-irrigated: 5–600 kg/ha N + 300 kg/ha P_2O_5 + 400 kg/ha K_2O from fertilizer

A_2 approx. 200 mm sewage containing 5–600 kg N + 300 kg P_2O_5 + 400 kg/ha K_2O from fertilizer

A_3 approx. 200 mm sewage containing 5–600 kg/ha N + 360 kg/ha P_2O_5 + 480 kg K_2O from fertilizer

A_4 approx. 200 mm sewage containing 5–600 kg/ha N + 420 kg/ha P_2O_5 + 560 kg/ha K_2O from fertilizer.

Plot size: 64 m²

Of the "B" factors, only the natural grass land remained unchanged ever the 10 years, while the other crops were varied. The "B" factors included lucerne, dactylis, onion couch, green canary grass, soya, fodder sugat-beet, beans, etc.

The small-plot experiments were arranged in split-plots as each experimental site, the inner design being a Latin square or random block.

The microplot experiments were also of random block design. At Ősi tall fescue, various grass mixtures, white clover, maize hybrids, and Hungarian brome grass were tested. Sudan grass was sown every year in the microplot experiment where the grasses were tested.

The effects of the microelements Co and Cu were studied in microplots with soils poor in these elements.

The investigations were continued with a view to avoiding N pollution. An analysis was made of the return water of drain-pipes laid in the irrigated plots. At Ősi a total of 15 driven wells were available for the purpose of studying ground-water pollution. Before irrigation the water was pumped out of them; the samples were taken 48 hours after irrigation. The drain-pipes were perforated from 2 m downwards and reached to a depth of 5–7 m.

In order to trace the leaching of N 16 lysimeters were made. They were 86 cm deep and had a surface area of 0.785 m². They were filled with soil from the trial ground, which was thoroughly packed and irrigated for a year, before being sown, first with a mixture of dactylis and white clover, and then with tall fescue as second crop.

The fodder crops were also examined for free NO_3 content. The object was find a correlation between the amount of N applied and the level of free NO_3 found in the plants.

At all three experimental sites the groundwater level was at a depth of 1.5–2.5 m below the soil surface, in a layer with good water conductivity. Naturally, it would have been better if the groundwater had been deeper than 3 m. During the years of the experiments the crops and research projects were always changed according to the problems arising in practice. The analyses were generally performed by the methods accepted in the COMECON countries. The P_2O_5 and K_2O were determined with the *Al* method, *Tyurin*'s method was used for the N determination and *Filimonov*'s method for the determination of free NO_3.

Results

The water was supplied by sprinkling irrigation. In the case of a 300 mg/l N-concentration scorching never occurred on the Várpalota grounds. In Leninváros, on the other hand, the same N-concentration caused severe scorching in beet, maize and even in lucerne. At Ősi even the grasses were seriously damaged when the sewage was diluted with calcareous water. It was assumed that the scorching was caused by the ammonia released when the pH was above 7. The sewage was made slightly acidic with inorganic and

organic acids. In this case scorching did not occur even at a N-concentration of 1000–1500 mg/l. From the results obtained with the method described it can be concluded that evaporation causes a 20–30% loss of N depending on the weather.

The experimental results will now be discussed for each separate topic.

One of the most important tasks was to examine the agricultural crops for quality. In the course of the experimental years even the simplest analyses showed a wide deviation in the data. For example, in the case of rainy weather, treatments irrigated with industrial sewage showed hardly any difference in dry matter content compared with non-irrigated treatments. In fact, in some cases the dry matter content of the non-irrigated treatments was found to be lower. In dry weather, on the other hand, it was the other way round. Over the average of 14 years the dry matter content in the non-irrigated treatments was roughly 2% higher than in those irrigated with industrial sewage. In the case of deep rooted plants (e.g. lucerne) this difference was much smaller (the ground water-level was high). It is interesting to compare the following results obtained at Várpalota:

Percentage dry matter content

	Irrigation with industrial sewage	Irrigation with fresh water	No irrigation
Grass mixture	21.15	22.14	23.58
Lucerne	22.14	19.04	21.16

Table 1

Changes in the components of grass mixtures and lucerne as a percentage of the fresh composition

Crop	Dry matter		Crude protein		Crude fat		Ash		Starch equivalent, kg		Digestible protein, %	
	industrial sewage	non-irrigated	industrial sewage	non-irrigated	industrial sewage	non-irrigated	industrial sewage	non-irrigated	industrial sewage	non-irrigated	industrial sewage	non-irrigated
Grass mixture												
1966	20.61	21.54	5.45	3.58	1.22	0.91	1.97	1.54	8.68	10.05	3.62	2.83
1967	20.23	23.84	4.13	5.78	0.64	0.74	2.18	2.77	11.36	13.52	2.84	3.98
1968	22.62	25.37	5.39	6.68	2.25	0.71	2.01	2.27	13.06	14.12	3.72	4.61
Total	63.46	70.75	14.97	16.04	4.11	2.36	6.16	6.58	33.10	37.69	10.18	11.42
Average	21.15	23.58	4.99	5.33	1.37	0.79	2.05	2.19	11.03	12.56	3.39	3.47
Lucerne												
1966	18.22	20.44	5.26	5.41	1.07	1.19	2.10	1.94	7.39	9.23	3.19	3.81
1967	21.08	20.47	5.05	5.33	0.55	0.48	1.45	1.87	10.72	11.94	3.85	4.26
1968	27.12	22.58	7.23	5.91	1.43	0.86	2.59	2.53	15.71	12.11	5.78	4.73
Total	66.42	63.49	17.64	16.65	3.05	2.53	6.04	6.24	33.82	33.28	12.87	12.84
Average	22.14	21.16	5.85	5.22	1.02	0.84	2.01	2.08	11.27	11.09	4.27	4.28

Table 2

Essential amino acid content in fodder samples, as a percentage of the dry matter content

Treatment	Leuc. + Isoleuc.	Phenyl alanine	Methion-ine	Valine	Tyrosine	Threonine	Glycine	Arginine	Histidine	Lysine	Cisteine	Triptophane	Dry matter
Green maize													
Ind. water	2.35	0.76	0.45	0.81	0.57	1.15	0.81	0.54	0.52	0.94	0.50	0.530	16.1
1/2 ind. water 1/2 fresh water	1.36	0.98	0.36	1.00	0.96	1.12	0.81	1.03	0.69	0.79	0.29	0.555	18.1
Fresh water	1.91	0.72	0.33	0.68	0.39	1.13	0.63	0.67	0.52	0.78	0.35	0.400	16.1
Control	2.37	0.80	0.28	0.52	0.50	0.95	0.63	0.36	0.60	0.99	0.32	0.580	25.9
Soya													
Industrial water	4.39	1.66	0.96	0.21	0.81	1.91	1.06	1.42	1.17	1.73	0.85	0.891	19.1
1/2 ind. water 1/2 fresh water	3.35	1.29	0.82	1.82	0.96	2.00	2.68	2.18	1.64	1.64	0.89	0.774	14.2
Fresh water	4.07	1.62	0.79	1.92	1.09	1.88	1.62	1.70	2.22	2.11	1.16	0.885	19.2
Control	3.48	1.45	0.74	1.52	0.47	1.66	1.18	1.11	1.15	2.64	1.01	0.715	19.8
Grass mixt.													
Industrial water	3.65	1.85	1.14	1.77	0.67	2.47	1.34	1.53	1.18	2.98	0.75	0.877	19.3
1/2 ind. water 1/2 fresh water	3.97	1.63	0.74	1.48	1.05	2.37	1.36	1.52	1.28	1.59	1.74	0.891	18.2
Fresh water	4.24	1.85	0.79	2.08	1.26	1.49	0.79	1.29	1.06	1.69	0.63	0.824	19.2
Control	3.51	0.93	0.57	1.22	0.68	2.00	1.14	1.47	1.14	2.05	0.97	0.977	19.8
Lucerne													
Industrial water	3.74	1.47	0.77	1.50	0.85	1.66	1.20	1.85	1.27	2.01	1.08	0.773	19.9
1/2 ind. water 1/2 fresh water	5.02	2.04	1.25	1.76	0.94	1.65	1.25	1.61	1.65	1.72	0.63	0.773	23.1
Fresh water	4.50	2.05	0.76	1.56	0.69	1.75	0.83	1.49	0.89	1.66	0.79	0.615	17.2
Control	2.94	1.19	0.78	1.25	0.78	1.53	1.25	1.28	1.16	1.47	0.88	0.521	20.1

Table 3

EAA index and biological value** of fodder crops*

		EAA index	BV**
Green maize	Industrial water	70.3	61.44
	1/2 industrial water 1/2 fresh water	71.7	62.98
	Fresh water	69.0	59.98
	Control	66.8	57.60
Soya	Industrial water	81.0	73.19
	1/2 industrial water 1/2 fresh water	78.1	70.00
	Fresh water	79.3	71.32
	Control	77.0	68.79
Grass mixt.	Industrial water	77.1	68.91
	1/2 industrial water 1/2 fresh water	71.5	62.76
	Fresh water	81.7	73.95
	Control	68.6	59.58
Lucerne	Industrial water	74.0	65.50
	1/2 industrial water 1/2 fresh water	77.5	69.34
	Fresh water	79.2	71.21
	Control	74.5	66.05

* EAA (essential amino acid) index: quantitative ratio of total amino acids of protein in the fodder crop to egg white (= 100). This determines the biological value of the protein in nutrients.

** BV (biological value): measure of utilizability of fodder protein; it also expresses to what extent the amino acid composition of the fodder examined satisfies the needs of the animals.

At Ősi, Hungarian brome grass (*Bromus inermis* Leyss) contained 29% dry matter, tall fescue (*Festuca arundinacea* L.) 26%, and green canary grass *(Typhoides arundinacea)* 30.2% dry matter when irrigated with sewage. The dry matter content naturally depends not only on the water supply but also on the developmental stage of the grasses. Species with well developed stems and few leaves contain more dry matter.

The analyses of other components are also influenced by similar factors. Table 1 shows the composition parameters of lucerne and a grass mixture. The annual average data reflect the results of more than one analysis. In these years even the crude protein content did not show a reliable trend; the crude fat content, on the other hand, increased in the plants in response to irrigation with industrial sewage. It should be noted that the non-irrigated treatment also received an abundant nitrogen supply (300 kg N/ha). In this experiment the aim was to discover whether the phenol content would cause adverse qualitative changes in the fodder crops. The objective of the analysis of essential amino acids was the same. The only conclusion that can be drawn from the

Table 4

Fresh composition of fodder crops given different treatments, Leninváros 1971

Treatment	Fodder crop	Dry matter	Organic matter	Crude protein	Crude fat	Crude fibre	N-free extract	Ash
		percentage						
A_1	Grass + clover	18.08	16.80	3.16	0.77	5.98	6.86	1.27
	Grass + lucerne	20.72	19.20	3.48	0.59	7.18	7.95	1.51
	Autumn mixture	15.82	14.60	3.35	0.67	6.17	4.41	1.22
	Green maize	14.25	13.00	1.98	0.28	4.77	5.93	1.25
A_2	Grass + clover	18.93	17.49	3.63	0.73	6.22	6.92	1.44
	Grass + lucerne	19.45	18.04	3.28	0.84	6.35	7.57	1.41
	Autumn mixture	18.58	17.31	2.80	0.61	8.03	5.86	1.27
	Green maize	14.10	12.94	2.09	0.27	4.79	5.78	1.16
A_3	Grass + clover	19.79	18.31	4.10	0.81	6.42	6.99	1.48
	Grass + lucerne	18.89	17.44	3.24	0.78	6.70	6.72	1.45
	Autumn mixture	17.88	16.60	3.06	0.55	5.64	7.25	1.28
	Green maize	15.77	14.60	2.10	0.38	5.10	6.94	1.07
A_4	Grass + clover	19.68	18.27	3.04	0.83	6.58	7.81	1.41
	Grass + lucerne	19.41	17.90	3.29	0.77	6.43	7.40	1.51
	Autumn mixture	18.47	16.96	4.25	0.72	6.16	5.73	1.51
	Green maize	15.69	14.17	2.24	0.29	5.30	6.34	1.52
A_5	Grass + clover	20.43	19.84	3.83	1.00	6.26	7.74	1.59
	Grass + lucerne	19.71	18.24	3.76	0.82	6.51	7.16	1.46
	Autumn mixture	18.38	17.01	4.12	0.61	5.79	6.49	1.38
	Green maize	14.00	12.47	1.87	0.29	4.59	5.73	1.53
A_6	Grass + clover	18.32	16.69	2.95	0.81	5.86	6.96	1.63
	Grass + lucerne	18.76	17.38	3.57	0.72	6.19	6.90	1.38
	Autumn mixture	16.75	15.54	2.93	0.37	5.87	6.37	1.21
	Green maize	13.81	12.38	2.14	0.26	4.58	5.40	1.43
A_7	Grass + clover	22.16	20.39	3.75	0.97	6.69	8.98	1.77
	Grass + lucerne	21.27	19.68	3.64	0.82	7.11	8.11	1.58
	Autumn mixture	19.53	18.09	3.66	0.85	5.95	7.63	1.44
	Green maize	18.02	14.26	1.93	0.41	5.64	6.29	3.76
A_8	Grass + clover	19.92	18.39	3.28	0.63	6.37	8.04	1.53
	Grass + lucerne	19.19	17.65	3.39	0.77	6.33	7.16	1.53
	Autumn mixture	15.80	14.85	2.83	0.67	5.79	5.57	0.95
	Green maize	13.38	12.17	1.44	0.26	4.62	5.85	1.21

data in Tables 2 and 3 is that at the concentrations applied the phenols did not cause unfavourable changes in the plants includes in the experiment.

The quality parameters of fodder crops were further examined at Leninváros (Table 4). As seen in the table, the dry matter content in treatment "A7" was 2.25% higher than in the irrigated treatments. The average dry matter content was 20.25% (18.02–22.16%) in the non-irrigated treatments and 18% (14.0–20.72%) in the irrigated ones. The crude protein content, on the other hand, showed hardly any variation. In other cases, e.g. at Várpalota, a 1–2% increase in crude protein content was pointed out in grass mixture, maize, soya, cabbage, and fodder sugarbeet under the influence of increasing rates of N application.

Large quantities of nitrogen supplied with the view of obtaining large yields caused an increase in the amount of free NO_3 not incorporated in the cell components of fodder crops. In the experiments carried out at Ősi great emphasis was laid on this subject. According to the results of analyses performed in 1975 the original grass contained 354 mg lucerne 231, sugar-beet 503 and onion couch 253 mg/100 g of free NO_3.

Subsequent analyses showed essential differences in free NO_3 content between species or even varieties in the case of identical rates of N application (500 kg/ha). In 1978, for instance, in treatment A_2 the free NO_3 content was 835 mg/100 g on average in green canary grass and 1570 mg/100 g in *Dactylis*. In the lysimeters, where nitrogen was oversupplied (1000 Kg/ha), the free NO_3 content of *Dactylis rose* to 2742 mg/100 g. In another experiment the free nitrate content of tall fescue was twice as high as that of Hungarian brome grass. In microplot experiments remarkable differences were observed between white clover varieties as well. In 1981 1.5% free NO_3 could be demonstrated and 0.56% in the experimental variety Kate.

The data obtained over several years of investigations show a wide deviation yet, the tendency is clear: the free NO_3 content depends on the amount of N supplied, and on the plant species and varieties tested. In the case of over-high rates of N application the danger of free NO_3 accumulation increases.

No less dangerous is the introduction of nitrogen into the ground-water. At Leninváros the salting experiment did not cause pollution; the effect of salt did not appear in the drinking water wells. In plots irrigated with sewage drain-pipes were placed in holes bored in the ground, or were dug into the ground. It was found that the nitrogen content in the return water of drain-pipes placed in the horizontal holes was lower than that in drain-pipes dug into the soil.

Experiments with drain-pipes were also conducted at Ősi (Table 5). Since the data showed a wide deviation, an attempt was later made to trace

Table 5

Analysis of return water from drain-pipes placed in horizontal holes bored in the soil, mg/l, 1975

Date of measurement	Depth								
	100 cm			150 cm			200 cm		
	NH_4	NO_3	NO_2	NH_4	NO_3	NO_2	NH_4	NO_3	NO_2
15 January	3.65	584	2.6	—	—	—	2.65	467.7	0.2
4 May	—	—	—	—	—	—	12.3	123.2	4.6
24 May	10.9	20.7	0.9	—	—	—	1.88	157.5	23.26
15 December	58.0	575	42.0	33.5	46.5	110	6.7	94.0	2.8

the ground-water pollution with the aid of observation wells. (These driven wells were perforated from a depth of 2 m to 7 m below the soil surface. Before irrigation the water was pumped out of them, and samples were taken 2 days after irrigation.) The nitrogen contents of the observation wells also showed variations. In some wells the N content was remarkably high, so they appear to have been placed in a basin formed by an impermeable layer. Uracyl was added to these wells but it could not be detected in any of the other wells. These wells were therefore excluded from further examinations. In fact, the ground-water had been polluted with nitrogen even before the irrigation began. Prior to starting the irrigation an official determination of the N content, was requested.

The results in the drinking water wells closest to the plant were:

	pH	NH_4	NO_3	NO_2
		mg/l		
Sample 1	7.6	18	126	8
Sample 2	7.6	15	—	0.17

This pollution was not necessarily caused by fertilization; large amounts of nitrogen are contained in mine pools and are also conveyed by sewers. In any case, this primary pollution made the investigations more difficult, and as a source of pollution was present later too.

In 1975 there were 9 observation wells; later this number rose to 15. In the meantime farm-scale irrigation was begun experimentally on 120 ha. During the irrigation the extent of N pollution did not increase in the observation wells. On the other hand, it was interesting to find an average quantity of 9.64 mg/l NH_4 and 16.36 mg/l NO_3 in the growth season when irrigation took place. By the end of winter, in February, the analyses showed 16.81 mg/l NH_4 and 164.97 mg/l NO_3. It was always in February that the extent of pollution was the greatest. This could perhaps be explained by N leaching; in soils of marshy origin the organic matter content is also high. But a more likely explanation is that as a result of autumn and winter precipitation, the water level in the lakes rises and the flow of ground-water increases; it is also at this time that most of the sewage is drained off anyway, every year the lower N value had been restored by spring.

The leaching of N was studied in lysimeters too. When the lysimeters were irrigated with an amount of water and nitrogen corresponding to the volume of sewage used in small-plot or farm-scale irrigation (60 mm), return water was very seldom obtained and then only from a few lysimeters. When 100 mm water was supplied 20–700 ml return water was obtained from 9 of

the 16 lysimeters. After irrigation with 100 mm, on the other hand, there were lysimeters in which the concentration of N was 701.4 mg/l, i.e. higher than in the irrigation water. Figures 1 and 2 show a correlation between the yields of the lysimeters, the amount of return water and its content of total nitrogen. This seems to be logical.

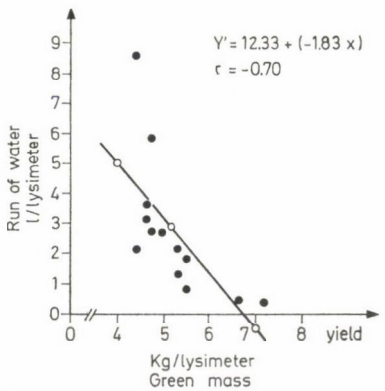

Fig. 1. Relationship between the amount of return water and the amount of yield

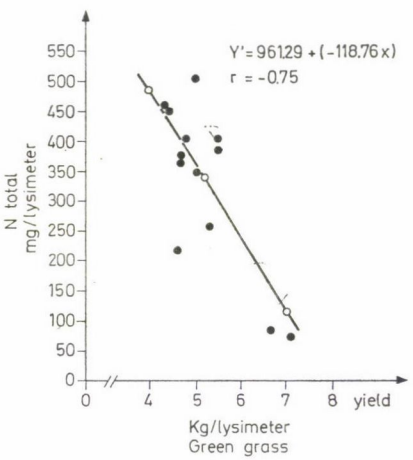

Fig. 2. Relationship between the amount of yield and the amount of total N in the return water

A feasible way of avoiding N pollution is to keep the N balance in view. The amount of nitrogen applied should be in equilibrium with the amount of nitrogen extracted by the prospective crop. Very large quantities of N can be extracted by crops with high N consumption. In one of the treatments at Leninváros 560 kg/ha nitrogen was supplied, and the amount of N extracted was

575 kg/ha with original grass,
575 kg/ha with *Dactylis*,
603 kg/ha with onion couch and
518 kg/ha with lucerne.

When irrigating with sewage, water management should be based on the water balance.

As seen from the above, the avoidance of environmental pollution is difficult, but possible. To sum up: if the given soils are irrigated with about 60 mm sewage (at an intensity of some 9–10 mm/h) nitrogen will not get into the ground-water. Although excessive precipitation occurring after irrigation may cause leaching, this danger also has to be reckoned with in the case of fertilization, when larger amounts of nitrogen are often used. The evaluation of the results of experiments at Várpalota and Leninváros was made on the basis of starch equivalent and digestible protein. In Tables 6–7 the values of starch equivalent and digestible protein produced per unit area with bulk fodders are seen. The differences shown in favour of irrigation with sewage suggest highly efficient utilization. In Figs 3–4 the trends of starch equivalent and digestible protein yield for a lucerne and grass combination and a dactylis crop in the Leninváros experiment are seen. As shown by the figures, in this case even higher starch equivalents and digestible protein yields were obtained for these fodder crops. The difference between the non-irrigated treatment

Table 6

Three-year averages of experimental results at Várpalota

Treatment				Starch equivalent		
				kg/plot	Mt/ha	%
A_2	B_4	Fodder sugar-beet	Irrigated with	201.06	11.37	141.88
	B_3	Grass with clover	industrial sewage	113.03	6.48	190.16
	B_2	Lucerne		108.50	6.17	160.11
	B_1	Soya (beans)		27.09	1.49	157.66
A_1	B_4	Fodder sugar-beet	Irrigated with	168.73	9.58	119.42
	B_3	Grass with clover	fresh water	110.68	6.27	184.55
	B_2	Lucerne		86.40	4.90	127.57
	B_1	Soya (beans)		24.35	1.38	141.64
A_3	B_4	Fodder sugar-beet	Irrigated with	177.54	10.17	125.67
	B_3	Grass with clover	1/2 ind. sewage	96.20	5.47	160.43
	B_2	Lucerne	1/2 fresh water	80.85	4.59	119.31
	B_1	Soya (beans)		29.69	1.69	154.99
A_4	B_4	Fodder sugar-beet	Non-irrigated	141.28	8.03	100.00
	B_2	Lucerne		67.78	3.85	100.00
	B_3	Grass with clover		59.67	3.41	100.00
	B_1	Soya (beans)		17.18	0.99	100.00
			$LSD_{5\%}$	30.69	1.74	

and those irrigated with industrial sewage of favourable composition was so great that in the experiments carried out at Õsi a statistical evaluation of the green mass was considered to be sufficient, so instead of the examinations mentioned above only an analysis of the yield components required for practical purposes was carried out. Financial reasons also justified the omission of analyses of starch equivalent, proteins, etc.

Table 7

Three years' yield averages of experiments at Várpalota

Treatment				Digestible protein		
				kg/plot	Mt/ha	%
A_2	B_2	Lucerne	Irrigated with	49.93	2.50	149.23
	B_4	Fodder sugar-beet	industrial sewage	34.66	1.97	150.07
	B_3	Grass with clover		31.95	1.82	164.31
	B_1	Soya (beans)		12.58	0.72	155.10
A_3	B_2	Lucerne	Irrigated with	35.65	2.03	121.09
	B_3	Grass with clover	1/2 ind. sewage	29.62	1.68	152.36
	B_4	Fodder sugar-beet	1/2 fresh water	26.70	1.52	115.64
	B_1	Soya (beans)		14.44	0.82	178.12
A_1	B_2	Lucerne	Irrigated with	35.25	2.00	119.74
	B_3	Grass with clover	fresh water	28.43	1.62	146.23
	B_4	Fodder sugar-beet		27.31	1.55	118.28
	B_1	Soya (beans)		11.12	0.63	137.38
A_4	B_2	Lucerne	Non-irrigated	29.44	1.67	100.00
	B_4	Fodder sugar-beet		23.10	1.31	100.00
	B_3	Grass with clover		19.44	1.11	100.00
	B_1	Soya (beans)		8.09	0.46	100.00
			$LSD_{5\%}$	5.01	0.29	

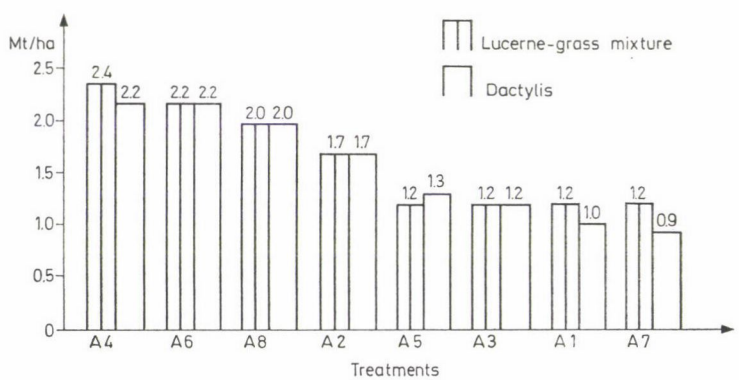

Fig. 3. Trends of starch equivalent yields for lucerne-grass mixture and *Dactylis* (Leninváros 1969–71). Treatments: A_1 348 kg/ha N; A_2 348 kg/ha N + 87 kg/ha P_2O_5 + 87 kg/ha K_2O; A_3 696 kg/ha N; A_4 696 kg/ha N + 174 kg/ha P_2O_5 + 174 kg/ha K_2O; A_5 1044 kg/ha N; A_6 1044 kg/ha N + 261 kg/ha P_2O_5 + 261 kg/ha K_2O; A_7 non irrigated; A_8 irrigated with fresh water 348 kg/ha P_2O_5 + 348 kg/ha K_2O

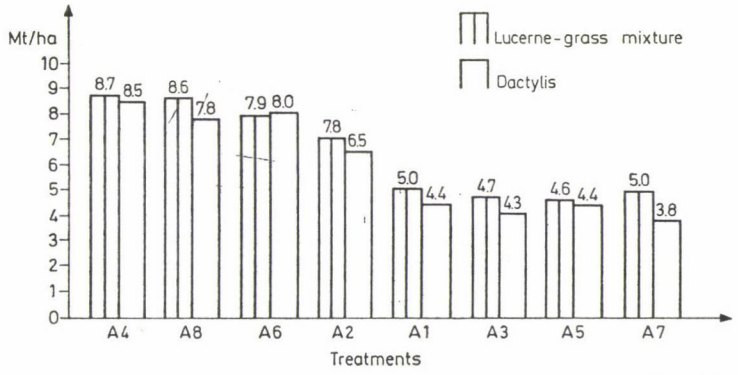

Fig. 4. Trends of digestible protein yields in lucerne-grass mixture and *Dactylis* (Leninváros 1969–1971). Treatments: A_1 348 kg/ha N; A_2 348 kg/ha N + 87 kg/ha P_2O_5 + 87 kg/ha K_2O; A_3 696 kg/ha N; A_4 696 kg/ha N + 174 kg/ha P_2O_5 + 174 kg/ha K_2O; A_5 1044 kg/ha N; A_6 1044 kg/ha N + 261 kg/ha P_2O_5 + 261 kg/ha K_2O; A_7 non irrigated; A_8 irrigated with fresh water 348 kg/ha P_2O_5 + 348 kg/ha K_2O

Of the experiments carried out at Ősi let us look first at the yield of original grass (Fig. 5). It should be mentioned that before the experiments were begun the original grass yielded 5–6 tons of green mass. In 1972 the area was fertilized and irrigated. It is almost unbelievable that in certain years the same grassfield gave yields 10–15 times larger than those obtained when it was neglected. Although aggressive grass species sown alone produced considerably larger yields than the original grassland, for some inexplicable reason they had a much shorter life span. Among the split-plot treatments which were also evaluated with variance analysis, treatments A_1 and A_2 are worth being discussed in detail (treatments A_3 and A_4 seldom showed yields higher than that of A_2, i.e. increasing rates of phosphorus and potassium were not really effective).

The yields of grasses in treatments A_1 and A_2 are compared to that of the original grassland in Table 8. It can be seen that after a mixture of dactylis and onion couch, lucerne was productive for 4 years, and green canary grass (sown after fodder sugar-beet and lucerne) for 3 years, while dactylis could be kept up for 3–4 years. When grass species were sown alone, they were destroyed by nematodes and corn-flies. No explanation has been found for the fact that in the original grassland the damage caused by these pests was negligible. The original grassland gave a statisfactory yield up to the end of the experiment.

In the microplot experiment, on the other hand, tall fescue was the longest living species and thus gave the largest volume of yield (Fig. 6). On the basis of the experimental results, the farm planted grassland, first on 120 ha then on 500 ha, mainly with tall fescue and grass mixtures. To start with they were processed into grass meal. Later the harvested crop was wilted. A further

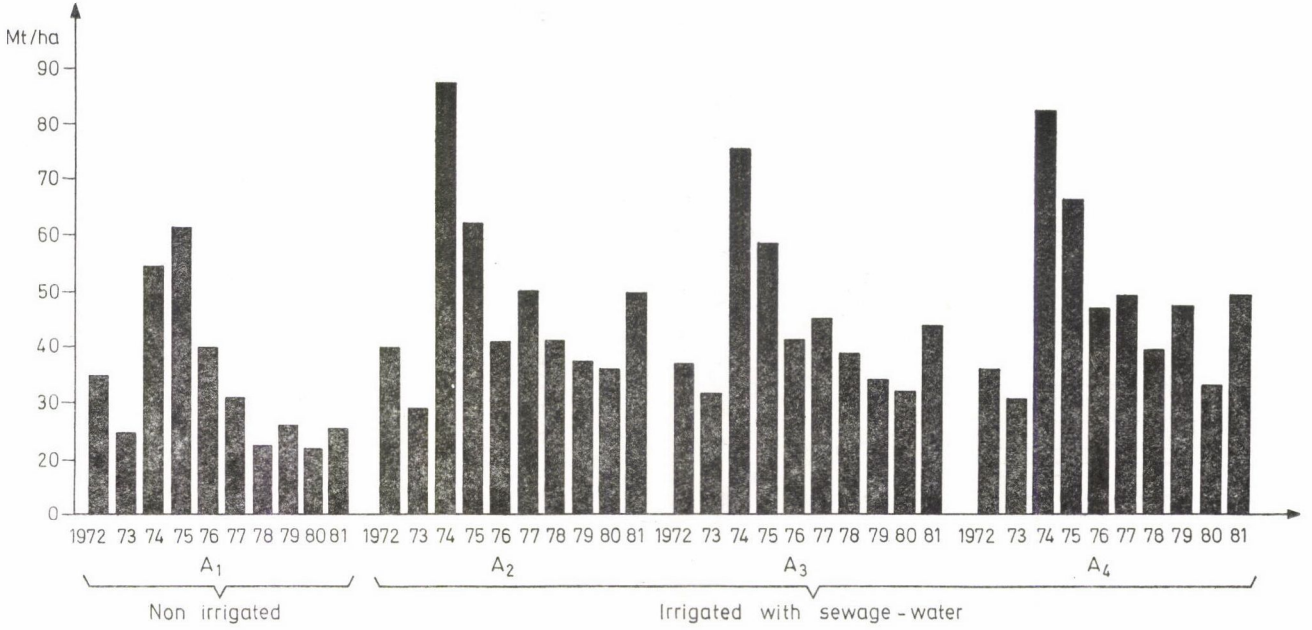

Fig. 5. **Green mass of grassland at Ősi**

Table 8

Results of roughage production in small-plot experiment, fresh crop Mt/ha at Ősi

	1971	1972	1973	1974	1975*	1976*	1977	1978	1979	1980	1981
Original grassland											
A_1 non-irrigated	5.5	34.6	24.2	54.1	61.0	38.7	39.3	21.5	24.5	20.6	25.6
A_2 irrigated		38.9	27.9	87.2	61.9	40.7	48.6	41.2	37.4	36.2	48.7
Dactylis + onion couch											
A_1 non-irrigated		23.1	32.6	71.5	82.3						
A_2 irrigated		34.8	44.9	91.3	82.7						
Lucerne											
A_1 non-irrigated		20.9	12.2	60.6	59.2						
A_2 irrigated		27.7	14.3	82.8	54.1						
Green canary grass											
A_1 non-irrigated						14.3	52.7	35.3	31.9	18.6	
A_2 irrigated						30.5	100.9	51.9	53.8	27.5	
Dactylis											
A_1 non-irrigated						14.2	53.6	24.5			
A_2 irrigated						25.9	87.4	53.5			

* In these years the level of ground-water was high, particularly in the small-plot experiment.

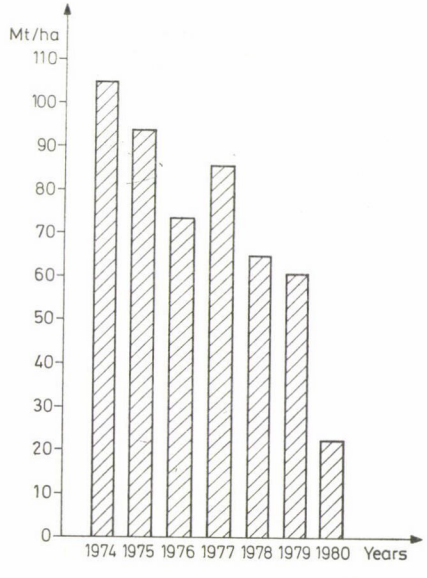

Fig. 6. Trend of green crop in tall fescue in microplot at Ősi. Treatments: 560 kg/ha N in sewage; 300 kg/ha P_2O_5 every second year; 350 kg/ha K_2O every second year

increase in energy prices forced the farms to make hay, although the yield was thereby reduced. Today, grazing seems to be the most expedient.

In the course of the experiments, fodder sugarbeet and grasses were found to make the best use of nitrogen. For fodder sugar-beet irrigated with industrial sewage fresh crops as high as 200 Mt/ha were obtained; the starch equivalent was 11 Mt/ha, including 5.9 Mt/ha digestible protein over the average of the yers 1965–1967. However, the farms can hardly cope with such an enormous bulk. The grasses caused various problems. Their disproportionately low purchasing prices, while not a decisive factor within the farm, does not encourage better grass management. With a view to higher economic efficiency, more marketable grain crops were therefore given preference. Legumes were included in the experiments for a number of years. They were difficult to protect from deer and hares. With the variety Seaway, yields as high as 2000 kg/ha were achieved on more than one occasion. Reckoning with a purchasing price of 18 Ft/kg this means a gross return of 36,000 Ft/ha compared to 15,000 Ft/ha for selling hay at present prices. The situation is similar for the short-vegetation soya varieties cultivable in Hungary.

On the grain crops, maize did not show satisfactory yield differences compared to the non-irrigated treatment until short vegetation single crosses were included in the experiment. With the latter, on the other hand, record yields were obtained. Excellent results were achieved with the following hybrids:

Szegedi SC 369
Anjou SC 256
Szegedi MSC 378
NK-PX MSC 20.

It should be mentioned that the large yields further reduced the already low microelement supplies of the soil. The amounts of Cu and Co in the fodder crops were no longer sufficient.

This suggests that it is worth supplying the microelements in question at higher rates; the after-effect in the following year is satisfactory. The quality of the fodder crops improved, though surplus yields were seldom obtained (Table 9, Figs 7–8).

Table 9

Testing of Cu with tall fescue and of Co with white clover (ppm)

	Desirable	Analysed	After spraying with 12 kg/ha Cu fertilizer	After-effect after 1 year	After spraying with 10 kg/ha Co fertilizer	After-effect after 1 year
Cu	6–10	4.8	26.15	6.6	—	—
Co	0.1–0.2	0.058	—	—	0.930	0.829

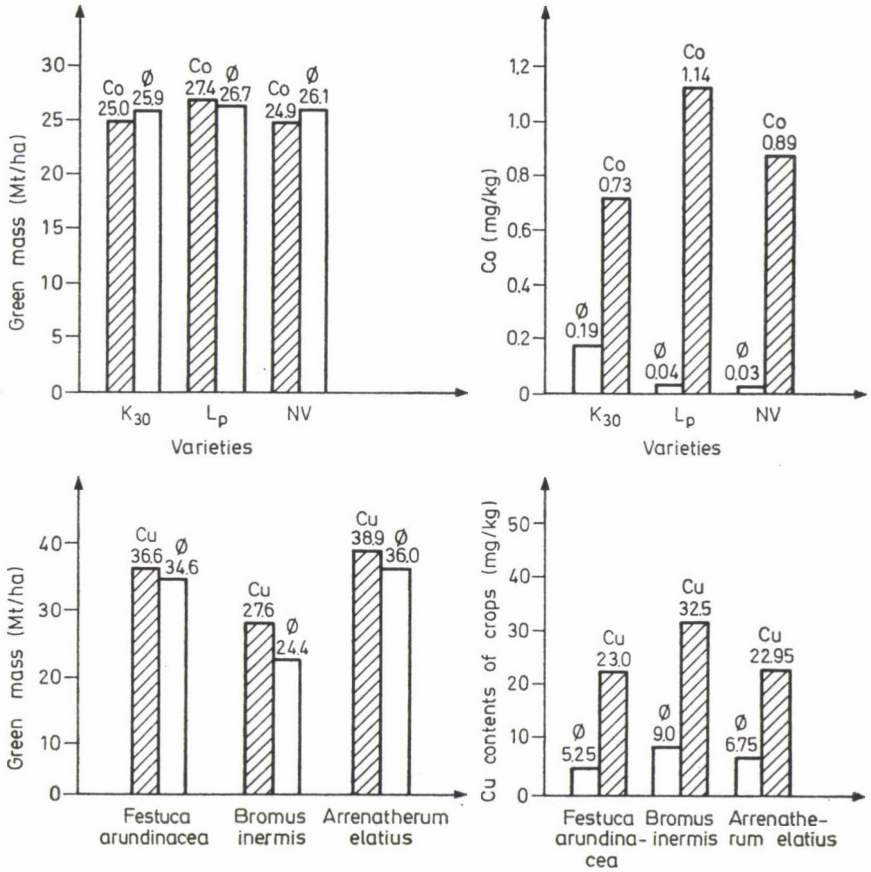

Fig. 7. Yields and Co contents of white clover varieties in the year of planting (Ősi 1978)

Fig. 8. Effect of Cu on the yield of grasses (Ősi 1978)

Naturally, soil analyses were also carried out during the experiments. At Várpalota the following results were obtained:

	Total N	P_2O_5	K_2O
		mg/100 g	
Before the experiment	288	7.2	36.25
End of the experiment	310	36.0	47.62

Thus, in response to a high rate of nutrition some increase in macro-elements was observed. On the marshy soil the increase in phosphorus was the greatest of all. Obviously differences were observed with changes in the "B"

factors. After fodder sugar-beet, for example, the potassium content decreased instead of becoming higher.

In the Leninváros experiments the total N was only determined by random tests and was not found to increase. The trend of NO_3, on the other hand, indicates that in treatments irrigated with sewage without the addition of phosphorus and potassium an increase in NO_3 occurred (the yield was smaller). The largest yield was obtained in treatments A_4–A_6; the potassium

Table 10

Nutrient content in the soils of treatments A_1–A_8 over the average of the factors at Leninváros

	Total N	P_2O_5	K_2O	NO_3
	mg/100 g			
Before the experiment	240	1–6	15	14
At the end of the experiment				
Treatment A_1	237.6	1	13	26.0
Treatment A_2		4	13	15.0
Treatment A_3		2	12	31.0
Treatment A_4		7	16	14.0
Treatment A_5	214.7	2	12	29.0
Treatment A_6	190.5	13	18	16.0
Treatment A_7		2	15	14.0
Treatment A_8		20	23	13.0

Treatment A_8 was not given nitrogen, the yield was low, P and K were found to increase.

and phosphorus contents of the soil increased in these cases to a relatively small extent (Table 10).

At Ősi the emphasis was laid on nitrogen autrophization; the investigations consisted mainly of the N analyses discussed above. The final nutrient balance of the soil was:

	Total N	P_2O_5	K_2O
	mg/100 g		
Before the experiment	400	6.00	23.50
End of the experiment	557	31.12	42.23

The results are averages of all treatments; since larger yields were seldom obtained in treatments A_3 and A_4 than in treatment A_2 the former increased the nutrient supplies of the soil. In treatment A_1, and particularly in treatment A_2, the increase in nutrients was slight. The amounts of Cu and Co decreased, but these deficiencies could be compensated by the application of microelements. This also served for the protection of the environment, and the animals were provided with healthier feed.

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MODEL LABORATORY SOIL EXPERIMENTS ON THE LEACHING AND VOLATILIZATION OF EPTC

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The leaching of EPTC with distilled water (corresponding to a rainfall of 60 mm) was small in sand and practically insignificant in sandy loam (Zala soil). For the loss of EPTC applied to the surface volatilization proved to be a very important process, greatly depending on the initial moisture content of the soil. Four days after treatment 25% of the EPTC applied could be detected in the soil and 10% in the sand at an initial moisture content amounting to 60% of the field capacity.

Introduction

Processes influencing the fate and behaviour of herbicides in soils are: movement with the rain water, volatilization, adsorption on soil colloids, decomposition by chemical, photochemical and microbial pathways and uptake by plants and organisms. The clarification of the reasons for insufficient herbicidal efficiency in fields is one of the fundamental questions for effective crop protection in agricultural practice. The leaching of herbicides in the soil and their volatilization from the soil are factors leading to an insufficient amount of the compound in the root-zone for effective weed control. These phenomena are related to the physical and chemical properties of herbicides and soils as well as to environmental features, i.e. temperature, air movement, amount of rain water, etc. The mobility is proportional to the herbicide solubility in the soil water and inversely proportional to the clay and organic matter content of the soil. Potential volatility is generally related to the vapour pressure of the compound. However, the effective vapour pressure may differ from the original one as a result of environmental factors (Anderson 1977). Both the mobility and the volatility are significantly dependent on the moisture content of the soil. Herbicides volatilize faster from wet than from dry soils. EPTC (S-ethyl di-n-propylthiocarbamate) was assumed to vapourize together with the soil water (Fang et al. 1961), but later their independent vapour loss was verified (Gray and Weireich 1965).

EPTC (water solubility 370 mg/l at 293 K, vapour pressure 4.5 Pa at 298 K; Worthing 1979) is a herbicide used primarily as a preplanting incorporated treatment for the control of most grasses, some small-seeded broadleaf

weeds and certain hard-to-kill perennial weeds. Numerous investigations have been made on the physical behaviour of EPTC in soils (FANG 1975); however, for Hungarian soils only a single study on the mobility of EPTC measured by a biotest method has been published (SÁRKÁNY 1978). The experiments described here were laboratory tests combined with gas-liquid chromatography because this method gives exact quantitative results.

Material and methods

All the experiments were made with Danubian HCl-washed sand (as a standard) and with sandy loam sampled from the 0–20 cm layer (characterized by the data in Table 1) and sieved to a granule size of less than 2 mm. Soil parameters were determined by the usual manner (BALLENEGGER and DI GLÉRIA 1962).

Table 1

Main characteristics of the sandy loam used in the study of EPTC movement and volatilization

Mechanical composition			Other properties	
	μm	%		
Clay	2	16.9	Organic matter	1.9%
Silt	2– 20	22.4	pH (KCl)	7.4
Fine sand	20–200	44.3	$CaCO_3$	9.2%
Coarse sand	200	16.4	Provenience Genetic classification	Zalaegerszeg meadow soil

For the mobility experiments (Fig. 1) a glass column made up of rings 2.5 cm in height with a 5.3 cm inside diameter was filled with air-dried soil or sand in small increments and after each increment a small volume of distilled water was added to adjust the initial moisture content. 100 μg of EPTC (in acetone) was sprayed on the top of a 39 cm high soil column after which the surface was covered with a 1 cm layer of soil. After artificial rain the column was sliced into single rings and their EPTC content was analysed (AMBRUS 1981).

The elution of EPTC in the soil was investigated (Fig. 1) in a similar but continuous glass column; the filling and irrigation were carried out as described above. The eluate was collected in 20–50 cm^3 fractions and their EPTC contents measured.

Volatilization of the herbicide was studied with both static and dynamic methods. For the static investigations 100 g portions of the air-dry soil and sand were placed into Erlenmayer flasks. After the addition of 100 μg of EPTC and water (up to the desired moisture content) the flasks were closed. The samples were aerated and stirred each day. For the dynamic method (Fig. 1) 100 μg of EPTC was sprayed on the top of a soil column 5 cm high with a 5.3 cm inside diameter. The EPTC removed from the column by a constant air flow (25 l/h) was absorbed in 600 cm^3 of n-hexane step by step in three stages.

Analysis. Soil and sand samples were dried with anhydrous sodium sulphate, then mixed intensively with 100 cm^3 n-hexane for 3 minutes. After filtration the extraction was repeated twice; the solutions were united and evaporated to 0.5–1 cm^3 and the EPTC content was measured by a Perkin-Elmer F-22 gas-liquid chromatograph equipped with a phosphorus and nitrogen selective alkali flame ionization detector. A 1.2 m $\times$ 0.6 cm $\times$ 0.18 cm pyrex glass column packed with 3% OV 17 on 150–180 μm Gas Chrom Q was used at 423 K. As an inner standard S-ethyl diisobutylthiocarbamate ("Butylate", "Sutan") was applied. Elution samples were extracted with 3 $\times$ 20 cm^3 n-hexane, then dried and concentrated before GLC.

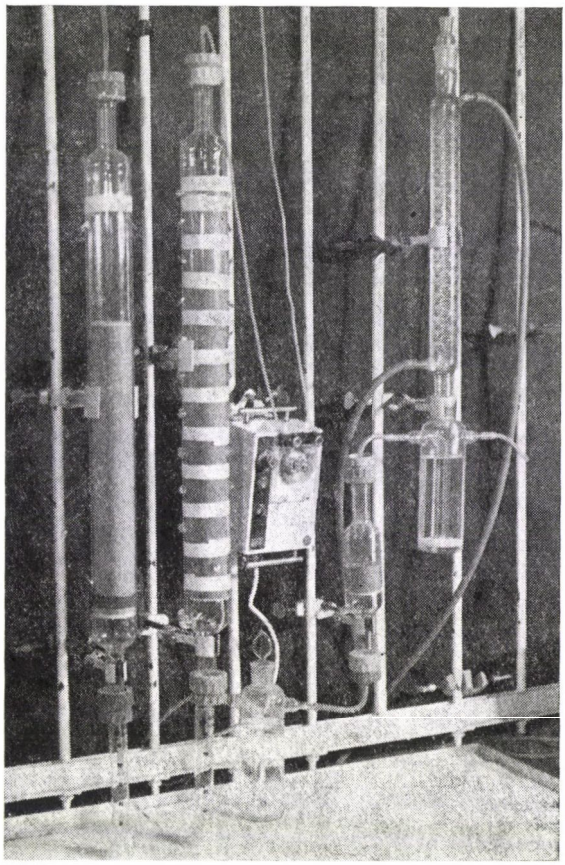

Fig. 1. Laboratory system to study the leaching and volatilization of herbicides into/from soil

Results and discussion

The leaching of EPTC in the sand and in the soil was investigated at an initial moisture content amounting to 60% of their field capacity with 10 mm of artificial rain corresponding to a slight rainfall in Hungary. The EPTC movement was small in the sand and practically negligible in the soil. The major part of the EPTC applied to the soil remained in the upper 0–2.5 cm layer, while approximately equal EPTC contents (about 0.15 μg) were found in each 2.5 cm layer of the column in the range from 5 to 39 cm, as a consequence of a small volume of the added water moving rapidly in depth carrying with it some of the compound in solution (CHARREAUX and JAQUINOT 1967). In the sand EPTC leached downwards up to 10 cm. In deeper layers the amounts of EPTC measured were similar to those found in the soil below 5 cm. The EPTC movement both in soil and in sand increased as the initial

moisture content decreased. This increase was not considerable for the soil but was extensive for the sand when 60 mm of artificial rain (equivalent to heavy rainfall) was added to the air-dry EPTC-treated columns (Fig. 2).

The experimental data illustrate the importance and the role of soil properties. Soil colloids reduce the leaching of herbicides in soils to an extent depending on their water solubility. In sandy loam, poor in clay and humus (Table 1), the mobility of EPTC significantly decreases compared to that in sand; consequently, leaching is not an important process for the loss of EPTC from Hungarian crop lands.

Similarly, the elution of EPTC from the soil (Fig. 3) was insignificant even for a great volume of water (equivalent to 700 mm of rain) when the

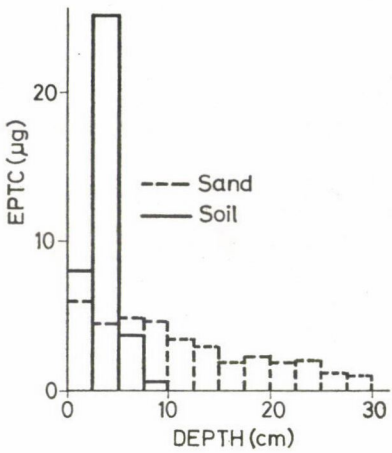

Fig. 2. Distribution of EPTC in initially air-dry sand and soil by the effect of 60 mm of artificial rain

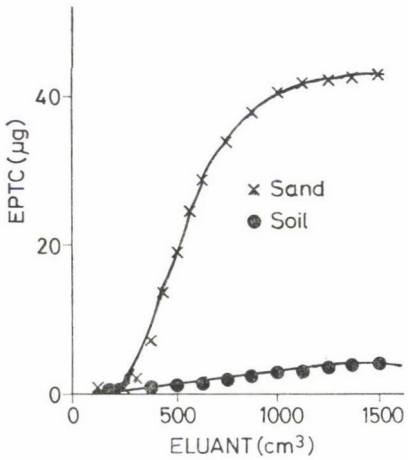

Fig. 3. Elution of EPTC. Initial moisture 60% of field capacity

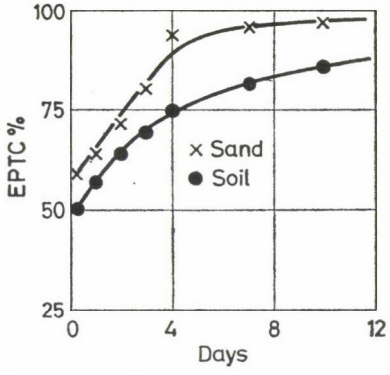

Fig. 4. Vapour loss of EPTC under static conditions. Initial moisture 60% of field capacity

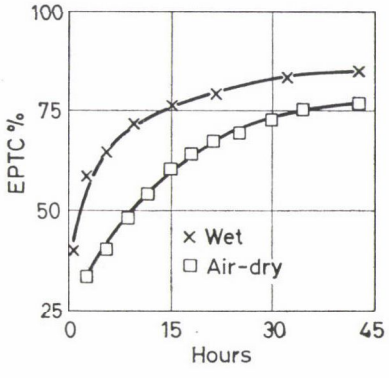

Fig. 5. Vapour loss of EPTC from sand under dynamic conditions. Initial moisture in wet sand 60% of field capacity

initial moisture content of the soil was 60% of the field capacity. A pregnant elution of the herbicide started from the sand after the infiltration of 130 mm water and was completed by 700 mm of artificial rain. Nevertheless, the pollution of subsoil water with EPTC is improbable in soils containing at least a small amount of clay and humus because the life-time of this herbicide is much shorter than the period needed for such a quantity of rainfall under field circumstances.

Vapour loss of EPTC proved to be very important from both the sand and the soil at an initial moisture content amounting to 60% of the field capacity. The volatilization was faster from the sand than from the soil (Figs. 4 and 5). Under static conditions (Fig. 4) 50% of the EPTC applied was found in the soil and 41% in the sand 15 min after treatment. On the fourth day the EPTC content was 25% in the soil and 10% in the sand. These findings are in agreement with results reported for field tests (CLIATH 1980). Only 1% of the EPTC was found in the soil and 0.5% in the sand after 4 weeks. The

vapour transport of EPTC under dynamic conditions was also investigated to obtain direct evidence for significant volatilization. The results obtained (Fig. 5) are similar to those found using the static method, indicating a faster vapour loss in the first period. Decreasing the initial moisture content of both sand and soil reduced the volatilization of EPTC. Thus, for effective weed control in the field, EPTC should reasonably be applied to dry or slightly moist soils even when the herbicide is incorporated into the soil almost immediately after being sprayed onto the surface.

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IMMIGRATION OF PLANT SPECIES INTO ABANDONES VINEYARDS AND STONE QUARRIES

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The investigations were carried out on two special habitat types, completely influenced by man: (1) stone quarries and (2) vine-growing areas. Recently, after the cessation of human influences, the natural flora has been trying to return to its former sites.

Analyses have been made in the following habitat types: (1) original vegetation, (2) rocky walls, (3) inner base, (4) bottom of the quarry. The vegetation of waste rocks was investigated separately. Phytosociological analyses have been made using the Braun-Blanquet scale.

It is generally characteristic of both habitats that

(1) in almost every case the species of weed associations can be found in younger communities;

(2) if the species of the original associations are also found, their cover-abundance and position most differ from the original ones;

(3) on the sites of analysis the chief tendencies of succession vary, leading to the formation of shrubs, forests and grassland, the latter being the most frequent.

Introduction

On the territory of the North Hungarian Hills, at the southern foot of the Carpathians, there are two special habitat types: (1) *stonequarries* and (2) *vine-growing areas*, completely influenced by man. After the cessation of this influence the natural flora can return to its former place. This process, of course, does not always result in the development of the original associations. This is especially due to the fact that, during *quarrying operation* not only the original vegetation but also the substrate or the most important characteristics of the locality are destroyed. On the other hand, the extracted area is usually directly contiguous with the natural plant cover, from which the immigration of the plants can take place (BARÁTH and TERPÓ 1956, BARÁTH 1963, 1964, 1967, SOÓ 1964–1980).

In *vine-growing regions* of the hills the soil has mostly remained. Boundaries, terraces and supporting walls protect the native flora and fragments of associations. In some regions the vine-growing has been interrupted several times during the last thousand years because of erosion of the soil or in consequence of economic, political and historical events. Most recently, in 1880, the vines were exterminated by phylloxera infection. After this the cultivation of numerous vineyards was discontinued for various reasons, one of which

was the large-scale erosion of the soil. On each occasion the plant species tried to colonize the regions which had become free. The vine-growing zone covers a large area and is contiguous with both the steppe woodlands and the associations of *Quercus cerris* and *Quercus petraea* (s.l.) in the hills (TERPÓ 1960, MÁTHÉ and KOVÁCS 1962).

The aim of the present work was:

(1) to call attention to the characteristic features and scientific and practical value of both habitat types. Another important point of view is the successional stage in which the formation of an association takes place. These new plant communities are also significant as they gave, and continue to give, shelter to many valuable (protected) plant species;

(2) to observe the penetration and competition of the adventive plants and the role of so-called weed-growing plants in the development of the vegetation (TERPÓ 1983, TERPÓ and BÁLINT 1983, MÁTHÉ 1980).

In the North Hungarian Hills, in associations which have evolved in the place of abandoned vineyards, the species *Stipa dasyphylla*, *S. stenophylla* (= tirsa !), *Polygala major*, *Galium tenuissimum*, *Inula ensifolia*, *Lathyrus latifolius*, *Adonis vernalis*, *Poa pannonica* subsp. *scabra*, *Campanula macrostachya*, *Dianthus collinus*, *Echium russicum*, *Amygdalus nana*, *Cerasus fruticosa*, *Pyrus pannonica*, etc. can be found. The phytosociological analysis of the abandoned vineyards has been carried out by BARÁTH and TERPÓ (1956) and BARÁTH (1963, 1964, 1967).

Material and methods

For the purpose of the examinations abandoned (non-working) stone-quarries were chosen where no *contaminating materials were placed* after quarrying. Besides the physical destruction of the vegetation, the removal of soil and the breaking of stone (mouldering, accumulation of rubble), the environment had not been influenced in any other way.

There are *two types of abandoned stone-quarries:*

(1) large-sized quarries with walls 20–50 (or even 100) m high and usually steep (vertical). The waste rock is placed in large piles, which serve as a special biotype for the plants;

(2) small stone-pits, only a few metres deep, the walls of which are inclining. The waste rock is put directly onto the brink of the pit.

The various parts of the quarry provide quite different life conditions for plants. Analyses have been made in the following habitat types:

(1) original vegetation associated with the quarry,

(2) rocky walls,

(3) inner base consisting of stones and partly of soil (mouldering),

(4) bottom of the quarry.

The vegetation of the *waste rock* is the subject of special research. The waste rock, consisting of small worthless (crumbling) stones, often made up of rubble mixed with soil, is usually kept near the quarries, sometimes on the brink of the stone-pits (Figs 1, 2).

For small stone-pits the waste rocks marge with the holes of small size, the edges of the walls abrade.

The *phytosociological analyses* have been made on the basis of the classes of quarries given above, according to the Braun-Blanquet scale, on sample plots of 4 and 25 m^2 in size, depending on the characteristic features of the area (+ = 1%, 1 = 1–5%, 2 = 2–25%, 3 = 2–50%, 4 = 50–75%, 5 = 75–100%).

In addition, the spread and retreat of species and their forms of propagation were also examined.

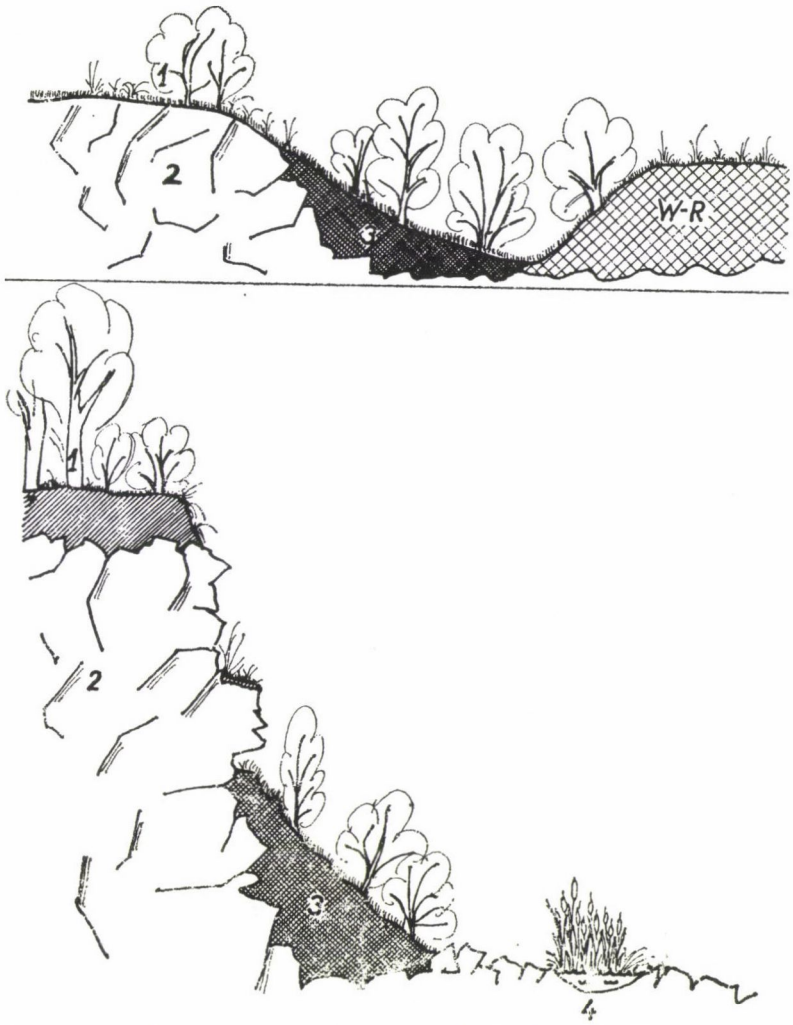

Fig. 1. Cross-section of a stone quarry. Interpretation in the text. (Upper drawing = small stone pit. Lower drawing — large stone quarry)

Results

A) *Vine-growing areas*

In the North Hungarian Hills *vine-growing* is mostly practiced on the southern, eastern and western slopes. It is here that abandoned vineyards are to be found, in the habitats of the following plant communities (Fig. 3):

(1) in the zone of *Aceri tatarico-Quercetum (pubescenti-roboris)*, which can also be found in the loess of the Hungarian Plain at the foot of the mountains (Zólyomi 1958);

(2) as the height above sea level increases, in the Transdanubian Central Hills (south west of the Danube Bend), in the region of the local associations of *Corno-Quercetum (Quercetum pubescenti-cerris);*

(3) in the north-eastern part of the Northern Hills (Mátra), in the former region of the association *Corno-Quercetum (Quercetum pubescenti-petraeae)* both cultivated and abandoned vineyards can be found.

Fig. 2. A stone quarry abandoned a short time ago

Locally in smaller regions (the Zemplén, Mátra, Buda and Pilis Hills and the foot of the Alps) vineyards were planted after the eradication of *Quercetum petraeae-cerris.* In the neighbourhood of Gyöngyös and Tállya of this species can be found which have returned to take the place of grapevines; the association is secondary. The process of forest development is always quicker in sites with thin soil.

In the territory of abandoned vineyards two habitat types can be found:

(a) site of vine plantation;

(b) site of supporting walls and boundaries. These latter are long heaps consisting of stones which were taken out during cultivation.

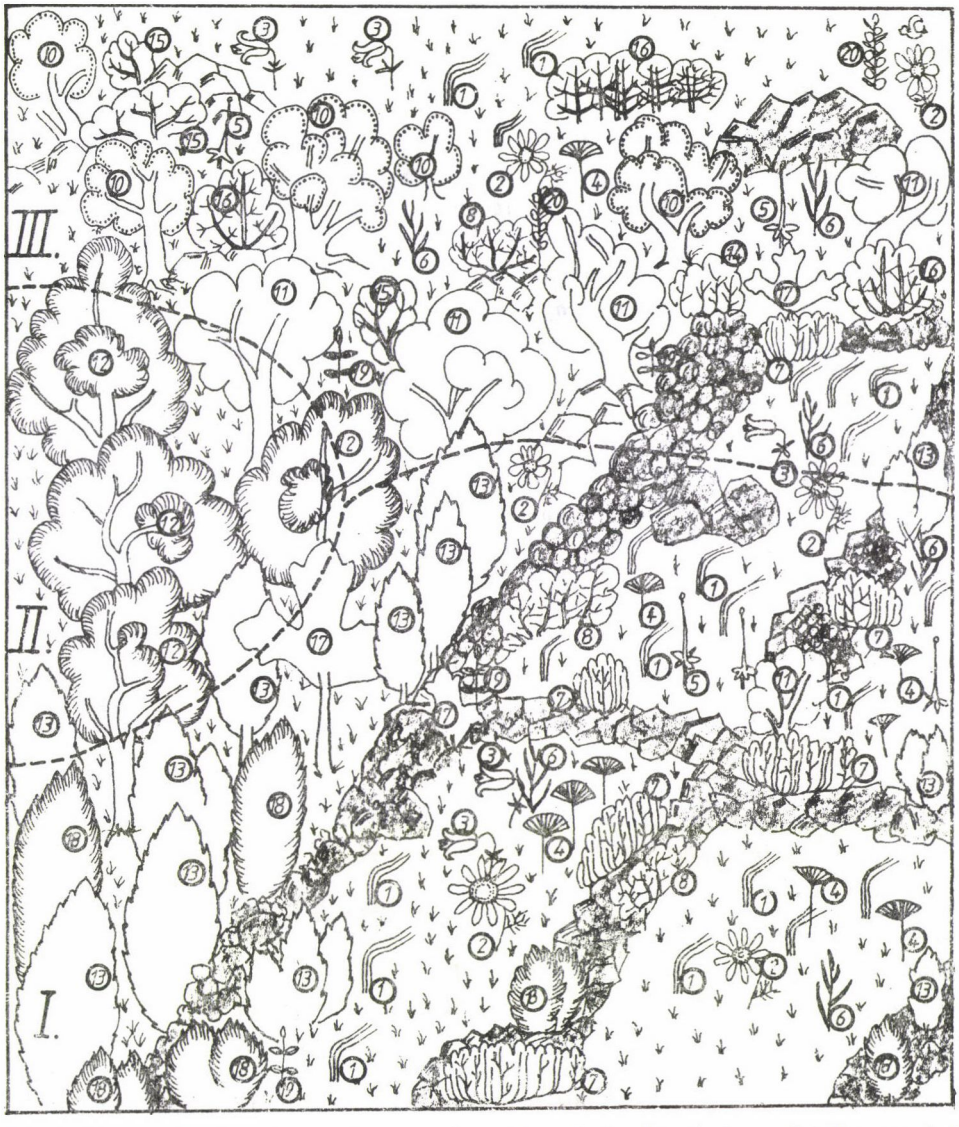

Fig. 3. Design of original vegetation and formation of abandoned vineyards. Characteristic species: 1 — *Stipa tirsa*, 2 — *Adonis vernalis*, 3 — *Pulsatilla grandis*, 4 — *Peucedanum cervaria*, 5 — *Geranium sanguineum*, 6 — *Inula ensifolia*, 7 — *Amygdalus nana*, 8 — *Cerasus fruticosa*, 9 — *Prunus spinosa*, 10 — *Quercus pubescens*, 11 — *Quercus petraea* (s.l.), 12 — *Quercus cerris*, 13 — *Cornus hungarica*, 17 — *Acer campestre*, 18 — *Ulmus campestris*, 19 — *Dictamnus albus*, 20 — *Echium russicum*. I. *Aceri tatarico-Quercetum*, II. *Quercetum petraeae-cerris*, III. *Corno-Quercetum*

On the site of vine plantation, associations of herbaceous plants have mostly developed (BARÁTH 1963):

(1) in dry habitats:

Campanulo-Stipetum tirsae
Cleistogeno-Festucetum rupicolae
festucetosum rupicolae
stipetosum dasyphyllae
botriochloetosum
stipetosum capillatae
Type of *Peucedanum cervaria*
Type of *Carex humilis – Rosa pimpinellifolia*

(2) in wet habitats:
Alopecuretum pratensis

(3) Associations of no particular character, 1, 2 or 5 years after the abandonment of cultivation, for example: *Echio-Melilotetum albi*, *Calamagrostietum epigeii*.

The constant-subconstant species of the associations mentioned for habitat (1) are as follows:

the following species have a value of constancy V:

Stipa tirsa (stenophylla)
Koeleria cristata
Festuca rupicola
Dianthus pontederae
Eryngium campestre

the following species have a value of constancy IV:

Aster linosyris
Dorycnium herbaceum
Euphorbia cyparissias
Galium verum
Lathyrus latifolius
Peucedanum cervaria
Potentilla recta
Scorzonera hispanica
Pisum elatior

The bounderies and supporting walls serve as shelter for woody plants, for example:

Acer campestre
Quercus petraea (s.l.)
Quercus pubescens
Quercus cerris
Fraxinus ornus
Sorbus torminalis
Pyrus nivalis var. *orientalis*
Pyrus pannonica
Colutea arborescens
Cornus hungarica
Cerasus fruticosa
Amygdalus nana
Rosa gallica (s.l.)
Viburnum lantana, etc.

However, the woody plants give shelter to numerous forest plants of the original association:

Brachypodium pinnatum
Dictamnus albus
Euphorbia polychroma
Vicia sparsiflora
Lithospernum purpureo-coeruleum, etc.

Vineyards with thick soil abandoned about 70–100 years ago, now have rich (secondary) *Campanulo-Stipetum tirsae (Stipetum stenophyllae pannonicum)* associations. Some of them are again being cultivated.

B) *Stone-quarries*

(1) *Original associations*

The *stone-quarries* examined are situated in the region of the Mátra Hills in the zone of *Quercetum petraeae-cerris* (Felsőcserkő, Sástő, Mátrafüred) and in the zone of *Aceri tatarico-Quercetum* in the foot-hills (Gyöngyös; 2 quarries at the southwestern foot of Sárhegy). Only one quarry lies in the zone of hornbeam beech wood (Pincekút).

The other group of quarries is found in the Buda Hills (Rókahegy, Szépvölgyi Road). The exploitation of the quarries stopped 10–15 years ago. Altogether 10 stone-quarries were investigated.

(2) *Plants of the rocky walls*

These are of different origin, because some of them derive from the native flora of the region, while others come from the ruderalized flora. In the zone of *Quercetum petraeae-cerris* the following species can be found most frequently: *Achillea nobilis* subsp. *neilreichii* (pioneer), *Anthemis tinctoria*, *Melica ciliata* (pioneer), *M. transsilvanica*, *Chamaenerion angustifolium*, *Linaria genistifolia*, *Lychnis coronaria*, *Veronica spicata*, *Poa nemoralis*, *Sedum* sp., *Echium vulgare*, *Inula conyza*, *Carduus acanthoides*, *Verbascum phlomoides*, *Lepidium campestre*, etc. (Fig. 4).

Of the woody plants, *Fraxinus ornus* and *Rosa canina* are to be found.

(3) *Plants of the base*

Again the *Melica* species, *Origanum vulgare*, *Clinopodium vulgare*, *Galium mollugo*, *Pulmonaria mollissima*, *Digitalis grandiflora*, *Linaria genistifolia*, *Inula ensifolia* and with only weak dominance, *Tussilago farfara*. In addition, there are usually woody plants forming the underbush: for example, *Pyrus pyraster*, *Acer campestre*, *Crataegus monogyna* (frequ), *Rosa canina*, *Cornus (sanguinea) hungarica* (frequ), *Rhamnus catharticus*, *Prunus spinosa* (frequ), *Ligustrum vulgare* (frequ), *Acer tataricum*, *Fraxinus ornus*, *Euonymus europaeus*, *Euonymus*

Fig. 4. Plants on the rocky walls of a small stone pit *(Melica ciliata, Cornus hungarica, Prunus spinosa)*

verrucosus, *Colutea arborescens*, *Salix capraea*, *Cerasus fruticosa*, *Ulmus procera*, *Populus tremula*, *Quercus patraea*, *Frangula alnus*, *Corylus avellana*, *Cerasus mahaleb*, *Berberis vulgaris*, *Rubus fruticosus* and *Clematis vitalba*.

(4) *Plants of the bottom of the quarries*

The vegetation has a much richer variety of species. Here, both the herbaceous plants of the base and some species of the grassland communities are to be found. In some places, where water accumulates, uliginal vegetation can also develop, for example in the amphitheatre-like quarry (5 hectares) in Sástó (Mátra Hills): *Typha angustifolia*, *Equisetum palustre*, *Lythrum hyssopifolia*, *Holoschoenus romanus*, etc.

Here the herbaceous vegetation has a mosaic-like composition. Pioneer species are mixed with the native flora and ruderalized plants. The species usually have little abundance (D). The species found most often are (Fig. 5):

Agrimonia eupatorium
Euphorbia cyparissias
Coronilla varia
Potentilla argentea
Origanum vulgare
Verbascum austriacum
Linaria genistifolia
Dorycnium herbaceum
Inula ensifolia
Potentilla recta
Calamagrostis epigeios
Lathyrus latifolius
Viscaria vulgaris
Seseli osseum
Digitalis lanata
Euphorbia pannonica
Clinopodium vulgare
Hypericum perforatum
Galium verum
Tunica prolifera
Dianthus collinus
Dianthus pontederae
Achillea collina
Achillea pannonica
Achillea nobilis subsp. *neilreichii*
Linum tenuifolium
Plantago media
Salvia pratensis
Salvia nemorosa
Adonis vernalis
Poa compressa
Peucedanum alsaticum
Echinops sphaerocephalus
Carlina vulgaris subsp. *intermedia*
Teucrium chamaedrys
Asperula cynanchica

(5) *Waste rocks*

Non-disturbed waste rocks, depending on the zone where they are situated, become populated relatively quickly. First, groups of *Tussilago farfara* appear. In the zone of hornbeam-beechwood a closed stand of *Salix caprea* has developed. In the zone of *Quercus cerris* and *Acer tataricum*, and generally in the region of *Quercus pubescens*, at the base of quarries associations of *Prunetalia* (thorn-bushes) can be found, mainly of the group *Prunion spinosae*. At the bottom of quarries the association may close. If the anthropogenic effect is entirely absent, it progresses towards an association of *Festucion rupicolae* Soó. In the case of increasing anthropogenic effect, such as the frequent appearance of tourists, etc. associations of *Plantaginetea majoris* may develop.

C) *Species of regenerating regions*

The characteristic species most often found in *regenerating regions* are *Adonis vernalis*, *Botriochloa ischaemum*, *Bromus erectus*, *Carlina vulgaris* subsp. *intermedia*, *Dorycnium herbaceum*, *Festuca rupicola*, *Inula ensifolia*, *Melica*

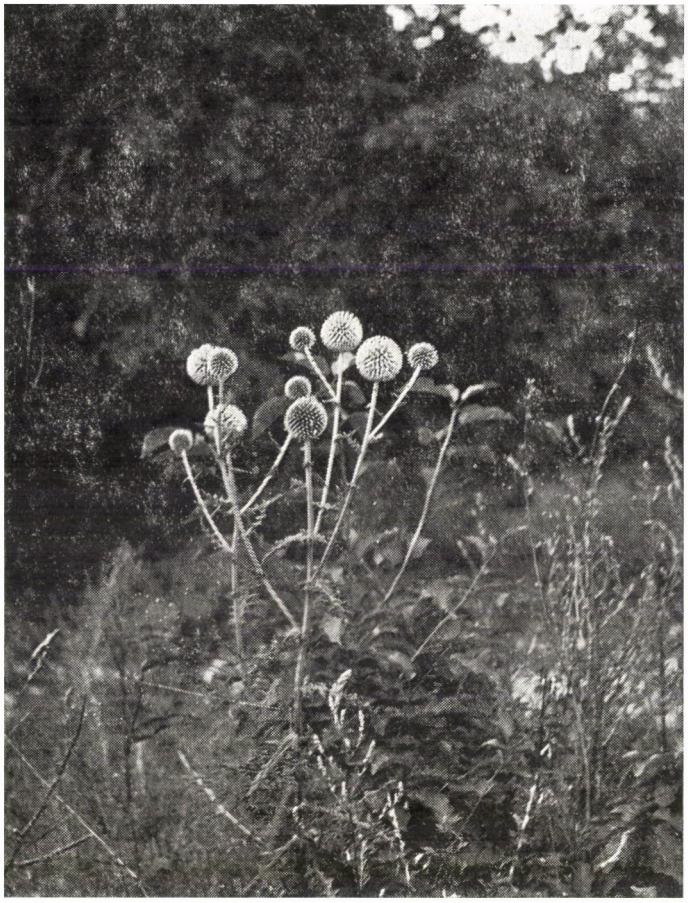

Fig. 5. Plants living in the inner base of a stone quarry

transsilvanica, ***Potentilla argentea***, *Scabiosa ochroleuca*, *Sanguisorba minor* and in some places *Dactylis glomerata*, *Galium verum*, *Seseli osseum* and *Petrorhagia prolifera* (Fig. 6.).

D) *Protected plants*

Mention should be made of the protection of the regions presented above. The Hungarian National Office for the Protection of the Environment and Nature has taken note of the abandoned quarries, though this is often mainly because of their geological importance. Some of the rich secondary vegetation of the abandoned vineyards is also granted protection, for example at the southern foot of the Mátra Hills, on the slopes above the town of Gyöngyös.

Protected plants (in Hungary) which have immigrated into the secondary biotopes investigated are:

Fig. 6. Inula ensifolia: a characteristic species of regenerating vegetations

Adonis vernalis, *Amygdalus nana*, *Aster amellus*, *Campanula macrostachya*, *Dianthus giganteiformis* subsp. *pontederae*, *Dictamnus albus*, *Echium russicum*, *Iris pumila*, *Iris variegata*, *Jurinea mollis*, *Linum flavum*, *Polygala major*, *Pulsatilla* species, *Stipa dasyphylla*, *Stipa tirsa*, etc.

E) *Adventive species*

The *adventive species* have not become dominant either in the grasslands or in other weedy stands. The following species can be found: *Ailanthus altissima*, *Robinia pseudoacacia*, *Solidago serotina*, *Ambrosia elatior*, *Acer negundo* and *Erigeron canadensis*. The *Stenactis* species are characteristic quarry plants and occasionally *Epilobium dodonaei* Vill. [*Chamaenerion angustissimum* (Graver) Sosnovskij] can be found (e.g.) Budapest, Rókahegy, etc.

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RAPID METHOD FOR DETERMINATION OF TOMATO LEAF AREA

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The relationship between tomato leaf area (Y) (Kecskemét export and Kecskemét jubileum varieties) and corresponding maximum leaf width (W) and maximum length (L) were studied in order to find a regression equation which could describe the relationship and make the lack of agreement between observed and estimated values of Y a minimum. The chosen equation was $\log \hat{Y} = -1.19 + 0.9.997 \log X$ where X was L multiplied by W. The mean absolute deviation % per leaf and per plant between the observed and estimated Y based on the chosen equation were 12.38 and 6.51% respectively. Tomato leaf area for leaves from 1 to 50 cm length and from 1 to 40 cm were width estimated and tabulated.

Introduction

The idea of finding a rapid method for determining tomato leaf area by measuring the maximum width and length of the leaf was stimulated by several factors:

(1) No reference to any such method was found in the literature.

(2) Leaf area determination by planimeter is labour-intensive, time consuming and subject to errors.

(3) An automatic leaf area meter is not always available.

(4) Although the automatic leaf meter is fairly rapid, it has some disadvantages, due to its failure to embrace the leaf to its maximum extent, especially for tomato leaves, which have characteristically cut leaf shapes, resulting in a negative error in leaf area or a positive error when the filter of the instrument is not clean enough. Moreover, the instrument cannot measure large tomato leaves without dividing them.

(5) Measuring leaf area by planimeter or automatic leaf meter requires the separation of the leaves from the plant, a practice which makes it impossible to follow the development of the same leaf throughout the season.

It was thus reasonable to suggest the present study, which only required the recording of the maximum width and length of the leaf in order to determine its area by employing the given equation or directly from the given estimation table.

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Material and methods

Leaf areas and the corresponding maximum leaf widths and lengths of 1439 tomato leaves of Kecskemét export and Kecskemét jubileum (dominant Hungarian varieties) were measured precisely by planimeter in order to study the correlation and regression coefficients between them and to find an equation which could describe the relationship. Leaves were sampled in two seasons, 6 times each at two-week intervals. Each sample represented all leaf shapes as in Fig. 1. The percentages of different leaf widths, lengths and areas used in the data are illustrated in Figs 2 and 3.

Since there were so many different kinds of curves*t* first a desicion had to be made as to what kind of curve should be fitted to the data. Therefore, the data mentioned were and continuous efforts were made to find the curve which would have the best correlation coefficient between leaf area, Y (as independent variable) on the one hand, and maximum leaf width (W), leaf length (L) and all their possible combinations, i.e. $L \times W$, $L + W$, L/W (as dependent variables) on the other. The type chosen seemed more logical and mathematically

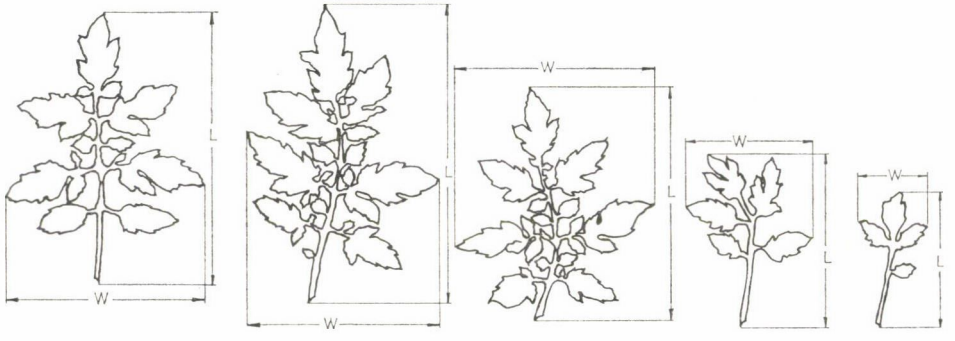

Fig. 1. Leaf stages used in the determination of tomato leaf area

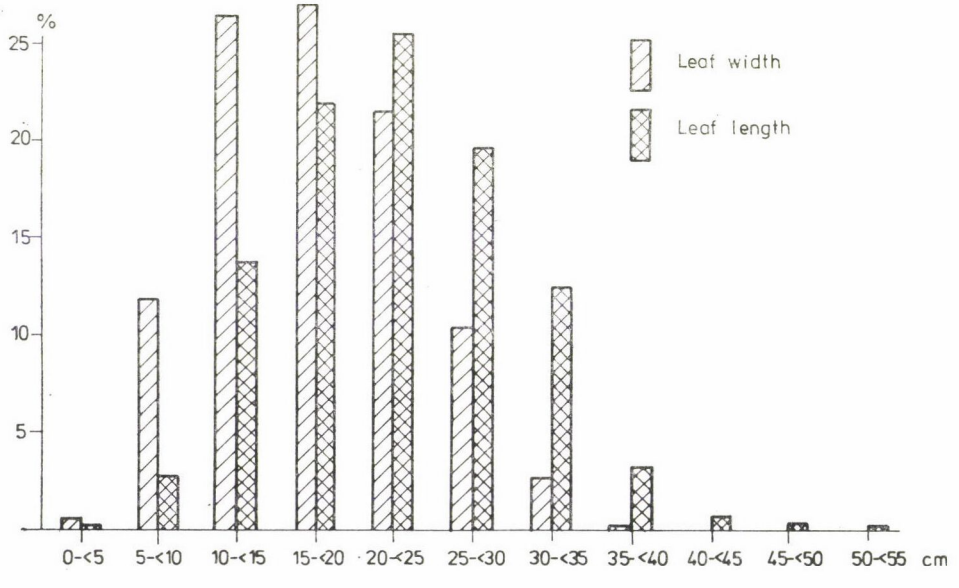

Fig. 2. The percentages of different leaf widths and lengths used in the data

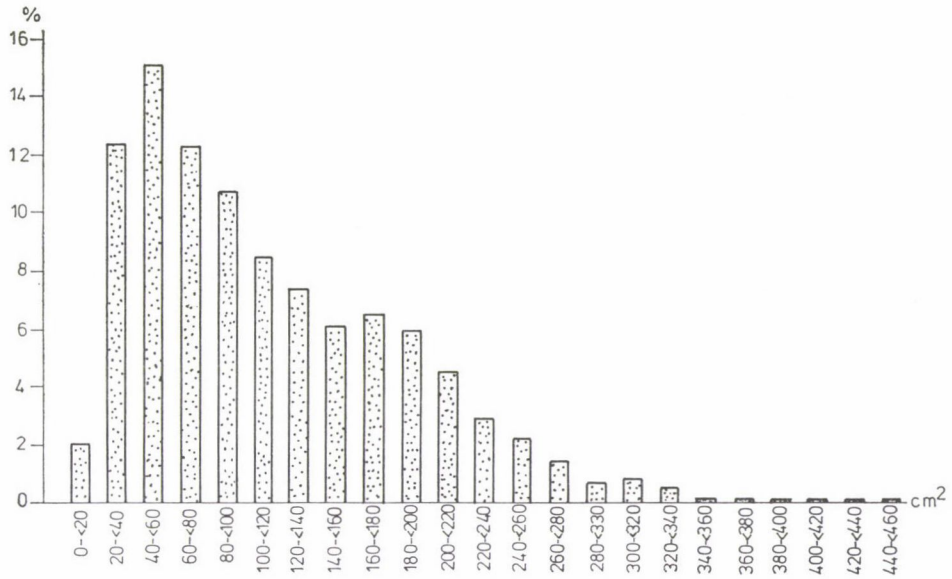

Fig. 3. The percentages of leaf areas used in the data

more simple to apply, and minimized the lack of agreement between observed and estimated values of Y. The latter was measured by the standard error of estimate (standard deviation from regression, s, LITTLE and HILLS 1975).

$$s = \sqrt{\frac{n}{n-2} \sum (Y \text{ "observed"} - Y \text{ "estimated"})^2}$$

the coefficient of correlation (r), and the mean absolute deviation % per leaf ($M.A.$) which was calculated as follows:

$$M.A. = \frac{\dfrac{\sum Y \text{ "observed"} - Y \text{ "estimated"}}{Y \text{ "observed"}} \times 100}{n}$$

where $n = 1439$.

All the types of curves studied were tested separately with each variety mentioned, but there was no significant difference between them. Therefore, the total data of the two varieties were employed to find an equation for both. It was noted that a wider or larger leaf had more small leaflets between the large leaflets along the leaf axis of symmatry. Therefore, an attempt was made to minimize the difference between estimated and observed Y values by calculating separate equations for leaves that had < 5, $5 < 10$, $10 < 15$, $15 < 20 \ldots$ cm width or length. An equation that had a (the intercept or point where a line crosses the Y axis) = zero was sought, in the hope that the lack of agreement would be minimized. According to OBÁDOVICS (1972) a linear equation was used in which b (regression coefficient) and r^2 (coefficient of linear determination) were calculated as follows:

$$b = \frac{\sum \dfrac{Y\,(observed)}{L \times W}}{n}$$

$$r^2 = \frac{s^2\,(estimated\ Y)}{s^2\,(observed\ Y)}$$

Results and discussion

A large number of tested curves and the corresponding regression equations were omitted and only the more valuable ones and their corresponding coefficients of correlation (r), variances of deviations from the regression (s^2), standard errors of estimate (s) and mean absolute deviation % per leaf ($M.A.$) were illustrated in Table 1 and Figs 4 and 5.

Assuming the homogeneity of variances of deviations from the regression, the tested regression equations were examined by *Bartlett*'s Test for

Table 1

Types of regression equations and corresponding r values, standard errors of estimate, variances and mean absolute deviations % per leaf

No.	Type of regression equation	r	s_*^2	s	$M.A.$
1	$\hat{Y} = 0.3048 \times X$ ($X = L \times W$) linear equation which has a = zero	0.970***	422.30 a	20.55	14.63
2	$\hat{Y} = 3.713 + 0.2914 \times X$ ($X = L \times W$) linear equation	0.960***	414.72 a	20.28	16.26
3	$\log \hat{Y} = -2.7 + 2.02 \log X$ ($X = L + W$) power function	0.974***	454.97 a	21.23	15.21
4	$\log \hat{Y} = -1.19 + 0.997 \log X$ ($X = L \times W$) power function	0.976***	411.18 a	20.36	12.38
5	$\hat{Y} = -2.78 + 0.334 \times X + 4.6 \times 10^{-5} \times X^2$ ($X = L \times W$) polynomial	0.975***	1124.26 b	33.53	20.05

*** Significant at 0.1% level
* Values which are indicated with similar alphabetical letters do not differ significantly

Table 2

Variances and their logs for the tested regression equations

Equation No.	Degrees of freedom "f_i"	$f_i s_i^2$	s_i^2	$\log s_i^2 f_i$	$(\log s_i^2)$
1	1438	607 267.4	422.30	2.6256	3 775.6128
2	1438	596 367.36	414.72	2.6177	3 764.2526
3	1438	654 246.86	454.97	2.6580	3 822.2040
4	1438	591 276.84	411.18	2.6140	3 758.932
Σ	5752	2 449 158.4			15 121.001
5	1438	1 616 685.8			4 387.1942
Σ	7190	4 065 844.3			19 508.195

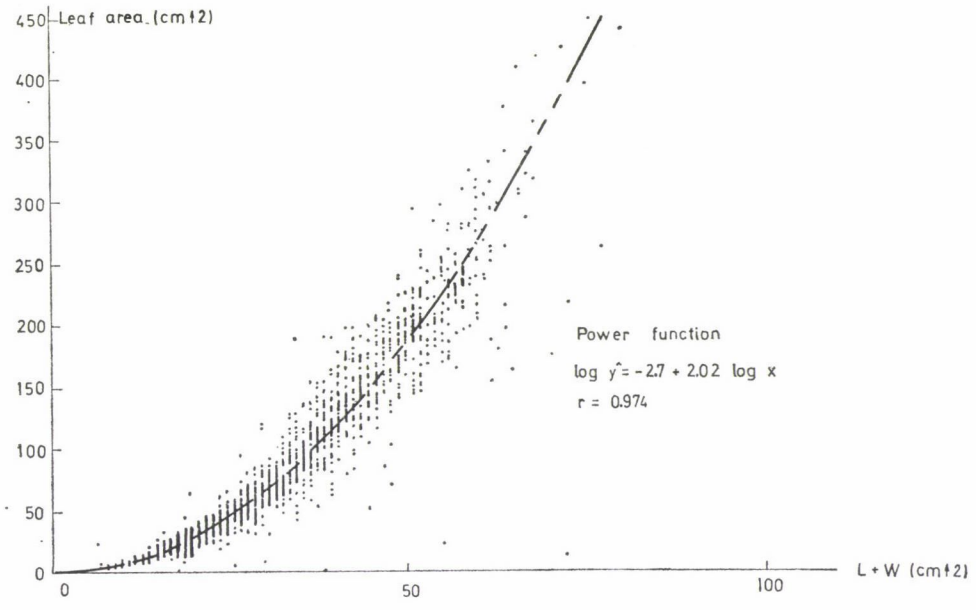

Fig. 4. Relationship between leaf area and length × width

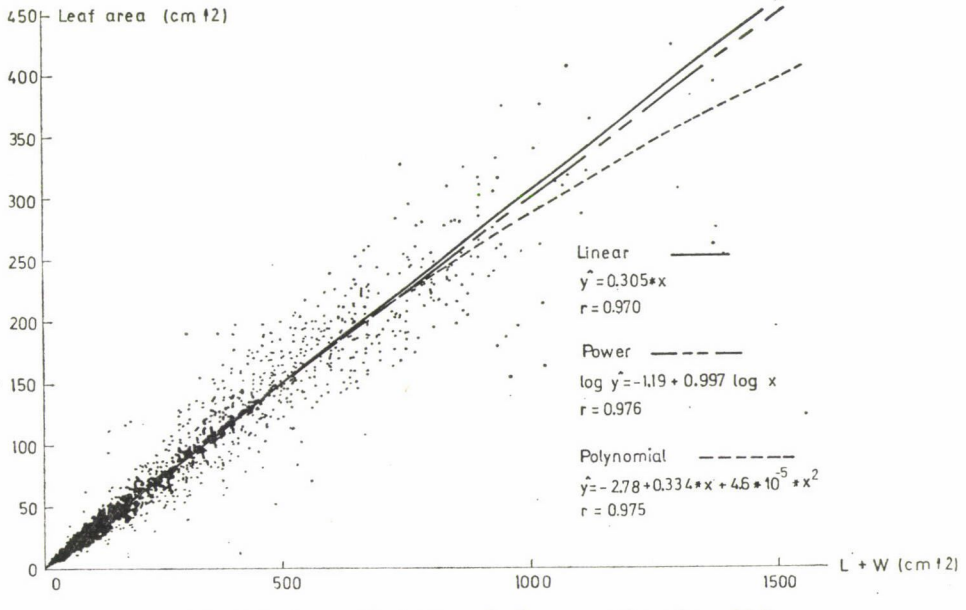

Fig. 5. Relationship between leaf area and length × width

Table 3

Tomato leaf length "L" and width "W" (cm) and their corresponding leaf

L \ W	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0																		
2	1	1																	
3	1	2	3																
4	1	2	4	5															
5	2	3	5	6	8														
6	2	4	5	7	9	11													
7	2	4	6	8	11	13	15												
8	2	5	7	10	12	14	17	19											
9	3	5	8	11	14	16	19	22	24										
10	3	6	9	12	15	18	21	24	27	30									
11	3	7	10	13	17	20	23	26	30	33	36								
12	4	7	11	14	18	22	25	29	32	36	40	43							
13	4	8	12	16	20	23	27	31	35	39	43	47	51						
14	4	8	13	17	21	25	29	34	38	42	46	50	55	59					
15	5	9	14	18	23	27	32	36	41	45	49	54	58	63	67				
16	5	10	14	19	24	29	34	38	43	48	53	58	62	72	77				
17	5	10	15	20	26	31	36	41	46	51	56	61	66	71	76	81	87		
18	5	11	16	22	27	32	38	43	49	54	59	65	70	75	81	86	92	97	
19	6	11	17	23	29	34	40	46	51	57	63	68	74	80	85	91	97	102	108
20	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114
21	6	13	19	25	32	38	44	50	57	63	69	75	82	88	94	101	107	113	119
22	7	13	20	26	33	40	46	53	59	66	72	79	86	92	99	105	112	118	129
23	7	14	21	28	35	41	48	55	62	69	76	83	90	96	103	110	117	124	131
24	7	14	22	29	36	43	50	58	65	72	79	86	93	101	108	115	122	129	136
25	8	15	23	30	38	45	52	60	67	75	82	90	97	105	112	120	127	135	142
26	8	16	23	31	39	47	55	62	70	78	86	93	101	109	117	124	132	140	148
27	8	16	24	32	41	49	57	65	73	81	89	97	105	113	121	129	137	145	153
28	8	17	25	34	42	50	59	67	75	84	92	101	109	117	126	134	142	151	159
29	9	17	26	35	44	52	61	70	78	87	95	104	113	121	130	139	147	156	165
30	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	152	161	170
31	9	19	28	37	46	56	65	74	84	93	102	111	121	130	139	148	158	167	176
32	10	19	29	38	48	58	67	77	86	96	105	115	124	134	144	153	163	172	182
33	10	20	30	40	49	59	69	79	89	99	109	118	128	138	148	158	168	177	187
34	10	20	31	41	51	61	71	81	92	102	112	122	132	142	152	163	173	183	193
35	11	21	32	42	52	63	73	84	94	105	115	126	136	146	157	167	178	188	199
36	11	22	32	43	54	65	75	86	97	108	118	129	140	151	161	172	183	194	204
37	11	22	33	44	55	67	78	89	100	111	122	133	144	155	166	177	188	199	210
38	11	23	34	46	57	68	80	91	102	114	125	136	148	159	170	182	193	204	216
39	12	23	35	47	58	70	82	93	105	117	128	140	152	163	175	186	198	210	221
40	12	24	36	48	60	72	84	96	108	120	132	144	155	167	179	191	203	215	227
41	12	25	37	49	61	74	86	98	110	123	135	147	159	172	184	196	208	220	233
42	13	25	38	50	63	75	88	101	113	126	138	151	163	176	188	201	213	226	238
43	13	26	39	52	64	77	90	103	116	129	141	154	167	180	193	205	218	231	244
44	13	26	40	53	66	79	92	105	118	132	145	158	171	184	197	210	223	236	250
45	14	27	41	54	67	81	94	108	121	135	148	161	175	188	202	215	228	242	255
46	14	28	41	55	69	83	96	110	124	138	151	165	179	192	206	220	233	247	261
47	14	28	42	56	70	84	98	112	127	141	155	169	183	197	211	225	239	253	267
48	14	29	43	58	72	86	101	115	129	144	158	172	186	210	215	229	244	258	272
49	15	29	44	59	73	88	103	117	132	146	161	176	190	205	219	234	249	263	278
50	15	30	45	60	75	90	105	120	135	149	164	179	194	209	224	239	254	269	283

area (cm^2) based on the equation $\log \hat{Y} = -1.19 + 0.997 \log X$

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
120																				
126	132																			
132	138	145																		
138	144	151	158																	
144	151	158	165	172																
149	157	164	172	179	187															
155	163	171	179	186	194	202														
161	169	177	186	194	202	210	218													
167	176	184	192	210	209	217	226	234												
173	182	191	199	208	217	225	234	242	251											
179	188	197	206	215	224	233	242	251	260	269										
185	194	204	213	222	231	241	250	259	268	278	287									
191	201	210	220	229	239	248	258	267	277	296	305									
197	207	217	227	236	246	256	266	276	286	295	305	315	325							
203	213	223	233	244	254	264	274	284	294	304	314	325	335	345						
209	219	230	240	251	261	272	282	292	303	313	324	334	344	355	365					
215	226	236	247	258	269	279	290	301	311	322	**333**	344	354	365	376	386				
221	232	243	254	265	276	287	298	309	320	331	342	353	364	375	386	397	408			
227	238	250	261	272	283	295	306	317	329	340	351	363	374	385	396	408	419	430		
233	244	256	268	279	291	303	314	326	337	349	361	372	384	395	407	418	430	442	453	
239	251	263	275	286	298	310	322	334	346	358	370	382	394	405	417	429	441	453	465	477
245	257	269	281	294	306	318	330	342	355	367	379	391	403	415	428	440	452	464	476	489
251	263	276	288	301	313	326	338	351	363	376	388	401	413	426	438	451	463	476	488	500
257	269	282	295	308	321	333	346	359	372	385	397	410	423	436	448	461	474	487	500	512
263	276	289	302	315	328	341	354	367	380	394	407	420	433	446	459	472	485	498	511	524
269	282	295	309	322	336	349	362	376	389	402	416	429	443	456	469	483	496	509	523	536
275	288	302	316	329	343	357	370	384	398	411	425	439	452	466	480	493	507	521	534	548
280	294	308	322	336	350	364	378	392	406	420	434	448	462	476	490	504	518	532	546	560
286	301	315	329	344	358	372	386	401	415	429	443	458	472	486	500	515	529	543	557	572
292	307	322	336	351	365	380	394	409	424	438	453	467	482	496	511	525	540	555	569	584
298	313	328	343	358	373	388	402	417	432	447	462	477	492	506	521	536	551	566	581	596

Homogeneity of Variances (JÁNOSSY et al. 1962) as in Table 2. The formula of *Bartlett*'s Test is:

$$\chi_0^2 = 2.3026 \left(f \log s^2 - \sum_{i=1}^{k} f_i \log s_i^2\right)$$

where $i = 1, 2, \ldots, k$, $f = \sum_{i=1}^{k} f_i$, $s^2 = \sum_{i=1}^{k} f_i s_i^2 / f$ and 2.3026 = factor for converting common logs to natural logs.

Substituting the known values in this equation, we have:

$$\chi^2 = 2.3026 \left(7190 \log \frac{4\,065\,844.3}{7190} - 19\,508.195\right) = 648.68$$

The chi-square (χ^2) value calculated requires an adjustment, and for this we need:

$$c = 1 + \frac{1}{3\,(\text{number of equations} - 1)} \cdot \frac{\text{number of equations}}{f_1} - \frac{1}{\Sigma f_i}.$$

Then χ^2 adjusted $= \dfrac{\chi^2 \text{ unadjusted}}{c} = \dfrac{648.68}{0.0036} = 180\,188.88.$

Reference was then made to a chi-square Table at 4 degrees of freedom (one less than the number of equations) and it was found that 180 188.88 far exceeded the tabular value (18.5) at the 0.1% level of significance. The evidence that the variances were heterogeneous was, therefore, very convincing.

A quick glance at the data was sufficient to convince us that Equation 5 had a much larger variance than the first four, which had fairly equal variances. Therefore, the homogeneity of variances within the first four equations was examined and according to *Bartlett*'s test the estimated χ^2 value was 4.94 as follows:

$$\chi^2 = 2.3026 \left(5752 \log \frac{2\,449\,158.4}{5752} - 15\,121.001\right) = 4.94.$$

The value of 4.94 was less than the tabular value at the 5% level of significance: evidence that the variances were homogeneous.

Since the first four regression equations were homogeneous in variances and significantly better than the fifth equation any of them can be used to calculate tomato leaf area, but since the regression equation of $\log Y = -1.19 + 0.997 \log X$ (where X is leaf width multiplied by leaf length) was the best (Table 1) because it had the highest coefficient of correlation (r), the lowest variance of deviation from the regression and the best mean absolute deviation % per leaf ($M.A.$), this was chosen for the determination of tomato

Table 4

Mean absolute deviation % of leaf area per plant

Plant No.	1	2	3	4	5	6	Mean %
No. of leaves/plant	44	53	40	20	42	22	
Deviation %/plant	7.05	8.11	6.06	8.17	5.58	4.42	6.51

Table 5

A homogeneity of variance test within 6 plants according to Bartlett's Test

Plant	Degrees of freedom, f_i	$f_i s_i^2$	s^2	$\log s^2 f_i$	$\log s_i^2$
1	43	40 950.62	952.34	2.9788	128.09
2	52	51 826.32	996.66	2.9985	155.92
3	39	43 039.23	1103.57	3.0428	118.66
4	19	14 903.41	784.39	2.8945	55.00
5	41	36 727.8	895.80	2.9520	121.04
6	21	15 094.38	718.78	2.8566	60.00
Σ	215	202 541.76			638.71

$$\chi^2 = 2.3026 \left(215 \log \frac{202\,541.76}{215} - 638.71\right) = 1.649 \text{ (not significant)}$$

leaf area. Since the methods mentioned in the introduction also have some errors in leaf area measurement, the equation chosen for the determination of tomato leaf area is recommended in spite of the fact that it has 12.38% and 6.51% (mentioned later) mean absolute deviation % per leaf and plant, respectively, which may be less, equal or larger than those of the other methods of determination.

To facilitate the determination of tomato leaf area based on this equation, the areas for leaves from 1 to 50 cm in length and from 1 to 40 cm in width were estimated and tabulated as shown in Table 3.

To complete the study, samples of 6 plants were taken randomly from the control, and the mean absolute deviation % of leaf area per plant measured by planimeter was calculated according to the chosen equation in order to know the range of error per plant resulting from applying the chosen equation. A figure of 6.51% was obtained (Table 4).

The homogeneity of variances was tested within the six samples also by *Bartlett*'s Test, which indicated that there was no significant difference within the samples, since the estimated Chi value (1.649) was much smaller than the tabulated one at the 5% level of significance, as indicated in Table 5.

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BIOCHEMICAL STUDIES ON EGYPTIAN LUPIN SEEDS *(LUPINUS TERMIS)* I. CHEMICAL ANALYSIS AND ELIMINATION OF BITTER TASTE

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Lupin seeds *(Lupinus termis)* were analyzed for moisture, ether extract (Nitrogen X 6.25), carbohydrates, crude fibre, ash and some minerals (Ca, P). The analysis showed that it contained relatively high crude protein content (40.64%), 7.04% ether extracts, 30.80% carbohydrates, 8.83% crude fibre, 2.5% ash, 0.439% Ca and 0.297% P. Technological treatments for elimination of bitter taste caused a sharp decrease in vitamin C and ash content while ether extract content was not affected. Besides, there was an apparent increase in per cent protein during all treatments as a result of the decrease in carbohydrates during soaking. Phosphorus (P) and calcium (Ca) content decreased. The soaking water contained more carbohydrates than proteins.

Introduction

Lupinus termis is a popular legume, the seeds of which are consumed in the Middle East as a snack, due essentially to their pleasant taste and to a lesser extent as a source of dietary protein (from the consumer's viewpoint). Termis seeds need special treatment to remove the bitter taste before consumption.

The chemical composition of lupin seeds has been investigated by several authors, including ZUCAS et al (1961), IKONNIKOVA (1962), EL-NOCKERASHY and OSMAN (1965), PETRUKHINA (1966), GLADSTONES (1970), ABDEL-KADER et al. (1975). These authors ascertained that all lupin species had high contents of protein, fat, Ca and P, and low contents of carbohydrates and copper.

The aim of the present work was to determine the changes that occur in the chemical composition, soluble matter and vitamin C content when lupin seeds are soaked and boiled several times to remove the bitter taste and make them suitable for human consumption.

Material and methods

Samples

Lupin seeds *(Lupinus termis)* were obtained from El-Minia Governate, Ministry of Agriculture, Egypt. The samples were rubbed with a dry cloth in order to clean them. Several technological methods were applied to remove the bitter taste that is inherent due to endogenous alkaloid substances. The bitter taste makes crude lupin unsuitable for human consumption.

Processing lupin seeds for human consumption

After preliminary work, the following three procedures were adopted for lupin seeds, as they proved to be efficient ways of eliminating the undesirable bitter property.

In the first procedure, a certain quantity of lupin seeds were soaked in running water for 6 hr, then boiled for 1 hr, and again soaked in tap water for 48 hr, changing the water every 2 hr. The treated seeds were sun-dried for 4–6 days until the moisture content reached 8–10%. During the second treatment, seeds were soaked for 9 hr, boiled for 1/2 hr, then soaked for 48 hr. Finally, the treated seeds were sun-dried as before. For the third treatment, samples were soaked for 12 hr, then divided into two parts, one of which as boiled for 1/2 hr (A) and the other for 1.5 hr (B). The both samples were soaked separately for 48 hr and dried as before.

Samples were taken and prepared according to the A.O.A.C. methods (ANONYMOUS (1965). Prepared samples were packed in approx. 300 ml glass jars and stored under refrigeration for analysis.

Methods of analysis

Lupin flour was analysed before and after processing for ascorbic acid, moisture, total nitrogen, ether extract and total soluble solids (TSS) according to the A.O.A.C. methods (ANONYMOUS 1965).

Phosphorus was determined colorimetrically using a Unicam SP 600 and a wavelength of 660 nm following the method of JACKSON (1958). Calcium was determined by precipitation as calcium oxalate after JACKSON (1958). The caloric value was calculated as reported by the American Meat Institute Foundation (ANONYMOUS 1960).

Results and discussion

The gross chemical composition and the energy value of 100 g raw termis seeds are shown in Table 1. The data reveal that Egyptian termis seeds have a relatively high protein content (45.23% on a dry weight basis) compared with other legumes such as lentils *(Eurium lens)* and broad beans *(Vicia faba)*, which contain 28.1 and 28.9% respectively, as reported by EL-NOCKERASHY and OSMAN (1965), VRIES and VAN DER LEE (1950) and GLADSTONES (1970).

The effects of the three treatments used in removing the bitter taste on the chemical composition of termis seeds are shown in Tables 2, 3, 4 and 5.

Table 1

Chemical composition of raw termis seeds

Contents	Proportion in relation to crude weight	Proportion in relation to dry weight
	%	
Moisture	10.13	—
Crude protein	40.64	45.23
Ether extract	7.04	7.83
Carbohydrate	30.80	34.27
Crude fibre	8.83	9.82
Ash	2.56	2.85
Calcium	0.439	0.489
Phosphorus	0.297	0.330
Kcal/100 g	349.12	388.47

Table 2

Effect of the first treatment on the chemical composition of termis seeds (Lupinus termis)

Estimates	Proportion in relation to dry weight, %			
	Raw	The first treatment		
		Soaking for 6 hours		
		Before boiling	Boiling for 1 hour	Boiling for 1 hour and soaking for 48 hours
Crude protein	45.23	45.17	48.99	52.53
Retained, %	100	99.87	108.31	116.14
Ether extract	7.83	7.84	7.98	8.03
Retained, %	100	100.12	101.92	102.55
Carbohydrate	34.27	34.34	30.67	26.89
Retained, %	100	100.35	89.50	78.47
Crude fibre	9.82	9.82	10.42	11.08
Retained, %	100	100	106.11	112.83
Ash	2.85	2.83	1.94	1.47
Retained, %	100	99.30	68.07	51.58
Calcium	0.489	0.462	0.459	0.488
Retained, %	100	94.48	93.87	99.80
Phosphorus	0.330	0.325	0.320	0.322
Retained, %	100	98.48	96.97	97.58
Kcal/100 g	388.47	388.60	390.46	389.95
Retained, %	100	100.03	100.51	100.38

Table 3

Effect of the second treatment on the chemical composition of termis seeds (Lupinus termis)

Estimates	Proportion in relation to dry weight, %			
	Raw	The second treatment		
		Soaking for 9 hours		
		Before boiling	Boiling for 1/2 hour	Boiling for 1/2 hour and soaking for 48 hours
Crude protein	45.23	45.19	49.36	53.36
Retained, %	100	99.91	100.13	117.97
Ether extract	7.83	7.83	7.99	8.01
Retained, %	100	100	102.04	102.30
Carbohydrate	34.27	34.32	34.13	26.06
Retained, %	100	100.15	87.92	76.04
Crude fibre	9.82	9.82	10.47	11.11
Retained, %	100	100	106.62	113.14
Ash	2.85	2.84	2.05	1.46
Retained, %	100	99.65	71.93	51.23
Calcium	0.489	0.478	0.459	0.479
Retained, %	100	97.75	93.87	97.96
Phosphorus	0.330	0.326	0.324	0.328
Retained, %	100	98.79	98.18	99.39
Kcal/100 g	388.47	388.51	389.87	389.77
Retained, %	100	100.01	100.36	100.33

Table 4

Effect of the third treatment (A) on the chemical composition of termis seeds (Lupinus termis)

Estimates	Proportion in relation to dry weight, %			
	Raw	The third treatment (A)		
		Soaking for 12 hours		
		Before boiling	Boiling for 1/2 hour	Boiling for 1/2 hour and soaking for 48 hours
Crude protein	45.23	44.24	48.22	52.92
Retained, %	100	97.81	106.81	117.00
Ether extract	7.83	7.83	7.91	8.02
Retained, %	100	100	101.02	102.43
Carbohydrate	34.27	35.28	31.30	26.48
Retained, %	100	102.95	91.33	77.27
Crude fibre	9.82	9.82	10.46	11.13
Retained, %	100	100	106.52	113.34
Ash	2.85	2.83	2.11	1.46
Retained, %	100	99.30	74.04	51.53
Calcium	0.489	0.462	0.459	0.478
Retained, %	100	94.49	93.87	97.75
Phosphorus	0.330	0.320	0.322	0.325
Retained, %	100	96.97	97.58	98.48
Kcal/100 g	388.47	388.55	389.27	389.78
Retained, %	100	100.02	100.21	100.34

Table 5

Effect of the third treatment (B) on the chemical composition of termis seeds (Lupinus termis)

Estimates	Proportion in relation to dry weight, %			
	Raw	The third treatment (B)		
		Before boiling	Boiling for 1 1/2 hours	Boiling for 1 1/2 hours and soaking for 48 hours
Crude protein	45.23	44.24	49.64	51.78
Retained, %	100	97.81	109.75	114.48
Ether extract	7.83	7.83	7.93	8.02
Retained, %	100	100	101.28	102.43
Carbohydrate	34.27	35.28	29.77	27.58
Retained, %	100	102.95	96.87	80.48
Crude fibre	9.82	9.82	10.74	11.13
Retained, %	100	100	109.37	113.34
Ash	2.85	2.83	1.92	1.49
Retained, %	100	99.30	67.37	52.28
Calcium	0.489	0.462	0.451	0.487
Retained, %	100	94.49	92.23	99.59
Phosphorus	0.330	0.320	0.321	0.323
Retained, %	100	96.97	97.27	97.88
Kcal/100 g	388.47	388.55	389.01	389.62
Retained, %	100	100.02	100.14	100.30

Table 6

Effect of various soaking and boiling treatments on the vitamin C content of Egyptian lupin seeds

No. of treatment	Conditions of treatment	Vitamin C content mg/100 g dry weight	% loss of vitamin C
	Raw	2.7	—
Treatment 1	Soaking for 6 hours	2.7	—
	Boiling for 1 hour	1.2	55.6
	Soaking for 48 hours	0.5	81.48
	Soaking for 9 hours	2.6	3.70
Treatment 2	Boiling for 1/2 hour	1.4	48.15
	Soaking for 48 hours	0.6	77.78
	Soaking for 12 hours	2.7	—
Treatment 3A	Boiling for 1/2 hour	1.3	51.85
	Soaking for 48 hours	0.7	74.07
	Soaking for 12 hours	2.7	—
Treatment 3B	Boiling for 1 1/2 hours	0.8	70.37
	Soaking for 48 hours	0.4	85.19

Table 7

The loss in soluble matter of termis seeds during the various treatments (% of dry weight)

Treatment	Total soluble solids	Soluble protein	Soluble minerals	Soluble carbohydrates
Soaking for 6 hours	0.110	0.055	0.026	0.029
Boiling for 1 hour	7.800	0.972	0.860	6.068
Soaking for 48 hours	6.400	1.774	0.544	4.082
Total loss	14.310	2.691	1.430	10.189
Soaking for 9 hours	0.120	0.069	0.032	0.019
Boiling for 1/2 hour	5.920	0.635	0.823	4.462
Soaking for 48 hours	0.010	1.768	0.535	5.707
Total loss	14.050	2.472	1.390	10.188
Soaking for 12 hours	0.172	0.112	0.041	0.019
Boiling for 1/2 hour	6.140	0.848	0.732	4.560
Soaking for 48 hours	8.000	1.769	0.607	5.624
Total loss	14.312	2.729	1.380	10.203
Soaking for 12 hours	0.172	0.112	0.041	0.019
Boiling for 1 1/2 hours	8.640	1.200	0.940	6.500
Soaking for 48 hours	6.250	1.773	0.509	3.968
Total loss	15.062	3.085	1.490	10.487

In all treatments, there was an apparent increase in nitrogen content due to the leaching out of carbohydrates during soaking and boiling. Soaking for 6 hr had no effect on protein content, while after boiling there was an apparent increase in protein. On the other hand, carbohydrates were reduced after the final soaking. The ether extract content was not significantly affected during the three treatments. The ash content decreased sharply during the treatments due to the leaching out of minerals with the exception of calcium and phosphorus in the soaking water. However, there were only minor differences in chemical composition between seeds treated with any of the investigated methods (Tables 2, 3, 4 and 5).

In addition, the caloric value of raw termis seeds, which amounted to 388.47 Kcal/100 g, was not significantly affected by the various treatments.

With regard to protein and ash, it seems that a large amount of ash and a low amount of protein (water-soluble nitrogen) were lost during soaking. Therefore, the ratio of the carbohydrate, protein, ash, and fat contents in the seeds (on a dry weight basis) may be different before and after soaking.

Table 6 shows the changes in the vitamin C content in lupin seeds before and after the treatments. In all cases, the vitamin C content was greatly decreased and in treatment 3B the rate of decrement was as high as 85%.

Therefore, a high loss of vitamin C content took place during soaking and boiling, so the vitamin C content is very low in lupin seeds, which should consequently not be evaluated as a vitamin C source.

From the results shown in Table 7 it can be seen that certain substances were leached out into the water during the soaking and boiling treatments. This involves some of the protein (water-soluble nitrogen) and ash (water-soluble minerals) and other substances such as water-soluble carbohydrates (e.g. pentosans and sugars).

The results revealed that the losses of total soluble solids after soaking in treatments 1, 2, 3A and 3B were 14.31%, 14.05%, 14.31% and 15.06% respectively. It was noticed that the loss of T.S.S. after boiling was higher than that after soaking for 48 hours during treatments 1 and 3B, while the loss after soaking for 48 hours was higher than that after boiling during treatments 2 and 3A. This could be due to the fact that the periods of boiling during treatment 1 and 3B were longer than those during treatments 2 and 3A. This could be due to the fact that the periods of boiling during treatments 1 and 3B were longer than those during treatments 2 and 3A.

This explains the differences between the chemical composition of the dry matter in raw and treated seeds.

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GENETIC ASSOCIATIONS AND SELECTION INDICES IN THREE HEIGHT GROUPS OF CASTOR (*RICINUS COMMUNIS* L.)

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Path analysis and correlation coefficients of ten attributes on seed yield estimated in three height groups of castor. Based on the associations, selection indices were constructed with different character combinations.

The results indicated that height has a distinct impact on character associations. Hence, different variables may be used in computing selection indices in three height groups. Also, the five-character index including seed yield proved to be more efficient than straight selection based on yield alone. Besides seed yield and racemes/plant, number of primary and secondary branches, and capsules/raceme in the dwarf group primary branches, day to maturity, and seed weight in the medium tall group; and days to flower, node number, and plant height in the tall group, formed the five-character index.

Introduction

Seed yield in castor is a complex entity determined by the interplay of various components, directly as well as indirectly. Simple correlations (JAISANI and PATEL, 1963; SINDAGI 1965; DORAIRAJ et al. 1973) measure the mutual association between two variables, but fail to provide the causal basis for such an association. Path analysis (WRIGHT 1921, 1923) not only permits the separation of correlation coefficients into means of direct and indirect effects, but also the study of specific forces acting to produce a given correlation in correlated variables (BHATT and REDDY 1981). Further, since selection based on yield alone will not be helpful, the use of a suitable selection index, applying different weights to various traits has proved its usefulness (HAZEL and LUSH 1943, SALIH and KHIDIR 1975).

Material and methods

The present investigation was carried out to assess the impact of plant height on character associations and to construct suitable selection indices in castor.

Fifty diverse varieties belonging to three height groups, viz., dwarf (22), medium tall (14) and tall (14), were grown in a randomized block design with three replications. The characters under study were, (1) days to flower, (2) number of nodes to main raceme, (3) number of primary branches, (4) number of secondary branches, (5) number of capsules/main raceme, (6) number of racemes/plant, (7) total plant height (cm), (8) days to maturity of main raceme, (9) 100-seed weight (g), (10) oil content (%), and (11) seed yield/plant (g). Oil con-

tent (%) was determined on a NMR-spectrophotometer. Path analysis was carried out as illustrated by DEWEY and LU (1959) using phenotypic correlations. Selection indices were constructed in three height groups as suggested by ROBINSON et al. (1951).

Results and discussion

The estimates of direct and indirect effects of then attributes and their correlations with seed yield are presented in Table 1.

Table 1

Path-coefficient analysis and phenotipic correlations of ten variables on seed yield in three height groups of castor

Correlated variables	Path coefficients in different groups		
	Dwarf	Medium tall	Tall
1. Days to flower			
Direct effect	—0.1153	1.0492	—2.5568
Indirect effect via:			
No. of nodes	0.2019	—0.4449	0.2431
No. of primary branches	—0.1135	—0.2825	0.1063
No. of secondary branches	—0.0667	2.1432	0.1475
No. of capsules/raceme	—0.0187	0.0080	—0.0253
No. of racemes/plant	—0.1070	—1.3175	—0.5131
Plant height	—0.0002	—0.2649	0.1109
Days to maturity	—0.1651	—1.4061	2.6095
100 seed weight	—0.0131	0.5333	—0.3431
Oil content	0.0076	—0.1379	0.0100
Total (rp)	—0.3902	—0.1201	—0.2120
2. No. of nodes			
Direct effect	0.2653	—0.5863	0.2783
Indirect effect via:			
Days to flower	—0.0878	0.7962	—2.2242
No. of primary branches	—0.0633	—0.1560	0.0267
No. of secondary branches	—0.0302	1.6131	0.1103
No. of capsules/racemes	0.0265	0.0162	—0.0708
No. of racemes/plant	—0.0617	—0.9531	—0.3457
Plant height	—0.0056	0.0783	0.2234
Days to maturity	—0.1291	—1.1169	2.2573
100 seed weight	—0.0060	0.5404	—0.2422
Oil content	0.0188	—0.3862	0.0093
Total (rp)	—0.0731	—0.1546	0.0224
3. No. of primary branches			
Direct effect	0.2830	2.0424	—0.3713
Indirect effect via:			
Days to flower	0.0462	—0.1451	0.7320
No. of nodes	—0.0594	0.0448	—0.0200
No. of secondary branches	0.1128	—4.0533	—0.1641
No. of capsules/raceme	0.0652	0.0209	—0.0149
No. of racemes/plant	0.1545	3.0260	0.6361
Plant height	—0.0065	0.2287	0.0781
Days to maturity	0.0471	0.6300	—0.7855
100 seed weight	—0.0126	—0.8366	0.2509
Oil content	0.0144	—0.3789	—0.0014
Total (rp)	0.6447**	0.5790*	0.3400

Table 1 (continued)

Correlated variables	Path coefficients in different groups		
	Dwarf	Medium tall	Tall
4. No. of secondary branches			
Direct effect	0.1566	—4.7585	—0.2500
Indirect effect via:			
Days to flower	0.0491	0.4726	1.5080
No. of nodes	—0.0511	0.1988	—1.1227
No. of primary branches	0.2039	1.7397	—0.2438
No. of capsules/racemes	0.0537	0.0167	0.0169
No. of racemes/plant	0.1998	3.3664	0.8032
Plant height	—0.0071	0.2544	—0.0376
Days to maturity	—0.0734	1.0848	—1.5475
100 seed weight	0.0474	—0.7094	0.2713
Oil content	0.0153	—0.0481	—0.0060
Total (rp)	0.5943**	0.6722**	0.3919
5. No. of capsules/raceme			
Direct effect	0.1403	0.0615	—0.1501
Indirect effect via:			
Days to flower	0.0154	0.1360	—0.4313
No. of nodes	0.0501	—0.1541	0.1313
No. of primary branches	0.1314	0.6950	—0.0369
No. of secondary branches	0.0599	—1.2957	0.0282
No. of racemes/plant	0.0702	0.5210	—0.0694
Plant height	—0.0039	0.3122	0.2550
Days to maturity	—0.0098	0.0254	0.6457
100 seed weight	—0.0200	0.3853	0.1503
Oil content	0.0041	—0.1344	—0.0021
Total (rp)	0.4378*	0.5522*	0.5207
6. No. of racemes/plant			
Direct effect	0.2206	3.6639	0.9202
Indirect effect via:			
Days to flower	0.0559	—0.3773	1.4257
No. of nodes	—0.0742	0.1526	—0.1046
No. of primary branches	0.1982	1.6368	—0.2567
No. of secondary branches	0.1418	—1.3721	—0.2182
No. of capsules/raceme	0.0446	0.0087	0.0113
Plant height	—0.0055	0.2478	—0.0321
Days to maturity	0.0771	0.8338	—1.4598
100 seed weight	—0.0083	—0.7785	0.2739
Oil content	0.0073	—0.4352	—0.0046
Total (rp)	0.6576**	0.6305*	0.5552*
7. Plant height			
Direct effect	—0.0157	0.4663	0.4337
Indirect effect via:			
Days to flower	—0.0017	—0.5961	—0.6540
No. of nodes	0.0942	—0.0984	0.1434
No. of primary branches	0.1170	1.0016	—0.0668
No. of secondary branches	0.0706	—2.5958	0.0217
No. of capsules/raceme	0.0345	0.0412	—0.0883
No. of racemes/plant	0.0772	1.9470	—0.0680
Days to maturity	0.0017	0.2113	0.6399
100 seed weight	0.0156	—0.0358	0.1028
Oil content	0.0249	—0.3602	—0.0012
Total (rp)	0.4183	—0.0188	0.4632

Table 1 (continued)

Correlated variables	Path coefficients in different groups		
	Dwarf	Medium tall	Tall
8. Days to maturity			
Direct effect	−0.1981	−1.8813	2.6184
Indirect effect via:			
Days to flower	−0.0961	0.7842	−2.5481
No. of nodes	0.1729	−0.3481	0.2399
No. of primary branches	−0.0672	−0.6840	0.1114
No. of secondary branches	0.0580	2.7438	0.1478
No. of capsules/raceme	0.0060	−0.0008	−0.0370
No. of racemes/plant	−0.0859	−1.6235	0.5130
Plant height	0.0001	−0.0524	0.1060
100 seed weight	−0.0061	0.6404	−0.3682
Oil content	0.0140	0.1880	0.0109
Total (rp)	−0.2014	−0.2341	−0.2320
9. 100 seed weight			
Direct effect	0.0738	1.6039	−0.5332
Indirect effect via:			
Days to flower	0.0205	0.3489	−1.6450
No. of nodes	−0.0217	−0.1975	0.1264
No. of primary branches	−0.0484	−1.0653	0.1747
No. of secondary branches	0.1005	2.1047	0.1272
No. of capsules/raceme	−0.0380	0.0148	0.0423
No. of racemes/plant	−0.0249	−1.7781	−0.4727
Plant height	−0.0033	−0.0104	−0.0836
Days to maturity	0.0163	−0.7512	1.8083
Oil content	0.0260	−0.1406	0.0135
Total (rp)	0.1008	0.1287	−0.4421
10. Oil content			
Direct effect	0.0908	−1.5133	0.0182
Indirect effect via:			
Days to flower	−0.0097	0.0856	−1.4016
No. of nodes	0.0549	−0.1496	0.1416
No. of primary branches	0.0450	0.5114	0.0283
No. of secondary branches	0.0265	−0.1513	0.0822
No. of capsules/raceme	0.0063	0.0055	0.0175
No. of racemes/plant	0.0177	1.0537	−0.2344
Plant height	−0.0043	0.1110	−0.0278
Days to maturity	−0.0306	0.2337	1.5645
100 seed weight	0.0211	0.1490	−0.3970
Total (rp)	0.2177	0.3456	−0.2082

Number of racemes/plant exhibited significant positive correlation with seed yield in three height groups. The correlations of primary and secondary branches and capsules/raceme with seed yield were highly positive in three height groups but were insignificant in the tall group.

In the dwarf group, none of the characters exhibited high direct effects on seed yield. However, the significant positive correlations of primary (0.6447) and secondary branches (0.5943), casules/raceme (0.4378) and racemes/plant (0.6576) with seed yield were due to both the direct and indirect effects.

In the medium tall group, days to flower depicted a high positive direct effect (1.0492); but its correlation with yield was low and negative (—0.1201), due to negative indirect effects via number of racemes/plant (—1.3175) and days to maturity (—1.4061). The significant positive correlation between number of primary branches and seed yield (0.5790) was mainly due to the high direct effect (2.0424); and therefore it may be selected for improvement in yield. Number of secondary branches showed a high negative direct effect,

Table 2

Expected genetic advance (G.A.) in seed yield from the use of various selection indices and their relative efficiency (R.E.)

Selection index	Dwarf	
	G.A.	R.E. (%)
Yield/plant	22.894	100
3 + 6	22.943	100.215
3 + 4 + 5	18.675	81.571
3 + 5 + 6	16.037	70.649
3 + 4 + 5 + 6	21.131	92.300
3 + 4 + 5 + 6 + 11	28.004	122.323

Selection index	Medium tall	
	G.A.	R.E. (%)
Yield/plant	21.261	100
3 + 6	44.241	208.084
3 + 6 + 8	46.090	216.782
3 + 6 + 9	46.173	217.168
3 + 6 + 8 + 9	47.218	222.083
3 + 6 + 8 + 9 + 11	48.408	227.683

Selection index	Tall	
	G.A.	R.E. (%)
Yield/plant	19.381	100
1 + 7	37.636	194.195
1 + 6 + 7	40.522	209.083
1 + 6 + 11	31.944	164.825
1 + 6 + 7 + 11	38.450	198.395
1 + 2 + 6 + 7 + 11	62.723	323.639

1. Days to flower
2. No. of nodes to main raceme
3. No. of primary branches
4. No. of secondary branches
5. No. of capsules/main raceme
6. No. of racemes/plant
7. Total plant height
8. Day to maturity of main raceme
9. 100 seed weight
10. Oil content
11. Seed yield/plant

(—4.7585) but its correlation was significantly positive (0.6722) due to positive indirect effects via number of primary branches (1.7397), racemes/plant (3.3664) and days to maturity (1.0848). The significant positive correlation between racemes/plant and yield (0.6305) was mainly due to its high direct effect (3.6639). Therefore, racemes/plant should be considered as an important component of seed yield in the medium group. Although days to maturity depicted a low and negative correlation with seed yield (—0.2341), its direct effect was highly negative (—1.8813); and hence early maturing medium talls may be selected to enhance yield.

In the tall group, days to flower showed a high negative direct (—2.5568) effect but its correlation with seed yield (—0.2120) was low and negative, due to positive indirect effect via days to maturity (2.6095). The significant positive correlation between racemes/plant and yield (0.5552) was due to both direct (0.9202) and indirect effects. Hence, days to flower and racemes/plant should be given adequate attention. Days to maturity revealed a high positive direct effect (2.6184), but a low and negative correlation (—0.2320) with yield, due to negative indirect effect via days to flower (—2.5481). Therefore, this attribute should not be selected in the tall group.

Information on the interrelationship between seed yield and its components is important in constructing selection indices and developing high-yielding lines. In the present investigation, racemes/plant showed a significant association with seed yield in three height groups. Besides racemes/plant, number of primary and secondary branches, and capsules/raceme in the dwarf group; primary branches, days to maturity, and seed weight in the medium tall group; days to flower, racemes/plant, and plant height in the tall group showed significant associations with seed yield. Hence, these traits were used in constructing selection indices in three height groups. Genetic advance and their relative efficiency were computed for various indices (Table 2).

In the dwarf group, the five-character index (122.32%) was more efficient than selection index based on seed yield only. In the medium tall and tall groups, all the indices proved to be more efficient than the index based on seed yield, with the five character index being the most efficient. Besides yield and racemes/plant, number of primary and secondary branches, and capsules/racemes in the dwarf group; primary branches, days to maturity, and seed weight in the medium tall group; and days to flower, node number, and plant height in the tall group formed the five-character index. Addition of yield to the index increased the efficiency and expected genetic advance.

The results indicate that height has a distinct impact on character associations. Therefore, different sets of traits in different height groups may be utilized in forming selection indices. Furthermore, the five-character index including seed yield proved to be the most efficient, and thus may be used in breeding programmes to enhance yield.

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LECTURE

GENETICS AND SELECTION – BASIS OF PRODUCTION FOR OPTIMUM BREEDING STOCK*

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Introduction

In most cases the breeding stock is an important factor in sheep production. The breed or cross-breed to which the animals belong, as well as the individual qualities of the sheep and rams, often determine the profitability of a sheep flock. For this reason it should be one of the tasks of animal science to show farms ways of improving their breeding stock. This starts with the choice of the optimum breed or cross-breeds.

It is clear that the use of more accurate testing methods, greater selection intensity or modern cross-breeding methods will lead not only to an increase in yields, but also to a rise in costs. But in many cases it has been shown that breeding material produced with the help of a good breeding plan and at higher costs is often more efficient than material produced using less suitable plans at low costs.

Sheep farming should never be judged without considering the environmental conditions. For this reason there is no "best" breed of sheep, which is superior to all other breeds under any conditions, but only a specific optimum breed or crosses, which are more suitable than other groups of sheep under special conditions. An alteration in the breeding stock is an alteration in the genetic predisposition of the sheep. Although, we are far from knowing all about the genetics of sheep, the findings achieved so far should be used to make breeding more efficient.

Furthermore, attention must be paid to the most important principles of selection, in order to avoid unnecessary failures and costs.

Genes and chromosomes

The carrier of inheritance from one generation to the other is desoxyribonucleic acid (DNA), which is located in sheep in 27 pairs of chromosomes and, a fact which is often overlooked, to a small extent also in the mitochondria.

A change in the structure of DNA, characterized as *gene mutation*, leads to new alleles. Such mutations generally have negative effects. Positive mutations of this kind lead among other things to merino wool, to hair of different colour on the face and leg, to a variation in the horns, to improvements in different traits, as well as in negative mutations to lethal and semilethal defects. At present a suitable artificial induction of positive mutations is not possible.

The diversity of alleles is the most important basis for genetic variation. As is well known, genetic vatiation is a presupposition for any breeding work. Without it no selection would ever be successful. The easiest way of increasing genetic variation is provided by cross-breeding. Gene technology is also able to increase genetic variation, but in sheep this method is not used in practice at the present time.

Displacements of DNA to other positions, characterized as *chromosome mutations*, can also contribute to genetic variation. It can also happen that there are losses of DNA or an enrichment of DNA. Translocations could be of special interest.

Chromosomal translocation in sheep was first found by BRUERE (1968) in New Zealand. There was a centric fusion of two acrocentric autosomal chromosomes. These Robertson

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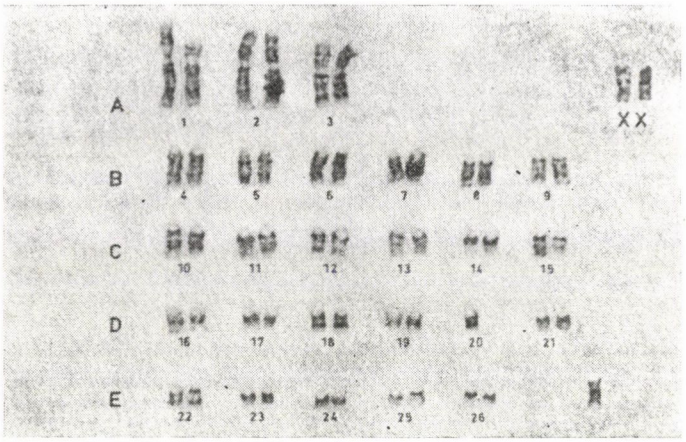

Fig. 1. The translocation of the set of chromosomes in a heterozygous female sheep can be well observed at A1 and D20

translocations were found in Romney and in Drysdale sheep (BRUERE, 1973, BRUERE and CHAPMAN 1974). After identification with the G-banding technique, the fertile carriers of translocation showed the participation of the following chromosomes (BRUERE et al. 1974):

Massay I	chromosomes 5 and 26
Massay II	chromosomes 8 and 11
Massay III	chromosomes 7 and 26.

The current paper deals with a translocation that has a direct influence on fertility. It is the 1/20-translocation, first described in a ram of the Blackfaced Mutton-type Sheep breed (Fig. 1) with the caryotype $2n = 54xy\ t\ (1p^-;\ 20q^+)$ at the Giessen Animal Breeding Institute (GLAHN-LUFT and WASSMUTH 1978).

The tupping of heterozygote carriers of translocation results in lower fertility (GLAHN-LUFT et al. 1984). The reduction in the number of twin births is easy to explain: during reduction division embryos with a deletion may developed, which are not able to survive (Table 1). While in the case of the fertilization of only one cell the sheep comes into heat again following the death of the embryo. So that there is simply a prolongation of the lambing time, in sheep having two or more fertilized eggs but only one surviving embryo, which has a balanced translocation or a normal set of chromosomes, the animal is still pregnant but will only bear a single lamb instead of twins or triplets.

Selection against this translocation is easy, because it can be significantly demonstrated even in young lambs, whether then are carriers or not.

Table 1

Type of birth in sheep with and without heterozygous translocation

Karyotype of females and males	2n = 54 XY 2n = 54 XX		< 2n = 54 XX 2n = 54 XY, 1 *pt*/1 *p*, 20+		2n = 54 XX, 1 *pt*/1 *p*, 20+ 2n = 54 XY, 1 *pt*/1 *p*, 20+	
Singles	n = 4	30.97%	n = 46	40.00%	n = 51	71.83%
Twins	n = 80	51.61%	n = 66	57.39%	n = 14	19.72%
		69.03%		60.00%		2.17%
Triplets	n = 27	17.42%	n = 3	2.61%	n = 6	8.45%
	n = 155		n = 155		n = 71	

The change of gene frequencies within populations

(1) *Selection for phenotype and single traits*

At present selection within breeds plays a most important role in sheep breeding The breed corresponds in a genetical sense mostly to the population.

While in previous centuries, during the development of local breeds, natural selection played an important role, the development of improved breeds is largely based upon selection by man. The new period of modern animal breeding and the development of improved breeds started with the work of BAKEWELL (1725–1795). For centuries an excellent phenotype, which inherits it favourable exterior and production qualities, was the aim of breeders working on the improvement of domestic animals. The principles for the production of breeding stock were defined by JUSTINUS (1815) as follows: further breeding of one or more equal stocks without foreign interference. For mating between relatives — in his opinion — the prototype is given by nature, where breeds having better vitality become dominant, irrespective of any relationship.

It is thanks to the influence of the theory of constancy that herd books became widespread and pure breeding gained in influence. Often the effect of pure breeding was overestimated. So the theory of individual potency, represented by von Nathusius and Settegast, directed attention to differences in the inheritance of sires of the same breed and the same degree of "pureness". The idea of progeny testing was born.

Furthermore, the most important foundations of modern breeding were laid down by WRIGHT and LUSH in their important contributions on population genetics and quantitative genetics, which cannot be discussed in detail in the present paper but are the fundamental basis for further considerations.

Concerning the results of selection response per year (R_y) within populations the formula according to Lush is this:

$$R_y = \frac{i \cdot r_{Ai} \cdot A}{a}$$

where i = intensity of selection = SD/p
SD = —election differential
p = phenotypic standard deviation
A = additive standard deviation
r_{Ai} = accuravy of estimating breeding value (depending on heritability, volume of information and degree of relationship)
a = generation interval

An increase in selection response is given in principle by increasing selection intensity, by an improvement in the information on the genotype, by increasing additive genetic variation and by shortening the generation interval. Because i and a are in a certain relationship, it was shown that in female sheep more successful selection can be reached by having a lower productivity number with a longers or by having a higher productivity number with a shorter generation interval (WASSMUTH 1971).

An incrtase in selection intensity can be reached by increasing the proportion of multiple births and by decreasing losses. Inseminations has a particularly strong effect on selection intensity, because a smaller number of rams is needed.

The first use of artificial insemination in practical sheep breeding was made by ILJA IVANOVICH IVANOV (1870–1932). From the research institute Askania Nova, whose director at the time was MIHAIL FJODOROVICH IVANOV (1871–1935), semen from valuable rams was sent by aeroplane over distances of several thousand kilometres.

Owing to this approach, productive livestock in the Soviet Union could be transformed, within a short period of time, into cultured ones.

The improvement of the technology for deep-freezing semen may considerably facilitate the spread of artificial insemination (SALAMON and LIGHTFOOT 1967, SALAMON 1971).

An increase in the accuracy of breeding value estimation can be achieved in particular by carrying-through progeny testing (increase in the volume of information, compensation of environmental effects) and by special testing stations (decrease of environmental variance and, for this reason, also increase in r_{Ai}). Progeny testing in general can produce more accurate information compared with performance tests on the individual, especially as the carcass quality can be judged more accurately in slaughtered offspring than in living individuals, but this lengthens the generation interval and increases the cost of testing. If the capacity of the

testing stations is smaller performance tests on rams provides more successful selection than progeny tests (NITTER et al. 1971). HANRAHAN (1976) pointed out that progeny testing is likely to be a very inefficient aid to selection when the traits under consideration are influenced by maternal genetic effects. These effects are an important source of variation in lamb growth up to weaning.

The phenotypical deviation from the mean P, if non-additive genetic effects are absent, is equal to the additive direct genetic effect A_0 (due to the individual's own genotype), the additive maternal genetic effect A_m (due to the females' genotype), the environmental component of total maternal impact C and the environmental effect peculiar to each individual.

$$\text{This, } P = A_0 + A_m + C + E \text{ (HANRAHAN 1976).}$$

Following the model of WILLHAM (1963), as was done by HANRAHAN (1976), NITTER and SCHLOTE (1979) distinguish between a direct additive component (A_d), a maternal additive component (A_m), deviations due to the individual's own dominance (D_d) and deviations due to dam's dominance (D_m), a direct non-maternal environmental component (U_d) and a maternal environmental component (U_m).

$$\text{This, } P = A_a + A_m + D_d + D_m + K_d + U_m$$

These authors propose the use of progeny testing stations in sheep breeding, specially for the selection of rams in sire lines. A new type of "performance test" is given by the production of monozygous twins, one of which can be tested and slaughtered in the station and dissected into meat, fat and bones, while the other if the results are sufficiently promising, can be used in breeding without suffering any disadvantages due to station testing (WASSMUTH and MEINECKE-TILLMANN 1980).

The aim of increasing additive genetic variance in general leads to a cross-breed with other breeds. This will be dealt with in a later chapter.

(2) *Selection for auxiliary traits*

The direct selection on traits like fineness of wool, wool density, wool variability, daily gain, food conversion, etc. is more and more often complemented by selection for auxiliary traits. This is especially the case for traits which are not testable, or only at high costs, and which have a suitable genetic correlation to an auxiliary trait.

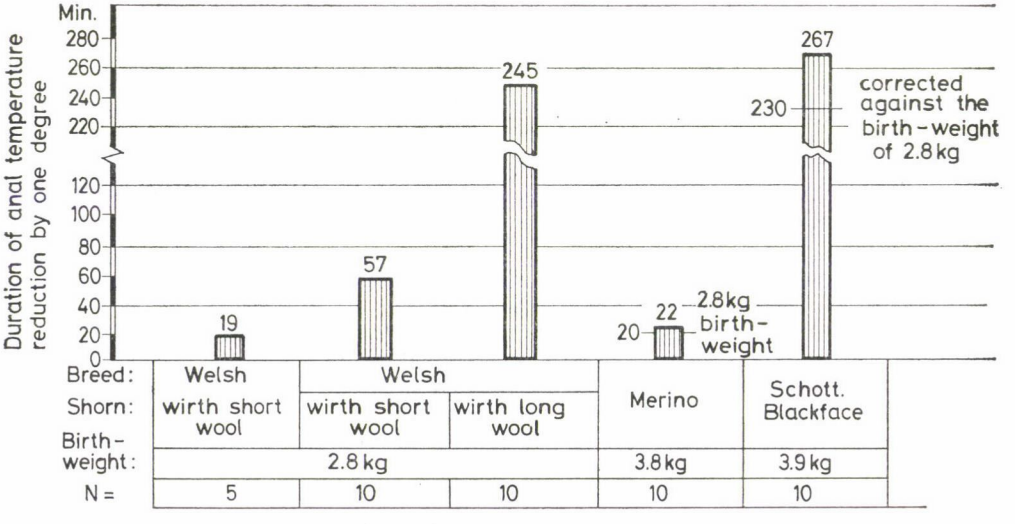

Fig. 2. Resistance to body cooling. Cold and exposure to wind which reduced anal temperature by one degree (SLEE 1978)

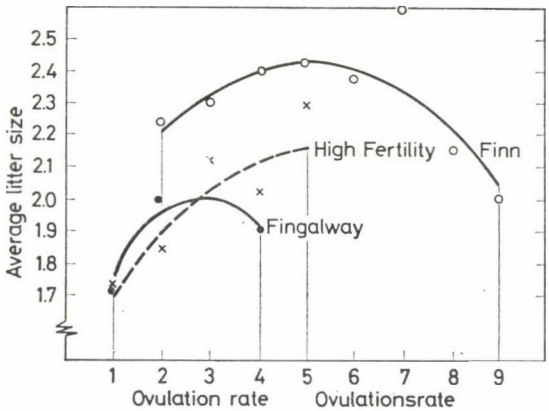

Fig. 3. Ovulation rate and litter size in shepp breeds (HANRAHAN 1976)

In some populations, therefore, the generally expensive investigations on food conversion are replaced by daily gain, although the progress of selection using the direct method is higher. Meat quality is often replaced by meat colour.

To improve vitality by breeding, measurements of hormone activities, enzyme activities (WOLANIS et al. 1979, 1980) physiological measurements such as the rectal temperature of lambs, frequencies of heart-beats and breathing (FLACH et al. 1980, JATSCH et al. 1979) and reactions to stress are used. SLEE (1978) measured the reaction to cooling down the body as the number of minutes required to reduce the rectal temperature by 1 °C (Fig. 2).

Table 2

Index Merinolandschaf (SCHÖPFEL, 1979)

	Group ø	Station ø	Different	Unit	Different × Unit
1. *Progeny test in station*					
daily gain (g)	409	356	+ 53	0.21	11.1
food conversion (S + E)	2194	2523	+329	−0.003	1.0
body fat (points)	3.8	3.9	− 0.1	−0.67	0.1
back and loin (p)	7.9	7.8	+ 0.1	0.91	0.1
kindquarter (p)	17.3	16.9	+ 0.4	0.91	0.4
pistol cut (%)	40.84	40.80	+ 0.04	1.68	0.1
kidney fat (%)	1.80	1.57	+ 0.23	−1.99	−0.5
					12.3
2. *Reproduction*	ewe	average			
lambing (%)	167	189	222 × 2 = −44		
raising (%)	167	172	− 5 × 1 = − 5		
					−49 : 3 = −16
3. *Performance*					
daily gain (g)	311	254	+ 56	0.13	7.4
conformation (p)	8	5	+ 3	1	3.0
wool quality (p)	6	5	+ 1	2	2.0
typet, etc. (p)	7	5	+ 2	3	6.0
					18.4

In general it is useful to select auxiliary traits which are a presupposition for marking the trait desired. In this sense ovulation rate could be thought to be a suitable basis for selecting for litter size. But HANRAHAN (1976) was able to show that ovulation rate is not always an accurate prediction in selection for litter size (Fig. 3). This example shows how important it is to first study the physiological and anatomical background of a trait.

(3) *Remarks on the selection index*

In practical sheep breeding selection is usually performed at the same time for several traits or auxiliary traits. Since HAZEL and LUSH (1942) proof has already been furnished of the fact that a selection index is superior to all other possibilities: an increase in the application of a selection index all over the world. In the Federal Republic of Germany its use in selecting rams is prescribed by law.

In sheep the economical weighing up of different traits is often more complicated than in other species. While, for example, an improvement in food conversion in pigs can be suitable for all the pigs of a population, in breeds of sheep the proportion of animals which can profit from this trait is very different. If part of a flock in a population used food without cost or minor cost, for example fattening of withers in transhumance, there is no interest in improving this trait. So realization coefficients must be used which characterize the segment of the population in which the improvement of the trait in question can be used. The cost of testing becomes more problematic, as the coefficient of realization becomes smaller. For example, in Table 2, an index and the calculation for a ram is shown, which is used in the Bavarian Sheepbreeders Association (SCHÖPFEL 1979).

The use of genetic material from different populations

(1) *The immigration of genes*

In pure-breed sheep it happens during intensive selection that the proportion of undesired genes will be minimized, and after a long period of selection a decrease in genetic variation can be observed. Under nearly constant environmental conditions this leads to a decrease in heritability coefficients.

Table 3

Crosses with the Finn breed (prolificacy)

Ewes	Cross	Control	Author
	192	175	
Finn × Border Leicester	179	161	DEEPLE and BARKER
	96	70	
Finn × Blackface	238		TEMPEST and BOAZ
Finn × Merinoland	164	120 (alive)	NITTER
	184	123 (born)	
Finn × Dorset Horn	210		ROBINSON
Finn × Texel	210	144	KALLWEIT
Finn × schwarzk. Fleischschaf	212	156	
Finn × schwarzk. Fleischschaf	221	141	HARTMANN et al.
	167	133	
Finn × Galway (ovulation rate)	230	160	HANRAHAN
	270	160	
Finn × Texel	203	238	KALLWEIT

This is one reason for taking the desired genes from other populations (Immigration). There are many examples of a melioration crosses which show success in breeding due to the immigration of genes.

A great number of newly established breeds has been founded by this kind of cross-breeding. Today there are also various projects to improve breeds with the help of genes from other breeds. One of many examples is the new Takirova breed in Turkey, constructed with the help of East Friesian Milksheep.

(2) "*Profit-Heterosis*"

Strong negative genetic correlations prevent a successful selection in those traits by pure breeding. Antagonisms between traits in sheep often depend on the level of yield (WASSMUTH 1979).

The frequently used term "Profit-Heterosis" can be discussed using fertility traits and carcass production as an example. In the United Kingdom this has often been combined with stratification.

In 3-breed-crosses the principle is the same. Here, the productivity number of cross-breed ewes increased when using B-position breeds with a large litter size.

Table 4

Comparison between crosses with Finn landrace and Romanov

Ewes	Cross	Control	Author
Finn × MM	173	134	JAKUBEC and
Romanov × MM	184		KRIZEK
Romanov × IF	212	124	DUBOIS and DOC (RICORDEAU et al.)
Romanov × BC	187	132	RICORDEAU et al.
Romanov × LIM	217	163	THERIEZ et al.
Finn × Finn	177		VERESS et al.
Finn × Finn	233		VERESS et al.
Romanov × Finn	231		VERESS et al.
Romanov × Romanov	257		VERESS et al.

MM = Merino Meat IF = Ile de France LIM = Limousine BC = Berrichon du cher

Table 5

Crosses with the Finn sheep (F_2 and backcrosses)

Ewes				Author
F_2	F_1	R_1 Finn	R_1 A	
191	190			RICORDEAU et al.
	184	171		NITTER
Ovulation rate	{230 {270	Ovulation rate	{200 {230	HANRAHAN
164	167	179	160	HARTMANN et al.

Table 6

Carcass quality of Finn cross lambs, slaughtered with 36 kg
(JAKUBEC 1956)

Maternal genotype			Fi×sF				sF	
Ram			sF	Fi×sF	Fi	Fi	Fi×sF	sF
Finn rate		%	25	50	75	50	25	0
Total		g	5207	5224	5246	5435	4990	5454
Body fat		g	1116	1388	1401	1521	1282	1034
Kidney fat		g	181	297	345	366	299	169
Total bone		g	1627	1670	1632	1701	1596	1692
	Meat	%	65.3	62.8	63.2	62.8	63.0	65.8
Rate	Body fat	%	14.0	16.7	16.9	17.6	16.2	12.5
	Bone	%	20.5	20.1	19.7	19.7	20.1	20.4
Meat surface		cm	12.5	12.3	11.6	12.3	12.1	13.3
Fat surface		cm	2.4	3.0	2.2	2.9	2.5	2.8
Meat	Mld	1 :	0.19	0.24	0.19	0.24	0.21	0.21
kidney	Separated	1 :	0.21	0.27	0.27	0.28	0.26	0.19
rate	Spine	1 :	0.42	0.46	0.50	0.43	0.43	0.28
	Thigh	1 :	0.14	0.18	0.15	0.17	0.16	0.13
Thigh length		cm	47.20	47.00	48.90	48.50	48.70	46.00
Thigh circumference		cm	26.70	25.40	25.90	26.30	25.80	27.10
Carcass length		cm	56.90	56.10	58.40	57.10	55.80	56.10

In B-position Finn sheep (MAIJALA 1967) and its cross-breeds, partly specially developed lines like the Improver from CADZOW (1968), East Friesian Milksheep and its crosses (HARTMANN and WASSMUTH 1976, POPP et al. 1976, KŐNIG et al. 1978, etc.) and Romanov (VERESS 1976, etc.) were used, KOVNEREV (1969) pointed out that under suitable management conditions the Romanov breed is able to lamb every 6 months. SEMENOV (1976) in the USSR and RICORDEAU et al. (1976) in France also report on very short lambing intervals.

Table 3–5 offer a short review of some of the reports given in 1976 in the sheep commission of EAAP. Prolificacy rate shows an increase both in the case of the Finn and the Romanov cross, but in the F_2 and R_1 genotypes a degree of reduction also occurs. JAKUBEC (1977) published a detailed report on the results of using these breeds for cross-breeding. With the growth of the rate of the Finn breed, the ratio of meat decreases, that of fat ennasices (Table 6). Some changes in carcass quality induced by using different proportions of Finn genes are shown.

The relative economic value of various litter types varies between intensive and extensive management systems. NITTER (1984) gives the following data (Tables 7–8).

Especially in Merinos, the use of Booroola is of interest as far as the number of lambs per litter is concerned (Fig. 4).

These fertile breeds are not only suitable for producing an effect of "Profit-Heterosis" or "Type-Heterosis" (as proposed by HORN to characterize this effect), but also for establishing new breeds to meliorate existing breeds. So Booroola are already used in Hungary to increase the number of multiple birth in Merinos.

There are many possibilities for using sire lines in a crossbreeding programme. As a rule sires of fatlambs belong to the well known mutton-type breeds. Under poor environmental conditions a 4-breed-cross may be superior to a 3-breed-cross, because losses in pure breed sires can be high.

(3) *Heterosis*

"Profit-Heterosis" is fully independent of the biological phenomen on of heterosis.

Using the definition that an increase in heterosis is represented by the superiority of the lambs compared with the average of their parents, heterosis can be maked by maternal effects.

Table 7

Losses in %

Ewes	F_1	Control	Author
F×DH	8.0		ROBINSON et al.
F×MM	20.8	23.0	JAKUBEC et al.
F×BF	25.0	6.0*	TEMPEST et al.
F×TEX	17.6	13.9	KALLWEIT
F×SF	25.0	12.8	
F×ML	29.4	18.7	NITTER
F×SF	32.0	23.0	HARTMANN et al.
(F×BL)×cross	22.1	24.9	DEEBLE et al.
ROM×BC	7.3	15.8	RICORDEAU et al.
ROM×LI	8.8	9.0	THERIEZ et al.
ROM×MM	18.8	23.0	JAKUBEC et al.
EF×BF	7.0	6.0	TEMPEST et al.
EF×MM	17.2	23.0	JAKUBEC et al.
(F×EF)×SF	21.8	22.7	HARTMANN et al.
CH×AW	21.5	16.2	FOX et al.
CH×local	18.7	3.6	

* = (BL×CH)

MM = Merino meat
BF = Blacke face
F = Finn landrace
TEX = Texel
SF = Schwarzköpfige Fleischschaf
BC = Berrichon du cher
DH = Dorset horn
BL = Border leicester
ML = Merino land
ROM = Romanov
LI = Limousine
EF = East frisian
AW = Awassi
CH = Chios

Table 8

Relative aconomic values of various litter sizes under intensive and extensive management systems (single = 100) (NITTER 1984)

	Intensive	Extensive
Single	100	100
Twin	180	180
Triplet	210	170
Quadruplet	100	50
Quintruplet	50	25
Sextruplet	25	0

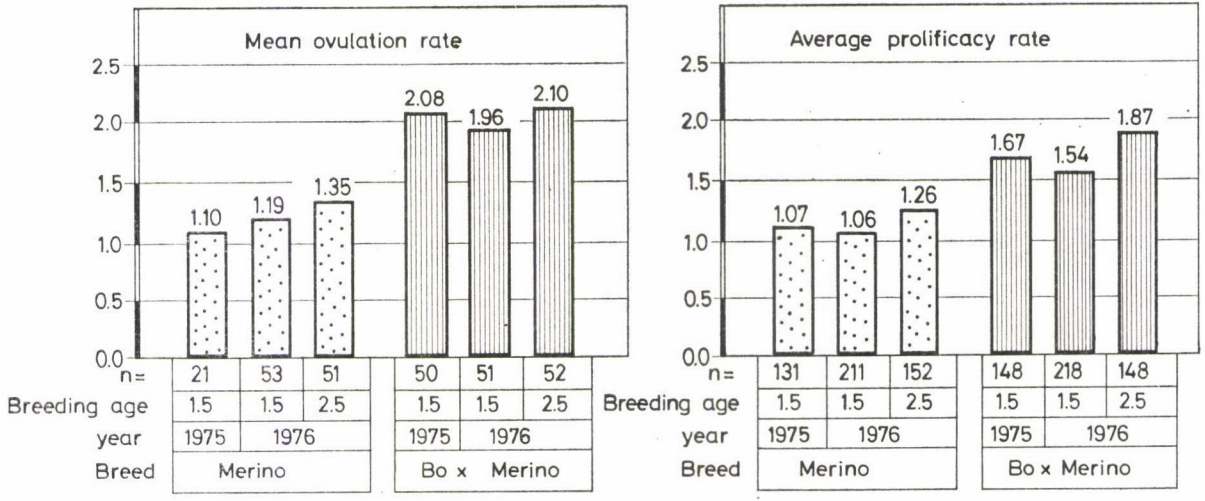

Fig. 4. Prolificacy in crossing merino and booroola ♂×merino ♀ (ALLISON, STEVENSON and KELLY 1978)

Using reciprocal crosses it is easy to eliminate such effects, mentioned already in the chapter on progeny testing. Maternal effects on the birth weights of lambs can be studied by embryo transfer, using sheep from different types (MEINECKE-TILLMANN 1977). Maternal effects can also occur owing to the influence of mitochondrial enzymes. But these also seem to play a role in some heterotic effects.

Cytochrome-c-oxydase is coded partly by nuclear and partly bymitochondrial DNA. In the case of heterotic effects the activity of this enzyme is often increased (DZAPO et al. 1973). There are many examples of the occurrence of heterotic effects in sheep breeding. As regards litter size, examples were presented by FOX et al. (1976), GOOT et al. (1976), HARTMANN and WASSMUTH (1976), KALLWEIT (1976), RICORDEAU et al. (1976) and NITTER (1976). Heterotic effects can also occur in an undesired way, for example in the amount of kidney fat in some Finn crosses (POPP et al. 1976). Heterosis will play a more important role in sheep breeding in the future.

Structure of populations

Improvements in breeding methods also lead to an increase is costs. A test in the stations may provide excellent data on selection for food conversion and carcass quality, but the financial expense is often remarkably high. These and other costs cannot be spent on all the sheep of a population, so there must be a structure within the population to use the advantages of breeding costs in an optimum manner.

The simplest structure in sheep breeding has already existed for some centuries: the better flocks breed rams, while the others breed only ewes and buy all their rams. The aim of many breeding organizations was to have a flock book in as many sheep flocks as possible in order give, to a better basis for selection.

Considering the high breeding costs, a three-tier structure is more suitable than a two-phase one. In a nucleus flock breeding can be carried out intensively and at higher costs; in the second step in the multiplier flock, the necessary number of breeding animals will be produced; and the third step is represented by flocks mainly concerned with fat lamb production.

The disadvantage of multiple steps is that it takes more time to bring progress from the first step to the production flock. It is possible to shorten this interval by inseminating sheep in step 3 by rams from step 1. In this respect the advantages of large-scale sheep farms over small ones is especially important.

One very interesting form is the system of an open nucleus. In such a flock, for example, all sheep giving extraordinary results in litter size are selected from the population to start the nucleus. This is how OWEN started his interesting work in this field. Within the nucleus strong selection takes place, but very good animals from the population can also enter the nucleus. All breeding rams are born in the nucleus.

In cross-breeding programmes 4 steps are possible though as a rule there are one 3. Steps 2 and 3 are combined to form a single step.

(1) Nucleus of pure-breed lines A, B and C
(2) Multiplying the breeding material
(3) Cross-breeding to get AB-ewes
(4) Production of AB ♀ × C ♂-lambs

The smaller the nucleus, the more in breeding depression is likely to occur. The responsibility of breeding in a nucleus is very much higher than in a normal population, because the consequences of an error or the spread of undesired genes is more harmful. But working with more efficient population structures may well important in the future.

For this reason, knowledge regarding genetic connections and the backgrounds of breeding must be intensified in the years to come.

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CHRONICLE

LIFE AND ŒUVRE OF ACADEMICIAN D. D. BREZHNEV (1905–1982)

(Received: 7 December 1983)

Dimitry Danilovich Brezhnev was born in 1905 as the child of a workman's family. He had a chequered carrer with endless organizing and creative activity. He worked to the end of his life, until his death on 4 April 1982, with unflagging enthusiasm.

He was very young when he joined the social movement as a member of the Komsomol. He was charged right from the beginning with arousing the cultural interest of young people, particularly in the state and cooperative farms. His sphere of action in this field was the leadingship of the social activities of young workers.

After graduating from Agricultural College in Voronezh (in 1934) he was charged with an even more difficult task. He was appointed manager of the Vegetable Experimental Station at Gribov, near Moscow. In his new job he soon met N. I. VAVILOV, the world-famous natural scientist, who investigated the geographical distribution of plants. His acquaintance with VAVILOV had a decisive effect on his future career. VAVILOV's attention was drawn to the young BREZHNEV's excellent capabilities and manifold interests and he invited him to take part in the research conducted under his guidance. BREZHNEV gladly accepted this flattering offer and, a post-graduate at the All-Union Institute for Plant Production (hereafter called VIR), he was given the task of studying the heterosis effect in tomato for his thesis. On VAVILOV's recommendation BREZHNEV was appointed head of the vegetable section of VIR even before defending his thesis (1937).

World War II caused an interruption in D. D. BREZHNEV's scientific work, as in the case of many of his compatriots. At the beginning of the Great Patriotic War he volunteered for military service and took part in the war till the end. During his military service he carried out political, educational and organizing work in the army. The news that the war had ended reached him in Prague.

In 1946 he resumed his work at the VIR where he had left off when the war broke out. One major task of the section he headed was to extend work on the clarification of the geographical distribution of wild and cultivated vegetable species and the collection of new plant material. In 1952 he defended a thesis based on an enormous bulk of material concerning the distribution of tomato. With this he made a substantial contribution to the gene centre research directed by VAVILOV.

A year later he was appointed to a professorship, and in 1956 he was elected a member of the All-Union Academy of Agricultural Sciences of the Soviet Union. At the same time he was charged with the vice-presidential duties of the Academy. He fulfilled this mission for 10 years. With the well-known initiative characteristic of him he extended the domestic activities and international relations of the Academy, extending the latter to Hungary, among others.

He was not diverted from his original scientific work even by his manifold social activities. He continued to direct studies on physiological and plant breeding questions concerned with vegetable cultivation within the framework of the VIR. He paid great attention to developing an up-to-date network of vegetable experimental sites and to modernizing their work. It is worth mentioning his support for the large-scale development of the Maikop Experimental Station, and later for the development of the Horticultural Research Institute and Vegetable Growing Station at Tiraspol.

In order to improve the cultivation and breeding of vegetables, D. D. BREZHNEV paid a great deal of attention to modernizing the organization system for vegetable seed production. At the breeding and seed production sites established within the framework of the VIR, many new vegetable varieties were produced and made available to farms.

In 1965 D. D. BREZHNEV was charged with the management of the All-Union Institute for Plant Production, one of the biggest scientific institutions in the world. Under the leadership of D. D. BREZHNEV and through the mobilization of the vast research system, independent teams were organized to study further plant species, and to collect and examine those which, in the course of preliminary research, had proved worthy of wider propagation and further breeding. This venture was extended beyond the area of the Soviet Union to those places in the world where gene centres of currently cultivated species are found. It was again within the framework of the VIR that investigations aimed at modernizing breeding methods were started and new varieties and propagation methods suitable for practical purposes were introduced.

A new feature of D. D. BREZHNEV's activity was the establishment of a wide laboratory network. A large number of laboratories were organized at different institutes and experimental stations in order to keep abreast with international progress in research. Special attention was paid to studies on the relationship between wild and cultivated species with the purpose of improving the viability of new varieties by transferring valuable characteristics (resistance, frost hardiness, drought tolerance, etc.) from certain wild species to cultivated ones.

When widening the collection organized by the VIR, a huge bulk of material accumulated, which in recent years has exceeded one hundred thousand items. The number of vegetable species and varieties alone has reached 25 000. The success of the breeding carried out under the guidance of the VIR is clearly reflected in the more than two thousand varieties and hybrids produced (including 356 new varieties of vegetables).

D. D. BREZHNEV's literary activity is hallmarked by the large number (460) of books and papers published during his life-time. Some of his prominent works are: a monograph on "Tomato", "Genetics of tomato" the part that deals with vegetable species in the series "The cultivated plants of the Soviet Union", the publications "Plant cultivation in Australia", "Vegetable production in the United States", "Wild relatives of cultivated plants" and "Man and flora".

The international appreciation of his work is reflected among other things by the fact that he was elected an honorary member of the Academy of Agricultural Sciences of the GDR, the French Academy and the Hungarian Academy of Sciences. He was an honorary doctor of the University of Horticulture, Budapest, and was a member of the European Plant Breeders' association the FAO International Committee on Plant Genetics, and scientific societies in various countries. He was awarded a gold medal by the Czechoslovak Academy of Sciences, the Cuban Academy of Sciences and by several other scientific institutes and organizations.

D. D. BREZHNEV's respect for tradition and his acknowledgement of the work of his predecessors is reflected in the way he took over and further developed the intellectual legacy of his world-famous professor, N. I. VAVILOV.

He paid great attention to young researchers and spent much time in educating them. Sixty of his students acquired the degrees of Ph.D.

The scope of his social activity was also extremely wide. Several times he was elected deputy of the Leningrad District, and as a member of the City Council the Party Committee, etc. For many years he was a member of the Agricultural Variety Qualifying Committee and vice-president of the Educational Society, the "Vavilov" Genetic and Breeding Society and the Soviet-Bulgarian Friendship Society. For years he was editor of the Agricultural Scientific Bulletin.

D. D. BREZHNEV's work was equally highly appreciated by the Party and State Management of the Soviet Union. As a recognition of his scientific work he was twice awarded Lenin Order and three times the Order of the Red Banner; he also held the Order of the October Revolution, the Order of the Great Patriotic War, and many other decorations. He was twice awarded the title of Hero of Socialist Labour. In 1952 he was given a State Prize.

His relations with Hungary go back over several decades. His name is a household word among breeders and vegetable growers in Hungary. He visited Hungary several times, took part in various programmes and made individual study tours. During the war he also took part in the liberation of Hungary and Budapest.

When in Hungary he visited the biggest agricultural research institutes (Agricultural Research Institute, Martonvásár, Vegetable Crops Research Institute, University of Horticulture, etc.). On Hungarian farms he studied the new organizational forms and cultivation methods, particularly for vegetable forcing, developed with a view to modernizing vegetable production. Towards the end of his life he visited Hungary to relax and receive medical treatment, but even on these occasions he combined his other activities with visits to institutes and farms.

Through the VIR he gave Hungarian researchers a great deal of help in their work. Samples of wild species suitable for breeding purposes and of other plant species not known in Hungary were regularly sent to Hungarian researchers for experimental purposes. Hungarian researchers were often received in the VIR and they were offered the opportunity to study various scientific problems and methods.

I was personally acquainted with D. D. BREZHNEV. At invitation of the All-Union Academy of Agricultural Sciences I was requested several times to deliver lectures in some large vegetable-growing districts, giving an account of the results attained in Hungary in the field of paprika production and breeding, vegetable production under plastics, and the modernization of farms. D. D. BREZHNEV arranged for the testing of new vegetable varieties produced in Hungary in the Soviet Union. The opportunity for passing on information on the cultivation of paprika in Hungary, and the possibility for testing new varieties must be particularly mentioned. This is how a close connection was later established with the workers of the Maikop Experimental Station in the Krasnodar district and with those of the Horticultural Research Institute in Tiraspol. The evaluation of the paprika variety collection was also extended to the Leningrad centre of VIR.

D. D. BREZHNEV did much to promote cooperation within the framework of the CMEA. As an example of his quick and efficient actions, mention may be made of his efforts on behalf of a publication on the international situation in tomato production. He took upon himself everything from an invitation to the authors through the compilation of the publication to ensuring printing capacity, and many other details.

In Hungary D. D. BREZHNEV is known as a scientist and public figure who tought with untiring determination to remove every obstacle to scientific progress. He did everything he possibly could for the development of agricultural sciences. When he was vice-president of the Academy of Agricultural Sciences he maintained his posts in Moscow and Leningrad, thus ensuring that his scientific work did not suffer on account of his activities at the Academy.

D. D. BREZHNEV's open, trustworthy personality helped him greatly in achieving his aims and in establishing and continually improving domestic and foreign relations. His memory is held in great respect by Hungarian researchers, too.

A. SOMOS

Acta Agronomica Hungarica, Vol. 35 (3–4), pp. 371–379 (1986)

BOOK REVIEWS

WILLEM C. BEETS: *Multiple Cropping and Tropical Farming Systems.* Longman, London, 1980.

The book has been published in Great Britain and the United States of America. It is a stop-gap work even in the extremely wide literature of tropical crop production and farm organization published in the English-speaking countries. The book discusses at length the system of tropical farms, the cultivation of tropical intercrops and the application of second cropping. The author is a connoisseur of tropical agriculture; as representative of the Asian Development Bank to Manila he has travelled all over the tropical regions of the world and become acquainted with their farming conditions.

Not much information is available on the special agrotechnical methods of marking use of the regional and climatic conditions e.g. by growing intercrops and practising second and third cropping.

In the introductory chapters, the general principles of tropical farming are given. The effect exercised by the tropical ecosystem on crop production, and the characteristic features of tropical crop production are shown from many aspects. Within this scope of questions the present situation of intercrop production is described and conclusions are drawn on the possibilities of further development in technology.

In the subsequent chapters a detailed analysis is found of the possibilities of cropping combinations, in the case of annual crops e.g.: cucurbitaceous crops or tropical beans between rows of maize, and combined production of sorghum and soybean. Under Indonesian conditions, highly intensive production system is the cultivation of manioc sown with peanut. After its harvest, maize is grown between the rows.

The cultivation of intercrops in standing cultures is discussed in separate chapters. In the tropical and subtropical zones of the world, the utilization of the row spaces of palm-trees for crop production is a widespread practice. In North-Africa, Alexandrian clover, lucerne or vegetables often are grown in the row spaces of date-palm groves. In India, black pepper, cocoa or pineapple are grown between the rows of coco-palm trees.

Further chapters deal with the aspects of economic and employment policy in the intercrops production. On the basis of thorough analyses, the peculiar production technology of intercropping is discussed. Useful and indispensable information is given concerning sowing time, row- and plant number, fertilization, irrigation and protection against erosion. The tolerance of plants grown as intercrops and the extent of their ability to suppress each other are further subjects of the book.

In the last part the author acquaints the reader with crop production of this kind all over the world, describing the research institutes and research sites concerned with intercrop production in the different continents.

The work may be of use for those elaborating crop production systems and technologies, agricultural experts going to tropical developing countries as well as for those studying tropical crop production at agricultural universities.

S. HÉJJA and B. BERÉNYI

Poljoprivredna Znanstvena Smotra (Scientific Agricultural Review), Zagreb, 1981. No. 56–57.

The journal Poljoprivredna Znanstvena is a publication of the Faculty of Agriculture of Zagreb University. It is a scientific review of agriculture which publishes papers on current problems in crop production, animal husbandry, horticulture, agricultural economics and other fields of agriculture. In the main, the scientific results of workers at the Faculty of Agriculture of Zagreb University are published, but works by other Yugoslav authors are also accepted. In addition M.Sc.

and Ph.D. theses submitted to and accepted by the Faculty are published in the journal, together with papers dealing with scientific education. The publication appears in Croatian, with English, German and French summaries.

In No. 56 and 57, published in 1981, papers covering a wide range of agricultural topics are found, including crop production, nutrient management, animal husbandry and agricultural economics.

In the first paper of No. 56 I. JURIĆ gives an account of experiments in which he studied the responses to nitrogen fertilization of inbred lines and hybrids belonging to the FAO 200 maturity group, as well as of FAO 600 lines and hybrids grown at various stand densities. Up to a dose of 180 kg/ha nitrogen, fertilization increased the net rate of assimilation at both stand densities (60 000 and 100 000 plant/ha), but with an increase in the plant number the net rate of assimilation per plant decreased for all lines and hybrids. The greatest difference between lines belonging to the FAO 200 and FAO 600 groups was shown for the leaf area, which is closely related with the yield.

Z. RACZ and T. NOVOSEK report on soil experiments in their paper "Study of some characteristics of soil types in the environs of Zagreb and Eszék". The authors studied the soil characteristics important from the point of view of mechanization, and classified the soil types according to the mechanical and physical aspects of the soil.

A. BUTORAĆ deals with questions of nutrient management. An account is given of the results of a four-year series of greenhouse experiments in which the effect of nitrogen, molybdenum and copper fertilizers on the hay yield of lucerne (*Medicago sativa* L.) was studied. The best results were obtained with complex NPK fertilization complemented with molybdenum and copper. The amounts of nitrogen and molybdenum accumulated in the stalk and leaf of lucerne were determined, and molybdenum was found to have a positive effect on the nitrogen uptake.

I. CIGLAR reports on the tracing of *Caropocapsa pomonella* populations. The populations were traced using the pheromone codlemone, a synthetic attractent, five months per trap were regarded as the critical value. The distribution of moths in the given observation period was studied at two sites, and the damage caused by them was illustrated.

NADA HULINA studied the appearance and spreading of saintfoin (*Onobrychis viviifolia* Scop.) on Mt. Medvednica. On the eastern slopes of the mountains saintfoin was the dominant species in certain phytocenoses. The appearance of the sub-Mediterranean plant in the continental zone of Croatia is an interesting ecological and phytogeographical phenomenon. Owing to its anti-erosive effect it is important for agriculture.

P. ŠOLIĆ writes of the taxonomic position and horticultural importance of *Scutelaria alpina* L.

OLGA ČIČA analyses the effect of the number of lactations and the age of the cow on milk production, butterfat percentage and total butterfat output in the cattle breeds Dapple red and Dapple black.

S. CANDIZ examined factors influencing the economical use of tractors in a number of state farms. Eleven optimum solutions were elaborated for cereal production using a linear programming method where the condition of the area to be sown and the number of available machines were taken as variables. The effect of the variables on the exploitation of tractors and the economic efficiency of the whole farm was studied by analysing the solutions.

The economic and technological implications of fertilizer consumption in some Slav farms were analysed by T. ŽIMBREK. The investigations were made in three large agricultural combines. Special attention was paid to the economical fertilization of major cereal crops.

SVETKA KORIĆ gives an account of *Triticum aestivum ramifera* as a new genetic source. *Triticum aestivum ramifera* S. K. was produced in Zagreb, at the Institute of Plant Breeding and Plant Production, by crossing two varieties belonging to the species *Triticum aestivum* ssp. vulgare. Its ramose spike is a morphological novelty, and the gene complex responsible for the ramification is considered as a new genetic source. *Triticum aestivum ramifera* possesses high genetic variability as regards both its biological and morphological properties.

M. MACELJSKI discusses the effect of temperature on the development of *Lixus junci* Boh., Col. Curc.

In the first paper of No. 57, M. MATIJAŠEVIĆ analyses the heritability of the sedimentation value for the flour of a number of wheat varieties, and examines the utilization of this factor in breeding. The heritability (h^2) of the sedimentation value of flour was determined from the crosses Libellula × Mirna, Libellula × B28 and Mirna × B28. The heritability index (h^2) in the stricter sense of the word ranged between 23 and 75%. Values higher than this were found when varieties originating from different genetic sources were crossed.

J. JAVOR's paper has the title: Contribution to a study of inheritance of wheat resistance to *Erisyphe graminis* f. sp. *tritici* DC Marchal races "0", "33" and "36".

Eighteen combinations of three resistance sources (C.I. 12632, C.I. 12633 and Weihenstephan 803-53) and two susceptible varieties (Fiorello and Little Club) were studied. The varieties mentioned were examined for resistance to the "0", "33" and "36" powdery mildew races at the three-leaf and fully developed stages; the inoculation was carried out with mixtures of more than one race. According to the results of the examinations the sources C.I. 12632 and C.I. 12633 are most likely to be of use in wheat breeding.

Z. VIDAČEK classified various soil types in East-Slavonia and Baranya from the point of view of irrigation. The soil characteristics most important from the point of view of irrigation and the factors influencing the irrigability of the given area were determined. By using the data obtained, a map was drawn to show whether different areas were suitable for irrigation. Maize areas suitable for irrigation were also indicated.

I. MILJKOVIĆ and S. DUGALIĆ wrote a paper on the growth and production of 16–22-year-old pear trees. In a semi-arid region of Croatia they studied the growth and yield of the following pear varieties: Williams, B. Clairgeau and Beurré Hardy on "A" stock in dense plantations. The variaties Williams and B. Clairgeau were spaced at 2.5×1.5 m, while the spacing for the variety B. Hardy was 2.5×1.25 m. Each variety grew well and gave an abundant yield. The average annual yield ranged between 530 and 702 q/ha. In the 7-year period the largest cumulative yield was produced by B. Clairgeau (4197 q/ha), followed by B. Hardy (3824 q/ha), while somewhat less was produced by the variety Williams (3710 q/ha). A significant difference in the cumulative yield was shown by the varieties examined.

N. MIROŠEVIĆ studied the pollen tube germination in the vine variety Moslavac bijeli. Applying a boron-containing spray immediately before flowering he found that the percentage pollen tube germination became higher both in vivo and in vitro.

The effect of the amount of dry whey in pig feed on the productivity of the animals was studied by N. CAPAN. He found that dry whey increased the productivity of the animals by 10–40% depending on the quantity of whey. A significant difference in weight increase was found between sucking pigs, weaned piglets and porkers. With pigs in the final phases of growth there was no significant difference due to the dry whey content.

T. BUDIN studied the question of making rational decisions under unstable conditions. Four basic models were mathematically elaborated, and were applied in an investigation in which the organization of a large farm had to be solved under unstable and chancy circumstances. With these models the problem of optimum production strategy was examined; the yields achieved by the farm, the condition of the machines and the suitability of the soils for cultivation were chancy of uncertain.

B. LALIĆ examined the economic efficiency of a livestock farm. In the first part of the paper the Basic Organization of Associated Labour (BOAL) managing the business activities of livestock farms is studied and compared with similar organization working in the field of crop production. In the second part, the results of investigations into the business activities of the BOAL organizations in individual livestock farms are published. The analysis of business activities in the livestock farms was carried out for each animal species separately. Differences were pointed out between the business activities and efficiencies of the BOAL groups observed. BOAL organizations dealing with poultry farming were the most successful, and those working in the field of cattle rearing the least efficient.

The journal offers a comprehensive view of agricultural research in Yugoslavia, as well as of current problems of research, production and education. Most of the questions studied are equally important for practical farming, and directives are given for the utilization of the results in practice.

MÁRTA MOLNÁR-LÁNG

KARL-HEINZ KREEB: *Methods and Vegetation Forms in View of the Ecosystem.* Bremen, 351 p. 84 figures, 22 tables. Ed.: Eugen Ulmer, Stuttgart, 1983.

This large-scale work, in the nature of a stop-gap handbook, is dedicated mainly to the author's two excellent masters: the 85-year old Prof. HEINRICH WALTER, and Prof. HEINZ ELLENBERG who celebrates his 70th birthday, though grateful thanks are also expressed to many other colleagues and institutions.

One of the special features of the book is that various lines of research in this important and vast field are not only introduced but also evaluated. In addition the reader becomes acquainted with different types of vegetation.

The sections are numbered according to the decimal system, and, apart from the bibliography, the list of plant names and the subject index, consists of three main chapters: (1) General knowledge of vegetation; (2) Methodology of the knowledge of vegetation: Treatment and description of the vegetation units; (3) Special knowledge of vegetation.

It should also be emphasized that besides methodology and vegetation types, ecological aspects are also given special attention. It is thus made clear that the vegetation is only part of the ecosystem, and the unity of the ecosystem can only be spoken of when the vegetal, animal, human and site factors are interpreted and discussed in connection with each other.

In this richly illustrated, elegant and extremely useful work the descriptions of the vegetation are based on the wide experience and professional knowledge that the author acquired in the course of investigations and study tours in Europe, the Near East, North and South America and Australia.

S. SÁRKÁNY

KUCKUCK—KOBABE—WENZEL: *Grundlagen der Pflanzenzüchtung* (Bases of Plant Breeding)

The fifth edition of this book, written by HERMANN KUCKUCK, professor of applied genetics at Hannover University, has been published under the auspices of the publisher Walter de Gruyter, West Berlin, in a very attractive form.

For the revision of the text and enlargement of the material, the internationally acknowledged excellent specialist called upon GERD KOBABE, professor of plant breeding at Göttingen University, and GERHARD WENZEL, director of the Institute for Resistance Genetics, Bohoum, for assistance.

The previous editions of KUCKUCK's book already occupied a prominent place in plant breeding literature, but the monograph written by this trio of authors deserves the highest professional acknowledgement. The book supplies exhaustive information on the full range of classical and up-to-date plant breeding methods, beginning with the simple procedure of mass selection, through cell and tissue cultures up to gene transfer.

The book consists of 254 pages with 52 figures and several tables, sketches and formulae, and is complemented with a rich bibliography and a subject index.

The major groups of subject are discussed in the following order:

Fundamental breeding methods;
Breeding by hybridization;
Production of hybrid varieties;
Special breeding and selection methods;
Variability of cell and tissue cultures;
Utilization of periclinal chimaeras;
Selection of apomixes;
Production and utilization of haploids;
Alteration of sexes;
Interspecific and intergeneric hybrids;
Relationship between plant breeding and plant growing.

Besides a detailed explanation of each subjects illustrative examples are found which make the comprehension and genetic interpretation of the text extremely easy. After the description of classical methods, the chapters which deal with cell and tissue cultures, plant induction, haploid production, rediploidization, protoplast production and fusion, gene transfer, the utilization of somatic mutation and early selection in vivo and in vitro are worthy of special attention.

For the last ten years the methodology of plant breeding has been enriched by many totally new methods based on discoveries made in molecular genetics and plantphysiology and mostly applied in the laboratory or phytotron. In this book all the novel procedures which have not yet been introduced into general practice but will undoubtedly become indispensable for breeding in the future have been introduced and genetically explained.

In this respect the authors have produced excellent, extremely useful monograph, from which many valuable thoughts and ideas can be derived by practising breeders, and which will also be of use for students at agricultural and horticultural universities and colleges and for those attending plant breeding extension courses.

J. LELLEY

Polnohospodarstvo (Agriculture): Veda, Vydavatelstvo Slovenskej Akadémie Vied, Bratislava

The journal, compiled in Slovak at Nyitra, the centre of agricultural higher education and research, and supplied with English and Russian summaries, is published every month.

The task which the journal Polnohospodarstvo sets itself: to cover various special fields with scientific papers of a high standard, has always been considered a daring venture. In its volumes the most recent research results on crop production, animal farming and agricultural economics are published. Most of the papers endeavour, very often with success to fulfil a double requirement: they analyse current agricultural problems facing practising experts thus helping them to find the best solutions; on the other hand, the research results enrich not only the practice of Slovak agriculture, but universal agrobiology, too.

In the papers in the crop production section great importance is attached to cereal

production. Part from wheat, the cultivation of spring barley has a long tradition in Slovakia. The publications of KRAUSKO et al. discuss in full detail the specific fertilization of barley and the relationship of other production factors. Outstanding results have been obtained by MAREK et al. in wheat grain vacuolization experiments on the variety Nap Hal.

Besides cereals, sugar-beet and potatoes are also important crops in Slovakia, as reflected by the publications, among others MIKOVIC's paper "Changes in the nitrogen content of sugar-beet during vegetation, and its incorporation in the crop". A number of publications deal with the question of fertilization, with special regard to quantity, quality and economic efficiency. The work by FALTANOVA and JURÁNI: "Nitrogen balance in agriculture" is worth special mention.

Studies on fodder crops are justified by the importance of livestock farming. Grassland management on mountain areas, as well as lucerne and clover production almost everywhere, give reasonable grounds for a thorough study of this area.

The main subjects of soil research are a detailed analysis of the extremely heterogeneous soil conditions in Slovakia and studies on the interaction between fertilization and the soil.

Research in the field of livestock farming is concentrated on cattle breeding, which has great traditions in Slovakia. Therefore in the livestock section of Polnohospodarstvo several publications discuss in detail the genetic, biological and feeding physiology aspects of breeding, with respect to both dairy and beef cattle. The research is also extended to special fields, as shown by VAVÁK's paper: "Behaviour biology of dairy cows".

The Slovak journal also pays due attention to questions of pig and poultry breeding, and even to apiculture and nutria breeding.

The most frequent key words in papers published in the section on agricultural economics are efficiency, intensity and rentability. A number of authors, e.g. BACA and BELICA just as VALASEK, deal with the organization, operation and economic questions of integrated production. Besides considering future possibilities, they also aim at exposing the problems of the present. This is done, for instance, by SIMO in his paper "Economic analysis of grain maize production". The author gives a critical analysis of the causes of high material costs, low concentration and poor efficiency.

The journal occasionally touches upon the results of food processing and agricultural mechanization.

In the news and reports section surveys of the development of some special line can be found. It is worth mentioning KRÁLOVIC's literary summary, published in English. "The C_3-, C_4-type photosynthetic pathways and the productivity of the plant", or MAJERCIAK's comprehensive evaluation of the situation and future of hybrid pig breeding.

The journal Polnohospodarstvo, published under the auspices of the Slovak Academy of Sciences, is recommended to the attention of all those who are engaged in agricultural research; it may also be of use to agricultural engineers engaged in the modernization of agriculture.

Z. BEDŐ

J. D. BEWLEY, M. BLACK: *Physiology and Biochemistry of Seeds in Relation to Germination 2.* Viability, Dormancy, and Environmental Control. Springer-Verlag. Berlin, Heidelberg, New York, 1982. p. 375.

The second volume of the latest monograph on the biochemistry and physiology of seeds gives in 375 pages, with the aid of 153 figures, a comprehensive view of viability, dormancy and the interactions of environment.

It was no easy task that the authors undertook. Such excellent works on the subject have been published in English as:

M. G. Nikolaeva: Physiology of deep dormancy in seeds in 1969 (in Russian in 1962); A. M. Mayer and A. Poljakoff-Mayber: The seed germination in 1975; the three volumes of Seed Biology edited by T. T. Kozlowsky in 1972; then under the editorship of A. A. Khan: The physiology and biochemistry of seed dormancy and germination in 1977, and its enlarged edition in 1982: The physiology and biochemistry of seed development, dormancy and germination.

In their recently published work Bewley and Black cite 1228 sources of literature. The list of literary references are given for each chapter separately. To facilitate the orientation, the most important works concerning group of subjects (or chapters) are listed separately. A total of 81 tables are included in the monograph. These numerical data reflect the extensive work of the authors. The style and view are uniform, which proves the authors' concern.

The main chapters are: (1) Viability and longevity, (2) Dormancy, (3) The release from dormancy, (4) The control of dormancy, (5) Perspective on dormancy, and (6) Environmental control of germination. The book is completed by the Glossary and index of English and botanical names, the Author index and the Subject index.

The subjects of the individual chapters are worth being listed, if only to show how up-to-date the treatment and rich the content is.

Chapter 1. Viability and longevity

The life-span of seeds (the oldest seeds — from the pharaoh's tomb to the incendiary bomb, life-span of seeds buried in soil); Viability of seeds in storage (recalcitrant seeds, orthodox seeds, the basic viability equations, improved viability equations; Microflora and seed deterioration; The biochemical basis of deterioration; Respiration and the production of ATP (non-viable seeds and embryos, seed populations with reduced viability and vigour); Protein and RNA synthesis; Chromosome aberrations and DNA synthesis (chromosome damage and repair); Metabolism of dry seeds; Changes in food reserves; Free fatty acids and interference with metabolism; Membrane changes and leakage (leakage of metabolites and integrity of the bounding membranes, the nature and cause of membrane damage).

Chapter 2. Dormancy

What is dormancy? (categories of dormancy, biological significance of seed dormancy, dormancy in cultivated plants, polymorphism and heteroblasty); Dormancy mechanisms; Embryo dormancy (control mechanisms in embryo dormancy, the role of the cotyledons, the role of inhibitors, embryo immaturity); Coat-imposed dormancy (Interference with water uptake, interference with gaseous exchange, inhibitors in the coat, prevention of the escape of inhibitors, the coat as a light filter, mechanical restraint); Two case histories (*Sinapis arvensis*, charlock, *Xanthium pennsylvanicum*, cocklebur); Coat-imposed dormandy — a retrospective view; Relationships between coat-imposed and embryo dormancy; The onset of dormancy (timing, control the genetic factor, environmental factors correlative effect hormones, secondary or induced dormancy, the development of hard coats; Endogenous germination inhibitors (chemical nature of inhibitors).

Chapter 3. The release from dormancy

Light and phytochrome; The phytochrome system (spectral sensitivity and photoreversibility); Energies for photoconversion; The escape time; Photochrome photoequilibria; Chemistry of phytochrome; The pathway of phytochrome photoconversion; The state of phytochrome in seeds; Seed hydration and sensitivity to light; Reversion of P_{fr} in darkness; Thermal processes connected with phytochrome action; Phytochrome location and the photosensitive site); Phytochrome and overview; Blue light effects; Response types; Temperature and the action of light (Constant temperature, Temperature alternations and shifts, Chilling); Temperature and the release from dormancy; Termination of dormancy by temperature alterations and shifts; Termination of dormancy by low temperature (Response types; Temperature and time requirements); Termination of dormancy by high temperature; Loss of dormancy in dry seeds — afterripening (Moisture content, temperature, oxygen); Finale — Replacement and interactions; Hard-coated seeds; Removal of dormancy by chemicals (Growth regulators, Gibberellins; Cytokinins; Ethylene; Plant and fungal products; Respiratory inhibitors; Oxidants, Nitrogenous compounds; Sulfhydryl compounds; Various other chemicals including anaesthetics).

Chapter 4. The control of dormancy

Introduction; Dormancy — events and causes (Metabolism of dormant and afterripened seeds; Dormancy and maturation; Chemical inhibition; Membrane properties and dormancy); Primary events in the release of dormancy (Phytochrome action; Chilling action; Alternating temperatures and afterripening); Secondary events in the release of dormancy — Physiological considerations (Hormones and dormancy; Hormones and light-terminated dormancy; Hormones and the low-temperature release from dormancy; Ethylene and dormancy; Water relations and growth potentials); Secondary events in the release from dormancy — Metabolic considerations (Perpetuated misinterpretations of studies on dormancy-breaking mechanisms; Hormonal effects on nucleic acid and protein synthesis; Fusicoccin and cell elongation; Hormonal effects on respiration; The pentose phosphate pathway — a role in dormancy breaking? Phytochrome-induced changes in metabolism).

Chapter 5. Perspective on dormancy

This contains a brief summary of the previous chapters.

Chapter 6. Environmental control of germination

Introduction; Light (Light-inhibited seeds; Dual effects of light); Spectral effects in photoinhibition (short-duration and intermittent far-red light; Prolonged or high-irradiance far-red light; Inhibition by pro-

longed blue light; Suppression of germination by white light — a re-examination); Light and seed burial; Shade and seed germination; Temperature (temperature minima, optima and maxima; Temperature and germination rate; The action of temperature; Temperature and germination ecology; Geographical adaptation and plant distribution; Chilling injury, Alternating temperatures); Oxygen and carbon dioxide; Secondary dormancy (Mechanism of secondary dormancy; Secondary dormancy in nature); Water stress (Drought during seed development and maturation; Germination under stress; Dehydration and rehydration following inhibition — effects on germination; Dehydration and rehydration following inhibition — effects on growth, yield and tolerance; Drought-hardening; Osmotic pretreatment — the priming of seeds; Salinity stress; Cellular changes associated with dehydration-rehydration treatments; Changes to membranes induced by desiccation-rehydration treatments; Desiccation-induced changes to metabolism and structure).

It must be pointed out that every piece of information the authors give is made useful by practical references. This particularly holds in respect of the external and internal factors controlling dormancy, the techniques that release or decrease the dormancy. Interesting are the new data on plant and fungal products which stimulate the germination of seeds (fusicoccin, cotylenol, cotylenin E, strigol, etc.). Similarly important contribution to our knowledge is made when we read about the biological bases of stress (effects of osmotics and salts, drought tolerance, etc.) and vigour. We are also informed about the most recent and highly important biochemical results which explain the natural or artificial senescence of the seed and of the peroxidation processes of the membrane lipids (free radicles, catalase, peroxidase, superoxid-dismutase).

The literature on seed physiology has been enriched with a fundamental and substantial work which, while usefully completing the so-far published monographs, gives in itself a comprehensive view of the scientific achievements in this special field.

L. Gy. Szabó

J. Hagin and B. Tucker: *Fertilization of Dryland and Irrigated Soils*. Springer Verlag, Heidelberg, 1983.

The Springer Verlag firm published the book "Fertilization of dryland and irrigated soils" by Professor Hagin and Tucker last year.

As suggested by its structure, it was originally intended to be a text-book. However, the large number of figures and the practical descriptions of methods make it a useful source of information for agricultural engineers in their practice, and for experts engaged in the development of production technology.

To give reasons for writing the book, and support the topicality of its information, the authors point to the enormous changes that have taken place in the practice of fertilization. These changes are most conspicuous on those arid and semi-arid areas where irrigation has partly or fully been introduced. The consequent increase in the intensity of production has resulted in a thorough transformation of the conception of fertilization and of the practice of farm management. Under the continental climatic conditions of Hungary, the system of fertilization similarly has undergone — or is undergoing — substantial changes, so it seems necessary to acquaint the reader with some of the established facts and methods described in the book.

This 188-page book discusses its subject in seven chapters, and includes 64 illustrative figures.

In *Chapter 1*, a survey is given of the geographical places and some ecological characteristics of the arid and semi-arid regions of the world. The authors describe the most important soil characteristics and indicate the role of irrigation on these often sick, dry soils.

In a list of the 16 elements indispensable for the plant life, the so-called non-fertilizer nutritive elements are discussed separately from the fertilizer components.

The diagram which shows the classification of the irrigation water can be used anywhere for qualifying the irrigation waters. Practical categories are set up for the quality of irrigation water as a function of the percentage of salt content and the micro-ohm/cm value of the electric conductivity.

In this context, it is worthwhile to present Fig. 1.5 of the book. (see; next page)

In a similarly expressive figure, numerical values indicate the salt tolerance of the most important 10–12 plants.

Chapter 2, the most detailed section of the book, devotes more than 40 pages to nitrogen. It discusses the most important nitrogen fertilizers, the ammonia and nitrate fertilizers separately, and lists a number of N-fertilizer products. The authors analyse the biological and production responses of plants to various nitrogen fertilizers, with examples of 10 plant species. Most remarkable is that part of the chapter in which the methods of applying the nigrogen fertilizers are described with the technological instructions for their immediate practical use.

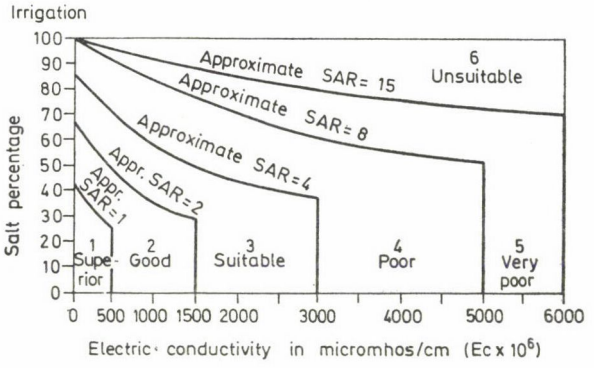

Fig. 1

Chapter 3 deals with phosphorus. After informing the reader about the major phosphorus fertilizers, the authors discuss the reactions of phosphorus in the soil, and the methods of applying the phosphorus fertilizers. An account is given of the ways of estimating the amount of the available phosphorus. To know the nature and extent of responses made by various plants to phosphorus fertilization is interesting from the standpoint of crop production as well.

The nitrogen and phosphorus concentrations in the different plant parts are summed up in tables; these concentration values are brought into connection with the fertilizer demands of the different plants.

It follows from the topic of the book that correlations are provided between the moisture content of the soil and the effect of nitrogen.

In *Chapter 4*, the potassium fertilizers are dealt with. The authors analyse the reactions of the potassium fertilizers in the soil; follow the movements of potassium in the soil; show the methods of estimating the amount of potassium available for the plant; describe several methods for the application of the potassium fertilizers in the practice of crop production. Correlations are outlined between the effect and role of potassium, and the yields of crops. For the latter, numerical values are given. On the model of several plant species, a comparison is made between the potassium concentration in the plant parts and the possible potassium fertilizer requirements and prospective yield increase.

In *Chapter 5*, we can read about the secondary elements and the microelements. The secondary elements are calcium, magnesium and sulphur; while zinc, iron, manganese, copper, boron and molybdenum are microelements. Sulphur is discussed in the fullest detail; the authors explain the circulation of sulphur and its linkage with other elements, and briefly touch upon its importance and role in the life of the plant.

In *Chapter 6*, the special fertilization practice and the multicomponent fertilizers are discussed. As for the multicomponent fertilizers, the authors explain that it is a new term used instead of the earlier name: mixed fertilizers. The multicomponent fertilizers contain at least two elements. The multicomponent solid and liquid fertilizers are discussed separately. The application of fertilizers in the irrigation water is a new method which may be of interest to the Hungarian agriculture. The irrigation water may be, biologically, a highly efficient means of fertilizer distribution, and simultaneously an economical one. However, the authors emphasize that its practicability greatly depends on external factors, e.g. on the type of soil, the plant grown, and last but not least on irrigation water used.

Favourable experiences are reported concerning the application of fertilizer by trickling irrigation. Meanwhile, attention is called to the fact that, in the case of over-irrigation, some 25–30% of the nitrogen fertilizer applied was washed off the root zone and thus lost. The demonstrated fertilizer-injecting pump may suggest the idea of introducing it into general practice. This pump mixes and conveys the fertilizer with the irrigation water. In one illustration we can see how the fertilizer solution can be carried from an open container to the irrigation system with a Venturi-system paddling method.

In this chapter the questions of fertilization are separately dealt with for salt- and alkali soils.

Finally, in *Chapter 7*, methods for the determination of fertilizer requirements are described. Some methods are based on visible

deficiency symptoms, others on plant analyses, while a third group rely upon a chemical analysis of the soil.

For the quantitative expression and measurement of the fertilization efficiency in the crop production, the authors use the traditional Mitscherlich equation. According to this equation, the correlation between the nutrient level and the volume of yield gives a logarithmic curve.

To summarize, this book is interesting, and useful even to the Hungarian representatives of the profession. In the first place, the way the authors introduce and discuss the material is remarkable. However, those — mainly beginners — who deal with the questions of fertilization and irrigation in tropical agriculture are furnished with such detailed instructions and theoretical and practical information as cannot be inquired under continental conditions.

This book of Professors Hagin and Tucker contains an up-to-date level of information, and well-arranged data that is important and useful for the production of crops under arid conditions.

I. PETRASOVITS

A. SOMOS: *The Paprika (Capsicum annuum* L.) in "Magyarország Kultúrflórája" (Eds.: I. Máthé and Sz. Priszter). Vol. 5, No. 13. Akadémiai Kiadó, Budapest (Hungary), 1985.

The paprika plant is a topic of constant interest, particularly in professional circles where every publication concerning this subject attracts attention.

This bulky monograph is an outstanding volume of the culture flora series. A. Somos, academician, took the majority of the authorship upon himself, but those who undertook to write some other chapters — K. Farkas, M. Glits, Erzsébet Felhős-Váczi, G. Csilléry — also guarantee the high professional level of the work.

The volume of 226 pages, in 15 chapters, supplies complete data and the results of available research concerning this important and popular vegetable, which con be outlined as follows:

— The name of the plant, though only traced back to the 16th century, has some historically cultural relations.
— The reader learns a great amount systematization, regarding the plant's growth environment within the northern areas of Central America and of South America, and gets acquainted with the genera and related genera. With the origin of the species confined to the "nuclear area", Bolivia is the location of an imaginary study tour. This chapter also supplies abundant genetic and breeding information.
— The historical survey of paprika cultiva tion, completed with factual data and names, satisfies a long-required need. The complete description can be found only here in a single chapter.
— The outer and inner morphology introduces the reader to the diversified appearance, structure and organism of the paprika plant. From the differentiation of the root to the inner structure of the pollen, the course of its evolution is revealed. Erzsébet Felhős-Váczi' microscopic photography and Anikó Tóth's excellent drawings deserve special attention.
— The chapter, in which the physiological aspects of paprika are discussed, contributes experimental data to the role played by temperature, light, water and nutrients in the metabolic processes, and information concerning the possibilities of control. The analysis of observations and investigations relative to blossoming and fertilization forms an integral part of this chapter.
— The chapter dealing with questions of plant protection treats the diseases, pests and their control in due proportions.
— The description of cultural practices follows the course of preparatory, propagation, tending and harvesting operations, while both forcing and field operations are equally supported by numerical data.
— The chapter on the cytogenetics and breeding of paprika acquaints the reader with the chromosomal characteristics and with the concept of haploidy and polyploidy, as well as their importance in plant breeding. A comprehensive view is obtained of the genetic relations that determine the breeding methods and the work of variety maintenance.
— An analysis of the components of paprika — dry matter, carbon hydrates, vitamines, colour substances, capsaicin, etc. — is completed by tabulated comparative evaluations.
— After the discussion of the cultivation and utilization aspects, data on marketing are presented to inform the reader of the current economical experiences.
— Finally, paprika varieties grouped by the major characteristics are described.

In summary, A. Somos and his co-authors have added an excellent volume to the series. The interest that this work is bound to arouse will probably soon call for the appearance of a new edition.

I. TAMÁSSY and K. MOZSÁR

The Fauna of the Kiskunság National Park Vol. I.

Edited by

S. MAHUNKA

In English. Forthcoming 1986. 512 pages, 48 figures, 8 tables. 17×25 cm.
Hardcover approx. $48.00 ISBN 963 05 3875 X

(Series: Natural History of the National Parks of Hungary 4.)

The Kiskunság National Park situated in the centre of the Great Hungarian Plain, as well as in that of the Carpathian Basin, is one of the most interesting national parks of Hungary, since within its boundaries there are highly varied biotopes like the saline puszta, the sand dunes, Juniper woodlands, inundation groves and a series of marshes.
These biotopes harbour a very special fauna which, elsewhere in Central Europe, has partly become extinct. This is why it is of paramount importance to explore and study this characteristic animal community. A multilateral investigation was proposed and subsequently carried out by the staff of the Hungarian Natural History Museum.
The field work lasted for four years (1977—1981). The collected material has been worked up by an international team of scientists. The taxonomic, faunistical, zoogeographical and ecological results brought to light many new features of interdependence. Basides the documentation of the natural gene bank "protected" here, the obtained data may be a source of inspiration for further comparative zoogeographical and ecological studies. The first volume includes contributions on the following groups of animals: worms, crustaceans, insects, mites, amphibians, reptiles and birds.
The book will be a useful handbook not only for zoologists or other specialists engaged in the study of animals but also for teachers and the layman interested in nature.

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