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Acta Agronomica Hungarica 36 (1—2), pp. 3—10 (1987)

COMPARATIVE STUDY ON MYCELIUM GROWTH AND INCREASE IN *PLEUROTUS* SPECIES

J. VETTER

DEPARTMENT OF BOTANY, UNIVERSITY OF VETERINARY SCIENCES, BUDAPEST, HUNGARY

(Received: 29 July 1985)

The subject of the comparative study described in the paper was the growth of mycelium cultures of *Pleurotus* species, the temperature dependence of growth, and the correlation between the growth of the diameter of thallus and the mycelium production of the species. On the basis of the results of examinations covering 17 *Pleurotus* species, the following can be established:

(1) The rate of growth shown on a solid culture medium at 24 °C — 0.7–11.2 mm/day — ranges between wide limits. Up to 30 °C, no decrease in the growth rate of most species occurs; at 33 °C, however, the growth is absolutely inhibited among five species and considerably slower among eleven species; while, in the case of one species *(P. cystidiosus)*, growth is the fastest at that degree of temperature.

(2) The examination of the dry mycelium production, besides characterizing the species from the standpoint of biomass production, has verified a correlation between the mycelium growth of the species and their mycelium production on a dry matter basis.

The index calculated in the course of the experiment to express the amount of sugar used for a unit mycelium formation characterizes well the differences in the sugar utilization of the species. These data make it possible to choose species forming mycelium with the highest degree of efficiency and the lowest energy consumption.

Keywords: *Pleurotus* species, mycelium growth, mycelium production

Introduction

Today the possibility of utilizing agricultural by-products through a mushroom species seems to be highly promising. We try to find those species that are most able to interweave the given lignocellulose-containing substrate (corn straw, maize stalk, shavings, etc.) quickly and efficiently, to expose it by means of enzymes, and either to produce a mushroom rich in protein, or to leave behind materials richer in protein, changed in composition, and transformed so as to be suitable for such other purposes as feeding animals. Those to be mentioned in the first place include the *Pleurotus* species, most of which are known as white-rot mushrooms. As to the mushroom's characteristics, it may be of decisive importance to settle the questions of how quickly the mycelium grows, what correlation the growth shows with the temperature, how this growth can be characterized, and what the relationship between growth and mycelium production is. Few systematic and wide

investigations have been made so far. Zadrazil (1974) studied the mycelium's growth and its dependence on temperature in four *Pleurotus* species. Similar data, though mainly from a taxonomic point of view, were published by Hilber et al. (1981). Of the Hungarian studies, the work by Balázs and Szabó (1979) should be mentioned here. According to Afanasyeva and Serebryannikov (1981) it is a question whether the intensity of mycelium growth on a solid culture medium gives a true picture of the mycelium production on a dry matter basis.

The experiments described in this paper, as a part of the physiological-enzymological experiment series with the *Pleurotus* species, took the above-mentioned questions into consideration.

Material and methods

To follow the growth of mycelium on a solid culture medium, *Moser*'s culture medium was used. After inoculation, the Petri dishes were incubated in a thermostat at 24, 27, 30 and 33 °C, respectively, with the diameter of the thallus regularly measured.

For the evaluation of the mycelium production, an experimental series was set up in a liquid culture medium after Nizkovskaya et al. (1979), which was incubated at 24 °C. On evaluating the flasks, the dry weights of the filtrated mycelia and the changes in the sugar concentration of the culture medium were determined (after Bilay 1973).

Results

Evaluation of growth in the mycelium cultures

The data of the experiment series are summarized in Table 1. The values of the average daily growth per species and the temperature variant are shown in Table 2. An examination of the values of the average daily mycelium growth, starting from those obtained at 24 °C, reveals substantial differences between the species. For example, the average daily growth was 11.2 mm for *P. calyptratus*, 2.7 mm for *P. ulmarius*, and only 0.9 mm for *P. dryinus*. A comparison of the growth values obtained at different temperatures shows more or less similar tendencies; with an increase in the temperature, the absolute values generally decrease. With a large proportion of the species examined, the average daily growth only slightly changes; it decreases somewhat at 27–30 °C, but between 30 and 33 °C the decrease is considerable. The only exception was *P. cystidiosus*, which showed the highest rate of growth at 33 °C. The inocula of several species (*P. elongatipes*, *P. sapidus*, *P. euosmus*, *P. ulmarius* and *P. columbinus*) did not even start growing at 33 °C; that is, their life processes are completely inhibited by a temperature of that high degree. The majority of these species are characterized by a minor extent of growth inhibi-

Table 1

Changes in the average diameter of mycelium thallus in Pleurotus species in response to incubation at 24, 27, 30 and 33 °C, between the 3rd and 30th day

	Temperature, °C	Diameter of thallus in mm on day No.								
		3	6	8	10	13	15	17	22	30
P. calyptratus	24	28	69	90	—	—	—	—	—	—
	27	24	69	90	—	—	—	—	—	—
	30	22	66	90	—	—	—	—	—	—
	33	8	16	24	34	55	65	75	90	—
P. candidissimus	24	—	4	16	45	54	64	80	—	—
	27	—	14	24	46	54	65	73	90	—
	30	—	7	11	12	14	16	20	21	24
	33	0	0	0	0	0	0	0	0	0
P. columbinus	24	—	12	19	27	33	38	43	56	65
	27	12	14	16	22	29	32	36	44	60
	30	—	12	16	21	28	32	36	47	64
	33	0	0	0	0	0	0	0	0	0
P. cornucopiae	24	11	35	51	67	85	90	—	—	—
	27	12	35	51	67	80	—	—	—	—
	30	11	35	55	72	80	—	—	—	—
	33	8	14	19	26	40	46	52	80	—
P. cystidiosus	24	—	19	24	32	39	45	48	59	71
	27	—	17	21	25	30	34	37	44	80
	30	16	22	26	32	36	41	47	55	85
	33	—	—	16	19	38	49	59	80	—
P. elongatipes	24	—	10	14	25	44	55	71	90	—
	27	—	6	7	10	13	17	26	32	47
	30	—	6	10	13	19	26	30	48	80
	33	—	0	0	0	0	0	0	0	0
P. eryngii	24	—	20	28	40	54	62	72	80	—
	27	—	20	29	36	59	69	—	80	—
	30	19	33	45	66	75	90	—	—	—
	33	—	8	13	17	24	31	37	52	80
P. eryngii var. *ferulae*	24	13	28	38	45	58	69	—	—	—
	27	12	28	36	48	62	69	—	—	—
	30	12	30	42	52	67	74	80	—	—
	33	12	22	28	34	42	52	60	80	90
P. euosmus	24	—	13	30	52	77	90	—	—	—
	27	—	12	28	48	68	90	—	—	—
	30	—	11	28	45	73	90	—	—	—
	33	—	0	0	0	0	0	0	0	0
P. dryinus	24	—	5	6	7	11	14	15	21	28
	27	—	6	7	8	11	16	19	20	28
	30	—	6	6	10	11	15	15	22	28
	33	—	—	7	8	8	8	9	9	9
P. florida	24	11	31	49	63	80	—	—	—	—
	27	9	29	—	65	80	—	—	—	—
	30	10	34	50	68	80	—	—	—	—
	33	7	10	17	25	38	45	56	80	—

Table 1 continued

	Temperature, °C	Diameter of thallus in mm on day No.								
		3	6	8	10	13	15	17	22	30
P. japonicus	24	15	32	45	64	77	85	90	—	—
	27	15	38	54	68	83	90	—	—	—
	30	12	34	52	70	82	85	90	—	—
	33	—	25	32	38	62	74	85	90	—
P. mutilus	24	28	65	78	90	—	—	—	—	—
	27	28	58	75	90	—	—	—	—	—
	30	26	49	63	78	90	—	—	—	—
	33	36	42	50	60	74	85	90	—	—
P. ostreatus	24	8	35	57	85	90	—	—	—	—
	27	8	41	68	90	—	—	—	—	—
	30	10	40	68	90	—	—	—	—	—
	33	6	18	32	45	73	90	—	—	—
P. passeckerianus	24	9	28	38	52	58	74	—	—	—
	27	8	25	37	48	63	66	—	—	—
	30	5	11	26	32	43	47	—	—	—
	33	3	8	9	11	12	15	—	—	—
P. pulmonarius	24	11	34	57	75	90	—	—	—	—
	27	14	47	68	80	—	—	—	—	—
	30	14	42	—	85	90	—	—	—	—
	33	6	15	22	—	59	78	80	—	—
P. sapidus	24	—	9	14	18	25	28	32	43	53
	27	—	6	6	6	11	15	18	24	30
	30	—	6	10	17	27	29	33	43	57
	33	—	0	0	0	0	0	0	0	0
P. ulmarius	24	—	8	14	18	25	28	32	43	53
	27	—	6	6	6	11	16	18	24	30
	30	—	6	7	10	17	18	22	28	38
	33	0	0	0	0	0	0	0	0	0

Note: (a) 0 indicates that the thallus did not start growing; (b) the sign—indicates that the maximum—80 or 90 mm—diameter has been reached

tion occurring at 33 °C. When the data of the species are simply averaged, all of these tendencies become clearly evident:

Temperature, °C	Average daily growth, mm
24	5.20
27	4.97
30	5.01
33	3.70

Of the full series of data, the growth dynamics for three species are represented in Fig. 1. *P. pulmonarius*, the best example of a rapidly growing species, reaches the possible limit of growth on the 8th to 10th day; at 33 °C,

Table 2

Average daily growth of mycelium diameter in species incubated at various temperatures on solid culture medium in Petri dishes, mm

Species examined	Temperature of incubation, °C			
	24	27	30	33
P. candidissimus	4.9	3.5	0.8	—
P. calyptratus	11.2	11.4	10.0	4.4
P. columbinus	2.2	2.0	2.1	0
P. cornucopiae	6.5	6.7	6.1	3.6
P. cystidiosus	2.4	1.9	1.8	3.6
P. dryinus	0.9	0.9	0.9	0.4
P. elongatipes	4.1	1.6	2.2	0
P. eryngii	4.8	4.6	5.0	2.7
P. eryngii var. *ferulae*	4.5	4.5	4.8	3.5
P. euosmus	5.9	5.3	5.6	0
P. florida	6.3	6.2	6.1	3.6
P. japonicus	5.6	6.8	5.4	5.0
P. mutilus	9.0	8.8	7.8	5.6
P. ostreatus	8.5	9.0	8.5	6.0
P. passeckerianus	4.7	4.4	3.4	0.9
P. pulmonarius	7.5	8.0	6.9	4.7
P. sapidus	1.7	1.5	1.9	0
P. ulmarius	2.7	1.0	1.2	0

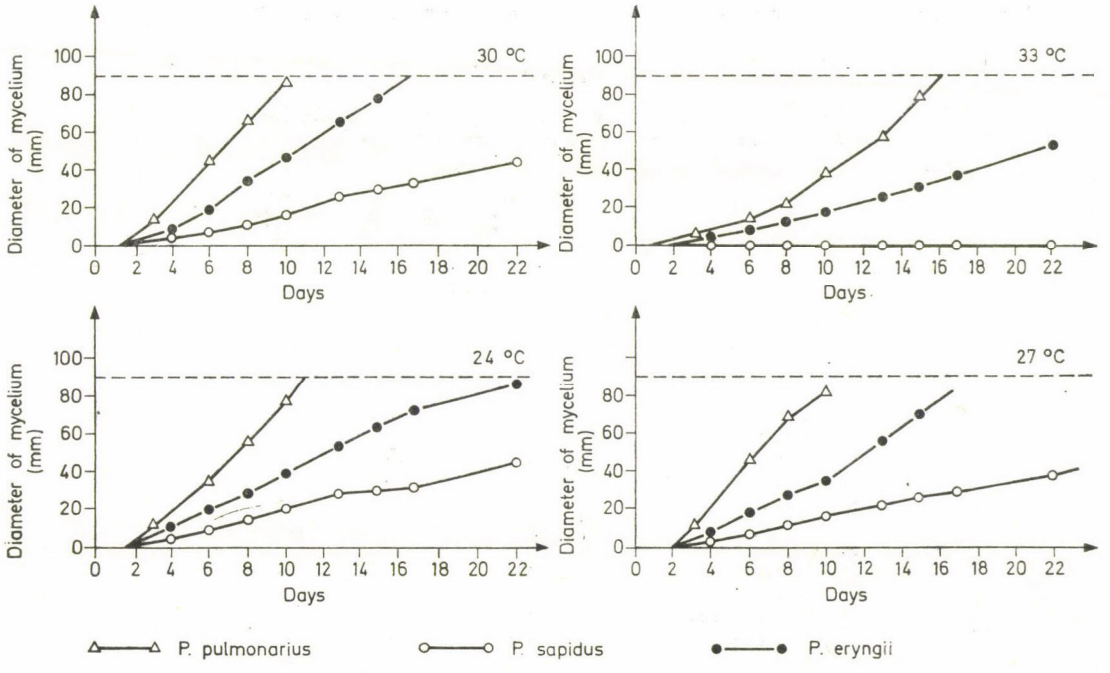

Fig. 1. Growth dynamics of mycelia between 24 and 33 °C

however, this occurs only around the 16th day. The growth of *P. eryngii*, the example of a medium rate of growth, also slows down considerably at that temperature. *P. sapidus*, a species of slow growth, has at 24 °C an average diameter of about 42 mm only, even on the 22nd day; the character of the growth curve shows little change at 27 and 30 °C, and at 33 °C complete growth inhibition occurs.

Examination of the increase of mycelium in a liquid culture medium

It is reasonable to inquire whether the growth of the mycelium on a solid culture medium truly reflects the actual increase of the biomass. The question is whether or not the conditions are influenced by the differences shown by the species concerning the structure and character of the mycelium, as described in an earlier paper (Vetter 1981). How, for instance, can the growth data of *P. sapidus* with its rich aerial mycelium, and of *P. dryinus* with its compact solid structure be compared?

In order to answer the above outlined question a comparative experiment was set up with a liquid culture medium. The dry weights of filtrated mycelia and the sugar concentration of the culture medium were measured. Table 3 describes the daily mycelium production, the glucose consumption and the index of sugar consumption per unit of mycelium production. The lowest mycelium production was found with the species *P. sapidus* (2.8 mg/day),

Table 3

Daily mycelium production in dry weight, glucose utilization, and sugar consumption per unit mycelium in the species examined

Species examined	Mycelium production dry matter	Glucose utilization	Sugar consumed in mg/ mycelium produced in mg
	mg/day		
P. candidissimus	5.0	11.7	2.34
P. calyptratus	5.6	12.5	2.23
P. cornucopiae	7.2	8.5	1.18
P. cystidiosus	6.4	7.4	1.15
P. elongatipes	4.3	7.1	1.65
P. eryngii	5.6	8.5	1.50
P. eryngii var. *ferulae*	8.7	10.0	1.14
P. euosmus	3.7	8.0	2.16
P. florida	6.6	7.4	1.12
P. japonicus	5.8	19.0	3.27
P. mutilus	11.9	19.0	1.59
P. ostreatus	7.0	13.0	1.85
P. passeckerianus	4.7	11.0	2.34
P. pulmonarius	9.3	16.0	1.72
P. sapidus	2.8	5.8	2.07
P. ulmarius	3.7	4.2	1.14

P. ulmarius and *P. euosmus* (3.7 mg/day); the highest was found with *P. mutilus* (11.9 mg/day). When comparing these results with the above data of mycelium growth, an essential difference in the order of succession is only found in a single case, with *P. cystidiosus*. The relation between the two indexes was examined with a regression correlation assumed. It was found that between the average linear growth (mm) of the mycelium thallus = X and the total mycelium production (mg) = Y, a regression correlation expressed by the equation $Y = 68.1 + 10.3\ X$ existed. This correlation is considered to be medium close ($r = 0.70$). Without over-estimating the importance of this correlation, we can say that the growth index of the thallus diameter generally can be used with good approximation for the determination of the growth intensity (production) of the species. A more complete picture is obtained, however, when the mycelium production is also characterized by the total amount of dry matter produced. An interesting parameter referring to the metabolism's dynamics is obtained when the amount of sugar consumption per unit of mycelium production is given. According to the third column of Table 3, the mycelium production is most efficient in the case of *P. cornucopiae*, *P. florida*, *P. cystidiosus*, *P. eryngii* var. *ferulae* and *P. ulmarius*. The largest quantity of sugar, on the other hand, is used by *P. japonicus* and *P. passeckerianus*.

Discussion

The growth dynamics of mycelia in the *Pleurotus* species was evaluated on the basis of changes in the diameter of the thallus. According to the data obtained, substantial differences were found, since the daily growth ranged from 0.9 to 11.2 mm *(P. dryinus – P. calyptratus)*. Zadrazil (1974) established the following order of growth: *P. ostreatus*, *P. florida*, *P. eryngii*, *P. cornucopiae*, which was essentially confirmed in the present study. The growth rate values of mycelia obtained by Hilber et al. (1981) at 23 °C, compared to our data, are:

	Average daily mycelium growth calculated on the basis of the work cited	Our own experiment data
	mm	
P. pulmonarius	8.5	7.5
P. ostreatus	7.0	8.5
P. cornucopiae	4.25	6.5
P. calyptratus	3.3	6.6–11.2
P. cystidiosus	2.1	2.4
P. eryngii	1.25–6.0	4.8
P. dryinus	0.7	0.9

That is, in many of these cases, good comparisons can be made. Li and Eger (1978), using a similar Petri dish method, pointed out that the growth of the thermophilous *P. florida* strains having reached maximum between 27.5 and 30 °C, showed a very sharp decrease. According to our data, the intensity of growth with most species is at a maximum between 24 and 27 °C. While the growth of *P. cystidiosus* was fastest at 33 °C, the mycelia of 5 species did not even start growing at that temperature.

Although a number of authors used a solid culture media and took the size of the thallus into consideration in studying the intensity of growth, some others expressed their doubts (Shivrina 1969, Afanasyeva and Serebryannikov 1981). For this reason we set up an experiment in which the mycelium production of the same species was studied in a surface culture. As it turned out, the order of growth agreed, but for a single exception *(P. cystidiosus)*, with the order set up on the basis of the increase in dry matter. According to the data of literature, the sugar consumption per unit of mycelium is favourable in the *Pleurotus species*, compared to the mycorrhizal and saprophytic fungi. Shivrina (1969) established the value of sugar consumption as 1.8–1.9 mg/g dry mycelium, which was confirmed in our experiments. The species show a considerable variation, the ratio being most favourable in regard to *P. cornucopiae*, *P. florida*, *P. eryngii* var. *ferulae* and *P. cystidiosus*. Besides the linear growth and the dry mycelium production, the sugar demand for each unit of mycelium formation is a highly important parameter of the species. When selecting species (strains) for optimum characteristics, this ought also to be considered an important parameter.

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PHYTOCENOLOGICAL STUDIES ON SWARDS SOWN WITH GRASS MIXTURES

A. Kovács

DEPARTMENT OF PHYTOTAXONOMY AND ECOLOGY, EÖTVÖS LORÁND UNIVERSITY, BUDAPEST, HUNGARY

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In most swards sown with different grass mixtures the proportions of the sown species had stabilized by the last growths in the year of sowing. The adventitious species found in the sown grass stand (such as *Stellaria media*, *Lamium amplexicaule* and *Geranium pusillum*) are not specific for the stand. The high individual numbers of these species do not influence the quantity and quality of the grass yield, because their height hardly reaches the level of cutting, so their role in the grass yield was negligible.

Keywords: phytocenology, ecology, swards, grass mixtures

Introduction

Comparative phytocenological and production studies on intensive swards sown with grass mixtures serve, especially under extreme ecological conditions, to establish a reliable basis for feeding animals on large-scale farms. The ratio between the populations of the various species composing the grass mixture, the way these populations from one growth change or stabilize from one year to the next, and the populations of perennial or annual species accompanying or replacing them, all have a considerable influence, even in the short term, not only on the individual numbers of the species sown and on the grass yield of the sward, but also on the quality and external yield components of the grass crop.

Considering that little knowledge is available on phytocenological questions concerning sown grass stands either in Hungary or abroad the present investigations were aimed at throwing light upon the cenological conditions of swards sown with various grass mixtures on ameliorated solonetz meadow soil supplied with identical rates of nutrient and water under semi-arid climatic conditions, with special regard to the sown species and their yearly dynamics, in the interest of developing high-yielding, long-lasting swards to be used for hay-making. This objective was all the more reasonable because the phytocenological aspects and production of the species used in the grass mixtures had already been studied in single species grasses in four-year cycles, under similar experimental conditions (Kovács and Cinkóczky 1974, Kovács and Angeli 1978, 1981, Kovács 1979, 1982a, b).

Material and methods

Experimental with intensive (fertilized, irrigated) swards sown with grass mixtures were set up on 14 March 1978 in the K-10 block of the Plesovszki pasture in the Kákai district of Szarvas State Demonstration Farm, in 100 m² plots with a random block design, in 4 replications (Fig. 1), with 4 different grass mixtures sown in rows spaced at 12 cm, with 500 g/100 m² seed with the following percentage weight ratios:

Mixture I:

Festuca arundinacea Schreb. ("G", AE 1975)	50%
Dactylis glomerata L. (Szarvasi 51, AE 1978)	30%
Trifolium repens L. f. *giganteum* Lagr. (Szarvasi 4, AE 1967)	20%

Mixture II:

Festuca arundinacea Schreb. ("G", AE 1975)	40%
Dactylis glomerata L. (Szarvasi 51, AE 1978)	35%
Lotus corniculatus L. ("G" keskenylevelű, AE 1969)	25%

Mixture III:

Bromus inermis Leyss. ("G", AE 1959)	50%
Festuca pratensis Huds. ("G", AE 1964)	35%
Trifolium repens L. f. *giganteum* Lagr. (Szarvasi 4, AE 1967)	15%

Mixture IV:

Bromus inermis Leyss. ("G", AE 1959)	40%
Festuca pratensis Huds. ("G", AE 1964)	35%
Lotus corniculatus L. ("G" keskenylevelű, AE 1969)	25%

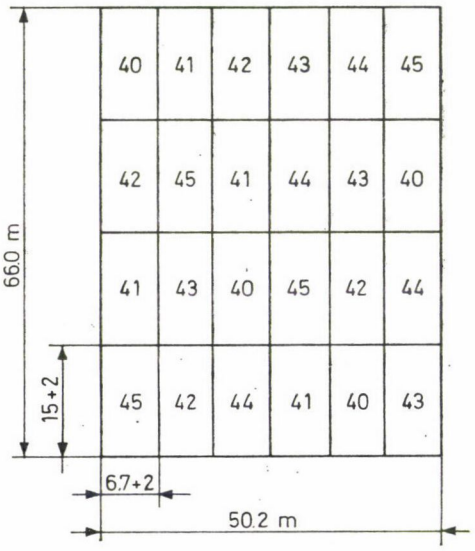

Fig. 1. Arrangement of the experiment: 40. Sward sown with *Festuca arundinacea*; 41. grass mixture I; 42. grass mixture II; 43. grass mixture III; 44. Sward sown with *Trifolium repens* f. *giganteum*; 45. grass mixture IV

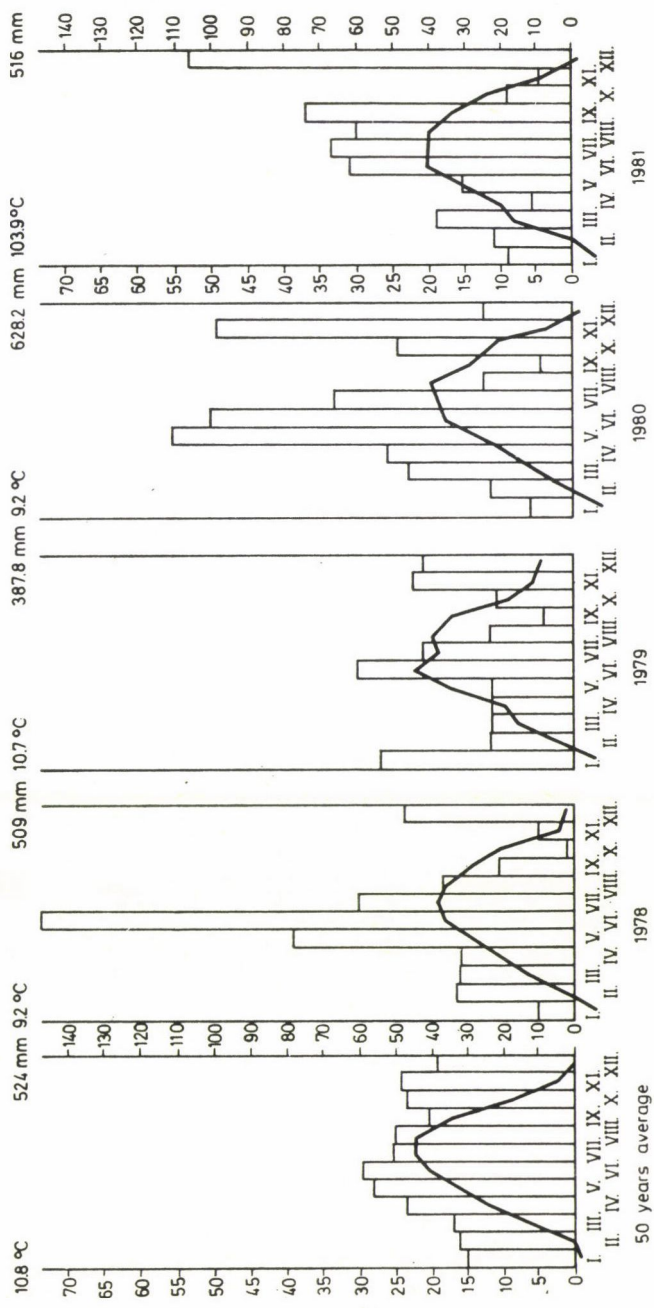

Fig. 2. Climate diagrams, Szarvas-Kákafok

Table 1

Cenological changes in a sward sown with a mixture of grasses (Festuca arundinacea + Dactylis glomerata + Trifolium repens f. giganteum) in 1978–1981

L.f.	Areal	Date of survey	1978 IV 24	1978 V 30	1978 VII 4	1978 VIII 15	1979 V 10	1979 VI 27	1979 IX 10	1980 IV 29	1980 VI 8	1980 VIII 13	1981 IV 22	1981 VII 10	1981 IX 2
		Total cover, %	100	100	100	100	100	100	100	100	100	100	95	100	100
		Average height, cm	40	50	40	20	80	60	40	55	60	30	70	50	25
		Growths	I	II	III	IV	I	II	III	I	II	III	I	II	III
H	Eua	*Festuca arundinacea*	2	2	+−1	1−2	1−2	1	2	1	1	2	2	2	2
H	Eua	*Dactylis glomerata*	3	5	4−5	3−4	4−5	5	5	5	5	4	5	5	5
H	Eu	*Lolium perenne*	+	+	+	+	+	+	+	+	+	+	+	+	+
Th-TH	M	*Lolium multiflorum*	−	+	1−2	+	+	+−1	+	+	+	+	+	+	+
H	Cpl	*Poa pratensis*	−	−	−	−	−	−	−	−	+	+	+	+	+
Th	Cos	*Echinochloa crus-galli*	−	−	+	+−1	−	−	−	−	−	+	−	+	+
Th	Eua	*Hordeum murinum*	−	−	+	+	−	−	−	−	+	+	−	−	−
Th	Eua	*Bromus sterilis*	−	+	+	−	−	−	−	−	−	−	+	−	−
Th	Adv	*Echinochloa spiralis*	−	−	−	+	−	−	−	−	−	−	−	−	+
Th	Eua	*Setaria viridis*	−	−	−	−	−	−	−	−	−	−	−	+	+
H	Eua	*Trifolium repens gigant.*	+	+	+	+−1	+−1	+	+	+	+	+	+	+−1	1
H	Adv	*Medicago sativa*	−	−	−	−	+	+	+	+	+	+	+	+	+
H	Eua	*Trifolium pratense*	−	−	−	−	−	−	−	−	−	−	+	+	+
H	Eua	*Lotus corniculatus*	−	−	−	−	−	−	−	−	−	−	+	+	+
Th	Cos	*Geranium pusillum*	1−2	1−2	+−1	+	+	+−1	+	+	+	+	+	+	+
H	Cos	*Taraxacum officinale*	+	+	+	+	+−1	+−1	+−1	+−1	+	+	+−1	+	1
H-G	Cos	*Convolvulus arvensis*	−	+	+−1	+−1	+	1	1	+	+	1	+	+	+−1
Th	Cos	*Polygonum aviculare*	−	−	+	+	+	+	+	+	+	+	+	+	1
G	Eua	*Cirsium arvense*	−	+	+	+	+	+	+	+	−	−	+−1	+	+

Th	Cos	*Stellaria media*	3–4	1–2	+	+	+	–	–	1	–	–	1	–	+
Th	Cos	*Capsella bursa-pastoris*	+	+	–	+	+	–	–	1	–	–	+–1	+	–
Th	Eua	*Lamium amplexicaule*	+–2	–	–	+	+	–	–	+–1	–	–	+–1	–	+
H	Eua	*Rumex crispus*	+	+	+	+	–	–	–	–	–	–	–	+	+
Th	Cpl	*Fallopia convolvulus*	–	–	+	–	+	+	+	–	–	–	–	–	–
Th	Cpl	*Ranunculus sceleratus*	–	+	+	–	+	–	–	+	–	–	–	–	–
Th	Cos	*Sonchus asper*	–	+	–	–	–	+	+	–	–	–	–	–	+
Th	Adv	*Amaranthus chlorostychys*	–	–	–	+	–	–	+	–	–	+	–	–	–
Th	Eua	*Atriplex tatarica*	–	–	–	–	–	–	–	–	–	–	+	+	+
Th-TH	Eua	*Matricaria inodora*	–	+	–	–	+	–	–	–	–	–	+	–	–
Th	Eu	*Adonis aestivalis*	+	–	–	–	–	–	–	+	–	–	–	–	–
TH	Eua	*Daucus carota*	–	–	–	–	–	–	–	–	–	–	–	+	+
Th	Eua	*Descurainia sophia*	+	–	–	–	–	–	–	+	–	–	–	–	–
Th	M	*Crepis setosa*	–	–	+	–	–	–	–	–	–	–	–	–	+
Th	Cos	*Hibiscus trionum*	–	–	–	–	–	+	–	–	–	+	–	–	–
H	Eua	*Lamium maculatum*	+	–	–	–	–	–	–	–	–	–	+	–	–
Th	Eua	*Lepidium draba*	–	–	–	–	+	–	–	–	–	–	+	–	–
Th	Eua	*Malva neglecta*	–	–	–	+	–	–	–	–	–	–	–	+	–
Th	Eua	*Matricaria recutita*	–	–	–	+	–	–	+	–	–	–	–	–	–
Th	Eua	*Papaver rhoeas*	+	+	–	–	–	–	–	–	–	–	–	–	–
Th	Cos	*Polygonum lapathifolium*	–	–	+	+	–	–	–	–	–	–	–	–	–
Th	Cos	*Sinapis arvensis*	+	+	–	–	–	–	–	–	–	–	–	–	–
Th	Cos	*Sonchus oleraceus*	–	–	–	–	–	–	–	–	–	–	–	+	+
Th	Eua	*Thlaspi arvense*	+	–	–	–	–	–	–	–	–	–	+	–	–
Th	Adv	*Veronica persica*	–	+	–	–	–	–	–	–	–	–	+	–	–
Th	Eua	*Veronica polita*	–	–	–	–	–	–	–	1	–	–	+	–	–

For 4 years prior to the sowing of the grass mixtures the land was occupied by single-species grass stands sown in the following order: *Festuca pratensis*, *Bromus inermis*, *Dactylis glomerata* and *Lotus corniculatus*, which were ploughed out in the autumn of 1976. Sowing in 1977 with the previously listed grass mixtures was unsuccessful.

The alkaline soil of the experimental field is a hydrocarbonate-sulphate solonchak-coated solonetz meadow soil over silty loess clay formed on the detrital cone and alluvial deposits of the Primeval-Maros and Körös rivers, on a degraded lowland loess. This alkaline soil was ameliorated in the autum of 1972 with 200 : 180 : 280 kg/ha NPK fertilizer and 4500 kg/ha $CaCO_3$. In the experimental period in question (1978–1981) basic fertilization with NPK = 70 : 80 : 80 kg/ha was carried out each October and top dressing with N = 45 kg/ha each March, 40 kg/ha supplementary N fertilizer was distributed after the cutting of each growth.

According to Bacsó's regional division the area falls within zone A/4, with 500 mm annual precipitation. The groundwater level is at a depth of 1–2 m, depending on the amount of precipitation and on the waterlevel in the near-irrigation canals. The 700–800 mm water lost due to evapotranspiration, the average 334 mm precipitation (averaged over the last 50 years) during the vegetation period (March–September), the high temperature fluctuations and the frequent droughts make irrigation imperative; 320 mm water was supplied each growth season by sprinkling irrigation on 4 occasions (April–July). The climate diagrams constructed for the experimental period show that 2 years of the 4 year experimental period were rainier and 2 droughtier than the 50-year average (Fig. 2). The 528 mm annual average precipitation characteristic of the area, the 10.8 °C annual mean temperature and the solonetz meadow soil mean that only xerophilous vegetation *(Festucetum pseudovinae, Festucetum rupicolae)* is able to form. For the mesophilous species included in the grass mixtures, and for the associated species which were mostly of mesophilous character optimum development could only be ensured, if there was adequate nutrient and water replacement.

Within the framework of the phytoproduction study a phytocenological survey was made on the grass stands in the 4×100 m² experimental plots before cutting in each of the 4 growth seasons. In this way 52 coenological surveys were made for each grass stand, using the Braun and Blanquet quadrate method and scale. The results are summed up as an economic grouping of the species in Tables 1–4.

Results

(1) In the first 1978 growth of sward sown with grass mixture I *(Festuca arundinaceae* + *Dactylis glomerata* + *Trifolium repens* f. *giganteum)* (Table 1) the percentage cover with populations of the sown species was 20% for *Festuca arundinaceae*, 40% for *Dactylis glomerata* and 1–3% for *Trifolium repens* f. *giganteus*, i.e. their proportions did not reflect the percentage weight ratio of the seed. The number of associated, mainly annual, weeds was 13, of which *Stellaria media*, *Geranium pusillum* and *Lamium amplexicaule* had a joint cover of 40–50%. In the third growth of the year of sowing many perennial and annual associate species appeared in the grass stand, after which the number of species continued to steadily increase. In the 3rd and 4th years of the experiment *Dactylis glomerata*, which among the sown species had the highest viability and made the best use of the N-fertilizer, achieved a stable coverage of 75%; the corresponding figures were 15% for *Festuca arundinaceae* and 1–3% for *Trifolium repens* f. *giganteum*. The low individual number of the latter hardly changed during the four-year period of the experiment; its share in the grass yield was always negligible and it never covered more than 5–7% of the area. This phenomenon can be explained by the cenotic effect of the two highly viable species: *Dactylis glomerata* and *Festuca arundinaceae*.

If the list of species for the first growth of 1978 is compared with that for the last growth of 1981, a value of 0.28 is obtained for Jaccard's similarity index and 0.43 for Sorensen's, which suggests that there were substantial changes in the associate species and an increase in the number of species. As regards the number of species in the successive growths, it was always the smallest in the second growth; this is a function of the ontogeny and regenerative ability of the different species.

In the 4×100 m^2 experimental plots 42 associate species were found over the four years. The number of adventitious constant and subconstant species was 9 (21%), while that of accidental species was 30 (71%); most of the latter were segetal or ruderal weeds. Of the adventitious species found in the grass stand up till the end of 1981, 6 were suitable for feeding purposes; their total cover was 2–3%.

Changes in the species composition of the sown stand are also shown by the ecological and areal spectra of species registered in the first growths of 1978 and 1981.

Ecological spectrum:

1978: Th — 56.25%, H — 43.75%
1981: Th — 44%, H — 40%, H-G — 4%, G — 4%, Th-TH — 8%.

Areal spectrum:

1978: Eua — 56.25%, Cos — 31.25%, Eu — 12.5%.
1981: Eua — 56%, Cos — 24%, Adv — 8%, Cpl — 4%, Eu — 4%, M — 4%.

It can thus be seen that the populations of the sown species had become stable by the 2nd year after sowing, *Dactylis glomerata* assumed a dominant character, and as a result of the natural succession of sown swards many perennial and annual species entered the grass stand, though in low individual numbers, which did not significantly influence either the quantity or the quality of the yield. The fresh crop of the grass stand was 51.2 t/ha and the hay yield 12 t/ha over the average of 4 years, which is equivalent to a medium yield level for intensive swards.

(2) In the first 1978 growth of sward sown with grass mixture II *(Festuca arundinaceae + Dactylis glomerata + Lotus corniculatus)* (Table 2), *Festuca arundinacea* covered 25–50% of the area and *Dactylis glomerata* 25%, *Lotus corniculatus* did not appear until the third growth, with a 0.1–1% cover, i.e. the size of the populations of the sown species did not reflect either the percentage weight ratio of the seed or the production aims. Of the adventitious species appearing in the grass stand, *Stellaria media* had a 15–30% cover and

Table 2

Cenological changes in a sward sown with a mixture of grasses (Festuca arundinacea + Dactylis glomerata + Lotus corniculatus) in 1978–1981

L.f.	Areal	Date of the survey	1978 IV 24	1978 V 30	1978 VII 4	1978 VIII 15	1979 V 10	1979 VI 27	1979 IX 10	1980 IV 29	1980 VI 8	1980 VIII 13	1981 IV 22	1981 VII 10	1981 IX 2
		Total cover, %	85	85	90	90	100	100	100	100	100	100	95	100	100
		Average height of grass, cm	40	50	50	20	80	60	40	55	80	50	25	65	55
		Growths	I	II	III	IV	I	II	III	I	II	III	I	II	III
H	Eua	*Festuca arundinacea*	2–4	2	1–2	1–2	1–2	1–2	2	1–2	1–2	2	2	2	2
H	Eua	*Dactylis glomerata*	2	4	4–5	3–5	4	5	5	5	5	4	4	4–5	4–5
H	Eu	*Lolium perenne*	–	–	1–2	+	+	+	+	+	+	1	+	+	+
Th-TH	M	*Lolium multiflorum*	–	–	+	+	–	1	+	–	–	1	+	+	+
Th	Cos	*Echinochloa crus-galli*	–	–	+	1	–	–	+	–	–	+	+	+	+
H	K	*Bromus inermis*	+	+	+	+	–	–	–	–	–	–	–	+	+
H	Eua	*Festuca pratensis*	–	–	–	–	+	+	+	–	–	–	–	–	–
Th	Adv	*Echinochloa spiralis*	–	–	–	–	–	–	–	–	–	+	–	+	+
Th	Eua	*Bromus mollis*	+	+	–	–	–	–	–	–	–	–	–	–	–
Th	Eua	*Bromus sterilis*	–	–	–	–	+	+	–	–	–	–	–	–	–
Th	Eua	*Hordeum murinum*	–	–	–	–	–	–	–	–	+	+	–	–	–
H	Eua	*Lotus corniculatus*	–	–	+	+	+	+–1	+	+	+	+	+	+–1	+–1
H	Eua	*Trifolium repens gigant.*	–	–	+	1	+	+	+	+	+	+	+	1	1
H	Adv	*Medicago sativa*	–	–	–	+	+	+	+	+	+	+	+	+	+
H	Eua	*Trifolium pratense*	–	–	–	–	+	+	+	+	+	+	+	+	+
H	Cos	*Taraxacum officinale*	+	+	+	+	+–1	+–1	1	1	1	+	1	+–1	+–1
Th	Cos	*Geranium pusillum*	+–1	+	+–1	+	+	+	+	+	+	+	+	+	+
H-G	Cos	*Convolvulus arvensis*	–	+	+	+	+	+–1	+	+	+	+	+	+–1	+–1
G	Eua	*Cirsium arvense*	–	+	+	+	+	+	+	+	+	+	+	+–1	+–1

Th	Cos	*Stellaria media*	2–3	1–2	+	+	+	–	+	1–2	–	–	+–1	–	+
Th	Cos	*Capsella bursa-pastoris*	+–1	+	–	+	+	–	–	+–1	–	+	+–1	–	–
Th	Eua	*Lamium amplexicaule*	1	+	–	+	+	–	–	+	+	–	+	–	–
H	Eua	*Rumex crispus*	+	+	+	+	–	–	–	–	–	–	+	+	+
Th-TH	Eua	*Matricaria inodora*	–	+	–	–	+	–	–	–	–	+	+	+	+
Th	Cos	*Polygonum aviculare*	–	–	–	–	+	+	–	–	+	–	+	+–1	+–1
Th	Cos	*Chenopodium album*	–	–	–	–	+	+	+	–	+	–	–	+	+
Th	Adv	*Amaranthus chlorostachys*	–	–	+	+	–	–	+	–	–	+	–	–	–
Th	Eua	*Veronica hederifolia*	+	+	–	–	–	–	–	+	–	–	+	–	–
Th	Eua	*Chenopodium urbicum*	–	–	–	–	–	–	–	–	–	+	–	+	+
Th	M	*Chenopodium vulvaria*	–	–	–	–	–	+	+	–	–	–	+	–	–
Th	Cos	*Hibiscus trionum*	–	–	–	–	–	–	+	–	–	+	–	–	+
Th	Eua	*Malva neglecta*	–	–	–	–	+	+	+	–	–	–	–	–	–
Th	Eua	*Papaver rhoeas*	+	+	+	–	–	–	–	–	–	–	–	–	–
Th	Cpl	*Ranunculus sceleratus*	–	–	–	+	+	–	–	–	–	–	+	–	–
Th	Cos	*Sonchus oleraceus*	–	–	–	+	–	+	–	–	–	+	–	–	–
Th	Adv	*Veronica persica*	–	–	–	–	+	+	–	–	–	–	+	–	–
Th	Eu	*Adonis aestivalis*	+	–	–	–	+	–	–	–	–	–	–	–	–
Th	Cos	*Amaranthus retroflexus*	–	–	–	–	–	–	–	–	–	+	–	–	+
Th	Eua	*Descurainia sophia*	+	–	–	–	+	–	–	–	–	–	–	–	–
Th	Cpl	*Fallopia convolvulus*	–	–	+	–	–	+	–	–	–	–	–	–	–
Th	Eua	*Galium aparine*	–	–	–	–	–	–	–	+	+	–	–	–	–
H	Eua	*Lamium maculatum*	+	+	–	–	–	–	–	–	–	–	–	–	–
Th	Cos	*Polygonum lapathifolium*	–	–	+	+	–	–	–	–	–	–	–	–	–
H	Eua	*Rorippa sylvestris kerneri*	–	–	–	–	–	–	–	–	+	+	–	–	–
H	Eua	*Stellaria graminea*	–	–	–	–	–	–	–	+	+	–	–	–	–
Th	Eua	*Thlaspi arvense*	+	–	–	–	+	–	–	–	–	–	–	–	–
Th	Eua	*Veronica polita*	–	–	–	–	–	–	–	+–1	+	–	–	–	–

Capsella bursa-pastoris, *Geranium pusillum* and *Lamium amplexicaule* a joint cover of 0.1–5%, while the other weed species had a 1–2% share in the total cover. In the year of sowing before the grass stand became closed many perennial grasses and papilionaceous species took root and the number of weed species increased, but the individual numbers remained negligible.

From the second year of the experiment the proportions of the sown species became relatively constant, with a 15% cover of *Festuca arundinacea*, a 75% cover of *Dactylis glomerata* and a 1–2% cover of *Lotus corniculatus*. Besides the species sown, 20 perennial and one annual species were found, of which *Trifolium repens* f. *giganteum*, *Taraxacum officinale*, *Convolvulus arvensis*, *Cirsium arvense* and *Polygonum aviculare* had a 1–2% cover. The total cover of the other mainly weed species was estimated to be 2–3%; consequently they had little influence on either the quantity or the quality of the grass crop, due to the coenotic effect of the two prevalent grass species sown.

A comparison of the list of species registered in the first growth of 1978 to that of the last growth in 1981 on the basis of the Jaccard (0.21) and Sorensen (0.35) similarity indices reveals that the adventitious species found in the stand not only increased in number during the experimental period, but some of them were particularly annual species, replaced by others.

In the course of four years 44 adventitious species were found in the 4×100 m^2 experimental plots. Ten of them (23%) were constant or subconstant, and 26 (59%) were accidental species, most of which were segetal or ruderal weeds. Of the species entering the grass stand up till the end of 1981, 8 were valuable from the point of view of animal feeding; their joint cover was 4–5%.

Changes in the species composition of the sown sward are shown by the ecological and areal spectra of the species registered in the first growths of 1978 and 1981.

Ecological spectrum:

1978: Th — 62.5%, H — 37.5%.
1981: Th — 43.48%, H — 39.13%, Th-TH — 8.69%,
H-G — 4.35%, G — 4.35%.

Areal spectrum:

1978: Eua — 62.5%, Cos — 25%, K — 6.25%, Eu — 6.25%.
1981: Eua — 43.48%, Cos — 20.43%, M — 8.69%, Adv — 8.69%,
Cpl — 4.35%, Eu — 4.35%.

It can thus be seen that the populations of the sown species had become constant by the last growths in the year of sowing; *Dactylis glomerata* assumed a dominant character, while *Lotus corniculatus* gradually increased its stand,

from an initial cover of 0.1% to 1–3% by the end of the 4th year, though not to the extent required by the cultivation aims. The negligible populations of the large number of adventitious perennial and annual (mainly weed) species did not substantially influence the size of the grass yield. The grass crop on this sward (50.9 t/ha fresh crop and 11.9 t/ha hay over the average of 4 years) was equivalent to a medium yield level for intensive grass stands.

(3) In the first 1978 growth of sward sown with grass mixture III *(Bromus inermis* + *Festuca pratensis* + *Trifolium repens* f. *giganteum)* the extent of cover by populations of the sown species was 25–40% for *Festuca pratensis*, 25–60% for *Bromus inermis* and 1–5% for *Trifolium repens* f. *giganteum*, i.e. proportions did not reflect the percentage weight ratio of the seed. The number of adventitious, mainly annual weed species was 13, of which *Capsella bursa-pastoris* and *Stellaria media* had a 5–15% share in the total cover. In the last two growths of 1978 many perennial and annual adventitious species appeared in the grass stand and the number of species increased from year to year. In the 2nd and 3rd years, of the experiment the coverage by *Festuca pratensis*, *Bromus inermis* and *Trifolium repens* f. *giganteum* became stable at 70, 20, and 2–3%, respectively, and by the end of the 4th year the two grass species showed a 40% cover each. In the meantime the number of adventitious species had doubled, but their joint cover remained below 10%. Of the papilionaceous species entering the sward, *Lotus corniculatus* increased its individual numbers through semination from year to year and its share in the grass stand grew at the same rate as that of *Trifolium repens* f. *giganteum*. As a result of the natural succession of sown grasses, the presence of *Taraxacum officinale*, *Cirsium arvense* and *Convolvulus arvensis* with a higher A–D indicates the beginning of a structural degradation of the sown grass stand.

When comparing the list of species in the first growth of 1978 to that in the last growth of 1981 on the basis of the Jaccard (0.25) and Sorensen (0.41) similarity indices it is found that the adventitious species entering the sown grass stand increased in number during the experimental period, and some of the annual weed species were replaced by others. The number of species was always smallest in the second growths in this case, too.

During the experiment 55 adventitious species were found in the 4×100 m^2 plots, of which 15 (27%) were constant or subconstant and 36 (65%) were accidental species. The extensive weed growth can be explained by the higher associability of the sown species. Of the adventitious species entering the grass standing till the end of 1981, 10 were valuable as fodder crops; their total cover was 10–15%.

Changes in the species composition of the sown sward are also shown by the ecological and areal spectra of species registered in the first growths of 1978 and 1981.

Table 3

Cenological changes in a sward sown with a mixture of grasses (Bromus inermis + Festuca pratensis + Trifolium repens f. giganteum) in 1978–1981

L.f.	Areal	Date of the survey	1978				1979			1980			1981		
			IV 24	V 30	VII 4	VIII 15	V 10	VI 27	IX 10	IV 29	VI 18	VIII 13	IV 22	VII 10	IX 2
		Total cover, %	83	98	100	95	100	100	100	100	100	100	100	95	100
		Average height of grass, cm	30	60	28	20	70	50	35	40	80	30	25	60	45
		Growths	I	II	III	IV	I	II	III	I	II	III	I	II	III
H	K	*Bromus inermis*	2–4	2	3–4	2	1–2	1–2	2–3	1–2	1–2	2	2	3	3
H	Eua	*Festuca pratensis*	2–3	4	2–5	4	4–5	5	4	5	5	4	5	3	3
H	Eua	*Dactylis glomerata*	–	+	+–1	+	+	+	+	+	+	+	+	+	+
H	Eu	*Lolium perenne*	–	+	+	+	+	+	+–1	+	+	1	+–1	1	+–2
Th-TH	M	*Lolium multiflorum*	–	+	+	+–1	+	+	+–1	+	+	2	+–1	+–1	+–1
H	Cpl	*Poa pratensis*	–	+	+	+	+	+	+	–	–	–	+–1	+–1	1
G	Eua	*Agropyron repens*	–	–	–	+	–	–	–	–	+	+	+	+	+
Th	Cos	*Echinochloa crus-galli*	–	–	–	+	+	–	+	–	–	+	–	+	+
Th	Adv	*Echinochloa spiralis*	–	–	–	+	+	–	+	–	–	+	–	+	+
Th	Eua	*Bromus sterilis*	–	+	–	–	+	–	–	–	+	–	–	–	–
Th	Eua	*Hordeum murinum*	–	+	+	–	+	–	–	–	–	–	–	–	–
H	Eua	*Festuca arundinacea*	–	–	–	–	–	–	–	–	–	–	+	+	+
H	Eua	*Trifolium repens gigant.*	+–1	1	+–1	+–1	+–1	+–1	+–1	+	+	1	+–1	1	1–2
H	Eua	*Lotus corniculatus*	–	–	–	+	+–1	+–1	+–1	+	+	1	+–1	1	+–2
H	Eua	*Trifolium pratense*	–	–	–	–	+	+	+	+	+	+	+	+	+
H	Adv	*Medicago sativa*	–	–	–	+	–	–	–	–	–	–	+	+	+
H	Eua	*Lathyrus tuberosus*	–	+	+	–	+–1	–	–	–	–	–	–	–	–
Th-TH	Eua	*Melilotus officinalis*	–	+	+	–	–	–	–	–	–	–	–	–	–
H	Cos	*Taraxacum officinale*	+	+	+	+	+–1	+–1	1	1	1	1	1–2	1	+–1
Th	Cos	*Geranium pusillum*	+	+–1	+	+	+–1	+	+	1	+	1	+–	+	+1
G	Eua	*Cirsium arvense*	+	+	+	+	+	+	+	+	+	+	+	+	+–1
H-G	Cos	*Convolvulus arvensis*	–	+	+	+–1	+	+	1	+	+	+	+	1	+–2
H	Eua	*Rumex crispus*	–	+	+	+	+	+	+	+	+	+	+	+	+
Th	Cos	*Capsella bursa-pastoris*	1–2	+	–	+	+	+	–	1	+	+	1	–	–

Th	Cos	*Stellaria media*	1—2	2	+	+	+	—	+	1	—	—	1	—	+
Th	Cos	*Polygonum lapathifolium*	+	—	—	—	+	—	+	+	—	+	+	+	+
Th	Cos	*Polygonum aviculare*	—	—	+	—	+	—	+	+	—	—	+	+	+—1
Th	Eua	*Lamium amplexicaule*	+—1	+	—	—	+	—	—	1	+	—	+—1	—	+
Th	Cos	*Chenopodium album*	—	—	—	—	+	—	—	—	+	—	—	+	+
Th	Cos	*Hibiscus trionum*	—	—	+	—	—	—	+	—	—	+	—	—	+
Th	Eua	*Malva neglecta*	—	—	—	+	+	—	+	—	—	+	—	—	—
Th	Eua	*Matricaria recutita*	—	—	+	+	—	—	—	—	+	—	+	—	—
Th	Cos	*Sonchus asper*	—	—	—	—	+	—	+	—	—	—	—	+	+
Th	Cos	*Sonchus oleraceus*	—	—	—	—	+	—	+	—	—	+	+	—	—
Th	Eu	*Adonis aestivalis*	—	—	—	—	+	—	—	+	—	—	+	—	—
Th	M	*Crepis setosa*	—	—	—	+	—	—	+	—	—	+	—	—	—
TH	Eua	*Daucus carota*	—	—	—	—	—	—	—	—	—	+	—	+	+
Th	Eua	*Descurainia sophia*	+	—	—	—	—	—	—	+	—	—	+	—	—
Th	Cpl	*Fallopia convolvulus*	—	—	—	—	+	+	+	—	—	—	—	—	—
Th	Eua	*Lepidium draba*	—	—	—	—	+	—	—	+	—	—	+	—	—
Th	Eua	*Papaver rhoeas*	+	+	—	—	+	—	—	—	—	—	—	—	—
Th	Cos	*Sinapis arvensis*	—	+	+	+	—	—	—	—	—	—	—	—	—
Th	Cos	*Amaranthus retroflexus*	—	—	—	—	—	—	+	—	—	+	—	—	—
Th	Eua	*Atriplex tatarica*	—	—	—	—	—	—	—	—	—	—	—	+	+
Th	Eua	*Chenopodium urbicum*	—	—	—	—	—	—	+	—	—	+	—	—	—
Th	M	*Chenopodium vulvaria*	—	—	—	—	—	—	+	—	—	+	—	—	—
TH	Eua	*Conium maculatum*	—	+	+	—	—	—	—	—	—	—	—	—	—
H	Eua	*Cichorium intybus*	—	—	—	—	—	+	+	—	—	—	—	—	—
H	Eua	*Lamium maculatum*	+	—	—	—	—	—	—	+	—	—	—	—	—
Th-TH	Eua	*Matricaria inodora*	—	+	—	—	+	—	—	—	—	—	—	—	—
Th	Eua	*Melandrium album*	—	—	—	—	+	+	—	—	—	—	—	—	—
H	Eua	*Plantago major*	—	—	+	+	—	—	—	—	—	—	—	—	—
Th	Cpl	*Ranunculus sceleratus*	—	—	—	—	+	—	—	+	—	—	—	—	—
H	Eua	*Rorippa sylvestris kerneri*	+	—	—	—	+	—	—	—	—	—	—	—	—
H	Eua	*Stellaria graminea*	—	—	—	—	—	—	—	+	—	—	+	—	—
Th	Eua	*Thlaspi arvense*	+	—	—	—	+	—	—	—	—	—	—	—	—
Th	Eua	*Veronica hederifolia*	+	—	—	—	+	—	—	—	—	—	—	—	—
Th	Eua	*Veronica polita*	—	—	—	—	—	—	—	+	—	—	+	—	—

Table 4

Cenological changes in a sward sown with a mixture of grasses (Bromus inermis + Festuca pratensis + Lotus corniculatus) in 1978–1981

L.f.	Areal	Date of the survey	1978 IV 24	1978 V 30	1978 VII 4	1978 VIII 15	1979 V 10	1979 VI 27	1979 IX 10	1980 IV 29	1980 VI 18	1980 VIII 13	1981 IV 22	1981 VII 10	1981 IX 2
		Total cover, %	60	75	85	85	90	98	100	100	100	100	100	100	100
		Average height of grass, cm	30	50	45	25	50	40	30	45	70	35	20	50	45
		Growths	I	II	III	IV	I	II	III	I	II	III	I	II	III
H	K	*Bromus inermis*	2	2	2	2	1	2	3	3	2	2	2	1–3	2–3
H	Eua	*Festuca pratensis*	2–3	3–4	4	4	4–5	4–5	3–4	2–4	4	4	4	4	3–4
H	Eu	*Lolium perenne*	–	+	1	+	+	+	+	+	1	1	1	1	1
Th-TH	M	*Lolium multiflorum*	–	+	1	+	+	+	+	+	2	2	1	1	1
H	Cpl	*Poa pratensis*	–	+	+	+	+	+	+	1	+	+	1	1	1
H	Eua	*Festuca arundinacea*	–	–	+	+	+	+	+	+	+	+	+	+	+
H	Eua	*Dactylis glomerata*	–	–	–	+	1	1	1	1	1	1	+	+	+
Th	Cos	*Echinochloa crus-galli*	–	–	–	+	+	–	+	–	+	1	–	+	+
H	Eua	*Alopecurus pratensis*	–	–	–	–	–	–	–	–	–	–	+	+	+
Th	Eua	*Bromus sterilis*	–	+	+	–	–	–	–	–	–	–	–	–	–
Th	Adv	*Echinochloa spiralis*	–	–	–	+	–	–	–	–	–	+	–	–	–
Th	Eua	*Hordeum murinum*	–	+	–	–	+	–	–	–	–	–	–	–	–
Th	Eua	*Setaria viridis*	–	–	–	+	–	–	–	–	–	+	–	–	–
H	Eua	*Trifolium repens gigant.*	1	+	+	1	1	+	1	1	1	2	1	1	2
H	Adv	*Medicago sativa*	+	+	+	+	+	+	+	+	+	+	+	+	+
H	Eua	*Trifolium pratense*	–	–	–	–	+	+	+	+	+	+	+	+	+
H	Eua	*Lotus corniculatus*	–	–	–	–	–	–	+	+	1	+	1	1	1
H	Cos	*Taraxacum officinale*	+	+	+	+	1–2	+–1	+–1	1	1	1	+–2	+–1	+–1
Th	Cos	*Geranium pusillum*	1	1	+–1	+	+	+	+	+–1	1	+	+–1	+	1
G	Eua	*Cirsium arvense*	+	+	+	+	+	+	+	+	+	+	+	+	+
H	Eua	*Rumex crispus*	+	+	+	+	+	+	+	+	+	+	+	+	+
H-G	Cos	*Convolvulus arvensis*	–	–	+	+	+	+–1	+–1	+	+	+	+	1	1–2
Th	Cos	*Polygonum aviculare*	–	–	–	+	+	+–1	+–1	+	–	+	–	+	+–1

Th	Cos	*Polygonum lapathifolium*	+	−	−	+	−	−	+	−	+	−	+	+	+
Th	Cos	*Capsella bursa-pastoris*	+	+	−	−	+−1	−	−	1	+	−	1	−	−
Th	Eua	*Lamium amplexicaule*	−	−	−	−	+	−	−	+−1	−	+	+−2	+	1
Th	Cos	*Sonchus asper*	−	−	−	+	−	+	+	−	−	+	−	+	+
Th	Cos	*Sonchus oleraceus*	−	−	−	+	−	+	−	−	+	+	+	+	−
Th	Cos	*Amaranthus retroflexus*	−	−	−	+	−	−	−	−	+	+	−	+	+
Th	Cos	*Stellaria media*	+−2	1−2	+	−	+	−	+	1	−	+	1−2	−	+
Th	Eua	*Matricaria recitita*	−	−	−	−	−	+	−	+	−	+	−	+	+
Th	Eua	*Atriplex tatarica*	−	−	+	+	−	−	−	−	−	−	−	+	+
TH	Eua	*Daucus carota*	−	−	−	−	−	−	−	−	+	+	−	+	+
Th	Cos	*Hibiscus trionum*	−	−	+	−	−	−	+	−	−	+	−	−	+
Th	Cpl	*Fallopia convolvulus*	−	−	−	−	+	+	−	−	−	+	−	−	−
Th-TH	Eua	*Matricaria inodora*	−	+	−	+	+	−	−	−	−	−	−	−	−
Th	Eua	*Veronica polita*	−	−	−	−	−	−	−	1	+	+	−	−	−
Th	Eu	*Adonis aestivalis*	+	−	−	−	−	−	−	+	−	−	−	−	−
Th	Adv	*Amaranthus chlorostachys*	−	−	−	−	−	−	+	+	−	−	−	−	−
Th	Cos	*Chenopodium album*	−	−	−	−	−	+	+	−	−	−	−	−	−
Th	Eua	*Chenopodium urbicum*	−	−	−	−	−	+	+	−	−	−	−	−	−
Th	M	*Chenopodium vulvaria*	−	−	−	−	−	+	+	−	−	−	−	−	−
Th	M	*Crepis setosa*	−	−	−	−	−	+	−	−	+	−	−	−	−
Th	Eua	*Descurainia sophia*	+	−	−	−	+	−	−	−	−	−	−	−	−
Th	Eua	*Lamium purpureum*	−	−	−	−	−	−	−	+	+	−	−	−	−
H	Eua	*Lamium maculatum*	+	−	−	−	+	−	−	−	−	−	−	−	−
Th	Eua	*Malva neglecta*	−	−	−	−	−	−	−	−	+	+	−	−	−
Th	Eua	*Papaver rhoeas*	−	+	+	−	−	−	−	−	−	−	−	−	−
H	Eua	*Rorippa sylvestris kerneri*	−	−	−	+	+	−	−	−	−	−	−	−	−
Th	Eua	*Sinapis arvensis*	−	−	−	+	+	−	−	−	−	−	−	−	−
Th	Eua	*Lepidium draba*	+	+	−	−	−	−	−	−	−	−	−	−	−
Th	Eua	*Thlapsi arvense*	+	−	−	−	+	−	−	−	−	−	−	−	−
Th	Eua	*Thlapsi ruderale*	−	−	−	−	−	−	−	−	+	+	−	−	−
Th	Adv	*Veronica persica*	−	−	−	−	−	−	−	−	−	−	−	+	+

Ecological spectrum:

1978: Th — 56.25%, H — 37.5%, G — 6.25%
1981: H — 44.83%, Th — 41.38%, G — 6.9%, H-G — 3.45%, Th-TH — 3.45%.

Areal spectrum:

1978: Eua — 62.5%, Cos — 31.25%, K — 6.25%.
1981: Eua — 55.17%, Cos — 24.14%, Eu — 6.9%, Cpl — 3.45%, K — 3.45%, M — 3.45%, Adv — 3.45%

Thus for 3 years from the beginning of the experimental *Festuca pratensis* was dominant and *Bromus inermis* had a subdominant character, while *Trifolium repens* f. *giganteum* steadily increased its population from 1% to 3–4%, as did the adventitious species *Lotus corniculatus*. The adventitious perennial and annual species found in the grass stand, which were mostly weeds, had little influence on the grass yield, which with a 4-year average of 50.4 t/ha fresh crop and 11.68 t/ha hay yield reached the medium yield level for intensive grasslands.

In the first 1978 growth of sward sown with grass mixture IV *(Bromus inermis + Festuca pratensis + Lotus corniculatus)* the populations of the two grass species sown both had a cover of 25%, while *Lotus corniculatus* did not emerge. Of the adventitious species, *Trifolium repens* f. *giganteum*, *Stellaria media* and *Geranium pusillum* covered 5–8% of the area. In the 3rd and 4th growth the ratio between the two grass species sown became constant at a cover of 60 and 30%, respectively. *Lotus corniculatus* appeared in the grass stand only at the end of the second year; its share increased at the same rate as that of the adventitious species *Trifolium repens* f. *giganteum*, from 1 to 8% of the total cover. In the 4th year of the experiment, as a result of the natural succession of sown grass stands the main species present were *Stellaria media*, *Convolvulus arvensis*, *Polygonum aviculare*, *Taraxacum officinale* and *Galium pusillum*, with a total cover of about 10–15%, which at the same time suggests the beginning of a structural degradation of the sward.

When comparing the list of species in the first growth of 1978 to that in the last growth of 1981 on the basis of the Jaccard (0.29) and Sorensen (0.44) similarity indices it is found that the adventitious species in the grass stand gradually increased in number during the experiment, some of the species being replaced by others.

During the 4 years of the experiment 51 adventitious species were found in the 4×100 m^2 plots; 14 of them were constant or subconstant (27%) and 30 (59%) were accidental species. Of the adventitious species found in the sward, 9 (18%) were important as fodder crops; their total cover in the last growth of the year 1981 was 18%.

Changes in the species composition of the sown grass stand are also shown by the ecological and areal spectra of species found in the first growths of 1978 and 1981.

Ecological spectrum:

1978: Th — 50%, H — 3.75%, G — 6.25%.
1981: H — 59.1%, Th — 27.2%, G — 4.54%, H-G — 4.54%, Th-TH — 4.54%.

Areal spectrum:

1978: Eua — 50%, Cos — 31.25%, Eu — 6.25%, K — 6.25%, Adv — 6.25%.
1981: Eua — 45.45%, Cos — 31.82%, Cpl — 4.55%, Eu — 4.55%, K — 4.55%, M — 4.55%, Adv — 4.55%.

It can thus be seen that from the very beginning *Festuca pratensis* became dominant with a cover of 60–70%, while *Bromus inermis*, with a 15–25% share, remained subdominant. The delayed appearance and negligible share in the grass stand of *Lotus corniculatus* was not in accordance with the cultivation aims. The yield of the grass stand (51 t/ha fresh crop and 11.9 t/ha hay over the average of 4 years) reached the medium yield level for intensive grasslands.

Summary

In most swards sown with different grass mixtures the proportions of the sown species had stabilized by the last growths in the year of sowing. In the case of grass mixtures I and II, *Dactylis glomerata* assumed a dominant character with a 75% cover, while for grass mixtures III and IV, *Festuca pratensis* became dominant with a cover of 60–70%. The papilionaceous species *(Trifolium repens* f. *giganteum* and *Lotus corniculatus)* did not reach a proportion corresponding to the cultivation aims (10%) in any of the grass mixtures; although their cover increased from year to year, it reached barely 3–5% in the last year of the experiment. This phenomenon can be explained by the peculiar effect of grasses on phytocoenosis and the influence of a high rate of N-fertilization.

The adventitious species found in the sown grass stand are not specific for the stand. Most of them either emerged from the seeds of segetal weed species left in the soil or were introduced from the neighbouring natural or sown swards. Species occurring in high individual numbers, such as *Stellaria media*, *Lamium amplexicaule* and *Geranium pusillum*, produce seed even before the first growth is cut; in most cases they are absent from the second growth, but in the third growth they are again represented in large individual numbers as small seedlings. The high individual numbers of these species do not influence the quantity and quality of the grass yield, because their height hardly reaches the level of cutting. The large number of other weed species had a total cover of less than 10% throughout the period of the experiment, so their role in the grass yield was negligible.

Surveys made on the basis of either Jaccard's or Sorensen's similarity index showed the natural succession or floristical degradation of sown swards, as did the ecological and areal spectra of the grass stands.

The amounts of nutrient (NPK = 235 : 80 : 80 kg/ha) and irrigation water (320 mm) supplied regularly during the growth season not only lessened the loss in grass yield in droughty years (1979, 1981), but also ensured a medium grass yield characteristic of intensive swards, i.e. an average 51 t/ha fresh crop and 12 t/ha hay.

On the basis of the phytocenological results obtained, it is recommended that the share of papilionaceous components in swards sown with the grass mixtures in question should be enlarged partly by using a larger quantity of seed, and partly by oversowing or adequate fertilization, because the component species of the grass mixtures included in the experiment are suitable under the given soil, climatic and cultivation conditions for the development of long-lasting, high-yielding grass stands for use as hayfields.

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EFFECT OF DIFFERENT LEVELS OF SOIL MOISTURE AND LIME AND MANGANESE APPLICATION ON THE GROWTH AND MANGANESE, IRON NUTRITION OF RICE IN AN ACID ALFISOL OF HIMACHAL PRADESH, INDIA

T. S. VERMA and B. R. TRIPATHI

DEPARTMENT OF SOIL SCIENCE AND WATER MANAGEMENT,
HIMACHAL PRADESH AGRICULTURAL UNIVERSITY, PALAMPUR, INDIA

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A green house experiment with rice as a test crop was conducted with two levels each of moisture and lime and three levels of manganese to investigate the effects of these treatments on growth, and manganese, iron nutrition of rice. The submergence, either without lime or without manganese application, reduced the grain and straw yield due to respective increase and decrease in iron and manganese contents. Yet, with either lime or manganese application, it increased them significantly, mainly due to the decreased iron content. While the application of lime under saturation did not affect the grain and straw yield, its application increased them significantly under submergence and irrespective of manganese application, mainly due to the decreased iron content and increased manganese content. The application of manganese either under submergence or with lime increased the grain and straw yield due to respective increase and decrease in manganese and iron content; but its application either under saturation or without liming did not affect them significantly. The application of lime and manganese together were proved quite beneficial for increasing the rice yield in the acid Alfisol of Himachal Pradesh.

Keywords: *Oryza sativa* L., growth, Mn-nutrition, Fe-nutrition

Introduction

In Himachal Pradesh, rice is generally grown on acidic soils under submerged conditions, and bronzing which was stated to be due to excess iron in rice plants and soils has been reported to cause substantial decrease in rice yield (Verma and Tripathi 1980). The liming of soils has been reported in general as a remedial measure for controlling the bronzing disease in rice (Ponnamperuma 1968, Takijima and Kanganayagam 1978). The application of manganese can also possibly alleviate bronzing disease due to its opposition with iron. However, we do not have any information concerning the possible effects of lime and manganese on growth, and manganese, iron nutrition of rice. Therefore, the purpose of the present study was to investigate the effects of lime and manganese application on growth in different levels of soil moisture and manganese, iron nutrition of rice in an acid Alfisol of Himachal Pradesh.

Material and methods

Clayey thermic typic hapludalfs was the test soil. This soil had pH, 5.2; organic matter, 1.21%; CEC, 14.5 m.e./100 g soil; silty clay loam in texture and contained 168.8, 4.5 and 348.8 ppm available N, P and K respectively. The respective amounts of DTPA extractable Fe, Mn, Cu and Zn in this soil were 18.8, 12.5, 8.35 and 8.62 ppm.

The soil, after being obtained from the field, was air dried, crushed and thoroughly homogenized. Two lots were separated and to one of them lime was applied and thoroughly mixed at the rate of 3 ton/ha in the form of $CaCO_3$. The limed soil was moistened to field capacity and allowed to remain so for fifteen days. This soil was again air dried and mixed. Five kg of limed (L_1) and unlimed (L_0) soil was put in each enamelled pot and basal doses of N, P and K were applied at the rate of 75, 50 and 50 ppm. The manganese in solution form of $MnSO_4 \cdot 3\,H_2O$ was applied at the rate of zero ppm Mn (M_0), 50 ppm Mn (M_1) and 100 ppm (M_2). All combinations of lime moisture and manganese were tested, for a total of twelve treatments, and there were three replications for each treatment. The soil in each pot was puddled manually by the addition of deionized water and seedlings of rice 20 days old (*Oryza sativa* L., var. Chana-988) were transplanted at the rate of five seedlings per pot and two seedlings per hill. The plants were allowed to grow to maturity under two moisture regimes, saturation (W_1) and submergence (W_2), by the addition of deionized water from time to time. The level of water under submergence was maintained at 4 cm above the soil surface throughout the experiment while, under saturation treatment, water was applied to saturate the soil only when cracks started to appear in its surface. An additional 25 ppm N was applied at 45 days after transplanting.

The aboveground portion of one plant was taken out of each pot at the maximum tillering (S_1) and flowering (S_2) stages of rice growth. The remaining three plants were harvested at maturity, the grain and straw were separated. The straw yield was represented as S_3, and grain yield was represented separately. The plant samples from each stage were first washed with deionized water and then with 0.01 N HCl, followed by five washings with deionized water. They were dried in an oven at 60 °C to a constant weight. After this, they were ground in a multimixer with glass container and steel blade. After they were digested with diacid mixture, manganese and iron were determined in the digest with an atomic absorption spectrophotometer.

Results and discussion

Effect of moisture, lime and manganese levels

A study of Tables 1 and 2 indicates that submergence over saturation increased the dry matter yield significantly at maximum tillering and flowering, and straw and grain at harvest. Similarly, it also increased the iron content significantly at all stages of growth, but reduced their content of manganese. Similar results have also been reported by Gangwar and Mann (1972). The workers at Irri (1963) have also reported a significant decrease in manganese content in an acid soil by flooding, although in the soil solution there was a large increase in manganese content.

While the liming did not affect the dry matter yield at maximum tillering and flowering, it increased the grain and straw yields significantly at harvest and decreased the manganese and iron contents significantly from maximum tillering until harvest. The application of manganese, although it increased the dry matter yield significantly at maximum tillering, affected neither dry matter, straw nor grain yield at later stages of growth. However, the manganese content in rice increased upon its application from initial

stages until harvest, while the reverse was true for the iron content. The significant and beneficial effect might have resulted only at later stages of lime application due to more complete reaction of lime with the soil over the course of time.

Interaction effect of moisture and lime

A study of Table 1 shows that moisture and lime interaction were found insignificant at any stage of rice growth on manganese content; but this interaction was observed to be significant at all stages of growth on iron content, and only at later stages of growth on straw and grain yield. The submergence with or without liming did not affect the dry matter yield at early stages of growth; but, at harvest, it decreased the grain and straw yield significantly without liming, and increased them significantly with liming. The manganese content in rice plants was reduced significantly due to submergence irrespective of lime application. Contrary to this, the content of iron was greatly increased upon submergence both with or without liming, but the extent of increase was higher when lime applications were omitted. The application of lime, while it did not affect the straw and grain yield significantly under saturation, increased them significantly under submergence. Lime was also observed to be responsible for decreasing iron content in rice plants under both soil moisture regimes, with higher relative decrease under submergence in comparison to saturation.

The effect of lime observed in this investigation accorded with the findings of Nhung and Ponnamperuma (1966) who reported that lime was of value to increase the rice yield only when applied under flooded rather than under moist conditions. Bronzing was reported in these soils as an alarming problem for rice (Verma and Tripathi 1980) and recently 680 ppm iron in rice plants at flowering was observed to be a sufficient concentration of iron to cause bronzing disease (Verma and Tripathi 1981). Therefore, the main effect of lime on yield under submergence in the present study was due mainly to the iron concentration decreased below this critical level. Similar results of lime on rice yield have also been reported by Mukhopadhya et al. (1967), and Giordano and Mortvedt (1972). This also explained the decrease in rice yield under submergence without lime application, where the iron concentration was generally more than 800 ppm.

Interaction effect of moisture and manganese

Similar to moisture and lime interaction, the moisture and manganese interaction was found significant only at later stages of growth on yield and at all stages on iron content (Table 2). Conversely, the interaction was not

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Table 1

Interaction effect of moisture × lime on yield and manganese, iron contents in rice at different stages of growth

	Yield, g/pot				Mn content, %				Fe content, ppm			
	S_1	S_2	S_3	Grain	S_1	S_2	S_3	Grain	S_1	S_2	S_3	Grain
W_1	3.37	7.94	13.95	6.10	0.13	0.11	0.08	0.04	468.51	424.25	245.83	180.81
W_2	3.94	8.29	14.93	6.80	0.10	0.09	0.05	0.03	724.16	745.75	520.83	227.08
L_0	3.53	8.20	13.97	5.47	0.13	0.11	0.07	0.04	650.16	636.00	429.16	216.25
L_1	3.77	8.02	14.82	7.42	0.10	0.09	0.06	0.03	542.50	534.08	337.50	191.25
W_1L_0	3.44	8.01	15.18	5.95	0.15	0.12	0.09	0.06	495.00	461.50	265.00	198.33
W_1L_1	3.30	7.87	12.72	6.25	0.12	0.10	0.07	0.03	442.00	387.00	226.66	162.50
W_2L_0	3.63	8.40	12.77	5.00	0.13	0.10	0.06	0.04	808.00	810.33	593.33	234.16
W_2L_1	4.25	8.12	16.89	8.60	0.09	0.07	0.05	0.03	643.00	675.16	448.33	220.00
					C.D. at 5% level of significance							
For moisture levels	0.32	0.30	0.64	0.62	0.0047	0.0033	0.0042	N.S.	13.90	6.51	5.37	3.53
For lime levels	N.S.	N.S.	0.64	0.62	0.0047	0.0033	0.0042	0.0045	13.90	6.51	5.37	3.53
For W × L interaction	N.S.	N.S.	1.02	0.90	N.S.	N.S.	N.S.	N.S.	19.66	9.20	7.59	4.99

Table 2

Interaction effect of moisture × manganese on yield and manganese, iron contents in rice at different stages of growth

	Yield, g/pot				Mn content, %				Fe content, ppm			
	S_1	S_2	S_3	Grain	S_1	S_2	S_3	Grain	S_1	S_2	S_3	Grain
M_0	3.29	7.65	14.36	6.10	0.09	0.07	0.05	0.03	640.37	625.25	408.75	220.62
M_1	3.45	8.06	14.90	6.68	0.11	0.10	0.06	0.04	593.25	587.00	386.25	211.25
M_2	4.23	8.62	14.05	6.27	6.14	0.12	0.08	0.04	555.37	542.75	355.00	179.27
W_1M_0	2.86	7.66	14.78	6.37	0.11	0.08	0.05	0.03	488.25	444.00	260.00	190.00
W_1M_1	3.27	7.67	14.24	6.35	0.13	0.11	0.06	0.03	466.75	431.75	245.00	183.75
W_1M_2	4.00	8.49	13.82	5.30	0.15	0.13	0.10	0.04	450.50	397.00	232.50	167.50
W_2M_0	3.73	7.65	13.94	5.80	0.08	0.06	0.04	0.03	792.50	806.50	557.50	251.25
W_2M_1	3.63	8.46	15.56	6.96	0.11	0.08	0.05	0.03	719.75	742.25	527.50	238.75
W_2M_2	4.47	8.75	15.28	7.30	0.13	0.11	0.07	0.04	660.25	688.50	477.50	191.25
					C.D. at 5% level of significance							
For Mn levels	0.41	N.S.	N.S.	N.S.	0.0057	0.0040	0.0051	0.0056	17.03	7.97	6.57	4.33
For WM interaction	N.S.	N.S.	1.41	1.08	N.S.	N.S.	N.S.	N.S.	24.08	11.27	9.30	6.12

Table 3

Interaction effect of lime × manganese on yield and manganese, iron contents in rice at different stages of growth

	Yield, g/pot				Mn content, %				Fe content, ppm			
	S_1	S_2	S_3	Grain	S_1	S_2	S_3	Grain	S_1	S_2	S_3	Grain
L_0M_0	3.63	7.34	14.64	5.50	0.11	0.08	0.05	0.03	701.25	684.00	452.50	236.25
L_0M_1	3.38	8.37	14.17	6.00	0.14	0.11	0.07	0.04	648.75	640.25	435.00	225.00
L_0M_2	4.31	8.90	13.88	5.97	0.16	0.12	0.09	0.04	600.50	583.50	400.00	187.50
L_1M_0	2.96	7.96	14.08	6.75	0.08	0.07	0.04	0.02	579.50	566.50	365.00	205.00
L_1M_1	3.58	7.76	14.62	7.36	0.11	0.08	0.06	0.03	537.75	533.75	337.50	197.50
L_1M_2	4.16	8.34	15.22	7.57	0.12	0.14	0.09	0.04	510.25	502.00	310.00	171.25
					C.D. at 5% level of significance							
For L × M interaction	N.S.	N.S.	N.S.	1.08	N.S.	N.S.	N.S.	N.S.	24.08	11.27	N.S.	6.12

found significant at any stage of the crop growth on manganese content. The application of manganese under submergence increased the grain and straw yield significantly, which might be due to a more ideal balance between iron and manganese in the rice, due to the significant increase in manganese content and decrease in toxic concentration of iron. However, the application of manganese under saturated condition showed no significant effect either on grain or straw yield. The manganese application under this moisture regime increased the manganese content and decreased the iron content; but the decrease in iron content was of lower magnitude in comparison to submergence, which might not have created an ideal balance between iron and manganese and was thus unable to increase the rice yield significantly. The submergence, without manganese application, decreased the grain and straw yield significantly; but it increased them significantly with manganese application, which was again due to the concentration of iron being decreased by manganese application. However, the submergence decreased the manganese content, both with and without manganese application, and increased the iron content; but the magnitude of decrease in manganese content and increase in iron content was more than 1.5 and 2.0 times without manganese, in comparison to manganese application. This indicated again that decrease in yield, due to submergence without manganese, was due to an excessive concentration of iron within the plants in the present study.

Interaction effect of lime and manganese

While the application of manganese without lime did not affect the grain yield significantly, its application with lime increased the grain yield significantly over that of no manganese application (Table 3). The content of manganese was increased upon its application both under limed and unlimed conditions, while the application of manganese decreased the iron content significantly at maximum tillering, flowering and harvest. Here again, the lime and manganese application counteracted the harmful effect of iron on rice yield. The application of lime, both with and without manganese application, increased the grain yield significantly with maximum increase under the treatment of 3 ton lime/ha, combined with 100 ppm manganese application. It is worth commenting that the content of iron in rice plants was the lowest, and that of manganese the highest under this treatment at all the stages of rice growth, in comparison to other lime and manganese treatment. This clearly emphasizes the importance of applications of limes and manganese together, for increasing the rice yield under present investigation, where excess iron was a problem.

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EFFECT OF GROWTH REGULATORS AND NPK FERTILIZERS ON THE TRACE ELEMENT CONTENTS OF SUNFLOWER IN CALCAREOUS SOILS

A. M. Salama and I. Buzás

INSTITUTE OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
OF THE HUNGARIAN ACADEMY OF SCIENCES, BUDAPEST, HUNGARY

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The results of field trials carried out in 1983 and 1984 to study the combined effect of growth regulators and NPK fertilizers on the trace element contents of sunflower plant tops grown on a calcareous sandy soil (A) at Őrbottyán and a calcareous loamy chernozem soil (B) at Nagyhörcsök are reported.

On soil (A), only a slight response was found in the Fe content due to growth regulator application. Cycocel markedly decreased the Cu content compared to kinetin and the control. Fe content was not influenced by fertilizer addition. Nitrogen alone markedly increased the Zn content, while the Cu content was decreased by NPK combinations. A marked reduction was noted in the Mn content when $N + K_2O$ and $N + P_2O_5 + K_2O$ were applied due to dilution.

On soil (B), growth regulators resulted in an increase in the Cu content, while cycocel markedly increased the Fe content. A marked increase in Fe content was also reported after the addition of $N + P_2O_5 + K_2O$, whereas $N + P_2O_5$ markedly decreased it. Both N and $N + K_2O$ significantly increased the contents of both Zn and Cu.

In both locations, growth regulators had no significant effect on either the Mn or Zn contents. Nitrogen fertilizer tended to increase the Mn content. A reduction in the Zn content usually followed P_2O_5 fertilization.

Finally, there was a significant interaction between growth regulators and NPK fertilizers in the Cu content on soil (A) in 1983.

Keywords: *Helianthus annuus* L., sunflower, growth regulators, NPK-fertilization, trace elements

Introduction

Sunflower (*Helianthus annuus* L.) has become a major crop in Hungary in the last decade. Few attempts have been made to characterize the Fe, Cu, Mn and Zn contents of sunflower plants as influenced by growth-regulating substances and NPK fertilizers. Studies on the effects of growth regulators on the trace element contents of sunflower plants have been limited. Studies with onion plants (El-Sherif and El-Habbasha 1977) showed that cycocel increased the uptake of micronutrients, especially Fe and Mn, with an increase in the rate of added nitrogen. Devlin et al. (1981) found that the root absorption of Zn by wheat was stimulated by cycocel; however, no effect was observed on the absorption of Fe. They also showed that the uptake of Fe and Zn by soybean roots was inhibited by cycocel application. Investigations with

Hibiscus sabdariffa L. in Egypt (El-Shaarawi et al. 1982) showed that GA increased the contents of Fe, Mn, Zn and Cu.

Kinetin is also essential for the growth of plant organs and tissues. Its involvement in the process of mobilization of inorganic and organic nutrients is well documented (Skoog and Armstrong 1970). Starck and Kozinska (1980) observed a stimulating effect of zeatin on the uptake and distribution of some ions in bean plants growing under stress conditions. Atonik is a plant biostimulant composed of sodium mono-nitroguaiacol and other aromatic compounds. Studies on the effects of this compound on sunflower plants have been limited.

Even though abundant data are available on sunflower fertilization, few attempts have been made to estimate the Fe, Cu, Mn and Zn contents of sunflower plants as influenced by N, P and K fertilizers. Nitrogen fertilizer had little effect on the elemental composition of sunflower achenes on fertile silt loam soil, whereas highly significant increases in Fe, Zn, Cu and Mn resulted from N application on droughty sandy soil (Robinson 1973). Sheppard and Bates (1980) also found that nitrogen fertilization increased the Mn and Zn concentration in rape leaves. Studies with mungbean plants (Bassiri et al. 1979) showed that increased levels of phosphorus in the soil caused markedly lower Zn concentrations in the tops. Lásztity (1983) reported that phosphorus fertilizer reduced the Fe, Zn and Cu contents in sunflower plants. In another trial, he added that the specific micronutrient contents of sunflower were not affected by NPK fertilizers.

The objective of this research was to study the combined effect of growth-regulating substances and NPK fertilizers, as well as their interactions on the trace element contents of sunflower tops under field conditions in calcareous soils.

Material and methods

Field trials were conducted in 1983 and 1984 at the Agricultural Experimental Stations (Őrbottyán and Nagyhörcsök) of the Institute of Soil Science and Agricultural Chemistry. A strip plot design with four replications was used. The main plots were devoted to growth-regulating substances as follows: untreated control, 1 : 1000 solution of atonik (sodium mono-nitroguaiacol and other aromatic compounds), 5 ppm kinetin (6-furfurylamino purine), 500 ppm cycocel (2 chloroethyl trimethyl-ammonium chloride), while the sub-plots were assigned to NPK fertilizer combinations, namely: unfertilized control, 200 kg N, 200 kg N + 150 kg P_2O_5; 200 kg N + 200 kg K_2O; 200 kg N + 150 kg P_2O_5 + 200 kg K_2O/ha. Some chemical and mechanical properties of the soils of the experimental fields are shown in Table 1. Total rainfall for the two seasons (April to August) were 196 and 296 at Őrbottyán and 211 and 238 mm at Nagyhörcsök, respectively. Ammonium nitrate (28%) was applied as a nitrogenous fertilizer at planting. The phosphate and potash fertilizers were applied in autumn as superphosphate (18% P_2O_5) and potassium chloride (60% K_2O). Growth-regulating substances were foliar sprayed once when the plants were 7 weeks old, except for atonik which was applied twice in 1984 at 4 and 7 weeks old. Seeds of the sunflower hybrid "IH 173" which is an oil-type cultivar, were hand-sown on the 15th and 17th of April at Őrbottyán in the 1983 and 1984 seasons, respectively. At Nagyhörcsök the seeds were machine-planted on April 17, 1983 and April 28, 1984. Each sub-plot had 6 rows, 8 meters long and 70 cm apart. Therefore, there were 57 000 plants per hectare (70 × 25 cm). Five plants from each sub-plot were sampled

Table 1

Physical and chemical analysis of the experimental soils

Soil contents	Soil types (locations)	
	Soil (A) calcareous sandy (Őrbottyán)	Soil (B) calcareous loamy chernozem (Nagyhörcsök)
Clay, %	10–15	40
pH (KCl)	7.1	7.3
$CaCO_3$, %	8.8	6.7
O.M. %	1.12	2.68
$NO_3 + NO_2$, ppm	20.3	15.4
P_2O_5, ppm	78.2	104.4
K_2O, ppm	97.2	265.2
Zn, ppm	2.8	2.3
Cu, ppm	2.6	3.6
Mn, ppm	80.1	150.0
Fe, ppm	87.5	50.0

80 days after sowing. The samples were ground and dried at 42 °C. The contents of Fe, Mn, Zn and Cu were determined at the Vas County Station for Plant Protection and Agriculture Chemistry.

Results and discussion

Effect of growth regulators on trace element contents

Cycocel had a marked effect on both the Fe and Cu contents of plant tops (Table 2). Foliar application of cycocel significantly increased the Fe content compared to the untreated control or to kinetin on soil (B) in the second season. However, this increase was not significant in the first season. This finding is in accordance with the observation of El-Sherif and El-Habbasha (1977). On soil (A), only a slight response was found to the application of growth regulators, except that a 1 : 1000 solution of atonik tended to increase the Fe content by 12 and 17% over the control in the first and second seasons, respectively.

The growth-regulating substances under investigation (Table 3) had no marked effects on the Mn and Zn contents in any of the experiments. However, atonik increased the Zn content on soil (B) compared to kinetin and the control. Furthermore, kinetin slightly increased the Mn content on soil (A) and decreased the Zn content by 8 and 20% on soils (A) and (B) respectively, in 1983.

Cycocel markedly decreased the Cu content on soil (A) compared to kinetin and the untreated control in 1984. However, the responses in 1983 were small and indefinite. On soil (B), a slight increase in the Cu content was

noted in both seasons due to the application of growth regulators. The highest increase (31% over the control) was recorded after cycocel application in 1984. All the data reported above seem to confirm the supposition that growth substances act as an important factor in the endogenous regulation of the uptake and distribution of ions (Starck and Kozinska 1980).

Effect of NPK fertilizers on trace element contents

The content of Fe (Table 2) was not markedly influenced by fertilizer application on soil (A), whereas a highly significant increase was observed after the addition of N in conjunction with P_2O_5 and K_2O compared to the other fertilizer treatments and the unfertilized control on soil (B) in 1984. On the other hand, P_2O_5 plus N significantly decreased the Fe content compared to other treatments, a phenomenon reported to occur with sunflower by Lásztity (1983). However no trend was established in 1983.

Mineral nutrition did not affect the Mn content in any of the experiments (Table 3), except that a marked reduction compared to the control was noted after the application of $N + K_2O$ and $N + P_2O_5 + K_2O$ treatments on soil (A) in 1984. These decreases may be attributable in some measure to dilution

Table 2

Effect of growth-regulating substances and NPK fertilizers on Fe and Cu contents of sunflower tops after 80 days from sowing in both seasons

Seasons and treatments	Soil types (locations)							
	Soil (A) (Őrbottyán)				Soil (B) (Nagyhörcsök)			
	Fe		Cu		Fe		Cu	
	mg/kg				mg/kg			
	1983	1984	1983	1984	1983	1984	1983	1984
G.R. substances								
Untreated	151	192	7.15	7.40	255	268	8.80	7.40
Atonik	169	225	7.20	6.70	246	328	9.96	9.40
Kinetin	150	188	6.70	7.90	235	266	10.05	8.30
Cycocel	150	213	7.90	6.00	271	404	10.53	9.70
F-test	N.S.	N.S.	N.S.	*	N.S.	*	N.S.	N.S.
$LSD_{5\%}$	—	—	—	1.2	—	91	—	—
NPK fertilizers								
Unfertilized	147	224	7.29	8.00	254	298	9.77	9.00
N	165	229	7.60	7.30	236	300	10.46	10.50
NP	153	203	6.72	6.60	261	245	9.39	6.90
NK	151	184	7.89	6.80	261	316	10.37	10.10
NPK	157	183	6.69	6.30	246	424	9.18	7.00
F-test	N.S.	N.S.	N.S.	N.S.	N.S.	**	N.S.	**
$LSD_{5\%}$	—	—	—	—	—	55	—	1.1

Table 3

Effect of growth-regulating substances and NPK fertilizers on Mn and Zn contents of sunflower tops after 80 days from sowing in both seasons

Seasons and treatments	Soil types (locations)							
	Soil (A) (Őrbottyán)				Soil (B) (Nagyhörcsök)			
	Mn		Zn		Mn		Zn	
	mg/kg				mg/kg			
	1983	1984	1983	1984	1983	1984	1983	1984
G.R. substances	44.2	70.3	19.0	21.8	68.0	74.2	21.7	20.0
Untreated	48.8	66.9	18.4	21.8	71.8	79.0	24.2	23.6
Kinetin	50.0	76.7	17.6	22.9	61.5	71.7	17.5	21.0
Cycocel	48.9	75.3	22.2	23.0	71.1	80.2	22.3	22.0
F-test	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
$LSD_{5\%}$	—	—	—	—	—	—	—	—
NPK fertilizers								
Unfertilized	45.1	77.1	18.8	27.6	63.7	75.9	19.0	21.9
N	54.2	82.2	24.9	26.1	67.5	78.8	26.1	25.3
NP	53.1	75.1	15.0	18.9	69.1	80.0	20.2	18.3
NK	43.4	63.5	19.3	19.6	73.2	70.0	23.0	24.3
NPK	44.0	63.6	18.5	19.7	67.0	76.5	18.7	18.5
F-test	N.S.	*	*	**	N.S.	N.S.	N.S.	**
$LSD_{5\%}$	—	11.1	5.3	4.2	—	—	—	4.1

caused by shoot yield increases, as reported in a previous paper (Salama and Buzás 1984). Moreover, N fertilizer tended to increase the Mn content of sunflower tops in both locations.

In both soil types, a reduction in the Zn concentration usually followed P_2O_5 fertilization (Table 3). Bassiri et al. (1979) reported a similar P—Zn antagonism with mungbean plants.

On soil (A), N alone markedly increased the Zn content compared with other NPK combinations in 1983. On the other hand, in the second season, the Cu content decreased as a result of NPK fertilizers, a response which might be attributed to dilution. On soil (B) the addition of either N or N plus K_2O markedly increased the contents of both Zn and Cu in 1984. The response found was greater due to applied $N + K_2O$ than to applied $N + P_2O_5$ or $N + P_2O_5 + K_2O$. This increase was not marked in the first season. Lásztity (1983) reported similar results.

Interaction between regulators and NPK fertilizers

A significant interaction between growth regulators and NPK fertilizers was observed in the Cu content (Table 4). The addition of nitrogen usually increased the Cu content, while N plus P_2O_5 decreased it after all growth

Table 4

Average Cu content of sunflower tops (mg/kg) as affected by the interaction between growth-regulating substances and NPK fertilizers on soil A after 80 days from sowing in 1983

Treatments	Untreated	Growth-regulating substances			
		Atonik	Kinetin	Cycocel	$LSD_{5\%}$
NPK fertilizers					
Unfertilized	6.87	7.17	7.33	7.80	2.10
N	7.00	7.53	7.37	8.50	
NP	7.70	6.57	5.97	6.63	
NK	8.07	7.67	7.40	8.43	
NPK	6.13	7.07	5.43	8.13	
$LSD_{5\%}$	2.11				

regulator applications in 1983 on soil (A). The differences between cycocel-treated and untreated plants became more pronounced when NPK fertilizer combinations were applied. This led to the suggestion that spraying sunflower plants with cycocel stimulated Cu uptake by the plant after fertilizer application. The highest average for the Cu content was obtained with a combination of N fertilizer with 500 ppm cycocel.

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SALINITY INDUCED BIOCHEMICAL CHANGES DURING GERMINATION OF CHICKPEA (*CICER ARIETINUM* L.)

C. V. MURUMKAR and PRAKASH D. CHAVAN
DEPARTMENT OF BOTANY, SIVAJI UNIVERSITY, KOLHAPUR, INDIA

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Influence of sodium chloride salinity on development of some enzyme systems during germination of seeds in chickpea variety chaffa has been studied. The germination percentage and seedling growth were affected to a considerable extent by salinity levels above 15 mmhos cm^{-1}. The high concentrations of all salt caused inhibition of enzymes α-amylase, acid phosphatase and peroxidase in seedlings at different germination stages. The dehydrogenase activity in embryo axis was suppressed by salinity. Activity of enzymes protease and catalase were stimulated due to salt stress. It is probable that salt sensitivity of chickpea at germination stage may be due to these metabolic disturbances.

Keywords: *Cicer arietinum* L., chickpea, germination, enzyme activity, salinity

Introduction

Seed germination represents one of the critical phases in the life cycles of crop species. The inhibition of seed germination by salt stress is well documented (Strogonov 1964, Ungar 1978). Both osmotic and specific ion effects have been shown to be involved in this process (Ayers 1952, Younis and Hatata 1971). However, the metabolism of germinating seeds under saline conditions is not fairly understood. In the present investigation, an attempt has been made to study the effect of salt stress on the development of some important enzyme systems during germination of gram (*Cicer arietinum* L.) seeds.

Material and methods

The seeds of chickpea variety chaffa which is widely cultivated in this zone were obtained through the courtesy of the Agricultural College, Pune. Healthy seeds were sorted out and their surfaces sterilized with 0.1% $HgCl_2$ solution for 5 minutes. Twenty seeds were put in sterilized petridishes for germination over Whatman No. 1 filter paper. The filter paper was moistened with 15 ml of distilled water (control) or salt solution. An extensive survey of International Rice Research Institute has shown that the salt concentration (0.4% W/V) gives an ECe of approximately 8–10 mmhos cm^{-1} at 25 °C and this can be considered as a discriminating level of salinity (Ponnamperumma 1977). Hence, for the present studies, 3 concentrations of NaCl, namely: 0.4%, 0.8% and 1.2% were chosen. The emergence of the radicle from its seed coat was acknowledged as the criterion for germination, which was measured every 24 hours. The experiments were carried out (in triplicate) at 28 °C in a ger-

mination chamber. After 120 hours, the growth of seedlings was recorded with respect to shoot length, root length, fresh weight and moisture content.

As the germination as well as seedling growth was seriously affected by highest dose of NaCl concentration (1.2%), the enzymatic studies were carried out in seeds subjected to 0.4% and 0.8% NaCl in the manner described earlier. The activities of enzymes α-amylase, protease, acid phosphatase, catalase, peroxidase and dehydrogenase were studied during different stages of germination in control seeds, and in seeds subjected to salt stress. The methods of Katsumi and Fukuhara (1969), Penner and Ashton (1967), Melachalan (1980), Herbert (1955), Maehly (1954) and Kittoch and Law (1957) were followed for estimation of α-amylase, protease, acid phosphatase, catalase, peroxidase and dehydrogenase, respectively.

Results and discussion

Effect of NaCl salinity on the germination of gram variety chaffa is recorded in Fig. 1. It is here evident that the germination is delayed due to salinity in the early hours. The germination percentage is not affected by 0.4% NaCl treatment. There is about 50% inhibition of germination due to higher doses of salt (0.8% and 1.2%). Though salt stress does not affect the emergence of radicle, it considerably retards further seedling growth. This can be clearly seen from Fig. 2. The growth of both root and shoot as well as fresh weight is retarded by salt stress and in the seeds subjected to highest dose of salinity (1.2% NaCl), no emergence of plumule was evident. Kheraduam and Ghorashy (1973) have studied salt tolerance of four Iranian cultivars of the chickpea at its germination stage. Their observations indicate that the germination is severely affected by 2% NaCl treatment. But these workers did not report the effect of salt stress on seedling growth. Inhibition of chickpea seed germination by salt stress was also evident in the experiments of Bharadwaj (1961) and Chandra (1979). All these findings indicate that chickpea can successfully germinate only in slightly saline medium.

In order to find biochemical basis of salt sensitivity of chickpea at germination stage, the enzyme analyses was carried out. The results are depicted in Fig. 3, which shows that the activity of α-amylase is lowered due to salinity during early (24 hr) and latter (96 and 120 hr) phases of germination. The inhibition is particularly significant at 120 hr phase. The work of Azhar et al. (1972) has indicated that α-amylase activity in 120 to 168 hrs during chickpea seed germination reaches its peak period. Salinity induced inhibition of α-amylase was evident in the experiments of several workers (Sarin and Narayanan 1968, Dzhanibekora 1972, Sheoran 1980) and this can lead to disturbance of normal carbohydrate metabolism.

A decrease in acid phosphatase due to salt stress during germination is evident from the stage of 48 hrs onwards. Acid phosphatase activity and germination capacity have been shown to be positively correlated (Janowaski and Iguacio 1977). It is shown by Flin and Smith (1967) that the enzyme is involved in the mobilization of nutrient reserves. Acid phosphatase exhibits a

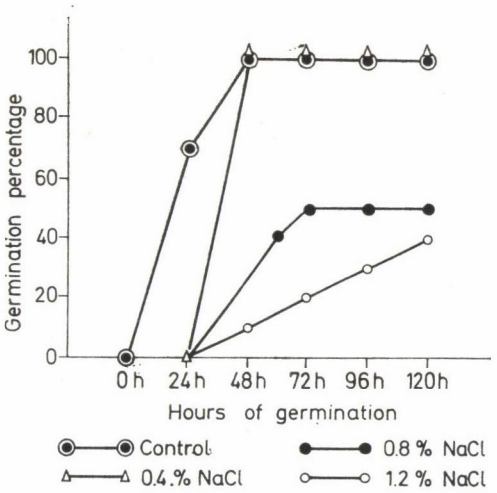

Fig. 1. Influence of salt stress on seedling growth of chickpea (*Cicer arietinum* L.) variety chaffa

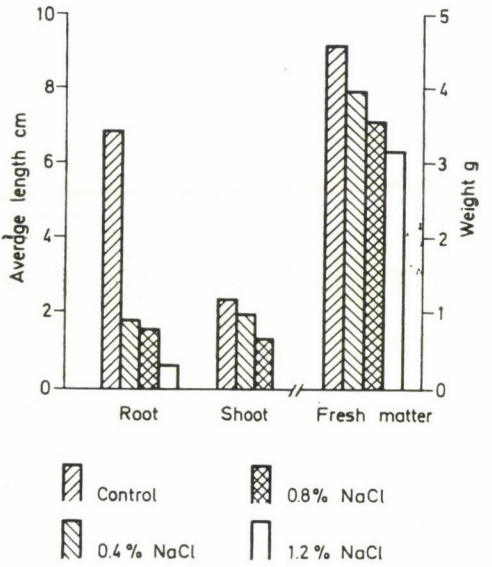

Fig. 2. Influence of salt stress on germination of chickpea (*Cicer arietinum* L.) variety chaffa

broad range of activity (De Leo and Sacher 1970) and it brings about hydrolysis of a number of phosphomono-esters, carbohydrate esters and even ATP. The inhibition of acid phosphatase by salt stress in chickpea seeds will certainly affect the hydrolysis of various reserve phosphates, thereby limiting the transport of phosphorus to the growing points of the embryo axis.

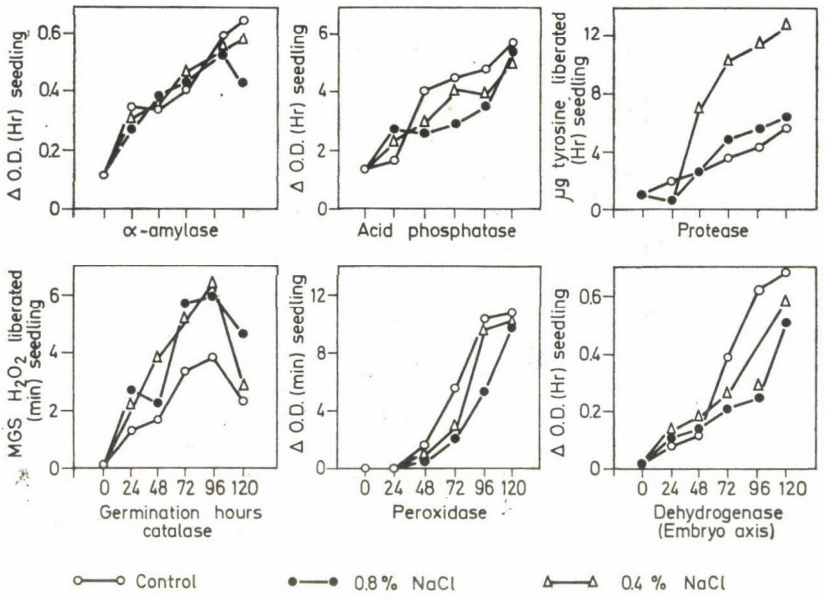

Fig. 3. Influence of salt stress on enzyme activities during germination of chickpea (*Cicer arietinum* L.) variety chaffa

The effect of salt stress on development of protease activity during chickpea seed germination is recorded in Fig. 3. The enzyme activity is suppressed by salt stress during the early phase of germination (24 hrs). However, at latter stages we can notice a significant stimulation of protease activity by salinity, especially at higher dosage. Though an increase in free amino acids is a common feature in salinized plants (Strogonov 1964), not much work has been carried out regarding the effect of salt stress on enzymes of protein metabolism. Prisco and Vieira (1976) observed that in germinating *Vigna sinensis* seeds, though the protein breakdown and turnover was delayed by the NaCl treatment, the total amount of proteolatic activity was unchanged by salinity. According to them, the inhibitory effects of salinity on seed protein reserve mobilization may be due to more inhibition of translocation of hydrolysis products than to inhibition of protease activity. Their studies mainly concentrated upon cotyledonary protease, while in present studies protease from whole seedlings is assayed. A synthesis of proteins is one of the important facets of germinating seeds, and the salinity induced proteolysis may have deleterious effects on the synthesis of important proteins. The increase in free amino acids resulting due to salinity induced proteolysis may also pose important problems in germinating seeds, as the deamination of these amino acids can lead to toxic accumulation of ammonia (Strogonov 1964).

It can be seen from Fig. 3 that the activity of catalase is stimulated due to salinity during all phases of chickpea seed germination. A substantial increase in catalase activity in plants grown under saline substrate was evident in the experiments of Strogonov (1964) and El Fouly and Jung (1970). According to Strogonov (1964) catalase is involved in regulating H_2O_2 level in plant cells which otherwise may prove fatal. Kali and Poljakoff-Mayber (1981) also pointed out the possibility that along with peroxidase and superoxide dismutase, catalase may play a role in protecting the leaf cells against oxygen toxicity caused by free radicals that may be formed in cells when growing under saline and extreme climatic conditions. In the light of these suggestions an increase in catalase activity in salt stressed chickpea seedlings can be considered an adaptive value. The increase in catalase may also reflect an intensification of respiratory activity due to salt stress (Paul and Mukherji 1972, Tregubenko et al. 1973).

It is evident from Fig. 3 that salinity has brought about a considerable decrease in peroxidase activity. No generalization can be made regarding the influence of salt stress on peroxidase activity, as there are reports of both intensification (Strogonov 1964, Heimberg 1970 and Molokov et al. 1973) and depression (Vasile 1963, Maliwal and Paliwal 1972, Flowers 1972 and Siegel et al. 1982) of peroxidase activity under saline conditions. A genotypic difference in *Brassica* in this respect was evident in the experiment of Stevens et al. (1978). According to Aleshin el al. (1971), peroxidase takes an active part in the adaptation of plants to salts and in heteroauxin metabolism. It is apparent from observations that chickpea lacks such an adaptive feature. An inhibition of peroxidase activity in germinating chickpea seeds due to metabolic inhibitors, like 8 azadenine cyclohreximide and pesticide endosulfon, was evident in the experiments of Srivastava et al. (1972) and Agarwal and Beg (1982), and this was accompanied by growth inhibition. Probably salinity induced inhibition of peroxidase can also be one of the reasons for retardation of growth in chickpea seedlings.

The influence of salt stress on dehydrogenase activity in embryoaxis of germinating chickpea seeds is depicted in Fig. 3. During the first 48 hours of germination, the enzyme activity is slightly elevated by salinity. However, in the later phase of germination, we can notice a considerable decline in dehydrogenase activity under saline conditions. In the present investigation, TTC reduction has been considered as a measure of a broad spectrum dehydrogenase activity. In the case of seeds, TTC reduction generally sheds light on their respiratory capacity and overall viability. Tagawa and Ishizaka (1964) studied respiration in rice roots under saline conditions. They found that with the increase in salt injury, O_2 uptake, reduction of TTC and oxidation of α-naphthylamine (α-Na) by the roots of rice plants decreased rapidly, which indicated a suppression of respiratory activity in roots due to salt stress. Chloride salinity

was found to inhibit dehydrogenase activity in barley, tomatoes, and sunflower grown in pot culture (Zhukovaskaya and Lyakhora 1969). Our findings also suggest the possibility that salinity might disturb the normal respiratory machinery in embryo axis, which will undoubtedly influence the growth pattern.

It is evident from this account that through alternation of enzyme activities, salinity brings about several metabolic disorders in germinating chickpea seedlings, which ultimately lead to growth depression. A detailed isoenzyme study will be more helpful in understanding the effect of salinity at the molecular level. Such studies are in progress.

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BIOLOGICAL NITROGEN FIXATION IN SOME FOREST ECOSYSTEMS

TATJANA PÁNTOS-DERIMOVA

DEPARTMENT FOR ECOLOGY, UNIVERSITY OF FORESTRY AND WOOD INDUSTRY, SOPRON, HUNGARY

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The activities of N-fixing bacteria in the A_{00}-subhorizon of the forest litter is, in general, lower than those in the A_0-subhorizon which contains larger quantities of available C- and energy-sources.

Considerable differences were detected in N_2-fixing activities of the A_0-subhorizons in soils of different ecosystems. The highest activity was measured in A_0 under an *Orno-Quercetum pubescenti-cerris* stand at the spring time, while the lowest in the A_0 under a *Piceetum excelsae* cultum stand.

The N_2-fixing activity was lowest in the acid, non-podzolic brown forest soil-profiles developed on sediments of Miocene origin. On the other hand, the highest activity was measured in a slightly alkaline rendzina soil rich in humic matter and formed on a Lajta limestone.

The total amount of fixed nitrogen calculated to the total soil profile depends on many variable parameters such as the depth of the individual soil horizons, pH, humus-content, water condition, the structure and composition of the forest stand, etc.

The intensity of N_2-fixation by free-living nitrogen-fixing bacteria is generally lower in soils of Hungarian forest ecosystems than in soils of the arable areas.

Keywords: nitrogen fixation, forest ecosystem, soil profiles

Introduction

Investigations related to the biological fixation of molecular nitrogen have lately been considerably extended and have resulted in many new scientific data and practical achievements.

The main reason is that the incorporation of N-atoms of N_2 into organic compounds by procaryotic organisms is the only way of nitrogen-fixation which excludes the contamination of the soils, lakes and rivers with large amounts of inorganic N-compounds, which are known to occur in many cases from the impurer use of artificial fertilizers containing inorganic nitrogen.

On the other hand, the industrial reduction of N_2 to NH_3 level is a procedure which requires an enormous energy input, and consequently it is very expensive.

To determine the amount of N_2 actually fixed in the forest soil, it is not enough to know the current N_2-fixing activity. Namely, the former depends on the weight and quality of the leaf-litter, and the root mass, as well

as the thickness and volume weight of the individual genetic horizons of the soil profile.

According to our results during the vegetation period the amount of N_2-fixed in forest soils was largest (6.742 kg N_2/ha) in a thinned stand of *Fagetum silvaticae*. It was followed in a decreasing order by the unthinned stands of this species (5.874 kg N_2/ha) and then by the stands of *Orno-Quercetum pubescenti-cerris* (4.979 kg N_2/ha). Finally, the lowest N_2-fixation (1.319 kg N_2/ha) was measured in a *Piceetum excelsae* cultum stand.

Under favourable conditions the members of the family *Rhizobiaceae* are able to cover about 70–80% of the N-uptake of plants living in symbiosis with them (Fjodorov 1952). Of the forest stands, the Robinieta and Alneta are characterized by this form of symbiosis.

Larger or smaller numbers of free-living N_2-fixing microorganisms are also found in every soil. As regards the N-surplus resulting from their activities, the estimates vary considerably (Fehér 1954, Pochon and De Barjac 1958, Ryzhova and Umariv 1979) due to the differing opinions on the source and amount of energy actually available in the soil for these organisms.

On the basis of experiments conducted on plants inoculated with mixed cultures of non-symbiotic N_2-fixing bacteria, Umarov (1982) pointed out that 25–35% of the assimilated carbon was utilized as a source of energy by these microorganisms.

Studying the N_2-fixing potential of the rhizosphere, Pántos-Derimova (1969) found that in the rooting zone of *Populus italica* "I-214" at various distances and depths from the collar aerobic N_2-fixing microorganisms were present in much greater numbers than in root remote soil region. The amount of anaerobic N_2-fixing microorganisms was very small both in the rhizosphere and in the rootless soil.

According to Sadykov and Umarov (1980), 50–80% of bacterial strains, isolated from the rhizosphere and phyllosphere of various plant species, possess N_2-fixing activity. The same authors stated that in the phyllosphere of *Betula alba* the productivity of N_2-fixation during the vegetation period was 7 kg N/ha. The same value was 10 kg/ha for *Phleum pratense*.

Also, the N_2-fixing activity of the microorganisms widely varies with the geography of the habitat. The amount fixed N_2 has a maximum of 1–2 kg/ha/year in the north (Jegorov 1979) while in the tropics it may even reach 100 kg (Dobereiner and Day 1976). According to the measuring data of Steyn and Dekwiche (1970), in Californian soils the weight of N_2-fixed in a non-symbiotic way ranged from 2 to 5 kg/ha/year. For the ploughed area of the Soviet Union, the amount of N-fixed in the soils and on the surfaces of plants was estimated 20 kg/ha/year by Mishustin (1983).

For the cultivated area of Hungary, the N-balance was estimated by Sarkadi (1979), who considered the amount of N_2-fixed by non-symbiotic

N_2-fixing microorganisms to be an average of 6 kg/ha/year. He points out that, with the increasing N-fertilization, the amount of N_2-fixed by the free N_2-fixing microorganisms decreases. The intensive industrialization and the related air pollution, on the other hand, increase the N content of the precipitation.

Pántos-Derimova (1969) studied the N-surplus caused by the activity of free N_2-fixing bacteria in field experiments with *Populus robusta* on a chernozem soil and *Populus italica* ("I-214") on a sandy soil. In a 60 cm deep layer the N-surplus was 16 kg N_2/ha/year in a meadow chernozem soil and than a third of that 5 kg N_2/ha/year, in a sandy soil. On the other hand, in those plots which were given NPK fertilization, and supplied before plantation with chopped maize stalks (8 t/ha), the N-surplus proved to be twice as much—34 and 10 kg N_2/ha/year, respectively. The share of the anaerobic N_2-fixing bacteria from the N-surplus was negligible.

On the basis of enzyme activity measurements carried out in samples of soils in several Hungarian forest ecosystems, it was established that the intensity of N_2-fixing activities in correlation with the total number of bacteria and the level of CO_2 production, was highest in the leaf-litter (Pántos-Derimova 1983). Details for the nutrient chains in microbial communities of the litter-layer are not fully known as yet. It can be supposed, however, that in the forest litter the N_2-fixing microorganisms can play a decisive role in activating the decomposition processes.

The goal of these studies presented as following was to contribute further data to the existing knowledge on the nitrogen-fixing activities of bacteria in the different soils of forest ecosystems.

Material and methods

The examinations were carried out in the following ecosystems: (1) a 116-year-old *Piceetum excelsae* cultum plantes on an acid, non-podzolic brown forest soil; (2) a 77-year-old forest-stand of *Orno-Quercetum pubescenti-cerris* of second growth on a rendzina soil; (3) a 104-year-old stand of a naturally thinned and unthinned *Fagetum silvaticae* on a brown forest soil with clay infiltration. Community-structural and habitat data for them were published by us earlier (Pántos et al. 1981, Pántos-Derimova 1983). Thinning was carried out in 1970 when 95.4 m^3/ha gross volume of wood was cut.*

The laboratory investigations covered the determination of current N_2-fixing activity and of the amount of actually fixed N_2 in the leaf-litter, the soil and the rooting zone. On sampling the litter-layer the one-year-old (A_{00}-level) and several-year-old (A_0-level) dead leaf-matter accumulated on the A_F-horizont were separated.

Since we did not carry out detailed root-biomass studies, the adequate data published by Majer (1984) for *Fagetum silvaticae* ecosystems constituted our starting point in estimating the root weight. Accordingly, we calculated the root weight to about 5.6% of the dry weight of wood. The conversion into dry matter was based on the m^3/ha value of the wood volume of those tree species that composed the stand, and on the kg/m^3 value of their volume weight

* Operative data from the Farkasgyepű Forestry of the Balaton-felvidék Forest and Wood Processing Farm.

Table 1

Average root weight in different forest stands (the root weight was considered as 5.6% of the dry weight of wood) (1)

Species (2)	Volume, m/ha (3)	Weight of wood, kg/m (4)	Dry weight kg/ha (5)	Rost weight kg/ha (6)
		Piceetum excelsae cultum (7)		
Picea (8)	594.680	430	255 712.40	14 319.89
Larix (9)	201.800	550	110 990.00	6 215.44
Fagus (10)	10.560	680	7 180.80	402.12
Total (11)	807.040	—	373 883.20	20 937.45
		Orno-Quercetum pubescenti-cerris (12)		
Qu. cerris (13)	176.520	720	127 094.40	7 117.29
Qu. sessiliflora (14)	22.360	650	14 534.00	813.90
Qu. pubescens (15)	11.360	720	8 179.20	458.04
Tilia cordata (16)	2.160	490	1 058.40	59.27
Prunus avium (17)	1.080	570	615.60	34.47
Total (18)	213.480	—	151 481.60	8 482.97
		Fagetum silvaticae (19)		
Thinned (20)	719.418	680	486 204.24	27 395.44
Unthinned (21)	878.188	680	597 167.84	33 441.40

related to dry matter. For the latter the data of Wagenführ and Scheiber (1974) were used (Table 1).

The soil-, litter- and root-samples in the stands of *Piceetum excelsae* cultum and *Orno-Quercetum pubescenti-cerris* were taken on 3 April, 17 July and 31 October 1979, while in that of *Fagetum silvaticae* the day preceding each of the above dates. The method of taking and preparing samples of leaf-litter and root was as we have already described (Pántos-Derimova 1969; Pántos et al. 1981).

The N_2-fixing activity was determined by the acetylene reduction method (Hardy and Knight 1967; Szegi 1979; Schöllhorn and Burris 1966; Dilworth 1966). For analyses, 1 g of the homogenized litter-matter and fine root-samples, as well as 5 g of soil-samples taken from various horizons at different depths, were placed into minute flasks in which the air was replaced by a gas mixture (acetylene, oxygen and argon). These tests were performed with three replications, with incubation taking place at 28 °C for 24 hours. The ethylene formed was determined with a HROM-4 gas chromatography (Hardy et al. 1971).

The vegetation period was taken for 180 days, with 60 days for each of the spring, summer and autumn periods. The values obtained on the above three dates were thus related to these periods. The sum of these values gave the estimated amount of N_2-fixed per ha in a non-symbiotic way during the entire vegetation period.

Results and discussion

The current N_2-fixing activity in the litter-layer of the studied ecosystems was in each case essentially lower in subhorizon A_{00} than in subhorizon A_0 (Tables 2, 3, 4, 5). This can be explained by the fact that the organic remainders of woody plants accumulating on the soil surface in a year start

decomposing with difficulty. Thus the non-symbiotic N_2-fixing microorganisms receive only small quantities of utilizable C-sources. It was particularly so in the case of the coniferous stand.

The level of N_2-fixing activity in the litter-layer was highest in subhorizon A_0 of the *Orno-Quercetum pubescenti-cerris* stand at the spring sampling time. By summer, and even more so by the autumn period, the N_2-fixation —especially in subhorizon A_0—was sharply reduced, probably due to the unfavourable water regime of the rendzina A_H-horizon. The latter is characterized by a crumby structure, a relatively adequate moisture content only in spring because of the snow's melting, and by the presence of a luxuriant rooting of the undergrowth. Most of the latter dries by midsummer. Owing to the dark colour of the relatively thin A_H-horizon, this soil grows very warm by summer—sometimes even reaching a temperature of 48 °C —, with a parallel increase in the evaporation and decrease in the moisture content of the whole profile.

The lowest level of N_2-fixing activity was measured in the litter-layer of the *Piceetum excelsae* cultum stand. It is explained by a relatively low concentration of available nutrients and energy sources caused by the high resistance of the here accumulated plant remnants to the comminuting activities of primary—animal—consumers and associated microbes.

As regards the N_2-fixing activity in the litter-layer, there were differences between the thinned and the unthinned *Fagetum silvaticae* stands; it was higher in the thinned than in the unthinned stand in both the A_{00}- and A_0-subhorizons. This was due first of all to the abundant undergrowth (850 kg/ha) in the thinned stand, compared to the 26 kg/ha weight of the undergrowth in the unthinned *Fagetum* stand. Besides, the smaller volume of leaf-litter under the thinned stand ensured a better soil aeration and more favourable ecological conditions for the transformation of the litter-matter.

The soil profiles of the ecosystems studied vary in depth and there are also differences in the thickness of the individual genetic horizons. For this reason the N_2-fixing activities can be estimated and compared only in relation to the horizons and subhorizons of the profile of studied genetic soil types of ecosystems. It is interesting to note that in the summer and autumn periods the activities of N_2-fixing bacteria could not be detected in any of the soils studied. This can partly be explained by the unfavourable moisture condition of these soils during such periods. It can also be supposed that, in this part of the vegetation period, there is a high multiplication rate of other microorganisms—mainly fungi—which, through a nutrient competition or a possible antagonistic effect, inhibit the growth of non-symbiotic N_2-fixing microorganisms.

The highest N_2-fixing activity was found in the slightly alkaline (pH 7.3–7.7 in KCl) rendzina soil, rich (7%) in humic matter and formed on a Lajta

Table 2

Biological N_2-fixation in the litter-longer, and A horizon of an acid non-podzolic brown forest soil and in the rooting zone under Piceetum excelsae cultum mixed stand (1)

Soil (2)				Current N_2-fixing activity (7)			Amount of N (12)			
Genetic horizons (3)	Depth cm³ (4)	Volume weight g/cm³ (5)	Dry weight of litter, soil and root, kg/ha (6)	Spring (8)	Summer (9)	Autumn (10)	Spring (13)	Summer (14)	Autumn (15)	In vegetation period (16)
				Dry matter (11)			kg/ha (17)			
A_{00}	Organic matter on soil surface in a year (18)		7 651	8.6	16.6	0.0	0.004	0.008	0.000	0.012
A_0	Organic matter in process of decomposition (19)		24 989	12.4	38.1	4.0	0.019	0.057	0.006	0.082
I	In total litter (20)		32 640				0.023	0.065	0.006	0.094
A	0–25	0.988	$24.700 \cdot 10^5$	1.7			0.252			0.252
	25–40	1.307	$19.605 \cdot 10^5$	0.8			0.094			0.094
B	40–63	1.342	$30.866 \cdot 10^5$	0.5	no (21)		0.093	no (21)		0.093
	63–90	1.383	$37.341 \cdot 10^5$	0.2			0.045		0.045	
C	90–110	1.702	$34.040 \cdot 10^5$	0.4			0.082			0.082
	110–120	1.422	$14.220 \cdot 10^5$	0.2			0.017			0.017
II	In soil total (22)		$16.772 \cdot 10^5$				0.583			0.583
III	In rooting zone (23)		20 937	124.2	302.7	84.5	0.156	0.380	0.106	0.642
	In the profile total (I + II + III) (24)						0.762	0.445	0.112	1.319

Table 3

Biological N_2-fixation in the litter and A-horizon of a redzina soil and in the rooting zone under an Orno-Quercetive pubescenti-cervis stand (1)

Soil (2)				Current N_2-fixing activity (7)			Amount of N (12)			
Genetic stages (3)	Depth cm^3 (4)	Volume weight g/cm (5)	Dry weight of litter, soil and root, kg/ha (6)	Spring (8)	Summer (9)	Autumn (10)	Spring (13)	Summer (14)	Autumn (15)	In vegetation period (16)
				Dry matter, $\mu g/kg$ (11)			kg/ha (17)			
A_{00}	Organic matter on soil surface in a year (18)		1813	22.6	19.2	3.9	0.002	0.002	ny	0.004
A_0	Organic matter in process of decomposition (19)		3766	268.2	91.3	6.7	0.061	0.021	0.002	0.084
I	In total litter (20)		5579				0.063	0.023	0.002	0.088
A	0–5	0.725	$3.625 \cdot 10^5$	15.6	no (21)		0.339	no (21)		0.339
	5–15	0.825	$8.250 \cdot 10^5$	10.7			0.530			0.530
	15–30	0.824	$12.360 \cdot 10^5$	5.6			0.415			0.415
	30–50	0.975	$19.500 \cdot 10^5$	4.1			0.480			0.480
C	50–100	Solid Lajta limestone						No measured		
II	In soil total (22)		$43.735 \cdot 10^5$				1.764			1.764
III	In rooting zone (23)		8483	4425.8	1610.1	107.3	2.253	0.819	0.055	3.127
	In the profile total (I + II + III) (24)						4.277	0.912	0.062	4.979

Table 4

Biological N_2-fixation in the litter and A-horizon of a clay-infiltrated brown forest soil and in the rooting zone a thinned Fagetum silvaticae stand (1)

Soil (2)				Current N_2-fixing activity (7)			Amount of N_2 (12)			
Genetic horizons (3)	Depth cm (4)	Volume weight g/cm³ (5)	Dry weight of litter, soil and root, kg/ha (6)	Spring (8)	Summer (9)	Autumn (10)	Spring (13)	Summer (14)	Autumn (15)	In vegetation period (16)
				Dry matter, μg/kg (11)			kg/ha (17)			
A_{00}	Organic matter on soil surface in a year (18)		3 520	37.6	92.8	41.6	0.008	0.020	0.009	0.037
A_0	Organic matter in process of decomposition (19)		9 210	110.7	190.7	67.1	0.061	0.105	0.037	0.203
I	In total litter (20)		12 730				0.069	0.125	0.046	0.240
A_1	0–16	1.227	$19.632 \cdot 10^5$	7.1			0.836			0.836
A_2	16–28	1.261	$15.132 \cdot 10^5$	0.7	no (21)		0.064	no (21)		0.064
B	28–75	1.297	$60.959 \cdot 10^5$	0.3			0.110			0.110
C	75–103	1.380	$38.640 \cdot 10^5$	0.2			0.046			0.046
II	In soil total (22)		$134.363 \cdot 10^5$				1.056			1.056
III	In rooting zone (23)		27 395	514.7	2718.3	80.1	0.846	4.468	0.132	5.446
	In the profile total (I + II + III) (24)						1.971	4.593	0.178	6.742

Table 5

Biological N_2-fixation in the litter and A-horizon of a clay-infiltrated brown forest soil and in rooting zone under an unthinned Fagetum silvaticae stand (1)

Soil (2)				Current N_2-fixing activity (7)			Amount of N (12)			
Genetic horizons (3)	Depth cm (4)	Volume weight g/cm³ (5)	Dry weight of litter, soil and root, kg/ha (6)	Spring (8)	Summer (9)	Autumn (10)	Spring (13)	Summer (14)	Autumn (15)	In vegetation period (16)
				Dry matter, μg/kg (11)			kg/ha (17)			
A_{00}	Organic matter on soil surface in a year (18)		4 526	24.5	58.8	28.0	0.007	0.016	0.008	0.031
A_0	Organic matter in process of decomposition (19)		12 820	79.7	153.2	43.5	0.061	0.118	0.033	0.212
I	In total litter (20)		17 346				0.068	0.134	0.041	0.243
A_1	0–12	1.060	$12.720 \cdot 10^5$	9.1			0.695			0.695
A_3	12–20	1.150	$9.200 \cdot 10^5$	1.0	no (21)		0.055	no (21)		0.055
B	20–45	1.329	$33.225 \cdot 10^5$	0.3			0.060			0.060
C	45–100	1.450	$79.750 \cdot 10^5$	0.2			0.096			0.096
II	In soil total (22)		$134.895 \cdot 10^5$				0.906			0.906
III	In rooting zone (23)		33 441	312.6	1973.5	68.7	0.626	3.960	0.138	4.725
	In the profile total (I + II + III) (24)						1.601	4.094	0.179	5.874

limestone as its parent rock, followed in decreasing order by the clay-infiltrated brown forest soils formed on loess under the unthinned and thinned *Fagetum silvaticae* forest stands. The higher values for the former can be explained with the larger volume of leaf-litter and an increased amount of C-sources, produced through its transformation and available for the non-symbiotic N_2-fixing microorganisms.

The N_2-fixing activity was lowest in the acid, non-podzolic brown forest soil developed on the sediments of a Micene origin. In this soil profile—unlike those of the former types—the activity of N_2-fixation changed irregularly from the topsoil to the parent-rock. The reason for this is found first of all in the very acid reaction of the soil, and in the alteration of its heterogeneous mechanical composition from layer to layer.

The intensity of N_2-fixation in the spring and summer samples of the rooting zone was many times higher than in those taken from the leaf-litter and soil, respectively, and in the *Piceetum* and *Fagetum* ecosystems it reached its maximum in the summer period.

The highest value in the rooting zone of the *Orno-Quercetum pubescenti cerris* stand was measured on the spring date of sampling. It decreased substantially throughout the summer, and particularly in the autumn.

Of the ecosystems studied, the *Piceetum excelsae* cultum showed the lowest N_2-fixing activity in the rooting zone. The corresponding values were higher in the thinned than in the unthinned stand of *Fagetum silvaticae.*

In our opinion the N_2-fixing activity of non-symbiotic microorganisms in the rooting zone depends first of all on the amounts and chemical composition of root exudates. Metabolic byproducts and nutrient competition by other organisms also act significantly. The more the C- and energy-source available for the free N_2-fixing microorganisms, and the smaller the number of the antagonistic organisms, the more likely will be the higher N_2-fixing activity.

Conclusions from the N_2-fixing activity on the amount of N_2 actually fixed per ha can be drawn only with great caution, since it also depends on the weights of litter and roots, on the thickness and volume weights of the genetic horizons of soil examined, as well as on the depth of the whole profile.

The amount of N_2-fixed in the soil profile during the vegetation period was largest under the thinned *Fagetum silvaticae* ecosystem, followed in a decreasing order by the unthinned stand, the *Orno-Quercetum pubescenti-cerris* —and finally—with an essentially lower value—by the *Piceetum excelsae* cultum ecosystem.

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QUANTITATIVE EVALUATION OF NITROGEN FIXATION BY CHICKPEA (*CICER ARIETINUM* L.) AS AFFECTED BY NITROGENOUS AND PHOSPHATIC FERTILIZATION IN SANDY LOAM SOIL

C. S. Singh, K. V. B. R. Tilak and N. S. Subba Rao

DIVISION OF MICROBIOLOGY, INDIAN AGRICULTURAL RESEARCH INSTITUTE, NEW DELHI, INDIA

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The field experiments were conducted with chickpea (*Cicer arietinum* L.) to assess the nitrogen fixation by using a labelled ammonium sulphate fertilizer in a sandy loam soil. In the first experiment done in 1979, two levels of nitrogen (20 and 100 kg N/ha) were used with barley (*Hordeum vulgare* L.) and sudan grass (*Sorghum vulgare* L. var. *sudanense*) as control crops. It was observed that the nodulation and nitrogen fixation by chickpea var. C 130 was higher at the 100 kg N/ha than at the 20 kg N/ha level. The nitrogen fixation at this level of fertilizer was 50.19 and 75.51 kg N/ha when compared with sudan grass and barley as the non-legume control crops, respectively. In the second experiment done in 1980, the performance of chickpea var. BG 215 was studied at two levels of phosphorous (80 and 100 kg P_2O_5/ha) in the presence of 20 kg N/ha applied as $(^{15}NH_4)_2SO_4$ using barley as a non-legume control crop. Even though the levels of phosphorous were admittedly narrower, a marked increase in nitrogen fixation at 100 kg P_2O_5/ha over 80 kg P_2O_5/ha was noticed.

Keywords: *Cicer arietinum* L., chickpea, nitrogen fixation, N- and P-fertilization

Introduction

Chickpea (*Cicer arietinum* L.) is a very important and suitable pulse crop for rain-fed agriculture in the winter season. Reports indicate that the grain legumes, in general, respond well to application of small amounts of a starter nitrogen (Pal and Saxena 1974, Prasad and Subbaiah 1982, Subba Rao 1976). In the case of chickpea on the alluvial and the red and yellow soils of India, responses as high as 25–26 kg grain/kg N were noticed (Prasad and Subbaiah 1982). It has also been reported by several workers that the application of a phosphate is highly beneficial to legumes in improving the grain yield and the nitrogen fixation by legumes (Sankaram et al. 1963, Khare and Rai 1968, Singh et al. 1976, Shukla and Yadav 1982). However, there is a paucity of information on the quantitative estimation of nitrogen fixation by the inoculated chickpea, as influenced by nitrogenous and phosphatic fertilizations. This paper, therefore, deals with the field experiments on the quantitative evaluation of the nitrogen fixation by chickpea using a labelled ammonium sulphate fertilizer.

Material and methods

The first experiment was laid out in 1979 in a randomized block design with the following treatments:

1. Non-legume$_1$ (sudan grass) at N_{20}
2. Non-legume$_2$ (barley) at N_{20}
3. Chickpea at N_{20}
4. Chickpea + sudan grass at N_{20}
5. Sudan grass at N_{100}
6. Barley at N_{20}
7. Chickpea at N_{100}
8. Chickpea + sudan grass at N_{100}

The treatments were replicated four times and the plot size was 3.5×2.4 m.

Chickpea var. G 130, barley var. Jyoti and sudan grass (seed obtained from IAEA, Vienna, Austria) were used. The soil received a uniform application of 100 kg P_2O_5/ha and 40 kg K_2O in the forms of superphosphate and muriate of potash, respectively, before sowing.

The second field experiment was laid out during the year 1980 in a simple randomized design with the following treatments:

1. Non-legume (barley) at 100 kg N/ha + 80 kg P_2O_5/ha
2. Non-legume (barley) at 100 kg N/ha + 100 kg P_2O_5/ha
3. Legume (chickpea) at 20 kg N/ha + 80 kg P_2O_5/ha
4. Legume (chickpea) at 20 kg N/ha + 100 kg P_2O_5/ha

Potash at the rate of 40 kg K_2O/ha was applied to all plots in the form of a muriate of potash at the time of sowing. A phosphatic fertilization was also made at the time of sowing in the form of a superphosphate. The treatments were replicated six times and the plot size was 3.5×8.0 m. Chickpea var. BG 215 and barley var. DL 165 were used.

The seeds of chickpea were inoculated with *Rhizobium* culture, obtained from Joe Burton of Nitragin Co., Wisconsin, USA.

Nitrogen was applied in the form of an ammonium sulphate. One square meter was demarcated at the centre of each plot for applying a labelled nitrogenous fertilizer in the form of $(^{15}NH_4)_2SO_4$ at the rates of 20 and 100 kg N/ha levels, wherever needed.

The dry weight of plants and the nodulation (number and dry weight) were recorded at different stages of the crop growth, and the grain yield was recorded at the time of the crop maturity (145 days after sowing). The plant samples were subjected to a nitrogen analysis at the different stages of crop growth by the micro-kjeldahl method (Jackson 1967). The plant samples were also analyzed for ^{15}N enrichment at the Seibersdorf Laboratory, IAEA, Vienna, Austria. The nitrogen fixation by the legume was calculated by employing the formula proposed by Fried and Middelboe (1977), as given below:

$$N_2\text{-fixed by legume} = \frac{\text{Atom \% } ^{15}\text{N excess (legume)}}{\text{Atom \% } ^{15}\text{N excess (non-legume)}} \times \text{total N in the legume crop.}$$

Results and discussion

It was obvious that the nodulation (both number and dry weight) and dry matter content of the plant increased with an increase in crop age in both the experiments (Tables 1 and 4). It was also evident that the number and weight of nodules per plant were slightly higher at 20 kg N/ha, suggesting that the application of N in the form of an ammonium sulphate at higher levels did not affect the root nodulation in the C 130 variety of chickpea indicating a synergistic effect in the use of biological and mineral N by the

legume. Pate and Dart (1961) noticed that low levels of N increased the nodules on the tap root of 3 legumes. Vincent (1965) observed progressive reduction of the nodule tissue with increasing N levels. According to Lie (1974), the nodule inhibition, formation and activity depend on the level and source of N employed. Islam and Saxena (1981) observed that in those plots where there was a low plant population of chickpea (16.6 plants/m^2), the contribution of symbiosis to the total N yield was much higher and the higher rate of N (100 kg N/ha) showed no adverse effect on the symbiotic nitrogen fixation. In the present study it was also observed that the root nodulation was more at a 100 kg N/ha than at a 20 kg N/ha level (Table 1).

The results presented in Table 2 show that there was a higher concentration of N in the plants at the early stages of the crop growth (30 days) than at the later stages, indicating a greater accumulation of the nutrient at early stages than at the later stages of the crop growth in proportion to the increase in age of dry matter, which may be ascribed to the greater absorbing power of actively growing roots at the early stages of the plant growth. As would be expected, the N concentration in the root and the shoot (excluding grain) decreased with the advancement in the age of the plant, but the decrease in the shoot (stem, leaf and pods) was more pronounced, especially at 90 days of

Table 1

Effect of nitrogen fertilization on nodulation and dry weight (g) of shoot at different stages of crop growth

	Number of nodules/plant						Dry weight of nodules/plant			Dry weight of shoot		
	Primary roots			Lateral roots			g					
	A	B	C	A	B	C	A	B	C	A	B	C
Chickpea, N_{20}	4.5	1.5	8.7	0.6	3.5	22.7	0.001	0.008	0.17	1.01	18.7	46.0
Chickpea + Sudan grass, N_{20}	4.7	1.3	8.2	0.3	4.3	26.7	0.005	0.013	0.24	1.31	48.3	36.4 (36.9)*
Chickpea, N_{100}	7.6	1.0	8.7	0.24	4.0	30.8	0.01	0.007	0.21	1.01	23.6	58.0
Chickpea + Sudan grass, N_{100}	7.7	1.3	7.6	0.2	3.0	29.6	0.008	0.007	0.17	1.18	52.9	68.0 (23.1)
Barley, N_{20}										0.96	15.0	66.3
Barley, N_{100}										0.98	19.9	90.6
Sudan grass, N_{20}										0.51	10.3	34.9
Sudan grass, N_{100}										0.72	14.2	37.1

A: 30 days; B: 90 days; C: 110 days
* Figures in parentheses represent dry weight of Sudan grass

Table 2

Nitrogen concentration (%) as influenced by nitrogen fertilization at different stages of crop growth

Treatments		Root (R) / Stem (S)	Nitrogen per cent			Harvest (140 days*)
			30 days	90 days	110 days	
Sudan grass	N_{20}	R	2.90	1.20	0.84	1.26
		S	4.69	1.82	1.57	
Barley	N_{20}	R	2.73	0.65	0.56	1.56
		S	2.53	1.18	1.40	
Chickpea	N_{20}	R	2.80	1.70	1.68	4.14
		S	6.94	2.94	3.31	
Chickpea + sudan grass	N_{20}	Chickpea R	2.66	2.56	1.90	3.86
		S	6.00	3.24	3.40	
		S. grass R	2.80	1.54	1.23	1.45
		S	4.90	2.99	2.05	
Sudan grass	N_{100}	R	1.94	1.45	1.76	1.48
		S	5.11	2.73	1.18	
Barley	N_{100}	R	2.86	0.56	0.54	1.93
		S	6.55	1.99	1.43	
Chickpea	N_{100}	R	2.52	1.99	1.43	4.26
		S	5.60	3.64	3.24	
Chickpea + sudan grass	N_{100}	Chickpea R	2.50	2.14	1.50	3.80
		S	6.40	3.70	2.97	
		S. grass R	2.40	1.56	1.12	1.53
		S	5.71	2.90	1.63	

* Per cent N in grain samples of chickpea and barley and in the fodder of sudan grass.

the crop growth than at the early stages which may be due to the dilution effect, i.e. redistribution of N from these parts to the developing reproductive bodies. Similar results were obtained by other workers (Lathwell and Evans 1951, Hammond et al. 1951, Pal and Saxena 1974). The concentration of N in the root and the shoot was more with a 100 kg N/ha than with a 20 kg N/ha level.

The symbiotically fixed N in the grain and the grain yield of the legume was more at a 100 kg N/ha level than at a 20 kg N/ha (Table 3), suggesting that the symbiosis was not affected by the application of a higher level of N (100 kg N/ha) in this variety of chickpea because this particular variety of chickpea (C 130) may have needed more N-input for the formation of the nodules and the subsequent N fixation. At 100 kg N/ha, the nitrogen fixation by chickpea was more with the barley (75.51 kg N/ha) than with the Sudan grass (50.19 kg N/ha), suggesting that barley suits better as a control crop than does Sudan grass.

A reduction in the dry weight of the nodules, and the nitrogen fixation by the legume was noticed when chickpea was grown in alternate lines with

Table 3

Effect of N levels on yield and N_2-fixation by chickpea

Treatments	N level, kg/ha	Atomic % ^{15}N excess	Total yield* (kg/ha)	Total N yield (kg/ha)	N derived from fertilizer (%)	Fert. N uptake (kg/ha)	Utilization of fert. N	A value, kg (N/ha)	A fixed N (kg/ha)		N_2-fixation (kg N/ha)	
									1	2	1	2
Sudan grass	N_{20}	0.202	4113	51.82	4.03	2.08	10.38	477.83				
	N_{100}	0.326	5446	80.80	32.60	26.60	26.60	206.80				
Barley	N_{20}	0.428	5388	84.11	8.55	7.19	35.93	213.98				
	N_{100}	0.524	5640	109.17	52.54	57.22	57.22	90.75				
Chickpea	N_{20}	0.093	1879	77.85	1.85	1.47	7.36	1062.43	585.34	848.46	43.46	62.99
	N_{100}	0.189	2780	118.45	18.90	22.36	22.36	428.23	171.93	337.48	49.59	75.58
Chickpea + Sudan grass	N_{20}	Chickpea 0.104	1793	69.26	2.07	1.45	7.26	948.26	489.64	—	34.46	—
		S. grass 0.209	2297	33.46	4.18	1.39	6.96	458.62	—	—	—	—
Chickpea + Sudan grass	N_{100}	Chickpea 0.309	1700	64.50	30.93	19.93	19.93	223.40	75.85	—	15.12	—
		S. grass 0.404	2733	34.67	40.40	13.95	13.95	147.60	—	—	—	—

* Grain yield of chickpea and barley and fodder yield of Sudan grass.
1, 2: Compared to Sudan grass and barley, respectively as non-legume crops.

sudan grass at a 100 kg level over A 20 kg N/ha even though the crop yield was more at the 100 kg N/ha level (Tables 1, 3).

During the year 1980, a maximum nodulation and dry matter production were recorded at 90 days of the crop growth (Table 4). The importance of the application of a phosphorous for a better nodulation and symbiotic nitrogen fixation by different legumes has been well documented (Hallsworth 1958, Ohlrogge 1963, Singh et al. 1968, Shukla and Yadav 1982). The amount of N fixed as calculated from A value for the legume at 90 days of the crop growth with a 100 kg P_2O_5/ha application was superior to an 80 kg P_2O_5/ha level, although no such difference was noticed at 30 and 60 days of the crop growth (Table 5).

Table 4

Effect of phosphatic fertilization on nodulation of chickpea and dry matter production of chickpea and barley at different stages of crop growth

Crop	Treatment	Number of nodules/plant					
		Primary roots			Lateral roots		
		A	B	C	A	B	C
Chickpea	$N_{20}P_{80}$	2.45	7.32	36.31	8.03	22.97	10.36
	$N_{20}P_{100}$	2.05	8.22	38.02	7.87	24.70	12.04
Barley	$N_{100}P_{80}$						
	$N_{100}P_{100}$						

Crop	Treatment	Dry weight of nodules/plant (g)			Dry weight of shoot/plant (g)		
		A	B	C	A	B	C
Chickpea	$N_{20}P_{80}$	0.019	0.150	0.286	0.399	1.988	5.359
	$N_{20}P_{100}$	0.014	0.109	0.279	0.383	1.787	6.383
Barley	$N_{100}P_{80}$				0.995	4.973	8.200
	$N_{100}P_{100}$				1.30	4.412	8.138

A: 30 days; B: 60 days; C: 90 days

Table 5

Nitrogen fixation (kg/ha) by chickpea as influenced by different levels of phosphatic fertilization

Levels of phosphorous (kg P_2O_5/ha)	Stages of sampling (days)		
	30	60	90
80	4.87	11.12	23.63
100	3.87	11.18	33.23

Table 6

Effect of phosphorus levels on different aspects of nitrogen distribution and fixation in chickpea (average of 6 replications)

Treatment	Phosphorous level (kg P_2O_5/ha)		Yield (kg/ha)	% N	Total N yield (kg/ha)	Atomic % ^{15}N excess	% N diff.	Fert. N-uptake (kg/ha)	% utilization of Fert. N	"A" value	A fixed N (kg/ha)	N_2-fixation (kg/ha)
Chickpea	80	G	1879.76	3.519	65.98	0.113	2.25	1.51	7.57	754.25	640.40	44.42
(20 kg N/ha)		S	4139.76	1.398	58.33	0.139	2.79	1.59	7.97	716.25	427.31	32.49
Barley	80	G	4375.96	1.690	73.66	0.275	27.55	20.32	20.32	263.76		
(100 kg N/ha)		S	6496.12	0.724	46.34	0.258	25.82	12.01	12.01	289.04		
Chickpea	100	G	2022.72	3.500	70.52	0.106	2.12	1.52	7.60	975.85	728.14	49.49
(20 kg N/ha)		S	4594.55	1.376	64.24	0.151	3.01	1.77	7.04	714.66	435.54	39.31
Barley	100	G	4575.87	1.682	76.37	0.290	29.05	22.46	22.46	247.79		
(100 kg N/ha)		S	7041.59	0.680	48.02	0.278	12.78	12.78	12.78	264.12		

G = Grain; S = Straw

The application of 100 kg P_2O_5 + 20 kg N/ha in the present study brought an increase of 7.6 per cent grain yield of chickpea over an 80 kg P_2O_5 + 20 kg N/ha level (Table 6). This indicates that for 1 kg P_2O_5, an increase of 7.15 kg of the grain was obtainable. This increase is due to an increase in the nitrogen fixation by the legume, as evident from Table 6. A marked increase in the net N_2 fixation (in grain + straw) (88.8 kg N/ha) was noticed at a 100 kg P_2O_5/ha level over an 80 kg P_2O_3/ha level (76.91 kg N/ha) (Table 6).

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FORECASTING OF *CERCOSPORA BETICOLA* INFECTION WITH THE HELP OF A NEW PROGNOSTIC-APPARATUS AND A SPECIAL NOMOGRAM

I. SZEPESSY

DEPARTMENT OF PLANT PROTECTION OF THE UNIVERSITY FOR AGRICULTURAL SCIENCES, DEBRECEN, HUNGARY

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A great deal of chemicals are used against plant diseases that are carried on the leaf surface by vaporization and dusting. The treatments have to be repeated several times within a growing season. The number of treatments and the quantity of chemicals used can only be reduced if the protection is based on a reliable prognostic. In case of sugar beet leaf-blight, the "DEFI-DOFA" instrument is recommended for registration of infection (Fig. 1), that was already described in detail elsewhere (Szepessy 1985). For calculation of the incubation time a special nomogram (Fig. 2) was constructed. Using these instuments, the protection is going to be more successful, the time of vaporizations can be optimalized, the number of treatments can be reduced.

Keywords: *Cercospora beticola*, sugar beet, infection forecasting, prognostic apparatus

Introduction

For infection by *Cercospora beticola* condensed water has to be present on the leaf surface of sugar beet for 6 hours at least. The "DEFI-DOFA" instrument shown (Fig. 1) displays how long the leaf surface was wet ("h").

The temperature of the period during which the leaf remains wet ("active temperature") is also measured. These 2 data are multiplied by the instrument and shown as "T×h". If this number reaches 180, the infection has taken place. There is a considerable disease if the product of multiplication reaches 210. The incubation time is calculated from this point, on the nomogram (Fig. 2). The highest day and the lowest night temperature measured can be set by the horizontal line. If the upper branch of the vertical line is placed on the value of the highest relative vapour content measured, the lower branch of the same line shows the expectable length of incubation time calculated in days.

Material and methods

Our investigations were carried out in 1984 in a sugar beet field of 70 hectare. Plots of 1 hectare were separated for each treatment. The treatments are described in detail in Table 1. As it is seen protection against *Cercospora* is also combined with leaf fertilization. Accordingly there are such plots of land in the *A*-block in case of which leaf fertilization was not applied, and in *B*-block plots leaf fertilizer was sprayed on the foliage at the given time

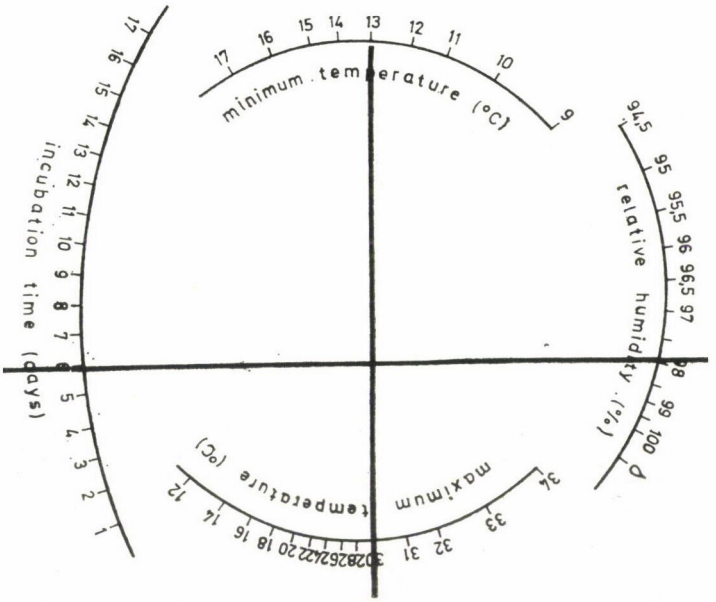

Fig. 1. Prognostic-apparatus for registration of infection

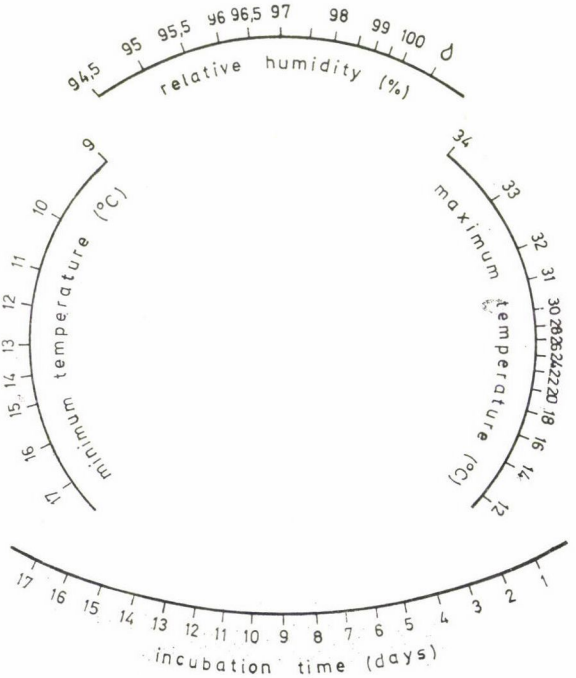

Fig. 2. Nomogram for calculating incubation time of *Cercospora beticola*

Table 1

Time of treatment in case of different experimental varieties

(1) Chemical used	(2) Time of treatments carried out on the various fields							
	A-1	B-1	A-2	B-2	A-3	B-3	A-4	B-4
Brestan 1.5 kg/ha	—	—	July 14	July 14	July 21	July 21	July 8	July 8
Miltox Special 3 kg/ha	—	—	—	—	—	—	July 27	July 27
Topsin Metil 70 WP 1.1 kg/ha	—	—	Aug. 7	Aug. 7	Aug. 13	Aug. 13	Aug. 19	Aug. 19
Peretrix (leaf fertilizer) 10 lit./ha	—	July 27	—	July 14	—	July 21	—	July 27

Protection against *Cercospora* has been grouped in the following way:

Plots No. 1 = without protection, fungicide was not used.

Plots No. 2 = on the basis of "DEFI-DOFA" reading, when in "h" position it shows 6 hours, in "T×h" position it shows 210 DFPM (dominant factor's product of multiplication) and it was sprayed immediately.

Plots No. 3 = On the basis of the "DEFI-DOFA" displayed values incubation time was calculated by the help of the nomogram. Sugar beet was sprayed after this time (Fig. 3).

Plots No. 4 = operative (routine) protection system. On the basis of experience and observation gathered during the previous years, after precipitation (rain) in the first place.

Fig. 3. Determination of incubation time in case of maximum temperature of 30 °C, minimum temperature of 13 °C and relative humidity of 98 per cent

Results

The results of the experiments were interesting and well utilizable in practice. In Table 2 data referring to the outbreak of the disease and the quality and quantity of the harvest are summarized.

Table 2

Effect of the different technologies on the harvest of sugar beet and appearance of Cercospora

(1) Marking	(2) Use of DEFI-DOFA	(3) Use of "DEFI-DOFA"l and nomogram	(4) Leaf ferti-ization	(5) Number of fungicide protections	(6) *Cercospora* %		(7) Digestion %		(8) Sugar production t/hectare
					Sep 1	Oct. 6	Sep. 1	Oct. 6	Oct. 6
A-1	—	—	—	—	42	14	11.57	13.94	4.53
B-1	—	—	+	—	41	19	11.41	13.83	4.64
A-2	+	—	—	2	12	17	12.08	15.41	5.05
B-2	+	—	+	2	10	14	12.19	15.54	5.15
A-3	+	+	—	2	7	9	12.17	15.81	5.11
B-3	+	+	+	2	4	7	11.94	16.14	5.40
A-4	—	—	—	3	13	12	11.84	15.13	4.88
B-4	—	—	+	3	19	12	12.07	15.00	5.01

It is clear that by using fungicide, *Cercospora beticola* can be pressed back, the sugar content of sugar beet and the average yield can be increased.

Moreover it was also proved that in case of instrumental protection system, fewer chemical treatments have to be applied than when using traditional technology. It has a great importance from economical—on the one hand—and environment protectional point of view—on the other. In addition to this the results (quantity, quality) are also better. As it follows from our experiments the "DEFI-DOFA" instrument is suitable for registration (appointing) of the time of *Cercospora beticola* infection. However, calculation of incubation time is also necessary for forecasting the infection. The nomogram shown was considered suitable for this purpose. It is advisible to spray the fungicide the day (or days) preceding the end of incubation time. Thus the treatment will be effective and the number of sprayings can also be reduced.

At last it has also to be taken into account that leaf fertilization will be economical provided that the plant is sound. In the given case the purposeful protection against *Cercospora* increased the positive effect of leaf fertilization.

Summary

The *Cercospora beticola* Sacc. fungus affects sugar beet year by year. The protection against it has to be carried out using fungicides.

The treatments will be effective, the number of sprayings can be reduced if the protection technology is based on prognostic. It is recommended to use "DEFI-DOFA" instrument for this purpose. With this instrument the time of infection can be registrated. After this comes the incubation period. Its length can be calculated using a nomogram. The necessary fungicide has to be sprayed during the days preceding the end of the incubation time.

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DIALLEL ANALYSIS OF PLANT AND EAR HEIGHT IN MAIZE

S. C. DEBNATH[1] and K. R. SARKAR

GENETICS DIVISION, INDIAN AGRICULTURAL RESEARCH INSTITUTE, NEW DELHI, INDIA

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Nine maize (*Zea mays* L.) inbreds and all their possible hybrids (excluding reciprocals) were analysed by the diallel method to elucidate the combining ability and the nature of inheritance of plant and ear height. The genotype × environment interaction analysis indicated greater importance of general combining ability (g.c.a.) × environment interaction than that of specific combining ability (s.c.a.) × environment for both characters. The parental performance seemed to be a good indicator of g.c.a. effects. Graphical as well as variance component analysis revealed the presence of partial to complete dominance in the inheritance of plant and ear height.

Keywords: *Zea mays*, diallel cross, combining ability, plant height, ear height

Introduction

Maize (*Zea mays* L.) is one of the leading cereals whose high per hectare yield can play an important role in reducing world food crisis. Considerable lodging occurs in many high-eared maize inbreds and hybrids when grown under modern maize production practices. Hence, breeding for low plant and ear height are also important objectives in a maize breeding programme. An understanding on the genetic architecture of the parents and the nature of gene action for plant and ear height is needed to determine the most effective breeding procedures necessary for a maize improvement programme. The present study was, therefore, taken up to elucidate the inheritance of plant and ear height, by analysing the performance of progeny from contrasting parents tested over three environments.

Material and methods

Nine inbreds and their 36 single crosses (excluding reciprocals) were grown in Delhi during kharif seasons of 1979 and 1980, and in Hyderabad during rabi season of 1980–81 in India. These were considered as 3 separate environments and were designated as E_1, E_2 and E_3, respectively. The diallel was developed at Maize Research Station, Amberpet Farm, Hyderabad, during rabi season of 1978–79. Details of the pedigrees and codes of the parental lines used are presented in Table 1.

[1] Present address: Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Resistenzgenetik, D-8059, Grünbach, West Germany.

Table 1

Pedigrees and codes of the parental maize lines

Original pedigree*	Code
1. Eto 25 — f — # — 1 — f³ — # — # — # — #	P1
2. CM 201: G715 — A1 — 2 — #	P2
3. CM 105: Peru 330 — # — 23B — 1 — f — f	P3
4. Eto 81 #³ — 2 — # — 2 — # — # — 2B — f — # — # — #	P4
5. Eto 297 — f — # — # — 6 — # — # — 1 bulk — # — # — #	P5
6. Eto 182 — (C) — 1 — 2 — 1 — f³ — 4 — 4 — 1 — # — 1 — f — f — #	P6
7. Syn C (8B) — # — # — 1 — 1 — f — #	P7
8. Cuba 43 — #² — 1 — 3 — # — 2 — f³ — f — # — #	P8
9. CM 110: PH3 — A — 6 — # — 1 — # — # — 1 — 1 — f — # — #	P9

* All these lines were further selfed for at least two generations

Experimental design was a randomized complete block with 3 replications. Each experimental plot consisted of 2 rows, both 5 meters long, with a row-to-row spacing of 0.75 m and a plant-to-plant distance of 0.25 m. Data for plant and ear height in cm were taken on 10 fully competitive plants in each plot. Ear height was recorded as the distance from the base of the plant to the top ear node attachment. Plant height was measured as the distance to the tip of the centre spike tassel. Statistical analyses were made on an entry mean basis. The combining ability analysis for each location was carried out following model 1 (fixed effect model) and method 2 (parents and one set of F_1's) described by Griffing (1965b). Pooled analysis over environments was done as per the procedure suggested by Singh (1973, 1979) for model 1 method 2. Relative importance of general combining ability (g.c.a) and specific combining ability (s.c.a.) was calculated by the ratio $2\sigma_g/(2\sigma_g + \sigma_s)$ given by Baker (1978) for fixed effect model, where σ_g and σ_s are the equivalent component of g.c.a and s.c.a, respectively. Heritability in narrow sense was estimated as suggested by Prem Narain et al. (1979).

$$\text{Heritability in narrow sense} = \frac{V_A}{V_A + V_D + V_E}$$

where, $V_A = 2\sigma_g$; $V_D = \sigma_s$ and V_E = error variance in the absence of epistasis.

Simple correlation between the g.c.a effects of the parents and the parental means was calculated for both characters using standard procedure.

While Griffing's (1956b) analysis is useful to breeders, Hayman's (1954) analysis is particularly useful for evaluating the mode of inheritance. Mather and Jinks (1971) have concluded that Hayman's (1954) analysis is the most useful for determining significance of principal genetic components. Hayman's (1954) analysis makes several assumptions that must be satisfied if this technique is to be considered appropriate for a given data set. The appropriateness of Hayman's (1954) analysis can best be considered through the use of 2 tests (Mather and Jinks 1971). The first test is a joint regression analysis of the array (row or column) variances (Vr) versus the parent-offspring covariances (Wr); the second test is an analysis of variance of (Wr — Vr). Array differences must be significant. Only if the joint regression reveals a unit slope and constant position across replications, and the analysis of variance shows consistency of (Wr — Vr), should Hayman's (1954) analysis be continued.

The genetic analysis based on the diallel cross technique of Hayman (1954) was described by Mather and Jinks (1971).

Results and discussion

Mean squares due to general combining ability (g.c.a) and specific combining ability (s.c.a) were highly significant for plant and ear height in each environment as well as in pooled analysis (Table 2). The variance due to g.c.a. contains only additive variance and epistatic interaction of the type of additive × additive, additive × additive × additive, etc., while s.c.a variance involves dominance variance and all types of epistatic interactions including also additive × additive, etc. (Griffing 1956a). Hence the g.c.a variance contains mainly the additive portion of genetic variance while the s.c.a, the non-additive portion. So the present study indicates the importance of both additive and non-additive component of variation in the inheritance of these characters.

The combined analysis of combining ability for both characters showed that g.c.a × E (environment) interaction variance was highly significant while the s.c.a × E interaction variance was non-significant (Table 2). This suggests

Table 2

Analysis of variance for combining ability

Source d.f.		Mean squares			
		Plant height			
		E_1	E_2	E_3	Pooled
G.c.a	8	608.29**	732.02**	1270.94**	2 280.22**
S.c.a	36	194.88**	226.46**	191.88**	512.52**
Error	88	30.09	39.32	90.08	
Environment (E)	2				2 860.44**
G.c.a × E	16				165.43**
S.c.a × E	72				50.34
Pooled error	264				53.13

Source d.f.		Mean squared			
		Ear height			
		E_1	E_2	E_3	Pooled
G.c.a	8	435.15**	243.61**	962.28**	1 415.57**
S.c.a	36	73.24**	70.68**	99.70**	200.14**
Error	88	13.62	13.92	33.08	
Environment (E)	2				13 193.81**
G.c.a × E	16				112.66**
S.c.a × E	72				21.74
Pooled error	264				20.21

** Significant at 1% level

Table 3

Estimates of components of g.c.a (σ_g) and s.c.a (σ_s), relative importance of g.c.a and s.c.a $\{2\sigma_g/(2\sigma_g + \sigma_s)\}$ and heritability percentage (h^2) in narrow sense

	Plant height				Ear height			
	E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
σ_g	52.56	62.98	107.35	67.49	38.32	20.88	84.47	42.28
σ_s	164.79	187.23	101.80	153.13	59.69	56.76	66.62	59.98
$\frac{2\sigma_g}{(2\sigma_g + \sigma_s)}$	0.39	0.40	0.68	0.47	0.56	0.42	0.72	0.59
h^2	35.04	35.74	52.80	39.56	51.11	37.14	62.89	51.33

that only the additive effects are influenced by environment while the non-additive effects are quite stable over environments. Hence, the g.c.a should be evaluated over each environment and studied separately. The s.c.a effects were consistent over 3 environments and the effects obtained from the pooled values would, generally, give correct position. The results were in agreement with Russell (1976), Cross (1977) and Younes and Andrew (1978), who observed that environmental interactions were more important for the additive gene effects than for non-additive gene effects.

The relative importance of g.c.a. is presented in Table 3. Pooled analysis as well as individual analyses in most of the cases indicated that the values of the ratio $2\sigma_g/(2\sigma_g + \sigma_s)$ for both plant and ear height were close to 0.5, indicating more or less equal importance of both g.c.a and s.c.a in the inheritance of these characters. Predominant additive genetic variance in the inheritance of plant and ear height was observed by Russell (1976), Krolikowski (1977), Harville et al. (1978) and Nawar et al. (1980), while Darrah and Hallauer (1972), S. B. Singh (1979) and Rood and Major (1981) reported over-dominance as well as a greater role of the non-additive component of variation.

The heritability estimates were lower for plant height than for ear height, both individually and in pooled analysis (Table 3). Hence, selection for ear height will confer rapid improvement compared to plant height.

The estimates of g.c.a effects and the *per se* performance of the parents for plant and ear height are presented in Tables 4 and 5, respectively. Negative estimates were desirable since they were correlated with shorter plant and ear height. Parents were classified as good, average and poor combiners, on the basis of their g.c.a effects. Inbreds with negative g.c.a effects significantly different from zero were considered good combiners, while parents showing insignificant estimates were classified as average combiners. Poor combiners had significant but positive g.c.a effects.

Pooled analysis showed that parents P1, P4, P6, and P8 were good general combiners for plant height, and parents P2, P5, P6, and P8 for ear height. Parent P3 was the poorest combiner, having highest significant positive estimates both for plant and ear height, and it was followed by P9 and P7.

The parents that showed consistent g.c.a effects for plant height in all 3 environments were P3, P4, P6, and P9; while for ear height, all parents except P5 were more or less very consistent over environments. Since the parents P6 and P8 had a concentration of favourable alleles for both plant and ear height, they were considered as the best parents among the 9 inbreds studied. These parents appeared worthy of exploiting in practical plant breeding utilizing the fixable components of variation.

The correlation coefficients between the g.c.a effects of the parents and the parental means for plant and ear height were positive and significant in individual and combined analyses (Table 4, 5). This indicates that the *per se* performance of the parents bear direct reflection of their respective g.c.a effects for both characters. It is also evident trom Tables 4 and 5 that most of the parents whit good g.c.a performance for plant height had also desirable g.c.a effects for ear height, which might be due to positive correlation between plant height and ear height.

Regarding the s.c.a. effects of the crosses, it was noticed that for plant height 13 crosses, ranging from −10.16 for the cross P3 × P7 to 15.58 for P1 × P4, had significant s.c.a. effects. Except the cross P3 × P7, a poor × poor combination, all had positive estimates. The worst hybrid P1 × P4 involved good × good combiners. Number of crosses showing significant s.c.a effects for plant height in E_1, E_2 and E_3 were 9, 8, and 1, respectively, all but P3 × P7 in E_1 having positive estimates.

Estimates of s.c.a effects for ear height in pooled analysis were significant for 13 crosses, 4 with negative and 9 with positive estimates, ranging from −7.32 for P3 × P9 (poor × poor) to 9.65 for the cross P1 × P4. The other 3 crosses having significant desirable s.c.a. effects in pooled analysis were P3 × P7 (poor × poor), P2 × P3 (good × poor) and P6 × P8 (good × good). Individual environment analyses for ear height indicated that 6 crosses in E_1, 11 in E_2 and 3 in E_3 had significant estimates, among which only P2 × P3 and P3 × P7 in E_2 and P3 × P9 in E_3 contributed negatively.

A comparison of the combining ability effects of the parents and corresponding crosses indicates that, in most of the cases, the g.c.a effects of the parents were not reflected in the s.c.a effects of the crosses in both characters. Thus in most cases, crossing 2 good combiners did not necessarily result in a good specific combination and the same was also true for the poor combiners. This emphasizes the need for actual crossing and testing of the single crosses in the hybrid programme. From the present results, it would be concluded that the prediction of hybrid performance based on their parental performance

Table 4

G.c.a effects and mean values (cm) of the nine inbreds along with correlation coefficient (r) between g.c.a effects and inbred means for plant height

Parents	E_1		E_2		E_3		Pooled	
	Effects	Means	Effects	Means	Effects	Means	Effects	Means
P1	— 4.68**	144.86	— 4.61*	139.56	— 1.78	168.53	— 3.69**	150.98
P2	— 1.09	159.46	— 3.74*	138.36	— 1.70	164.20	— 2.18	154.01
P3	9.21**	195.56	10.97**	188.33	16.78**	218.36	12.32**	200.75
P4	— 3.70*	145.66	— 8.16**	129.76	—10.24**	145.20	— 7.37**	140.21
P5	3.59*	157.43	6.37**	166.23	— 8.40**	148.86	0.52	157.51
P6	—12.36**	141.36	—11.21**	132.13	—11.55**	147.13	—11.71**	140.21
P7	3.91*	174.73	1.43	172.16	10.20**	200.46	5.18**	182.45
P8	— 5.41**	150.70	— 2.64	165.63	— 6.68*	154.40	— 4.91**	156.91
P9	10.52**	189.16	11.16**	189.56	13.38**	210.33	11.83**	196.35
S.E. $\pm$ (g_i)	1.52		1.74		2.63		1.19	
S.E. $\pm$ ($g_i - g_j$)	2.28		2.60		3.95		1.79	
S.E. $\pm$ (Mean)		5.48		6.26		9.49		2.43
r	0.92**		0.93**		1.00**		0.97**	

*, ** Significant at 5% and 1% level, respectively

Table 5

G.c.a effects and mean values (cm) of the nine inbreds along with correlation coefficient (r) between g.c.a effects and inbred means for ear height

Parents	E_1		E_2		E_3		Pooled	
	Effects	Means	Effects	Means	Effects	Means	Effects	Means
P1	— 0.85	66.66	—0.42	57.20	2.55	99.96	0.43	74.44
P2	— 6.05**	62.10	—5.41**	53.46	— 3.33*	88.46	—4.93**	68.01
P3	9.90**	101.13	8.22**	89.50	15.31**	137.50	11.14**	109.38
P4	— 0.11	58.20	—1.49	56.20	— 2.47	78.66	—1.36	64.35
P5	0.29	66.60	0.21	62.93	— 9.17**	72.36	—2.89**	67.30
P6	— 3.68**	70.40	—3.97**	59.56	— 5.99**	91.66	—4.54**	73.87
P7	3.85**	83.63	2.64*	77.06	8.87**	116.93	5.12**	92.54
P8	—10.25**	57.13	—5.14**	65.36	—13.53**	74.03	—9.64**	65.51
P9	6.89**	84.76	5.36**	80.26	7.75**	115.06	6.67**	93.36
S.E. $\pm$ (g_i)	1.02		1.03		1.59		0.73	
S.E. $\pm$ ($g_i - g_j$)	1.53		1.55		2.39		1.10	
S.E. $\pm$ (Mean)		3.69		3.73		5.75		1.50
r	0.87**		0.88**		0.95**		0.92**	

*, ** Significant at 5% and 1% level, respectively

is probably unsatisfactory, since in most cases both *per se* performance and g.c.a performance of the parents were not reflected in s.c.a effects of the crosses.

The results from s.c.a estimates indicates that the cross P3 × P7, which has significant desirable effects both for plant and ear height, may be considered as the best among the crosses with respect to plant and ear height; and the inbreds P3 and P7 can be utilized in future breeding programme to exploit non-additive component of variation.

The best 5 hybrids on the basis of *per se* performance, along with their respective s.c.a effects, are presented in Table 6. With respect to *per se* per-

Table 6

Best five hybrids on the basis of per se performance in order of magnitude along with their respective s.c.a effects

	E_1		E_2		E_3		Pooled	
	Hybrids	SCA effects	Hybrids	SCA effects	Hybrids	SCA effects	Hybrids	SCA effects
Plant height	P6 × P8	−7.60	P6 × P8	−4.41	P4 × P6	−5.00	P4 × P6	0.89
	P1 × P8	−3.82	P4 × P6	2.91	P2 × P6	0.59	P6 × P8	3.41
	P2 × P6	0.81	P1 × P7	−9.59	P5 × P8	2.55	P2 × P6	3.29
	P4 × P6	4.75	P7 × P8	−9.69	P4 × P8	6.99	P1 × P8	0.77
	P1 × P6	11.77*	P2 × P6	8.45	P1 × P6	4.44	P1 × P6	8.96*
Ear height	P6 × P8	−5.22	P6 × P8	−3.58	P6 × P8	−7.52	P6 × P8	−5.44*
	P2 × P8	−0.25	P4 × P6	−2.36	P5 × P8	−3.28	P2 × P8	3.45
	P1 × P8	−0.35	P7 × P8	−4.55	P2 × P5	−2.14	P5 × P8	2.15
	P7 × P8	−3.35	P2 × P4	0.18	P4 × P6	−5.45	P1 × P8	1.04
	P2 × P6	2.92	P4 × P8	0.65	P2 × P8	5.55	P7 × P8	−3.23

* Significant at 5% level

formance, the crosses P6 × P8 and P1 × P8 were among the best 5 hybrids in combined analysis for plant and ear height. It is evident from Table 6 that the best hybrid P3 × P7 with respect to desirable significant s.c.a effects for plant and ear height was not, however, among the best 5 hybrids on the basis of *per se* performance. This indicates that *per se* performances of the crosses do not reflect in their respective s.c.a effects.

Genetic analysis revealed highly significant genotype effects ($P < 0.01$) for both characters in all 3 environments. Variance of each row (Vr), and the covariance between the parents and their F_1 hybrids in each row (Wr), were calculated for each member of the array (Mather and Jinks 1971). Differences in the sum of variances and covariance (Wr + Vr) across replicates were significant ($P < 0.01$) indicating that non-additive genetic variation existed for plant and ear height. Differences between covariances and variances

(Wr — Vr) were not significant, indicating that non-additive variation occurred solely in the form of independently distributed dominance effects (Mather and Jinks 1971).

Joint regression analysis of Wr versus Vr was highly significant ($P < 0.01$) and replicates within all environments were in agreement with respect to member position in both plant and ear height. The linear regression coefficient (b) differed significantly from zero but not significantly from unity (Figs 1, 2). Thus, analysis of the (Wr — Vr) and regression offered support for the adequacy of the simple model of inheritance for plant and ear height. In the graphs for both plant and ear height in E_1 and E_2, the Wr intercept was near the

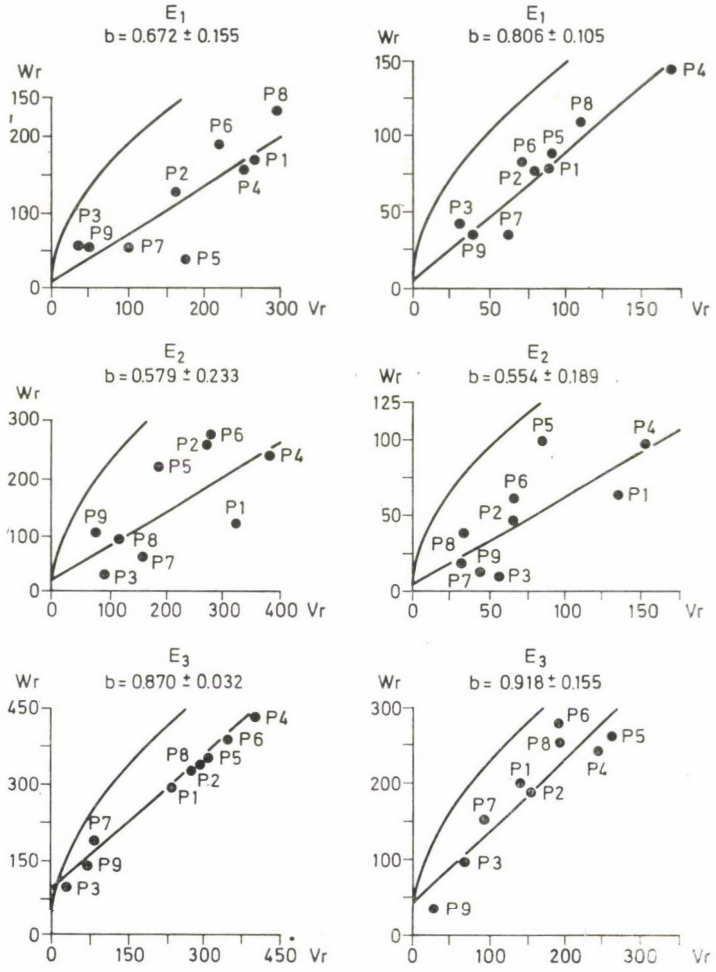

Fig. 1. Wr/Vr graphs for plant height in maize
Fig. 2. Wr/Vr graphs for ear height in maize

origin indicating that dominance was almost complete. The positive intercept of the Wr/Vr graphs (Figs 1, 2) in E_3 indicates that dominance for ear and plant height was incomplete. Position of array members showed that inbreds P3, P7, and P9 were closest to the Wr intercept indicating that they contain principally dominant alleles for plant and ear height (Figs 1, 2). These inbreds had highest plant and ear height as well as highest positive g.c.a estimates (Tables 4, 5). Parents P4 and P6 had maximum recessive alleles for plant height and only P4 for ear height in all three environments. P4 and P6 had the shortest plant height and P4 had the shortest ear height (Tables 4, 5). Thus, from the graphs, incomplete to complete dominance for increased plant height was observed.

A comparison of the scatter of the array members in the (Wr/Vr) graph (Figs 1, 2) and the g.c.a effects of the parents (Tables 4, 5) indicates that, in most of the cases, parents having more of dominant alleles also contain high GCA effects, and vice versa for both characters. However, the relationship is more for plant height than for ear height. Again, the scatter of all array members and the degree of dominance from graphical analysis are not constant in all 3 environments. This might be due to the genotype $\times$ environment interaction which was also observed in combining ability analysis pooled over environments. Thus, the results of graphical analysis confirms the results of combining ability analysis.

Both additive (D) and dominance (H_1 and H_2) components were involved in the control of plant and ear height (Table 7), confirming the conclusion from (Wr — Vr) values as well as from analysis of variance for combining ability where both additive and non-additive components were found important in the inheritance of these characters (Table 2). H_1 and H_2 were unequal for both characters except in E_3 for plant height, indicating that positive (u) (increasing plant and ear height) and negative (v) alleles were not equal. The values of $H_2/4\ H_1$ confirmed this conclusion since the ratio $H_2/4\ H_1$ was less than 0.25 in all cases except in E_3 for plant height indicating that positive (increased height) and negative alleles frequencies were unequal in the parent inbreds (Table 7). The F values were positive and highly significant in all 3 environments for both characters, indicating that there were more dominant than recessive alleles in the parent inbreds regardless of positive and negative direction. The dominance ratio $(H_1/D)^{0.5}$ was almost 1.0 in E_1 and E_2 indicating that dominance for increased plant and ear height was almost complete. In E_3, however, the ratio of $(H_1/D)^{0.5}$ was smaller than 1.0, suggesting partial dominance in the inheritance of both characters. The degree of dominance observed in Wr/Vr graph confirmed these findings. These results also correlate with that of relative importance of g.c.a and s.c.a where these components were observed to be more or less of equal importance in the inheritance of plant and ear height (Table 3).

Table 7

Analysis of genetic variation for plant and ear height

Components of variation/Derived values	Plant height			Ear height		
	E_1	E_2	E_3	E_1	E_2	E_3
D	365.88 ±36.77**	515.11 ± 60.52**	744.17 ±15.54**	200.86 ±10.53**	142.77 ±22.25**	459.61 ±25.16**
H_1	465.76 ±81.16**	602.03 ±133.59**	176.06 ±34.31**	198.87 ±23.24**	201.93 ±49.12**	211.39 ±55.53**
H_2	384.84 ±69.77**	482.23 ±114.84**	173.28 ±29.50**	135.99 ±19.98**	157.27 ±42.22**	168.37 ±47.73**
F	256.42 ±85.78**	419.69 ±141.20**	386.97 ±36.27**	109.61 ±24.57**	108.97 ±51.91*	183.99 ±58.69**
$(H_1/D)^{0.5}$	1.13	1.08	0.49	1.00	1.19	0.68
$H_2/4H_1$	0.21	0.20	0.25	0.17	0.19	0.20

*, ** Significant at 5% and 1% level, respectively

This study therefore, indicates that it is difficult to attain simultaneous improvement for both characters, as there is involvement of both additive and non-additive genetic components. The combined improvement of such characters should be based upon exploitation of both components of genetic variance. Breeding methods such as reciprocal recurrent selection and full-sib family selection may be followed to exploit both additive and non-additive components in the population derived from these parents.

Summary

Nine maize (*Zea mays* L.) inbreds and all their possible hybrids (excluding reciprocals) were analyzed by the diallel method to elucidate the combining ability and the nature of inheritance of plant and ear height. Both additive and non-additive genes were important for both characters studied. The results from the genotype × environment interaction analysis indicated greater importance of general combining ability (g.c.a) × environment interaction than that of specific combining ability (s.c.a) × environment for both characters. The heritability estimates were higher for ear height than that of plant height. The parental performance seemed to be a good indicator of g.c.a effects. Parents P1, P4, P6, and P8 were good general combiners for plant height and parents P2, P5, P6, and P8 for ear height. The cross P3 × P7 exhibited desirable s.c.a effect for plant and ear height while the crosses P3 × P9, P2 × P3, and P6 × P8 for only plant height. Graphical as well as variance component analysis revealed the presence of partial to complete dominance in the inheritance of plant and ear height. The results from Vr — Wr graph and variance component analysis correlated with those of combining ability analysis.

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DIALLEL ANALYSIS FOR COMBINING ABILITY IN PEA

S. P. SINGH* and R. P. SINGH
CROP RESEARCH STATION, GHAGHRAGHAT, BAHRAICH, INDIA

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A diallel analysis for the combining ability in pea revealed that the g.c.a. and s.c.a. variances were significant for all the traits with a preponderance of additive gene action. A high heritability estimate was observed for 100 grain weight in both the generations. The parents T 163 and A 87 were superior on the basis of their g.c.a. effects. In specific cross combinations, generally high × low and low × low combiners were involved. The five crosses T 163 × B 58, T 163 × Silma, B 58 × M 45, K 56 × M 45, and K 56 × A 137 showed A significant s.c.a. effect for grain yield per plant in both the generations.

Keywords: *Pisum sativum* L., pea, combining ability, heritability

Introduction

The ability of parents to combine well depends upon various complex genic interactions, which cannot be fully judged by phenotypic performance and adaptation qualities. The combining ability gives indications of the genetic behaviour of the parental material. It is, therefore, desirable to select the parents for hybridization on the basis of their combining ability. The earlier studies on combining ability in pea are very scanty and dealt with only a few characters involving a limited number of varieties. Therefore, the present study was undertaken on an 8 × 8 diallel cross to derive information on the general and specific combining ability variances and the effects for six quantitative characters.

Material and methods

A set of eight varieties of pea (*Pisum sativum* L.) including four high combiners (T 163, T 9, M 45, A 87) and four low combiners (Silma, K 56, A 37 and B 58) was involved in all possible combinations to produce 28 F_1s (one way crosses) in 1978–79. The resultant 28 F_1s along with their 8 parents were grown in 1979–80, and 28 F_2's and their 8 parents in 1980–81, in a randomized block design with three replications. Each F_1 was represented by a single row plot, and F_2 and parents by a four-row plot five meters long. The spacing was kept at

* Present address: CIMAP, Regional Centre, Anandashram, Fairi Falls Road Observatory (P.O.) Kodalkanal-624 103, India.

60 cm and 15 cm between and within rows, respectively. Five plants in F_1 and parent, and 25 plants in F_2 were randomly chosen for recording the observations on (1) plant height (cm), (2) number of branches, (3) pods/plant, (4) length of pods (cm), (5) 100 seed weight (g), and (6) grain yield/plant (g).

The statistical analysis was conduced according to Griffing (1956b) model 1 method II.

Results and discussion

The analysis of variance (Table 1) revealed significant differences among genetypes for all the characters in both the generations. Thus it indicated an adequate amount of variability present in the material. The g.c.a. (general combining ability) and s.c.a. (specific combining ability) variances were found highly significant for all the characters in both the generations which indicated that both additive and non-additive gene actions were involved in the expression of the traits. The predominance of additive genetic variability indicates that genetic advance can be made by simple breeding procedures involving selection based on progeny performances.

The estimates of genetic variances, the degree of dominance and heriatability are presented in Table 2. The estimates of variances for g.c.a. ($\hat{\sigma}^2$g) and s.c.a. ($\hat{\sigma}^2$s) indicated that both additive as well as non-additive genetic components are involved in determining the inheritance of these traits. However, the magnitude of $\hat{\sigma}^2$g was higher in F_2 generation than $\hat{\sigma}^2$s for all the traits except pod length, for which high $\hat{\sigma}^2$s and partial dominance were recorded. This was evident from the proposition of g.c.a./s.c.a. as well as presence of overdominance. It is therefore likely that the presence of dominance and linkage disequilibrium might have resulted in an over-estimation of non-

Table 1

Analysis of variance for six economic traits in an 8×8 diallel of pea

Sources	d.f.	Generation	Plant height (cm)	Number of branches	Pods/plant	Pod length (cm)	100 seed weight (g)	Grain yield/plant (g)
Replications	2	F_1	140.585	73.375	2.509	0.175	1.29	1.389
	2	F_2	401.287	1.39	8.438	0.002	10.128	7.185
Crosses + parents	36	F_1	448.953**	17.876**	767.133**	1.797**	55.83**	33.665**
	36	F_2	2 159.241**	6.98**	23.989**	1.624**	92.933**	29.663**
Error	72	F_1	70.136	0.961	133.852	0.228	1.23	5.724
	72	F_2	252.716	3.03	9.112	0.363	5.809	5.495
G.c.a	7	F_1	105.807**	7.176**	318.157**	0.858**	77.238**	130.143**
	7	F_2	75 043.042**	230.61**	9.408**	0.643**	1 817.705**	543.985**
S.c.a	28	F_1	160.587**	5.626**	240.102**	0.522**	4.602**	231.144**
	28	F_2	740.813**	2.764**	7.651**	0.458**	11.387**	13.667**
Error	72	F_1	23.785	0.320	44.617	0.076	0.411	1.963
	72	F_2	1.203	1.010	3.037	0.121	1.936	1.832

(*) P = 0.05, and (**) P = 0.01

Table 2

Estimates of genetic parameters for different characters in pea

Genetic parameters		Characters					
		Plant height (cm)	Number of branches per plant	Pods per plant	Pod length (cm)	100 grain weight (g)	Grain yield per plant (g)
Genetic variances	F_1	−5.478	0.155	7.806	0.310	7.264	10.100
	$\hat{\sigma}^2_g$ F_2	7 430.283	22.785	1.340	0.019	180.632	53.032
	F_1	136.802	5.306	195.485	0.476	4.191	229.181
	$\hat{\sigma}^2_s F_2$	739.610	1.754	0.797	0.337	9.451	11.835
G.c.a./s.c.a.	F_1	*	0.029	0.040	0.651	1.743	0.044
	F_2	10.046	12.990	1.681	0.056	19.112	4.481
Degree of dominance	F_1	*	5.851	5.004	3.918	0.759	4.764
	F_2	0.315	0.277	4.212	5.120	0.228	0.472
Heritability (%)	F_1	*	5.200	6.100	10.000	75.900	85.500
	F_2	95.200	94.200	7.600	4.400	96.900	88.500

$\hat{\sigma}^2_g$= Estimates of g.c.a. variance; $\hat{\sigma}^2_s$= Estimates of s.c.a. variances
* = Estimates of g.c.a. were negative in F_1

additive components. In the case of the F_1 generation, the situation differd where $\hat{\sigma}^2$s was higher than $\hat{\sigma}^2$g for all the characters except 100 grain weight, for which over-dominance was operating. Under such a situation, population improvements followed by recurrent selections to accumulate desirable genes and to facilitate the breaking of linkages would be more appropriate, as suggested by Frey (1975) in self-pollinated crops.

The high heritability estimates (Table 2), in order of merit, were recorded for 100 grain weight in the F_1 and F_2 generations, and for plant height, number of branches and grain yield per plant in the F_2 generations. The co sistency of heritability from the F_1 to F_2 generations for 100 grain weight,nwhich is one of the major yield-contributing characters, indicated a considerab e amount of additive gene action in controlling the inheritance of this trait. lThe heritability estimates were higher in the F_2 than in the F_1 for all the characters except pod length. This might be due to the dominance deviations causing a bias in the estimates. However, such a bias is reduced in the advanced generations, as pointed out by Miller and Rawlings (1967), because of a change of the repulsion phase linkage into coupling phase linkages.

The main yield components in pea are pods/plant, seeds per pod, and seed index (Sancha and Singh 1973, Pandey and Gritton 1975). When the desirables were considered along with the significant g.c.a. effects and the corresponding mean performance of the parents (Table 3), the best parents were T 163 and A 87 for plant height; B 58 and A 87 for number of branches; B 58 and K 56 for pods/plant; Silma for pod length; T 163, M 45, T 9, Silma

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Table 3

General combining ability for six economic traits in pea

Parents		Plant height (cm)		Number of branches/plant		Pods (plant)		Pods length (cm)		100 seed weight (g)		Grain yield/plant (g)	
		Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect
T 163	F_1	93.00	3.43*	3.00	−0.83**	35.00	−5.29*	5.17	−0.29**	17.27	2.08**	18.03	1.97**
	F_2	147.00	57.25**	5.83	0.41	17.34	1.34*	6.20	0.01	14.16	11.53**	14.23	1.70**
B 58	F_1	71.00	0.67	10.00	1.58**	49.33	6.14**	3.60	−0.39**	5.96	− 6.46**	10.64	−1.53**
	F_2	96.67	−63.75**	6.33	−0.21	14.00	−0.79	6.00	−0.52**	15.67	−58.98**	9.07	−0.71
K 56	F_1	91.00	0.76	5.67	−0.59*	40.33	7.08**	6.14	−0.03	14.66	− 0.44*	13.77	−0.50
	F_2	150.00	−154.20**	8.67	−0.07	13.34	1.27*	6.47	0.08	21.46	−12.09**	11.90	−0.80*
M 45	F_1	89.67	−0.20	6.00	−0.39*	27.67	−0.69	4.83	−0.12	18.20	0.97**	11.74	0.54
	F_2	145.34	5.91**	9.84	−0.13	12.67	−1.09*	6.70	0.03	17.40	20.30**	6.84	0.08
T 9	F_1	93.00	−2.70	8.00	−0.12	37.33	−2.96*	5.60	−0.42**	16.23	1.43**	13.30	0.72
	F_2	134.34	−4.08	8.34	0.33	16.84	0.14	6.10	0.18	22.14	− 5.15**	12.40	0.30
A 137	F_1	72.66	−3.60*	5.67	0.21	24.00	−4.19*	5.30	0.15	17.13	0.21	11.50	−1.26**
	F_2	158.34	54.26**	7.34	0.04	13.67	0.54	6.10	−0.19	25.00	20.98**	16.00	−0.05
Silma	F_1	61.66	−3.63*	4.00	−0.73*	32.33	−0.29	5.57	0.30**	19.70	2.61**	17.07	−0.34
	F_2	114.34	102.24*	8.83	0.17	12.34	−0.84	6.47	0.28	23.60	20.14**	13.40	−0.62
A 87	F_1	85.27**	5.27	4.67	0.88**	21.33	1.21	5.53	−0.03	18.83	1.48**	13.74	0.39
	F_2	2.25**	2.25**	4.67	−0.20	8.00	−0.54	4.34	0.14	9.77	10.64**	10.71	−0.89*
SE (g ii)	F_1		1.443		0.167		1.976		0.082		0.121		0.189
	F_2		0.324		0.297		0.515		0.103		0.101		0.411

SE (g ii) = Standard error of general combining ability effects

Table 4

Specific combining ability for six economic traits in pea

Cross		Plant height		Number of branches/plant		Pods/plant		Pod length (cm)		100 seed weight (g)		Grain yield/plant (g)	
		Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect
T 163×B 58	F_1	90.00	2.23	5.34	−2.03**	41.00	−3.51	4.14	−0.42	8.70	1.18*	14.64	5.41**
	F_2	151.67	21.19**	9.67	1.41	13.67	4.74**	6.16	0.60	21.54	−0.31	12.80	2.19*
T 163×Silma	F_1	75.66	−7.79*	5.67	0.59	46.00	7.92	6.27	1.01**	20.53	1.57**	17.94	2.31*
	F_2	124.34	15.59**	8.50	0.05	14.34	1.12	6.64	−0.29	29.40	2.26*	15.07	3.87**
B 58×M 45	F_1	83.00	−1.13	5.34	−2.47**	88.00	38.89**	4.40	−0.33	10.46	−0.17	9.97	3.45**
	F_2	113.34	30.66**	6.34	2.96**	10.00	3.51*	6.34	0.54	14.90	6.19**	8.34	2.38*
B 58×A 137	F_1	91.34	10.60*	11.67	3.26*	43.00	−2.61	5.54	0.53*	7.83	−2.05**	12.67	−2.46*
	F_2	140.00	20.83**	8.67	−0.05	12.84	1.04	5.70	0.37	26.34	−1.74	14.00	5.78**
K 56×M 45	F_1	56.00	−28.23**	4.00	−1.64**	51.67	1.63	4.70	−0.40	16.56	−0.09	13.07	5.72**
	F_2	83.67	12.37**	4.33	1.64*	6.67	2.11	4.87	0.42	18.66	9.37**	3.80	4.75**
K 56×T 9	F_1	81.00	0.73	4.67	−1.24*	51.00	3.23	5.80	0.16	18.70	1.57**	11.94	4.14**
	F_2	94.34	54.03**	5.34	2.36**	6.67	1.54	6.00	0.63*	21.87	7.15**	9.14	3.69**
K 56×A 137	F_1	85.34	4.50	6.34	0.09	71.37	24.79*	6.34	0.97	16.30	0.39	15.64	1.21
	F_2	146.34	48.19**	7.34	2.15*	10.64	0.63	6.34	1.01**	21.17	4.49**	10.24	4.04**
M 45×T 9	F_1	84.00	3.23	6.67	0.56	32.00	−8.01	6.20	0.65**	18.23	−0.29	12.30	−0.77
	F_2	142.34	13.03**	7.50	1.42	13.84	1.74	6.94	−0.63*	21.00	5.65**	11.40	2.57*
SE (s ii)	F_1		4.421		0.513		6.052		0.250		0.581		1.105
	F_2		0.995		0.911		1.580		0.315		1.261		1.227

SE (s ii) = Standard error of specific combining ability effects

and A 87 for 100 grain weight; and T 163 for grain yield per plant in the F_1. In the F_2 the best combiners were T 163, M 45, A 137, Silma and A 87 for plant height; T 163 and K 56 for pods/plant; T 163, M 45, A 137, Silma and A 87 for 100 seed weight; and T 163 for grain yield per plant (Table 3). Among them, parent T 163 and A 87 were considered to be the best combiners in both generations when all the characters are taken together. Hence, parents T 163, and A 87 could be exploited as they possessed a considerable frequency of the desirable additive genes, when assessed from two successive diallel generations over two years.

The desirability of parents combined with high additive × additive interaction effects is likely to yield better recombinants in the cross combinations, with a high yield on the advancement of generations. Normally, the s.c.a. effects would not contribute considerably in the improvement of self-pollinated crops except where the commercial exploitation of heterosis is feasible. However, in the production of a homozygous line, the interest of the breeder usually rests upon transgressive segregations shown by the crosses. Jinks and Jones (1958) suggested that the superiority of hybrids *per se* might not indicate their ability to produce transgressive segregates owing to non-fixable effects. Therefore, in an autogamous crop like pea, a study of segregating generations for the s.c.a. effects would be important as a study of F_1s. Hence, the s.c.a. effects of 28 cross combinations along with their parents were studied in the F_2 generation. Out of 28 crosses, the best eight, along with their mean values in the F_1 and F_2 generations for all the traits, are shown in Table 4. Of these eight combinations, T 163 × B 58, T 163 × Silma, B 58 × M 45, K 56 × M 45 and K 56 × T 9 in both the F_1 and F_2; and B 58 × A 137, K 56 × A 137 and M 45 × T 9 in the F_2, had both the positive and significant s.c.a. effects for grain yield. They involve two of the three possible combinations between the parents of high and low g.c.a. effects (i.e. high × low and low × low). The cross T 163 × B 58 in the F_1 and F_2, involving at least one parent with a significant g.c.a. effect and another with a poor g.c.a. effect, could give rise to a new population through the desirable transgressive segregants, if the additive genetic system present in the good combiner and the complementary epistasis effects present in the crosses react mutually to maximize the desirable plant attributes, which could then be exploited for further breeding. For the efficient utilization of these cross combinations, it is suggested to make an *inter se* crossing of these involving the (high × low) g.c.a. effects of the F_1 generation, in every possible combination. Thus, the multiple parents could create a central gene pool which supplement the faster genetic recombinations and break those genetic blocks, that are present.

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A COMPARISON OF GENOTYPES OF *MEDICAGO MEDIA* GROWN IN STERILIZED AND DISEASED SOIL

F. M. KATEPA and P. D. WALTON[1]

DEPARTMENT OF PLANT SCIENCE, UNIVERSITY OF ALBERTA, EDMONTON, ALBERTA, CANADA

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The object of this glasshouse study was to compare the performance of four strains of *Medicago media* grown in sterilized and unsterilized soil from fields which showed symptoms of "alfalfa sickness". Plant height, leaf area, leaf weight and disease score were recorded over a seven week period. The resistant strain (F.R. — 2B29 × 2G169) was taller, had a higher leaf area and leaf weight and a lower root necrosis score than the other three strains when grown on both sterilized and unsterilized soil. The synthetic strain Br1 ranked second for all these characters.

Keywords: *Medicago media*, alfalfa, disease resistance, leaf area, leaf weight specific leaf weight

Introduction

Faechner and Bolton (1978) used three cycles of recurrent phenotypic selection to isolate high yielding clones resistant to "alfalfa sickness" which were used, in different combinations to produce five synthetic strains (Br1, Br2, Br3, Le1 and Le2). Four of these strains are now under test in the Agriculture Canada Alfalfa Uniformity Trials. Lines were also selected for susceptibility to the same soil condition. Crosses were made between pairs of lines showing respectively high and low resistance to "alfalfa sickness".

The term "alfalfa sickness" refers to a specific condition of poor growth of alfalfa in north and central Alberta (Webster et al. 1967). The sickness is characterized by stunted and spindly growth of young plants, with yellowish, flaccid leaves that bear irregular necrotic patches. The roots, particularly the lateral ones, develop brown lesions and become girdled, leading to plant collapse (Damirgi et al. 1976, 1978). Affected fields exhibit characteristic irregular patches of vigorous plant growth (Webster et al. 1967).

The cause of alfalfa sickness is unknown and may depend on a number of factors which include a *Pythiaceaceous* fungus (Darmirgi et al. 1979). Field

[1] Respectively Graduate Student (now Lecturer, University of Zambia, Lusaka) and Professor.

and glasshouse studies (Faechner and Bolton 1978, Goplen and Webster 1969, Webster et al. 1967 and 1973) indicated that the "sickness" is not caused by an excess or deficiency of soil moisture or mineral nutrients and it is not related to nematodes. "Alfalfa sickness" has been demonstrated in the glasshouse by using soil from a field containing diseased plants. Sterilization using steam or vapor controls the condition.

Individual crosses and a synthetic strain from Faechner and Bolton's selections have been used in this study to evaluate the performance of the genotypes in sterilized and unsterilized soil.

Material and methods

The four alfalfa genotypes studied were two F_1 crosses, one from resistant parents (2B29 × 2G169 = F.R.) and the other from susceptible parents (GP130 × 1V58 = F.S.), a synthetic line developed from resistant clones (Br1) and the commercial cultivar Beaver.

The genotypes were grown in sterilized and unsterilized soil; a light textured chernozem collected from random locations within a diseased field at Spruce Grove, Alberta, from depths up to 15 cm. After mixing and sieving through a 6 cm wire mesh screen, the soil was stored in a cold room at 4 °C before use. At planting, part of the soil was autoclaved at 130 °C for 30 minutes at a pressure of 1.8 kilograms per square centimeter.

The seeds were scarificed with sand paper and germinated on moist filter paper. Six 13 centimeter plastic pots of sterilized and 6 pots of unsterilized soil were planted for each of the 4 genotypes, with 4 plants in each pot. A commercial inoculum of *Rhizobium meliloti* was applied. The experimental plot was 1 pot containing 4 plants and a split-plot design with 6 replications was used to analyze the data with the 4 genotypes, and the soil treatments assigned to the main and subplots, respectively.

After the second week, a weekly destructive sampling was carried out for 6 consecutive weeks from both soil treatments for each genotype. Plant height, leaf area, leaf dry weight and root necrosis scores were recorded. The experiment was maintained at 18 °C under natural lighting (April to August, 1984) in the glasshouse.

Results

The analysis of variance revealed significant differences among the genotypes, between the two soil types, and over all the traits (Table 1). Significant genotype × soil interactions were observed for height, specific leaf weight and root necrosis. Genotype × time was significant for plant height, leaf area and root disease. Leaf area and disease showed a significant 3-way (genotype × × soil × time) interaction. Table 2 gives the mean plant height, leaf area, leaf dry weight, specific leaf weight and disease score for the 4 genotypes in both soil types at the seventh week. In general, the cross from resistant parents (F.R.) was the most vigorous plant in terms of height, leaf area and leaf weight, and gave the lowest root lesions score, followed by Br 1, Beaver and the cross from susceptible parents (F.S.). Plants in sterilized soil were more vigorous than those in the unsterilized soil. The only significant differences for specific leaf weight are between F.R. and the other three genotypes in the

Table 1

Analysis of variance for plant height, leaf area, leaf weight, specific leaf weight (S.L.W.) and root necrosis of 4 alfalfa genotypes grown for 6 weeks on sterilized and unsterilized soil

Source	Mean square values					
	Genotype G	Soil type S	Time T	G×S	G×T	G×S×T
D.f.	3	1	5	15	5	15
Plant height	360**	1 279**	5 630**	8**	35**	4
Leaf area	33 868**	192 280**	1276 400**	82	8792**	54 111**
Leaf weight	0.29**	1.85**	5.49**	0.30	0.61	0.25
S.L.W.	0.41**	0.51**	0.14**	0.68**	0.33	0.18
Root necrosis	2.41**	65.55**	2.30**	2.40**	3.05**	0.39**

*, ** F-values significant at P = 0.05 and P = 0.01 respectively

Table 2

Mean plant height (cm), leaf area (cm^2), leaf dry weight (mg), specific leaf weight (S.L.W.) (mg/cm^2), and disease score (D.S.) for four alfalfa genotypes in I. sterilized soil and in II. unsterilized soil in week 7, averaged over 6 replications*

Trait	Genotype			
	Beaver	Br 1	F.S.	F.R.
I. Sterilized				
Height	38.5b**	38.3b	31.8c	41.2a
Leaf area	519.2b	550.2ab	447.0c	620.4a
Leaf weight	1111.4c	1168.0b	760.8d	1414.5a
S.L.W.	2.2a	2.3a	1.9a	2.4a
II. Unsterilized				
Height	28.3c	31.2b	22.3d	33.7a
Leaf area	342.3b	424.5a	266.2c	401.9a
Leaf weight	584.9c	724.9a	553.2d	657.5b
S.L.W.	2.0b	1.8b	2.2b	3.4a
D.S.	2.2b	1.9b	3.3a	2.0b

* Disease score; 1–5, 1 = no lesions, 5 = dead plant

** Numbers followed by the same letter in a row are not significantly different at P < 0.05

unsterilized soil in the seventh week. Table 3 illustrates the development of disease (as indicated by the root lesions score) in the unsterilized soil. Significant genotypic differences were recorded in the fourth week, showing that F.S. has a higher score than Beaver and Br 1. Above F.R. has the lowest score followed closely by Br1, then Beaver and F.S. After the fifth and sixth weeks the disease scores do not rise significantly.

Table 3

Mean disease score of 4 alfalfa genotypes grown in "alfalfa sick" soil for each of 6 weeks, averaged over 6 replications*

Week	Genotype			
	Beaver	Br 1	F.S.	F.R.
2	1.4a**	1.3a	1.2a	1.2a
3	1.6a	1.7a	1.7a	1.4a
4	1.9b	1.7b	2.3a	2.0ab
5	2.4b	1.8c	2.9a	1.4d
6	2.2b	2.0bc	3.4a	1.7c
7	2.2b	1.9b	3.3a	2.0b

* Disease score; 1–5, 1 = no lesions, 5 = dead plant
** Numbers followed by the same letter in a row are not significantly different

Discussion

These results demonstrate that previous selection for resistance and susceptibility to alfalfa sickness (Faechner and Bolton 1978) was effective; and resistant strains grown in "sick" soil are taller, display a higher leaf area, leaf weight and lower root necrosis score. With the exception of the disease score, these same characteristics were also observed in the sterilized soil, indicating that selection has resulted in greater overall productivity, possibly by increasing components of net assimilation rates including photosynthetic area (increased number area and weight of leaves). Pierce et al. (1969) found that leaf weight accounted for 64% of the variation in photosynthesis in alfalfa. Tan (unpublished) found two "alfalfa sickness" resistant genotypes to have high levels of dry matter yield and nitrogen fixation, while Faechner and Bolton (1978) postulate that their resistant genotypes have the capacity to manufacture assimilates in excess of the requirements of the bacteria *(Rhizobium melitoti)* and the "alfalfa sickness" pathogen so that the plants retain assimilates for high dry matter yields.

The disease progression illustrates that "alfalfa sickness" is a juvenile plant disease and does not increase with plant age. Faechner (1977) alluded to this and showed that selection for resistance was effective with juvenile plants. The absence of "alfalfa sickness" root lesions in sterilized soil is consistent with the observation that soil sterilization is effective in controlling "alfalfa sickness" (Faechner and Bolton 1978, Webster el al. 1967). Br 1 grown in the Alfalfa Uniformity Trials has, on average, given yields 6% higher than those obtained from Beaver over a three-year period. The trial reported here indicates that, where "alfalfa sickness" is prevalent, Br 1 should outyield Beaver substantially.

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DECOMPOSITION OF SOME ORGANIC MATERIALS IN A HILLY SOIL OF RAJASTHAN

L. L. SOMANI*

RAJASTHAN COLLEGE OF AGRICULTURE UDAIPUR, INDIA

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Hill soil of Rajasthan was incubated with six organic materials, namely FYM, dhaincha *(Sesbania aculeatus)*, guar *(Cyamopsis tetragonoloba)*, wheat straw, rice husk and poultry manure, for a period of 120 days, to study organic matter buildup, mineralization of nutrients, activities of micro-organisms and enzymes, and soil aggregation. These organic materials raised the organic matter content over control by 109.11, 62.53, 54.43, 78.48, 77.22 and 89.27 per cent, respectively. Fast decomposing non-humified materials like dhaincha and guar had very high nutrient mineralization, with the partly-humified materials, FYM and poultry manure, coming next. Wheat straw and rice husk caused considerable immobilization, primarily during the early stages of incubation. Mineralization of nitrogen, phosphorus and sulphur of practical importance occurred only after 90 days of incubation. Icubation with dhaincha and guar lowered the soil pH. The humified materials (FYM and poultry manure) maintained a static pH after 120 days. The effects on waterstable aggregates (>0.25 mm) paralleled those on CO_2 evolution ($r = 0.97$). The organic materials had erratic effects on enzyme activity and microbial population. Our results caution against using CO_2 evolution as a measure of microbial activity in the soil.

Keywords: soil organic matter, decomposition, mineralization, nitrogen, phosphorus, sulphur

Introduction

The organic matter in soil and the use of organic manures are traditionally associated with soil fertility (Cooke 1967). It is probably due to the general impression that organic matter levels of soils cannot be improved under tropical conditions, that very few investigations have been carried out in India to study the effect of organic manuring on soil organic matter buildup, and the consequent effect on soil properties.

Maintenance and raising of organic matter level under tropical and subtropical conditions is controversial (Keen 1946, Bear 1950, Jenny and Ray Choudhari 1967). Keeping in view the problem of maintaining soil organic matter level under Indian conditions, an integrated approach has therefore been made in the present investigation, by studying the carbon dioxide evaluation from different kinds of organic materials (both wide and narrow C : N, C : P and C : S ratios) with simultaneous changes in nutrient mineralization, microbial population, enzyme activity and water stable aggregates.

* Present address: S. K. N. College of Agriculture, Jobner, India-303329

Material and methods

Soil was collected from a hill of Udaipur (India) for the purpose of this investigation. The soil fits the order of alfisols, the sub-order of ustalfs and the great group of haplustalfs, according to the 7th approximation system of soil classification (Soil Survey Staff, 1967). The physico-chemical analysis of the soil showed organic carbon content of 0.568%, total nitrogen 0.0493%, organic P 152 ppm, organic S 75 ppm, pH 8.1 and clay loam texture. The experiment was divided into 2 sets; the first set designed to measure the rate of decomposition of the added organic materials, and the second to study mineralization or immobilization of nutrients, water stable aggregation, enzyme activity and microbial changes.

In the first set, dried and powdered organic materials (farmyard manure, rice husk, wheat straw and poultry manure) were mixed with soil samples at a rate equivalent to 0.5 g carbon per 100 g soil. The chemical analysis of organic materials used is shown in Table 1.

Table 1

Chemical composition of organic materials

Organic materials	Constituents							
	C %	N %	P %	S %	K %	C : N	C : P	C : S
Farm Yard Manure (FYM)	32.91	1.32	0.63	0.53	0.53	25 : 1	52 : 1	62 : 1
Dhaincha (green manure)	48.32	2.68	0.39	0.46	0.86	14 : 1	124 : 1	101 : 1
Guar (green manure)	36.80	2.63	0.33	0.38	1.07	14 : 1	112 : 1	97 : 1
Wheat straw	39.64	0.55	0.16	0.13	3.13	72 : 1	248 : 1	305 : 1
Rice husk	42.33	0.82	0.17	0.15	2.88	52 : 1	249 : 1	282 : 1
Poultry manure	34.51	1.22	0.44	0.46	0.78	28 : 1	78 : 1	75 : 1

The C : N, C : P and C : S ratios are narrow in poultry manure and farmyard manure, but are wider in rice husk and wheat straw. The green manures of dhaincha and guar are intermediate. One hundred gram portions of such treated soil samples were placed in 500 ml conical flasks and incubated at a constant temperature of 30 ± 1 °C. The soil under all the treatments was moistened to 60 per cent of the water-holding capacity. A control set without any organic matter was also provided. The CO_2 evolved was absorbed in 1 N NaOH solution contained in a tube kept suspended inside the flask. The mouths of the flasks were kept completely sealed during the experimental period. The tubes containing NaOH solution were taken out at periodic intervals and the excess alkali was back titrated with 0.5 N HCl after addition of excess $BaCl_2$ solution, and the amount of CO_2 evolved was thus calculated. All the treatments were incubated in triplicate.

In the second set, 2 kg of soil were placed in each of the 21 wide-mouth bottles after mixing with required quantities of appropriate organic materials (7 treatments $\times$ 3 replications). The treatments and conditions of incubation were essentially the same as those for CO_2 evolution. The bottles were closed with lids containing a small hole for free movement of air. The containers were weighed periodically and weight loss was compensated by adding distilled water. Soil samples were drawn at intervals of 5, 10, 20, 30, 60, 90 and 120 days and analysed. The soil samples were collected from surface to bottom of each bottle. Five cores of 2 cm diameter were taken from each of the bottles at all the above referred specific intervals. These samples were pooled to give one sample of about 150 g. These soil samples with moisture content equivalent to 60 per cent water-holding capacity were kept at 4 °C for studying microflora and enzyme activity.

Organic carbon was determined by Tyurin's method, as described by Kononova (1966). Mineral nitrogen was extracted with 0.2 N KCl, and nitrogen in the extract determined, according to the method of Bremner (1965). Mineralizable organic phosphorus was determined by increase in 0.002 N H_2SO_5 extractable phosphorus using Dickman's and Bray's (1940) method for colour development. Mineralized sulphur was measured by increase in sulphate

sulphur, extracted with potassium dihydrogen phosphate (500 ppm P), and determined turbidimetrically by the method of Chesnin and Yein (1950).

Microbial population was enumerated by the procedures outlined by Allen (1957) using soil extract agar for bacterial and actinomycetes, Martin rose bengal agar media for fungi, and Jensen's media for *Azotobacter* counts. PH was determined in soil: water suspension 1 : 2.5 and water stable aggregates were determined using Yoder's (1936) technique.

Urease activity was determined by the procedures of Hofmann and Teicher (1961) as modified by Balasubramaniam et al. (1972). The unit of urease activity is expressed as mg NH_4-N released per 100 g oven dry soil in three hours incubation. The activity of enzyme hydrolyzing sucrose (invertase activity) in the soil sample was estimated by the method described by Balasubramaniam et al. (1972). The intertase activity is expressed in mU/g of oven dry soil (one milli-unit/mU) represents the amount of enzyme which will catalyze the hydrolysis of carbohydrates to release 1×10^{-3} micromoles of glucose per minute at 37 °C. The activity of the enzyme β-glucosidase was determined by the method outlined by Hayano (1973). One unit of β-glucosidase was defined as the amount that releases one μ mole of p-nitrophenol per minute at 30 °C and pH 4.8 in McIlvaine buffer.

Results and discussion

The chemical analysis of organic materials used is shown in Table 1. The C : N, C : P and C : S ratios are narrow in poultry manure and FYM, but are wider in rice husk and wheat straw. The green manures of dhaincha and guar are intermediates.

CO_2 evolution and humus build-up

The cumulative values of CO_2 evolved after various incubation intervals, presented in Fig. 1, show a rapid evolution of CO_2 during the first 5 days of incubation, under all the treatments. This rapid release may be attributed to the accelerated decomposition of native soil humus and dead cells, on remoistening of an air-dry soil (Birch 1958, Guar et al. 1971, Debnath and Hajra 1972) and to the rapid decomposition of readily available water-soluble constituents of added materials (Melin 1930, Guar et al. 1971). With advancement of incubation periods there is a gradual decrease in CO_2 evolved, and after 90 days of incubation the evolution of CO_2 was very slow. It is evident from Fig. 1 that both the green manures (dhaincha and guar) are fast decomposing and therefore can not be considered good sources from the standpoint of humus buildup. After 120 days of incubation with dhaincha and guar, an amount equivalent to 43.16 to 62.00 per cent of the added carbon was lost over the control. Incubation with narrow ratio humified materials, such as FYM and poultry manure, resulted in the loss of only 10.97 to 27.60 per cent of the added organic carbon; while the wide ratio non-humified materials such as wheat straw and rice husk maintained an intermediary rate, losing 19.95 to 50.45 per cent of the added carbon over the control. The treatments involved FYM, dhaincha, guar, wheat straw, rice husk and poultry manure increased the organic carbon content of the soil by 109.11, 62.53, 54.43, 78.43, 77.22

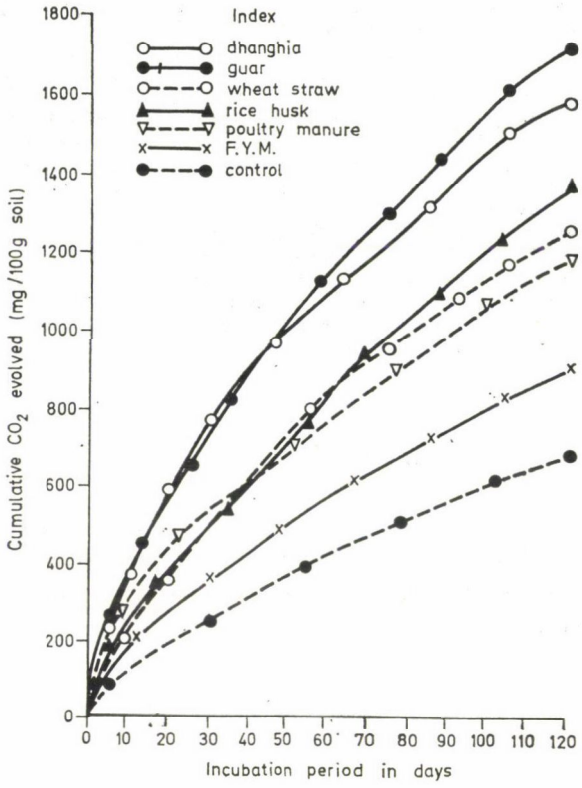

Fig. 1. Cumulative evolution of CO_2 after various periods of incubation of soil with organic materials

and 87.87 per cent respectively over the control. Similar results were reported by Guar et al. (1971) and Debnath and Hajra (1972). The differential decomposition may be attributed to the low C : N ratio of dhaincha and guar as compared to that of wheat straw and rice husk. Cooke (1962), Charkraborty and Sen (1967) and Debnath and Hajra (1972) also reported that nitrogen-rich materials metabolize more rapidly. Though FYM and poultry manure have a narrow C : N ratio as compared to wheat-straw and rice husk, they maintain a steady and uniform decomposition, as they are already humified organic materials (Guar et al. 1971).

Mineralization of N, P and S

The quantities of nitrogen, phosphorus and sulphur mineralized under various treatments, presented in Figs 2, 3 and 4, show an increased mineralization in control soil as well as those incubated with FYM and poultry manure. Mostly after 20–30 days of incubation there was a decline in the N, P and S

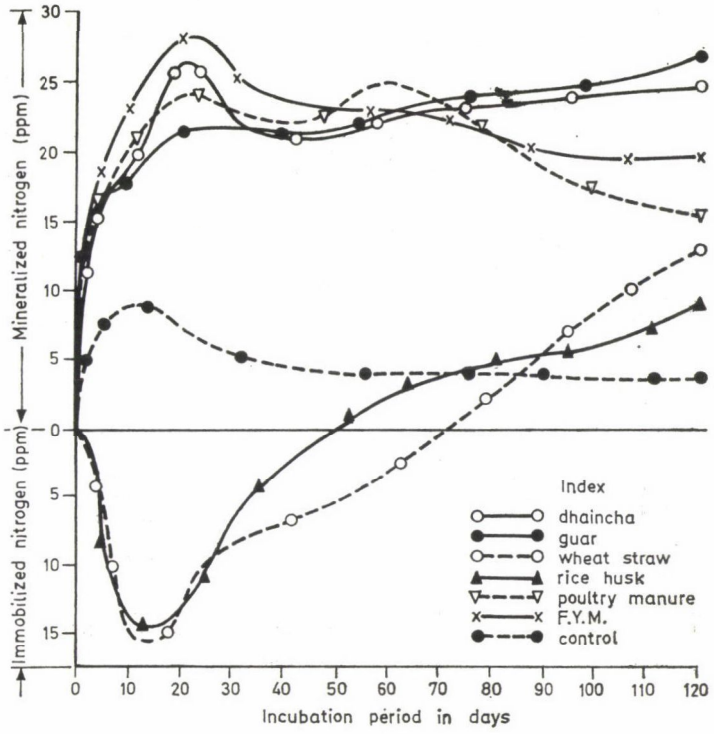

Fig. 2. Mineralization of nitrogen after various periods of incubation of soil with organic materials

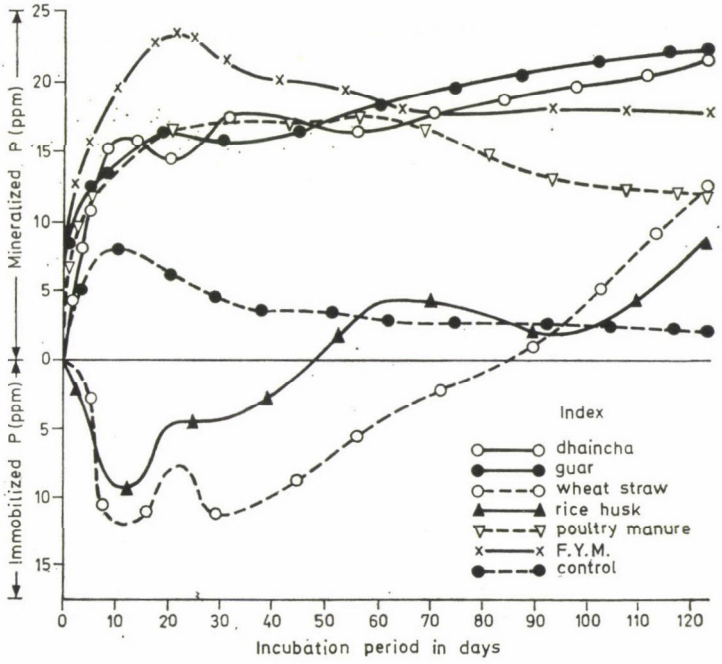

Fig. 3. Mineralization of organic phosphorus after various periods of incubation of soil with organic materials

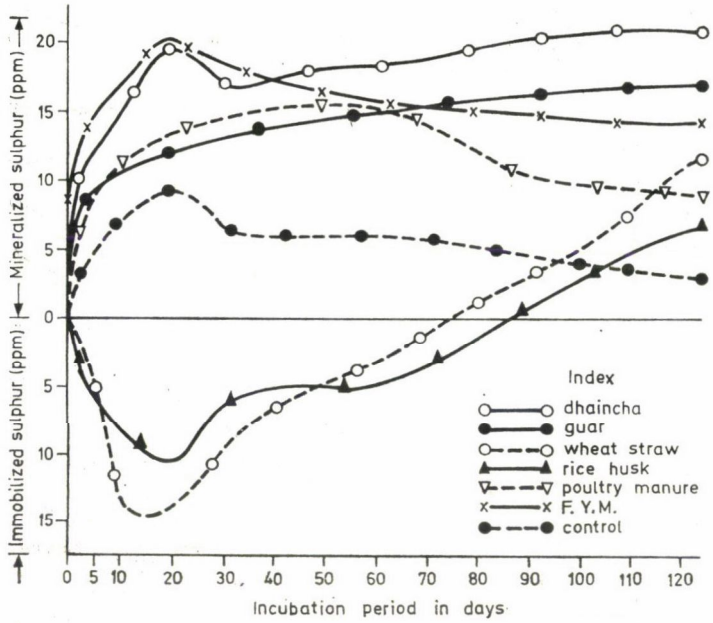

Fig. 4. Mineralization of organic sulphur after various periods of incubation of soil with organic materials

mineralized with FYM and poultry manure. An increased release of nutrients during the early stages of incubation thus followed gradual immobilization of these nutrients with aging, except for wheat straw and rice husk. Cooke and Cunninghum (1958) and Haque and Walmsley (1972) also reported an increased mineralization following air drying, which appeared akin to partial sterilization. A rapid mineralization of phosphorus during the early stage might also be due to the solubilizing effect of CO_2 and organic acids on iron, aluminium, magnesium and calcium phosphates (Sen and Bains 1955) and also due to their complexing action on these ions, which prevents them from reacting with phosphates (Rajagopalan and Idanani 1965). A significant portion of mineralized nutrients might come from the release of nutrients held in organic combination with native or applied organic matter.

A general decline in nutrient mineralization rates in the later stage of incubation could be attributed to decreased microbial activity as the microbial population ages (Haque and Walmsley 1972) or to incorporation of these nutrients in the bodies of micro-organisms (Garrestsen and Hoop 1957, Starkey 1966). A high level of NH_4-N in the soil can also lead to such a decline as shown by Harda and Kai (1968). Furthermore, in the case of sulphur, the emission of volatile sulphur compounds including methyl mercaptan and dimethyl disulphide under aerobic conditions, as products of methionine decomposition,

has been observed by Cooke and Cunninghum (1958) and Fredric et al. (1957). Micro-organisms capable of producing methionine and crysteine are known to exist (Young and Maw 1958) and, since SO_4-S can provide sulphur for cysteine synthesis, it is possible that volatilization losses under aerobic conditions may occur via methionine (Nicolson 1970).

A totally different situation was observed with treatments involving wheat straw and rice husk (materials with wide C : N, C : P and C : S ratios). On account of high microbial decomposition during the early stages of incubation, there was a high demand for nitrogen, phosphorus and sulphur by these micro-organisms. This gave rise to a rapid immobilization of mineral N, P and S. After an incubation period of about 20–30 days, the extent of immobilization decreased and part of the nitrogen, phosphorus and sulphur synthesized into microbial cell substances mineralized by autholysis, as is evident from a net decrease in immobilized nutrients. Only after an incubation period of about 90 days did any mineralization of practical significance occur. Kaila (1950) and Fuller et al. (1956) also reported that wheat straw immobilized phosphorus if the P content of straw was below 0.2%. It is the mineral content of the added organic matter, rather than of the final mixture, that plays the important role in mineralization or immobilization of nutrients (Freney and Stevenson 1966). Barrow (1960) suggested sulphur mineralization could be expected if the C : S ratio of the added material is below 200. The data on composition of organic materials presented in Table 1 substantiate the immobilization of nitrogen, phosphorus and sulphur by wheat straw and rice husk insofar as their C : N, C : P and C : S ratios are 72 : 1, 248 : 1 and 301 : 1 for wheat straw and 52 : 1, 249 : 1 and 282 : 1 in rice husk.

The relationships between the amount of carbon, nitrogen, phosphorus and sulphur mineralization were investigated, and the correlation coefficients obtained are presented in Table 2. The pattern of nitrogen, phosphorus and

Table 2

Correlation coefficients (r) for relationships between carbon, nitrogen, phosphorus and sulphur mineralized after various periods of incubation with organic materials

Element	Incubation period in days						
	5	10	20	30	60	90	120
C and N	0.325	0.286	0.316	0.295	0.327	0.566	0.778
C and P	0.223	0.234	0.214	0.227	0.487	0.464	0.707*
C and S	0.236	0.240	0.185	0.204	0.208	0.475	0.729*
N and P	0.993**	0.992**	0.986**	0.990**	0.933**	0.985**	0.988**
N and S	0.978**	0.982**	0.975**	0.984**	0.944**	0.954**	0.942**
P and S	0.986**	0.995**	0.964**	0.988**	0.907**	0.965**	0.064**

** Significant at 1% level
* Significant at 5% level

sulphur mineralization appears to be analogous, since the values of correlation coefficient are highly significant.

It is interesting to note that the amounts of nitrogen, phosphorus and sulphur mineralized after various incubation periods do not have any significant relationship with carbon mineralized (CO_2 evolved) except after 120 days. This indicates that carbon is not initially mineralized at the same rate as nitrogen, phosphorus and sulphur, and that a stage of equilibrium is achieved after 4 months of incubation, when relationships between mineralization of carbon and nitrogen, carbon and phosphorus, carbon and sulphur become significant.

From the above discussion on mineralization of carbon, nitrogen, phosphorus and sulphur in soils incubated after additions of wide and narrow C : N, C : P and C : S ratio materials, it is evident that organic materials like FYM, poultry manure, dhaincha and guar (organic materials with narrow ratios) have an increased mineralization of nitrogen, phosphorus and sulphur over controls, especially during early periods of incubation. This indicates their importance in improving crop yields by making more nitrogen, phosphorus and sulphur available for plant growth. The wide ratio materials, like wheat straw and rice husk, caused immobilization of native nitrogen, phosphorus and sulphur reserves in the soil especially during early stages of decomposition in soil and may adversely affect early crop growth when there is heavy nutrient demand. This could be counteracted by applying additional fertilizer.

(1) The effect of adding 6 sources of organic matter (representing a wide range of C : N ratios) on water stable aggregates was studied after 120 days incubation. The data presented in Table 3 show that the structural index percentage of water-stable aggregates >0.25 mm of the soil increased considerably over the control, on account of the addition of various organic materials.

Table 3

Effect of organic materials on stable aggregates after 120 days of incubation

Treatments	Percentage distribution of aggregates of various sizes (mm)						
	2.0–5.0	1.0–2.0	0.5–1.0	0.25–0.50	Total above 0.25	0.10 to 0.25	Below 0.10
Control soil	3.2	3.5	4.1	5.5	16.3	36.8	46.9
Soil + FYM	4.8	5.8	6.0	10.3	26.9	50.3	22.8
Soil + Dhaincha	10.9	12.2	9.8	11.9	44.8	38.5	16.7
Soil + Guar	12.1	14.5	8.7	14.2	49.5	31.7	18.8
Soil + Wheat straw	11.4	8.6	6.4	12.1	38.5	34.7	26.8
Soil + Rice husk	8.2	14.5	5.3	14.8	42.8	24.8	32.4
Soil + Poultry manure	6.1	8.1	8.2	9.9	32.3	42.6	26.1

Maximum increase in structural index was recorded by dhaincha and guar, followed by wheat straw and rice husk, and the least increases occurred under treatments involving additions of poultry manure and FYM.

According to Russel (1958), Martin and Waksman (1940), Martin (1942) and Somani (1974) the aggregating effect of organic materials depends on the nature and rapidity of their decomposition, implying that the more rapid the decomposition, the greater is the binding effect. This is confirmed by the value of the correlation coefficient between cumulative values of CO_2 evolved and structural index ($r = 0.97$) which is significant at 0.1% level.

The FYM and poultry manure improved the structural index to a smaller extent, and only increased the water stable aggregates of the size 0.10 to 0.25 mm. This implies that, in order to improve the structural index, fast decomposing organic materials are important. It is well known that better aggregation is the result of microbial exudation of cementing materials (Chester et al. 1957, Harris et al. 1966) which are likely to be produced in larger quantity when fast decomposing materials are added to the soil.

(2) The results of changes in soil pH during decomposition of organic materials has been presented in Table 4. A sudden increase in the pH of the

Table 4

Soil pH after various periods of incubation with organic materials

Treatments	Incubation in days						
	5	10	20	30	60	90	120
Control soil	8.2	8.2	8.1	8.1	8.1	8.1	8.0
Soil + FYM	8.2	8.3	8.3	8.1	8.0	8.1	8.0
Soil + Dhaincha	8.1	7.9	7.8	7.7	7.7	7.7	7.6
Soil + Guar	8.1	8.1	8.0	7.8	7.9	7.8	7.8
Soil + Wheat straw	8.2	8.3	8.3	8.4	8.3	8.2	8.2
Soil + Rice husk	8.1	8.3	8.4	8.2	8.2	8.2	8.2
Soil + Poultry manure	8.3	8.4	8.2	8.1	8.0	8.1	8.0

soil at the beginning, due to addition of FYM, poultry manure, rice husk and wheat straw, was followed by a gradual fall with the progress of incubation, after 120 days incubation. The soil incubated with reice husk and wheat straw maintained a higher pH than did the control. Soils incubated with dhaincha and guar continued decreasing pH with the progress of incubation. Increases in pH due to addition of organic matter were also reported by Bansal and Bhattacharya (1955), and Debnath and Hajra (1972) and could be attributed to quick release of bases, particularly K, from added organic materials. A decrease in pH with decomposing leguminous material corroborates the finding

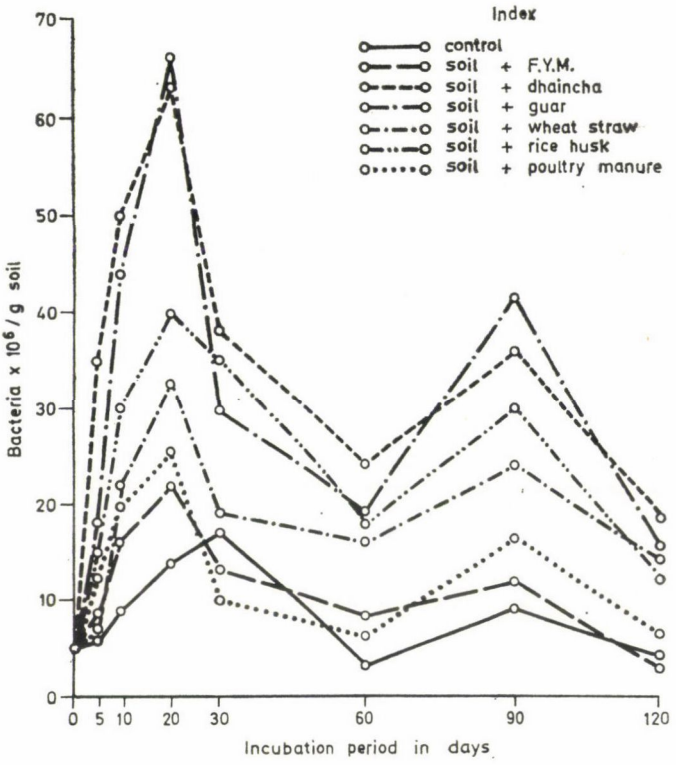

Fig. 5. Changes in bacterial population during organic matter decomposition in soil

of Smith and Burns (1965) and Balasubramanian et al. (1972). This lowering of pH is caused by the formation of organic acid during decomposition. Such changes in pH are transitory (Smith and Burns 1965) and are specially important in terms of micro-element availability, because these changes occur in an environment where complexing substances are available.

(3) Data presented in Figs 5, 6, 7 and 8 show that addition of various organic materials resulted in fluctuating trends in the microbial density. Maximum bacterial population was observed at 30 to 90 days, while that of actinomycetes occurred at 20 and 90 days. After these, there followed a decline in all the treatments under study. FYM, poultry manure, dhaincha and guar (materials with narrow C : N ratio) recorded increase in fungal population at 10 and 90 days of incubation. On the other hand, wheat straw and rice husk maintained fungal counts below control. These organic materials markedly increased *Azotobacter*, possibly due to the availability of stimulating organic substances formed during the course of decomposition (Guar et al. 1971). Decreased *Azotobacter* population with dhaincha and guar may be due to the prolifera-

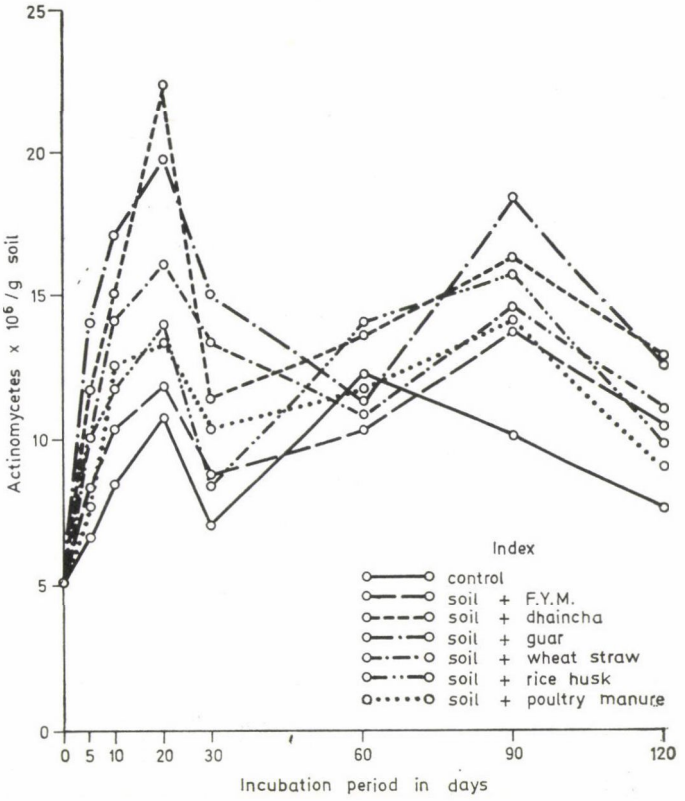

Fig. 6. Changes in actinomycete population during organic matter decomposition in soil

tion of other groups of micro-organisms which are either inhibitory and/or competitive. The decreased *Azotobacter* population can also be attributed to inhibitory decomposition products.

No relationship could be observed between microbial population and CO_2 evolution. Alexander (1961) and Guar et al. (1971) have also reported that with diversity of microbial population having differential growth rate and activity, and with 1 variety of carbon sources, the observance of a significant relationship is unexpected. Some significant relationship could be observed only when carbon sources are homogeneous and the microbial population comprises one species.

Data on invertase activity presented in Fig. 9 show that addition of the organic materials considerably increased the activity of enzyme hydrolyzing sucrose over the control. The enzyme activity under treatments involving additions of different organic materials could be ranked in the following order: Control < FYM < poultry manure < guar < dhaincha < wheat straw

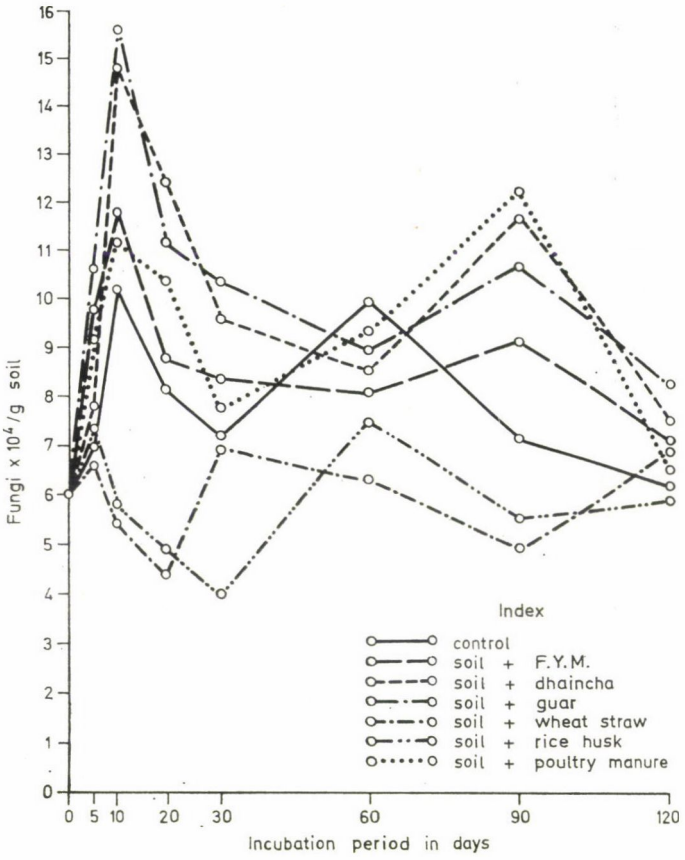

Fig. 7. Changes in fungal population during organic matter decomposition in soil

< rice husk. Drobnik (1957) also found low intertase activity under legume as compared to grass, while Balasubramanian et al. (1972) reported that humified materials, such as FYM or poultry manure, did not alter the invertase activity of the soil to any appreciable extent. Possibly, the invertase derived under the influence of humified organic materials undergoes more rapid breakdown compared to invertase derived under the influence of fast decomposing organic materials. Moreover, the prolonged existence of organic matter during the humification of FYM and poultry manure may also have inactivated the enzyme held in them.

The trend of β-glucosidase activity at various incubation intervals presented in Fig. 10 shows that the activity of β-glucosidase is not related to the organic matter content in the soil, but depends on the characteristics of the decomposing organic materials. The fast decomposing organic manures of

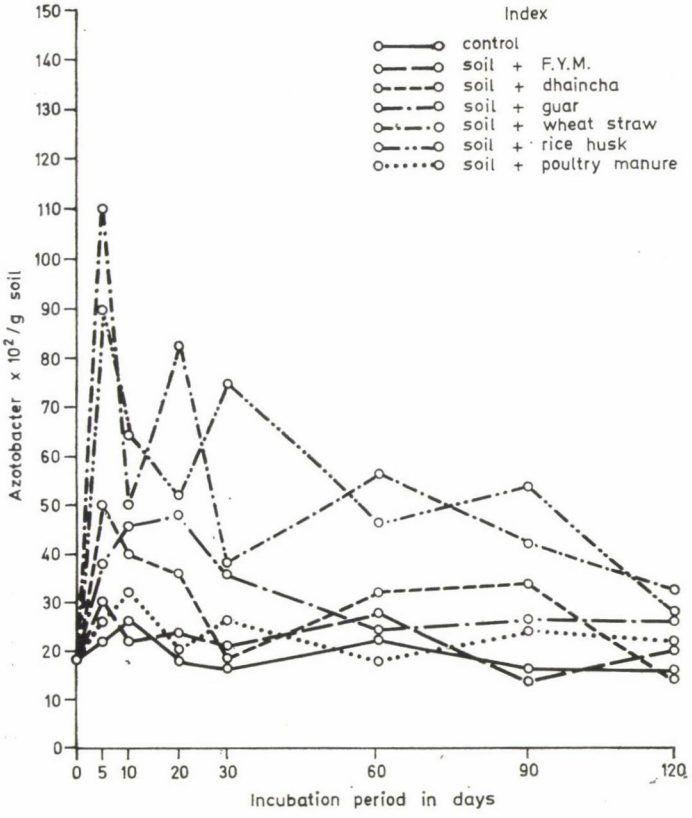

Fig. 8. Changes in azotobacter population during organic matter decomposition in soil

dhaincha and guar tremendously increased the activity of β-glucosidase during the early periods of decomposition, but later gradually decreased it. The activity was less, as compared to treatments involving addition of humified organic materials, such as FYM and poultry manure, which maintained highest activity at the end of the incubation period. In the case of wheat straw and rice husk treatments, the activity remained below that of the control and it was only after 90 days that it became greater. Hayano (1973) also observed that the activity of β-glucosidase was not related to organic matter content in the soil. It appears that β-glucosidase activity is composed of two factors; the activity of specific groups of organic compounds of biological origin, and the β-glucosidase activity of mineral and dead organic constituents of the soil.

The activity of enzyme urease presented in Fig. 11 shows that incubating the soil with dhaincha and guar caused enormous increases in urease activity FYM and poultry manure coming next, while wheat straw and rice husk did

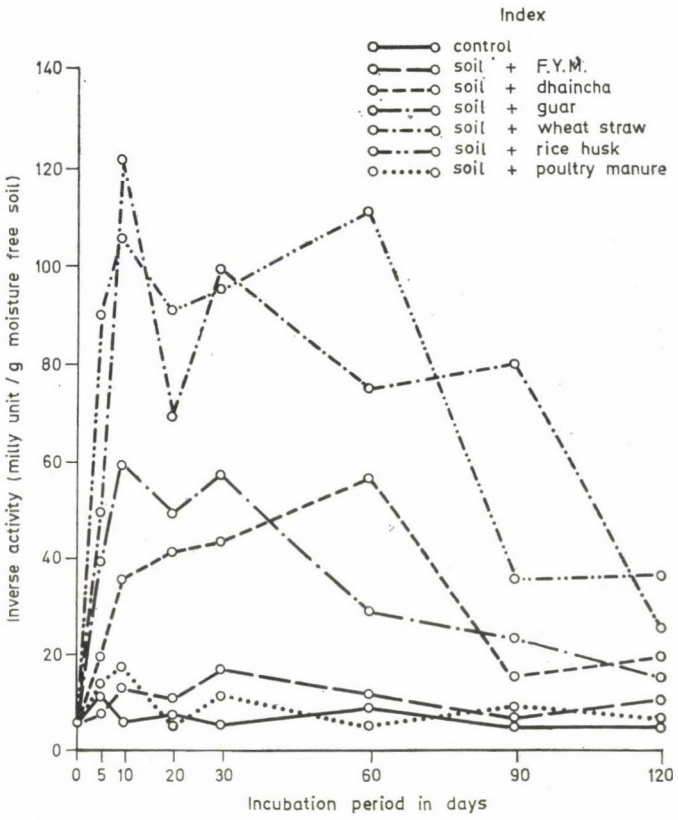

Fig. 9. Changes in invertase activity during decomposition of organic matter in soil

not alter the urease activity to a great extent. Increase in urease activity with increasing building of organic matter is well known (Skujins 1967, Balasubramanian et al. 1972). However, an enormous increase in urease activity under treatments involving addition of dhaincha and guar (which are fast decomposing organic materials) indicates that the urease activity is greatly influenced by the nature and chemical composition of organic matter. Evidently green succulent organic materials like dhaincha and guar, which contained more nitrogenous matter, had favoured the production of urease by soil microorganisms. FYM and poultry manure, although nitrogen rich materials, did not enhance the urease activity greatly; perhaps because they are humified materials. Although increasing urease activity with increasing organic matter has been reported (Skujins 1967), there appears to be no such relationship, which could be attributed to the differential rates of decomposition of the organic materials under study.

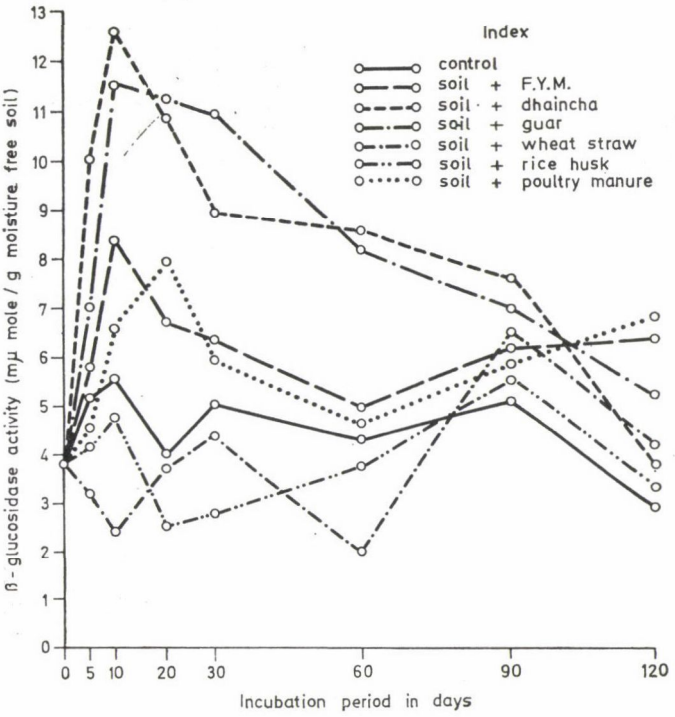

Fig. 10. Changes in β-glucosidase activity during decomposition of organic matter in soil

It is clear from Figs 5, 6, 7 and 8, representing microbial population, and Figs 9, 10 and 11, showing enzyme activity, that the peak periods of enzyme activity and microbial population did not correspond to the same incubation period. Although many workers have reported that the activity of invertase and urease is generally related to the number of micro-organisms in the soil (Nowak 1964 and Skujins 1967), the results of the present investigation do not follow this trend. This may be attributed to variations in microbial population decomposing different organic materials, differing rates of metabolism and growth of these micro-organisms.

The results of the present study show that enzyme activity cannot be employed to characterize the manurial value of various organic materials under study and that enzymatic activity does not serve as an index either for microbial activity in the soil nor for the fertility of soil. While it is reasonable to assume that differences in microbial population and enzyme activity would occur, the relationship between their qualitative composition and synthetic abilities under the influence of heterogenous source of organic materials requires further investigation.

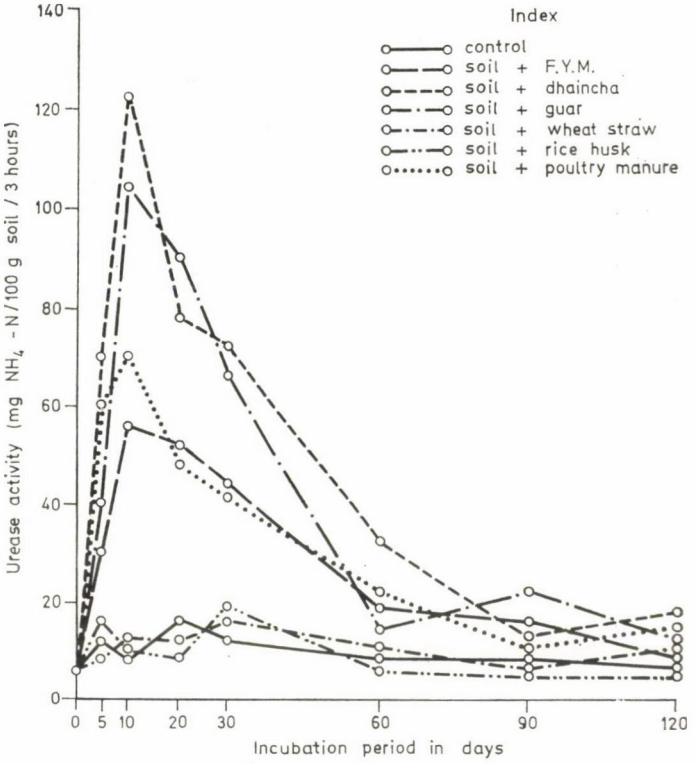

Fig. 11. Changes in urease activity during decomposition of organic matter in soil

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COMPARATIVE ANALYSES OF SOIL Ca MEASURED BY EUF AND OTHER METHODS

Á. PUSZTAI* and ÉVA ELEK**

* RESEARCH INSTITUTE FOR SOIL SCIENCE AND AGRICULTURAL CHEMISTRY OF THE ACADEMY OF SCIENCES, BUDAPEST, HUNGARY
** PLANT PROTECTION AND AGROCHEMISTRY CENTRE OF THE MINISTRY OF AGRICULTURE AND FOOD, BUDAPEST, HUNGARY

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Investigations were aimed at the determination of Ca-supplying capacity of soils. In the course of this work data of a bio-test (pot experiment) has been compared with the results of four laboratory methods. A very close correlation has been found between the Ca uptake of the alfalfa and the Ca-content of the soils determined by the Scheibler, the AL and the potentiometric methods. The data gained by the EUF method gave a very poor correlation with the plants' Ca-uptake.

Keywords: soil Ca-content, bio-test, alfalfa, EUF-method

Introduction

Recommendations for using lime-fertilizing and liming are still dependent on such traditional data as hydrolytic acidity, pH, etc., which do not express directly the Ca-supply of soils. For this reason those methods which show directly the amount of "available" Ca^{2+} are of importance.

In serial analyses those methods are especially important which enable more elements to be determined from an extract. The EUF, the flame fotometric determination of Ca^{2+} in the AL-extract and with ion-selective electrode in the water saturation extract are methods of this kind. Our aim was to compare the available traditional and new Ca determining methods on the samples of a liming model experiment. The methods were compared with each other, with the yield and with the Ca taken up with the crop.

Material and methods

Our study was carried out in a two-factorial pot experiment. The weight of each pot was 1.8 kg. Each pot was filled with 0–20 cm layer of a brown forest soil with clay illuviation of non-calcareous Ragály, very acidic ($pH_{KCl} = 4.8$; $y_1 = 22.5$) and very poor in available phosphorus. As for liming treatment we mixed 0, 1.0, 2.5, 5.0 and 10.0% $CaCO_3$ with the soil thus making the non-calcareous brown forest soil similar to calcareous brown forest soil (max pH = 7.2). P_0, P_1 and P_2 phosphorus levels were made on $N_{260}K_{170}$ mg/kg base adding 200 mg/kg $CaHPO_5$ to each level. The experiment was carried out in repetitions with alfalfa.

A part of the soil and plant analyses was made in the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, the EUF analyses in the laboratory of Plant Protection and Agrochemistry Centre of the Ministry of Agriculture and Food in Tanakajd (1., 2., 3.). The results of the 5 cuttings of alfalfa were evaluated with analysis of variance and are shown in Table 1.

Table 1

The yield of alfalfa and pH depending on the liming and P-fertilization (dry matter g/pot)

1. Average

$CaCO_3$, %	P_0	P_1	P_2	$LSD_{5\%}$	Average	%	pH_{KCl}
0.0	3.1	4.3	6.7		4.7	100.0	4.6
1.0	6.7	9.3	10.7		8.9	189.4	6.7
2.5	6.3	9.2	11.8	0.9	9.1	193.6	7.1
5.0	7.5	10.1	12.6		10.1	214.9	7.2
10.0	7.6	10.9	13.2		10.6	225.5	7.2
$LSD_{5\%}$		0.9			0.5	10.6	
Average	6.2	8.8	11.0	0.4	8.7	185.1	
%	100.0	141.9	177.4	6.4	140.3		
pH_{KCl}	6.6	6.6	6.5				

Results and discussion

The analysis of variance of the yield showed that the effect of liming as well as the P-fertilization was significant. The linear effect of P-fertilization was also significant. The lime effect in great doses showed a declining tendency. The efficiency of P-fertilization increases proportionally with the lime dosage and the linear component of liming rises proportionally with the P dosage.

According to the data of plant analyses, the Ca content of alfalfa even if 1.0% $CaCO_3$ was mixed with the soil reached the 3.0%, which is considered to be optimal in plant analyses and practically did not change with the further increase of lime dosage.

We removed the larger roots after the last cutting 5 months from the beginning of the experiment.

Average samples weighing 1.5 kg each were taken from the treatments and the soil analyses were made from these. From the analyses we have shown the ones referring to the Ca-content of the soil in Figure 1. The figure shows the yield and Ca uptake of alfalfa in relation to the average of the phosphorus treatment. The Ca concentrations of water saturation extract (meq/l) were measured with Ca ionselective electrode (IE) ORION-typ, and the amount of Ca on the EUF filter paper (ppm) with flame photometer. We took the quantity

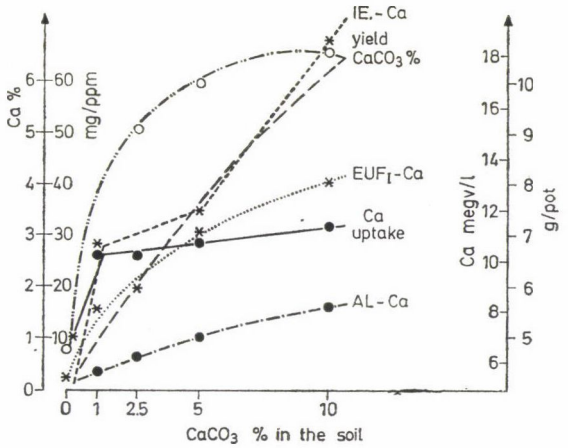

Fig. 1. The effect of liming and P-fertilizer on the Ca-content of soil and alfalfa

of $CaCO_3$ determined with Scheibler apparatus as $CaCO_3$% and the Ca content of the AL-extract measured with flame photometer as AL–Ca%.

Figure 1 shows that the amount of carbonate established with Scheibler's method linearly with liming, although we did not get back intirely the added $CaCO_3$ quantity. The change in the Ca determined in the AL-extract and in the water saturated extract was almost linear with liming. A good Ca growth was seen on the filter paper as well. The quantity of $CaCO_3$ added to the soil was not shown either in the separate EUF fractions or in the sum of the fractions, therefore has not been shown in the figure. With full knowledge of the facts, it seems that the Ca values determined from the EUF solution showed a negative correlation with P-fertilizing as opposed to the yield.

Table 2

The linear correlation coefficients (r-values) and their significance (n = 15)

	Lime dose	Yield	Ca uptake	Scheibler	AL	EUF_I	Ionselective	EUF_{II}	Fractions		
									1–2	3–6	7
Lime dose	—	0.53	0.53	0.98	0.98	0.88	0.91	0.40	0.36	0.39	0.40
Yield	*	—	0.99	0.60	0.62	0.45	0.56	0.44	0.44	0.43	0.43
Ca-uptake	*	***	—	0.59	0.62	0.46	0.58	0.49	0.46	0.48	0.49
Scheibler	**	**	*	—	0.98	0.87	0.88	0.43	0.39	0.43	0.43
AL	***	**	*	***	—	0.88	0.91	0.47	0.43	0.46	0.47
EUF_I	***	+	+	***	***	—	0.91	0.67	0.61	0.65	0.71
Ionselective	***	*	*	***	***	***	—	0.56	0.52	0.54	0.59
EUF_{II}	no	+	+	+	+	**	*	—	—	—	—
1–2	no	+	+	no	+	*	*	—	—	—	—
3–6	no	+	+	+	+	**	*	—	—	—	—
7	no	+	+	+	+	**	*	—	—	—	—

We calculated the linear regression for the characterization of the correlation of soil and plant parameters, the *r*-values, the significance of which are shown in Table 2. According to this, those Ca-values proved to have the closest correlation with the lime doses which were determined with the Scheibler, AL, IE and EUF_1 method. The data of Scheibler, AL and IE method showed a significant correlation with the yield of alfalfa and with the Ca uptake. The values obtained by EUF-filter paper showed a correlation only at LSD = 10%.

Summary

The effect of different liming and P-fertilization on the yield of alfalfa was compared in a model pot experiment with the Ca content extracted with the yield and determined from the soil with different methods. The Scheibler, the AL, the water saturated extract (IE) and the EUF methods were compared.

In the experiment the lime dosage and the Ca uptake showed a better correlation with the data determined with the Scheibler, AL and IE methods than with the ones determined with the EUF method. The most reasonable Ca values were obtained by using the EUF method on filter paper. According to our results the EUF solution fractions and the sum of the fractions do not indicate the $CaCO_3$ content of the soil.

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EFFECT OF HYDROLYTIC ENZYMES OF STORAGE FUNGI ON SEED DETERIORATION

G. C. MONDAL[1], D. NANDI[2] and B. NANDI[3]

[1] RUBBER RESEARCH INSTITUTE OF INDIA, GUWAHATI, ASSAM, INDIA
[2] BANGABASI COLLEGE, CALCUTTA, INDIA
[2] DEPARTMENT OF BOTANY, BURDWAN UNIVERSITY, BURDWAN, INDIA

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The production of cellulose (Cx) and endo-polygalacturonase (endo-PG) of some predominant storage fungi (viz., *Aspergillus fumigatus*, *A. funiculosus*, *A. niger* and *A. chevalieri*) isolated from stored oilseeds was studied both on liquid basal and seed media. The activity of cellulase (Cx) was found to be very high in all fungi, except *A. chevalieri*, on both media. Production of endo-PG was high in *A. niger* and *A. chevalieri* but quite low in *A. fumigatus* and *A. funiculosus*, both in the culture filtrate and in the extract from inoculated seeds. The important role of these hydrolytic enzymes in seed deterioration was observed, as evidenced by higher loss in oil content, germinability and organic dry matter of seeds.

Keywords: seed storage, deterioration, fungi, hydrolitic enzymes

Introduction

The problems of fungal deterioration of oil seeds in storage, leading to considerable loss of edible oil, have received increasing attention in recent years. Seed coats, which are chemically composed mainly of cellulose and pectin, are acted upon by the fungi during invasion through secretion of extracellular hydrolytic enzymes like cellulase (Cx) and polygalacturonase (Bateman and Millar 1966, Mohanty and Addy 1971, Chacko et al. 1978). According to Wood (1967), the pectolytic enzymes cause dissolution on middle lamella in the seed coats, thereby releasing the unicells which are then degraded easily with cellulase (Cx), thus facilitating for seed spoilage.

The present investigation has been undertaken to study the relative efficacy of production of hydrolytic enzymes by some storage fungi predominantly associated with deteriorating oilseeds, with the ultimate aim of preventing the loss of edible oil, which incidentally has shown a considerable price increase in recent years.

Material and methods

Aspergillus fumigatus Fresenius, *A. niger* van Teighem, *A. chevalieri* Thom and Church and *A. funiculosus* Smith, frequently associated with two cultivars of sesame (*Sesanum indicum* L. vars. reddish-brown and black), two species of mustard (*Brassica campestris* L. var.

yellow *sarson* and *B. juncea* (Coss) and one of linseed (*Linum usitatissimum* L.) under natural storage, were used in this present study. For the enzyme studies, both seeds and liquid basal media were used and the seed deterioration was measured in terms of the decrease in germinability, oil content and organic dry matter.

The fungi were grown separately on liquid basal media containing carboxymethylcellulose (CMC) — 1.0%, KNO_3 — 0.2%, KH_2PO_4 — 0.3% and $MgSO_4 \cdot 7\,H_2O$ — 0.5% following Prasad (1979). Media (50 ml) in Erlenmeyer flasks (25 ml) were sterilized at 1 kg/sq cm pressure for 15 minutes and inoculated with 0.5 ml spore suspension (6×10^5 spores/ml) of the fungus, prepared from a nine-day-old culture, maintained on salt-malt-agar. The flasks were incubated at 30 ± 2 °C for 15, 30 and 45 days. The contents of the flasks were then filtered through G-sintered glass filter. The mycelial mats, after thorough washing with deionized water, were dried at 70 °C until constant weight was obtained, and the filtrate was used for the studies of extra-cellular enzymes.

The production of cellulase (Cx) in the filtrate was determined by measuring the reduction in viscosity of a 0.5% CMC solution, using an Ostwald Viscosimeter (Muse et all 1972). The change in viscosity of the reaction mixture containing 5 ml of CMC solution, 2 ml of 0.1 M sodium-citrate buffer at pH 5.6 and 2 ml of enzyme in culture filtrate, was measured at 35 °C in intervals of 30, 90 and 180 minutes. A set with the heat-inactivated culture filtrate (at 100 °C for 30 minutes) served as a control. The enzyme activity was expressed as a percentage of reduction in viscosity of CMC.

The fungi were grown separately on the same medium used for cellulase activity, except with apple pectin (1.5%) in place of CMC. After different periods of incubation, the mycelial mat was collected by filtration, washed thoroughly with deionized water and dried at 70 °C until constant weight was obtained. The filtrate was assayed for endo-polygalacturonase (endo-PG) from the loss in viscosity of 1.2% pectin solution, using 0.1 M sodium-citrate buffer at 4.6 pH. The sodium-citrate (0.1 M) buffers at 4.6 and 5.6 were prepared following Gomori (1955).

For the extraction of enzymes in fungal deteriorated seeds, freshly harvested and healthy oilseeds (70 g) were used. The surfaces were sterilized, washed thrice with deionized water, and partially dried to 9.0, 9.3, 6.5, 10.5 and 6.9% moisture respectively, in rapeseed, linseed, sesame black, Indian mustard and sesame brown. These were then inoculated separately with 0.5 ml spore suspension (6×10^5 spores/ml) of the predominant fungi which was isolated earlier and incubated at 30 ± 2 °C for 25, 30 and 45 days. Seed extracts were prepared by grinding the oilseeds (20 g) in 40 ml of sterile deionized water. These were passed through G_2-sintered glass filter and the filtrates were used for enzyme studies. An identical set without inoculation served as control. Cellulase (Cx) and endo-PG were determined following the same procedure used in the assay from culture filtrate.

The germinability was tested by placing 400 surface-disinfected seeds on sterilized Petri dishes containing moist filter paper (ISTA, 1966) and incubating the dishes at 30 ± 2 °C for 7 days. Those seeds which produced seedlings with normal roots of 5 mm were taken to be germinated.

The dry matter of seeds was determined by thoroughly cleaning 600 seeds of uniform size of each type (in triplicate), except linseed (from 300 seeds), with sterile deionized water and drying at 80 °C for 48 hours, following Ward and Diener (1961).

The oil was extracted using a petroleum ether (b.p. 40–60 °C) by the Soxhlets technique for 4 hours, following Meara (1955), and expressed as a percentage of dry weight of the seeds.

Results

A. funiculosus and *A. chevalieri* produced the highest and the least quantities of Cx cellulase, being equivalent to the loss in viscosity of 76.3% and 9.5%, respectively on the synthetic medium, as was evident from two extreme cases of reduction in viscosity by thirty-day-old cultures (Table 1). In the case of *A. fumigatus*, a considerable amount (71.3%) of the enzyme was recorded in the fifteen-day-old culture which decreased to 8.2% after 45 days. In *A. niger*, the reduction in viscosity showed 64% in 15 days which decreased

slowly to 43.6% in the forty-five-day-old culture. The rate of reduction in viscosity was comparatively very high during the initial phase of incubation and statistically significant up to 90 minutes and thereafter in some cases. No loss in viscosity was observed in the heat-inactivated culture filtrates. The mycelial dry weight of all the test fungi except *A. niger* increased gradually, reaching a peak after 30 days of growth, but decreased thereafter (Table 2). In *A. niger*, the mycelial dry weight was highest at the end of the experimental period, but least in *A. fumigatus* after 30 days.

Table 1

The loss in viscosity of the carboxymethylcellulose (CMC) and the pectin solutions using cellulase (Cx) and PG in culture filtrates of some predominant seed storage fungi

Fungi	Dry weight of mycelium/50 ml medium (mg)*						Time interval (min)	[a] Loss in viscosity (%)*					
	Incubation (days)							Incubation (days)					
	15		30		45			15		30		45	
	CMC	Pectin	CMC	Pectin	CMC	Pectin		CMC	Pectin	CMC	Pectin	CMC	Pectin
Aspergillus fumigatus	90	65	115	50	98	42	30	36.1	0	8.8	3.5	6.8	3.5
							90	57.6	8.5	18.3	10.6	7.7	3.5
							180	71.3	8.5	21.5	14.1	8.2	5.3
A. funiculosus	105	80	125	60	110	55	30	21.0	5.5	48.6	6.2	11.7	5.5
							90	31.9	8.9	70.1	10.3	25.8	5.5
							180	48.7	12.2	76.3	14.0	29.8	5.5
A. niger	198	185	220	192	225	198	30	28.0	42.3	26.3	17.2	24.2	8.5
							90	52.7	57.6	44.5	48.2	40.1	17.0
							180	64.0	69.2	53.7	60.3	43.6	34.0
A. chevalieri	98	105	108	115	102	120	30	0	16.7	4.7	16.8	4.1	25.5
							90	0.6	39.3	8.3	40.1	6.3	40.4
							180	5.2	47.0	9.5	65.9	9.0	47.9

* Mean value of three replicates, [a]Loss in viscosity in control $< 5\%$

Table 2

The effect of carboxymethyl cellulose (CMC) and pectin on the growth of some seed storage fungi on liquid basal media

Fungi	Dry weight of mycelium/50 ml medium (mg)					
	Incubation (days)					
	15		30		45	
Carbon source:	CMC	Pectin	CMC	Pectin	CMC	Pectin
Aspergillus fumigatus	90	65	115	50	98	42
A. funiculosus	105	80	125	60	110	55
A. niger	198	185	220	192	225	198
A. chevalieri	98	105	108	115	102	120

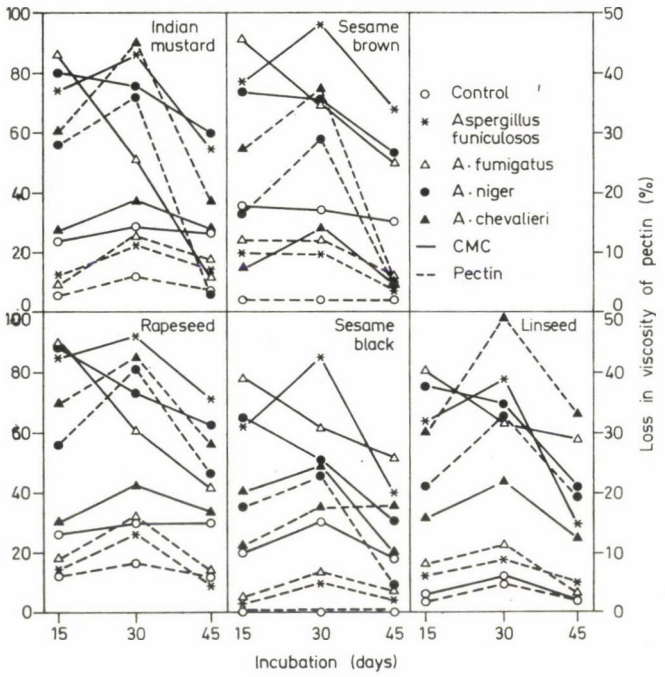

Fig. 1. Loss in viscosity of carboxymethylcellulose (CMC) and pectin solutions using extracts of seeds inoculated with predominant storage fungi

A. funiculosus produced the highest (96.0%) and *A. chevalieri* the least (29.0%) amount of Cx cellulase also on the seeds of reddish-brown sesame cultivar after 30 days of incubation (Fig. 1). On the other hand, *A. fumigatus* and *A. niger* showed more or less identical activity of the enzyme on most of the test seeds and the rate of production was found to be highest in both cases after 15 days of incubation.

A. niger showed the highest (69.2%) activity of endo-PG on a synthetic medium after 15 days and then decreased with a longer incubation (Table 1). *A. fumigatus* and *A. funiculosus* showed the minimum and almost identical enzyme activity. In these fungi, the enzyme activity increased to some extent in a thirty-day-old culture and then decreased after 45 days. *A. chevalieri* showed a fairly high production (47.0%) after 15 days which increased sharply (65.9%) in a thirty-day-old culture. The rate of reduction in viscosity was statistically significant only in the cases of *A. niger* and *A. chevalieri* in most of the phases of incubation. Here also the heat-inactivated enzyme showed no loss in viscosity. The increase in mycelial dry weight of the fungi on pectin was more or less similar to those on the CMC media, but the amount of mycelial mat was comparatively lower in the former (Table 2).

The activity of endo-PG on the seeds was found to be the maximum in linseed and the minimum in sesame black infected by *A. chevalieri* after 30 days (Fig. 1). Both *A. fumigatus* and *A. funiculosus* showed more or less identical activity in all the test seeds. Their rates of production were highest after 30 days of incubation.

A gradual reduction in germinability of the test seeds was recorded (Fig. 2). Both *A. niger* and *A. fumigatus* caused the maximum loss after 45 days. The rate of reduction in germinability was found to be the highest at the end of the experimental period.

The dry matter of control seeds remained unchanged from the initial values even after different incubation periods (Fig. 3). A gradual decrease was, however, noted in the inoculated seeds with the maximum caused by *A. niger* and *A. fumigatus* after 45 days.

The uninoculated seeds showed no change in their oil content (Fig. 4). In the seeds inoculated with test fungi, a gradual loss of oil was recorded throughout the experimental period. Comparatively, *A. niger* caused a much higher reduction of oil in all the seeds, except linseed where *A. fumigatus* was the most efficient followed by *A. niger*, *A. funiculosus* and *A. chevalieri* in descending order.

Discussion

The examination of different oilseeds from private storehouses revealed a preponderance of *Aspergillus* spp., which resulted in decreases in germination (Mondal et al. 1981), as well as changes in the total oil content and the chemical properties of the oil (unpublished data). A strong cellulolytic (Cx) activity was exhibited in both the culture filtrate of the fungi and the extracts from the seeds infected by *A. fumigatus*, *A. funiculosus* and *A. niger*, but not by *A. chevalieri*. A high PG activity was noted in both *A. niger* and *A. chevalieri*. On both media, the rate of production of Cx cellulase by *A. fumigatus* and *A. niger* was the highest during the first, and by *A. funiculosus* and *A. chevalieri* during the second phase of incubations and then decreased to some extent. On the other hand, the production of PG was the highest in the second phase by all the test fungi on both media except *A. niger*, where it was the highest in the first phase on the synthetic medium. This indicated that the fungi secreted a high amount of the enzymes in synthetic as well as in seed media which could cause a rapid tissue disintegration, as was evident from the greater loss in dry matter, germinability and oil content of the seeds. This would facilitate the pathogenic penetration and the establishment in the seed tissue. Subsequently, the production of this particular enzyme decreased to a certain extent suggesting that only small quantities of enzyme were enough to cause further maceration (Husain and Rich 1958, Vidyasekaran et al. 1966).

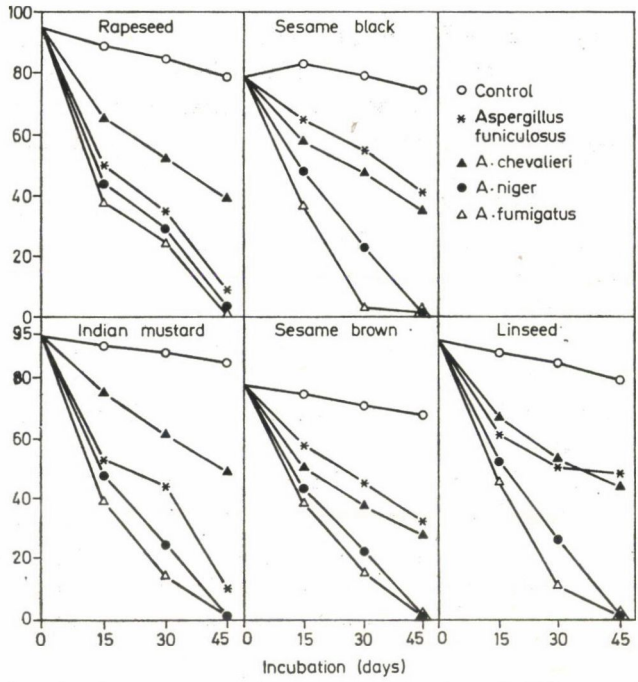

Fig. 2. Effect of predominant storage fungi on germination of different oilseeds stored in the laboratory

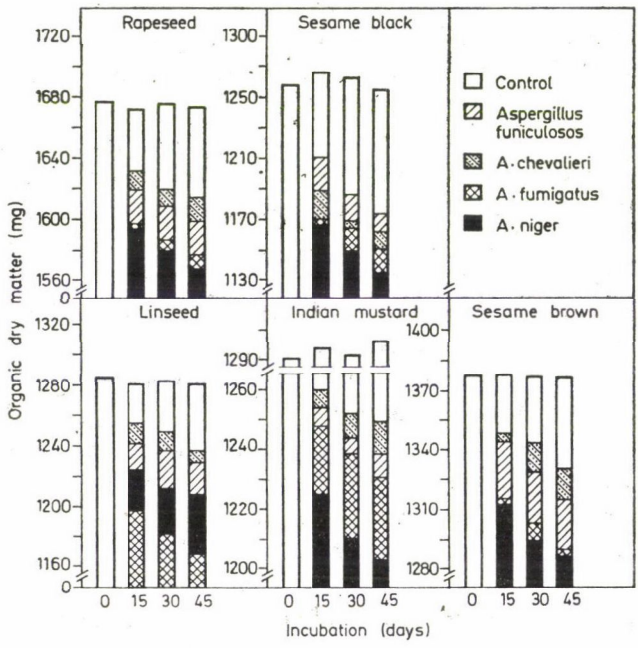

Fig. 3. Effect of predominant storage fungi on organic dry matter of different oilseeds stored in the laboratory

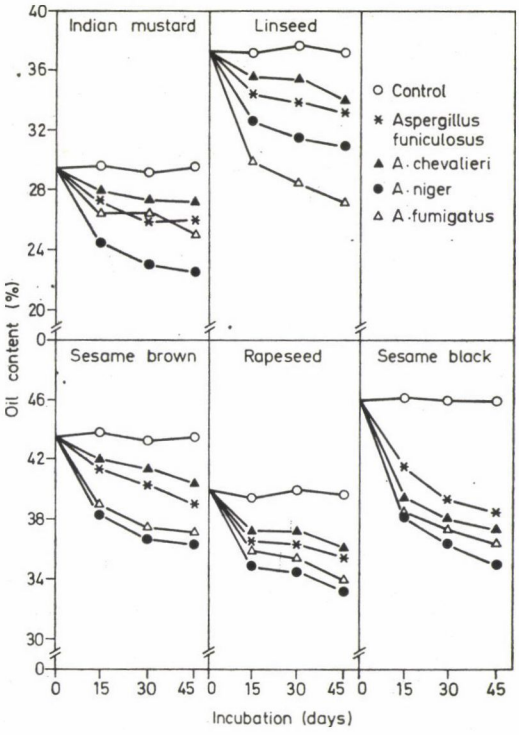

Fig. 4. Effect of predominant storage fungi on oil content of different oilseeds stored in the laboratory

The germinability was reduced to a great extent in all the seeds by the infection of *A. niger* and *A. fumigatus*. This might be partly due to the utilization of major food reserves, as was evidenced by the loss in dry matter and the oil content of the seeds (Figs 3 and 4), and partly to the production of toxic metabolites (unpublished data) in the seeds.

The reduction of the oil content in the test seeds due to infections by the fungi was in full conformity with the observations of Ward and Diener (1961) and Singh and Prasad (1977). *A. niger* and *A. fumigatus* caused a much higher loss in the oil content than did the others. The loss in oil often varies depending on the organism and the type of seed. Such variations might partly be due to the presence of higher unsaturated fatty acids, and partly depending on the metabolic activities of the fungus, as pointed out by Milner (1950).

The production of the extra-cellular PG by the four seed-borne fungi suggested that these organisms were capable of degrading the α-1,4 linkage between the galacturonosyl moieties in the polymer of galacturonic acid, and could cause an extensive tissue disintegration by the digestion of the cementing structures of the cell wall in the seeds. The rapid rate of reduction of vis-

cosity indicated a random cleavage of α-1,4 glycosidic linkage of the pectin chain through the activity of endo type PG, as pointed out by Bateman and Miller (1966). Finally, the resultant components could be acted upon by the Cx type of cellulase, hydrolyzing the β-1,4 linkage and converting it into a simpler substance (cf. Prasad and Bilgrami 1977). This could possibly cause the seed-coat to become more permeable and help these fungi to invade the embryo and utilize the major food resources for their establishment into the seed tissue, which finally leads to a loss in germinability, oil content and organic dry matter of the seeds.

The study of the activity of these enzymes of seed-borne fungi thus helped in understanding the attributes of individual fungal species in the extent of seed deterioration.

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EFFECT OF SULPHATE SUPPLY ON THE NITROGEN, SULPHUR AND AMINO ACID METABOLISM OF ANGORA RABBITS

I. N- AND S-METABOLISM

MÁRIA TELEKI, JOLÁN JÉCSAI and B. JUHÁSZ

RESEARCH INSTITUTE FOR ANIMAL NUTRITION, DEPARTMENT OF PHYSIOLOGY, HERCEGHALOM, HUNGARY

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The authors fed adult Angora rabbits with feed containing 11% and 17% protein, separately, and completed the feed for the experimental groups with 0.2% Na_2SO_4.

The sulphate supply improved the apparent digestibility of sulphur and the S retention of animals on both levels of protein. The amount of N excreted in the faeces slightly increased, but that excreted in the urine decreased, with the consequence that the N retention of the experimental Angora rabbits improved on both protein levels. The sulphate supply produced the most favourable result in the case of a 1 : 0.41 ratio of N : S.

With low (11%) protein content concentrates in the feed, the "total" S content of the blood did not change (42–42 mmol/1); while, in the case of more (17%) protein, it fell from 81.7 to 55.3 mmol/1. The "total" sulphur content of the liver and spleen slightly increased.

Keywords: Angora rabbits, feed mixtures, N-, S- and amino acid metabolism

Introduction

In recent years several authors (Bouchard and Conrad 1973, Doyle and Moir 1979) described a favourable effect exercised by the inorganic sulphur content of the feed on nutrient conversion, if the feed contained little of methionine, or of methionine and cystine together. Sulphur is present in the feed not only in the form of amino acids, thiamin and biotin, in an organic bond, but also as sulphate, in an inorganic bond.

However, according to Dziewiatkowski (1962), a large proportion of these inorganic compounds consists of not readily soluble alkali sulphates, and—on the other hand—in the inorganic bonds the sulphur is highly oxidized. The higher animal organism in the intermediary metabolism is but slightly—if at all—able to reduce the sulphur. Here the oxidative processes dominate. The reduced sulphur contained in the amino acids first becomes oxidized then incorporated into some other organic bond, and finally, in consequence of further oxidation, passes over to an inorganic bond.

The anaerobic micro-organisms living in the digestive tracts of certain animals (ruminants, rabbits) are able to reduce the sulphur. In the course of

the synthesis of the organic bonds, the reduced sulphur is incorporated in amino acids containing sulphur and in other sulphur-containing compounds (heparin, mucopolysaccharides) (Giesecke and Hendericks 1973).

The role of inorganic sulphur in covering the sulphur requirements of monogastric animals, except for the rabbit is very restricted (Hennig 1972).

According to some authors, the rabbit is also able to make use of sulphur present in the sulphate bond in its intermediary metabolism. Inaba (1973) pointed out the presence of A sulphate-activating enzyme in the mucous membrane of the rabbit's colon. Under the influence of the enzyme, a "sulphate donor" is produced, which activates the sulphate radicle and passes it to an acceptor, and from this, through a receptor the amino acids are synthetized. Fromageot and Chapeville (1955) found that, when they eliminated the microbal activity by washing out the digestive tract, the rabbits were unable to incorporate the introduced radioactive sulphur in methionine and cystin. In the auricular cartilage there was still a considerable amount of radioactive sulphur.

According to Kulwick et al. (1954) only the microbes present in the digestive tract build the sulphur in organic bonds, which in consequence of caecotrophy is absorbed and utilized in the intermediary metabolism.

In earlier investigations, we found that owing to the wool production in Angora rabbits the sulphur-containing amino acids were limiting factors. We therefore set up an experiment to determine, besides supplementing the sulphur-containing amino acid, what other source of sulphur is available to satisfy the sulphur requirements of Angora rabbits.

The daily wool production of Angora rabbits is 2.0–2.5 g. According to the analysis, one gram of wool contains 38 mg sulphur. At the same time, the feed consumed by the Angora rabbits has little content of sulphur of sulphur-containing amino acids.

The sulphur-containing amino acid requirement for producing Angora rabbit wool is 0.6–0.8% (Schlolaut 1977). Our experiments were aimed at finding out to what extent the Angora rabbits would be able to make use of inorganic sulphur given *per os* in the form of Na_2SO_4 in wool production, and how it would influence the amino acid-, N- and S-metabolism of the animals.

Material and methods

Sixteen adult male Angora rabbits (body weight: 3697 $\pm$ 158 g) were divided into four (A, B, C and D) groups (n = 4).

The animals in group A and B consumed a feed mixture containing 11% protein; in group C and D the protein content of the feed was raised to 17% with extracted sunflower seed-meal added to it, whereby the "total" sulphur content of the mixture also grew. The sulphur content of the feed in group B was raised to the level of "total" sulphur (S) contained in the feed of group C with 0.2 per cent Na_2SO_4 mixed in. The S-content of feed in group D compared to C was also increased by the addition of 0.2 per cent Na_2SO_4 (Table 1). The feed

mixtures were consumed by the animals from shearing to shearing (75 days) in 140 g rations once a day.

On the 14th day after shearing, the animals were placed in separate hutches, to determine the N- and S-metabolism.

The period of examination consisted of 1a seven-day preparatory and a five-day experimental phase. The feed consumption was measured every day. With the earlier determined feed rations, the animals consumed the feed quantities given in Table 1.

During the five-day experimenta lperiod, the urine and faeces were measured daily then preserved by deep freesing until the analyses were performed.

From the feed components, urine and faeces samples (per day and animal) the quantity of N excreted was determined after Kjeldahl, and the total amount of S determined by the turbidimetric method of Notters and Head (1971).

At the end of the metabolic experiments, blood was taken from the auricular vein of the animals to determine the S-content. The animals were put to death without being bled, the livers and spleens were removed and preserved by freezing until the S-determination.

At both beginning and end of the experiments, the amount of wool shorn was measured and the staple thickness determined by lanometry.

Table 1

Quantities of nutrients consumed with the daily ratio of feed (g/animal/day)

Groups	11% protein		17% protein	
	A (n = 4)	B (n = 4)	C (n = 4)	D (n = 4)
Dry matter	122.8 ±	122.8 ±	123.3 ± 0.02	120.8 ± 0.04
Nitrogen	2.6 ±	2.6 ±	3.7 ± 0.02	3.6 ± 0.03
Raw fibre	18.3 ±	18.3 ±	18.2 ± 0.60	18.1 ± 0.50
Crude fat	4.2 ±	4.2 ±	4.2 ± 0.70	4.2 ± 0.40
N-free extractable matter	76.3 ±	76.3 ±	75.8 ± 3.60	75.7 ± 3.70
S in amino acid bond	180.0 ±*	180.0 ±*	196.3 ± 1.80*	192.3 ± 9.80*
S given in the form of Na_2SO_4	—	72.2 ±*	—	70.4 ± 11.20*
Total S	293.2 ±*	365.4 ±*	367.6 ± 7.70*	421.5 ± 28.70*
N : S ratio	1 : 0.11	1 : 0.14	1 : 0.10	1 : 0.12
Total S as a percentage of the dry matter of feed	0.23	0.30	0.30	0.36
Total S mg/100 g feed	209.40	261.00	263.79	308.79

* = mg quantity of S

Table 2

Total sulphur contents in the feed components

Feed components	mg/g
Maize	1.0
Wheat	1.4
Barley	1.5
Sunflower seed-meal (extracted)	4.8
Lucerne hay	3.6
Wheat straw	3.0
Premix	9.5

Results

The sulphur contents of the components of the feed mixtures in the experiment are given in Table 2. As seen from the data, the S-content while rather low in the cereals is relatively high in the extracted sunflower seed-meal and lucerne straw. The S-content of the wheat straw is higher than expected.

S-metabolism

Under the influence of sulphur given in the form of Na_2SO_4 the apparent digestibility of S substantially increased on both protein levels (Table 3). In response to S given is excess, the amount of S excreted with the faeces decreased rather than increased. The apparent digestibility of S was highest in group B, where the feed with the S-supplement contained the same quantity and percentage of S as in the C group; but the ratio of N : S was — in our opinion — the most favourable (1 : 0.14) in this one of the four feed variations. The apparent digestibility of S was lowest in group C, where the ratio of N : S (1 : 0.10) was the least favourable.

The data of S excreted in the urine and those of the S-retention are shown in Table 4. The amount of S excreted in the urine increased on both protein levels in response to S supplied. In spite of this, the retention of S improved in the B- and D-group alike. It was best in group B (47.3%) where the ratio of N : S was 1 : 0.14, and worst in groups C (33.7%) where the same ratio was only 1 : 0.10.

N-metabolism

As a response to the S supply, the amount of N excreted with the faeces slightly increased at both protein levels, while the apparent digestibility of N showed a parallel decrease (Table 3). The amount of N excreted with the urine, on the other hand, decreased. The increased amount of urinary N in group C, compared to group A, was the consequence of the higher N-ration. The N-content in the urine of those animals in group D did not follow this trend; in their urine, the same quantity of N was found as in that of the animals in group A, where the N-ration was lower.

As a consequence of the reduced amount of N excreted with the urine, the retention of N improved at both levels of protein.

Wool production, staple thickness

The wool production of animals consuming a concentrate containing 11% protein decreased, in comparison to the amount of wool produced under better feeding conditions prior to the experimental period. In group A the

Table 3

Apparent digestibility of sulphur

Experimental groups	S uptake	S in the faeces	Digested S	Apparent digestibility of S %
	mg/day			
A	293.2 ± —	101.2 ± 18.7	192.0	65.5
B	365.4 ± —	83.3 ± 21.3	282.1	77.2
C	367.6 ± 7.6	129.6 ± 47.0	238.0	64.7
D	421.5 ± 28.7	111.8 ± 21.3	309.6	73.5

Table 4

S excreted with urine, and the S balance

Experimental groups	S uptake	S in the faeces	S in the urine		S retention	
	mg/day		mg/day	%	mg/day	%
A	293.2	101.2	79.5 ± 24.3	27.1	112.5 ± 24.4	38.4
B	365.4	83.3	109.2 ± 22.6	29.9	172.9 ± 30.3	47.3
C	367.6	129.6	114.4 ± 61.2	31.1	124.0 ± 61.9	33.7
D	421.5	111.8	149.7 ± 55.6	35.5	159.8 ± 57.7	37.9

Table 5

Results of nitrogen balance

Experimental groups	N-uptake g/day	N in the faeces		N in the urine		N retention	
		g/day	%	g/day	%	g/day	%
A	2.59 ± —	0.74 ± 0.14	28.7	1.53 ± 0.19	59.0	0.31 ± 0.28	11.9
B	2.59 ± —	0.78 ± 0.09	30.0	1.35 ± 0.27	52.1	0.45 ± 0.26	17.4
C	3.74 ± 0.02	1.06 ± 0.07	28.3	1.81 ± 0.14	48.4	0.87 ± 0.31	23.2
D	3.63 ± 0.03	1.11 ± 0.18	30.6	1.54 ± 0.25	42.5	0.98 ± 0.37	27.0

Table 6

Wool production, staple thickness

Nutrients groups	11% protein		17% protein	
	A (n = 4)	B (n = 4)	C (n = 4)	D (n = 4)
Wool production 9/75 drugs	159.1 ± 29.4	166.4 ± 21.3	182.3 ± 18.1	191.2 ± 15.3
Daily average wool production, g	2.1 ± 0.3	2.2 ± 0.3	2.4 ± 0.2	2.5 ± 0.3
Staple thickness, μm*	16.5 ± 0.9	16.8 ± 2.7	17.0 ± 3.1	16.8 ± 3.5

* Micrometer

wool production fell from 187.2 ± 25.3 g to 159.1 ± 29.4 g (15%). In group B where the feed was supplemented with S, the decrease was less (from 188.9 ± 33.8 g to 166.4 ± 21.3 g; 12.5%) (Table 6). Of the groups consuming feed with 17% protein content, the wool production of group C (182.3 ± 18.1 g) agreed with the amount of wool shorn at the beginning of the experiment. In group D, the amount of wool was 188.8 ± 23.1 g at the beginning, and 191.2 ± 25.3 g at the end of the experiment. There were 75 days between the two dates of shearing in each case.

The staple thickness (17.0 ± 2.92 μm) was not affected by the S-supply.

"*Total*" *S-content of blood samples*

When the feed had 11% protein content, the S-supply did not influence the total S-content of the blood; it was 42.5 mmol/l in group A, and 41.1 mmol/l in group B.

When the feed contained 17% protein, the total S-content of the blood was 81.7 mmol/l in group C, and only 55.3 mmol/l in group D. The reason —in our opinion—is that the ratio of N : S was better in the feed of group D than in that of group C (Table 7).

Table 7

"Total" sulphur content in blood, liver and spleen

Nutrients groups	11% protein		17% protein	
	A	B	C	D
Sulphur content of blood mmol/l	42.50	41.10	81.70	55.30
Sulphur content of liver dry matter	5.88	6.22	—	—
Sulphur content of spleen mg/whole spleen	4.48	4.78	—	—

"*Total*" *S-content of liver and spleen*

This parameter was established only for those groups where the feed contained 11% protein. The liver contained 5.88 ± 0.72 mg S in group A, and 6.22 ± 0.77 mg S in group B, per 100% dry matter. The "total" amount of S found in the whole volume of spleen was 4.48 ± 1.38 mg in group A, and 4.78 ± 1.28 mg in group B.

Conclusions

Owing to the relatively small number of experimental animals, the S supply could not be expected to bring about significant differences in the utilization of either S or N. That is, with such a small population the individual differences of the animals greatly affect the results obtained. Thus far-reaching conclusions cannot be drawn from them.

Several authors (Coombe and Christian 1969, Langland et al. 1973, Kennedy and Siebert 1975) found a close relationship between the quantity of S contained in the feed and that which was excreted in the faeces. On the other hand, in the experiment carried out by Teller et al. (1977) with cattle, in the caase of feeding maize silage enriched with urea and containing little sulphur the S-supply decreased, rather than increased the amount of S excreted in the faeces. The same was observed in our experiment with feeds of either protein level. Most authors hold the opinion that in response to sulphate supplied, the S retention increases if the S-content of the feed ration does not satisfy the demand of the animal (Starks et al. 1953, Sasse and Baker 1974).

The results we obtained suggest that it is not enough to ensure the absolute amount of sulphur required; the question must be considered in relation to the amount of nitrogen ingested. This was proved by the results of animals in group B, where the same total amount of S was consumed as in group C. Still, since the sulphur partly came from Na_2SO_4, the % retention was better because of the much better N : S ratio in the feed of group B (1 : 0.14).

The sulphate supplied with the feed increased the retention of S at both protein levels. In any case, the result allows us to draw the conclusion that the S-content of the feed ration did not cover the S requirements of the animals.

As to the S-demand of Angora rabbits, we cannot rely on literary data. On the basis of the results of experiments carried out with cattle, there is undoubtedly a definite relationship between S-supply and N-conversion. According to Thomas et al. (1951), Kennedy and Siebert (1973) the sulphate supply has a positive influence on the utilization of N only when the feed ration does not contain sufficient sulphur. It can be supposed that the sulphate supply increased the N retention in groups B and D in our experiment for the same reason. Namely, the animals in these groups excreted less N with the urine than those in groups A and C, which consumed the same amount of N. At a low (11%) protein level, the N retention improved by 5.5, while at a higher (17%) protein level, only by 3.8 per cent in response to the S-supplement. However, the ratio of N : S in the feed was 1 : 0.14 in group B, while only 1 : 0.12 in group D. From the results obtained, we have drawn the conclusion that the feed components used in the feeding practice for Angora rabbits do not cover the S-requirements of the animals. In supplementing the

feed with sulphur, the ratio of N : S, rather than the usual concentration of S, must be taken as S basis.

The "total" S-content of the blood did not increase under the influence of S supplied; on the contrary, especially in the case of 17% protein contained in the feed it decreased, which may be explained partly by the higher quantity of sulphur excreted with the urine and partly by the better utilization. In the course of experimenting with sheep, White (1980) found that inorganic sulphur ratios caused no increase in the S-content of the blood.

According to Kandylis (1983) in the case of feeds poor in sulphur, the sulphate recirculates from the blood plasma to the rumen. In this process, the sulphate content of the saliva plays an important role. The transfer of the sulphate from the blood plasma to the rumen is a function of the sulphate concentration in the plasma. In the case of sulphur deficiency, the sulphate recirculated to the rumen probably has a decisive role in the sulphur metabolism of ruminants.

We suppose that a similar process may take place in the Angora rabbit where the coecum may act the part of the rumen.

With feeds containing 11% protein, the S-content in the liver and spleen slightly increased in response to the S-supply. To S-toxicosis we have found a single literary reference (Raisberg 1982); the author reported changes in the grey matter of the brain of cattle caused by more than 2% sulphate in their feed.

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AN IN VITRO MULTIENZYME METHOD FOR STUDYING THE DIGESTIBILITY OF PROTEINS

JOLÁN JÉCSAI, MARIANNE SZELÉNYI-GALÁNTAI and B. JUHÁSZ
DEPARTMENT OF PHYSIOLOGY, INSTITUTE FOR ANIMAL NUTRITION, HERCEGHALOM, HUNGARY

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The experiments were aimed at elaborating a quick, well-reproducible in vitro multienzyme protein digestion technique. The in vitro results were compared with values determined on the basis of in vivo N-metabolism and digestion tests with rats.

On the digestion of either animal or plant proteins, a significant correlation ($P < 0.001$) was found between the in vivo and in vitro results.

The multienzyme protein digestion method elaborated can be suitable for the quick determination of the in vitro digestibility of feed proteins.

Keywords: protein digestibility, in vivo N-metabolism, in vitro N-metabolism multienzyme digestion method

Introduction

Conclusions on the reeding value of proteins can be drawn from their amino acid composition. However, in many cases the analysis of data are more indicative of the quality of proteins than are the animal experiments. The main reason for this is the deficient digestion of the proteins, that is the incomplete absorption and utilization of the amino acids. It is therefore of decisive importance to know the digestibility of the amino acids besides their composition when judging the biological quality of the feed proteins.

The digestibility of proteins was studied with time-consuming and expensive in vivo biological methods. Attempts have lately been made to elaborate new quick, exact and cheap in vitro techniques. These methods consist of enzyme systems set up so as to hydrolize the polypeptide chains of proteins at as many points as possible, simulating thereby the protein digestion taking place in the digestive system of animals.

The extent of proteolysis is determined by various methods: In the in vitro techniques, digestion was first modelled by a single enzyme (Menden and Cremer 1966, Buchanan 1969, MSZ 6830–77). The use of more enzymes was later suggested (Saunders et al. 1973, Rhinehard 1975, Hsu et al. 1977, 1978, Satterlee et al. 1979, 1980, Rich et al. 1980, Pedersen and Eggum 1981, 1983). Methods using 3 or more enzymes are called multienzyme techniques.

In our in vitro studies 3 enzymes were used and the analytical measurings were performed after Hsu et al. (1977). The method is based on the principle that the proteolytic enzymes used break the peptide bonds of the proteins, and in the course of the hydrolysis more and more carboxyl and amino groups are released from the protein molecule. As a result pH of the medium decreases at a rate proportionate to the extent of hydrolysis and the digestibility of proteins.

Material and methods

(a) *Materials*

For the examinations 91 seeds and grains, respectively (11 of wheat, 12 of barley, 40 of maize, 6 of peas, 6 of horse-bean, 10 of lupine, 6 of soya), and 9 samples of animal origin (fishmeal, beef, skim milk-powder, 3 miscellaneous animal proteins, egg-powder, a single-cell protein: named pruteen, casein), were used. A total of 100 samples were taken under examination.

(b) *Enzymes*

Trypsin	1.3 mg/ml	1770 BAEE/mg	(Sigma)
Chymotrypsin	4.2 mg/ml	44 U/mg	(Sigma)
Pronase	2.4 mg/ml	20 U/mg	(Kőbányai Pharmaceutical Works)
Pepsin	1.0 mg/ml	26 U/mg	(Calbiol)
Pancreatin	6.5 mg/ml	47 U/mg	(Kőbányai Pharmaceutical Works)

(c) *In vitro measuring*

Of the ground and sifted experimental material, a quantity containing 400 mg crude protein was suspended in 50 ml distilled water in a thermostable receiver.

The temperature was kept at 37 °C by means of an ultrathermostat. The suspension, while constantly stirred, was adjusted to pH 8.0 (with 0.1 mol/l HCl or 0.1 mol/l NaOH), and 5 ml multienzyme solution of pH 8.0 was added to the system. The changes in the value of pH as a function of time (in 10 and 15 minutes, respectively) were followed with a digital pH meter. The activity of the multienzyme solutions was checked by standard casein in each case. The in vitro measuring was carried out by using two multienzyme solutions. One of them consisted of trypsin, chymotrypsin and pronase, the other of trypsin, chymotrypsin and pancreatin. In the case of animal proteins, predigestion with pepsin on the basis of a description by Pedersen and Eggum (1983) was carried out and the effect of the Ca^{++} ion on digestion was also examined.

The crude protein content in the samples was determined according to the Hungarian standard.

(d) *In vivo determination*

The method followed the description of Bock et al. (1964) and Eggum (1973). The experiments were carried out with young male albino rats of Wistar-strain. The actual and apparent digestibility of samples was reckoned on the basis of N-metabolism tests (Szelényi-Galántai 1969).

(e) *Statistical analysis*

The results of in vivo and in vitro examinations were evaluated by biometric methods (Sváb 1981). From the in vitro data and the results of animal experiments, the correlation coefficients and the constants dependent on the quality of proteins were calculated. Thus, the equation: $TD = a + b \cdot pH_{15}$, where a and b are constants dependent on the quality of protein, while pH_{15} is the value of pH measured after 15 minutes. The buffer capacity or the various types of protein was measured by titration with a 0.01 mol/l HCL solution.

Results

The experiment results obtained with in vivo and in vitro methods are summarized in Table 1. According to our measuring data, the multienzyme solution containing pancreatin gave significantly better results than that containing pronase; thus in the table the in vitro digestion results obtained with the former are shown. For plant proteins tested in larger numbers, the averages of the examination results are given. In the table beside the feed samples, as well as the digestibility values determined by the two methods and the differences between them, are seen. The data in the table reveal that any considerable difference between the results obtained with the in vivo and in vitro methods, respectively, was only found in the case of egg-white and fishmeal. In comparison to the in vivo method, the digestibility of the egg-white was 11.9% lower, while that of the fishmeal 5.4% higher when determined by the in vitro method. As for the other animal proteins the difference between in vivo and in vitro digestibility was −2.0% and +2.6%, respectively.

The digestibility of maize samples measured with the two methods showed differences of −3.5% and +3.1%, respectively. On the average of the large

Table 1

In vivo and in vitro digestibility of proteins (%)

Materials examined		Crude protein	In vivo TD*	In vitro TD*	Difference, Δ
Animal proteins					
Fishmeal		69.8	79.8	85.2	+5.4
Fresh beaf		15.5	95.9	97.8	+1.9
Skim milk powder		33.8	90.6	88.6	−2.0
Mixed animal protein meal		42.3	75.9	77.1	+1.2
Mixed animal protein meal		42.8	75.7	77.5	+1.8
Mixed animal protein meal		33.4	73.8	76.4	+2.6
Egg-powder		49.1	94.1	82.2	−11.9
Pruteen		67.5	85.1	86.9	+0.8
Casein		83.3	99.9	99.1	+0.8
Plant proteins					Greatest difference
Maize	(n = 40)	9.6 ± 1.3	92.8 ± 2.0	92.7 ± 1.3	−3.5–+3.1
Barley	(n = 12)	14.1 ± 2.2	85.5 ± 1.5	86.1 ± 1.2	−2.8–+3.4
Wheat	(n = 11)	12.6 ± 1.5	89.1 ± 4.4	88.9 ± 2.2	−4.4–+4.8
Pea	(n = 6)	22.9 ± 0.7	80.7 ± 5.6	79.8 ± 3.5	−3.4–+2.0
Horse-bean	(n = 6)	27.4 ± 1.0	77.0 ± 2.2	79.1 ± 2.2	−2.0–+4.3
Lupine	(n = 10)	39.6 ± 7.5	81.5 ± 3.1	81.5 ± 2.1	−2.9–+2.5
Extr. soymeal	(n = 6)	40.7 ± 3.1	74.5 ± 2.2	74.2 ± 2.2	−1.0–+0.4

* TD = True digestibility

volume of examination material, the values of in vivo and in vitro digestibility were practically the same: 92.8 ± 2.0 and 92.7 ± 1.3, respectively.

The digestibility of barley protein showed a −2.8% to +3.4% difference; on the average of the samples the in vivo results were 85.5 ± 1.5%, the in vitro values 86.1 ± 1.2%.

The greatest difference between the two methods was obtained on studying the digestion of various wheat protein samples (−4.4 + 4.8%). The average value of digestibility was, however, the same in vivo (89% ± 4.4) as in vitro (88.9 ± 2.2).

For the digestibility of proteins in the seeds of legumes (pea, bean, lupine, soya) an average of −3.4 + 4.3 difference was indicated. The percentage values of average digestibility can be regarded as practically identical. The in vivo digestibility of pea protein was 80.7 ± 5.6: and its in vitro value 79.8 ± 3.5%. The horse-bean was digested in vivo to 77.0 ± 2.2% on the average, while the value obtained with the multienzyme digestion method was 79.1 ± 2.2%. The digestion of lupine and soymeal samples gave the same result with the two methods. The preliminary treatment with pepsin increased the buffer capacity in certain samples (pruteen, fishmeal) and did not generally improve our results (Table 2).

In the case of certain samples, the added calcium-ion somewhat influenced the proteolysis (Table 3).

In Table 4 the coefficients of correlations between the in vivo and in vitro digestibility of proteins of various origin, as well as the standard deviation for the coefficients and the regression equations, are contained.

As seen in this table, on the digestion of animal proteins the coefficient of the correlation between the results of the two methods is r = 0.87, s = 4.94,

Table 2

In vitro digestibility of proteins of animal origin after preliminary treatment with pepsin (%)

Materials tested	Without predigestion TD*	With predigestion TD*	Difference (Δ)
Fishmeal	85.2	85.0	−0.2
Fresh beaf	97.8	97.8	—
Skim milk-powder	88.6	90.8	+2.2
Mixed animal protein meal	77.1	77.8	+0.7
Mixed animal protein meal	77.5	77.9	+0.4
Mixed animal protein meal	76.4	76.5	+0.1
Egg-powder	82.2	81.9	−0.3
Pruteen	86.9	85.3	−1.6
Casein	99.1	100.3	+1.2

* TD = True digestibility

Table 3

Effect of Ca^{++}-ions on in vitro digestibility of animal proteins

(8 mg Ca^{++} added per sample, incubation time: 15 minutes)

Sample	Percentage change *in vitro* feed digestion
Fishmeal	+1.84
Fresh beaf	+1.18
Skim milk-powder	+0.83
Mixed animal protein meal	+1.35
Mixed animal protein meal	+1.37
Mixed animal protein meal	+1.39
Egg-powder	—
Pruteen	+2.03
Casein	+1.00

Table 4

Correlation coefficients and regression equations for in vivo and in vitro protein digestibility

Animal proteins (n = 9)

r = 0.87 s = 4.94

TD = 210.23 — 17.57 x

Plant proteins (n = 91)

r = 0.91 s = 2.05

TD = 206.24 — 16.58 x

Maize (n = 40)

r = 0.88 s = 1.83

TD = 157.78 — 8.61 x

Barley (n = 12)

r = 0.94 s = 3.24

TD = 204.28 — 16.61 x

Wheat (n = 11)

r = 0.87 s = 2.97

TD = 242.87 — 21.05 x

Legumes (n = 23)

r = 0.94 s = 2.18

TD = 220.05 — 20.05 x

s = Standard deviation
TD = True digestibility
x = pH value in 15 minutes

and the correlation is significant ($P < 0.001$). The true digestibility determined in vitro was calculated on the basis of the regression equation TD = 210.23 — — 17.57 x.

The results of experiments with plant proteins were also evaluated according to the variety.

Between the in vivo and in vitro digestibility values of maize, a significant correlation was found. The correlation coefficient was r = 0.88, s = 1.83: the regression equation TD = 157.78 — 8.61 x.

With the barley proteins the correlation coefficient was r = 0.94, s = 3.24: the correlation used for determining the in vitro digestibility TD = = 204.28 — 16.61 x.

For wheat the correlation coefficient was r = 0.87, the standard deviation s = 2.97 and the regression equation TD = 242.87 — 21.05 x.

For leguminous seeds the correlation coefficient was r = 0.94, the standard deviation s = 2.18 and the regression equation TD = 220.05 — 20.05 x.

The results obtained with all the proteins of vegetal origin taken into consideration were: r = 0.91, s = 2.05 and the regression equation was TD = = 206.24 — 16.58 x.

Conclusions

On the basis of the experimental results detailed above, we consider the multienzyme protein digestion method, based on the decrease in the value of pH in a given time (10–15 minutes) under the influence of a solution of digestive enzymes (trypsin, chymotrypsin, pancreatin) added to the material of analysis, to be suitable for determining the in vitro true digestibility (TD) of various (vegetal, animal) protein sources.

Our experiments were carried out with a hundred (n = 100) feed samples, most of which (n = 91) were seeds (or grains) of plants (Table 1).

We compared the results with TD data obtained in in vivo N-metabolism tests with rats, and on this basis found the TD values determined in the in vitro experiment to show significant correlation both in the case of animal (r = 0.87) and vegetal (r = 0.91) proteins (Table 4).

On the basis of our experiments we agree with those authors (Marschall et al. 1979, Bodvell et al. 1980), who are of the opinion that a close correlation between the in vivo and in vitro results is only found when the origin (animal or vegetal) of the protein sources is also taken into consideration; namely, the proteins originating from different sources (animal or vegetal) are not uniformly sensitive to proteolysis. Therefore, specially arranged regression equations are required for the reliable evaluation of their digestibility.

According to our investigations, predigestion with pepsin did not substantially influence the extent of hydrolysis of animal proteins (Table 2). The probable reason is that the pepsin and chymotrypsin primarily break the

proteins at similar peptide bonds. Furthermore, the preliminary treatment with pepsin also increased the buffer capacity of certain protein solutions, so that the results obtained for them were less reproducible.

In our experiments to determine the in vitro digestibility, we also examined the Ca^{++}-ion for its influence on digestibility as suggested by Pedersen et al. (1983). The 8 mg Ca^{++}-ion added per sample caused only very slight differences in our digestibility results (Table 3). We think that the effect of minerals and trace elements on digestibility is rather complex, therefore further thorough studies must be carried out on the effects of metal ions.

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EFFECT OF Ni-SUPPLY ON THE FATTENING PERFORMANCE OF YOUNG BULLS AND ON THE TREND OF CERTAIN BIOCHEMICAL PARAMETERS

ÁGNES RÉGIUS-MŐCSÉNYI, E. SZŰCS, M. ANKE*,
M. SZILÁGYI and S. SZENTMIHÁLYI
ÁTK RESEARCH INSTITUTE FOR NUTRITION, HERCEGHALOM, HUNGARY

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Under the conditions of practice, authors studied the effect of Ni-supply on the fattening performance and feed conversion in young bulls, and later on the composition of carcasses, the Ni-contents of various organs and the enzyme activity of the blood serum.

The nutrient and mineral contents of the experimental feed rations were the same in all three groups, except for the Ni supply.

In the different organs of the animals, the Ni-content increased in response to the supplement, the level of Ni-supply being best reflected in the liver and the testicles. The results of the experiments prove that in Hungary primary nickel deficiency need not be reckoned with even in the case of rations containing an extremely small amount of Ni.

Keywords: bulls, fattening performance, Ni-supply, Ni-content of organs

Introduction

The vital importance of nickel has been pointed out by a number of authors and research teams, respectively (Anke 1973, Anke et al. 1974, Nilsen 1974, Nilsen and Girond 1975, Schnegg and Kirchgessner 1976, 1980, Spears et al. 1978, 1979). The participants at the Ni Symposium in 1980 accepted the view of the Ni requirement for ruminants being less than 500 ppb/μg/kg feed dry matter.

Material and methods

The experiment was carried out in 3×3 groups — one control and two experimental groups — from the age of 100 days to 200, 350 and 500 days of age, with 7–8 animals per group kept tied up and fed individually. In groups one and two, the ration for the bulls consisted of maize silage, ground corn, urea and wheat straw with adequate mineral supplement. Group three represented as a farm control. In the course of the experiments hair samples, and after slaughtering organ samples were taken, the latter to be considered in regard to the data of literature published on this subject. In the case of dwarf pigs and goats, the Ni status is best reflected in the kidney, liver, cerebrum and ribs according to Anke et al.

* Karl-Marx-Universität, Leipzig

(1982), while others found the eyes and testicles to be also good indicator organs (Schnegg and Kirchgessner 1980).

To determine the enzyme activity, blood samples were taken. From certain muscular tissues (m. longissimus dorsi, m. psoas major, m. semitendinosus) of animals slaughtered at the age of 500 days, dry matter, protein and fat contents were determined. The preparation and mineral content analysis of feeds, hair and organ samples were carried out after Anke and Risch (1979), while Ni was determined colorimetrically with dimethyl glyoxime (Oelschlager 1955).

The nutrient and mineral contents of feeds were the same in the two experimental groups, and met the requirements of the animals, the difference being only in the Ni-supply. In the course of the experiment carried out in three phases, the Ni-supply in group one was 0.63, 0.70 and 0.75 mg/kg, respectively. Group two was given a Ni-supplement of 5 mg/kg feed dry matter, in the form of $NiCl_2 \cdot 6\ H_2O$. Group three consumed fattening feed and represented the control; its Ni-supply in the successive phases was 0.97, 1.02 and 1.07 mg/kg, respectively.

Results

As seen from the data, the Ni content of the feeds given in the three phases of the experiment showed a rather wide fluctuation:

Maize silage	(n = 12)	0.448 — 1.985 mg/kg dry matter
Ground corn	(n = 8)	0.155–0.605 mg/kg dry matter
Wheat straw	(n = 9)	0.180–0.223 mg/kg dry matter

Table 1 shows the Ni-supply in the three age groups of the animals, as related to the dry matter content of feed.

Table 1

Ni-supply to fattening bulls in different phases of the experiment (mg/kg dry matter)

	100–200		100–300		100–500	
	days of age					
−Ni	(7)	0.63	(7)	0.70	(7)	0.75
+Ni	(7)	5.63	(7)	5.70	(7)	5.98
Control	(8)	0.97	(8)	1.02	(8)	1.07

According to the data in the so-called Ni-deficient groups, actual Ni-deficiency could not be brought about in any of the experimental phases (200, 350, 500 days of age), since the Ni-content of the ration exceeded in each case the required amount (>500 μg/kg) (Anke et al. 1980). This is, in the first place, due to the fact that the vegetation of Hungary is richer in Ni than the data of the literature suggest, and the Ni-content in the forages of Hungary is much higher than in the similar forages of the GDR (Régius-Mőcsényi et al. 1982).

The fattening results for the 500-day-old young bulls are contained in Table 2. The fattening period covered 403 days. The 5 mg/kg Ni-supplement

Table 2

Effect of Ni-supply on the fattening results of 500 days old young bulls

	Experimental groups		
	—Ni	+Ni	Control
Number of experimental animals	7	7	8
Age in days			
At the beginning of the experiment	102	101	103
at the end of the experiment	513	500	505
Feed consumption in kg dry matter			
Total	3876	3589	3661
of which grain	921	874	892
maize silage	2464	2298	2349
feed straw	458	416	418
Nutrient consumption (kg)			
Starch equivalent	1607	1495	1474
Digestible protein	274	252	235
Live weight (kg)			
at the beginning of the exp.	124	117	139
at the end of the exp.	564	553	562
Average daily weight gain (g)			
Nutrient consumption (kg/kg live weight)	1072	1095	1055
Starch equivalent	3.65	3.43	3.48
Digestible protein	0.622	0.580	0.556

did not significantly increase the average daily weight gain compared to the experimental group (0.75 mg/kg Ni) and the farm control group (1.07 mg/kg Ni). The result agrees with the literary data (Anke et al. 1980, 1982, Spears 1979). The amount of energy and protein used for a unit of weight gain of the animals poorly supplied with Ni (group one) was somewhat higher compared to that in the Ni-supplemented group, but the animals of the control group did not use more nutrients either than the Ni-supplemented animals, although their Ni-supply was similar to that of the Ni-deficient group (0.97–1.07 mg/kg).

In Table 3 the slaughtering and boning results of bulls slaughtered at the age of 500 days are summarized. The differences found with the carcasses are supposed to be related to the different fattening or slaughter weights rather than to the Ni-supply. The slaughter weight percentage and the meat-, fat- and bone ratios did not show any correlation with nutrition. The results are accidental. The area of eye muscle was largest in the Ni-supplemented

Table 3

Effect of Ni-supply on the slaughtering parameters of 500 days old bulls

		Experimental groups		
		—Ni	+Ni	Control
Live weight before slaughtering (kg)		532	526	522
Carcass weight (chilled) (kg)		305	305	292
Dressing (%)		57	58	56
Abdominal suet (%)		16	18	16
Weight of boned carcasses, kg (%)				
Lean meat, kg ()* %		108 (71)	109 (72)	104 (71)
Bone, kg (%)		25 (17)	25 (16)	26 (18)
Fat, kg (%)		11 (7.3)	10 (7.0)	10 (6.6)
Other, kg (%)		7 (4.9)	7.3 (4.9)	6.6 (4.5)
Area of eye muscle (cm^2)		98	103	80
Nutrient composition of muscles				
Water content	LD%	77	77	75
	PS%	75	75	75
	ST%	77	77	76
Crude protein	LD%	21	22	23
	PS%	22	22	21
	ST%	21	22	22
Crude fat	LD%	2.1	2.2	1.7
	PS%	3.6	3.4	3.2
	ST%	1.3	1.5	1.3

* The number in brackets is the percentage ratio to the slit halves

group (103 cm^2); this, however, like the composition of the musculature, does not show any correlation with the other data (Szűcs et al. 1983).

Table 4 shows the enzyme activity of the blood serum in those bulls given different Ni-rations and slaughtered at different ages. The enzyme activity was found to be independent of the level of Ni-supply, which proves that the Ni-supply was satisfactory in all groups (Spears et al. 1978, 1979, Kirchgessner and Schnegg 1980, Szilágyi et al. 1982, Mőcsényi et al. 1983).

According to the data of Kirchgessner and Schnegg (1980) the activity of alkaline phosphatase in the blood serum decreases in response to Ni-deficiency. Changes of this nature could not be verified in our experiments, nor could changes related to an oversupply of Ni; all results fell within the normal range of values.

In Table 5, the Ni-contents in the testicles and livers of calves slaughtered at the age of 200 days are summarized. Anke et al. (1982) found the kidney, liver, cerebrum and rib of both dwarf pig and goat to be suitable indicators of the Ni-status. The testicles and livers of 200-day-old calves clearly reflect

Table 4

Enzyme activity of blood serum in young bulls of different age and Ni-suply (U/l)

Age in days	Group	n	LDH	HBDH	AST	ALT	ALD	CPU	AP
200	−Ni	7	929 ± 65	—	34.9 ± 9.6	5.7 ± 1.2	14.1 ± 1.9	27.2 ± 18.0	237 ± 59
	+Ni	7	894 ± 94	—	36.3 ± 8.2	6.9 ± 2.5	16.4 ± 1.5	35.1 ± 23.9	200 ± 41
	Control	8	830 ± 76	—	35.7 ± 3.4	7.7 ± 2.9	12.5 ± 1.7	17.4 ± 8.3	183 ± 20
350	−Ni	7	—	—	37.3 ± 4.9	9.3 ± 3.8	—	27.0 ± 10.0	216 ± 18
	+Ni	7	—	—	34.0 ± 6.0	10.3 ± 4.3	—	24.7 ± 9.2	207 ± 31
	Control	7	—	—	29.3 ± 2.1	12.0 ± 3.1	—	31.3 ± 11.1	185 ± 25
500	−Ni	7	780 ± 46	577 ± 118	33.8 ± 5.6	8.3 ± 2.6	—	32.0 ± 10.7	159 ± 14
	+Ni	7	817 ± 157	637 ± 115	30.7 ± 4.6	9.1 ± 4.8	—	29.6 ± 13.5	150 ± 18
	Control	8	810 ± 89	592 ± 98	32.1 ± 5.7	8.1 ± 2.6	—	23.8 ± 9.5	156 ± 11

Table 5

Ni-content of testicles and liver from 200-day-old bulls (μg/kg dry matter)

	−Ni			+Ni			Control		
	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
Testicles	(7)	245 ± 97		(7)	445** ± 125		(8)	223 ± 90	
Liver	(6)	341 ± 130		(7)	878** ± 477		(7)	349 ± 66	

** = < 0.01

the level of Ni-supply. That is, while in the group without Ni-supplement and in the control group the liver and testicle contained nearly the same amount of Ni, in the group given a 5 mg Ni-supplement the testicles and livers of animals contained almost twice as much Ni (testicles: 445 μg/kg dry matter compared to 245 and 223 μg/kg; liver: 878 μg/kg dry matter compared to 341 and 349 μg/kg, respectively).

Table 6 shows the Ni-contents in the testicles, livers and kidneys of 350-day-old calves. Although differences depending on the level of Ni-supply did exist, they were of a lesser extent—except for the testicles—than in the former age group. The livers and testicles of 500-day-old bulls (Table 7) contained significantly more Ni in the case of a 5 mg/kg Ni-supplement, but in the Ni-contents of the kidney and cerebrum no change depending on the level of Ni-supply was found (Régius-Mőcsényi et al. 1983). On the basis of our present knowledge and the literary data, this fact cannot as yet be explained.

As seen from the section "Materials and methods", hair samples were also taken from the animals of each group in all three phases of the experiment. According to the results of the analyses, differences in the Ni-supply did not influence the microelement content of the hair (Zn, Mn, Fe, Cu); the results were within the normal range of values.

Table 6

Ni-content of testicles, liver and kidney from 350-day-old bulls
(μg/kg dry matter)

	—Ni			+Ni			Control		
	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
Testicles	(7)	554	± 191	(7)	970**	± 399	(7)	618	± 283
Liver	(7)	619	± 86	(7)	656*	± 196	(7)	576	± 96
Kidney	(6)	350	± 127	(7)	580*	± 156	(7)	531	± 187

* = < 0.05
** = < 0.01

Table 7

Ni-content of testicles, liver, kidney and cerebrum from 500-day-old bulls
(μg/kg dry matter)

	—Ni			+Ni			Control		
	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
Testicles	(6)	472	± 117	(6)	794**	± 254	(6)	411	± 104
Liver	(6)	284	± 106	(6)	600**	± 217	(8)	269	± 116
Kidney	(6)	583	± 167	(6)	624	± 162	(7)	632	± 305
Cerebrum	(5)	402	± 172	(5)	403	± 100	(7)	456	± 147

** = < 0.01

Discussion

As it turned out in the course of the experiment, in group one set up as the Ni-deficient treatment, the Ni-deficiency was misleading. Namely, the Ni-supply of the nickel-deficient groups exceeded in all three phases 500 μg/kg feed dry matter. As previously mentioned, the vegetation of Hungary contains nickel in quantities larger than expected. However, when the experiment was started, the results of national surveys (Régius-Mőcsényi et al. 1982) were not yet available, and the experimental rations were determined on the basis of GDR data (Anke et al. 1980). The surveying data evaluated in the course of the experiment unequivocally confirmed that the Ni-content of maize plants grown for silage in Hungary was much higher than that found in the GDR, and the Ni-supply of animals in group one was 700 μg/kg feed dry matter on the average.

This is much more than the quantity determined by Spears et al. (1979), who found that a satisfactory urease activity of the rumen required 300–350 μg/kg feed dry matter of Ni.

Namely, the urease enzyme requires much Ni for its activity; and in the case of a deficient Ni-supply, its activity and in consequence the decomposition of protein will decrease, which may even influence the weight gain. Higher than necessary Ni-rations did not improve the fattening results, nor did the enzyme activity values change.

According to our experiment results, a primary nickel deficiency and the loss of production related to it need not be reckoned with in Hungary, even in the case of rations containing extremely small quantities of nickel. An average 700 μg/kg Ni covered the animals' requirements in every case (Spears et al. 1978, 1979, Anke et al. 1982); although, in response to a Ni-supplement of 5 mg/kg, the protein conversion slightly increased, supposedly due to an increase in the activity of the urease enzyme. According to the results of enzyme analyses, the Ni-supply met the requirements in groups one and three, since the 5 mg/kg Ni-supplement did not cause changes, nor could any toxic effect be pointed out (Schnegg and Kirchgessner 1977, Szilágyi et al. 1982).

The different Ni-rations did not influence the Zn-, Mn-, Fe- and Cu-contents of the hair, as an indicator reflecting the level of supply.

According to the results of our experiments, the Ni-content of the kidney and cerebrum hardly, if at all, changes as a function of the supply, which cannot as yet be fully explained. It can be supposed, however, that the difference in Ni-supply between the groups was not sufficiently large. Namely while in the experiment carried out by Anke et al. (1977) there was an actual Ni-deficiency (100 g/kg feed dry matter) and the supplement was 10 mg/kg, that is a hundredfold compared to the Ni-deficient treatment. In the present experiment, the supplement (5 mg Ni/kg) was only about eight times more as

compared to the 630 g Ni/kg feed dry matter. In the experiment performed under such conditions, the level of Ni-supply was best reflected in the testicles and the liver.

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LECTURES

THE GLOBAL PROBLEMS OF SALT-AFFECTED SOILS*

I. SZABOLCS

RESEARCH INSTITUTE FOR SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
OF THE HUNGARIAN ACADEMY OF SCIENCES, BUDAPEST, HUNGARY

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Introduction

Salt-affected soils which occur in different environmental conditions, have diverse morphological, physical, chemical, physico-chemical and biological properties; but one common feature, the dominating influence of electrolytes on soil-forming process, joins them into one family. A certain concentration of electrolytes determines not only the morphology of the soil profile, but also those physical, chemical and biological properties which lead as a rule to low fertility and limited agricultural value of the land affected by salinity. If this adverse effect of electrolytes exists, their influence dominates the soil-forming processes and soil properties to such degree, that it cannot be balanced by common agricultural methods such as fertilizers, agrotechnics, etc., unless removing or neutralizing the excess of electrolytes (Kovda 1947, Szabolcs 1979).

While the decisive influence of electrolytes is common in all salt-affected soils, their chemical composition, as well as the threshold values of their concentration hazard, varies depending on environmental, pedological, and even economical conditions.

In many soil classification systems the term "Salt-Affected Soils" is limited to those saline and alkali soils, where the neutral or alkaline hydrolizing sodium salts dominate. It is true, that the most part of salt-affected soils in the world belongs to these two groups. However, speaking on the global importance of the problem, all the soils, which developed under the dominating influence of electrolytes should be included in the system.

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The grouping of salt-affected soils

In a broad sense, the salt-affected soils can be divided into the following groups:

(1) The saline soils that develop under the influence of the electrolytes of sodium salts with nearly neutral reaction (dominantly, Na_2SO_4, NaCl, seldom $NaNO_3$).
(2) The alkali soils that develop under the influence of electrolytes capable of alkali hydrolysis (mainly Na_2CO_3 and $NaHCO_3$).
(3) The salt-affected soils that develop mainly owing to the presence of $CaSO_4$ (gypsiferous soils) or seldom in the presence of $CaCl_2$.
(4) Salt-affected soils, which develop under the influence of magnesium salts.
(5) Acid sulphate soils, in which the salt content is composed mainly of $Al_2(SO_4)_3$ and $Fe_2(SO_4)_3$.

In Table 1, the listed groups of salt-affected soils are demonstrated, indicating the chemical type of electrolytes dominating in soil-forming processes, and the developed soil type, as well as the environmental conditions, where such a type dominates. The table shows also the main adverse effect of different groups of salt-affected soils with which agricultural practice is confronted, in land utilization. The principal method for reclamation of the different types is also indicated in the table.

As the Table 1 clearly shows, salt-affected soils may develop under very different climatical conditions, from desert to tropics. It should also be mentioned that salt-affected soils occur in different altitudes, from sea level up to several 1000 meters. It is also clear from the table that the pH of different salt-affected soils is very diverse, practically covering the whole pH spectrum of soils. In Figure 1 the pH spectrum of salt-affected soils is demonstrated.

Figure 1 shows that the different groups of salt-affected soils have specific chemical reactions, saline soils are nearly neutral, alkali soils may have pH value as high as 12–13, while acid sulphate soils have as low as 1–2.

The negative influence of high salt concentration or extreme pH value is also associated with different groups and it is specific, as indicated in Table 1.

The demonstrated grouping does not replace the numerous classification systems of salt-affected soils, but displays a broad and complete picture on diversity of properties, environmental conditions, and practical possibilities of their utilization (Kovda and van der Berg-Hagan 1967, Richards 1954, Szabolcs 1979).

The global importance of salt-affected soils

The question of why the salt-affected soils became a world problem can be answered as follows:

Table 1

Grouping of salt-affected soils

Electrolyte(s) causing salinity and/or alkalinity	Type of salt-affected soil	Environment	Main adverse effect on production	Method for reclamation
Sodium chloride and sulphate (in extreme cases – nitrate)	Saline soils	Arid and semi-arid	High osmotic pressure of soil solution (toxic effect)	Removal of excess salt (leaching)
Sodium ions capable of alkaline hydrolysis	Alkali soils	Semi-arid Semi-humid Humid	Alkali pH Effect on water physical soils properties	Lowering or neutralizing the high pH by chemical amendments
Magnesium ions	Magnesium soils	Semi-arid Semi-humid	Toxic effect, high osmotic pressure	Chemical amendments Leaching
Calcium ions (mainly $CaSO_4$)	Gypsiferous soils	Semi-arid Arid	Acidic pH, toxic effect	Alkaline amendments
Ferric and aluminium ions (mainly sulphates)	Acid sulphate soils	Sea shores, lagoons with heavy, sulphate-containing sediments	Strongly acidic pH, toxic effect	Liming

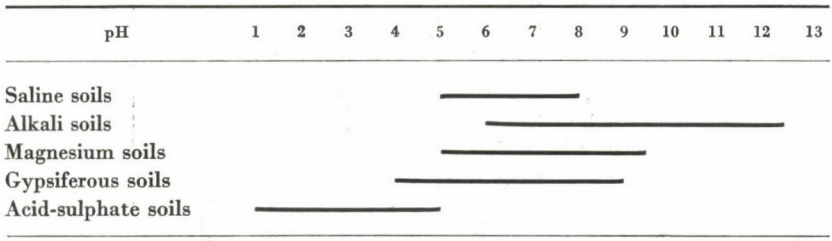

Fig. 1. pH spectrum of different salt-affected soils

Table 2

Salt-affected soils on continents and subcontinents (thousand ha.)

North America	15.755
Mexico and Central America	1.965
South America	129.163
Africa	80.538
South Asia	87.608
North and Central Asia	211.688
South East Asia	19.983
Australasia	357.330
Europe	50.804
Total:	954.832

Extension of salt-affected soils in the world

Nearly 10% of the total land surface is covered with different types of salt-affected soils. Table 2 demonstrates the distribution of salt-affected soils in the World (Kovda and Szabolcs 1979).

Table 2 shows that no continent in our globe is free from salt-affected soils. They are distributed not only in deserts and semi-deserts, but also frequently in fertile alluvial plains, river valleys and coastal areas, close to densely populated areas and irrigation systems.

Global distribution of salt-affected soils

Figure 2 shows a draft of distribution of salt-affected soils of the world, including all those types indicated in Table 1.

In the territory of nearly 100 countries there exist different types of salt-affected soils. In the following list of those countries, salinization and/or alkalization of soils not only occur but represent serious problems (magnesium salinity and acid sulphate soils not included).

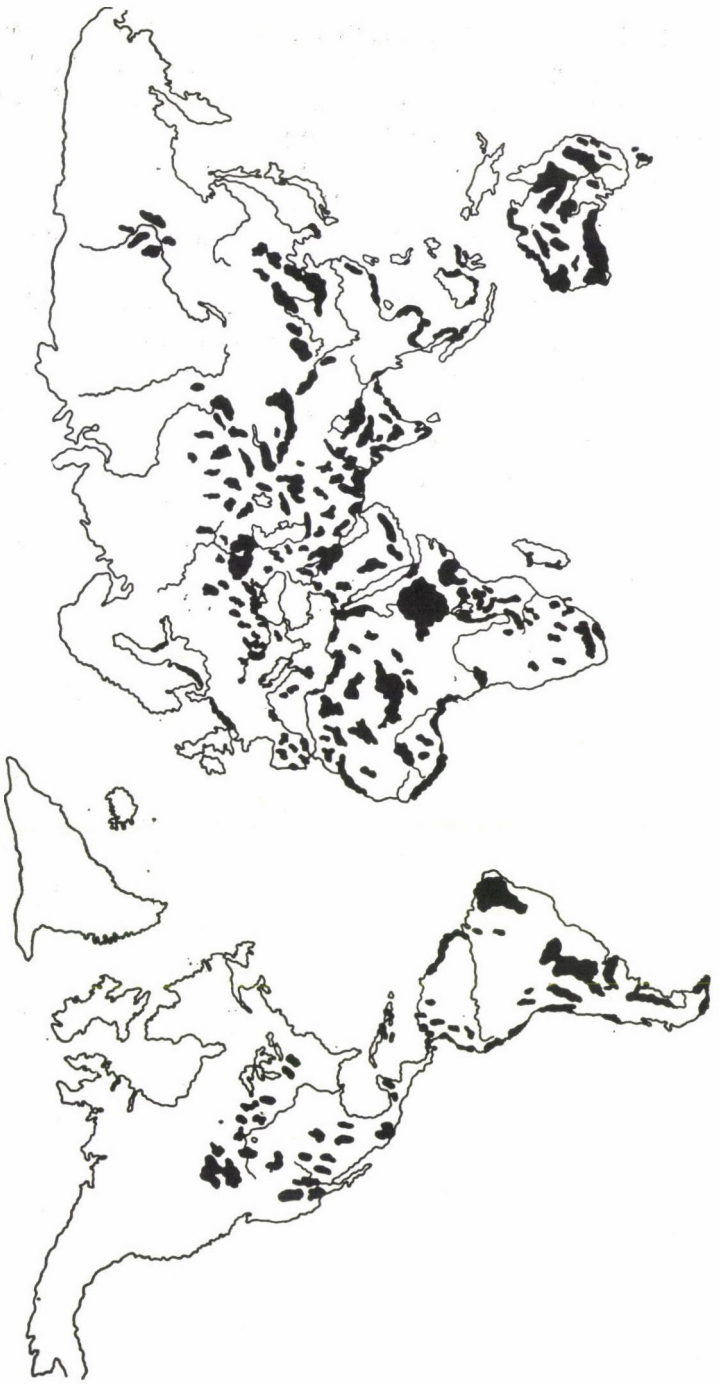

Fig. 2. Global distribution of salt-affected soils

Europe: Austria (Husz 1965), Bulgaria, Czechoslovakia, Cyprus, France, Greece, Hungary, Italy, Portugal, Rumania (Obrejanu 1964, Sandu 1966), Spain, the USSR (Pekatoros 1962, Novikova 1967), and Yugoslavia (Zivkovič 1965, Miljkovič and Plamenac 1979, Szabolcs 1979).
North America: Canada and the USA (Richards 1954),
Mexico and *Central America:* Cuba and Mexico.
South America: Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, Paraguay, Peru, Venezuela.
Africa: Afars and Issas Territory, Algeria, Angola, Botswana, Chad, Cameroon, Egypt, Ethiopia, Gambia, Ghana, Guinea, Kenya, Liberia, Libya, Lalgash Rep., Mali, Mauritania, Morocco, Niger, Nigeria, Portuguese Guinea, Senegal, Sierra Leone, Somalia, South West Africa, Sudan, Tanzania, Tunisia, Zaire, Zambia, Zimbabwe (Aubert 1962).
Near and Middle East and South Asia: Afghanistan, Bangladesh, Burma, India, Iran, Iraq, Israel, Jordan, Lebanon, Kuwait, Muscat and Oman, Pakistan, Quatar, Sarawak, Saudi Arabia, Sri Lanka, Syria, Trucial States, Turkey, Yemen (Symposium 1979).
North and Central Asia: China, Mongolia, USSR.
South East Asia: Indonesia, Cambodia, Malaysia, Thailand, Vietnam.
Australasia: Australia, Fiji (Peck et al. 1983, Pels and Stannard 1977, Loveday 1985), Solomon Islands.

The rapid increase of world population and the demand for food by more than 6 billion people at the close of this century will make it imperative to exploit the land resources more intensively, but soil salinity defeats this goal. At the same time the area of arable land decreases in most countries, while the extension of salt-affected soils increases.

Secondary formation of salt-affected soils caused by irrigation

Not only the salt-affected soils, having formed due to primary soil-forming processes, pose a serious problem, but sometimes even more do the so-called "secondary salinization and alkalization". Secondary salinization and alkalization, mainly caused by improper methods of irrigation, started with the introduction of irrigated agriculture in dry areas of ancient Asia, Africa and America, several thousand years ago.

The lack of rainfall demanded the application of irrigation in many ancient agricultural systems. The problem stemmed from the fact that such systems developed mainly in arid regions where, according to the landscape geochemistry of deserts and semi-deserts, this promotes salt accumulation. This problem affected nearly all the ancient cultures employing irrigation.

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

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 produces for a long time, feeding large populations in places that are now bare deserts. It is also well known that in ancient China, the Indus Valley and South America, vast territories turned into deserts affected by salinity during irrigation by ancient societies. 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 and, in consequence, the degradation of the fertility of soils and other adverse effects were recognized too late to prevent their development. This process forced people to leave the land that had become saline, and others to cease production or to shift the irrigation to another place which, in many cases, also became salinized with time. As long as new territories 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 (Kovda 1947).

In spite of sad experiences the secondary salinization of irrigated and surrounding areas has not diminished, but on the contrary is still increasing.

According to the estimates of FAO and UNESCO (United Nations Educational, Scientific and Cultural Organization), as much as half of all the existing 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 where irrigation has only recently begun.

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

The mentioned losses and damages are not evenly distributed among the irrigating countries. In some of them the damage may be relatively small, while in others it actually constitutes the major problem in the agriculture or even in the national economy of the country in question. Unfortunately, we are rich in sad examples. In Pakistan, Nazir Ahmad (1965) carried out statistical analyses in respect of secondary salinized land. According to his data out of 35 million acres of total irrigated territory, salinized areas account for 5.3 million acres after a few years of irrigation. He indicated among the causes of secondary salinization in Pakistan, the joint effect of irrigation and ground 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 Kovda (1980) that more than 40% of irrigated soils in Iraq and Iran is affected by secondary salinization. A country report on salinity in Syria estimates the adverse effect as follows (FAO, 1971):

(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 cotton per year.

(c) In about 60 000 ha, the yield decreased by 20%, and the total loss is estimated at about 18 000 tons of cotton per year.

At present no continent is free from the occurrence of this very serious 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 is noteworthy that these last examples, and many other irrigated regions, are far from being arid areas and the majority of salts accumulating are associated with the sodium salts capable of alkaline hydrolysis, and not with the neutral sodium salts we are familiar with in desert and semi-desert areas.

Prospects of development of irrigation and consequent world extension of secondary salinization and alkalization

Although irrigation goes back to prehistoric times, its rapid development only started about 200 years ago, as Table 3 indicates (Alekseevsky 1971).

From Table 3 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 very remarkable trend has resulted not only in increased world agricultural production, but also in a number of technical and environmental problems.

Despite the availability of much information, the figures concerning the lands of the world where irrigation has been introduced are very diverse in their sources. Between 150 and 250 million hectares, widely different accounts and estimates 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 records of those which are in permanent operation. This is the reason, in all probability, why the data of FAO (Food and Agricultural Organization of the

Table 3

Development of irrigation in the world

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

United Nations) and ICID (International Council for Irrigation and Drainage) are always different as to the acreage of irrigated land.

It is evident that the neglected or obsolete irrigation systems are rather frequent and account for a very high percentage of all existing systems.

In some countries, like Egypt, nearly all of the agricultural land is irrigated. The corresponding figures are: 70% in the Madagascar Republic, 26% in Thailand and 50% in Pakistan. Similar ratios exist in many arid and semi-arid countries. In less arid or semi-humid countries, the irrigated land often comprises only a small percentage but this amount is sharply increasing. In 1970 nearly 13% of the total agricultural land was irrigated in France, more than 10% in Spain and nearly 15% in Greece.

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 area surrounding irrigated land is a vast desert which makes possible the disposal of brackish water and offers the possibility of tolerating such adverse consequences of irrigation, as the 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 (Szabolcs and Darab 1982).

The increase of irrigated territories in different countries and regions is remarkable. In the USA, for example, the area under irrigation has doubled between 1949 and 1973 to 21 million hectares. Another example: in the USSR every year, 1 million ha of newly irrigated land are brought under cultivation, and it is planned to increase the acreage of irrigated land from 27 to 40 million hectares in a few decades. In Kenya, the area of irrigated land has 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.

Many prognoses are available concerning the development of irrigation

to the 21st century. Some of them are local or country reports, but others 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 next century. Unfortunately no reliable predictions are available on the hazards 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 hazards 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 dangers of recent and predicted extension of irrigation in various countries (Shainberg and Shalhevet 1984).

The future development of irrigation will affect salt and water balances on a global scale. The big irrigation systems, plans for diverting rivers and constructing huge water reservoirs, may cause remarkable changes in the water and salt balance over large areas, even countries or subcontinents. The migration of salt does not stop at the boundaries of administrative farming units, nor at state borders, and if the further extension of irrigation will not be governed by proper prediction of possible risks, it may cause real global disaster.

First of all, the potential salt-affected soils should be characterized.

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, as 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. For this reason the diagnosis of 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 later periods of the 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 hazard of secondary salinization is evidently bigger in desert areas than in humid regions where natural leaching processes remove soluble salts. In many arid and semi-arid areas practically all soils, or a major part of them, can be described as potentially saline. In consequence of the above-described regularities, the determination, grouping, characterization and mapping of secondary salt-affected soils must be performed in the context of the local environmental and economic conditions.

Table 4

Extension of existing and potential salt-affected soil in some European countries

Country	Salt-affected soils (ha)	
	Existing	Potential
Austria	500	2 500
Czechoslovakia	25 000	80 000
Hungary	740 000	885 000
Italy	500	400 000
USSR	28 000 000	18 000 000

Still we do not have proper data and records on the world-wide extension of potentially salt-affected soils.

Evidently, the area of potential salt-affected soils is much bigger than that of recently salt-affected soils. In some European countries, surveys have been carried out in order to estimate the territories of potentially salt-affected soils. Table 4 outlines some results of this study (Szabolcs 1974).

As the data in Table 4 clearly demonstrate, even in those European countries where the hazard of salt accumulation is far not the most expressed the extension of potentially salt-affected soils is similar to or bigger than the area of recent salinization. Evidently, in arid conditions, this ratio will be much higher.

Effects of irrigation on the salinity except crop and soils

The extension of irrigation affected not merely the greater irrigated land but also the neighbouring non-irrigated territories. As long as irrigation was confined to small areas, its environmental effect was evidently much less than that of big irrigation systems affecting large surrounding regions.

The effect of irrigation on the biosphere (besides the irrigated crop), increased tremendously parallel with the sharp development of this method including all adverse effects, like

— 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 against the development of agriculture and human civilization but also for restraining the present level of production.

Some recent studies describe the adverse effects of salinity not only on plants but also on animals. The increased electrolyte contents of the environment, particularly of waters and soils, cause excessive salt intake of animals,

thus 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. Kidneys and other organs suffer from saline and sodic waters; the total body water increases and there is an expansion of extracellular volume. Other disorders also occur in the wake of the salinization of soil and water, particularly in dry areas (Peck, Thomas and Williamson 1983).

Impact of man-made factors other than irrigation on salinity

However irrigation, i.e. saline irrigation water and/or saline ground water or both, trigger adverse processes on a global scale, it is worth while also to list the other forms of secondary salinization or alkalization after Kovda (1980) due to the importance of the phenomenon:

(a) The formation of secondary alkaline or saline soils resulting from overgrazing and compactness of sod meadow land:

— along the contact belt of mountainous foothills and plains,
— on low terraces of valleys after flooding by rivers was excluded by barrage construction.

(b) The formation of secondary saline soils as a result of disposal of brackish water pumped from:

— petroleum wells,
— coal mines,
— industrial plants.

(c) Communal sludges and wastes.

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

(e) 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.

(f) The formation of waterlogged and saline soils along non-lined canals, as a result of water seepage, ground water elevation and evaporation.

(g) Appearance of saline soils on valley terraces above and after the construction of a dam (as a result of the submerging of subsoils water following reservoir formation).

Based on this, we have to agree that man-made salinization threatens the destruction of the global biospheric mechanism, with an influence not only directly on the soil but also indirectly, on several processes from photosynthesis to the cycling of bioelements (C, O, N), etc. Such influences must also be taken into account in respect of the soil organic 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 biosphere of our planet.

Concluding remarks

This paper attempted to characterize the growing importance of soil salinity and alkalinity. The main features of salt-affected soils interpreted their division into groups according to their properties and to the environmental conditions of their formation.

The paper also estimated the global extension of salt-affected soils, as well as their distribution in different areas.

At present, and particularly in the future irrigated agriculture will play an increasing role in the formation of salt-affected soils and the extension of secondary salinization causing greater and greater harm for agriculture and even for the national economy of many countries, mainly in developing areas.

It was beyond the aims of this paper to discuss the mass and energy flow of formation or the different classification systems of salt-affected soils. It was also impossible because of this limited space to describe the different methods for prediction, prevention and reclamation of salinity and alkalinity which should be associated with local environmental and economical conditions. Nevertheless, the study and proper application of such methods have vital importance for the food production and for the conservation of the global biosphere (Szabolcs 1979).

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DAIRY CATTLE IMPROVEMENT THE ISRAELI EXPERIENCE*

R. Bar Anan, M. Ron and J. Weller
INSTITUTE OF ANIMAL SCIENCES, THE VOLCANI RESEARCH CENTER, BET DAGAN, ISRAEL

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Background

Dairy cattle improvement in Israel started in the early twenties with the importation of Friesian bulls from the Netherlands and Germany and upgrading of indigenous dairy cows of the Damascene breed. In 1947, 10 Holstein bulls were imported from Canada and they and their sons were heavily used through A.I.. In the early fifties, several shipments of Holstein bulls and cows were imported from the U.S.. From 1953 there were only small imports of bulls every second year for A.I., the last import was in 1962. Since then all bulls are home-bred. There is no commercial semen import. About 150 doses of semen are imported annually for breeding a third of the prospective bull dams, mainly to keep the inbreeding percentage low.

For the past 30 years, nearly 100% of cows have been bred by A.I., and 75% of them by proven bulls. There are altogether 100 000 cows, 60% of them milk-recorded. Every year 40–50 young bulls are reared. Young bulls are mated to first-lactation heifers to produce approximately 100 milk-recorded daughters. Heifers calve at two years of age and assessment of bulls starts when they are five years old. The poorest ones are culled and the very best returned to service at five years of age. Culling of bulls continues through first, second and even third lactations of daughters. The final selection ratio after progeny testing is at least 1 : 10.

Newly proven bulls are, on return to service, mated to nulliparous heifers for testing the sire effect on calving difficulty and calf mortality. Sires proven for both yields and calving ease are nominated for heifer matings. Sires unsuitable for heifer matings are used for cow matings. Thus genetic gain for milk yield is not impeded.

Milk yield

The mean milk yield per cow has more than doubled in the past 30 years. In the seven years between 1976–83, milk yield increased by 1250 kg and 60% of the gain was genetic. Fat increased by 46 kg and 37% of this gain was genetic. The annual genetic gain was 107 kg milk, 2.6 kg fat (Table 1).

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Selection affected the genetic variation among sires-of-sons, especially with respect to first-lactation milk yields (Table 2). As a consequence, the regression of the Predicted Difference (PD) of sons for first-lactation yields on the PD of their sires has fallen below the theoretical expectation.

The standard deviation (SD) among the mean PD's for first-lactation milk of paternal half-sib sires was only 60 kg milk (Table 3), one quarter of the SD of PD within half-sib sire groups (Table 2). The findings show that sires selected for producing sons were genetically quite similar for first-lactation yield although they were from three strains: Israel, U.S. and Sweden. The reduced variation on the sire-to-sire path for first-lactation yield accentuates the importance of:

Table 1

Annual means of yield traits in the Israeli Holstein population

Year	No. of lactations	Milk	Fat	% Fat
		kg		
1976	13 254	7435	229.9	3.12
1977	24 415	7487	232.7	3.13
1978	24 744	7716	241.4	3.15
1979	24 237	7781	244.4	3.16
1980	25 389	7993	256.9	3.24
1981	29 001	8222	261.8	3.20
1982	29 527	8421	269.0	3.22
1983	14 212	8680	276.1	3.21
Regression coefficients for annual yields				
Phenotypic		180	6.9	0.015
Genetic		107.4	2.56	−0.0093
Genetic as %		60%	37%	

Table 2

Regression coefficients, (b_g)[a] *of PD sons* (y) *on PD sires* (x)

Lactation	No. of sires	Sons/ sire	PD kg milk		
			SD_x[b]	$SD_{x\|y}$[c]	b_g
First	19	4.4	177	239	0.32
Second	16	3.8	213	242	0.42
Third	11	2.5	234	224	0.56
Pooled	22	4.5	214	281	0.35
Change from 1st to 2nd	15	3.5	164	197	0.49

[a] The theoretical expectation of $b_g = 0.5$
[b] SD_x = Standard deviation of PD of sires of sons
[c] $SD_{x|y}$ = Standard deviation of sons, PD within sires

(i) 2nd and 3rd lactation yields for the sire-to-sire selection path, and

(ii) the sire-to-cow improvement path. Partly as a result of the latter findings, bulls are kept alive in Israel during the waiting period; thus, the best ones can be used extensively on the sire-to-cow path.

Heritabilities for milk yields which were estimated in contemporaneous cow populations were around 0.2. However, when the sire variance was estimated within genetic groups, the heritability was reduced to about 0.13 (Table 4). The low heritabilities were due to genetic similarity of the bulls within bi-annual birth groups.

Correlated response

The correlations between the sire PDs for some ecomonically important characteristics are presented in Table 5. Milk production was negatively correlated with fat per cent and positively correlated with persistency. There was no correlation between milk yield and either conception rate or calving difficulty.

Table 3

Intraclass correlations $(t)_g$[a] *among PD sons within sires* (x)

Lactation	No. of sires	Sons/ sire	PD kg milk	
			SD_x	t_g
First	37	4.6	60	0.09
Second	34	4.3	125	0.28
Third	25	3.9	104	0.25
Pooled	41	5.1	82	0.12
Change from 1st to 2nd	31	3.8	88	0.24

[a] The theoretical expectation of $t_g = 0.25$

Table 4

Heritabilities estimated within herd/year/season and genetic group

	Lactation	
	First	Second
Milk (kg)	0.13 (0.23)	0.14 (0.19)
Fat (kg)	0.10	0.11
% fat	0.17	0.19
% persistency	0.09 (0.14)	0.10 (0.17)
% conception	0.03	0.02

FCM estimates without groups for 1971–1977 in brackets

Table 5

Correlations between Predicted Difference characters

Trait 1 : Trait 2	No. of sires	r	Sign.
Milk yield : % fat	282	−0.50	***
Milk yield : % mastitis	282	0.18	**
Milk yield : % conception	282	0.09	
Milk yield : % persistency	282	0.43	***
Milk yield : % culling	282	−0.55	***
Milk yield : % heifer mate CDM[1]	46	0.08	
Milk yield : % heifer daughter CDM	184	0.07	
FCM 1st : FCM 2nd	184	0.74	***
FCM 2nd : FCM 3rd	90	0.80	***
% conc. : % persistency	283	0.25	***
% conc. : % culling	283	−0.37	***
% persis. : % culling	283	−0.27	***

[1] CDM = calving difficulty and calf mortality
** $0.001 \leq P < 0.01$
*** $P < 0.001$

Table 6

Standard deviations among means and effects of conception rate

Variable	No. of classes	SD	
		Mean	Effect
Cows			
Parity	4	1.35	1.66
Insemination month	24	8.95	8.33
Stage of lactation	8	1.83	1.05
Calving condition	3	2.97	2.60
Inseminator	48	4.36	3.65
Service sire	112	8.40	3.37
Sire*	127	3.72	2.27
Herd	190	6.67	3.95
Heifers			
Insemination month	24	2.86	2.96
Insemination number	4	2.83	2.76
Inseminator	49	6.12	5.94
Service sire	31	3.74	3.78
Sire*	102	4.23	1.11
Herd	190	7.94	6.38

* Predicted difference

Conception rate

Table 6 portrays the magnitude of various effects on conception rates (CR). The factors with the greatest effect on cow CR were the month of insemination, herd, inseminator and service sire. The SD among sires PD for CR was 2.3%, which was greater than the SD of parity and days from calving class effects. Therefore, some consideration is given to selection of sires for CR.

Table 7 presents non-genetic effects of milk yield on CR. High peak yield, post-partum, or big yield changes during the month of insemination negatively affected the CR of cows within-herd. However, management for high yields across herds apparently affected CR positively, at least in first lactation (Table 7).

Rate of gain

Between 1960–1975 sires were progeny tested for rate-of-gain of sons and dairymen took account of growth rate in sire selection on the sire-to-sire and sire-to-cow improvement paths. Breeding for growth did not affect milk yields, however tended to increase heifer calving difficulties and heifer days dry, and to decrease yields of heifers which calved before the age of two years (Table 8). Progeny testing for growth of bull calves was discontinued when the price ratio kg milk/kg liveweight did not warrant further improvement for liveweight gain at the cost of dairy characteristics.

Calving performance

Since 1965, sires are tested for calving ease of mates and daughters. The mean per cent of heifer calving difficulties in the population was 12% at the beginning of the improvement program. At present the unweighted mean

Table 7

The effects of economically fat-corrected milk yields preceding (ECM_p) *and following* (ECM_f) *insemination on conception rate* (CONC)

	No. of Insem.	Mean ECM_p (kg)	Effects within herds on CONC[1] per kg		No. of herds	Correlation between herd mean ECM_p and CONC
			ECM_p	$\lvert ECM \rvert$[2]		
			%			
1	26 218	27.2	−0.26[3]	−0.44	97	0.20*
2	20 590	32.7	−0.20	−0.20	97	−0.02
3	20 437	34.6	−0.20	−0.46	88	0.13

[1] Significant at $P \leq 0.001$
[2] $\lvert ECM \rvert$ = absolute difference of $ECM_f - ECM_p$
[3] Significant heterogeneity ($P = 0.03$) of regression slopes for CONC by herd-year ECM_p
* $0.01 < P \leq 0.05$

Table 8

Associations with PD[1] of bull-calf-live-weight at 12 months of age

	Heifers		Cows	
	Sire	r	Sire	r
Liveweight[2]	27	0.67**	20	0.76**
FCM yield	142	−0.01	119	0.05
Precocity[3] of FCM yield	52	−0.33*		
Culling rate	94	0.18	104	0.16
Days open	60	0.06		
Days dry	60	0.37*		
Sire effect DIFF[4]	87	0.31*	138	0.13
Sire effect MORT[5]	87	0.21	138	0.17
MGS[6] effect DIFF	94	0.01	104	−0.31*
MGS effect MORT	94	−0.05	104	−0.10

[1] PD = predicted difference
[2] Liveweight of heifers at 12 mos of age, cows at maturity
[3] Precocity: (Y1 − Y2) − (A1 − A2)
Y, A = FCM yields at <2 and >2 yrs of age. 1 = Daughters, 2 = herd/year/season contemporaries
[4] DIFF = calving difficulties
[5] MORT = perinatal calf mortality
[6] MGS = maternal grandsire
* $0.01 \leq P < 0.05$
** $0.001 \leq P < 0.01$

Table 9

SD of PD for sires for % calving difficulty (DIFF) and % calf mortality (MORT)

Parity	Trait	Sire			MGS			Population
		N	Mean	SD	N	Mean	SD	Mean 1985,
			%			%		%
1	DIFF	37	9.2	3.0	87	9.2	2.1	6.5
	MORT	37	8.3	2.4	87	8.0	2.1	6.7
>1	DIFF	62	3.8	1.1	49	3.6	0.9	2.6
	MORT	62	4.0	1.0	49	4.1	0.9	3.2

of sires is 9% and the population mean is 6.5% (Table 9). This considerable reduction in incidence of calving difficulties has been achieved mainly through breeding heifers by sires selected for calving ease. Perinatal calf mortality has similarly been reduced by direct selection for the trait and indirect selection via the positive correlation between the two characters. The genetic correlation between calving difficulty and calf mortality was near unity for heifers and above 0.65 for multiparous calvings (Table 9).

Table 10

Correlations between PD for calving difficulty and calf mortality

Parity	Effect	N	r	r_g
1	Sire	37	0.86***	0.96
>1		59	0.71***	0.83
1	MGS	87	0.79***	0.98
>1		49	0.56***	0.66

N = Number of sires of >0.6 repeatability
MGS = Maternal grandsire
r_g = Genetic correlations
*** $p < 0.001$

Table 11a

Correlations between heifer and cow calvings

Effect	Character	N	r	r_g
Sire	DIFF[1]	33	0.84***	0.94
	MORT[2]	33	0.65***	0.72
MGS	DIFF	45	0.47***	0.54
	MORT	45	0.32*	0.37

Table 11b

Correlations between sire and MGS effects

Parity	Character	N	r	r_g
1	DIFF	32	0.52**	0.59
	MORT	32	0.56***	0.64
>1	DIFF	30	0.11	
	MORT	30	−0.13	

[1] Calving difficulty
[2] Calf mortality
* $0.01 \leq p < 0.05$
** $0.001 \leq p < 0.01$
*** $p < 0.001$
r_g Genetic correlations

There is a very high correlation for calving difficulties between heifer and cow calvings (Table 11a), however both the mean incidence and the SD among cow calvings is too low (Table 10) to be a reliable criterion for selecting sires for heifer inseminations.

The correlations between sire and maternal grandsire effects on calving performance were above 0.5. It appears that the genotype of the calf has the dominating effect and it masks any maternal effects. The important consequence is that selecting by the direct sire effect on calving ease will improve calving ease also in the following generations.

Present developments

The present breeding policy is orientated to increase FCM yields in general and to pay special attention to 2nd lactation yields. Breeding for size is limited to:

(i) the approval of bull dams which are average or above average in size,

(ii) individual selection by dairymen who prefer proven bulls which sire daughters of average or above average size.

Calving ease is kept high by breeding approximately 90% of heifers by bulls proven for both yield and calving ease.

Several developments are now taking place which will affect improvement. Veterinary diagnoses for every milk recorded cow are integrated in the cow data bank, together with data of inseminations, calvings, linear type appraisal and milk records. Input of data for half the milk recorded herds is carried out on the farms which maintain interactive computer contact with regional computing centres. Protein, cell count and bacteriological milk test records will soon be available country-wide.

Milk quotas have become very stringent and consequently interest has shifted to health and beef characteristics. At the slaughter houses carcasses are identified and progeny testing for growth rate and carcass quality has been re-started. The computing facilities now available have made multi-trait BLUP routines possible, thus increasing the accuracy of genetic evaluations.

Genetic engineering endeavours to create the ideal dairy cow, however it seems that we are not far off even with the conventional approach.

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BOOK REVIEWS

"*Studies about Humus*". *Transactions of the VIIIth International Symposium of Humus et Planta. Prague, August 1983.* (Report.) Published by Res. Inst. of Crop Production, Prague-Ruzyne

The papers presented at the symposium are summarized in two volumes, on 401 pages, in an extremely shortened form. The summaries, together with the appendix, contain the material of 236 lectures. The publication differs from the usual method of grouping the subjects of symposia. The first volume contains the material of the symposium in English, and the second volume in Russian; so that the abstracts of papers presented in English are found in the volume published in English while those of the Russian are contained in the Russian volume, with a brief summary of the English paper in the Russian and the Russian papers in the English volume.

Considering that the papers are not grouped by subject we attempted to classify the extremely rich material on the basis of the main subject. This classification reveals that the subjects cover the processes of humus formation and transformation, the role of humus substances in soil fertility, and the chemical composition of the humus. Besides, there are valuable data in the material of the symposium on the relations of humus and biological activity, on the role of humus substances in environment protection, and on the possibilities of making use of the organic waste materials and of the biomass.

The main subjects of the 236 papers presented at the symposium are.

Subject	Number of papers
Humus and soil fertility, organic matter management and fertilization	32
Composition and chemical properties of humus substances	48
Humus and biological activity in the soil	48
Humus substances and physical properties of the soil	2
Humus formation and transformation	30
Humus in various soils and plants	30
Humus and nitrogen	16
Utilization of biomass (organic waste material and liquid manure)	18
Role of humus substances in environment protection	18
Total lectures	236

It can be seen from the above list which subjects hold the centre of international interest. Most of the research work is invariably concentrated on the chemical characteristics and biological activity of the humus components. However, the list reveals that increasing attention is being paid to the applied research of humus. This tendency has been apparent for 10–12 years, and the investigations have been stimulated by basic research concerning the chelate-forming, adsorption, nutrient-supplying and retarded N-supplying ability of the humus substances. Thus, beside such classical subjects as the humus formation and transformation, and

the humus substances in various soil types or plants, researches related to the utilization of biomass and the role of humus in environment protection have obviously come into prominence.

The symposium of Humus et Planta is regularly organized in Prague, Czechoslovakia, by the Institutes of the Czechoslovakian Academy of Sciences. This programme, which was launched in the fifties, has become extremely important in international scientific life, as shown by the wide international participation at the symposium held in 1983. Among the authors of the lectures, the activity of researchers from the Italian and Spanish universities and institutes has been steadily increasing. It should be noted that the material of the symposium covers an extremely wide range of subjects from the basic humus researches to those suitable for application in practice.

The research results in the summarized material of the symposium clearly show the new approach to the humus problem. The present view of the relationship between humus and soil fertility is particularly important, as it was emphasized in Prof. Novák's introductory lecture. The intensive use of soil, the agricultural production, the new methods of production technology and the increased fertilization equally render an up-to-date organic matter management necessary. However, this consists not only of organic manuring, but means the agricultural utilization of biomass, peat, plant residues as well.

The latest humus research includes studies on the role of humus components in environment protection. Since 10–15 years the number of papers presented at the Humus et Planta symposia on this subject has been increasing, and many data have been published on the interaction of humus components and pesticides on the one hand, and on the heavy metal binding ability of the humus components, on the other. These toxic substances represent great danger for the environment, and the humus components play and important role in binding and inactivating them. At the VIIIth International Symposium on Humus et Planta this point was perhaps given still greater emphasis than at the previous ones.

L. HARGITAI

Soil Biology and Conservation of the Biosphere. Edited by J. Szegi, Akadémiai Kiadó, Budapest, 1984. Vols 1–2. p. 902

The two volumes contain in 902 pages the material of papers presented at the International Conference on Soil Biology (8th Soil Biology Conference) organized by the Soil Biology Section of the Hungarian Society for Soil Science and held between 26 and 28 August 1981 at Gödöllő. The carefully compiled and well arranged work is completed with tables and figures.

The papers of the conference were grouped in 6 sections, as follows:

Subject	Number of papers
Effect of fertilization on the biological processes of soil	17
Interaction between pesticides and soil organisms	14
Role of the living organisms of soil in the synthesis and decomposition of organic matter	14
Importance of biological nitrogen fixation for soil fertility	12
Living organisms of soil and their role in the soil ecosystem	20
Role of soil organisms in the transformation processes of soils	10
Total	87

In the series of international programmes organized by the Soil Biology Section of the Hungarian Society of Soil Sciences, this conference was the eighth. The Soil Biology Section has always organized its programmes in definite scope of subject with emphasis laid on a variety of main fields. One particularly valuable feature of the 1981 conference is that the latest results of Hungarian and inter-

national researches on soil biology can be read in two well edited volumes.

Beyond the results of basic research in soil biology and soil microbiology, the 87 papers sum up results in such important questions as the effect of fertilization on the humus components and on the biological processes of organic matter management. Some papers dealt with the analyses of soil biology processes, e.g. investigations into the interaction between pesticides and soil organisms. So the subjects of the sections clearly expressed the leading idea of the conference: "Soil biology and protection of the biosphere".

The material of the lectures was published in English. The subjects of papers in the different sections can be summarized as follows:

G. Miller (GDR) in his lecture introducing the subject "Effect of fertilization on the biological processes of soil" gives an account of the results of long-term experiments carried on since 1966, in cooperation between the Leipzig and Keszthely universities. According to the results of experiments, the microbiological characteristics and the microbe population show the most favourable trend when fertilization is carried out in combination with an organic manuring. The favourable effect of a combined application of fertilization and organic manuring on the soil biology, through an increase in the enzyme activity was supported by the results of other papers as well. Several papers deal with the effect of fertilization on the enzyme activity, and with the relationship between fertilization and cellulose decomposition.

Papers giving accounts of investigations on the interaction between pesticides and soil organisms threw a new light upon the question. Proper doses of herbicides, for example do not considerably influence the biological activity and the related enzyme activity values. Higher than the suggested normal doses may, however, inhibit nitrogen fixation by the azotobacters. This calls attention to the need of a careful application of pesticies, and rational rates and methods of pesticide application.

At the same time, the biological activity of soils plays an important role in protecting the soil; investigations related with the activity of the oil-decomposing bacteria with the view of controlling the oil contaminations of soil and waters are today of primary importance.

In the section "Role of soil organisms in humus synthesis and decomposition" are summarized many interesting results. For example, the microorganism Clostridium sporogenes is responsible for the decomposition of plant remnants; and protein-containing compounds introduced in the soil, the protein-like parts of organic manures, also decompose under the influence of this microorganism. A part of the papers discussed the decomposition processes of straw, corn stalk, lucerne, stubble and root remnants through the action of microorganisms. These results are extremely important from the point of view of biomass transformation.

The largest number of lectures, almost a quarter of them, were held in the section "Living organisms of soil and their role in the soil ecosystem". The papers dealt with the multiplication of bacteria and fungi under various soil conditions also with the composition of microorganisms in the soil, and with factors determining the multiplication of fungi and the dominance of certain species within the same category. Further subjects were the relationship between microorganisms and enzyme activity and the role of human activity on the composition of microorganisms.

Few papers were dealing with the role of microorganisms in the transformation processes of the soil, although this subject is extremely important, for the soil biological questions of recultivation were discussed in this section. The development and influencing of biological activity in eroded or technogenic soils is a highly important task. According to Hungarian and foreign experiences (Szegi et al., and others) this question is of great interest not only theoretically, but also for the elaboration of practical recultivation methods. The soil biology researches converge again at this point with the questions of biosphere protection in everyday practice,

and confirm the correctness of the objectives of the conference expressed by its motto: "Soil biology and conservation of the biosphere".

L. HARGITAI

Round Table Conference on Food Production–Nutrition–Health. Edited by S. Rajki and A. Bruce. Akadémiai Kiadó, Budapest, 1983. p. 250

The members of the Royal Swedish Academy of Sciences and of the Hungarian Academy of Sciences established a scientific workshop with the purpose of studying the agricultural possibilities of improving the level of nutrition. This book contains the introductory papers presented and the contributions made at the round table conference of the work-teams held between 11 and 23 June, 1978/1981 January at Uppsala. The conference was attended by the leading scientists of Northern, Eastern and Central Europe concerned in agriculture, food processing and nutrition, from a total of 12 countries, including Iceland, the Soviet Union, Norway and Yugoslavia. The UNESCO and the UNU (United Nations University) were also represented at the conference.

The first meeting dealt with the new food sources. The introductory paper was given by Belikov (Moscow) on the basis of a joint work with the academician Scrjabin. Materials discarded so far (e.g. whey, blood, animal tissues of low value, poor quality fish) may be new food sources. The vegetal products so far utilized as feedstuff may also be used as meat extenders. The utilization of microorganisms on mineral hydrocarbons was expounded in some detail.

The debate pointed out the manifold character of the question. Remarkable was the contribution of Láng (Budapest) about the natural energy sources in Hungary.

The second meeting dealt with fishing and fish processing (Production and technological handling of fish). The introductory paper was delivered by Dagbjartsson (Reykjavik) on the world production and preservation of fish. After that, the nutrition sanitary aspects were made known by Braekhan (Bergen); in the course of the debate further items of information were added to his statements.

The third session discussed the dairy products. The role of milk in nutrition was elucidated by the valuable presentation of Jul (Copenhagen). Some points of this paper: milk in the nutrition of backward countries; value of lactalbumen; economic and energy aspects. This introductory paper was followed by the of Engst (Potsdam–Rehbrücke) on the role of butterfat in nutrition. The debate covered medical and economic aspects.

The fourth meeting dealt with cereals. In the introductory paper (Grain production and the future of the human race) Rajki (Martonvásár) gave a comprehensive view of the development trends of cereal production. The aspects of nutrition and health were summarized by Munk (Copenhagen). Rakowska and Wolski (Warsaw) spoke of the perspectives of triticale and rye.

Vegetables were the subject of the fifth meeting. The introductory paper was given by Vas (Budapest) on the aspects of nutrition and processing. The points which he stressed were: cultivation factors influencing the nutritive value by the example of the tenderness of peas; new principles of heat treatment; importance of correct storage; toxic components. Stojchev (Sofia) detailed the biological aspects of vegetables in the nutrition. In the course of the debate the subject was discussed from many new points of view.

The subject of the sixth meeting was: "Refined food", by which sugar consisting of pure saccharose, separated eating fats, etc. are understood. In the introductory paper Ahlström (Helsinki) dealt with the evaluation of food with the help of an index called "nutrient density", which expresses the nutrient content of a food in relation to its energy value. The debate covered the reduction of the protein value in the presence of glucose (through the Maillard reaction occurring on heating), and the questions of undernourishment, overnourishment and energy uptake.

The subject discussed at the seventh meeting was the role of fats in human nutrition. In his introductory paper Szostak (Warsaw) pointed out the importance of fats as components of the cell membranes, as sources of essential fatty acids, as vehicles of fat soluble vitamines and as regulators of the lipids of blood — apart from their role in supplying energy. The debate was held on the latter questions.

To summarize the subjects of the meetings, the following groups of topics were examined:

(1) Sanitary aspects of diets, the definition of balanced diet (Ahlström).

(2) Preservation of food. Energetic aspects of food supply (Vas).

(3) Perspectives of the new food sources (krill, triticale, etc.) (Belikov).

(4) Diet prognosis for 2000 (Munch).

(5) Priority tasks of food- and nutrition science in the next 20 years (Rajki).

The appendix contains Gunnar Broreg's commemoration of the great Swedish scientist under the title "Linnaeus and Nutrition".

Sz. Török and K. Vukov

Somos, A.: *The paprika.* Akadémiai Kiadó, Budapest 1984. p. 302

The author had previously published two paprika monographs in Hungarian (1961 and 1981). With the results since attained by an ever-widening research activity this English monograph duly represents the theoretical and — above all — practical achievements of several decades. The reputation of the Hungarian paprika is indicated if only by the international acception of its Hungarian name.

Chapter 1 analyses the importance of the paprika, giving details of its nutritive value and chemical composition. A brief survey is then given of the origin and distribution of paprika, and of its cultivation and utilization both in Hungary and world-wide. Attention is called to the fact that the discovery of the C-vitamin content is linked with the name of a Hungarian researcher, the Nobel Prize winner Albert Szentgyörgyi; and the role that capsicin, pigments, carbohydrates, essential oils, fatty acids, amines, organic acids, minerals and microelements play in nutrition is pointed out.

Chapter 2 deals with the botanical characterization of the paprika plant, gives the taxonomic place of the genus Capsicum, describes the Capsicum species and illustrates the major varieties in 23 colour pictures. The morphological characterization covers all organs from seedling to seed, and the inner morphological treatment — based on Mrs. Görgey's original anatomical sections and drawings — is likewise concerned with every organ of the plant.

Chapter 3 analyses the effect of ecological factors on the life processes of the paprika plant. Here again the author refers to the practice of cultivation when discussing the role of light, temperature and water, mostly on the basis of his own and his Institute's investigations. The results of experiments aimed at clearing up the influence of the main nutritive elements (nitrogen, potassium, phosphorus) and of other macro- and microelements on the development of the paprika plant are made known to the reader. An important section of this chapter deals with photosynthesis and respiration under various ecological conditions.

In *Chapter 4*, the cultivation of paprika is discussed at length. Soil demand, preparation of sowing, germination stimulation, sowing time, and sowing methods for a number of Hungarian varieties are treated mostly on the basis of the author's own experiments. Information on agrotechnical questions, such as seedling raising, forcing, plant density, plant tending, weed killing, etc., is accompanied by practical instructions. A special section deals with such cultural practices as drying storage, qualification, packing, etc., of red peppers. An explanation, supported by ecological reasons, is given of the concentration of seasoning paprika cultivation in the districts of Szeged and Kalocsa. Methods for growing early table paprika for the market under either field- or greenhouse conditions or in a plastic tent, are described in detail.

The use and effects of various pesticides applied at different stages of development are discussed. Information is provided on the conditions and requirements of mechanical cultural practices.

Chapter 5 deals with the questions of paprika breeding and -seed production. After defining the objectives of breeding, the author discusses the chromosome relations of the genus Capsicum, and the breeding problems of haploid, diploid and triploid plants. Within the scope of flowering and fertilization biology are treated the matters of sterility and compatibility, resistance breeding, heterosis effect, etc. Further, the reader is acquainted with the production of super-elite seed and F hybrid seed, as well as with their storage.

Chapter 6 surveys the diseases and pests of the paprika plant. Of the non-infectious damages those caused by sun-scald, sand storm, hail, uneven water supply, and fertilizer toxication are mentioned. Of the virus infections the tobacco mosaic, cucumber mosaic and alfalfa mosaic diseases are listed. The paprika stolbur is given as an example of mycoplasmic diseases. As bacterial diseases the Pseudomonas fruit rot and the Xanthomonas infection are described. Among the fungal diseases, damping off caused by Phythium and Rhizoctonia, infections by Phythophthora and powdery mildew, damages done by Bothrytis and Sclerotomia, and fruit spots caused by Colletotrichum, Verticillium and Fusarium, respectively, are characterized. Cuscuta pentagona is mentioned as a flowering plant parasite of the paprika plant. Of animal pests 10 polyphagues are listed together with their damages and the methods of control (Pesticides).

Each chapter concludes with a detailed bibliography.

Á. MÁTHÉ

M. J. DOVER: "*A Better Mousetrap Improving Pest Management for Agriculture*", September 1985. Library of Congress, Catalogue Card Number 85-62028

This publication is one of those issued by the American World Resources Institute several times a year.

It is concerned with the protection of farmers against the damages of chemicals which they use. At the same time it raises the problem of pesticides to the level of public interest, since the inhabitants of the earth are all exposed to some kind of poisoning (digestive disturbances, neuralgia, and occasionally permanent lesions, etc.) as the price of the fight for healthy fruit and vegetables.

The publication attaches great importance to refining the integrated plant protection in which the pesticides are applied reasonably; that is, only up to the threshold of the economic harm caused by the damaging organism concerned, leaving the environment intact. Special care must be taken to protect the useful living organisms, including the microbial pesticides, the bacteria and viruses that through gene surgery and mass propagation have come close to the efficiency of chemical pesticides. The latter could be more safely applied in the developing countries.

The emphasis is laid upon the role of resistant varieties in the modern plant protection.

A description is given of the new method of insecticide application: the insecticides are distributed by means of special spray heads so that the active agent and the vehicle are brought together in a mixer designed for this purpose only at the very moment of spraying.

A. MESZLÉNY

Scientia Agriculturae Bohemoslovaca

The journal published by the Czechoslovakian Academy of Sciences appears as a quarterly periodical. Its papers are published in English and Russian, with summaries written in four languages — English, Russian, German and Czech — at the end of each edition in the form of a literary register that contains the abstract, the key words and the bibliographical data in each paper.

The *Scientia Agriculturae Bohemoslovaca* primarily describes the results of agricultural and sylvicultural research in Czechoslovakia, but accepts papers from any other country for publication. Also, the scientific results achieved in all branches of agriculture can be found in the journal, so it provides a comprehensive picture of the major tendencies and the high quality of Czechoslovakian research. As well as studies on questions of crop production, it deals with livestock farming, forestry management and problems of environment protection. The papers are longer than average, due mostly in each case to a full literary review, and a discussion after the results presented. Several of the authors make use of photographic illustrations.

We recommend the journal *Scientia Agriculturae Bohemoslovaca* to those who are engaged in agricultural research or who participate in higher education, as well as to any large enterprises that carry on innovative work.

Z. BEDŐ

TH. SCHLIESSER and D. STRAUCH (eds): *Disinfection in animal keeping, meat- and milk processing*. Ferdinand Enke Verlag, Stuttgart, 1981. (455 pp., 56 gigs, 49 tables. Price: DM 34.—)

The importance of disinfection both in animal keeping and in the processing and trade of foodstuff of animal origin has increased lately. The causes are, on the one hand, the concentration of the livestock and formation of large stocks, which create favourable conditions for infection chains; on the other hand, a steady increase in hygienic requirements related with foods of animal origin. To protest the consumers' health the threshold values of drug residues tolerated in food are lowered. Thus increasing emphasis is laid on prevention. One of the means of this is the regular and efficient disinfection.

The book is divided in 5 main chapters written by known specialists in the respective fields.

Chapter 1 (Th. Schliesser) after clearing the major concepts discusses the action mechanism of physical (heat, irradiation) and chemical disinfectants. As for the chemical agents, first the concept of the range of action is explained, then the influence of proteins and environmental pH conditions on their efficiency, the preconditions of a lasting effect and the toxicity of chemicals to human and animal organisms are dealt with. The question of their economic efficiency is also discussed. Special subchapters deal with the effect of chemical disinfectants on various materials and surface conditions, and with the resistance of microbes to disinfectants. In short, the chapter gives information on the action mechanism of the most important groups of compounds (aldehydes, alcohols, halogens, chlorinated disinfectants, bases, oxidatives, phenol derivatives, heavy metal salts, surfactants), on their lowest effective and toxic concentrations, and lists the field of practical application for each group of compounds. After a description of the testing methods of disinfectants, the different forms of chemical disinfectants (gas, aerosol, solution), then the disinfection of the skin of hand and body surface, are discussed.

The general section is followed by chapters on disinfection in cattle and pig keeping (D. Strauch), poultry keeping (H. Geissler), meat processing (U. Schmidt and L. Leister) and dairy farming (G. Kielwein). With pictures of apparatuses, process diagrams and tabulated data these special chapters provide practical advice to the readers for choosing the chemicals and techniques most suitable for the given purpose. At the end of each chapter those interested in the details can

find useful literary references, primarily German authors.

In the preface the editors recommend the book to veterinarians, animal breeders, and to those representatives of the profession who are working in governmental and communal offices, research institutes, as well as in meat- and milk processing units. However, for teachers and students who can read German the book may also be of use. The clear structure of the chapters and the well arranged list of contents and subject index make it easy to find the information required.

This reprint of the book first published in 1981 contains a list of disinfectants accepted by the Society of German Veterinarians in 1984, and suggestions concerning their use.

The handy pocket book (12×19 cm in size) offers much practical information for foreign readers as well. Its use is made easy by its small size and clear typography.

T. SZENT-IVÁNYI

R. REPETTO: *Paying the Price: Pesticide Subsidies in Developing Countries, World Resources Institute.* Washington D.C., 1985.

Different national and international assistance agencies are compelled to supervise and restrict the use of pesticides to the necessary level out of economic reasons on the one hand and environmental ones on the other. A detailed economic study was issued on this problem entitled "Paying the Price" by Robert Repetto, senior economist of the World Resources Institute, at the end of last year. The study is the first part of a four-part worldwide investigation, dealing with the question of the effectiveness of government pesticide subsidies allocated in the developing countries.

It is difficult to gather reliable and compatible data from each country in question, as almost nothing is known about the effectiveness of the subsidies. Little is known about the health and environmental costs of current patterns of pesticide use. Moreover, little enough is known about how pesticides are now being used. Thus the study implicates nine countries (China, Colombia, Ecuador, Egypt, Ghana, Honduras, Indonesia, Pakistan and Senegal) in which pesticide subsidies range from 15% (Senegal) to as high as 90% (China) of the full annual cost, with a 44% median value. It also provides tables accurate, as far as possible, on the total domestic pesticide supply of these countries from 1982 to 1984.

The most remarkable finding in this paper is that the current government pesticide subsidies support, first of all, only the wealthier farmers (as the use of chemicals is in any case necessary on larger parcels), and they are compelled to an excessive use of pesticides which leads to increased environmental damages. "These subsidies encourage farmers to use more chemicals than they would if they had to pay the full costs" — says the report.

R. Repetto also emphasizes the fact that although humanity knows about and suffers from the side effects of chemical pesticides, including accidental poisonings contaminated food and water supplies, and the destruction of beneficial species, pesticide regulations have not been established yet in the countries mentioned above.

The author suggests the termination or modification of these subsidies, since in addition to the fact that they undermine efforts to promote integrated pest management, they claim government revenues that could otherwise be used in other agricultural development programs, and they distort the economic damage threshold. The subsidies do not even reach their goal: they support others than those who bear the costs and suffer the environmental losses.

This evidently requires detailed economic analysis in these countries in order to stop wasting money on ineffective subsidies and subsidizing the sale of dangerous chemicals to untrained farmers. International assistance agencies such as The World Bank and the U.S. Agency for International Development (AID) also have interests in this problem, either directly through agricultural develop-

ment loans or indirectly through support for local agricultural credit programs.

According to the proposal of the paper, the amount of money devoted to such subsidies might be better spent in different ways: "on extension programs to inform farmers about pesticide safety and integrated pest management techniques; on research programs to develop biological controls and better plant protection methods for important crops; on pest monitoring networks; and on better enforcement of existing pesticide regulations".

A. SZÉKÁCS

Methods for Evaluating Pesticides for Control of Plant Pathogens. Edited by K. D. HICKEY, 1986, 312 p, APS Press, St Paul, USA.

This book contains 73 individual papers in ten parts summarizing the present status of the screening methods for evaluating pesticides. The methods are presented on the basis of the individual experiences of authors. These are not recommended as standards, but can serve as references for persons interested in screening methods for agrochemicals controlling plant pathogens.

The 1st part (*Preliminary considerations*, 8 papers, 1–49 pp), discusses the problems related to standard requirements in methods used for Pesticide Registration (Nelson and Biehn), to safe handling, storage and disposal of pesticides (Weaver). The logical, statistical principles that apply to the design of the experimental technique, and the collection and the analysis of data were reviewed and suggestions made for the improvement of experiments and reporting results as well (Nelson). Further general requirements were reported for calibration and correct characterization of experimental methods and conditions such as soil properties (Nesmith and Avearge), site selection procedures for field evaluation of nematocides (Bird et al.), ground-operated sprayers for applying foliar pesticides to orchards and vineyards (Steiner), irrigation systems for chemigation (Threadgill). It is very important to clarify these problems, because the consequences of misuse of pesticides, including environmental contaminations, spills, and poisonings, can be very embarrassing and expensive to both industrial and institutional establishments and can destroy an otherwise well-organised and respected chemical control program.

In the 2nd part (*Laboratory and greenhouse procedures*, 17 papers, 50–115 pp) pertaining to inoculation and evaluation methods, the isolation and identification of soil-borne fungi are described, for *Rhizoctonia solani* (Papavizas and Lewis), *Cylindrocarpon* spp. (Griffin and Tomimatsu), *Phytophthora* spp. (Mitchell et al.), *Pythium* spp. (Mitchell and Rayside). The problems of the inoculation in the case of apple scab and brown rot of stone-fruits (Szkolnik) and the way to investigate the influence of physical factors on fungicidal efficacy with the example of apple tree/apple scab (Szkolnik) are discussed.

Monitoring resistance is shown to benomyl of *Venturia inaequalis*, *Monilia* spp. (on stone fruit), *Cercospora apii*, *C. arachidicola*, *C. beticola*, *Erysiphe cichoracearum* (on cucurbits) and *Podosphaera leucotricha* (Yoder et al.) and that of *Erwinia amylovora* to streptomycin (Thompson). Fungicide testing methods are outlined for the evaluation of efficacy against post-harvest decay of pome fruits caused by *Penicillium expansum*, *Botrytis cinerea*, *Gloesporium* sp. and *M. fructicola* (Rosenberg et al.), and that of citrus fruits caused by *Diplodia natalensis*, *Diaporthe citri*, *Alternaria citri*, *Colletotrichum gloeosporioides*, *Phytophthora* spp., *Penicillium* spp. and *Geotrichum candidum* (Eckert and Brown).

There is detailed a greenhouse evaluation method as a prerequisite for field evaluations of seed-treatment fungicides against soil and seed-borne pathogens of sugar beet seedlings such as *Pythium ultimum*, *P. aphanidermatum*, *R. solani*, *Aphanomyces cochloides*, and *Phoma betae* (Leach and MacDonald). The greenhouse procedure is described to evaluate protectant and systemic fungicides for phytotoxicity, control and residual activity against *Sclerotinia homeocarpa*, *R. solani* and *P. aphanidermatum* on greenhouse-grown grasses with prevision of field evaluations (Sanders

and Cole), to evaluate the volatile action on the detached rose leaves infected by *Sphaerotheca pannosa* var. *rosae* (Coyier).

The evaluation of soil-applied fungicides is shown against *Fusarium* spp. in chrysanthemum propagating material as an example of integrated nutrition and disease management based on the combinations of optimal nitrogen fertilization and the rotated application of benomyl and propiconazole (Engelhardt and Woltz). A bioassay useful for detecting fungicidal residues is detailed based on the inhibition of sugar fermentation of baker's yeast by fungicides (MacHardy).

The ensuing chapters reflect the heterogeneity and complexity of the fungicide screening in the field conditions.

For instance, *in the 3rd part* (*Field test procedures for fruit* and *nut crops*, 15 papers, 116–181 pp) evaluation methods for foliar, fruit and stem diseases are presented.

Most of the methods included describe the monitoring efficacy of fungicides against pathogens causing stone-fruit diseases as *M. fructicola* on blossoms of the delicious fruit tree (Szkolnik and Hickey), *Dibotron morbosum* on plums (Rosenberg and Jones), cytospora canker (Travis and Hickey), *M. laxa* (Ogawa et al.) and *Stigmina carpophila* (Ogawa et al.) on several commercial and delicious stone-fruit varieties, *Taphrina deformans* on peaches (MacSwan and Dooley), *Blumeriella jaapii*, *M. laxa*, *M. fructicola*, *Pod. oxyacenthae*, *Alternaria* spp. on tart cherries (Jones and Ehret).

The principles of fungicides testing on peaches which can be adapted for other cases too are discussed suggesting some criteria for planning and maintaining the orchard, plot design, inoculation, application and evaluation of efficacy (Zehr).

Methods are presented for the evaluation of fungicides controlling diseases caused by *V. inaequalis*, *P. leucotricha*, *Gymnosporangium juniperi-virginae*, *G. claviceps*, *Gloeodes pomigena*, *Zygophiala jamaicensis*, *Botryospaera obtusa*, *B. dothidea*, *Glomerella cingulata* on apple tree taking also phytotoxicity evaluation into consideration (Hickey et al.). There are also methods included for screening fungicides against crown and root diseases of citrus and pome fruit trees caused by *Phytophthora* spp. (Timmer and Mellis), and diseases on grapefruit and sweet orange caused by *Mycosphaerella citri*, *Diaporthe citri*, *Elsinoe fawcettii* (Whiteside). Accurate methods of disease assessment are presented for the control of pecan *(Hicoria pecan)* disease caused by *Cladosporium carygenum* (Bertrand and Gottwald) and for the disease severity of stem canker caused by *Cytospora leucostoma* (Bertrand and English). This method is useful to evaluate other stem diseases too.

Methods are adressed for the evaluation of fungicides to control diseases of grape-vine caused by *Uncinula necator*, *Plasmopara viticola*, *Guignardia bidwellii*, *B. cinerea*, *Phomopsis viticola* and *Eutypa lata* (Pearson) likewise strawberry diseases caused by *Mycosphaerella fragariae*, *B. cinerea* and *Phytophthora cactorum* (Paulus and Ellis).

In the 4th part (*Field test procedures for vegetable crops*, 8 papers, 182–209) the methods are intended as a guide for conducting field tests to determine fungicidal efficacies, having practical values to those who have limited experience in vegetable fungicide evaluation.

There are separately discussed both early and late blights of celery caused by *Cercospora apii* and *Septoria apii*, respectively, with a rating scale for disease assessment (Lacy et al.), clubrot of crucifers caused by *Plasmodiophora brassicae* (Kroll and Lambe), lettuce drop caused by *Sclerotinia minor*, *S. sclerotiorum* (Johnston), Botrytis leaf blight on yellow onions caused by *B. squamosa* (Lorbeer) and white rot of *Allium* spp. caused by *S. cepivorum* (Johnston). The considerations, and some procedures currently used, are summarized in the papers intended for evaluation of fungicides for the control of late blight *(Phytophthora infestans)* on potato, with proposals to determine proper dosage, application interval and other factors (Manzer et al.). It also discusses diseases on tomato caused by *A. solani* (early blight), *S. lycopersici* (septoria leaf spot) and *Colletotrichum coccodes* (anthracnose) (Stephens et al.), and also bacterial diseases caused by *Xanthomonas campestris* pv *vesicatoria* and *Pseudomo-*

nas syringae pv *tomato* (Gitaitis et al.). Special attention is given to critical factors such as initiating uniform disease pressure, chemical application and methods for disease evaluation.

The 5th part (*Field test procedures for field crops*, 7 papers, 210–236 pp) includes a review on methods, providing general information for evaluating fungicides for alfalfa foliar diseases (Stutteville). General procedures are described, which may serve as a gide to test fungicides for control of foliar diseases of tobacco, especially blue mold *(Peronospora tabacina)* (Nesmith) and its soil-borne diseases caused by *Phytophthora parasitica*, *Thielaviopsis basicola* and *Pseudomonas solanacearum* (Csinos et al.).

The methods described for the evaluation efficacy of compounds in controlling the principal diseases of peanut can be used to study rates, application intervals, degrees of resistance in peanut genotypes, and disease management strategies with reduced dosages or extended application intervals in the case of foliar diseases caused by *Cercospora arachidicola*, *Cercosporidium personatum* and *Puccinia arachidis* (Stokes). The same applies to soil-borne pathogens such as *Sclerotinia minor* and *Cylindrocarpon crotolariae* (Phipps and Porter), and application of fungicides through irrigation systems for control of leaf spot diseases caused by *C. arachidicola* and *C. personatum* and southern stem rot caused by *Sclerotium rolfsii* (Backman).

A method is outlined to select fungicides in a special dosage of ammoniumnitrate that could be used as tools in crop loss studies and also integrated pest management systems against *Leptosphaeria nodorum*, powdery mildew and leaf rust on small grains (Frank and Cole).

In the 6th part (*Field test procedures for ornamentals and turfgrasses*, 3 papers, 237–247 pp) methods are included for evaluating foliar fungicides for the control of Ascochyta blight incited by *Didymella ligulicola* on chrysanthemum (Engelhard), a screening with both natural and artifical inoculation of turfgrasses and also environmental modifications (Sanders and Cole). Methods used in Florida to evaluate chemical control of fungal foliar diseases are reviewed (Chase and Brunk).

In the 7th part (*Field test procedures for seed treatments*, 4 papers, 248–260 pp) methods and techniques discussed are restricted to fungicide tests with true seed. There are summarized general suggestions of seed treatment testing, easily modified depending on the crop, cultivar, disease and type of data desired (Mathre and Hansing).

The national test for control efficacy against *Pythium ultimum*, *R. solani*, *T. basicola* complex on cotton seeds, including greenhouse pre-screening procedure for field test, is presented (Minton et al.). A method provided as a guideline for establishing test plots, treating and planting soybean seeds, obtaining the data and interpreting the results (Whitney). Procedures are detailed for fungicide screening to study both plug-mix planting and fluid drilling, with the example of tomato disease (*P. aphanidermatum* and *R. solani* system) and may be applicable to similar techniques where carriers of seeds also serve as media for seedling development (Sonoda and Phatak). These procedures can be used for any small seed crop.

In the 8th part (*Field test procedures for tree injection*, 2 papers, 261–269 pp) are included methods for the treatment of the perennial and other long-lived plants (fruit and landscape trees), showing the possibilities and great potential of tree injection. There are given suggestions based on the uniformity of approaches, reviewed problems of applications, evaluation criteria and future needs, discussed the role of tree physiology and distribution phenomena in trees, with the example of Dutch Elm Disease (Stipes and Campana). Inoculation method is outlined for the control of *MLO*, including symptom intensity rating indexes, and for the observation techniques for pear decline and peach X-diseases, as well as the determination of disease loss and tree vigor. The paper indicates direction for future research (Lacy).

In the 9th part (*Field test procedures for soil treatments*, 3 papers, 270–280 pp) are proposals for the chemigation of soil with

Metham by an irrigation system (Adams) likewise inoculation and assessment of treatments for control of crown gall caused by *Agrobacterium tumefaciens* (Moore). A method is detailed for assaying populations and evaluating fungicides for control of soil-borne pathogenic fungi, reviewing techniques and media for isolating and identifying such species and races of fungi as *Rhizoctonia*, *Fusarium*, *T. basicola*, *S. rolfsii*, *S. cepivorum*, *Pythium*, *Phytophthora*, *Verticillium albo-atrum*, *V. dahliae*, *Cylindrocladium*, *Helminthosporium*, *Alternaria*, *Macrophomina*, *Trichotecium*, *Phymatotrichum*, *Aspergillus*, *Fomes annosus* (Sumner and Csinos).

In the 10th part (*Nematicide test procedures*, 6 papers, 281–307 pp) the first paper (Johnston) describes the general information on test materials, and both environmental and cultural conditions which should be recorded during field tests of experimental nematicides, to achieve meaningful evaluation.

Methods are enumerated for determining nematode population responses to control agents (Barker). The paper provides a glossary of descriptive terms.

There is also a descriptive review of plant responses to nematicide applications (Orr and Heald). There are reviewed and discussed methods of evaluating nematicides applied through sprinkler irrigation systems (Johnston) and methods for revealing the effect of disease complexes on evaluation and non-target effect of nematicides excluding organophosphates and carbamate non-fumigant substances (Starr and Kenerley). A method, using eggs, cysts, hetched second-stage juveniles of *Heterodera schachtii*, is included for screening chemicals (Steele).

G. Oros

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CHRONICLE

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A NEW METHOD OF DETERMINING THE PERICARP THICKNESS OF MAIZE GRAIN

M. Neményi* and L. Gy. Szabó**

* AGRICULTURAL UNIVERSITY, MOSONMAGYARÓVÁR, HUNGARY
** PHARMACY CENTRE, PÉCS, HUNGARY

(Received: 23 November 1985)

The conventional methods for determining the thickness of the maize grain's pericarp make use of the microscope and the micrometer. We found that these methods do not provide reliable information (because of differences in genotype and methodological technics). We have elaborated a new, more reliable method. From the characteristic dimensions of the kerner we determined its surface; then, after soaking it, we removed the pericarp, dried it in thermostat and measured its weight. From these data we determined the pericarp's thickness by means of the relationship given above. The thicknesses thus determined agreed with those measured by microscope in sections made from kernels with an equilibrium moisture content. With this method the thickness can be quickly and exactly determined for a large number of kernels, without any special laboratory equipment. Since the mass and thickness of the pericarp are in close correlation, the conclusions drawn from the data of the 8 hybrids examined can be regarded as universally valid.

The pericarp plays an important role in the matters of maturing, water loss from the grain crop while standing. Resistance to pathogens and energy input in artificial drying. At the same time, few data are available for settling the question of how, and to what extent, the parameters of the pericarp influence the characteristics of the whole kernel. To satisfy all demands upon the pericarp simultaneously is a difficult task for the breeders. Kernels having a thick pericarp are more resistant to pathogens, cold, and mechanical forse alike. On the other hand, they require — according to some authors — a higher energy input on drying. Furthermore, the higher mass ratio of the pericarp reduces the biological value of the feed. To examine the functioning of the pericarp, the rapid and exact determination of its thickness is very important. This paper present the results of investigations towards this determination

Keywords: grain, maize, pericarp thickness determination

Introduction

The inheritance of pericarp thickness and its alteration through breeding have been dealt with by a number of authors (Richardson 1960, Helm and Zuber 1969). A full survey of the methods generally used so far to measure the thickness of the pericarp was given by Wolf et al. (1969). In their study they analyzed two measuring methods in some detail.

With the so-called microscope method, the pericarp was soaked in water at room temperature for 0.5–1 hour. Then the grains were frozen, and from

the 40 μm thick longitudinal layers were excised, then stained. The thickness of the stained pericarp was measured with a calibrated ocular micrometer. According to the alternative, so-called micrometer method, the grains were soaked for 3–4 hours; the crown cap and the tip cap were cut off; the pericarp was removed and soaked for 24 hours in a glycerine solution of 1 : 3 ratio, then air dried at a temperature of 25 °C and relative humidity of 50%. The pericarp thickness was measured with a micrometer. With these two methods, 17 strains and two commercially produced double cross hybrids were examined. The thickness of the pericarp was determined for 10 grains by both methods. The data determined from these two measuring methods showed A close correlation ($r = 0.85$) but the values obtained from the second method were lower. The average pericarp thickness of the 19 strains and hybrids was 146 and 116 μm, respectively, according to the two measuring methods. Further, on the side of the germ the pericarp was found to be thinner. There were no significant differences between the left-side and right-side measuring results (flat sides related to the longitudinal axis). Finally, the order of succession of the hybrids, according to the percentage mass ratio of the pericarp, was in correlation with their order by pericarp thickness.

We wish to call special attention to the latter statement to which the authors added that the coefficient of correlation between the mass of pericarp and the thickness of pericarp was 0.84 when the latter parameter was determined with the first — microscope — method, and 0.72 when the second — micrometer — method was used.

Between the averages of pericarp thickness, determined by the two measuring 1 method for the 19 strains and hybrids, respectively, there was a difference of +30 μm, which in itself is rather considerable. Also, in the case of the individual hybrids the values obtained with the two measuring methods showed differences ranging between the limits of +95 and −3 μm. These differences are such that they indicate the inadequacy of either (or both) of the two measuring methods. It is not clear how the authors determined the actual pericarp thickness.

However, a detailed analysis of the measuring methods reveals that these substantial differences were due to the inequality of conditions. On using the microscope method, grains with a natural water content were soaked; while, when measuring with micrometer, the removed pericarp was previously dried. Since the pericarp thickness depends on the water content of the pericarp, too, the pericarp — having been soaked — was thicker when measured by microscope than when dried, as in the case of measuring with a micrometer. According to the authors cited, this measuring error is partly caused by the fact that the measuring tips of the micrometer press the pericarp's surface, which decreases its thickness. They also call attention to the difficulties in making sections: the damaged tissues, the twisting of the material, the break-

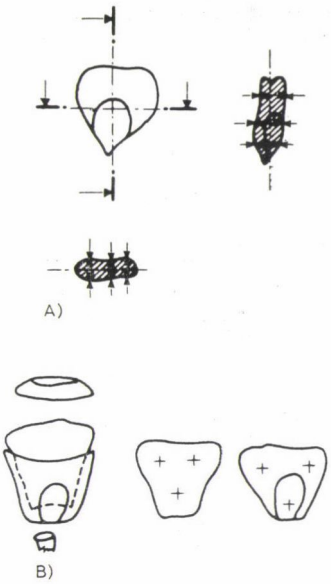

Fig. 1. The measuring of the pericarp thickness (A), and removed pericarp to the micrometer-measuring (B)

ing off of the pericarp; besides, it is particularly difficult to make sections from some hybrids.

It follows from the foregoing that the determination of the pericarp thickness should be made exact, since the present methods are only suitable for obtaining data for comparison (order of succession by size) and do not enable the exact determination of the pericarp's parameters.

Material and methods

The examinations covered 8 hybrids (2 hybrids of each of the FAO 200–500 maturity groups): Anjou 256 SC, Pioneer 3965, A/MTC, Szegedi SC 369, NK-PX 20 MSC, MV SC 434, Pioneer 3709 MSC, Szegedi MSC 515, Pioneer 3780 MSC. The measuring was, in essentials, carried out in the way previously described. However, having learned from the problem raised by Wolf et al. (1969), we modified the two methods published by them. For example to avoid the swelling of the pericarp we did not soak the grains before measuring them by microscope. From the frozen samples, 30 μm thick longitudinal and cross sections were prepared by a microtom (Fig. 1). With most sections only one side could be evaluated because, from grains with a near equilibrium moisture, sections are difficult to make. Especially on the germ side of the kernel, excisions had to be repeated several times in order to obtain evaluable sections. In this way 30–40 kernels of each hybrid were examined. These evaluable longitudinal sections could be made for 3 hybrids (Szegedi SC 369, NP-PX 20 MSC, Pioneer 3780 MSC).

Before removing parts of the pericarp required for measuring with a micrometer (Fig. 1B), we soaked the grains for 1–2 hours at room temperature. The removed pericarps were dried in a thermostat at 70 °C to constant weight. Then, after a half hour of soaking they were measured for thickness with a dial gauge at the points indicated in the figure. Pericarps of 25 kernels of each of seven hybrids were examined with this method (the pericarp fo the hybrid Szegedi SC 369 could not be removed whole). The pericarp thickness of Pioneer

3780 MSC and Szegedi MSC 515 was also measured dry. In several cases, since the dry pericarp has an undulate surface which is difficult to smooth out, repeated measurings at the same position brought different results.

Results and discussion

The new method of pericarp thickness determination

The averages of pericarp thickness measured by a microscope (Table 1), clearly show that the pericarp is thinner on the germ side than on the dorsal side. The difference is particularly remarkable in the hybrid Pioneer 3780 MSC

Table 1

Pericarp thickness of three maize hybrids as measured by microscope (with calibrated ocular lens)

Name of hybrid	Dorsal side				Germ side				Average of dorsal and germ side			
	Pericarp thickness, μm	s	Confidency interval	n	Pericarp thickness, μm	s	Confidency interval	n	Pericarp thickness, μm	s	Confidency interval	n
Szegedi SC 369	61.25	9.98	$\pm$2.82	51	55.34	8.40	$\pm$2.34	47	58.38	9.61	$\pm$1.94	98
NK-PX 20 MSC	66.32	21.66	$\pm$4.87	79	63.64	8.36	$\pm$5.26	12	65.97	2.04	$\pm$4.28	91
Szegedi MSC 515	95.63	32.27	$\pm$7.50	74	64.66	11.35	$\pm$3.76	38	85.12	30.73	$\pm$6.15	112

Konf. int.: range of confidence
P = 5%

(31 μm). There was no significant difference in pericarp thickness between the right and left sides. These findings agree with those published by Wolf et al. (1969).

Table 2 contains the expected values of pericarp thicknesses measured by a micrometer. A comparison of the data of the two tables shows that the pericarp of the hybrid NK-PX 20 MSC is thinner when measured with a microscope, while that of Pioneer 3780 MSC is found thinner with the dial gauge. That is, the reliability of the two methods of measuring varies from hybrid to hybrid. It is also remarkable that the pericarps of Szegedi MSC 515 and Pioneer 3780 MSC became thicker by 38–38 μm after soaking, which means that even a half hour of soaking caused a considerable change in size.

Further, it can be established that the pericarps of the hybrids thicken to different extent when soaked. Thinner pericarp showed only a 10–20 μm change in thickness.

The difficulties we encountered with both Methods were similar to those mentioned by Wolf et al. (1969). With an equilibrium moisture content

Table 2

Expected values of pericarp thicknesses measured with micrometer

Name of hybrid	Pericarp thickness, expected value, μm	s	Confidence interval	Note
Anjou 256 SC	50.91	8.513	±1.38	Number of measuring per hybrid, n = 150. The removed pericarp was soaked in distilled water for 0.5 hour
Pioneer 3965 A/MTC	55.73	15.687	±2.54	
NP-PX 20 MSC	44.35	9.358	±1.52	
Pioneer 3709 MSC	54.09	14.835	±2.40	P = 5%
MV SC 434	52.47	5.394	±0.87	
Pioneer 3780 MSC	107.15	19.999	±3.23	
Szegedi MSC 515	115.33	16.200	±2.62	
Pioneer 3780	69.43	12.751	±1.94	Measuring was performed with dry pericarp
Szegedi MSC 515	74.33	11.739	±1.90	

enabling the exact measuring (about 14%, wet base), it is difficult to cut sections; it requires great skill and much time, and cannot even be accomplished with all hybrids. In the case of measuring with a micrometer, on the other hand, the problem is represented by the removal of the pericarp in one piece.

Accordingly, since the inaccuracy of the conventional methods cannot be eliminated we have elaborated a new method for the determination of the pericarp thickness.

The new method consists in essentials of the following: from the mass and density of the pericarp, or from the surface of the kernel — with the pericarp regarded as a parallelepiped — we calculated the thickness of the pericarp (the mass of the kernel and the mass ratio of the pericarp need to be determined as well, since they are characteristic of the variety).

For the determination of the surface of the kernels a relation containing their characteristic dimensions is given by Neményi and Szodfridt (1985). This was used when we determined the surface (A). Accordingly, the thickness of the pericarp was determined with the relationship

$$t_p = \frac{m \cdot m}{\varrho \cdot A} 10^{-3} \ (\mu m) \tag{1}$$

where t_p is the thickness of the pericarp, m(g) the mass of the kernel, m^* the mass ratio of the pericarp (decimal), ϱ (gmm^{-3}) the density of the pericarp and A (mm^2) the surface of the kernel.

The density of the pericarp can be taken for $\varrho = 1.3 \cdot 10^{-3}$ (gmm^{-3}) on an average, while the series of $m \cdot m^*$ is the mass of the pericarp m_{pericarp} (g), so the relationship (1) is reduced to the formula

$$t_p = \frac{0.77\, m_{\text{pericarp}}}{A} \ (\mu\text{m}) \tag{2}$$

(m_{pericarp} is the coat of the whole kernel including the crown cap).

The basic data of calculation and the pericarp thicknesses determined with the relationships (1) and (2), respectively, are contained in Table 3. Comparing the pericarp thickness data of Tables 1 and 3, it can be established that the difference between the pericarp thicknesses calculated with the relationships (1) and (2), and the values obtained with the microscope measuring method does not exceed ± 3 μm. Since, according to both the published data and our own measuring results, there is a close correlation between the thickness and the mass of the pericarp, we can establish that this new method is suitable for the fast and exact determination of the pericarp's thickness.

Table 3

Characteristics of kernel in the hybrids examined, and pericarp thicknesses determined with the new method

Name of hybrid	Characteristic dimensions of kerner			Kernel		Mass ratio of pericarp	Pericarp thickness determinated with the new method, μm
	Length	Width	Thickness	Surface, mm^2	Mass, g		
	mm						
Anjou 256 SC	10.04	9.04	4.49	192.98	0.29	0.520	63.80
Pioneer 3965 A/MTC	10.30	7.43	4.53	184.66	0.30	0.0762	95.23
Szegedi SC 369	10.65	9.43	5.28	228.04	0.34	0.0488	55.97
NK-PX 20 MSC	11.75	8.17	4.80	223.17	0.30	0.0673	69.59
MV SC 434	11.36	7.82	4.51	210.10	0.31	0.0617	70.03
Pioneer 3709 MSC	10.84	8.65	4.74	205.10	0.31	0.0785	91.01
Szegedi MSC 515	10.80	8.10	4.78	227.01	0.34	0.0745	85.80
Pioneer 3780 MSC	12.10	7.73	4.86	205.70	0.36	0.0671	87.80

For the 8 hybrids examined we found the following relationship between the mass ratio of the pericarp (m^*) and its thickness:

$$t_p = 1.202 \cdot 10^3\, m^* - 1.58 \ (\mu\text{m}) \tag{3}$$

With this relationship, the calculation of the thickness can be faster because the surface of the kernel need not be determined. However, the exact value is given by the relationships (1) and (2).

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POTASSIUM CONCENTRATION IN WHEAT AT SOME GROWTH STAGES AS AN INDICATOR FOR THE K-STATUS OF PLANTS

N. RAMA RAO and G. S. SEKHON

POTASH RESEARCH INSTITUTE OF INDIA, GURGAON, INDIA

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The wheat crop (*Triticum aestivum* L. cv HD 2329) was raised to maturity in a sand media using 9 kg capacity enamelled culture pots. Different amounts of K were supplied through nutrient solution, keeping other nutrients at an optimum level. Samples of different plant parts were collected at six growth stages. Quadratic equations fitted between K concentrations in different plant parts at various growth stages and grain yield indicated that plant analyses performed at either tillering, bloom, fruiting or maturity stages could be used to diagnose the K sufficiency or insufficiency in plants. The critical K levels, below which reduction in the grain yield was more than 10% of the maximum were as follows: At seedlings stage (30d) — 3.8%; At tillering stage (45d) — 4.1% in whole seedlings; At bloom (70d) — 3.2% in top leaves; 2.9% in lower leaves and 2.7% in stem; At grain formation period (100d) — 2.1% in top leaves and 2.1% in stem and maturity — 2.5% in leaves and 2.3% in stem. On the basis of sensitivity of K concentration in plant tissue to changes in K content in the growth medium and its stability. The tillering stage is preferred.

Keywords: wheat, potassium contents, growth stages, K-status

Introduction

In India, wheat is the principal grain crop grown on 21.4 million hectares, largely in intensively cultivated regions. Potassium is one of the nutrients progressively tending to limit yields as better crops are being raised with larger usage of nitrogenous and phosphorus fertilizers. Plant analyses performed on crops raised on bench-mark soils, together with soil analyses, may aid in a better monitoring of fertility changes in these soils. Also, they may help in diagnosing K deficiencies in the those crops growing on the fields. This requires that K concentrations, associated with different degrees of deficiency at various growth stages, must be established. Although studies on critical levels of K for wheat have been published (Acharya and Jadar 1957, Boldyrev 1960, Melsted et al. 1969, Baker and Tucker 1973), the information is often limited to a specific growth stage, or a portion of the vegetative period of growth. Most work on K fertilization of wheat is, however, restricted to response studies. Several workers (Mugwira and Bishnoi 1980, Karlen and

Whitney 1980, Schwartz and Kafkafi 1978) have observed a rapid drop in the K concentration of wheat during its growth period. Hence it is important to specify the growth stage for the sampling of a wheat plant for diagnostic purposes.

The present study was undertaken to examine the changes in K concentration in wheat at different K levels in the media, to construct the K concentration yield curves at different growth stages, to establish the levels of K sufficiency and deficiency at several growth stages and to determine the most suitable plant part and growth stage for the sampling of a wheat plant for diagnostic purposes.

Material and methods

Wheat (*Triticum aestivum* L. cv. HD 2329) plants were grown in the greenhouse from Dec. 1983 to April 1984. The big enamelled pots were filled with potassium-free acid-washed quartz sand. For acid washing, the sand was treated with a mixture of 17% w/v HCl and 1% oxalic acid and passed with a continuous steam at 20 lbs/sq. inch (=141 kg/cm^2) pressure for 6 hrs.

The nutrient solution according to Agarwala and Sharma (1976) had the following composition: nitrogen (12.00 meg/l), phosphorus (4.00 meg/l), sulphur (4.00 meg/l), magnesium (4.00 meg/l), calcium (6.00 meg/l) and sodium (1.33 meg/l) and micronutrients: iron 5.6 ppm), manganese (0.55 ppm), copper (0.064 ppm), zinc (0.065 ppm), boron (0.37 ppm), molybdenum (0.02 ppm), cobalt (0.006 ppm), nickel (0.006 ppm) and chloride (3.55 ppm). The potassium nitrate was used to supply K in different concentrations (0.002–10.0 mM) in the nutrient solution. Calcium nitrate and calcium chloride were used to make the indicated concentrations of nitrogen and calcium. The pH of the nutrient solution was maintained between 5.8 to 6.2. Three replicates were provided.

The volume of the nutrient solution was increased with growth. During the first 15 days after germination, it was 200 ml daily; between 15–45 days, 400 ml; and between 45th to harvest, 800 ml. The pots were also irrigated with glass-distilled water during hot sunny days. Within 15 days of the harvesting of the crops, only distilled water was supplied.

The sampling was done at a particular growth stage (Table 1) and separated into different plant parts. These were washed first with water containing 0.3% teepol detergent

Table 1

Details of sampling procedure adopted

Age of wheat plant (after emergence)	Physiological stage	Plant parts sampled
15 days	Early seedling	Whole plant seedling
30 days	Seedling stage (4th leaf in mother tiller)	Whole plant
45 days	Tillering stage	Whole plant
65– 70 days	Bloom stage	Top two leaves, lower leaves stem and spikelet
95–100 days	Grain formation stage	Top two leaves, lower leaves stem, and spikelet
120–130 days	Maturity	Stem, leaf, and grain

to remove dust particles, and then thrice successively with distilled water. The excess moisture on the surface of the plant parts was removed by pressing them on filter paper and subsequently drying them in a hot-air oven at 70 °C for 48 hrs. The oven-dried samples were ground in a wiley mill, to pass through a 50 mesh sieve. These were then stored in plastic containers for subsequent analysis.

The plant samples were digested in sulfuric acid and hydrogen peroxide. The potassium content in aliquots of the digest was estimated on EEL-Corning Flame Photometer.

Results and discussion

Effect of potassium on K concentration in plant, dry matter production and grain yield

The effects of different amounts of potassium in the nutrient medium on K concentration in the whole plant, the dry matter production and the grain yield are presented in Table 2. The data indicate a gradual increase in K concentration in the plant with an increase in the amount of K in the nutrient medium up to 10 mM, the highest amount applied in this study. However, the dry matter accumulation and the grain yield formation increased significantly only up to 3.00 mM, beyond which the yield showed no change.

Table 2

Effect of potassium on K concentration, dry matter production and grain yield of wheat

Amount of K in the nutrient medium (mM)	K concentration in the plant (%)	Dry matter (g/plant)	Grain yield (g/plant)
0.02	0.44	3.67	1.67
0.05	0.49	7.18	2.86
0.10	0.52	8.54	4.06
0.50	0.62	13.60	6.80
1.00	0.77	16.99	7.82
2.00	1.35	19.92	8.82
2.50	1.43	21.57	9.65
3.00	1.63	22.80	10.87
4.00	1.87	21.23	10.32
6.00	2.12	22.25	10.47
10.00	2.49	21.85	9.66

Potassium concentration in both the stems and leaves of wheat at various stages of its growth is presented in Fig. 1. The results indicate that a sharp increase in the whole plant was observed up to tillering and afterwards, a rapid decrease was observed up to flowering in both stems and leaves. Accordingly, the critical levels of K in a wheat plant, below which its yield performance will be unfavourably affected, will vary at different stages. Inciden-

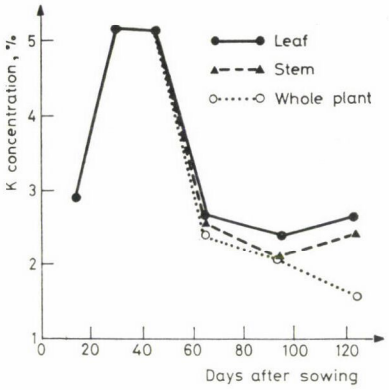

Fig. 1. Changes in K concentration in plant parts (stem, leaf and whole plant) against age in wheat plant (2.0 mM K in the nutrient solution)

tally, it emphasized the importance of the growth stage for diagnostic purposes and the determination of critical levels specific to various growth stages for an appraisal of plant analysis data.

The effects of applied potassium on the K concentration in the whole plant at four growth stages are presented in Fig. 2. All the stages except the seedling (15d) stage showed an almost linear relation to applied potassium. The low relationship in the early stage is a reflection of less dependence of the plant on an external K supply. Viets et al. (1954) found that in all cases, the plants were adequately supplied with K at this stage. A better relation-

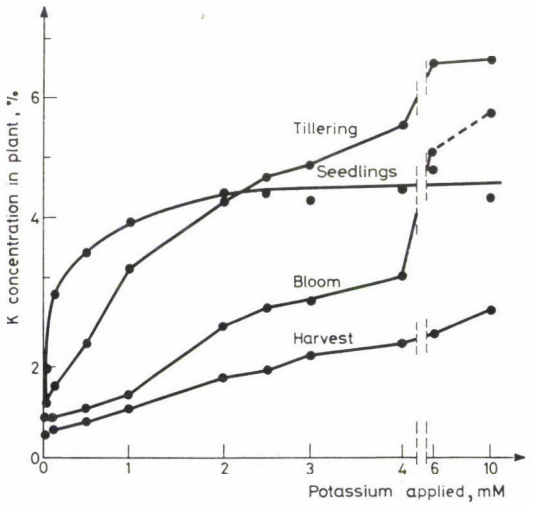

Fig. 2. Changes in K concentration in whole plant at some growth stages versus K applied in the nutrient media

ship in this study appears to have been obtained because the growth medium was acid-washed quartz sand. Among other stages, the plant at the tillering stage appears to be most sensitive to the supply of K in the media. Therefore, the evaluation of plant analysis data at this stage appears to be the best guide for the K nutrition of the plant. Performing an analysis at this stage will provide the possible advantage of a mid-term correction of deficiency to the benefit of the current crop.

Relationship between K concentration in plant parts and grain yield

The potash application is relatively new in comparison with nitrogen in wheat. Macy (1936), who studied plant analysis data in an effort to examine the concepts of plant nutrition, found that the relationship between the concentration of a limiting element in the plant growth and the yield increase was curvilinear. Cook (1967), Ulrich and Hills (1973) also observed a similar relationship. Hence, quadratic equations were fitted between the potassium concentrations in different plant parts at various growth stages, and the grain yield and the coefficient of correlations were calculated. The quadratic equations and the corresponding coefficient of correlation values, describing relationship between the grain yield. The Y and K concentrations in the indicated plant part, X used in the present study are given in Table 3. A perusal of data shows that in general, the K concentration in the tissue correlated well with the grain yield. However, a high coefficient of correlations was obtained in the cases of *(a)* whole seedlings at 30 days and at tillering stage (45 days),

Table 3

Coefficient of correlations between grain yield and K concentration in plant parts at various growth stages

Growth stage	Plant part	Quadratic equation describing relationship between grain yield "Y" and K concentration in indicated plant part "X"	Coefficient of correlation R
Early seedling stage	Whole seedling	$Y = 4.60 + 5.87x - 0.60x^2$	0.82
Seedling stage	Whole seedling	$Y = 0.35 + 3.43x - 0.30x^2$	0.84
Tillering stage	Whole seedling	$Y = 0.42 + 3.16x - 0.26x^2$	0.88
Bloom stage	Top leaves	$Y = 3.33 + 3.14x - 0.30x^2$	0.74
	Lower leaves	$Y = 4.23 + 2.97x - 0.31x^2$	0.73
	Stem	$Y = 3.33 + 3.14x - 0.30x^2$	0.74
Grain formation stage	Top leaves	$Y = 2.22 + 5.21x - 0.81x^2$	0.80
	Lower leaves	$Y = 4.88 + 2.53x - 0.17x^2$	0.63
	Stem	$Y = 1.84 + 5.50x - 0.83x^2$	0.74
Harvest	Leaves	$Y = 4.52 + 2.77k - 0.33x^2$	0.64
	Stem	$Y = 3.60 + 3.70x - 0.50x^2$	0.74

(b) top leaves at bloom (70 days) and fruiting (100 days) stage and stem at bloom; fruiting and at harvest. The highest coefficient of correlation was observed at the tillering stage (45 days) with an increasing trend from the early seedling stage. There was little relationship between the K concentration in spikelets and grains and the grain yield. The value are not presented here. The poor correlation between the K concentration in grains and the final grain yield is probably due to a tendency of grain and fruits to maintain constant composition. As Viets et al. (1954) have observed, it is of little value to sample before the plant has developed sufficiently, so that a spread exists in the nutrient concentrations. The growth rate at the seedling stage (15 days) was low and the difference in the K concentration in plants supplied with low and high K was less. Hence, a comparatively low coefficient of correlation between the K concentration in the while plant at this stage ($R = 0.82$) and the yield was noted. However, by another 30 days, the growth had picked up and there was a sufficient spread in the K concentration, so that an increase in R value (0.88) at 45 days in the whole plant could be observed.

According to Ward et al. (1973) the best stages for sampling in all small grain crops are the tillering (stage 3), boot (stage 10.1) and heading (stage

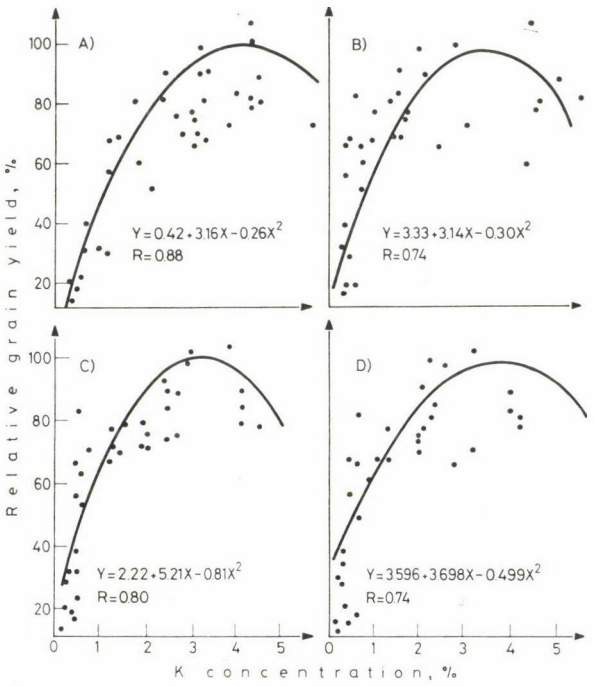

Fig. 3. Relative grain yield and K concentration in tissues of wheat plant. A = whole plant at tillering stage (45d); B = top two leaves at bloom stage (70d); C = top two leaves at grain formation period (105d); D = stem at harvest

10.3). Furthermore, he recommended the whole above-ground plant portion of the plant at tillering stage and either the whole above-ground plant or upper leaves for later stages. Acharya and Jadar (1957), Acharya et al. (1958), Backer and Tucker (1973) and Melsted et al. (1969) have taken the above-ground plant portion for nutrient indexing in wheat. In the present study, highly significant correlations between the K content in plant parts and the crop yield have been observed in some selected plant parts, throughout the tillering stage to the harvest.

Sufficiency ranges of K in plant parts

To work out the K sufficiency ranges in different plant parts at various growth stages, the K concentration in these plant parts was plotted against the correlative grain yield. The plots for the plant parts where highest relations were observed are given in Fig. 3. From these graphs the K concentration ranges in the plant parts such as, sufficiency (0–10% yield reduction), slight deficiency (10–20% reduction), moderate deficiency (20–40% reduction) and extreme deficiency (40% yield reduction) in accordance with the Engel and Zubriski (1982), were worked out and are reported in Table 4. The slight deficiency range which corresponds to the critical levels reported by various workers (Acharya and Jadar 1957, Melsted et al. 1969, Baker and Tucker 1973, Boldyrev 1960) covers the interval where a reduction in the grain yield exceeds 10% of the optimum. Accordingly, 3.8% and 4.1% in the

Table 4

Proposed calibration table for appraising K status of wheat

Growth stage	Plant part	K concentration in indicated plant part (%)			
		Sufficiency	Slight deficiency	Moderate deficiency	Extreme deficiency
		Reduction in yield from maximum, %			
		0–10	10–20	20–40	>40
Early seedling (15 days)	Whole plant	5.00–3.60	3.60–3.10	3.10–2.30	<2.30
Seedling (30 days)	Whole plant	5.60–3.80	3.80–3.10	3.10–1.00	<1.00
Tillering (45 days)	Whole plant	6.10–4.10	4.10–3.30	3.30–1.10	<1.10
Bloom (65–70 days)	Top leaves	5.10–3.20	3.20–2.40	2.40–1.30	<1.30
	Lower leaves	4.70–2.90	2.90–2.10	2.10–0.90	<0.90
	Stem	4.20–2.70	2.70–2.00	2.00–1.20	<1.20
Grain formation (95–100 days)	Top leaves	3.00–2.10	2.10–1.60	1.60–0.90	<0.90
	Lower leaves	4.70–2.80	2.80–2.10	2.10–0.95	<0.95
	Stem	3.30–2.10	2.10–1.60	1.60–1.00	<1.00
Maturity (130 days)	Leaves	4.10–2.50	2.50–1.80	1.80–0.70	<0.70
	Stem	3.80–2.30	2.30–1.70	1.70–0.80	<0.80

whole seedlings at 30 days and 45 days (tillering stage), 3.2% in top leaves and 2.9% in lower leaves at the boot stage (70 days), 2.2% K in top leaves and 2.8% K in lower leaves at the grain formation period (100 days) and 2.5% K in leaves and 2.3% K in stem at the harvest, are the sets of critical levels. According to the literature, 1.5 to 3.0% K in leaves at the boot stage has been reported to be the critical levels (Melsted et al. 1969, Acharya and Jadar 1957, Baker and Tucker 1973). The corresponding values in the present study were worked out to be 2.9% to 3.2%.

Therefore, the results indicate that plant analysis can uncover a hidden hunger for potassium and that this analysis may be performed at either the tillering, bloom, grain formation period or maturity stage. The potassium content in the whole plant at the seedling stage (30 days) and the tillering stage (45 days) and in the top leaves at the bloom or the grain formation period appears to be the best indicator.

The sensitivity of the K concentration in the plant tissue and its stability are two desirable criteria for defining the stage of growth. Figure 2 depicts the relationship between the K content in the growth medium and the K concentration in various plant parts. Evidently, within the range of practical interest, the K concentration in the plant at its tillering stage is most sensitive to changes in the K content in the growth medium. During the tillering stage, higher K uptake rates were observed by Mehrotra and Lehri (1967). Furthermore this work reported a high positive correlation between the chemical composition at the tillering stage and the final grain yield.

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EVALUATION OF ANALYTICAL METHODS FOR MONITORING THE RESPONSE OF WHEAT TO Zn ON ALLUVIUM DERIVED SOILS OF S.E. PUNJAB, INDIA

R. L. Bansal and G. S. Sekhon

DEPARTMENT OF SOILS, PUNJAB AGRICULTURAL UNIVERSITY, LUDHIANA, INDIA

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The relative efficiency of four extractants for estimating the available Zn in soils of the S.E. region of Punjab State was studied. Bulk samples of 29 soils ranging in ammonium acetate-dithizone extractable Zn from 0.22 to 2.25 ppm were subjected to a greenhouse study. The grain yield and Zn content in wheat increased significantly at 5 ppm Zn application. The responses to Zn uptake by the wheat crop were correlated with the Zn extracted from soils with four different extractants. The highest coefficient of correlation between the laboratory estimates of available Zn and the Zn uptake and yield was found in the case of ammonium acetate-dithizone extractable Zn. The next highest coefficient of correlation was found with EDTA, followed by DTPA and 0.1 N HCl. The critical levels of available Zn estimated by ammonium acetate-dithizone, DTPA, EDTA and 0.1 N HCl, below which economic responses to applied Zn could be expected, were 0.50, 0.70, 1.50 and 2.64 ppm, respectively.

Keywords: wheat, Zn-content, uptake, grain yield

Introduction

A large number of chemical extractants have been proposed for the determination of the available Zn in different types of soils, but the suitability of a particular extractant is limited to certain types of soils and may not give correct information for soils with different physico-chemical characteristics. The DTPA extraction method is widely adopted in many soil-testing laboratories in the world, as it differentiates better between micronutrient deficient and non-deficient soils (Lindsay and Norvell 1978). Zinc deficiency has been frequently reported in various crops and soils in Punjab (Takkar et al. 1976, Takkar 1982). The soils of the south-eastern region of Punjab, developed on alluvium, are generally coarse in texture, high in pH and low in organic matter (Sekhon et al. 1972). Such soils have been shown to be more prone to Zn deficiency (Takkar 1982). Keeping these facts in view, the present study was designed to examine the suitability of other extractants vis-à-vis DTPA and also to establish the critical limit for wheat using a statistical model in the soils of the south-eastern part of Punjab State.

Material and methods

Twenty-nine surface soil samples (0–15 cm depth) representing a range of DTPA-extractable Zn contents were collected from three dominant soil series of the S.E. region of Punjab. The classification of the soils used in this study is given in Table 1. The soil samples were analysed for texture, pH, organic carbon and $CaCO_3$ by the standard procedures (Jackson 1967) and for extractable Zn by the following four methods.

Table 1

Classification of soils used in this study

Soil number	Soil series	Classification*
1–13	Vijalpur	Fine loamy, mixed, hyperthermic family of typic Ustochrepts
14–20	Tulewal	Fine loamy, mixed, hyperthermic family of Udic Ustochrepts
21–29	Fatehpur	Sandy, mixed, hyperthermic family of typic Ustipsamments

* Sehgal and Sharma (1982)

(1) Ammonium acetate-dithizone extractable Zn: 2.5 g soil were shaken with 25 ml 1N ammonium acetate solution (pH 7.0) and 25 ml 0.01% dithizone in CCl_4 for 2 h and the centrifuged; a 10 ml aliquo of the dithizone phase was transferred to a separating funnel containing 25 ml 0.02 N HCl to bring the extracted Zn into the aqueous phase. 10 ml sodium acetate buffer (pH 4.7), 1 ml 16% $Na_2S_2O_3$ solution and 10 ml 0.001% dithizone in CCl_4 was added to the aqueous phase and Zn was estimated colorimetrically (Shaw and Dean 1952).

(2) DTPA extractable Zn: 10 g soil were shaken for 2 h in 20 ml 0.005 M DTPA buffer solution (diethylene triamine penta acetic acid containing 0.1 M triethanol amine and 0.01 M $CaCl_2$ adjusted to pH 7.3 with distilled HCl), centrifuged and filtered (Lindsay and Norvell 1978).

(3) EDTA extractable Zn: 2 g soil were shaken in 20 ml of 1% Na_2 EDTA solution for 2 h, centrifuged and filtered (Allan 1961).

(4) 0.1 N HCl extractable Zn: 2 g of soil were shaken in 20 ml 0.1 N CHl for 1 h, centrifuged and filtered.

A greenhouse experiment was conducted to obtain the biological indices of plant-available Zn. Polythene-lined pots were filled with 3 kg soil and three replications were provided in a completely randomized block design. The soil was treated with $ZnSO_4$ solution to provide 0, 2.5, 5.0 and 10 ppm Zn. A basal application of 125, 25 and 50 ppm N, P and K was given by means of ammonium sulphate, potassium dihydrogen orthophosphate and potassium sulphate, respectively. The wheat variety Kalyansona was grown as a test crop. The pots were irrigated with deionized water during plant growth and the crop was raised to maturity. Samples of grain and straw were taken. The plant samples were washed successively with 0.1 N HCl, distilled water and deionized water during plant growth and the crop was raised to maturity. Samples of grain and straw were taken. The plant samples were washed successively with 0.1 N CHl, distilled water and deionized water, oven dried at 70 °C weighed and ground. The samples were wet ashed with a $HNO_3-H_2SO_4-HClO_4$ ternary acid mixture (9 : 3 : 1). The Zn in all the soil filtrates and the plant extract was measured with a Varian Techtron AA 120 atomic absorption spectrophotometer.

Bray's percentage yield was chosen to evaluate the parameter of soil Zn availability, and was calculated as:

$$\frac{\text{Yield without Zn application}}{\text{Yield with optimum Zn application}} \times 100$$

The Bray's percentage Zn uptake was also calculated using the same formula. The Cate and Neison (1971) statistical model was followed to determine the critical level of available Zn.

Results and discussion

Some characteristics of the experimental soils are given in Table 2. The texture of these soils varied from sand to sandy loam, the pH from 8.1 to 9.8 the organic carbon from 0.05 to 0.5% and the CaCO from nil to 2.43%. Thus the soils are coarse in texture, alkaline in reaction, non-calcareous and low in organic matter.

The relationships between the ammonium acetate-dithizone, DTPA, EDTA and 0.1 N HCl extractable Zn were highly significant ($r = 0.53$ to 0.73). This indicates that all these methods extract nearly 28 to 53% Zn from the same pools. However, some extracted a larger proportion of the Zn pools than others because of the differences in their solution strength (Table 3). The data in Table 3 revealed that the Zn values differed appreciably between the

Table 2

Some characteristics of soils used greenhouse pot experiment

Soil No.	Texture*	pH	Organic carbon	$CaCO_3$	Clay
			%		
1	SL	8.0	0.50	0.34	14.5
2	SL	9.1	0.52	0.42	18.8
3	SL	9.0	0.31	0.27	16.5
4	LS	9.1	0.21	0.14	12.5
5	SL	8.8	0.44	2.43	19.2
6	SL	9.0	0.34	0.45	15.3
7	SL	8.6	0.31	0.06	18.5
8	SL	8.6	0.26	—	14.4
9	SL	9.0	0.51	1.12	16.0
10	SL	8.8	0.45	1.29	16.3
11	SL	8.6	0.45	0.06	15.9
12	SL	8.9	0.26	0.20	12.5
13	SL	8.8	0.40	0.50	8.4
14	SL	8.4	0.28	0.11	12.3
15	LS	8.5	0.30	0.50	12.0
16	SL	8.7	0.28	—	15.2
17	SL	8.1	0.41	—	13.2
18	LS	8.7	0.31	0.08	13.5
19	SL	9.5	0.28	—	14.7
20	LS	8.9	0.16	—	12.0
21	LS	9.0	0.08	0.59	9.5
22	SL	9.0	0.37	0.20	15.4
23	LS	8.9	0.19	—	13.8
24	S	8.8	0.19	—	8.5
25	LS	9.4	0.11	—	10.0
26	LS	8.8	0.49	1.23	9.0
27	S	9.0	0.05	—	6.9
28	LS	9.5	0.24	—	12.1
29	LS	9.8	0.05	0.14	9.9
Mean		8.9	0.30	0.35	13.3

* S = Sand, LS = Loamy sand, SL = Sandy loam

Table 3

Content of zinc extracted by different extractants
(ppm)

Soil No.	Zinc extracted by			
	Ammonium acetate-dithizone	DTPA	EDTA	0.1 N HCl
1	0.45	0.67	2.20	3.44
2	0.50	0.70	1.05	3.00
3	0.40	0.57	1.30	2.08
4	0.25	0.47	0.90	1.96
5	0.67	0.90	2.50	2.24
6	0.60	0.87	1.85	5.00
7	1.30	1.21	1.25	3.40
8	0.64	0.72	1.30	3.84
9	0.64	0.87	2.85	2.96
10	0.40	0.67	1.85	3.34
11	2.25	2.56	5.60	6.95
12	1.15	1.27	2.30	2.96
13	0.22	0.43	1.30	2.48
14	0.40	0.58	0.85	2.12
15	1.50	1.05	3.10	5.20
16	0.70	0.85	0.65	3.08
17	0.40	0.60	1.50	3.12
18	0.84	1.05	4.80	4.76
19	0.50	0.67	1.50	2.80
20	0.25	0.43	0.50	2.16
21	1.50	1.07	0.97	2.12
22	0.60	0.82	1.50	3.68
23	0.40	0.52	0.50	1.68
24	0.65	0.43	0.70	2.04
25	0.45	0.47	0.50	1.40
26	1.08	0.82	2.05	2.76
27	0.80	1.40	1.20	2.64
28	0.25	0.37	0.60	2.48
29	0.60	0.43	0.75	1.00
Mean	0.70	0.81	1.65	2.99

methods. The mean values of Zn extracted by ammonium acetate-dithizone, DTPA, EDTA and 0.1 N HCl were 0.70, 0.81, 1.65 and 2.99 ppm, respectively. The extractability decreased in the order 0.1 N HCl, EDTA, DTPA and ammonium acetate-dithizone. This indicates that the efficiency of different extractants to solubilize Zn from these soils varied considerably. This can be attributed to the nature of the extractant, the pH of the solution, the kinetics of the reaction and the mode and time of extraction.

In order to evaluate the suitability of a particular method in predicting the response of crops to Zn application, the coefficients of correlation were worked out between the Zn extracted by differed extractants and Bray's percentage grain yield and the Zn uptake by wheat (Table 4). The results indicate that ammonium acetate-dithizone extractable Zn had the highest significant correlation with Bray's percentage yield ($r = 0.69$) and Bray's per-

Table 4

Coefficient of correlation between different variables and the soil critical values

Extractant	Bray's % yield	Bray's % zinc uptake	Soil critical value, ppm
Ammonium acetate-dithizone	0.69**	0.52**	0.50
DTPA	0.52**	0.48**	0.70
EDTA	0.57**	0.51**	1.50
0.1 N HCl	0.42*	0.32	2.64

**, * Significant at 0.01 and 0.05 probability

centage Zn uptake ($r = 0.52$). A very good correlation between the Zn extracted by dithizone and the plant uptake and response of crops to Zn fertilization in different soils has been reported by several workers (Shaw and Dean 1952, Mithyantha et al. 1971). Ammonium acetate-dithizone is recommended as an extractant for available Zn in both a cid, alkaline and calcareous soils in many parts of the world (Jackson 1967).

The available Zn estimated by 1% EDTA gave the next best significant correlation with Bray's percentage yield ($r = 0.57$) and Bray's percentage Zn uptake ($r = 0.51$). It might be noted that Tucker and Kurtz (1955) found that the amounts of Zn extracted by EDTA and dithizone were approximately equal. However, their procedure utilized EDTA and neutral normal ammonium acetate, and this may have extracted less Zn than the aqueous EDTA solution used in the present study. These results are in conformity with those of Brown et al. (1971).

DTPA extractable Zn gave a significant correlation with Bray's percentage yield ($r = 0.52$) and Bray's percentage Zn uptake ($r = 0.48$), which is in agreement with the results of Lindsay and Norvell (1978) and Bansal et al. (1980).

Zn extracted by 0.1 N HCl gave a significant correlation only with Bray's percentage yield ($r = 0.42$). This could be due to the fact that some soils contain free CaCO*j* and hydroxyl ions which react with HCl and affect its extractability of available Zn. It appears that the fraction of soil Zn extracted by 0.1 N HCl, but not by ammonium acetate-dithizone is poorly correlated with plant availability. On the basis of these comparisons of the different methods used, ammonium acetate-dithizone, DTPA and EDTA best predicted the Zn availability to the plant. Among these methods, DTPA and EDTA are the most rapid methods and can be successfully used in soil-testing laboratories.

Response to Zn and soil critical values

The data in Table 5 indicate that there was a successive significant increase in wheat grain and straw yield up to 5 ppm Zn application. The grain and straw Zn concentrations in the control treatment were 17.7 and 7.5 ppm, increasing to 42.9 and 21.7 ppm for a 10 ppm Zn application. Similarly, Zn uptake also increased significantly with successive levels of Zn application. This indicates that the response of wheat to Zn application in these soils can be obtained by an application of 5 ppm Zn which gave an increase of about 120% in wheat grain yield over the control treatment.

Table 5

Effect of zinc application on the yield, zinc concentration and zinc uptake by wheat (average of 29 soils)

Parameters	Zinc applied to greenhouse pots (ppm)				C.D. at 0.05
	0	2.5	5.0	10.0	
Grain yield (g/pot)	5.75	6.67	7.07	6.75	0.24
Straw yield (g/pot)	9.74	10.41	10.62	10.51	0.83
Grain Zn concentration (ppm)	17.7	30.0	36.7	42.9	2.0
Straw Zn concentration (ppm)	7.5	13.2	16.8	21.7	1.4
Zn uptake (μg/pot)	181.4	336.0	429.0	519.2	32.7

Mostly, Cate and Nelson's (1965) graphic procedure is used to estimate the critical limits. The major objection against this procedure has been the human bias in drawing the lines, particularly, that parallel to the *Y*-axis. Additionally, this approach appears subjective since it does not provide an adequate test of the goodness of fit for the data. In order to rectify these errors, Date and Nelson (1971) subsequently reported a statistical method for the determination of the critical level of nutrients. The present data were thus subjected to this statistical model. The critical values obtained for ammonium acetate-dithizone, DTPA, EDTA and 0.1 N HCl were 0.50, 0.70, 1.50 and 2.64 ppm, respectively.

Adding the number of soils below a critical level, where a plant response accorred, and the number of soils above these values, where a response did not occur, and calculating this figure in terms of a percentage for all the soils, gives an overall predictive value. The predictive values thus calculated for ammonium acetate-dithizone, EDTA, DTPA and 0.1 N HCl were 62, 62, 62 and 55% respectively. This again brings out the superiority of the first three methods over 0.1 N HCl. However, the extractants EDTA and DTPA can be used with advantage over the ammonium acetate-dithizone method. The critical level for the EDTA extraction method suggested by the present study is

1.50 ppm. Singh and Takkar (1981) reported 1.42 ppm EDTA extractable Zn as the critical value for Punjab soils. The DTPA method has been adopted as an index of available Zn in many places (Takkar and Mann 1975, Lindsay and Norvell 1978, Bansal et al. 1980), but the critical value below which economic responses are obtained varies considerably. Lindsay and Norvell (1978) and Brown et al. (1971) found 0.50–0.80 ppm Zn as a tentative limit below which a response might be expected to added Zn. The present study suggests 0.70 ppm DTPA extractable Zn as the critical limit below which economic responses are likely to occur. This study also suggests 0.50 ppm ammonium acetate-dithizone and 2.64 ppm 0.1 N HCl extractable Zn as the critical values.

The correlations between the Zn extracted by different methods and the pH, organic carbon, $CaCO_3$ and clay contents were non-significant. A narrow range for these parameters in the 29 soils included in this study was probably responsible for the lack of these correlations.

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BIOLOGICAL SPECTRUM OF A GRASSLAND COMMUNITY AT DIBRUGARH

S. K. SARMA

DEPARTMENT OF LIFE-SCIENCES DIBRUGARH UNIVERSITY, ASSAM, INDIA

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The biological Spectrum of an area, previously occupied by a tea garden, is studied. The spectrum includes *Phanerophytes* (4.4%), *Chamaephytes* (2.9%), *Hemicryptophytes* (10.2%), *Cryptophytes* (7.3%) and *Therophytes* (75%).

Keywords: grassland community, life forms

Introduction

The biological spectrum, which is a statistical distribution of species among different life forms, can indicate the flora of an area on physiognomic basis or can indicate the influence of different environmental and climatic factors upon the growth and development of the flora of that locality. Unless the flora is not much disturbed by biotic factors, the biological spectrum can indicate the climate of the area studied. Raunkiaer (1943) who proposed a system to determine the biological or phyto-climatic spectrum of an area's flora, on the basis of the position of perennating buds during the unfavourable period of its growth, is very much useful for such a study. The species of different life forms clearly indicate that they have evolved according to their response to different ecological factors. Thus, the growth of species of specific life forms indicates the nature of prevailing factors in a locality.

A number of workers have studied the biological spectra of different regions. Bharucha and Dave (1944), Bharucha and Ferreira (1941) have studied the biological spectra of different regions of India. Cain (1950) also reported the influence of different factors upon the growth of species. Pandeya (1964) studied the life forms of flora in the grasslands of Sagar and reported the influence of grazing upon the development of floras. Ansari and Singh (1979) studied the biological spectrums of a forest in Gorakhpur, and contradictory to Raunkiaer's hypothesis, reported it to be a therophytic plant climate. Misra and Misra (1979) also studied the biological spectrum of a tropical grassland at Berhampur, and reported it to be a thero-chamaephyte.

Material and methods

The study site covers an area of approximately 500 acres of land including the Dibrugarh University campus (27°29′ N lat. et 94°58′ E long). Trough this site runs the busy 37 National Highway. Twenty years before, the land was occupied by a tea garden, until the tea bushes and shade trees were removed from the area for the establishment of the Dibrugarh University. After this removal, most parts of the area were open to disturbances by

Table 1

Climatological data of Dibrugarh for the year 1981

Months	Temperature average at 12 °C A.M.	Rainfall (mm)	Relative humidity % at 12 A.M.
January	20.5	39.3	64.6
February	22.8	88.9	69.3
March	25.5	165.3	65.7
April	26.8	192.0	68.3
May	29.5	299.2	66.7
June	31.6	519.8	70.6
July	30.7	462.5	69.6
August	30.8	311.0	72.0
September	29.7	297.4	68.2
October	28.4	116.5	67.8
November	29.3	60.9	71.4
December	21.5	40.9	61.6
		Total = 2593.7	

people and their herbivorous animals. Some parts of the area are occupied by University buildings, and some others have continuing construction growth of the Univerity; but most of the area remains open and throughout the year herbivorous animals can be seen grazing. The climate of the area is warm and humid, with rain mainly from the North-East monsoon in the summer months. The annual rainfall for the year 1981 was 2593.7 mm (data obtained from State Irrigation Dept., Dibrugarh). The temperature and relative humidity is shown in Table 1. The site lies upon by a plain in which the local human habitation sparse.

Observations and discussion

In the present study, a total of 68 species were found. In another paper, the community structure of the grassland is described, including a list of different species. The biological spectrum of the grassland revealed *Phanerophytes* (4.4%), *Chamaephytes* (2.9%), *Hemicryptophytes* (10.2%), *Cryptophytes* (7.3%) and *Therophytes* (75%). The *Phanerophytes* are represented by *Melastoma malabathricum* L., *Solanum torvum* Swartz and *Murraya koeningii* Spreng.

The study revealed that most of the species of the area are grasses and forbs. The results show that the percentage of *Therophytes* was maximum, while those of *Chamaephytes* and *Phanerophytes* minimum. Since the spectrum shows the dominance of *Therophytes*, the flora of the site can be called *thero*

phytic. Bharucha and Dave (1944), in studying the grassland in Bombay, reported the high therophyte value to be an indication of the influence of man and animal. Cain (1950) also proposed the high percentage of *Therophytes* in grasslands to be the result of overgrazing and the ultimate development and spread of weedy grasses. Pandeya (1964) confirms the life forms of different grassland associations to be influenced by grazing.

The present study also shows that in this area, where the intensity of grazing is too high and also the human disturbance is more, the flora is therophytic. The *Phanerophytes*, *Cryptophytes* and *Hemicryptophytes* develop in the

Table 2

Biological spectrum of the present study compared with that of Raunkiaer's normal spectrum

	Phanero-phyte	Chamae-phyte	Hemi-crypto-phyte	Crypto-phyte	Thero-phyte
			%		
Raunkiaer (1934)	46.0	9.0	26.0	6.0	13.0
Present study	4.4	2.9	10.2	7.3	75.0

less disturbed parts of the study site. From this, it can be concluded that in the present site the development of maximum therophytic flora in the grassland association, is mainly the result of biotic interference, along with the periodicity of climate. In Table 2, the biological spectrum of the present study is compared with that of Raunkiaer's normal spectrum. The comparision shows that the percentage of *Therophytes* is about 6 times more here than that of the normal spectrum: while those of *Phanerophyte*, *Chamaephyte* and *Hemicryptophyte* are about 11, 3 and 2.5 times less, respectively.

In conclusion it can be said that as the biological spectrum relates to the floras, and not to the bulk of the species, their social value is lost and therefore the preponderance of one life form over the other has a very limited meaning. The biological spectrum generally indicates the influence of environmental factors, where biotic interference can play a significant role. For example, in the present study site it shows that the phanerophytic floras of the site have been reduced to therophytic ones by biotic interference. This can be inferred from the prevailing nature of phanerophytic floras in the nearby undisturbed localities.

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EFFECT OF INCREASING NITROGEN DOSES ON THE DIAMETER, N-CONTENT AND WEIGHT OF THE APPLES CV. JONATHAN

J. Papp, A. H. Aziz and Ilona Kobzos

DEPARTMENT OF POMOLOGY, UNIVERSITY OF HORTICULTURE, BUDAPEST, HUNGARY

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For five consecutive years of experiments, the effect of increasing N-doses was studied on the diameter and weight of the developing fruits of the apple cultivar Jonathan. Increasing the N-doses did not increase but reduced the size and weight of apples. Increased N-doses resulted in a higher N-content in fruits but this did not produce larger fruits. This characteristic seems to be specific with the cultivar Jonathan.

Keywords: apple, N-fertilization, N-content, N-supply

Introduction

Nutrient supply, and especially nitrogen supply in apple orchards, is a long-disputed question. As Bergmann (1980) remarks, one of the main reasons for contradictions is the great difficulty of following the nitrogen metabolism in apple trees, complicated by compound regulation systems.

Until now, nobody could satisfactorily describe all the interrelations which exist between the nitrogen supply of apple trees and the quality of their fruits. Especially disputed are the effects of different doses of nitrogen fertilizers on the two most important qualitative characteristics, the size and the weight of fruits.

The process of the growth of apples is mainly regulated by their water and nutrient supply and by the temperature changes during the vegetation. Practically all cells of a given fruit are initiated at the first stages of fruit development. Later, during stages of steady growth of the fruit, the number of cell remains unchanged, but they greatly increase in size. This indicates a close relationship between the size of fruit and that of the cells. A larger fruit, therefore, has a looser histological structure, which negatively influences its storability.

In the literature, we find controversial opinions regarding the effect of nitrogen on the quality of apples. According to Hilkenbäumer (1962) large doses of N-fertilizer have an indirectly adverse effect on strorability only if they had produced too big a fruit. In this case, for example, cv. Jonathan

becomes more susceptible to Jonathan breakdown. O'Daniel (1974) states that too heavy a dose of nitrogen causes an increase of leaf area which results in a too steady increase of the fruit size. In the experiments of Hacsatrjan (1975), the nitrogen was increased from 100 kg/ha to 200 kg/ha. The higher dose of N increased the average weight of fruits as well as the number of large apples. N-fertilization however, brought decreased apple sizes in the experiments of Bovay (1965). According to Shear and Horsfall (1952) the level of N-fertilization has only a slight effect on the fruit size, if applied to older tress. Bünemann (1959), Williams and Billingsley (1974) found a positive relationship between increasing doses of nitrogen and the size of fruits. Lehova (1972), from her 4 years of experiments, concluded that the size of apple depends not on the doses of nitrogen, but primarily on the yield. Hansen (1980) reports that ample doses of nitrogen during the early stages of fruit development of apple cv. Golden Delicious have contributed to the formation of larger fruits. In the experiments of Ferree and Cahoon (1978), N-fertilizers with different speed of N-release were applied in different doses. They found that N-fertilization did not decrease the alternate bearing of trees, but neither could it balance the usual decrease in fruit and shoot size during the years of heavy yields. Smith Kenworthy and Bedford (1979) studied the effect of different N-doses at three different levels of watersupply. Only minor differences were observed between the various qualities of fruits from the different treatments. During several years of experiments of Engel and Gezerel (1981), N-fertilization usually increased the size of apple. Haynes (1981), with cv. Golden Delicious, found a positive interaction between N-fertilization and the growth and weight of trees and the size of fruits. Dojcsev, Lehova and Makariev (1981) reported, simultaneously, that N-fertilization in an orchard of Golden Delicious did not significantly effect the growth of trees and the size of fruits.

Waller and Rowe (1980) studied the interaction between the N-content of fruits and their quality. According to the author's results, storage problems and other qualitative anomalies can be expected at N-content valued above 80 mg N/100 g fruit.

Our experiments were set up in order to study the effect of different doses of N-fertilizers on the size and weight of Jonathan apples, and to find some correlation between the fruit size and its N-content.

Material and methods

The experiments were carried out in the Szigetcsép field of the Experimental Farm of the University of Horticulture. The orchard was planted with Jonathan on M 9 in 1963, with a spacing of 4×3 meters. The crown formation was the Hungarian hedgerow system.

The long-term N-fertilization experiments were started in 1972, with treatments N 0, N 50, N 100, N 200, N 400 and N 800 kg/ha. Nitrogen was given in the form of NH_4NO_3, twice: half in the spring and half in the autumn. The soil in the experimental orchard was a moderate alkalenescent floody one with medium organic content.

A total of 20 trees each treatment were selected for continuously measuring the changes in the fruit size. 5 marked fruits from each tree (100 fruits from each treatment) were measured at intervals of 10–14 days from the end of the cell-divisions in fruits until the time of harvest. The largest diameter of the fruits was measured by a slide-gauge. During the time of harvest the fruits marked for measurements were picked measured and weighed.

During the experimental years of 1983, 1984 and 1985, the fruits were analyzed for N-content in order to determine the relationship between the N in fruits and the fruit size and weight.

During the statistical evaluation of data, the methods of factorial analysis of variances and factorial analysis of regression were applied.

Results

The effect of increasing N-doses on the size of apples was studied at ten times. These times were determined by the number of days after the main blossoming period. The experimental results are shown in Table 1.

Table 1

Effect of increasing doses of N-fertilization on the size of the developing Jonathan apples in mm (Szigetcsép, 1981–1985, averaged data)

Treatment, kg/ha	The age of apples (days from the main blooming time)										%
	22	39	55	67	74	89	103	120	129	140	
N-Ø	18.6	27.5	33.7	39.8	45.7	50.0	55.6	61.2	64.5	67.0	100
N-50	18.2	27.1	33.4	39.0	44.9	48.9	54.3	60.1	62.9	65.7	98.1
N-100	18.7	27.3	33.4	39.2	45.0	49.3	54.8	60.9	64.1	66.9	99.9
N-200	18.6	27.0	33.1	39.0	44.9	49.1	54.7	60.7	63.5	65.9	98.4
N-400	18.2	26.7	32.8	38.5	44.1	48.3	53.9	59.4	62.8	65.2	97.3
N-800	17.6	26.6	33.3	39.0	44.9	49.0	54.7	60.5	62.9	65.8	98.2
$SD_{5\%}$	0.5	0.7	0.7	0.8	0.8	0.8	n.s.	0.9	1.2	1.7	

Contrary to expectation, increasing N-doses did not increase but rather decreased the size of apples. Treatments of 400 and 800 kg/ha N gave the most cases of significant decrease in fruit size, as compared to the control without N-fertilizer. At the time of harvest, there was a slight decrease in fruit size from the N-treatments, as compared with the control. The difference was significant only with the treatment 400 kg N/ha.

With only one exception, nitrogen fertilization significantly increased the N-content of Jonathan apples, as compared to the non-fertilized control (Table 2). This increase of N-content, however, was not accompained by an increase in size of the Jonathan apples.

In the average of 5 experimental years, increasing N-doses generally caused a decrease in weight of Jonathan apples, similar to that of fruit sizes. The average weight of fruits varied in the different years according to the quantity of yield (Table 3).

Table 2

Effect of increasing doses of N-fertilization on the N-content of the developing Jonathan apples in mg/100 g fresh weight
(Szigetcsép, 1983–1985, averaged data)

Treatment, kg/ha	The age of apples (days) from the main blooming time)								
	22	39	55	67	74	89	103	120	140
N-Ø	248.5	196.3	109.6	108.0	86.0	77.0	61.6	54.5	43.1
N-50	286.8	220.0	115.2	110.2	93.3	80.3	64.9	65.2	47.4
N-100	294.0	209.5	117.8	107.2	90.2	80.7	60.6	62.2	52.2
N-200	310.5	227.2	136.1	110.3	102.4	80.4	72.0	76.7	51.8
N-400	310.5	236.3	139.0	118.2	96.0	83.9	74.2	66.0	51.1
N-800	326.2	220.5	135.1	132.9	106.3	83.2	72.4	69.3	49.7
$SD_{5\%}$	5.1	5.5	6.0	5.0	4.7	2.6	2.9	2.2	2.4

Table 3

Effect of increasing doses of N-fertilization on the weight of Jonathan apples in g
(Szigetcsép, 1981–1985)

Treatment, kg/ha	1981	1982	1983	1984	1985	5-year average	%
N-Ø	106.5	126.0	122.0	124.8	97.1	115.3	100
N-50	110.9	119.1	123.3	106.1	91.6	110.2	95.6
N-100	108.3	125.5	125.5	122.6	97.0	115.8	100.4
N-200	104.0	119.3	121.2	124.3	95.5	112.9	97.9
N-400	97.8	121.8	113.3	124.2	93.2	110.1	95.5
N-800	115.2	124.3	124.3	104.3	101.4	113.9	98.8

$SD_{5\%}$ for 5 years: A × B (interaction) = 8.5
A (year factor) = 3.6
B (treatment factor) = 3.9

Table 4

Analysis of correlation between the size, weight and N-content of apples at the time of harvest
(Szigetcsép, 1981–1985)

Correlations	1981		1982		1983		1984		1985	
	r	n	r	n	r	n	r	n	r	n
Between N-content and diameter of fruit	−0.081	36	−0.309+	36	−0.349*	36	−0.446***	24	−0.011	24
Between N-content and weight of fruit	0.125	36	−0.51***	24	−0.69****	24	−0.32	24	−0.118	36

Remarks: + = at 10% level of significance
* = 5% level of significance
*** = at 1% level of significance
**** = at 0.1% level of significance

The correlations between the N-content, diameter and weight of fruits are shown in Table 4.

A significantly negative correlation between N-content and the diameter of fruits was found in 1983 and 1984. Only two of the five experimental years, 1982 and 1983, showed a significantly negative correlation between the N-content and weight of fruits.

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A COMPARATIVE STUDY IN STOMATAL AND SOME LEAF ANATOMICAL CHARACTERS OF TWO CULTIVATED JUTE SPECIES (*CORCHORUS CAPSULARIS* L. AND *C. OLITORIUS* L.)

S. M. A. HOSSIAN and N. K. PAUL

DEPARTMENT OF BOTANY, UNIVERSITY OF RAJSHAHI, RAJSHAHI, BANGLADESH, INDIA

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The objective of this study was to determine the variation of some stomatal and leaf anatomical characteristics of jute, and the interrelationship among these characters.

Significant varietal differences were found in the number of epidermal cells per mm^2 and mean cross-sectional areas of the epidermal and of the palisade parenchyma cells. The present study indicated that the higher fibre yield of *C. olitorius* was associated with the smaller mean cross-sectional area of epidermal cell; whereas, the lower fibre yield of *C. capsularis* was associated with the larger mean cross-sectional area of epidermal cells; further that the leaf are increased with the decreasing leaf thickness and the mean cross-sectional area of epidermal cells (lower surface).

Keywords: cross-sectional area, higher fibre, leaf area, leaf thickness, lower fibre, stomatal characters, stomatal frequency

Introduction

The importance of stomata and leaf anatomy in the control of the physiological mechanism of plants has received considerable attention. Studies on the frequency and size of stomata and their relationship with carbon assimilation, transpiration and respiration in different species have been made by several investigators. Moreover, in practical agriculture, studies on the efficacy of the foliar absorption of nutrients have received some attention as a means of obtaining a higher yield of crop plants. A number of workers have shown differences in stomatal frequency between plant genera. Varietal differences in the stomatal frequencies within single plant species have been reported in a number of crop plants.

Several studies have pointed to important relationships between the leaf anatomical characteristics and the photosynthetic performance in a number of plant species. Therefore, an understanding of the relationships of photosynthetic rate with leaf morphology and leaf anatomy may be helpful in manipulating a higher photosynthetic rate as well as in selecting plants of high photosynthetic rate, without a direct measurement of photosynthesis.

Material and methods

The following varieties of two cultivated species of jute were used in the present study: *Corchorus capsularis;* Full green (F.G. 7), D 154, Lal Naris (L.N.), and CVE-3; *C. olitorius*, O_2 and C.G.

The earthen pot which was 29.5 cm diameter and 16 cm depth was filled with 8.97 kg top soil and 0.03 kg cow dung. The soil was a mixed type, having more of clay and less of sand, taken from a fallow land. The pots were arranged in a randomized block design with 10 replications. On 15 June, 1982, six seeds of each of the six varieties were sown in each pot.

For stomatal and leaf anatomical characters, the fully matured tenth leaf was used. Peelings were taken from the upper and the lower surfaces of the tenth leaf and the number of stomata of five microscopic fields was counted and subsequently converted to the number per mm^2 of leaf. With the help of a camera lucida, the outline of five randomly selected stomata were drawn on a paper and guard cell length and breadth, and pore length were measured and converted to micron (μ).

For the study of the leaf thickness and the mean cross-sectional areas of palisade and spongy parenchyma cells, the leaf segments were fixed in a fixative (3 parts 70% ethyl alcohol and 1 part glacial acetic acid). After the discolouration, the leaf segments were transferred into 70% ethyl alcohol. The transverse sections from the preserved leaf segments were cut and the leaf thickness in μ was measured from the drawing. The areas of palisade and spongy parenchyma cells were drawn with the help of a camera lucida on paper. The mean cross-sectional areas of the palisade and spongy parenchyma cells were estimated by dividing the area of the palisade and spongy parenchyma cells by the respective number of cells. In the same way the areas of he upper and lower epidermal cells were estimated from the peeling. The data were analysed statistically.

Results

Mean, along with F and LSD at 5% values of some stomatal characters of four varieties of *C. capsularis* and two varieties of *C. olitorius* are presented in Table 1. The varietal differences were significant for all the stomatal characters, except for the guard cell breadth of the upper surface.

The stomatal frequency was always greater on the lower surface than that of the upper surface of the leaf in all the varieties. The number of stomata per mm in both the surfaces of the leaf was higher in *C. capsularis* than that of *C. olitorius*. Of the two species of jute, the highest length of the guard cell in both the surfaces was found in *C. capsularis* also. The highest guard cell breadth was found in *C. olitorius* for the upper and *C. capsularis* for the lower surface and the highest stomatal pore length was found in *C. capsularis* on both surfaces.

The varietal differences in the stomatal frequency within a single plant species have been reported in alfalfa (Cole and Dobrenz 1970), in jute (Mitra and Basu 1974, Talukder and Hashim-Ali 1974, Gopalakrishnan and Saha 1977, Saha and Paul 1984), in soybean (Ciha and Brun 1975), in rape, kale, turnip and swede (Paul 1980), in sweet potato (Shamsuddin 1983) and in rape seed (Islam and Paul 1984).

In the present investigation *C. capsularis* had a higher stomatal number per mm^2 in both the surfaces than that of *C. olitorius* (Table 1). But the reverse results were observed by Mitra and Basu (1974) and Saha and Paul (1984).

Table 1

Mean, F and LSD at 5% values of some stomatal characters of C. capsularis and C. olitorius varieties

Species	Variety	No. of stomata/mm²		Guard cell length (μ)		Guard cell breadth (μ)		Stomatal pore length (μ)	
		Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
C. capsularis	F.G.7	114	212	33.93	31.93	8.99	8.81	21.43	18.68
	D 154	142	307	31.11	27.74	9.14	8.64	17.34	17.19
	L. N.	147	402	31.02	30.60	9.88	8.04	19.36	17.95
	CVE-3	113	333	34.73	32.58	9.73	8.52	20.33	18.98
	Mean	129	313	32.69	30.71	9.43	8.50	19.61	18.20
C. olitorius	C. G.	117	246	30.99	25.92	9.61	7.32	17.18	15.53
	O_2	138	283	29.36	25.75	9.56	6.87	13.85	16.97
	Mean	127.50	264.50	30.17	25.83	9.59	7.09	15.51	16.25
	F	3.55**	14.01***	3.55**	20.93***	0.93	16.07***	9.42***	3.93**
	$LSD_{5\%}$	23.56	38.17	2.84	1.91		0.64	2.11	1.98

Table 2

Simple correlation coefficients between the area of 10th leaf, number of epidermal cells and stomatal character

	Area of 10th leaf (1)	No. of epidermal cell		No. of stomata		Guard cell length		Guard cell breadth		Pore length (stomata)	
		Upper (2)	Lower (3)	Upper (4)	Lower (5)	Upper (6)	Lower (7)	Upper (8)	Lower (9)	Upper (10)	Lower (11)
(1)	1.00	0.062	0.006	0.036	−0.007	−0.368**	−0.491**	−0.066	−0.009	−0.462**	−0.124
(2)		1.00	−0.093	−0.068	−0.213	−0.142	−0.304*	−0.043	0.428**	−0.123	−0.032
(3)			1.00	0.557**	0.064	−0.132	−0.114	−0.005	−0.317*	−0.204	−0.158
(4)				1.00	0.109	−0.302*	−0.059	−0.153	0.089	−0.605**	−0.271*
(5)					1.00	−0.408**	−0.637**	−0.782**	−0.702**	−0.482**	−0.616**
(6)						1.00	0.486**	0.485**	0.386**	0.761**	0.439**
(7)							1.00	−0.312*	−0.361**	0.614**	0.738**
(8)								1.00	0.141	0.203	0.236
(9)									1.00	0.383**	0.324*
(10)										1.00	0.746

Gopalakrishnan and Saha (1977) reported that *C. capsularis* had a higher stomatal frequency only on the upper surface than that of *C. olitorius*. They further reported that in *C. capsularis* the stomata were of similar size on both the surfaces, but in the present investigation the guard cell length, guard cell breadth and stomatal pore length of the lower surface were generally smaller than that of the upper surface in both the species (Table 1). The varietal differences in the guard cell length, guard cell breadth and stomatal pore length within a plant species have been reported in jute (Mitra and Basu 1974 and Saha and Paul 1984), in rape, kale, turnip and swede (Paul 1980), in rape seed (Islam and Paul 1984) and in sweet potato (Shamsuddin 1983).

The number of stomata of the upper surface was negatively correlated with the guard cell length (upper) and the stomatal pore length (upper and lower). On the other hand, the number of stomata of the lower surface was negatively correlated with the guard cell length (upper and lower), the guard cell breadth (upper and lower) and the stomatal pore length (upper and lower) (Table 2), indicating that the guard cell length, the guard cell breadth and the stomatal pore length increase with the decreasing stomatal frequency. Ciha and Brun (1975) reported a significant negative correlation between the stomatal frequency and the guard cell length in soybean cultivars of abaxial surface. Brown and Rosenberg (1970) in sugar beet, Paul (1980) in rape, kale, turnip and swede, Saha and Paul (1984) in jute, Islam and Paul (1984) in rape seed and Shamsuddin (1983) in sweet potato also reported that both the adaxial and abaxial stomatal frequencies were negatively correlated with the guard cell length, the guard cell breadth and the stomatal pore length.

Table 3

Mean along with F and LSD at 5% values of some anatomical characters of C. capsularis and C. olitorius varieties (in μ)

Species	Variety	No. of epidermal cell/mm²		Area of epidermal cells (μ²)		Leaf thickness (μ)	Mean cross-sectional area of palisade parenchyma cell (μ²)	Mean cross-sectional area of spongy parenchyma cell (μ²)
		Upper	Lower	Upper	Lower			
C. capsularis	F.G. 7	627	647	1354	1373	189.43	521.89	315.97
	D 154	669	668	1346	837	197.96	501.81	320.96
	L. N.	566	715	1106	1133	225.63	613.14	375.86
	CVE-3	594	638	1122	1045	220.16	663.10	394.34
	Mean	614	667	1232	1097	208.29	574.98	351.78
C. olitorius	C. G.	586	609	993	913	198.61	537.90	366.25
	O_2	675	695	1169	857	195.79	587.66	346.71
	Mean	630.50	652	1080	885	197.20	562.78	356.48
	F	5.85***	2.76*	4.66**	8.28**	1.89	7.38**	2.01
	$LSD_{5\%}$	54.72	66.71	69.79	51.65		68.78	

Significant varietal differences were found in the number of epidermal cells per mm^2 and mean cross-sectional areas of the epidermal and of the palisade parenchyma cells (Table 3). The present study indicated that the higher fibre yield of *C. olitorius* was associated with the smaller mean cross-sectional area of epidermal cell, whereas, the lower fibre yield of *C. capsularis*

Table 4

Simple correlation coefficients between the area of 10th leaf leaf thickness, mean cross-sectional areas of palisade and spongy parenchyma cells and of epidermal cells

	Area of 10th leaf (1)	Leaf thickness (2)	Area of the		Area of epidermal cell	
			Palisade parenchyma cell (3)	Spongy parenchyma cell (4)	Upper (5)	Lower (6)
(1)	1.00	−0.255*	−0.109	−0.119	0.319*	−0.446**
(2)		1.00	0.130	0.522**	−0.498**	0.278**
(3)			1.00	0.446**	−0.521**	−0.089
(4)				1.00	−0.449**	−0.093
(5)					1.00	0.341**

was associated with the larger mean cross-sectional area of epidermal cells. The area of the tenth leaf was negatively correlated with the leaf thickness and the mean cross-sectional area of the epidermal cells (lower surface), (Table 4), indicating that the leaf area increased with the decreasing leaf thickness and the mean cross-sectional area of epidermal cells (lower surface). The leaf thickness was positively correlated with the mean cross-sectional area of the spongy parenchyma cell, this indicated that the greater leaf thickness was associated with the large mean cross-sectional area of spongy parenchyma cells, the contribution of the palisade parenchyma cells to the leaf thickness was less important.

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THE NATURE OF INTERFERENCE BETWEEN FATHEN (*CHENOPODIUM ALBUM* L.) AND LUCERNE (*MEDICAGO SATIVA* L.)

M. P. L. D. MARTIN* and R. J. FIELD

PLANT SCIENCE DEPARTMENT, LINCOLN COLLEGE, CANTERBURY, NEW ZEALAND

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The interference between fathen (*Chenopodium album* L.) and lucerne (*Medicago sativa* L.) was studied in a glasshouse, and in a field experiment using de Wit's (1960) replacement series model.

Fathen was more competitive than lucerne during the establishment phase up to the first harvest, as shown by the shoot dry matter yield, relative crowding coefficient and relative yield of the two species. The competitive ability of fathen decreased and that of lucerne increased following defoliation, so that lucerne was almost equally as competitive as fathen at the third harvest in the glasshouse experiment and more competitive than fathen in the field experiment.

The product of the relative crowding coefficient and the relative yield total were close to unity, implying that the two species "completed for the same space" (i.e. competitive interference) and they were "mutually exclusive".

Keywords: *Chenopodium album*, *Medicago sativa*, competitive interference, relative yield

Introduction

A previous study on the interference of fathen with lucerne during the establishment phase showed that the fathen was the more competitive of the two and that both species were "mutually exclusive" (Martin 1984). However, there seems to be a scarcity of information on the nature of interference between fathen and lucerne following defoliation, despite the practical feasibility of controlling the weeds, including fathen, in lucerne stands, by proper grazing management (Langer 1973). The present study deals with an experiment in a glasshouse, and a field experiment conducted according to de Wit's (1960) replacement series model, to investigate the nature of interference between fathen and lucerne during their establishment and following their defoliation.

* Present address: Ministry of Primary Industries, Koronivia Research Station, P.O. Box 77, Nausori, Fiji Islands.

Material and methods

Glasshouse Experiment

This experiment was conducted in a glasshouse maintained at 28°/15 °C day/night under 16 hours of light and 8 hours of darkness (using 4 extra 400 Watt Phillips HLRG Lamps), and a relative humidity of 70%. The soil used was a moderately infertile, sandy clay loam with a pH of 6.4, and contained 2230 $\mu g\ g^{-1}$ N [extracted in H_2SO_4 (Bremner 1965)] 16 $\mu g\ g^{-1}$ P [extracted in $NaHCO_3$ (Olsen and Dean 1965)] and 260 $\mu g\ g^{-1}$ K [extracted in $(NH_4)_2\ COOCH_3$ (Chapman 1965)].

The monocultures and mixtures of lucerne and fathen were grown in plastic pots ($15 \times 15 \times 12.5$ cm) containing 5 kg of this soil, according to the replacement series model of de Wit (1960), where 0, 1, 2, 3 and 4 plants of lucerne were combined with 4, 3, 2, 1 and 0 plants of fathen, respectively. This resulted in a replacement series of 5 stand types with a constant overall density of 4 plants/pot. These treatments were arranged in a randomised block design with 6 replicates.

The lucerne (cv. Rere) seeds inoculated with *Rhizobium*, and the fathen seeds were sown on 28 August 1981. The lucerne and fathen plants emerged 4 and 7 days, respectively, after sowing. Both species were thinned to the required number of plants/pot 12 days after sowing, and all of the late-germinating fathen seedlings were removed as they emerged. The pots received NPK at the rate of 150 kg ha^{-1} of urea, 200 kg ha^{-1} of superphosphate and 100 kg ha^{-1} of muriate of potash before sowing.

Aerial compartments made of plastic were attached to the rim of each pot as the plants grew in height, so that the plants in each pot were restricted to similar aerial space and prevented from touching and shading by those plants in neighbouring pots. The upper rims of the aerial compartments were maintained at the maximum height of the plants. All of the plots were watered regularly to keep the soil close to its field capacity.

The first harvest was made 50 days after sowing by cutting the plants at 3 cm above the soil level. The second and third harvests were made at 30-day intervals by cutting the regrowth at the same height. In each harvest, the shoot dry weight of both species was measured.

The variance analyses were carried out on all of the data collected. The competition between the two species was analysed using the two-species competition model of de Wit (1960), following the least squares method of Thomas (1970). The competition between these species was assessed using: the relative crowding coefficient of (1) lucerne and (2) fathen: (3) their product (de Wit 1960; Hall 1974a, b); the relative yields of (4) lucerne and (5) fathen; and (6) their total (de Wit 1960; de Wit and van den Bergh 1965).

$$k_{lf} = O_{lf}Z_f/(M_l - O_{lf})Z_l \quad (1)$$

$$k_{fl} = O_{fl}Z_l/(M_f - O_{fl})Z_f \quad (2)$$

$$K = k_{lf} \times k_{fl} \quad (3)$$

$$RY_l = O_{lf}/M_l \quad (4)$$

$$RY_f = O_{fl}/M_f \quad (5)$$

$$RYT = RY_l + RY_f \quad (6)$$

In these equations: k_{lf} and k_{fl} are the relative crowding coefficients; RY_l and RY_f are the relative yields; O_{lf} and O_{rl} are the shoot dry matter yields in mixtures; M_l and M_f are the shoot dry matter yields in monocultures; and Z_l and Z_f are the relative plant frequencies of lucerne and fathen, respectively.

Field experiment

This experiment was conducted at the Ashley Dene farm of Lincoln College, Canterbury, as a part of a major field experiment on the effects of sowing date, seeding rate and herbicide application on the establishment and the first year production of lucerne (M. P. L. D. Martin, J. G. H. White and R. J. Field, unpublished). The soil at this site was Eyre Stony Silt loam with

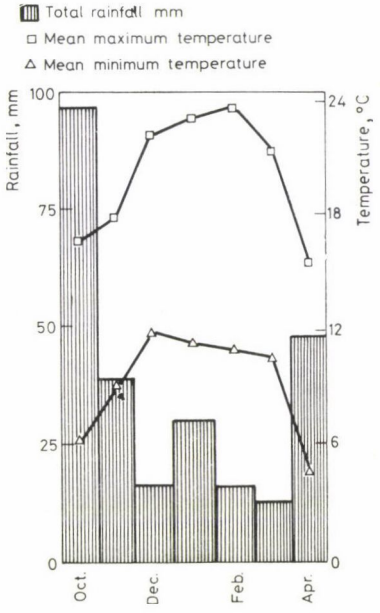

Fig. 1. Climatic date of the field experimental site during the experimental period

a pH before liming of 5.9 and contained 14 μg g^{-1} P (extracted in $NaHCO_3$) and 160 μg g^{-1} K [extracted in $(NH_4)_2COOCH_3$]. The trial area was previously in turnips and the land was prepared by cultivating and harrowing, followed by an application of 2.5 t ha^{-1} of lime. 250 kg ha^{-1} of reverted superphosphate was also applied at the time of drilling. The climatic data at the site during the experimental period are summarized in Fig. 1.

The treatments consisted of 5 stand types of monocultures and mixtures of lucerne and fathen (40 lucerne plants/m^2, 30 lucerne + 10 fathen plants/m^2, 20 lucerne + 20 fathen plants/m^2, 10 lucerne + 30 fathen plants/m^2, and 40 fathen plants/m^2) formed according to the replacement series model of de Wit (1960). These treatments were replicated 6 times in a randomised block design. The various densities and frequencies were achieved by thinning on 15 November 1981 of lucerne/fathen stands in plots sown on 30 October (emerged on

6 November) using 8 kg of seeds/hectare, and they received no herbicide treatments. All of the late emerging plants of these two and other species were regularly removed.

The first harvest was made on 5 January 1982 (67 days after sowing) by cutting the plants at 3 cm above the soil level. At the second and third harvest made on 9 February and 27 April (at 35 and 77 days interval, respectively) the regrowth was cut at the same level. The shoot dry matter yield of the two species was measured.

The analyses of the data collected were identical to those of the glasshouse experiment.

Results

Glasshouse experiment

The dry matter yield of the two species at the three harvest dates are shown in the replacement series diagrams (Figs 2a–c). At the first harvest taken 50 days after sowing, the monoculture yield of fathen was more than twice that of lucerne. In mixtures, the yield of fathen was significantly greater than that expected and the yield of lucerne was significantly less than had been expected ($P < 0.001$) (Fig. 2a). The expected yield is the yield of each species in a mixture, if they compete fully and have equal competitive abilities. At the second harvest, the yield of fathen was not significantly greater than that of lucerne in the monoculture. In mixtures, the yield of fathen was slightly greater and that of lucerne was slightly less than expected (Fig. 2b). At the third harvest, both species had the same yield in the monoculture, and the actual yields in the mixture were the same as the expected yields (Fig. 2c).

The relative crowding coefficient of lucerne (k_{lf}) was much lower than that of fathen (k_{fl}) at the first harvest (Table 1a). At the second harvest the difference was less, and at the third harvest the two species had almost similar relative crowding coefficients. The product of k_{lf} and k_{fl} was very close to unity at all three harvests.

The relative yield of lucerne (RY_l) was much less than, slightly less than, and very similar to, that of fathen (RY_f) at the first, second and third harvests, respectively (Table 1a). The relative yield total was very close to unity at all of the harvests.

Field experiment

The replacement diagrams showing the yield of the two species at the first two harvests (Figs 2d and e) show identical trends to those of the glasshouse experiment (Figs 2a and b). However, at the third harvest the yield of

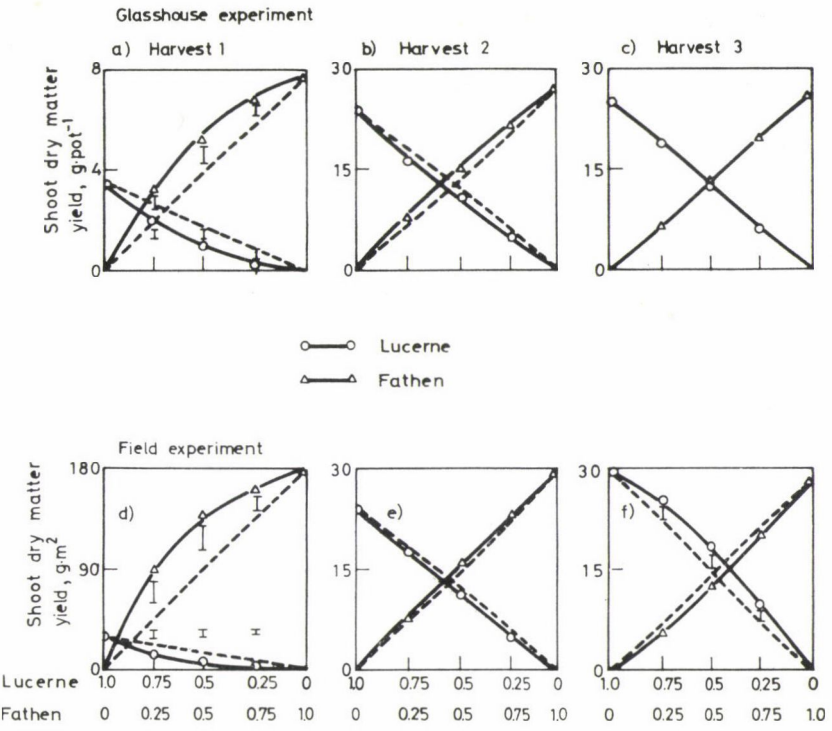

Fig. 2. Replacement diagram of shoot dry matter yields of lucerne and fathen et various harvests of the glasshouse (a–c) and field experiment (d–f). Vertical bars indicate LSDs (P = 0.05) from the expected yield (i.e. the corresponding dotted line)

lucerne in the mixtures was significantly greater than the expected yield, while that of fathen was slightly less than the expected yield (Fig. 2f).

Table 1

Relative crowding coefficient of lucerne (k_{lf}) and fathen (k_{fl}) and their product (K); and relative yield of lucerne (RY_l) and fathen (RY_f) and their total (RYT)

	(a) Glasshouse experiment			(b) Field experiment		
	harvest					
	1	2	3	1	2	3
k_{lf}	0.424	0.809	1.017	0.322	0.883	1.610
k_{fl}	2.150	1.289	0.992	3.099	1.105	0.800
K ($=k_{lf} \times k_{fl}$)	0.912	1.043	1.009	0.998	0.976	1.288
RY_l	0.330	0.455	0.503	0.271	0.474	0.594
RY_f	0.654	0.551	0.498	0.725	0.521	0.453
RYT ($= RY_l + RY_f$)	0.984	1.006	1.001	0.996	0.995	1.047

As in the glasshouse experiment, the relative crowding coefficient of lucerne was less than that of fathen at the first harvest, but this difference was reduced at the second harvest (Table 1a and b). However, at the third harvest, the relative crowding coefficient of lucerne was greater than that of fathen (Table 1b). The product of the crowding coefficients was close to unity at all three harvests.

The relative yield of lucerne was much less than that of fathen at the first harvest, and slightly less at the second harvest. At the third harvest, however, the relative yield of lucerne was appreciably higher than that of fathen (Table 1b). The relative yield total was very close to unity at all three harvests.

Discussion

Fathen was more competitive than lucerne during the early establishment phase (harvest 1), as demonstrated by both its larger relative crowding coefficient and its larger relative yield (Table 1a and b). At this stage the mechanism involved seemed to be the competition for light, because the fathen has a tall canopy and a large leaf area which shades the lucerne. This was also the case in a previous study of these species (Martin 1984). The importance of canopy height and leaf area on the outcome of competitive interference for light have been demonstrated in numerous studies (e.g. Black 1958, Iwaki 1959, Williams et al. 1978).

Lucerne, being a pasture plant well adapted to grazing with the ability to give rise to a large number of shoots from buds at or close to the crown (Smith 1972, Langer 1973), suffered less following defoliation than did fathen. The regrowth of fathen from axillary buds on the stubble was slow, so that the competitive advantage given by canopy height and leaf area during establishment disappeared with time.

In the field experiment, lucerne acquired superiority in its competition over fathen at the third harvest (Fig. 2f and Table 1b). This is presumably due to the better shoot growth of lucerne in response to defoliation and the detrimental effect of the repeated defoliation on fathen (Ahmed 1982), aided by the deeper penetration of the lucerne roots to lower soil horizons (Chamblee 1972, Peterson 1972), particularly due to the dry weather (Chamblee 1972) prevailing in February and March, with only 27 mm of rainfall (Fig. 1), and the longer interval of 77 days between the second and third harvests. This may have resulted in the lucerne roots absorbing moisture and possibly nutrients from soil horizons nut reached by the fathen roots. This was not possible in the glasshouse experiment, where the soil was kept close to its field capacity by regular watering and the rooting depth was restricted to only 12.5 cm by the depth of the pots.

The products of the relative crowding coefficients and the relative yield total of the two species are close to unity (Table 1a and b). According to *de Wit's* theory (1960), which was reiterated concisely by Hall (1974a and b), this implies that fathen and lucerne "competed for the same space", i.e. competitive interference, and they are "mutually exclusive".

The practical implication of the present results is that, although fathen is more competitive than lucerne and could suppress its growth when present in sufficient population during the early stages of growth, by proper grazing management this competitive advantage of fathen can be oversome.

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SUPPLEMENTARY INVESTIGATIONS CONCERNING THE INTRODUCTION OF *AGARICUS MACROSPOROIDES* INTO CULTIVATION

G. Bohus

MUSEUM OF NATURAL SCIENCE, BUDAPEST, HUNGARY

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The paper contains the results of ecological and cultivation technical experiments carried out since the completion of the study published in 1978 and which promote improvements in the method.

Keywords: Agaricus macrosporoides, acidic media, acidic peat, fructification, fruit body formation, medium and fruit body, phenomena of senescence.

Introduction

Problems of too many fruit body primordia. Necrosis of fruit body primordia

From the point of view of cultivation the high vigour of fruit body formation is, in fact, a positive feature of the species. The problem lies in the fact that the number of fruit body primordia is much larger than the number of fruit bodies actually developing from them. This is of no consequence as long as the primordia are alive, because their nutrients are gradually used up for fruit body formation. When, however, part of the primordia die, their nutrients are lost from the point of view of mushroom production, in addition to which they may become infected with saprophytic fungi.

The aim is thus to reduce the number of primordia and promote their survival.

The number of primordia is increased when the culture medium is rich, particularly with respect to nitrogen sources. For example, twice as many fruit body primordia developed in the case of 10% soya flour, than when 5% soya flour was used. Furthermore, certain inocula, while still enabling large yields to be obtained, may increase the number of fruit body primordia. It is thus advisable to use inorganic sources of nitrogen instead of organic ones, which are also more expensive.

The optimum (16–17 °C) cultivation temperature makes the early appearance of fruit bodies possible; these utilize the nutrient reserves, thus preventing the formation of further fruit body primordia.

Another method of hindering the appearance of primordia may be to lower the pH level of the culture medium. Further experiments are, however, required to determine the correct pH level, lest a decrease in yield should occur.

In preventing the fruit body primordia from becoming necrotized a favourable effect can be achieved with improved aeration. When open cultivation was applied, with ventilation once or twice a day, instead of the experimental closed cultivation carried out over a long period of time, where centilation took place slugishly through a cotton filter, necrosis was observed seldom, if at all.

Phenomena of senescence

The results of investigations into the process of senescence in higher fungi were summed up by Gramms (1979) as follows: "Der Verfall der allgemeinen Stoffwechselaktivitäten erfolgt kontinuierlich oder sprunghaft und beginnt mit dem Erlöschen der Konkurrenzkraft gegenüber Substratmikroorganismen und der Verfall des Flaumbilds, womit der Kulturstamm seine technische Bedeutung verliert . . . Mit diesen Eigenschaften geht die Fähigkeit der Fruchtbildung auf Unsterilsubstraten verloren. Es folgen dann Abbauerscheinungen wie verringerte Myzelwachstumraten, Verlust der Paarungsfähigkeit bei Einspormyzellen . . . In diesem Stadium endet auch die Fähigkeit zur Fruchtbildung auf sterilsubstraten. In dieser letzten Phase der Senescenz nimmt der Anteil des submersen Myzelwachstums auf Kosten des Luftmyzels zu, wobei sich die aeroben Atmungswerte verringern und der Gärungstoffwechsel dominier."

The senescence of *A. macrosporoides* takes place partly in accordance with, and partly differently from this pattern:

Although the growth rate of the mycelium may slow down, the competitiveness with microorganisms remains unchanged, and the fruit body production is more or less the same. For example, a satisfactory yield was obtained even when the mycelium growth rate fell to one-fifth compared to the control. Sudden senescence could quite often be observed in the monosporic cultures. In such cases the mycelium becomes cottony, an abundance of aerobic mycelium is formed, the hyphae, the knottedness of the mycelium disappear, and — naturally — fruit body primordia do not develop even months later. Cottony mycelia may occur — though seldom — in cultivation. In this case fruit body formation can hardly be expected. Cottony mycelium can be produced artificially, by lowering the pH value of the culture medium. Due to the possibility of sudden senescence, it is advisable to maintain monthly subcultures on a malt medium for 6 months at 16–20 °C, at which temperature the appearance of fruit body primordia can be reckoned with, so that in such cases the survival of the strain can be ensured from an earlier subculture.

Material and methods

Problem of fruit bodies growing in places other than the surface of the culture medium

In the course of the experiments it was often found that fruit bodies appeared not only on the open upper surface but also between the wall of the culture pot and the surface of the culture medium.

The most important role was played by the light. The previous paper (1978) contained the following passage: "If transparent culture pots are used and the intensity of the light is sufficiently high (about 400 lux), fruit bodies may appear not only on the open horizontal upper surface, but also though to a lesser extent, on the closed side walls. (More precisely: if the lateral surface of the culture receives enough light.) When the light intensity was reduced, all the 134 fruit bodies grown during one observation period appeared on the horizontal open surface."

The experiment took place in the following way: In a thermostat maintained at around 17 °C the light intensity on the upper shelf was about 400 lux, while about 60 lux reached the upper horizontal surface of cultures placed on the lower shelf, and even less the lateral surfaces. All the fruit bodies appeared on the upper surface, which received an illumination of 60 lux, and none on the side walls. Later, cultures with no sign of fruit body development on the upper surface were placed on the upper shelf. In a some of them fruit bodies later grew on the side walls as well.

In order to further study the effect of light, cultures grown in glass pots were placed in black plastic bags so that the edges of the bags were level with the surface of the medium or the culture. After 80 days of cultivation 24 fruit bodies were found to have grown on the surfaces of the cultures, and none on the side walls, this was confirmed by subsequent observations.

The other factor that determines the location of the fruit bodies is the atmospheric humidity. This, however, acts in a different way. At low humidity the majority of the fruit bodies are formed inside the culture medium irrespective of the light, and often grow horizontally or downwards. In such cases fruit bodies appearing on the surface may also be horizontal.

Intermediate culture medium, or the relation between inoculum and yield

In numerous experiments with cob grist as substratum and an inorganic sources of nitrogen the yield average was about 100% if the inoculum was wheat, millet or cob grist spawn prepared by the usual method (Bohus 1978).

If wheat grain spawn prepared by M. Bécsy and stored for months in

refrigerator was used as inoculum, then the yield percentage was high, sometimes as much as 150% (Table 1).

Table 1

Relationship between wheat grain spawn prepared by M. Bécsy and kept in a refrigerator for months inoculum and the yield

Culture medium	Date of inoculation	Number of replications	Strain	Number of days from inoculation	Yield, %*
Basic material:	1981				
Cob grist	24 September	2		61	122
Source of Nitrogen:	16 September	1	14/3	90	153
Inorganic	3 December	4		90	155
	30 December	1		75	166
	27 November	2		65	138

* Yield percentage = weight of fruit bodies related to the dry matter of the culture medium. For example, if the weight of the fruit bodies is 150 g and the dry matter weight of the culture medium is 100 g, the yield percentage is 150%

The yield percentage is similarly high if the basic material of the inoculum is commercial string cut into small pieces (Bohus 1978), (Table 2).

Table 2

Effect of inoculum based on chopped string on the yield

Culture medium	Date of inoculation	Number of replications	Strain	Number of days from inoculation	Yield, %
Basic material:	1975				
Cob grist	7 March	2	14/74	90	136
Source of nitrogen:					
Organic	19 March	2		90	151

From the foregoing it is clear that the intermediate culture media may have an influence on the yield.

High yields at particularly early dates

The highest yields were generally obtained on a culture medium with the following composition: wheat straw + organic nitrogen source + acidic peat + additives. Sterilization: at 120 °C for 1 hour. Inoculation: 350 g (wet weight) culture medium mixed with 6 g (dry matter weight) cob grist spawn. The maximum yields obtained in this case are interesting because the amount of culture medium per pot was relatively small (Table 3).

Table 3

Yield percentage in the experiments in group 1

Time of inoculation	Inoculum	Strain	Method of inoculation	Yield % on the 60th day	Yield % on the 90th day
1975					
7 April				191	—
17 April				161	181
8 May				125	162
13 May	Cob grist	14/74	Mixing in to the	100	151
15 May	spawn		culture medium	122	146
24 May				128	168
30 May				109	155
20 June				111	148
10 July				120	160
21 July				109	149
5 August				77	138
13 September				119	141
1976					
29 March				109	187
			Mean:	—	157

Table 4

Yield percentage in the experiments in group 2

Time of inoculation	Inoculum	Strain	Method of inoculation	Yield % on the 60th day	Yield % on the 90th day
1977					
13 December		14/3–1		105	123
1978					
23 January				99	110
10 February	Cob grist	14/3–1	Mixing in to the	100	112
5 May	spawn	14/3–1	culture medium	77	119
7 June				76	111
1979					
4 May				88	122
1981					
March		14/74–4		65	128
1980					
31 January	Wheat grain spawn			87	123

In the 2nd group of experiments the culture medium had the following composition: cob grist + inorganic nitrogen source + additives. Sterilization: at 85–100 °C for 1 hour. Inoculation: by mixing with cob grist spawn or in one case with wheat grain spawn (Table 4).

In group 2 the yield average was 118% on the 90th day. The yields were lower than in the former group, presumably due to the inorganic source of nitrogen, since much lower yields were also obtained in the control which was set up according to the method used in group 1, but with an inorganic source of nitrogen. It should be noted, however, that even in the case of inorganic sources of nitrogen outstandingly high yields (about 150%) were obtained when wheat grain spawns stored for a considerable time in a refrigerator were used as inoculum.

In the first experiment in group 3, the culture medium was composed of wheat straw + cob grist + acidic peat + organic nitrogen source + additives; while in the other two experiments cob grist, organic nitrogen source and additives were the components of the culture medium (Table 5).

Table 5

Yield percentage in the experiments in group 3

Time of inoculation	Inoculum	Strain	Method of inoculation	Yield % on the 60th day	Yield % on the 90th day
1976					
13 February	Cob grist spawn	14/74	Mixing in to the culture medium	100	121
17 March				116	148
24 March				82	125

Table 6

Difference in fructification time between parallel cultures

Delay in days	Number of cases	Delay in days	Number of cases
0	25	12	3
1	21	13	3
2	14	14	9
3	17	15	4
4	18	16	1
5	5	17	1
6	5	18	4
7	12	21	4
8	7	22	3
9	5	24	3
10	3		
11	4		

Results and discussion

Examination of the dispersion of fructification

On examining the delay in fructification in one culture compared to a parallel, uniformly treated culture it was found that in spite of the uniform circumstances there were occasionally considerable delays, though in more than half the cases the delay was less than 5 days (Table 6).

Relationship between the quantity of culture medium and the size of the fruit body

If for some reason the fructification is delayed, the fruit body will be larger. This, too, shows that the mechanism which prepares the way for fruit body formation (the production of readily mobilized nutrients) is continuous.

Table 7

Quantity of culture medium and weight of fruit body

Dry matter weight of culture medium (g)	Maximum weight of fruit body (g)
1693	220
332	172
116	93
88	79
67	64
54	42

The size of the fruit body is related with the quantity of culture medium. The closeness of this relationship is indicated in Table 7 on the basis of a considerable number of experiments.

It should be noted that the 220 g fruit body was produced on a culture medium placed in a natural environment.

Disturbances in fructification

Under conditions unfavourable either for the process of interweaving (e.g. above-optimum temperatures) or for fruit body formation (e.g. good moisture conditions combined with higher than necessary temperature) stroma

is formed, which may cover almost the entire culture surface touching the glass wall. The nutrient reserves are partially or fully consumed for the stroma formation. If conditions favourable for fruit body formation ensue, the insufficient reserve of nutrients will lead to a delay in the development of fruit bodies, which will of course, only be produced at all if the favourable conditions last (Table 8).

Table 8

Stroma formation

Date of inoculation	Number of replications	Interweaving at 25 °C	Further incubation at 25 °C	Stroma formation	Appearance of fruit bodies after incubation, number of days
		number of days			
1976 16 July	2	35	73	+	—
1976 29 July	7	35	60	+	—
1979 16 January	—	28		+	48
1981 25 July	—	35		+	50
1981 29 July	2	35		+	50 and 60

There is also a failure to produce fruit bodies when a rich, cottony mycelium is formed. In this case not even fruit body primordia appear. This is attributable to some genetic change, and the cause may be similar to the above, e.g. the maintenance of an interweaving temperature of around 25 °C for too long a period, or may be something quite different.

The question now is wheather there is any relationship between the observations made under natural conditions and the conclusions drawn from the experiments. It often happens that even though weather conditions have become favourable for mushroom production, a sufficient amount of mushrooms is not produced. Could it perhaps be supposed on the basis of the experiments that mycelium thalli which were ready for fructification and possessed sufficient nutrient reserves (since the weather was favourable for this process) were unable to produce fruit bodies for long because the change in the weather required for fructification did not occur) that in the meantime the mycelium thalli became unfit for fructification as their reserve nutrients had been used up for stroma formation or for some other purpose. This would then explain why, in such cases, mushrooms appear in smaller quantities, if at all, even when the weather finally changes for the better, or appear with some delay if the favourable weather proves lasting.

Storage in a refrigerator and viability of the inocula

Experiments designed to discover whether the viability (i.e. the rate of interweaving and the amount of yield) would remain unchanged, showed that it may even increase (Tables 9, 10).

Table 9

Yield percentage for wheat grain spawn stored for a long period in a refrigerator
(Inoculum: Bécsy, H. 15/3. 14/3. T.v. 1981. III. 30.)

Date of inoculation	Number of replications	Months of storage in a refrigerator at 4–5 °C	Yield, %	Number of days from inoculation	Note
1981					
24 September	2	5	122	61	
8 October	4	5	95*	52	Cultivation in box*
16 November	1	6.5	153	90	
30 December	4	7	155	90	Cultivation in box
30 December	1	8	166	75	

* Cultivation discontinued because of the re-use of the box

Table 10

Yield percentage for wheat grain spawn stored for a long period in a refrigerator
(Inoculum: Hr 12/2, 14/74. T.v. 1981. III. 30.)

Date of inoculation	Number of replications	Months of storage in a refrigerator at 4–5 °C	Yield, %	Number of days from inoculation
1981				
27 December	2	7	138	65
1982				
18 March	2	11	128	75

According to the data in the tables, in the case of wheat grain spawns prepared using *Bécsy*'s method, storage in a refrigerator for a long time had a highly favourable effect on the yield. (The basic material of the culture media was cob grist, and the source of nitrogen was inorganic. Sterilization took place at 90–100 °C. The inoculum was mixed with the culture medium.)

Carbon dioxide content of the air and fruit body formation

In a previous paper (Bohus 1978) the above experiments were evaluated from an ecological point of view, while now the production biology aspects are taken into consideration. It was found that in *A. macrosporoides* the growth of mycelium, and the formation and growth of fruit bodies were undisturbed even at a fairly high carbon dioxide concentration. For some time the aeration of the cultures in the experimental cultivation took place through a narrow strip of artificial cotton. This proved to be insufficient, because the carbon dioxide quantity increased reaching 1.65% during the period of fructification, about ten times the amount required to inhibit fruit body formation in *A. bisporus*.

In the case of *A. macrosporoides* concentrations even higher of carbon dioxide failed to cause inhibition; the interweaving of the mycelium and the appearance of fruit body primordia took place normally even in cultures which were not aerated, as proved by the following experiment.

After mixing the inoculum with the culture medium the cultures were kept hermetically sealed for a month, i.e. for one-third of the three-month period required for the completion of cultivation. The experiment, which included two cultures, was repeated three times, and the average yield was found to be normal: 109, 100 and 104%.

Covering the culture medium after interweaving is completed

To study the possible favourable effect of covering in the cultivation of bisporus champignon, experiments were carried out with peat, and with sawdust buffered to various pH values. Since covering turned out to provide no positive advantage, it does not appear to have any importance in practice as yet. On the other hand, the contamination of the fruit bodies by the covering material is definitely a disadvantage.

Examination of the effect of acidic peat

Acidic peat sometimes has a yield-increasing effect while in other cases it is ineffective or even inhibitive, depending on the composition of the culture medium.

It was a positive effect when the culture medium consists of wheat straw + straw meal + alfalfa meal + soya flour. Sterilization is required at 120 °C. The best way of inoculation is mixing the cob grist spawn with the culture medium. In this case the yield average is 159%. This is the highest

yield average obtained so far (experiments Nos 1–14 in Table 11). When the sterilization temperature was lower acidic peat did not give such a great increase in yield (experiments Nos 15 and 16). The yield may also be high when inorganic nitrogen sources are used instead of organic ones (experiments Nos 17–19). In the control (experiments Nos 20–23) without peat theyield was about half of the above figures. The acidity has nothing to do with these results, because the culture medium was acidified in the control as well.

Acidic peat has no effect when the basic culture medium is cob grist. In this case the average yield is 104% (experiments Nos 24–31). Experiment No. 29 is an exception: here the outstanding yield can be attributed to the effect of the string spawn used for inoculation.

Quantity of yield in highly acidic media

In an earlier publication (Bohus 1978) it was stated that a good yield could be obtained on a culture medium with a pH value at 4.5. In the present experiments mushrooms were found to grow even at a pH value as low as 4.1.

The next question studied was the trend in yield on culture media with pH values at 4.0–4.4. In the experiments organic nitrogen sources were used so that there would be no obstacle to the acidification of the culture medium. According to the results of three experiments the yield was 38% (the pH of the culture medium at the end of production was 4.1) or 44% 90 days after inoculation, or 75% after 95 days, which is considerably lower than the usual values of 100% or more.

Thus, a highly acidic culture medium, between 4.0 and 4.4 pH, is no longer favourable for fruit body formation. Two more phenomena could also be observed: the culture medium was only slowly interwoven by the mycelium, which then became very thick, almost cottony.

Additional data on the role of temperature

The temperature required for fructification is 16–18/19 °C. However, temperature lower than this (12–14.5 °C) also proved suitable for inducing the development of fruit bodies. Experiments aimed at settling this question gave positive results. Regular fruit body formation could be observed; the rate of growth was naturally slower, though not to the expected extent. Two fruit bodies, each originally 1 cm in size, grew considerably in the course of a week, one of them becoming 50 g in weight and the other 82 g.

Fruit body induction could be observed at temperatures still lower than this. For example, on one occasion a fruit body started growing in a culture kept at 10 °C and in 20 days attained normal size.

Table 11

Composition of culture medium, and yield percentage

Serial number	Date of inoculation	Nature of culture medium and quantity	Strain	Temperature of sterilization	Inoculum	Method of inoculation	Yield % and number of days
1	1975. IV. 7.	Wheat straw + straw meal + organic nitrogen source + acidic peat + additives	14/74	120 °C	Cob grist spawn	Mixed with the culture medium	228/98
2	IV. 17.						181/71
3	V. 8.				Straw spawn		150/81
4	V. 15.						146/82
5	V. 24.						190/88
6	V. 24.				Rice hull spawn		133/88
7	V. 30.				Cob grist spawn		155/82
8	VI. 20.						145/81
9	VII. 10.						183/82
10	VII. 21.						148/88
11	VIII. 5.						138/90
12	IX. 3.						141/77
13	1976. II. 7.						148/81
14	V. 13.						151/70
15	1975. X. 5.			111 °C			118/78
16	XI. 4.			115 °C			120/80
17	1976. I. 20.	Wheat straw + straw meal + inorganic nitrogen source + acidic peat + additives					114/75
18	III. 29.			120 °C			187/85
19	1981. XI. 23.						145/86
20	1975. III. 27.	Control			String inoculum	Inoculated in the centre of the surface	93/98
21	1974. II. 14.	Rye straw + organic nitrogen source + additives	14/3		Wheat grain spawn		79/80
22	XI. 27.						86/84
23	XII. 18.						95/90
24	1975. IV. 9.	Cob grist + organic nitrogen source + acidic peat + additives	14/74	115 °C	Cob grist spawn	Spread over the surface	114/77
25	1976. III. 17.					Mixed with the culture medium	108/85
26	III. 24.						119/90
27	VI. 24.	Cob grist + inorganic nitrogen + acidic peat + additives					87/80
28	VIII. 6.						88/70
29	1975. XI. 19.	Cob grist + organic nitrogen + acidic peat + additives			Wheat grain spawn	Inoculated in the centre of the surface	81/65
30	IV. 8.				String inoculum		116/93
31	III. 19.						151/90
32	1974. XII. 23.		14/3		Wheat grain spawn		124/90
33	1976. I. 30.						101/94

Prospects of cultivation in the summer months

It was repeatedly found from year to year that experiments in which fructification took place in the summer months were not successful, or not sufficiently so. The reason for this is known: during this season it is difficult

Table 12

Effect of fructification in the summer months on the yield

Period	Production temperature	Number of cultures	Total number of fruit bodies
1977			
5–25 July	18.5–19 °C	20	10 (few this is very)
26 July–15 August	19 –20 °C	24	5

to keep the temperature below 18 °C. The numerical data are contained in Table 12.

It was also observed that at 19–20 °C some of the fruit bodies only grew to a height of a few cm, then stopped developing.

Storage of inocula at 25 °C, and viability

If storage was continued at 25 °C after interweaving was completed, wheat grain and cob grist spawns were found to remain viable for 45–55 days. Temperatures lower than this do not seem to be suitable because of the appearance of fruit body primordia.

Effect of low temperatures

The experiment is of interest from an ecological point of view, as it indicates whether the mycelium of the species suffers damage in the frozen soil.

When the culture was stored at —8 °C for one day no deleterious effect was observed. When the culture was kept at —8 °C for one day, followed by two days at around 23 °C and then a further day at —8 °C, no inhibitory or damaging effect was observed.

Cultures kept at —8 °C for four days, on the other hand, suffered frost damage; the mycelium did not resume growing for some time even at an optimum temperature and when it later did so, growth probably started from the intact parts of the mycelium.

In cultures kept at —24 °C for one and a half days inhibition or damage was again observed: the fruit bodies developed 30–40 days later than usual.

According to the results of the experiments the damage caused by low temperatures depends on the temperature, on the duration and occasionally on the repetition of the could effect. Since the temperature in the upper layers of the soil seldom falls to 8 °C below zero, it is not likely that the mycelium of this species suffers damage in nature.

Does the mycelium disintegrate in shaken culture fluid ?

Is it possible to produce inoculum in a shorter time by this method?

The culture fluid was *Treschow*'s synthetic culture fluid, 20 ml portions of which were kept in (100 ml flasks). Shaking was carried out at 19–20 °C for 10 days using a mechanical shaker. The strains examined were: 14/3–1, 14/3–1 (1), 14/3–3 (3), 14/3–5, 14/74–4, 14/74–6, 14/74–7, 14/74–8, 14/74–9, 14/74–10, 14/74–11, 14 and 22.

Among these strains more or less disintegrating mycelia were found in 14/3–3 (3), 14/74–4, 14/74–9 and 14; when shaking was completed some 30 to 100 mycelium thalli were found floating in the solution.

For the purpose of producing inoculum the shaken cultures were poured over sterilized wheat culture medium together with the culture fluid. Interweaving took about one-third of the time required with the usual method of inoculation.

Cracking of fruit bodies

For strain 14/74, which has a tendency to crack, cracking occurs when the air is relatively dry. When the humidity is 80%, instead of 95–100%, all the fruit bodies will crack. Cracking occurs even at high air humidity if the illumination is provided by fluorescent tubes placed relatively close to the fruit bodies. In this case as many as 40% of the fruit bodies may be damaged. No cracking is observed when the illumination is supplied by diffuse light. The deleterious effect of direct light can be explained by the fact that its heating effect — however slight — makes the air above the mushroom surface drier, and so the situation is practically the same as if the vapour content of the whole environment were lower.

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AGRICULTURAL UTILIZATION OF ALCOHOL EXTRACTED FROM SWEET SORGHUM, AND OF THE BY PRODUCT

I. Kapocsi[1], J. Lazányi[1], J. Csontos[1], B. Kovács[2], J. Zombori[3] and E. Babóczky[4]

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The agricultural utilization of liquid manure produced in livestock farm was studied in sweet sorghum growing. 60—70 t/ha green forage yield was attained even in the case of relatively poor soil condition. The juice squeezed from chopped plant contained 14—17 per cent of sugar and was processed into alcohol by a simple procedure on the spot.

The spirits thus produced can be mixed with gas oil by adding emulsifying agents, and made suitable as fuel for Diesel motors.

The material of high dry-matter content, left behind from the fresh crop chopped and squeezed on the spot after harvesting, can be excellently preserved. It provides a feed of good quality readily consumed by ruminants.

Keywords: biomass, dry matter, energy-saving, fresh juice, green yield, surface tension, stability, sweet sorghum, viscosity

Introduction

The continuous energy supply is a precondition of production based on up-to-date technical procedures. For Hungary — as for any other country — it is of primary interest to pay increased attention to developing up-to-date, energy-saving procedures and technologies, and to make efforts to explore and utilize further energy carriers.

In the agricultural production and food industry of Hungary there are possibilities to increase production with considerable energy savings, on the one hand, and produce energy, partly as a substitute for hydrocarbon, and alcohol, on the other. According to the latest research results the production and processing of sweet sorghum show some promise in this respect.

Owing to the rising prices of energy carriers in the last decade, the interest in producing alcohol from the biomass has grown all over the world, and many authors (Blotkamp et al. 1981, Horton 1980) consider it as the most economical way of utilizing the biomass. According to Freeman et al. (1972)

[1] Research Institute of the Debrecen University of Agricultural Sciences (DATE), Karcag, Hungary
[2] Research Institute of Distilling Industry, Budapest, Hungary
[3] Technical Institute of the Ministry of Agriculture and Food (MÉM), Gödöllő, Hungary
[4] Hungarian Petroleum and Natural Gas Research Institute, Veszprém, Hungary

and Beatty (1978) the highest output of alcohol can be achieved by sweet sorghum production.

Observations concerning the utilization of sweet sorghum for distilling purposes were first reported in Hungary by Löffler and Papi-Balogh in 1868.

In Hungary sweet sorghum cultivation on a larger scale is linked with the name of Surányi, who elaborated a technology for sweet sorghum production in Hungary (Surányi 1941, 1942). The juice squeezed from the defoliated stem with a roller press contained 14–17 per cent sugar. The fresh juice, a liquid of light colour suitable for human consumption was either fermented and processed into alcohol, or concentrated to 55–60 per cent dry matter content to prevent fermentation, then stored as a syrup.

Material and methods

Characterization of sweet sorghum strains and hybrid combinations

The experiment was carried out with strains and hybrid combinations produced at the Research Institute of the Debrecen University of Agricultural Sciences, since high sugar content sorghum varieties suitable for distilling purposes are not commercially produced in Hungary. As a standard, the prospective variety "Szentesi édes" was used. The nutrient demand of the plants was satisfied by applying liquid manure from specialized pig farms. With a patented process of the Research Institute 800 m^3/ha liquid manure was distributed which corresponds to 395 kg/ha N, 205 kg/ha P_2O_5 and 384 k g/ha K_2O active agent. The major phenological data, productivity and sugar content of the varieties sown under operative conditions were determined before harvesting, too.

The *plant height* of the sweet sorghum varieties examined ranged from 173 to 233 cm. The hybrid combination TC-404 was the highest and the strain ZK-112 the lowest of all (Table 1). There was a plus-minus difference in shoot number compared to the planned stand of 400 thousand plant/ha. The thickest stand was formed by the ZK-102 strain where the number of shoots was 870 thousand per ha. The hybrid combinations TC-404 and TC-3212 and prospective variety "Szentesi édes" did not even reach a shoot number of 400 thousand/ha.

The largest yield of *panicle* was obtained with the hybrid combination TC-253: 14.4 kg/10 m^2. The ratio of panicles is important from a feeding point of view, namely, grains at the stage of waxen ripeness greatly increase the feeding value of the crop left behind after pressing. Of the varieties examined the prospective variety "Szentesi édes" gave the largest leaf yield, 10.3 kg/10 m^2, which corresponds to a leaf ratio of 19.4 per cent.

The analysis of the *stalk* ratio revealed that with the exception of the three early silage sorghum hybrids (TC-253, TC-2318, TC-3212), 70% of the green mass was represented by the stalk.

The *sugar contents* of hybrid combinations and early strains reached maximum by the time of the first analysis or even before. The total sugar content of hybrids remained below the sugar level of strains, of which ZK-122, ZK-112 and ZK-102 proved the best.

Results and discussion

Farm-scale experiments

The plant material of the comparative trial of sweet sorghum varieties was harvested with a *John Deere* type field chopper. We harvested 15–18 tons of sweet sorghum a day, at the stage of waxen ripeness. Of this volume, 5 m^3

juice could be reliably produced, and its continuous daily treatment and further processing was made possible for us. The plants were cut 10 cm above the ground and chopped into 3–5 mm pieces. The juice was extracted with a LUXOR-1 type grape-squeezer, then conducted into DETK-5 type containers where the process of fermentation took place. The plant parts left behind were ensiled and converted into good quality mass feed.

Of the varieties we only harvested those which in the preliminary examinations had been found to produce the largest green yield, were easy to squeeze, and the juice had the highest sugar content. At the time of harvesting, the juice extraction percentage was the highest (38.65%) with the ZK-112 strain, and the lowest (33.97%) with the hybrid combination TC-404. The sugar content of the juice ranged from 9.58% to 15.85%, depending on the variety. According to the sugar content of juice and the juice output the ZK-112 strain yielded 3500–3600 kg/ha sugar. Similarly good results were attained with the ZK-112 and ZK-103 strains.

As for the alcohol output, we can establish that the largest amount of alcohol could be produced with ZK-122 (1372.4 l/ha). More than thousand litres of alcohol can be produced with the varieties ZK-103, Zl-108 and ZK-112. The hybrid TC-404 with its low juice extraction percentage and low sugar content gave the poorest results of all (Table 2).

Utilization of the alcohol

The use of alcohol as a fuel for petrol engines has spread all over the world, and investigations are being made whether it might be applied as a Diesel fuel as well. Since in the Hungarian farms only Diesel motors are employed, we aimed at making use of the alcohol in this way. The only stipulation was to make no alteration of the power machines.

It is a well-known fact that alcohol does not mix with Diesel-oil. They immediately separate; the alcohol goes to the top, the oil to the botton. Materials that would ensure a permanent emulsion of the two components and create the thermotechnical conditions expected from the Diesel-oil, must be searched for.

Stability is an important requirement of the emulsion. Stability is largely determined by the specific weight difference, viscosity and surface tension of the materials to be dispersed, and by the distribution of the dispersed part, which can be influenced through the conditions of production: the sequence and temperature of the materials to be mixed. The stability of the emulsion can be further increased by adding the so-called cotenzydes to it.

The application-technical examinations are performed with a "water in oil" type emulsion. The composition of the emulsion is: 9.5% alcohol, 14.9%

Table 1

Major yield data of a comparative variety trial with sweet sorghum

Variety	Plant height, cm	Shoot number, piece/m²	Plant weight	Leaf weight	Stalk weight	Panicle weight	Stalk	Leaf	Panicle	Total sugar (%)			
			kg/10 m²				dry matter %			12 August	17 August	23 August	30 August
TC-404	233	39	65.1	9.7	48.1	7.3	24.0	35.5	57.0	9.65	10.86	9.58	14.50
TC-253	193	47	54.8	7.9	37.5	9.4	22.0	41.0	61.5	10.70	8.61	7.57	7.97
ZK-108	195	54	52.9	6.6	40.3	6.0	21.0	34.0	62.5	11.58	12.33	10.30	13.86
ZK-122	187	78	60.9	8.7	43.9	8.3	26.0	31.5	62.5	14.20	15.59	15.30	17.38
ZK-103	178	58	43.1	6.3	32.2	4.6	22.0	32.0	52.5	14.98	15.05	14.66	14.89
ZK-112	173	71	41.7	6.1	32.0	3.6	24.0	33.5	57.0	12.80	13.96	15.85	16.26
Szentesi édes	200	39	56.0	10.3	42.1	3.7	17.5	30.5	53.0	7.68	10.85	9.55	13.15
ZK-102	191	87	43.6	6.1	31.9	5.6	19.5	30.0	65.5	16.29	14.40	10.51	15.86
TC-3212	205	39	65.4	9.0	43.1	13.3	24.5	33.0	57.5	14.24	11.48	10.39	10.94
TC-2318	200	41	58.9	9.2	41.9	7.8	24.5	31.5	52.0	10.74	14.75	8.32	9.23
Average	—	—	—	—	—	—	22.5	33.25	58.4	12.28	12.78	11.20	13.40

Table 2

Major yield parameters of the sweet sorghum varieties processed

Variety	Time of harvest	Average yield	Juice	Plant parts left behind	Juice extraction percentage	Sugar content of juice	Sugar output of juice, kg/ha	Alcohol content of mesh, V/V	Alcohol, e/ha
		t/ha			%				
ZK-102	08. 26.	53.9	20.78	33.12	38.57	10.51	2183	4.68	972.50
ZK-112	08. 30.	58.3	22.53	35.77	38.65	15.85	3571	4.96	1117.49
ZK-103	09. 01.	58.4	21.37	37.03	36.59	14.66	3132	5.28	1129.40
ZK-122	09. 02.	60.2	22.76	37.44	37.81	15.30	3482	6.3	1372.43
TC-404	09. 03.	58.5	19.87	38.63	33.97	9.58	1904	3.36	667.63
ZK-108	09. 06.	56.7	21.65	35.05	38.18	10.30	2230	4.68	1013.22

water, 74.4% gas oil and an emulsifying agent. This emulsion remains stable for 7–8 days, then the stability is upset by the evaporation of the alcohol. Therefore the emulsion had better be produced in the required amount on the spot.

The bench tests and the examination of long-term operation (at present 880 hours of motor working) were carried out with the D-240 type motor of

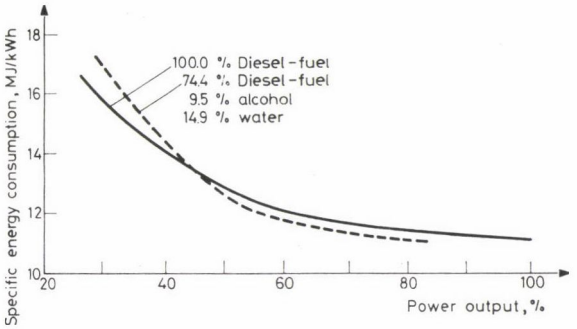

Fig. 1. Trend of specific energy consumption with gas oil and with water–alcohol–gas oil emulsion, respectively

the MTZ-82 tractor. The tractor was used in various agricultural operations (ploughing, conveying, cutting, etc.) at a rate of loading generally corresponding to the loading conditions of the MTZ tractors. We did not make any alteration on the engine.

The results of bench tests are given in Fig. 1. They show that the power engineering characteristics of the mixture of gas oil–water–alcohol we used come close to those expected from the Diesel-fuel.

Utilization of the by product

After the extraction of the juice from the sweet sorghum the crushed plant material left behind — 35–40 t/ha — can be preserved with various techniques. Due to its consistency, the material is highly suitable for making senage. When stacked and gradually packed by machine, then covered with plastic sheets and weighted it provides good quality feed. The components of the senage are contained in Table 3.

By another method of preservation the crushing removed from the squeezer is immediately placed in air-tight plastic sacks and stacked. The values of components of the material preserved in plastic sacks are seen in Table 3.

From the material left behind after the extraction of juice, with a dry matter content of 45–50% excellent quality pellets can also be made with a low energy input; for the values of components see Table 3. The digestible

Table 3

Values of components in the sweet sorghum senage per kg feed

	Senage		
	stored in stack	stored in plastic sack	pressed
	gramm		
Dry matter	322	359	899
Digestible crude protein	19	20	20
Starch equivalent	170	186	509
P_2O_5	1	2	4
K_2O	3	4	9
Na_2O	0.1	2	4
Mg	0.4	1	1
Lipids	17	14	30
Fibre	84	102	213
Ash	17	20	55
Fe	102 milligram	52 milligram	320 milligram
Cu	1 milligram	1 milligram	2 milligram
Mn	6 milligram	9 milligram	25 milligram
Zn	6 milligram	8 milligram	20 milligram

crude protein content in the pellet, prepared from the sweet sorghum following the extraction of juice is less than in that made of lucerne; the other characteristics are nearly the same. When used in farms for feeding ruminants, the crude protein content can be increased by adding carbamide to the feed. The amount of pellets obtainable from a unit area is two and a half to three times as much as that yielded by the lucerne. The composition value of feeds made of sweet sorghum is greatly increased by the 5–6 t/ha waxen ripe grains left in the crushing.

According to the results of feeding experiments with ruminants, the feed made of sweet sorghum after the extraction of juice is willingly consumed by the animals.

Summary

The agricultural utilization of the liquid phase of liquid manures produced in livestock farms with the method elaborated and patented by the DATE Research Institute is simple and cheap. The nutritive elements of liquid manures are very well utilized by the sweet sorghum. A 60–70 t/ha green yield can be attained with liquid manure even in the case of relatively poor soil conditions, 35–40% of which can be converted into a sweet juice with a simple procedure on the spot.

The juice which contains 12–15% sugar, depending on the variety, can be fermented into alcohol again on the spot, from which spirits of high alcoholic strength can be produced in agricultural distilleries.

The spirits thus produced can be mixed with gas oil by adding emulsifying agents, and made suitable as fuel for Diesel motors.

The material of high dry matter content, left behind from the fresh crop chopped and squeezed on the spot after harvesting, can be excellently preserved. It provides a feed of good quality readily consumed by ruminants.

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EFFECT OF CEMENT KILN DUST ON THE RADIATION AND WATER BALANCE AND YIELDS OF WINTER WHEAT

ANGÉLA ANDA

RESEARCH STATION OF AGROMETEOROLOGY, KESZTHELY, HUNGARY

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The changes in radiation and water balance were examined in 1982/83 on winter wheat polluted with cement dust. Similarly, we tried to determine the extent of changes regarding dry matter production and yields. The radiation uptake of the polluted stand increased, though surplus radiation was not utilized in photosynthesis; but it increased the other components of energy balance (detectable and latent heat). One of the reasons for yield losses was the deterioration of fecundity as a result of pollution. The unfavourable effect of pollution (in plant production) can slightly be decreased by providing an additional water-supply.

Keywords: cement kiln dust, solar radiation, water balance, winter wheat, yield

Introduction

Some of the various industrial, enterprises that pollute the atmosphere are thermal power stations, steam, electric and metallurgical works and cement kilns. Cement kilns, since they process raw materials by crushing, milling and heating, generate a considerable amount of dust. Mainly the dust from heating furnaces, which consists of fine grains, gets into the atmosphere and it can be carried away for great distances depending on atmospheric conditions. In this way, it can endanger life, living plants in particular.

The cement kiln is dangerous because it brings about negative changes in the metabolic processes of the plant. A result of pollution is higher plant temperature, which decreases photosynthetic intensity (Dässler and Börtitz 1979; Lal and Ambasht 1982). Hanus and Tóth (1977) have found that the photosynthetic intensity of plants polluted with cement dust is increased at the early phase of pollution and the depression described by others, occurs only later. The other vital process essentially affecting production is respiration, whose intensity was found to be decreased by most of the authors (Hanus and Tóth 1977; Borka 1981).

The damage done by pollution to photosynthesis and respiration causes a decrease in dry substance production. The rate of decrease gradually lessens as distance from, the source of pollution increases (Singh and Rao 1981).

Because of the change in dry substance a depression was also found in the energy contents (Singh and Rao 1981; Lal and Ambasht 1982).

According to the majority of authors, yields were lower on polluted plots (Lecrenier and Piquer in Darley 1966; Thompson et al. 1968; Singh and Rao 1981; Borka 1981, etc.). As opposed to these findings, Pajenkamp (1961) reported an increase in the yields of red clover and beet grown on polluted areas. The same was found by Stratman and Van Haut in Darley (1966) in their experiment with polluted oat. Scheffer et al. (1966) take an intermediate position with his findings-stating that pollution did not affect plant yields.

Up to now, there has been no general opinion regarding the effect of cement dust pollution on plants. The diversity of results can be attributed to several reasons (different physical and chemical properties of dusts used in the experiments, various doses of dusts applied, difference in the susceptibility of plant species and varieties to pollution, etc.).

We wanted to determine the character and degree of changes in the vital processes and yields of wheat caused by pollution by simulating dust encrustation, as it occurs under natural conditions.

Material and methods

Our experiments were conducted at the Agrometeorological Research Station of Keszthely, in 1982/83, on Mv-8 winter wheat cultivar, as a marker. Sowing was done by machine in fields and by hand in pots (5 million plants ha^{-1}). On 26th October, 1982 the production of dry substance was determined during the spring (end of March–beginning of June) by taking samples each week (from 4×20 plants in every treatment). We harvested on 8th July 1983, at which time not only yields, but the total dry matter production was taken into account.

The rate of dust-pollution we applied was equal to the pollution measured under natural conditions in the area around the Cement and Lime Mills on the Danube under the prevailing wind direction, at a distance of 10 km from the industrial chimney (15–20 g m^{-2}). The dust used in the experiment was collected under the chimney of the Kiln, during the whole vegetative period. We dusted the plants by hand every 2–3 days, using various filters, usually during the early morning period before the evaporation of the dew. The rate of pollution was checked by incinerating the leaves.

In addition to field trials, we examined the water balance of wheat using a Thornthwaite-type compensation evapotranspirometer. The pot of the evapotranspirometer (hereinafter ET-pot) — a metal pot with a surface of 4 m^2 and 1 m deep — was placed in the stand and the rate of supplementary water-supply was adjusted to the water-demand of plants during the whole measuring period.

The following treatments were applied during the experiment:

	Dust applied g m^{-2} $month^{-1}$	Repetition
Control plot	–	4
Polluted plot	15–20	4
ET-pot control	–	4
ET-pot polluted	15–20	4

Each sample contained 20 plants. The surface of the plots (adjusted to the ET-pot) was 4 m². The same agrotechnics were used in each treatment (with the exception of water-supply of ET-pot).

The differences in radiation balance occurring as a result of pollution were characterized by measuring albedo (a):

$$a = \frac{r}{S} \tag{1}$$

where r = reflection
S = total solar irradiance

Solar irradiance was measured by using a *Janisevszkij*-type hand-hold albedometer, and diurnal variation was obtained from the hourly values.

Light efficience for a week's period was obtained from the total (global) radiation:

$$\eta = \frac{17.18 \cdot W}{S} \cdot 100\ (\%) \tag{2}$$

where η = efficience
W = dry matter contents (g)
S = global radiation

The dry matter contents of wheat were transformed into energy by taking every gram of dry matter of the plant energy-quantity corresponding to 17.18 kJ (Seštak et al. 1971).

The growth of polluted and control plants between t_1 and t_2 points of time were characterized by the relative growth rate (RGR):

$$\mathrm{RGR} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{1}{W} \cdot \frac{\mathrm{d}W}{\mathrm{d}t} = \frac{\ln W_2 - \ln W_1}{t_2 - t_1} \tag{3}$$

where t_1 and t_2 = time of measuring
W = dry matter

This equation can be used provided that the dry matter contents continuously change between t_1 and t_2 points of time.

The assimilating surface values were compared by using a leaf-area index (LAI). The size of leaf-area was determined through the Montgomery equation:

$$L = h \cdot 0.75 \cdot s \tag{4}$$

where L = leaf area
h = length
s = width

During harvest-time, yields were evaluated (grain, straw, determining the weight of 1000 grains) and the plants were tested for fecundity in each treatment (number of grains per ear, 1000 grain weight).

Results and discussion

As a result of the pollution, a thin layer of dust formed on the wheat leaves, and remained constant by the repeated pollution. No visible injuries were observed on leaves (rip, necrosis), though the susceptibility to diseases (blight in the plot and mildew in ET-pot) was increased among the polluted plants.

The radiation balance of polluted plants changed on clear days, and there was a decrease in the amount of reflex radiation; consequently, the albedo value was also decreased (Fig. 1). Pollution caused greater changes during the morning hours and the difference — between control and plants polluted with cement dust-decreased by the afternoon. The hygroscopic dust-

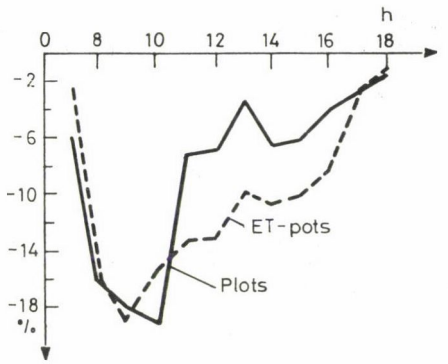

Fig. 1. Changes in diurnal variation of albedo on clear days in 1983 as a result of pollution with cement dust

layer on leaf surface became impregnated with water by the morning (from dew and the air) and — since the albedo of water is low — the reflex radiation in the stand polluted with dust decreased as a result of the humid dust-layer. As this layer dried up, the albedo of the plants polluted with cement dust approached that of the control plants. The dust-layer on polluted plants grown in evapotranspirometer dried up more slowly as a consequence of supplementary water-supply and the lower albedo value was maintained for a longer period of time (Fig. 2). Based on the average measuring values on several

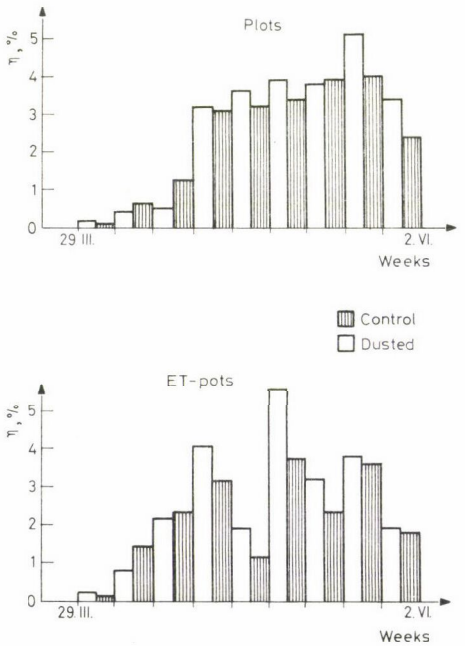

Fig. 2. Efficience of wheat in control and dusted plant canopy

clear days, albedo value decreased by a daily mean of 8.3% in polluted plots in 1983 and by 10.3% in ET-pots. On overcast days pollution was found to have no measurable effect on radiation balance.

If albedo (on polluted wheat) decreases, the radiation uptake of the stand will increase. Light efficience values give ample information to determine whether it actually was utilized in photosynthetic processes (Fig. 2). Pollution did not considerably effect the efficience; there were weeks when the

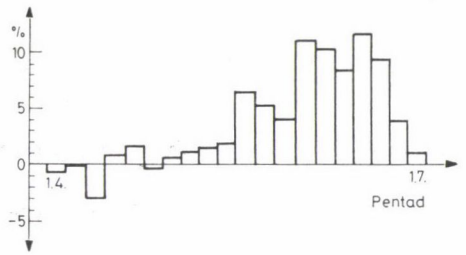

Fig. 3. Changes in values of the evapotranspiration as a result of cement pollution in pentads of 1983

utilization of light was higher and lower on plants polluted with cement than on control plants. Later on, the parameters characterizing wheat polluted with cement became lower, as a rule. During the whole spring period (29 March–8 June) efficience decreased by 8.6% in the polluted plot and by 16.3% in the ET-pot with cement pollution. Consequently, the surplus radiation did not appear in photosynthesis or in dry matter production in the polluted plants. Hence it follows that this amount of energy was not utilized in photosynthesis, but it brought about an increase in some other components of energy balance (latent heat and sensible heat).

Based on evapotranspiration measurement, we established that the transpiration of plants polluted with cement showed a significant rise from the first of May (Fig. 3). During the whole period of observation polluted plants transpirated by 19.5% more than the control plants. The time of increased water-consumption (in canopy with cement pollution), coincides with the time of higher LAI values on polluted wheat. That is, greater leaf surface was one of the reasons for the increased water consumption. The other important reason may have been the rising temperature of plants polluted with cement which — according to the hourly measurings, constituted a daily average of 1.5–2.5 °C. The greatest differences were observed in the afternoon, when the water-supply of polluted plants was hindered as a result of more intensive transpiration.

The assimilatory surface was increased as a result of pollution (Fig. 4). At the early stages of applying cement dust, there was no difference between

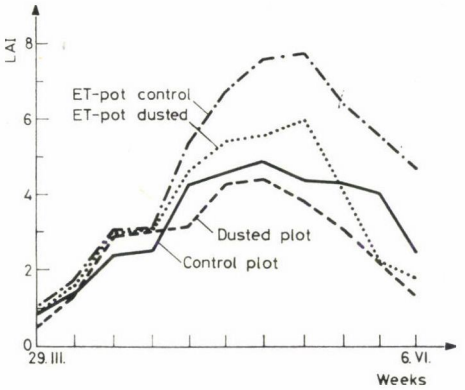

Fig. 4. The values of assilatormiy surface (LAI) in each treatment

single treatments concerning LAI values for plants polluted with cement and that of the control wheat plants.

Beginning from 25 April, up to the end of vegetative period, the total leaf surface of the polluted plot was greater on the average by 13.4% and by 25.9% in ET-plots with cement pollution than in the control. Neither the tendency of LAI curve nor the time for the development of the maximum leaf-area showed any considerable change following pollution in either the plot or the pot.

LAI values in ET-pots (with cement pollution and control) became much higher than those in the plot. The considerable increase in the number of unproductive shoots as a result of supplementary water-supply accounted for it, and it also resulted in a larger assimilatory surface and higher LAI values. The effect of the above-mentioned difference on yields was only moderate.

The growth intensity of single plants receiving different treatments can also be compared with the relative growth rate (RGR), which denotes the rate of mass increase per unit volume (Figs 5 and 6). It is one of the most

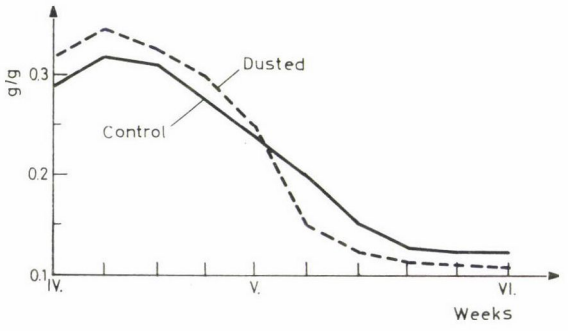

Fig. 5. The growth intensity (RGR) of wheat in control and dusted plots (1983)

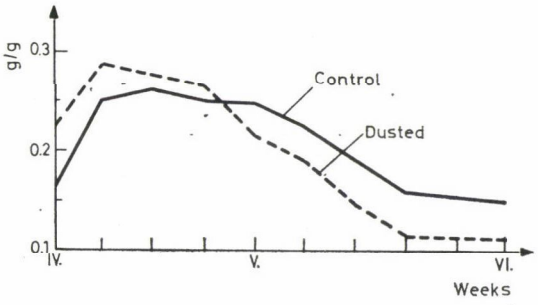

Fig. 6. The growth intensity (RGR) of wheat in control and dusted ET-pots (1983)

adequate growth parameters, which is independent of the amount of increasing mass, and proportional with the shape of the growth curve.

At the intensive growth stage, the growth rate of polluted plants was greater than in the control. Later on, however, the trend RGR altered following treatment, and the dry matter production of plants polluted with cement dust was lower. The decrease in production (for plants polluted with cement dust) occurred about two weeks later in ET-pots. Consequently the development of pollution inhibiting growth can be slightly delayed by applying an additional water-supply.

Besides total dry weight, we examined the change in dry weight of the ear every week, in each treatment (Fig. 7). As expected (note the shape of RGR curve), the mass of polluted ears was lower than that of the control, which in itself can be responsible for the lower yields of polluted wheat. The dry weight of polluted ears was lower on plots by 2.7% and in ET-pots by 5.2%.

At harvest, the amount of dry weight produced on the unit area and its distribution was determined in every treatment (Fig. 8). As a result of pollution, in the plot the amount of straw was reduced by 28% and that of the ears by 26.3%. The values of the above parameters were somewhat different in ET-pots with cement pollution: specifically, the amount of straw from the

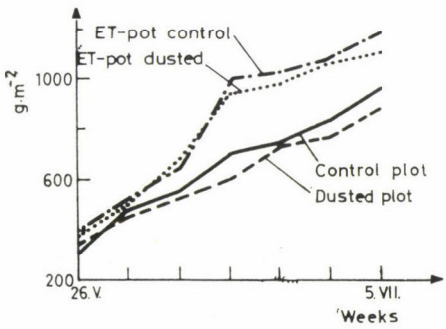

Fig. 7. The dry weight of ear in each treatment (1983)

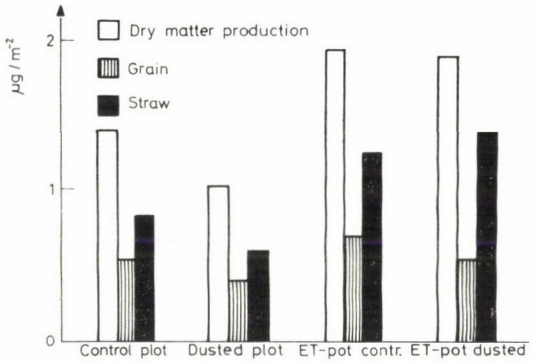

Fig. 8. The dry matter production on unit area and its distribution (1983)

polluted wheat that received a supplementary water-supply rose by 11.1%, while the yield was 21.7% lower. Plants grown in ET-pots produced greater vegetative masses than those grown in the plot, and the rate of surplus yields was not proportionate with the increased vegetative mass. The additional water-supply, both in the polluted and control evapotranspirometers increased the unproductive tillering.

The deviation concerning the fecundation of wheat following pollution was also examined (Fig. 9). As we found fewer grains developed in the lower portions of the ear in the lower four pikelets than in the ears of the control plants.

The level of 1000 grain weight also provides information on fertility; 1000 grain weight was 22.4% higher in the polluted plots and 12.6% higher in ET-pots with cement pollution. This means that the fertility on the polluted plants deteriorated, so those grains that had been set, had greater space for

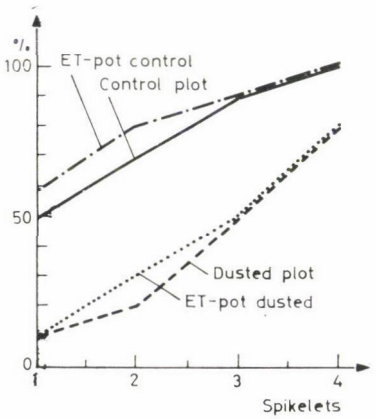

Fig. 9. The fecundation of wheat in the lower four spikelets (1983 at harvest)

Table 1

Changes in the 1000 grain weight as a result of pollution with cement dust

	1000 grain weight (g)	Changes (%)
Control plot	380.75	
Dusted plot	466.25	+22.4
ET-pot control	418.25	
ET-pot dusted	471.67	+12.8

Significance: 5%

growth than those in the control. The increase in 1000 grain weight partly compensated for yield losses (in the polluted stand), but failed to make up for the total loss.

In summary, we can state that cement pollution had a negative effect on the dry matter production and yield of wheat, which can be slightly improved by an additional water-supply.

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EVALUATION OF RATES, METHODS AND SOURCES OF ZINC APPLICATION TO WHEAT

P. N. TAKKAR and R. L. BANSAL

DEPARTMENT OF SOILS, PUBJAB AGRICULTURAL UNIVERSITY, LUDHIANA, INDIA

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The effect of rates, methods and source of Zn fertilization on yield, Zn content and its uptake in wheat was studied in two field experiments on a Zn-deficient Fatehpur loamy sand soil. Zinc sulphate was broadcast and band placed in the soil at 0, 2.8, 5.6 and 11.2 kg Zn ha^{-1}, and sprayed on the foliage as 0.5, 1.0 and 2.0% solution. Also multimicronutrient mixtures, containing variable composition of micronutrient cations were evaluated. Broadcast application of 5–6 and 11.2 kg Zn ha^{-1}, four sprays of 0.5% and one spray of 2.0% zinc sulphate solutions were significantly superior in increasing the grain yield, Zn content and Zn uptake to other methods, rates and sources of Zn for wheat. Multimicronutrient mixtures compared with zinc sulphate were either equal or less efficient and/or uneconomical.

Keywords: multimicronutrient mixture, plant Zn, Zn uptake, residual Zn

Introduction

Among the micronutrients, the deficiency of Zn is most wide spread in crops and soils of the world (Takkar and Randhawa 1976, Randhawa and Nayyar 1982, Takkar 1982). Soil or foliar application of zinc sulphate is generally recommended for the correction of Zn deficiency. However, very limited information is available on efficient rates, methods and sources of Zn for whest. Hypothetically, foliar application of higher concentration of zinc sulphate solution may be more or equally efficient as its placement in the soil as band or broadcast. One spray of higher concentration of zinc sulphate solution at a critical stage of Zn deficiency may be equally effective, if not more, as 2 to 4 of lower concentration and as its placement in soil.

During the last few years, a number of micronutrient mixtures have appeared in the market and claims are being made that these have better efficiency than zinc sulphate in ameliorating the Zn deficiency in crops. These claims are made on the hypothesis that besides Zn, latent deficiencies of other micronutrients may also be a factor in arresting the crop yields. Nevertheless, experimental evidences to support this are lacking. Theoretically, indiscriminate application of these mixtures is not advisible because their application can be both expensive and dangerous. The danger lies in the application of

unwanted micronutrients which may aggravate the deficiency of a micronutrient whose adsorption or utilization may be hindered because of antagonistic interaction. Moreover, the nutrient mixtures are always expensive due to the additional cost of unwanted elements. In the present investigation the efficiency of soil and foliar application of zinc sulphate versus multimicronutrient mixtures was examined for wheat.

Material and methods

Experiment I

A field experiments was conducted on a Fatehpur loamy sand (Ustisamments) soil at village Barewal, Ludhiana, Pubjab. In this experiment, the soil and spray application of zinc sulphate was compared with Nu-spartin and Sahayeeld-101 (Table 3). The experiment was conducted in a field where 35 day old wheat (WG 357) showed severe Zn deficiency symptoms (Takkar et al. 1971, Takkar 1980). The field was divided into three blocks, each having 14 plots of 100 sq.m. The treatments shown in Table 3 were given to the standing crop and were randomized within a block.

Experiment II

In this experiment, band and broadcast applications of zinc sulphate and multimicronutrient mixtures — trace, as well as the seed treatment of Sahayeeld-101 and Booster were compared (Table 4). The experiment was conducted in a field adjoining the Experiment I. The zinc-deficient wheat crop was ploughed in, and the field was divided into three blocks, each having 10 plots of 30 sq.m. the DTPA extractable Zn of this field was 0.48 mg kg^{-1}. The treatments shown in Table 4 were randomized within a block, wheat (WG 377) was sown, 45 days later than the normal sowing.

All the plots, of both the experiments, received N, P and K at 120, 26 and 49 kg ha^{-1} respectively. A brief description of the mode of application and the content of Zn, Cu, Fe and Mn in the multimicronutrient mixtures is given in Table 1. At maturity 5×2 m central portion of each plot was harvested for grain and straw yield determinations. Soil and plant samples were taken after the harvest of crop. Plant samples were washed successively with 0.1 N HCl, distilled and deionized water, dried in a hot air oven and ground in a Willey mill. One g plant material was digested in triple acid mixture containing $HNO_3-H_2SO_4-HClO_4$ in the ration 9 : 1 : 3 soil samples were ground and passed through 0.5 mm plastic screen. Available Zn was estimated with DTPA method (Lindsay and Norwell 1978). The Zn in soil extracts and Plant digests was measured with atomic absorption spectrophotometry. Soil organic carbon, pH, electrical conductivity and $CaCO_3$ were estimated according to the procedure of Jackson 1968. Soil texture was determined by hydrometer method (Sur and Singh 1976).

Results and discussion

The physico-chemical characteristics of the experimental soils are given in Table 2. The soils are low in organic carbon and available P, deficient in Zn, marginal in Cu and adequate in Fe and Mn.

Experiment I

Zinc deficiency symptoms disappeared and marked recovery in crop conditions was recorded after 10 days of Zn application. The recovery was more pronounced with zinc sulphate than with other sources. Soil application of

Table 1

Description of micronutrient mixtures

Sr. No.	Name of the product	Micronutrients % in the product				Mode of application	Rate and method of application
		Zn	Cu	Fe	Mn		
	Nu-spartin (Enriched with lignin- and sugar-free organic material in pre-digested form)	5.28	2.80	0.88	3.20	Soil Foliar	10 kg/ha 4.5 kg/ha, 3 sprays at 20 days interval
	Sahayeeld-101 (Chelated compound)	0.05	0.05	0.10	0.05	Foliar Seed treatment	625 ml/500 litre water/ha; 1st spray at 21 days after sowing and subsequent 3 sprays at 15 days interval 625 ml/10 kg seed
	Booster Ireat (Inorganic salts enriched with life promoting harmones)	7.96	2.20	0.64	14.0	Seed treatment	62 g Booster + 20 g gum acacia in water mixed with 10 kg seed, dried and sown
	Trace (mixtures of inorganic salts)	6.5	0.0035	4.25	10.0	Soil	55 kg/ha as broadcast

Table 2

Physico-chemical characteristics of the experimental soils

Parameter	Experiment I	Experiment II
Texture	Loamy sand	Loamy sand
pH*	8.6	8.1
Electrical conductivity* (mmhos/cm^{-1} at 25 °C)	0.20	0.20
Calcium carbonate (%)	0.40	0.50
Organic carbon (%)	0.24	0.33
P (kg/ha^{-1})	8.00	13.00
Zn (mg/kg^{-1})	0.40	0.48
Cu (mg/kg^{-1})	0.26	0.28
Fe (mg/kg^{-1})	3.80	3.40
Mn (mg/kg^{-1})	3.60	4.20

* 1 : 2 soil/water suspension

Table 3

Effect of zinc sulphate and multimicronutrient mixtures on wheat yield. Zn uptake and residual soil Zn (Experiment I)

Method and Source	Rate of application	Number of sprays	Yield, kg ha^{-1}		Zn content, mg kg^{-1}		Zn content, g ha^{-1}	Soil Zn, mg kg^{-1}
			Grain	Straw	Grain	Straw		
A. Soil application kg/ha^{-1} Zn		—						
$ZnSO_4 \cdot 7\ H_2O$	2.8	—	1650	4910	16.6	10.7	81	0.50
$ZnSO_4 \cdot 7\ H_2O$	5.6	—	2050	5350	17.1	11.0	96	0.88
$ZnSO_4 \cdot 7\ H_2O$	11.2	—	2220	5420	20.5	11.7	110	1.21
Nu-spartin	0.53	—	1720	4800	15.7	9.7	74	0.36
B. Foliar application per cent								
$ZnSO_4 \cdot 7\ H_2O$ solution	2	1	2150	5650	16.6	10.8	97	0.62
$ZnSO_4 \cdot 7\ H_2O$ solution	1	1	1950	5050	14.7	10.2	96	0.42
$ZnSO_4 \cdot 7\ H_2O$ solution	0.5	4	2050	5470	10.2	12.7	100	0.50
$ZnSO_4 \cdot 7\ H_2O$ solution	0.5	3	1970	5450	14.5	11.0	93	0.42
$ZnSO_4 \cdot 7\ H_2O$ solution	0.5	2	1900	5100	13.2	12.5	84	0.32
$ZnSO_4 \cdot 7\ H_2O$ solution	0.5	1	1700	5000	12.3	11.2	77	0.31
Nu-spartin solution	2.25	3	1920	5250	14.0	12.1	91	0.24
Sahayeeld-101	0.125	3	1750	5000	12.5	12.1	82	0.37
C. Control (No zinc)			1450	4790	11.9	9.5	63	0.19
$LSD_{0.05\%}$			360	680	3.4	—	33	0.21

zinc sulphate at 5.6 and 11.2 kg Zn ha^{-1}, significantly increase the grain yield, Zn content and its uptake (Table 3). Four sprays of 0.5% and one spray of 2% zinc sulphate solution, though slightly inferior, were also as good as soil application of 11.2 kg ha^{-1} from zinc sulphate. Although one spray of 1% zinc sulphate solution and three of Nu-spartin significantly increased the yield and Zn uptake, these were markedly inferior to soil application of 11.2 kg Zn ha^{-1} from zinc sulphate as well as foliar application of 2% zinc sulphate solution. The maximum grain yield response (770 kg ha^{-1}) was noted in soil treatment of 11.2 kg Zn ha^{-1} followed by one and four foliar spray on zinc sulphate solution of 2% (770 kg ha^{-1}) and 0.5% (660 kg ha^{-1}), respectively. The substantial increase in wheat yield with soil and foliar application of zinc sulphate has emanated from the significant increase in Zn concentration of both grain and straw. In check plot the Zn content in grain was 11.9 mg kg^{-1} and it rose to 20.5 mg kg^{-1} with soil and 16.6 mg kg^{-1} with foliar application of zinc sulphate. The grain yield increased non-significantly with the soil application of Nu-spartin, and foliar application of Sahayeeld-101. This is attributed to the lower content of Zn in the multimicronutrient mixtures (Table 1) which were unable to meet the Zn requirement of crop to the needed extent. Low values of DTPA Zn in these compared to zinc sulphate treatments attest the above observations (Table 3). The results thus clearly reveal that one spray of higher concentration (2%) of zinc sulphate solution, if sprayed timely (that is, during the third week of growth), on wheat, can mitigate its deficiency as well as the application of Zn to the soil.

Experiment II

Regardless of the method of application, Zn application significantly increased the grain yield (Table 4). Though the yield response from broadcast application of Zn was more than its band placement, the difference between the two methods was insignificant. The increase in grain yield at 2.8, 5.6 and 11.2 kg Zn ha^{-1} rates was 280 and 190, 550 and 400 and 570 and 470 kg ha from broadcast and band placement, respectively. This arose from concurrent, significant and successive, increase in available Zn, Zn content as well as its uptake in wheat with increasing rates of its application, baring 2.8 kg ha^{-1} band placed Zn (Table 4). The Zn content in wheat grain of check plot was 10.2 mg kg^{-1} and it rose significantly to 14.1/14.3 mg kg^{-1} with 11.2 kg Zn ha^{-1}. Similarly, Zn uptake also increased significantly from 66 g ha^{-1} in control plots to 104/116 g ha^{-1} in 11.2 kg ha^{-1} Zn plot (Table 4). The superiority of broadcast application of Zn to band placed Zn have also been reported (Takkar et al. 1974).

Trace applied to soil and the seed treatment with Sahayeld-101 and Booster caused an insignificant increase in yield as well as in Zn content and

Table 4

Effect of zinc sulphate and multimicronutrient mixtures on wheat yield. Zn uptake and residual soil Zn (Experiment II)

Mode of application	Source	Rate	Yield, kg ha^{-1}		Zn content, mg kg^{-1}		Zn uptake, g ha^{-1}	Soil Zn mg kg^{-1}
			Grain	Straw	Grain	Straw		
A. Soil								
Band	$ZnSO_4 \cdot 7\ H_2O$	2.8 kg · ha^{-1} Zn	2410	4560	12.6	11.5	83	0.67
Broadcast	$ZnSO_4 \cdot 7\ H_2O$	2.8 kg · ha^{-1} Zn	2500	4800	13.1	12.7	91	0.74
Band	$ZnSO_4 \cdot 7\ H_2O$	5.6 kg · ha^{-1} Zn	2620	5170	13.3	13.0	101	0.99
Broadcast	$ZnSO_4 \cdot 7\ H_2O$	5.6 kg · ha^{-1} Zn	2770	5160	13.8	13.9	108	10.5
Band	$ZnSO_4 \cdot 7\ H_2O$	11.2 kg · ha^{-1} Zn	2690	5140	14.1	12.9	104	1.14
Broadcast	$ZnSO_4 \cdot 7\ H_2O$	11.2 kg · ha^{-1} Zn	2790	4970	14.3	13.1	116	1.48
Broadcast trace		3.5 kg · ha^{-1} Zn	2300	5190	12.6	10.5	84	0.54
B. Seed								
Treatment	Sahayeld-101	62.5 ml kg^{-1}	2370	5070	10.4	11.1	81	0.40
Seed treatment	Booster treat	6.2 g kg^{-1}	2340	4890	11.4	12.1	87	0.30
C. Control (No zinc)			2220	4390	10.2	10.0	66	0.25
$LSD_{0.05\%}$			160	530	2.9	—	23	0.28

its uptake in wheat. This has arisen from low amounts of Zn in these mixtures (Table 1). The recommended rates of these mixtures by the manufacturers appear to be inadequate to meet fully the crop requirement for Zn and consequently have resulted in an insignificant yield response. After the crop harvest the deficient levels of DTPA extractable soil Zn (0.30 to 0.54 mg kg^{-1}) in these treatments verified the above observations. The superiority of zinc sulphate over other Zn sources namely zinc acetate, Zn dross, ZnO, Zn frits and Nu-spartin, for wheat and maize under pot house conditions have been shown by Bansal et al. (1978). The present study also suggests that zinc sulphate is the most effective source of Zn in comparison to other Zn source including the investigated multimicronutrient mixtures. Also, single foliar application of higher concentration (2%) of $ZnSO_4 \cdot 7\ H_2O$ during the third week of wheat growth is equally better than a large number of sprays of lower concentration (0.5%) of zinc sulphate.

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FROST RESISTANCE IN VARIOUS WINTER WHEAT VARIETIES DURING WINTER

O. Veisz and Erna Rajki

AGRICULTURAL RESEARCH INSTITUTE OF THE HUNGARIAN ACADEMY OF SCIENCES, MARTONVÁSÁR, HUNGARY

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Winter wheat varieties were studied for frost resistance under field conditions. From the point of view of overwintering the winter was mild in each of the 4 years examined. The soil temperatures under the snow cover were not critical, so that even those varieties as most sensitive to frost could overwinter relatively well. The winter 1982–83 differed from the previous three winters in its air temperature exceeding by far the many-year average. The frost resistance of the varieties examined showed the following trend: Mir. 808 retained a high level of hardiness for a long time, Bez. 1 gradually became slightly less resistant to frost, while B. 1201 and Rana 1 lost hardiness at a faster rate. The development of hardiness was similar in 1980–81, 1981–82 and 1982–83, while in 1979–80 the plants reached maximum hardiness later. The lowest overwintering percentages were registered in February. The effect of rehardening at the end of winter was observed every year except 1980–81. For the varieties overwintered in boxes placed outdoors on the soil surface, significant differences were found in the first 3 years; but in 1982–83 the overwintering values of the varieties showed no variations.

Keywords: winter wheat, frost resistance, field conditions

Introduction

Beyond production potential and disease resistance, the wheat varieties must have a resistance to extreme climatic conditions if large and reliable yields are to be attained. This is of particular importance in Hungary where the weather conditions in winter are variable: every variation may occur ranging from a moist winter weather of Mediterranean character with minimum temperatures of −8 or −10 °C to a dry, snowless winter with a lasting cold of −25 or −30 °C.

The direct effect of frost in the course of winter, the cold wind, the lack of snow cover, the frozen soil which causes deficiencies in water and nutrients, the excessive moisture in the soil, and the early spring frost equally endanger the winter wheat (Lelley and Rajháthy 1955).

Frost resistance is a part of the winter hardiness but it is not identical with it. The basic impulse of the action of winter is the reduction of temperature, the other factors are related with it, that is why those wheats as resistant

to frost generally tolerate the winter also well, and this makes it possible to draw reliable conclusions from frost resistance on winter hardiness (Rajki 1980).

Hardening is of great importance in the development of winter hardiness. The hardening of a given species depends on:

(a) the genetically determined adaptability of the species;

(b) the factors that influence the manifestation of this characteristic.

The development of frost resistance is influenced by the temperature, the light, the precipitation, the development stage of the plants, the different hardening optima of the species and varieties, etc. (Olien 1967, Andrews 1958, Roberts and Grant 1968, Steponkus 1978).

Frost resistance is most easily studied under field conditions, in which the plants raised outdoors are exposed to natural conditions of growth and hardening. Frost damages can be partly determined in different periods during winter, and partly at the beginning of spring.

Tumanov and Borodina (1929), Yurjev (1950) and others sowed several varieties of wheat seed in wooden boxes filled with soil at an optimum time for sowing in autumn. Several of these varieties were known for frost resistance. During the winter, the authors examined the extent of destruction and used the surviving plants for breeding purposes. To determine the overwintering percentage Alessi and Power (1971) lifted plants from the frozen soil of a partly-open container which had been sunk in the soil prior to freezing. The plants thus hardened under natural conditions were tested under artifical conditions in a glasshouse.

To judge the winter hardiness, Lelley established a frost station at Mátraszentlászló, which is at an altitude of 830 m above sea level. Here, the plants examined were preserved for further use, and at the same time the breeding material was exposed to extreme stress under natural conditions (Bálint 1966).

Harvey at the University of Minnesota was the first to use artificial freezing in studying the process of hardening and the phenomenon of frost resistance at the end of the last century. Around the turn of the century a series of papers, describing various technical instruments by which day length, temperature and illumination could be controlled, came from the research stations of the USA and other countries (Dexter 1956). The plants could be raised, frozen and their survival studied at chosen and controlled temperatures. For the last 25–30 years the use of such equipment in studying frost resistance has become regular and indispensable. Under the changeable weather conditions of Hungary in winter this purpose is well served by the phytotron constructed in 1972 at the Agricultural Research Institute of the Hungarian Academy of Sciences.

The present paper describes the results of a four-year study (1979–1983) on frost resistance in several winter wheat varieties during winter.

Material and methods

The experiments were carried out at the Agricultural Research Institute of the Hungarian Academy of Sciences in Martonvásár with 9 winter wheat varieties, including varieties with differing degrees of frost resistance, which had proven important in the wheat production of Hungary.

The germinated wheat grains were planted in the middle of October into wooden boxes used in raising plants in a phytotron. The box size was $42 \times 30 \times 13$ cm, and the depth of planting 3.5–4 cm. The growth medium was a 3 : 1 ratio mixture of vegetable soil and sand. In every box, 20 plants were grown in each of 9 rows. The experiment was set up with 4 replications. The boxes were placed on poles laid outdoors on the ground surface. The larger part of the boxes were transferred to the freezing chamber of the phytotron (C-812) early in December, January, February and March, and frozen at −6, −12, −15 and −18 °C, respectively; 4 boxes were forced without previously freezing them in a phytotron and used as a control. In the course of freezing in the phytotron, the temperature was gradually lowered with a 12-hour treatment at each temperature. The freezing was followed by 3 weeks treatment on a GB-48 type raising bench at a 16 °C day and 15 °C night temperature and at a 10 000 lux (Q-115) illumination. The plants that survived the freezing could be easily marked off from those that had died.

To show the results of our experiment, we chose 4 of the 9 varieties tested, which best represented the characteristic examined. In earlier experiments we found that Mironovszkaya 808 (Mir. 808) possessed the highest frost resistance, the Mv-varieties generally were of the same level as Besostaya 1 (Bez. 1), the old Hungarian variety Bánkúti 1201 (B. 1201) represented the medium hardy varieties, while NS Rana 1 those with poor frost resistance.

Results

The temperatures of air, open soil and the soil of boxes were measured outdoors from the beginning of the experiment. The soil temperatures were registered by a sensing-device placed at a depth of 5 cm (Fig. 1).

With the temperature values of the 4 years summarized, it can be seen that the winter of 1982–83 essentially differed from the 3 previous. Average temperatures below zero were only observed in February, but not even then was the temperature of the soil in the boxes lower than −3 °C. In the winters of 1980–81 and 1981–82 the temperature was similar. In both years a sharp fall in temperature in December was followed by a warming period which was longer in 1980–81 and shorter in 1981–82. January was cold in both years. In February a slight rise in temperature was followed by two minor cooling periods in 1980–81, while in 1981–82 the February air temperature remained around −2 °C. In the winter of 1979–80 the air temperature was similar to that in the subsequent two years, except for the sharp fall in the December temperature. The temperature of the boxes placed on the soil surface was similar in 1979–80 and 1980–81. In 1981–82 the more intensive cooling of the air in the middle of December made its effect felt in the soil temperature of the boxes. In February 1982 the temperature of the boxes placed on the soil surface remained below 0 °C, while in the previous two years it was above zero.

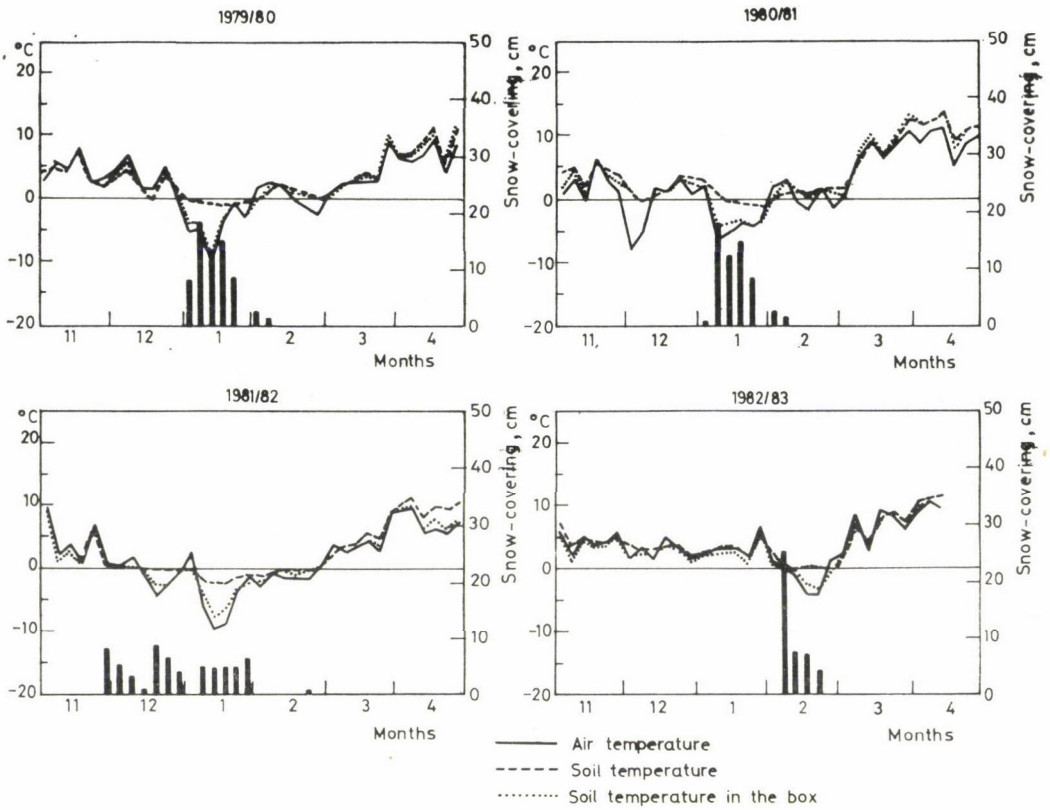

Fig. 1. Average of the air and soil temperatures

To be able to characterize the frost resistance of a variety, we must know the temporal changes and the level of this feature under the given ecological conditions. In our experiments we characterized the frost resistance for each variety by taking into consideration the result of freezing at various temperatures in different periods of the winter. The frost resistance shown by the four varieties in 4 years, on 4 dates of testing at 5 freezing temperatures was evaluated with a four-factor analysis of variance. The results are contained in Tables 1–6.

The temperatures of the boxes placed on the soil surface showed differences among the varieties in the 4 years of the experiment even without freezing in phytotron (Table 1). For the varieties B. 1201 and Rana 1 the results of freezing at —6 °C agreed with the plant number obtained without freezing, while at the other temperatures the survival percentage showed a gradual significant decrease. The differences in the frost resistance of the varieties examined on the average of the 4 years can be definitely determined. Identical survival percentages were obtained on freezing Bez. 1 at —18 °C,

Table 1

Frost resistance of winter wheat varieties at different freezing temperatures (%)

Variety	Without freezing	Freezing temperatures			
		—6 °C	—12 °C	—15 °C	—18 °C
Mir. 808	97.1	95.9	97.2	91.1	84.2
Bez. 1	93.1	92.6	92.3	80.9	62.9
B. 1201	72.4	73.4	65.4	35.8	12.9
Rana 1	58.3	64.1	32.5	9.5	2.7

$LSD_{5\%} = 4.251$

B. 1201 at —12 °C and Rana 1 at —6 °C. In the case of the varieties B. 1201 and Rana 1, this difference in the level of frost resistance could be observed at lower temperatures as well; e.g. the survival percentage was the same for Rana 1 at —12 °C and B. 1201 at —15 °C, or for Rana 1 at —15 °C and B. 1201 at —18 °C.

In Table 2 the average values arranged by variety and freezing date are seen. The results obtained for the variety Mir. 808 at the 4 testing times showed no significant differences; in the case of Bez. 1 and Rana 1 only the December and January freezing results were similar, while the variety B. 1201 also gave a significantly lower survival percentage in January. The survival percentage was the lowest in February for all varieties. The time required for the varieties to reach maximum frost resistance could not be reliably determined in the 4 years examined, since the vernalization was completed by the beginning of December and the varieties reached the maximum of hardiness by that time. Contrary to the literature, it was in December and January rather than in January and February that the varieties in our experiment reached maximum frost resistance, and the survival percentage was lower in February.

Table 2

Frost resistance of winter wheat varieties on different freezing dates (%)

Variety	Time of freezing			
	December	January	February	March
Mr. 808	95.1	93.4	91.6	92.3
Bez. 1	88.3	87.9	79.3	82.1
B. 1201	63.9	59.2	33.6	51.3
Rana 1	44.1	47.1	16.2	26.4

$LSD_{5\%} = 3.802$

In Table 3 the average values are grouped by variety and year. The differences between the years are clearly seen: they are smaller in the case of positively frost-resistant varieties and greater with the less hardy ones. The tendency is the same; the survival percentage increased through 3 years — from 1979–80 to 1981–82 — in all varieties, while in the last year it decreased to some extent in the case of Bez. 1 and B. 1201. The difference between the lowest and highest survival percentages was 6% in the variety Mir. 808, 20% in Bez. 1 and B. 1201, and 22% in Rana 1. The meteorological conditions of the winter of 1981–82 had a favourable influence on the process of hardening and on its long-term persistence.

Table 3

Frost resistance of winter wheat varieties in the years concerned (%)

Varieties	Years			
	1979–80	1980–81	1981–82	1982–83
Mir. 808	90.3	93.6	96.1	92.5
Bez. 1	74.7	86.4	92.0	84.3
B. 1201	43.8	43.9	63.9	56.4
Rana 1	25.9	21.7	43.4	42.7

$LSD_{5\%} = 3.802$

The results averaged by the temperature and date of freezing are summarized in Table 4. The lowest survival percentages were obtained in February at all freezing temperatures, partly because the level of hardiness decreased by that time. By March the surviving plants became hardy again and gave higher survival percentages at all freezing temperatures, compared to the February results of freezing. In December and January the plants

Table 4

Effects of freezing at different times on the survival of plants (%)

Freezing temperature	Time of freezing			
	December	January	February	March
Without freezing	93.7	96.2	62.1	68.8
— 6 °C	94.8	95.2	67.6	68.6
—12 °C	75.8	77.7	63.3	70.6
—15 °C	58.7	54.2	47.0	57.6
—18 °C	41.3	36.1	35.8	49.5

$LSD_{5\%} = 4.251$

grown without freezing and those frozen at —6 °C showed the same rate of survival, while in the material kept at —12 °C, —15 °C and —18 °C, respectively, the survival percentage gradually decreased and showed significant differences. At the same time, in February and March the survival percentages for plants raised without freezing and those frozen at —6 °C and —12 °C, respectively, could be considered identical, and only —15 °C and —18 °C

Table 5

Effect of freezing in different years on the survival of plants (%)

Freezing temperature	Years			
	1979–80	1980–81	1981–82	1982–83
Without freezing	79.4	76.5	76.3	88.7
— 6 °C	80.1	74.2	82.8	89.2
—12 °C	61.3	65.3	87.9	72.8
—15 °C	39.6	47.8	72.1	58.0
—18 °C	33.1	43.3	50.2	36.1

$LSD_{5\%} = 4.251$

treatments gave significantly decreasing values. The survival percentage obtained in February at —6 °C significantly exceeded the number of plants raised outdoors without freezing and carried indoors at that time. This proves that the level of hardiness was low, but the surviving plants when placed under suitable conditions were able to resume hardiness. It was due, on the one hand, to the February weather conditions and on the other hand, some degree of rehardening also took place in the course of the freezing procedure, since the 2nd phase of hardening is rendered possible by the freezing programme.

The average values by freezing temperatures and year are shown in Table 5. The number of plants grown without freezing, while more or less the same in the first 3 years, was essentially higher in 1982–83 compared to the previous years. This can be explained by the higher survival percentages. in February and March of varieties with low resistance to frost. The highest survival percentages in response to freezing at —6 °C were obtained in 1982–83, while the —12, —15 and —18 °C treatments gave the best results in 1981–82. These data also prove that in 1981–82 the weather conditions enable a long persistence of hardiness, while in the winter of 1982–83 this hardiness did not reach the level of the previous years.

Plants frozen in December, January and February gave the highest values in 1981–82 (Table 6), while the values obtained with the March treatment were significantly higher in 1982–83 than in the previous 3 years. The

71.1% March value of that final year was due to the higher rate of resistance and rehardening at the end of winter in varieties with low resistance to frost. The January percentage of survival in 1979–80 was — on one single occasion during the 4-year experiment — significantly higher than the December value. This unambiguously proves that the varieties did not yet reach maximum

Table 6

Effect of freezing at different times of different years on the survival of plants (%)

Time of freezing	Years			
	1979–80	1980–81	1981–82	1982–83
December	59.2	73.5	81.4	77.3
January	67.3	68.2	82.2	69.9
February	47.6	51.2	64.9	57.0
March	60.6	52.7	67.1	71.1

$LSD_{5\%} = 3.802$

hardiness by December. In 1980–81 and 1982–83 the survival percentage was highest in December and decreased significantly in January and February. In 1980–81 rehardening did not take place, and the March value was the same as in February. In 1979–80, 1981–82 and 1982–83 the survival percentages were reliably higher in March than those obtained with plants frozen in February.

Discussion

On the frost resistance study of winter wheat varieties, numerous publications have appeared giving accounts of the results of experiments carried out with different methods and different varieties. Consequently, a numerical comparison of our results to those in the literary data would not be reasonable. Yet, it is possible to discuss some methodological questions.

The survival percentages of plants raised under natural conditions and examined at various times during winter showed reliable differences, in agreement with observations by Tumanov and Borodina (1929), Sunneson and Peltier (1938), Worzella and Cutler (1941), Weibel and Quisenberry (1941), Yurjev (1950), Dexter (1956). In the boxes place on the soil surface there were significant differences in the survival percentages of the varieties in 3 of the 4 years examined. In the mild winter of the fourth year, on the other hand, no destruction occurred. This vindicates the opinion held by Dexter (1956), Alessi and Power (1971), Kostecki (1972), Steponkus (1978), namely that the frost resistance of winter wheat varieties cannot be evaluated under

field conditions in countries where the weather in winter is variable, even in the case of examinations performed under extreme conditions (e.g. culture pots placed on the surface of the soil).

Tumanov (1935), Yurjev (1950), Dexter (1956), Koch (1972), Dorofeev et al. (1973) raised and hardened plants under field conditions, then froze them at various times during winter at different temperatures under controlled conditions. They found that the varieties reached their maximum frost resistance in January and February and later gradually lost it. Of the 4 years of our experiment, in 1979–80 the varieties reached maximum frost resistance in January; and in the 3 subsequent years the maximum was reached already in December. The effect of rehardening at the end of the winter, depending on the year, could be observed in the above authors' experiments in agreement with ours.

The winter weather in the 4 years of the experiment was favourable for wheat growing, so we think it necessary to continue the field experiments hoping that extreme winter conditions will make it possible to acquire further knowledge of the subject.

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EFFECT OF WEEDING ON GROUNDNUTS IN SUDAN GEZIRA

ALI ABULGASIM

ARAB PLANNING INSTITUTE, SAFAT, KUWAIT

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The groundnut (*Arachis hypogaea* L.) experiment was carried out at the Gezira Research Station to investigate the difference between certain weeding practices. In all, 12 treatments were compared.

Failing 10 weed proved to be a bad practice, while one weeding at one month from sowing seemed quite satisfactory. However, two or more weedings might be preferred if considered economical.

Keywords: *Arachis hypogaea*, groundnuts, weeding practices

Introduction

It has been suggested that in the irrigated Gezira (Sudan) weeds accounted for about an 80% reduction in the groundnut (*Arachis hypogaea* L.) pod yields (Ishag 1971). He dealt with the effect of weed control on flowering, yield and yield components. The purpose of this experiment was to obtain more detailed information on the effect of the time and number of weedings on the growth of groundnuts judged by the plants total dry weight.

Material and methods*

An ashford branch spreading bunch variety was planted in 60 cm rows, 15 cm between plant holes. Two seeds treated with 1 gm Dildrex B/1b, were sown per hole. The experiment was sown in mid June 1965 and was irrigated once every 14 days.

A randomized complete block (R-C-B) was used with a replicates. The weeds were controlled by hand according to the following treatments (See the following page).

Periodic plant samples were taken from an area of 0.6 sq.m. The plants were separated into roots, stems, leaves (remainder) and pods. The different parts were weighed fresh and after drying overnight at 105 °C in a ventilated oven.

* For detailed description of the experiment see Ishag (1977)

Weeding (Days from sowing)	Number of weedings
0	0
15	1
30	1
45	1
60	1
15–30	2
15–45	2
15–60	2
30–45	2
30–60	2
15, 30–45	3
15, 30, 45–60	4

Results

For the purpose of this paper, the only factor under study is the total dry weight (g/plant), since for other those factors such as leaves, pods, etc., the same technique could be applied.

Individual samples

As a preliminary stage we will consider the individual samples where we have 9 sampling dates. In Table 1 we have set out the treatment means at each of these sampling dates together with the mean square error (M.S.E.).

Now, in order to see the performance of the weeding treatments in comparison to each other, we have divided these into single degrees of freedom (d.f.) orthogonal comparisons. These comparisons were (Table 2):

a = Control vs. average effect of all others.

b = Difference between weedings at 15 days and at 30 days.

c = Difference between weedings at 45 days and at 60 days.

d = Average effect of weeding at (15, 30) vs. average effect of weeding at (45, 60).

e = Weeding at (15–30) vs. weeding at (15–45).

f = Weeding at (30–45) vs. weeding at (30–60).

g = Average effect of weeding at (15–30, 15–45) vs. weeding at (15–60).

h = Weeding at (15, 30–45) vs. weeding at (15, 30, 45–60).

i = Average effect of weeding at (15, 30, 45, 60) vs. average effect of weeding at (15–30, 14–45, 15–60, 30–45, 30–60).

j = Average effect of weeding at (15, 30, 45, 60, 15–30, 15–45, 15–60, 30–45, 30–60) vs. average effect of weeding at (15, 30–45, 15–30, 45–60).

k = Average effect of weeding at (15–30, 15–45, 15–60) vs. average effect of weeding at (30–45, 30–60).

Note that these comparisons were made either test the difference between the time of weedings, and the number of weedings, or both.

Table 3 shows the calculated *t*-values for the individual samples comparisons. In this study we are doing multiple comparisons for orthogonal contrasts and so we have used as critical values, the Studentized maximum modulus for 11 contrasts as suggested by Bechhoffer and Dunnett (1982). Thus, the critical values h_v (p, o, α) where p = 11, the number of contrasts, v = 55 d.f. for error and α the significance level, are such that h_v (11, 0, 0.5) = 2.95, while h_v (11, 0, 0.1) = 3.51.

It is clear from the table that at first there were no significant differences. This may be due to the fact some weedings were not applied at that time. As the plants continued to grow the differences became clearer.

The comparisons *A* and *B* did not show any significant differences for the whole sampling period, indicating that no difference existed, neither between weeding after 15 days and that after 30 days, nor between those after 45 days and after 60 days. However, after 8 weeks from sowing it was becoming clear that, on average, weeding practices were superior to no weeding.

Also, at 8 weeks, comparisons *E*, *H*, *T* and *J* were significant, the first indicating that weeding at 15 and 30 were better than those at 15 and 45. The second indicated that 4 weedings were better than 3 weedings. Comparison, i. indicated that, on average, 2 weedings were better than 1 weeding while the fourth comparison, *J*, showed that, on average, 3 and 4 weedings were superior to either 1 or 2 weedings.

On later sampling dates, the above significant differences were not apparent on all occasions except for comparison *J* on the sampling date at 70 and 130 days and comparison K on the sampling date at 100 days.

One possible explanation for the variation in the results of the significance tests on later sampling dates is that certain plots were attacked by a leaf spot disease *Cercospora* spp. towards the end of the season. This resulted in the plants shedding some of their leaves and hence the recorded total dry weight was less than expected, had the plant been healthy. A remedy for such a situation would have been to measure the effect of the disease on each plot and adjust the results by carrying out some adjusted analysis such as covariance analysis. Unfortunately, this was not done.

Combined analysis

Having done a separate analysis for each sample and compared the treatments at each stage, it would be informative to examine the performance of these treatments as time progresses.

Table 1

Mean total dry weight on the various sampling dates (g/plant)

Days after sowing / Weeding treatment	No Weeding	15	30	45	60	15 & 30	15 & 45	15 & 60	30 & 45	30 & 60	15, 30 & 45	15, 30, 45 & 60	M. S. E. with 55 d. f.
	A	B	C	D	E	F	G	H	I	J	K	L	
14	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.6	0.6	0.5	0.6	0.5	0.02
21	1.1	1.0	1.1	1.2	1.2	1.0	0.9	0.9	0.9	1.0	1.0	1.1	0.73
28	1.1	1.2	1.1	1.0	1.3	1.1	1.3	1.6	1.3	1.2	1.8	1.2	0.17
35	1.5	2.0	1.4	1.7	1.7	2.1	2.0	2.1	1.4	1.6	2.0	1.7	0.29
42	2.5	5.0	3.0	3.9	2.6	5.7	5.0	4.0	2.7	3.1	4.0	3.3	11.01
56	4.1	8.5	5.9	6.5	4.9	13.1	7.1	11.6	8.5	8.2	13.4	9.7	11.43
70	9.5	22.6	15.0	10.1	16.6	18.9	27.9	18.9	17.4	17.3	24.2	24.7	29.97
100	22.1	56.3	46.6	41.5	26.7	61.4	46.3	50.3	55.6	58.1	60.3	58.5	185.48
130	44.5	86.9	115.5	83.6	55.6	105.9	111.1	100.1	9.14	105.7	116.3	134.6	801.80

Table 2

Orthogonal comparisons (L_i) among the various weeding treatment combinations

Comparison / Weeding treatment	No Weeding	15	30	45	60	15 & 30	15 & 45	15 & 60	30 & 45	30 & 60	15, 30 & 45	15, 30, 45 & 60	
	A	B	C	D	E	F	G	H	I	J	K	L	ΣL_i^2
a = Avs. others	−11	1	1	1	1	1	1	1	1	1	1	1	132
b = Bvs. C	0	−1	1	0	0	0	0	0	0	0	0	0	2
c = D vs. E	0	0	0	−1	1	0	0	0	0	0	0	0	2
d = (B, C vs. D, E)	0	−1	−1	1	1	0	0	0	0	0	0	0	4
e = F vs. G	0	0	0	0	0	−1	1	0	0	0	0	0	2
f = I vs. J	0	0	0	0	0	0	0	0	−1	1	0	0	2
g = av. (F, G) vs. H	0	0	0	0	0	−1	−1	2	0	0	0	0	6
h = K vs. L	0	0	0	0	0	0	0	0	0	0	−1	1	2
l = (B, C, D, E) vs. (F, G, H, I, J)	0	−5	−5	−5	−5	4	4	4	4	4	0	0	180
j = (B, C, D, E, F, G, H, I, J) vs. (K, L)	0	−2	−2	−2	−2	−2	−2	−2	−2	−2	9	9	198
k = (F, G, H) vs. (I, J)	0	0	0	0	0	2	2	2	−3	−3	0	0	30

Table 3

The t-values and tests of significance for various comparisons on different sampling dates

Sampling date \ Comparisons	A	B	C	D	E	F	G	H	I	J	K
14	0.75	1.22	1.22	0.0	0.0	−1.22	1.41	−1.22	−.026	0.12	−0.32
21	0.20	0.20	0.0	0.43	−0.20	0.20	−0.12	0.20	−0.79	0.10	0.05
28	1.03	−0.42	1.27	0.0	0.85	−0.42	1.94	−2.54	1.33	2.03	0.54
35	1.27	−1.94	0.0	0.0	−0.32	0.65	0.19	−0.97	0.95	0.42	2.82
42	0.95	−1.04	−0.68	−0.55	−0.37	0.21	−0.81	−0.37	0.52	−0.22	1.62
56	3.30*	−1.33	−0.82	−1.09	−3.07	0.89	−1.89	3.51**	3.44*	3.02*	1.78
70	4.17**	−2.40	2.05	−2.44	2.84	−0.03	−1.65	0.16	2.64	3.54**	2.24
100	5.10**	−1.24	−1.89	−3.13*	−1.93	0.32	−0.52	−0.23	3.01*	2.39	−0.83
130	4.94**	1.75	−1.71	−2.72	0.32	0.87	−0.59	1.12	2.09	3.28*	0.69

* h_{55} (11, 0, .05) = 2.95
** h_{55} (11, 0, .01) = 3.51

Table 4

Results for Early Season

Treatment	Regression M. S.	Parameter estimates			Max. dry weight at (Weeks)**	R^2
		α	β	L		
No Weeding	1.0194	0.78	−0.246	0.086	1.4	0.93
15	6.120*	3.54	−2.20	0.40	2.75	0.95
30	1.524*	1.94	−0.919	0.179	2.57	0.90
45	3.208*	2.64	−1.499	0.279	2.69	0.91
60	1.041	0.58	−0.064	0.064	0.5	0.95
15 & 30	8.413*	4.58	−2.907	0.507	2.87	0.95
15 & 45	6.181*	3.40	−2.133	0.393	2.71	0.96
15 & 60	3.642	1.34	−0.78	0.200	1.95	0.98
15 & 45	1.208	1.20	−0.501	0.121	2.07	0.93
15 & 60	1.855	1.36	−0.678	0.157	2.16	0.95
15, 30 & 45	3.283*	1.36	−0.706	0.186	1.90	0.95
15, 30, 45 & 60	2.128	1.48	−0.751	0.171	2.20	0.94

* Significant at 5% level
** Max. is at $-\beta/2\gamma$ weeks

In order to do this we ran a curvilinear regression separately for each treatment. Also, we divided the growing season into 2 periods: early, covering the period from sowing to the sixth week, and late, from seventh week to the nineteenth week. This was done since was a marked change in the accumulation of total dry matter after the sixth week. Also it is known that the early growth of the groundnuts determine to a large extent the final yield. The model fitted in both cases was:

$$E(Y) = \alpha + \beta t + \gamma t^2$$

where Y = total dry weight on sampling day at t days from sowing. t = time from sowing. α, β and γ are parameters to be estimated.

Combined analysis results

Table 4 shows the performance of weeding treatment as affected by time. In almost all of these treatments the regression on time was significant. However, for the late season, the sample R values were larger than those for the early season (Table 5). This was so since we had only a few points to fit the curve.

For the early season, the signs of the parameters γ, β, α were positive, negative and positive, respectively, indicating that a maximum total dry weight is always attainable. The time to reach maximum total dry weight, in weeks, is shown in column 6 of the table.

Table 5

Results for late season

Treatment	Regression M. S.	Parameter estimates			Max. dry weight at (weeks)**	R^2
		γ	β	α		
No weeding	483.125*	5.02	— 1.69	0.20	8.5	0.99
15	1853.97*	—55.82	8.21	—0.03	0.0	0.0
30	3695.22*	53.46	—12.66	0.86	14.7	0.90
45	1978.28*	142.93	—26.55	1.25	21.2	0.99
60	603.01*	27.64	— 4.68	0.33	14.2	0.99
15 & 30	2776.21*	—11.89	0.16	0.33	0.0	0.00
15 & 45	3010.51*	—42.6	7.03	—0.05	0.0	0.99
15 & 60	2430.22*	21.73	— 5.44	0.52	10.5	0.99
30 & 45	2165.11*	—36.75	4.33	0.14	0.0	0.99
30 & 60	2964.67*	—17.27	0.31	0.34	0.0	0.99
15, 30 & 45	3291.30*	15.93	— 4.62	0.54	8.6	0.99
15, 30, 45 & 60	4635.80*	47.51	—11.26	0.86	13.1	0.99

* Significant at 5% level
** Max. is at $-\beta/2\gamma$ weeks

It is to be noted that the maximum total dry weight was attained at very early stages for poor weeding treatments, such as treatment A (no weeding) and E (weeding after 60 days). It would appear that the plants had a good emergence at first and then, due to intensive weeds, their growth was suppressed and hence they reached their maxima very early, at which time their pods would not have developed fully.

The results for the late season as shown in Table 5 reveal that both parameter estimates β and γ had negative signs sometimes.

A feasible explanation for these unexpected patterns might be due to the leaf spot disease, *Cercospora* ssp. Thus, the leaf shedding decreased the total dry weight at later stages and hence, it would appear that the plants had attained their maximum total dry weight and then decreased.

Conclusions

The data analysis indicated that the time of weeding and the number of weedings play an important role in the growth of groundnuts, as reflected in the total dry weight,

It appeared that 1 or 2 weedings most necessary. The most promising treatments were weeding after 15 or 30 days if 1 weeding is applied; 15, 30 or 30, 45 in case of 2 weedings. However, in order to choose the proper number of weedings, it might be necessary to evaluate the difference in response economically. No weeding proved to be a very poor practice and must be excluded. Weedings after 45 or 60 days gave very poor results since the weeds would have grown extensively, giving no chance for the plants to survive. In fact, weeding after 60 days was very much comparable to no weeding.

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GERMINABILITY AND VIGOUR OF WHEAT SEED COMPARTMENT AT DIFFERENT PERIODS OF STORAGE

MOHAMED ODIEMAH

DEPARTMENT OF CROP SCIENCE, FACULTY OF AGRICULTURE TANTA UNIVERSITY, KAFER TEL-SHIEKH, EGYPT

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The viability, germinability, vigour and seedling growth of new harvested and ageing winter wheat seeds were tested for cultivars MV_5 and Mv_8. Viability was determined on the basis of tetrazolium method (TZ), and seedling growth was expressed as shoot length and dry weight. In general these characters are interconnected, and the notion of seed viability germination and vigour, namely implies its storability. Seed vigour significantly decreased during storage, and these reductions precede declines in both viability and germinability. Percentage germination of new harvested seeds was significantly lower than stored seeds for one year, mainly due to high moisture content of fresh seed dormancy. The worst percentage of germination and vigour were for the seeds at the longest period of storage (5 years). A descending trend in shoot length and dry weight was found by increasing storage period. However, seeds stored more than two years under ordinary room atmosphere were definitely of poorer quality. Therefore, a controlled atmosphere is essential for safe long-term storage of wheat seeds, even for a few years. Also the results showed that the cultivars were significantly different in seed characteristics of storability, generally due to genetic makeup. Hence, the seed quality of Mv_8 cultivar was better than of Mv_5, either seed stored or not.

Keywords: seed vigour, storage period, wheat cultivars

Introduction

Seldom are seeds harvested and immediately planted without undergoing at least a brief storage period. Longer storage periods, 1 to 5 years, are necessary for seeds which may be expensive of difficult to produce, or for those cultivars which are not produced every year due to lower demand by growers. Vigour is manifested in the capacity of rapid seedling development, high tolerance to stress factors in the environment, good growth and development of the plants (Maguire 1977, and Perry 1980); hence it is a physiological character determined by the genetype and modified by the environment. The factors that influence viability of seed as given most frequently in literature are seed moisture content, storage temperature and storage period. Corruthers (1911) studied the germination of so-called white and red wheat grains of the 1896 crop each for 9 years. Extension of the storage period to 8 years caused a further reduction in viability, so that only 29 and 51% of white and red

wheat grains, respectively, were still alive at the end of this time. Whymper and Bradley (1934) pointed out that the desiccation of wheat grains to 4.1% moisture, followed by sealing and storage in the laboratory in the dark, preserved viability for up to about 19 years. Bacchi (1958) adjusted moisture content of freshly harvested wheat grains to different levels and stored it in sealed containers at room temperature (12–30 °C). Grains of 7.8, 9.2 and 11.1% moisture content had a germinating capacity of 96, 95 and 92%, respectively, after 30 months of storage. Grains of 13.1% moisture content remained completely viable for 12 months, but thereafter their germinating capacity decreased markedly.

The fundamental reason for storage of seed is, of course, to preserve or maintain its physiological quality by minimizing the rate of seed deterioration (Delouche et al. 1973). Although it is known that oxygen is usually deleterious to viability, the quantitative relationships of oxygen pressure and period of viability have not yet been defined; but the relationship between temperature, moisture content and period of viability had been examined in detail for wheat (Roberts 1973). Storage in a controlled atmosphere, such as CO_2, O_2, N_2, etc. or in a partial vacuum may prolong seed life better than storage in air. However, when seed moisture content and temperature are high, an O_2 atmosphere tends to accelerate the loss of viability.

The beneficial effects of controlled atmospheres on seed longevity are usually not evident during the first few years of storage (Bass 1973). In general the physiological, biochemical and genetic changes which might take place during storage has been reviwed by Roos (1980). The changes to be discussed may be altered or even negated by alteration of the storage conditions. Nevertheless, the paper reports here the relationship between the period of storage under ordinary room conditions and seed characteristics of storability in winter wheat.

Material and methods

Winter wheat seeds of the cultivars Mv_5 and Mv_8 were harvested at full ripeness in the years 1979, 1980, 1981, 1982, 1983 and tested in 1984, at the laboratory of the Institute for Plant Production and Qualification, Budapest. The seeds were stored up to the year 1984 in paper sacks at ordinary room atmosphere (temperature 18–20 °C and relative air humidity 40–70%). These seeds were further dried and the moisture content of stored and not-stored of their mass were 8 and 13%, respectively. All samples of seeds were cleaned and sorted of thickness using a 2.5 mm sieve. Then, the tests were carried out as follows:

Viability was determined by the tetrazoletopographic methods. The tetrazolium test (TZ) was designed as a complete block with two replications of 100 seeds each concerning the samples of different storage periods. Standard laboratory techniques were followed according to Grabe (1970) and ISTA (1976).

For germination, 4×50 seeds were germinated at 20 °C for 7 days using moist rolled towels. The percentage germination was determined and the counts of abnormal and dead seeds were recorded according to ISTA Rules (1976). Shoot length was measured from the kernel level to the apex of shoot for 10 normal seedlings, taken randomly. Dry weight determined after the seedling materials for each replicate were oven-dried at 8.0 °C for 24 h (in

grams). To determine vigour, 4×50 seeds were germinated at 10 °C for 12 days using the rolled towel method, and those seedlings that had at least 4 cm length of coleoptile (shoot) were categorized as vigorous.

All data were subjected to statistical analysis of variance. L.S.D. at the 0.05 level of probability was calculated to compare means.

Results

Analysis of variance (Table 1) indicated that both cultivar and storage period (year) had a highly significant effect on viability, germinability, vigour and seedling rowth (shoot length and dry weight). With one exception of the cultivar, the effect on dry weight was significant at ($P = 0.1$). The magnitude of variance per year was much larger than cultivar. This means that the

Table 1

Mean squares of wheat cultivar and storage period for seed characteristics

S.O.V.	d.f.	Viability	Germination	Vigour	Shoot length	Dry weight
Cultivar (C)	1	37.5***	374.1***	383.8***	10.8***	0.02+
Year (Y)	5	550.9***	5499.9***	5504.6***	58.7***	0.37***
(C×Y)	5	8.4**	80.5***	86.5***	0.2**	0.01 ns
Error	33	1.6	4.7	5.6	0.05	0.01
C.V. %		1.4	3.4	4.9	2.9	9.7

+, *, **, *** = Significant at the 0.1, 0.05, 0.01 and 0.001 levels of probability, respectively
ns = not significant

variance component is mainly due to storage period and partially due to genetic constitution. The (cultivar year) interaction had highly significant influence on the considered characters, except in the case of dry weight. This denotes variation between the two cultivars, possibly due to the process of aging which occurred faster in seed of one cultivar than another.

The results (in Table 2) show that significant differences in germination were found between means of different storage years and between means of both cultivars, where Mv_8 was higher percent than Mv_5. The highest germination percentage was obtained after 1 year of storage, but the lowest percent was at the last period (after 5 years), 95.3% and 53%, respectively. The percentage germination of new harvested seeds was significantly lower than stored seed for 1 year. This may be due to the high moisture content of fresh seed dormancy which resulted in reduced germination. Also seed viability significantly declined during storage time, and this reduction was followed by great significant decline in germinability and vigour. Moreover, the descent of vigour came to zero after 5 years of storage. As well, the data indicates that

Table 2

Means of seed characteristics of two winter wheat cultivars at different storage periods

Storage period and cultivar	Viability	Germination	Vigour	Shoot length, cm	Dry weight, g
	%				
(Not stored)	99.5	93.0	91.0	15.8	1.200
For 1 year	98.0	95.3	88.5	15.7	1.000
For 2 years	97.5	91.5	52.0	14.1	0.800
For 3 years	96.8	80.5	40.8	12.0	0.600
For 4 years	94.0	79.8	08.3	11.9	0.500
For 5 years	68.8	53.0	00.0	08.5	0.500
$LSD_{0.05\%}$	2.0	2.2	3.2	0.2	0.100
cv. Mv_5	91.2	81.1	42.3	12.4	0.700
cv. Mv_8	93.7	83.3	51.3	13.6	0.800
$LSD_{0.05\%}$	1.1	1.3	1.8	0.1	0.100

a descending trend in shoot length and dry weight related to an increasing time of storage. However, it can be concluded that there was a general trend towards decrease in wheat seed characteristics by increasing storage time under the conditions of this study. It may therefore be proposed that this phenomenon is due to seeds which deteriorated rapidly when exposed to open air during storage, more than 1 year, in spite of the variation between cultivars.

Consequently, Fig. 1 demonstrates the relation between the period of storage and seed characteristics as average above two cultivars used. It is obvious that aging of wheat seed was most pronounced after 1, 2 and 4 years of storage for vigour, germinability and viability, respectively. Therefore, it can be suggested that the notion of seed viability, germinability and vigour namely implies its storability. These characters are interconnected, but practically, the vigour is considered a good indicator for wheat seed quality under storage conditions. In general, these findings agree with the previous results of Carruthers (1911), Whymper and Bradley (1934), Bacchi (1958) and El-Keholy (1973).

Discussion

Under the conditions of this study and the obtained results, it could be discussed in general that a grain of wheat is also a living organism whose very existence is geared to ultimate production, and because of this, it will undergo various modification during storage while continuing to respire. The rate of degradation will vary, depending above all on storage temperature and humid-

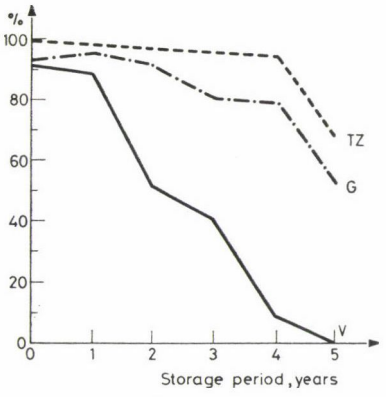

Fig. 1. Wheat seed comportment via viability (TZ), germination (G) and vigour (V) during storage period

ity but also on the length of time the grains are exposed to these factors. The behaviour of a grain of wheat is thus determined by conditions in the immediate surroundings. When these are unfavourable (i.e. low temperature, or inadequate humidity for short storage period), the grain's vital processes of both respiration and germination are slowed down and as a result no harmful effect will be evident. On the contrary, under favourable conditons these vital processes are accelerated and nourished by the internal food reserves.

Respiration is a continuous process which occurs throughout the storage period and is essential to keep the grain alive. The intensity and nature of respiration is, however, dependent on the amount of oxygen in the storage room as well as on the temperature and moisture content of the grain. In the presence of oxygen the following respiration reaction takes place:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ H_2O + 6\ CO_2 + 2850\ kJ/mol$$

This occurs when the air between the grains is renewed. The amount of heat produced may be very great and cause over-heating which leads to a coagulation of proteins and loss of dry matter. In the absence of oxygen the reaction is fermentative in nature, resulting in the production of alcohol lactic or acetic acid. Although respiratory phenomena are perfectly normal in stored grain, the aim in efficient conservation is to limit them as much as possible. Germination, even in its initial stages, has very serious consequences as it brings about a number of fundamental modifications in the grain. These include increased enzyme activity, starch degradation, loss of dry matter, and deterioration in quality. In addition this also may cause degeneration of some mechanism in the cells which could be interpreted in terms of DNA and RNA upon which enzymatic reactions depend. These explanations are similar to

that reported by Bass (1973). Delouche and Baskin (1973), Roberts (1973), Poichette (1980), Grzesiuk and Tuczkiewicz (1982).

Furthermore, during the storage period, loss of cereal seed viability is associated with the accumulation of considerable genetic mutations. For example, Roberts (1978) found that loss of 50% viability in barley seeds under any storage conditions is equivalent to treating fresh seeds with 10 000 *Y*- of *X*-rays. But if viability is maintained at a high level, — either by conventional storage method, or by using imbibed storage then the accumulation of mutations is insignificant. As it is already known that vigour depends on viability and germinability of seed, it is also manifested in high tolerance to stress conditions, good seedling growth and development of the plants. Therefore, vigour is considered a good indicator of wheat seed quality under storage conditions. Finally, it can be concluded that adequately dried seeds in moisture barrier containers can be stored safely for 1–2 years at ordinary room temperature and much longer at low temperatures. Thus, a controlled atmosphere is essential for safe long-term storage of wheat seeds, even for a few years.

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PRINCIPAL COMPONENT ANALYSIS BASED ON WRICKE'S ECOVALENCE VALUES FOR GROUPING ENVIRONMENTS AND VARIETIES

Z. BEDŐ, J. MATÚZ,* L. BALLA and Z. BARABÁS*

HUNGARIAN ACADEMY OF SCIENCES, AGRICULTURAL RESEARCH INSTITUTE, MARTONVÁSÁR, HUNGARY
* CEREALS RESEARCH INSTITUTE, SZEGED, HUNGARY

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The matrix formed from *Wricke*'s ecovalence values was evaluated by principal component analysis. This method is suitable for comparing varieties and environments as well as for classifying varieties by adaptability.

The classification of varieties by this method shows a relationship with the results of the *Eberhart–Russel* model, since varieties with a positive first principal component have a special adaptability while those with a negative value, a stable adaptability. With more components taken into consideration, our results can be used for a more detailed classification.

In our experiment, among the varieties of special adaptability GK Kincső and GK Boglár were found to belong to the same group. On the basis of the third principal component they can be placed in two further subgroups. Again from the other group, two subgroups can be formed in which Martonvásári 8 and Martonvásári 9, on the one hand, and Martonvásári 10, on the other, can be placed. The varieties of stable adaptability can be divided as follows: Martonvásári 4 and GK Szemes show the same reaction, while GK Ságvári differs from them in adaptability.

Keywords: adaptability, genotype × environment interaction, principal component analysis, variety classification, wheat, yield performance

Introduction

Some authors determined the interaction of genotype × environment by unifactorial statistical methods (Wricke 1962, Finlay and Wilkinson 1963, Eberhart and Russel 1966, Perkins and Jinks 1968). In this way the varieties can be placed in different groups by adaptability (Bell 1972, Schmidt et al. 1973, Borojevic 1975, Ozeki and Sasaki 1975, etc.). However, in the unifactorial statistical methods there is no such parameter by itself as grouping the varieties; instead adaptability generally is determined on the basis of 2–3 parameters. Of the multifactorial methods the principal component analysis (PCA) was first used by Okuno et al. (1971) and Perkins (1972) for studying the adaptation of varieties.

For grouping eight Hungarian varieties by their adaptability, we used the principal component analysis based on Wricke's (1962) ecovalence values, and compared the results with the method of Eberhart and Russel (1966).

Material and methods

In the experiment series seven varieties and one variety candidate were tested. GK Boglár, GK Ságvári and GK Kincső are varieties of the Cereals Research Institute: Martonvásári 4, Martonvásári 8, Martonvásári 9 and Martonvásári 10 are those of the Agricultural Research Institute of the Hungarian Academy of Sciences; GK Szemes is a variety candidate of the Cereals Research Institute. The experiments were set up at four locations: Martonvásár, Lászlópuszta, Szeged and Kiszombor in four replications, arranged in Latin block design, sown on two dates: 11 October 1982, and four weeks later on 8 November. The agrotechnics of the experiments were adjusted to the practice regularly followed at the respective sites. To determine the adaptability we used two methods: the *Eberhart–Russel* model, and the principal component analysis evaluating the matrix formed from the ecovalence values. In the latter cases we determined *Wricke*'s ecovalence vallue for each variety and site without squaring. From this we formed a basic matrix and evaluated it by principal component analysis (Bedő et al. 1982). By this method we also carried out the grouping of locations. The factor weights come from an irrotational matrix.

Results

Of the four experimental locations two are the places for breeding the Szeged, the others for breeding the Martonvásár wheat varieties, so the ecological conditions determining the adaptability of the varieties, and those differing from them, equally affected the results of our experiments. The differences in the locations are clearly shown by the result of the principal component analysis (Fig. 1). On the basis of the first two principal components, the two Szeged experiments are close to one another. The Martonvásár experiments (Bulgárföld, Lászlópuszta) essentially differ from them and form a separate group. The Kiszombor experiments differed from both groups; here, even the difference between the two sowing dates was greater than in the other places. The two sowing times were separated on the basis of the third principal component. The October date of sowing in each case had a positive value, while that in November showed a negative value. With the first three

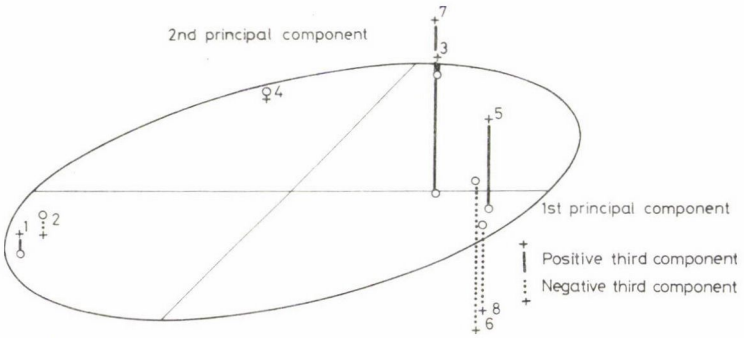

Fig. 1. Grouping of locations on the basis of the first three principal components. (1) Szeged October; (2) Szeged November; (3) Kiszombor October; (4) Kiszombor November; (5) Bulgárföld October; (6) Bulgárföld November; (7) Lászlópuszta October; (8) Lászlópuszta November

Table 1

Principal component analysis made from the ecovalence matrix of locations

Location	Main components			
	1	2	3	4
Szeged (October)	−0.8057	−0.4891	0.0762	0.2340
Szeged (November)	−0.8708	−0.1832	−0.0708	−0.3474
Kiszombor (October)	0.1210	0.9098	0.0599	−0.3496
Kiszombor (November)	−0.4868	0.7784	−0.0293	0.3402
Bulgárföld (October)	0.8400	−0.1261	0.3410	−0.3743
Bulgárföld (November)	0.6882	0.0763	−0.5776	0.3836
Lászlópuszta (October)	0.5716	−0.0093	0.6702	0.4424
Lászlópuszta (November)	0.8795	−0.2571	−0.3340	−0.1234
L_i	49.2%	22.4%	12.8%	11.4%

Note: L_i = cumulative lambda value

principal components the cumulative lambda value (L_i) is 84.4% by which a considerable part of the total variance can be expressed (Table 1).

The yield of the varieties tested in the different treatments can be seen in Fig. 2. The grain yield was influenced in the greatest measure by the sowing time, followed by the effect of the location, and then of the variety. The highest yield was harvested at Bulgárföld from the October sowing, the lowest yield at Kiszombor from that of November.

To compare the varieties for adaptability, we evaluated the yield data by the *Eberhart–Russel* model and the principal component analysis. The principal component values of the varieties are contained in Table 2. Accord-

Table 2

Principal component analysis made from the ecovalence matrix of varieties

Variety	Principal components			
	1	2	3	4
Martonvásári 4	−0.8617	0.3104	0.1547	0.2220
GK Boglár	0.4973	0.6344	0.1871	0.5455
Martonvásári 8	0.6462	−0.2373	0.6787	−0.1822
GK Ságvári	−0.7704	−0.5523	−0.0482	0.1752
Martonvásári 9	0.8837	−0.2700	0.2640	−0.0685
GK Kincső	0.5462	0.5662	−0.4456	−0.4028
Martonvásári 10	0.5849	−0.5149	−0.5413	0.2225
GK Szemes	−0.8810	0.1018	0.1234	−0.3668
L_i	52.5%	19.1%	13.7%	9.5%

Note: L_i = cumulative lambda value

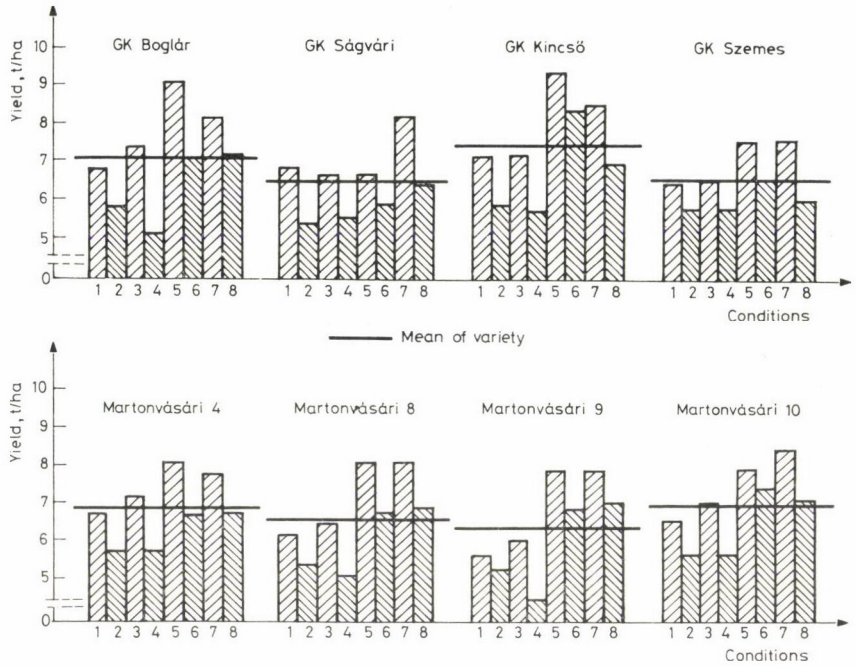

Fig. 2. Yield potential of wheat varieties under different conditions. Conditions (location and date of planting) (1) Szeged October; (2) Szeged November; (3) Kiszombor October; (4) Kiszombor November; (5) Bulgárföld October; (6) Bulgárföld November; (7) Lászlópuszta October; (8) Lászlópuszta November

ingly, 71.6% of the total variance [cumulative lambda (L_i) value] was determined by the first two, and 85.3% by the first three principal components made 94.8% of the total variance.

On the basis of the results of the Eberhart–Russel model (Table 3) in the experiment series set up at four sites with two sowing times, GK Kincső

Table 3

Adaptability of the varieties studied on the basis of the Eberhart and Russel (1966) model

Variety	$\bar{x}$	b	s_b
	t/ha		
Martonvásári 4	6.86	0.84	0.036
GK Boglár	7.09	1.22	0.089
Martonvásári 8	6.63	1.07	0.031
GK Ságvári	6.50	0.72	0.347
Martonvásári 9	6.44	1.16	0.156
GK Kincső	7.42	1.23	0.211
Martonvásári 10	6.97	1.10	0.063
GK Szemes	6.55	0.67	0.084

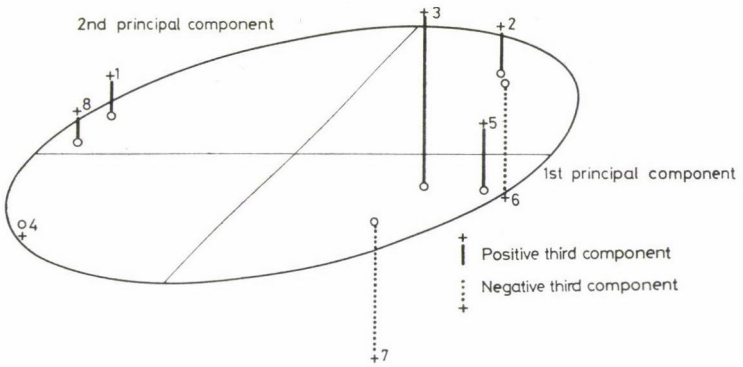

Fig. 3. Grouping of varieties on the basis of the first three principal components. (1) Martonvásári 4; (2) GK Boglár; (3) Martonvásári 8; (4) GK Ságvári; (5) Martonvásári 9; (6) GK Kincső; (7) Martonvásári 10; (8) GK Szemes

and GK Boglár excelled in productivity. They are at the same time varieties with narrow special adaptability, cultivable under ideal conditions. Their first two components (Fig. 1) in the ++ range are close to one another (Fig. 3). The third principal component shows more variance, and on this basis they can be placed in two subgroups.

According to the first two principal components, the Martonvásári 8, Martonvásári 9 and Martonvásári 10 are found in the +— quarter. The three varieties can be differentiated on the basis of the third principal component. Here the Martonvásári 10 has a negative value, but the Martonvásári 8 and 9 have positive values for the principal component. Their regression coefficient is between 1.07 and 1.15. In better environmental circumstances they gave higher yield, while in the case of unfavourable conditions they were only capable of a lower than average production. Their yield stability is better than that of GK Kincső and GK Boglár, but all five varieties display higher plasticity than stability.

On the other hand, the first principal component is negative in those varieties which show a high yield stability and low plasticity. Of them Martonvásári 4 and GK Szemes belong to the same group, as their first three principal components are close to each other. Their regression coefficients are lower than 1, with low standard deviation, so their yield stability can be calculated with high probability.

The first principal component of GK Ságvári is also negative, so this variety can be placed among those with stable yield potentials, but the standard deviation of its regression coefficient is substantially higher than that for either Martonvásári 4 or GK Szemes. On the basis of the first two principal components, this is the only variety found in the —— quarter.

According to our results the principal component analysis made from the ecovalence matrix can be effectively used for grouping varieties by their

adaptability. The classification shows a close relationship with the results of the *Eberhart–Russell* model. The positive first principal component indicates the special, and the negative value the stable adaptability.

With more components taken into consideration, a more detailed classification becomes possible. The varieties or genotypes can be classified for various purposes; for example, to determine the type of adaptation for the genotypes after Shorter et al. (1977) when the crossing partners are to be chosen; to choose varieties for the various growing sites; to select the genotype of given adaptability using a standard variety; or to find out the effect of the pedigree and origin of the genotype on the basis of phenotype under various ecological conditions.

The method described is suitable as well for the classification of environments. In this case the principal component analysis may assist in increasing the efficiency of selection, defining the growing districts, determining the varietal composition for each growing district, comparing the different agrotechnical methods, etc.

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YIELD RESPONSE TO IRRIGATION OF MAIZE HYBRIDS ON LIME COATED CHERNOZEM SOIL

J. NAGY

UNIVERSITY OF AGRICULTURAL SCIENCES, DEBRECEN, HUNGARY

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The maize hybrids examined respond differently to fertilizers and irrigation water. Plots without fertilization clearly show the differences in the nutrient exploitation capacity of the hybrids. The results of more than ten years of experimentation prove that irrigation increases the yield of maize in case, but particularly in the situation of drought. At the same time, the response of the maize hybrids to irrigation varies. From the results of the experiment the following conclusions can be drawn:

(1) The yield responses of the maize hybrids to the increasing rates of fertilization can be characterized with quadratic functions.

(2) The hybrids show differences in their natural nutrient exploitation capacities

(3) Irrigation has a yield-increasing effect; besides the effects of the season and the nutrient supply, the extent of yield increase depends considerably upon the hybrid grown.

(4) There is a close interaction between irrigation and nutrient status. Irrigation may increase the utilization of fertilizers by 10–25 %.

(5) The response to irrigation of the maize hybrids examined shows a great variation. As a result of irrigation the yield surplus of a hybrid making good use of irrigation water can be much larger than that of a hybrid with poor irrigation water utilisation.

Keywords: hybrids, irrigation, maize, yield

Introduction

Beside the cultivation factors that determine the yield of maize — soil cultivation, nutrient supply, variety — the importance of ensuring an adequate water supply is increasing. The natural water status does not always satisfy the water demand of plants. In Hungary maize is sown in 3–10% on the average of the irrigated area. It is indispensable to supply irrigation water to maize over a wide area of the large Hungarian farms if reliable and high maize yields are to be obtained.

The results of more than ten years of experiments carried out by the Crop Production Department of the Debrecen University of Agricultural Sciences prove that the yield of maize is increased in general, and particularly in the case of drought, by irrigation.

In Europe — with the annual 400–600 mm precipitation of the temperate zone — the so-called "classical irrigation" system adjusted primarily to the

phenological phases of plants in the vegetation period has developed. Bocz (1978) elaborated an irrigation system new to the world for table-lands with relatively deep ground water. On these areas the upper 200 cm soil layer is greatly dependent on the atmospheric conditions; in years poor in rainfall, the 50–160 cm medium layer of soil becomes extremely dry. Irrigation ensures the continuous water supply and undisturbed physiological functioning of the plants. In the case of water deficiency, disorders occur in the physiological processes (Derco 1979, Realla 1978, Filippov and Visnevszkij 1978). Szász (1963) experimentally pointed out the extent of water supply to be one of the most decisive yield-regulating factors in Hungary. According to Gulov (1977), on areas poor in rainfall, irrigation is the determinant of yield. Harmati (1984) is of the opinion that irrigation can be expected to be sufficiently effective only on soils well supplied with nutrients; it helps to expose the natural nutrient content of the soil and to promote the utilization of the fertilizers distributed. According to the experiment of Szász (1968) the better the water supply, the richer the mineral nutrient supply must be. Wide investigations made by Ruzsányi (1975) verified that a favourable nutrient supply improved the water utilization of plants. The effect of irrigation is in direct proportion to nitrogen fertilization. While without nitrogen the yield was 53%, in the case of 90 kg/ha N supplied a 110% yield surplus was obtained (Debreczeni 1976). Irrigation and fertilization may influence not only the quantity of yield but also the chemical composition of the crop, and the many-sided examination of the effect of irrigation is therefore an important task (Győri 1978). According to Szőke Molnár (1977), in certain parts of Hungary, irrigation will be more and more indispensable for the reliability of intensive maize production. Posgay (1983) holds that proper indication of irrigation can be given only with the knowledge of the rainfall and soil conditions of the specific location. In case the precipitation and the available water content of the soil do not satisfy the demand of the crop, the deficiency must be made up for by irrigation (Petrasovits 1969). On the basis of agrometeorological data Antal et al. (1972) established that the Great Hungarian Plain received sufficient rainfall only in 25% per cent of the years studied. On the shallow chernozem soil, the droughts caused greater yield losses then on the deep topsoil of the Tisza alluvium. Even the yield stability of the excellent hybrids manifests itself only above a certain threshold of water supply (Széll 1984).

Material and methods

At the Central Arable Experiment Station of the Debrecen University of Agricultural Sciences, two important elements of the variety-specific technology of the cultivated maize hybrids have been studied with the KITE (Nádudvar) production system since 1979: their responses to fertilization and irrigation, as well as the interaction between the two factors.

In 1983 the following hybrids were included in the experiment: Pioneer 3901, Pioneer hybrid 3906 — 75 188 plant/ha without irrigation and 84 034 plant/ha in an irrigated stand; PAU 340, Pioneer hybrid 3747, PAU 398, JX 97 — 59 524 without irrigation, 75 188 plant/hr under irrigated conditions. The irrigation was carried out on 6 June 1983 with 80 mm water. The production potential of the maize hybrids was studied in a NPK fertilization experiment using a constant rate of 1 N : 0.75 P_2O_5 : 0.88 K_2O. In the five fertilization treatments a basic dose of 158 kg and the double, triple, quadruple and quintuple of that were applied, respectively; and a plot was left without fertilization as a control. The arrangement of the small plot experiment was: split-split-plot. The net area of the plots was 21 m^2. The evaluation of the experiments was carried out in the computer centre of the university with variance analysis and regression analysis.

The soil of the experiment is chernozem formed on loess, with a deep humus layer, which provides every possibility for a maximum yield to be attained. The water capacity of the soil is good, its porosity sufficient for the maize plant. The humus content is 3.2%; the soluble P_2O_5 content in the untreated plots 40–50, the K_2O content 100–200 mg/1000 g soil. The groundwatertable is at a depth of 6–8 m, so it has no immediate role in the water supply of the plant stand. From the removal of the forecrop to the sowing of maize, and from sowing to harvesting the maize, the amount of natural rainfall was 163 and 312 mm, respectively. Compared to the temperature conditions of the experimental area established on the basis of a fifty-year average, the effective heat sum of the vegetation period in 1983 showed a difference of +198.2 °C.

Results

The maize hybrids examined responded variously to fertilization and irrigation. Figure 1 shows the results of plots left without fertilization in 1983. The data clearly show the differences between the hybrids in their natural nutrient-exploiting capacities. The widest difference is nearly 3 t/ha. The yield responses of maize hybrids to increasing rates of fertilization can be characterized by quadratic functions (Figs 2–7). Of the hybrids included in the experiment series the following ones showed significant yield increase in response to irrigation: Pioneer hybrid 3901, Pioneer hybrid 3747, Pioneer

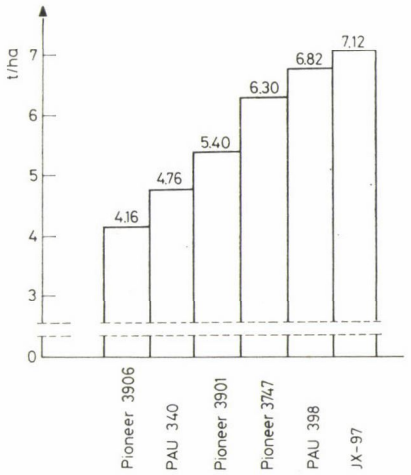

Fig. 1. Yield of maize hybrids without fertilization (Hajdúszoboszló, 1983)

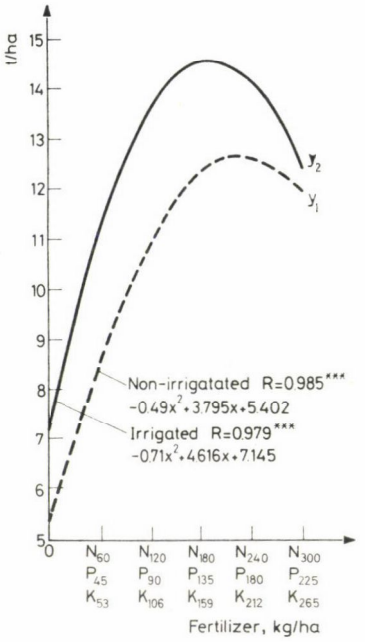

Fig. 2. Yield of maize, Pioneer 3901 (Hajdúszoboszló, 1983)

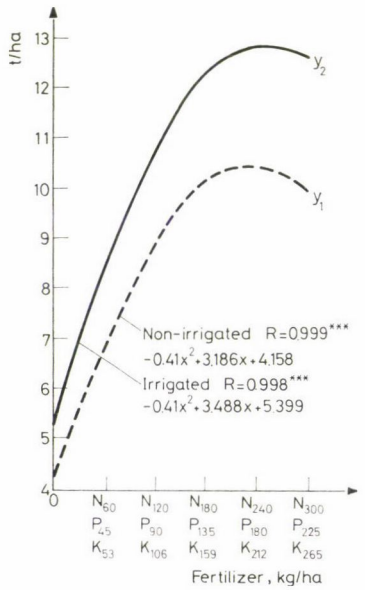

Fig. 3. Yield of maize, Pioneer 3906 (Hajdúszoboszló, 1983)

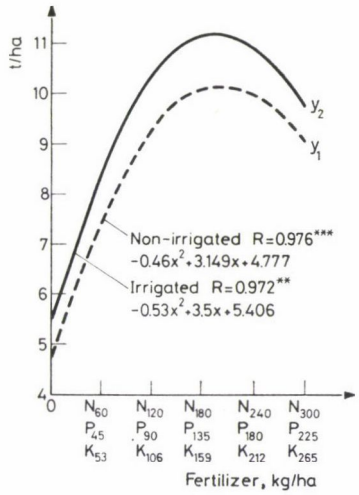

Fig. 4. Yield of maize, PAU 340 (Hajdúszoboszló, 1983)

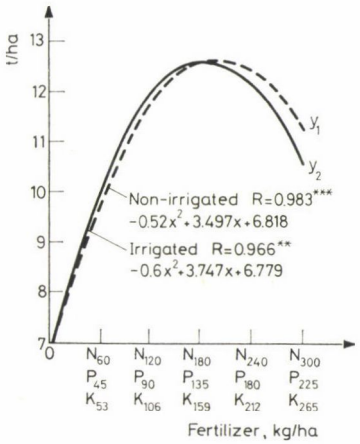

Fig. 5. Yield of maize, PAU 398 (Hajdúszoboszló, 1983)

hybrid 3906, JX-97. The yield surplus caused by irrigation was largest with the hybrids Pioneer 3901 (2880 kg/ha, Table 1) and Pioneer 3747 (2368 kg/ha, Table 3). The yield surplus obtained by irrigation was equally considerable in treatments giving small and large yields, respectively (Fig. 2). Under the influence of irrigation, Pioneer 3747 produced a reliable 2303–2541 kg yield surplus. With the rising level of nutrient supply, the yield of Pioneer 3906 substantially grew, and the rate of yield increase caused by irrigation also became higher. The hybrids JX 97 and PAU 340 responded moderately to

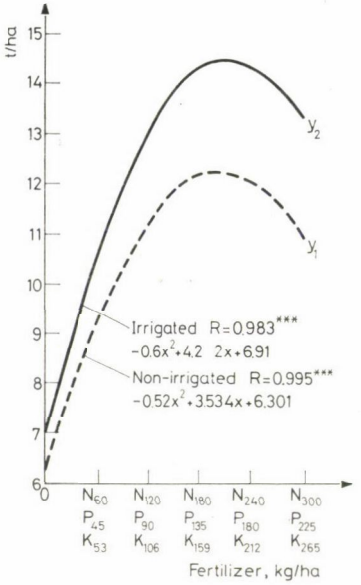

Fig. 6. Yield of maize, Pioneer 3747 (Hajdúszoboszló, 1983)

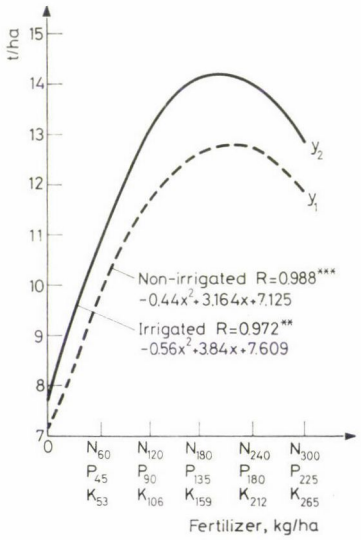

Fig. 7. Yield of maize, JX-97 (Hajdúszoboszló, 1983)

irrigation (Tables 2–3). The yield responses of PAU 398 to irrigation showed no reliable change. The results of the experimental series conducted under the site conditions of Hajdúszoboszló (East of the river Tisza) can be used — naturally — on areas with similar site conditions.

Table 1

Effect of irrigation and fertilization on the yield of maize hybrids (t/ha), in 1983

NPK	Pioneer hybrid 3901			
	Yield, t/ha		Yield surplus	
	non-irrigated	irrigated	t/ha	%
Ø	5.045	6.653	1.608	31.9
1	9.402	11.925	2.523	26.8
2	11.016	13.432	2.416	21.9
3	11.657	14.537	2.880	24.7
4	12.964	13.587	0.623	4.8
5	12.014	12.850	0.836	6.9
Average	10.350	12.164	1.814	12.9

Fertilization $LSD_{5\%} = 0.5945^{***}$
Irrigation $LSD_{5\%} = 0.3432^{***}$

NPK	Pioneer hybrid 3906			
	Yield, t/ha		Yield surplus	
	non-irrigated	irrigated	t/ha	%
Ø	4.089	5.343	1.254	30.9
1	7.016	8.453	1.437	20.5
2	8.984	11.027	2.043	22.7
3	10.062	12.021	1.959	19.5
4	10.254	12.646	2.392	23.3
5	10.062	12.730	2.668	26.5
Average	8.411	10.370	1.959	23.9

Fertilization $LSD_{5\%} = 0.4176^{***}$
Irrigation $LSD_{5\%} = 0.2411^{***}$
*** P = 0.1%

Table 2

Effect of irrigation and fertilization on the yield of maize hybrids (t/ha) in 1983

NPK	PAU 340			
	Yield, t/ha		Yield surplus	
	non-irrigated	irrigated	t/ha	%
Ø	4.382	4.956	0.574	13.1
1	8.204	9.141	0.937	11.4
2	9.096	10.481	1.385	15.2
3	10.053	10.466	0.413	4.1
4	9.594	10.904	1.310	13.7
5	9.385	9.876	0.391	5.2
Average	8.452	9.304	0.852	10.5

Fertilization $LSD_{5\%} = 0.3313^{***}$
Irrigation $LSD_{5\%} = 0.1913^{***}$

NPK	PAU 398			
	Yield, t/ha		Yield surplus	
	non-irrigated	irrigated	t/ha	%
Ø	6.526	6.385	−0.141	−2.2
1	10.140	10.416	0.276	2.7
2	12.053	12.251	0.198	1.6
3	12.449	12.559	0.110	0.8
4	11.868	11.233	−0.635	−5.6
5	11.628	11.030	−0.598	−5.4
Average	10.777	10.646	−0.132	−1.4

Fertilization $LSD_{5\%} = 0.3564^{***}$
*** P = 0.1%

Table 3

Effect of irrigation and fertilization on the yield of maize hybrids (t/ha) in 1983

NPK	Pioneer hybrid 3747			
	Yield, t/ha		Yield surplus	
	non-irrigated	irrigated	t/ha	%
Ø	6.277	7.054	0.777	12.4
1	9.403	10.074	0.671	7.1
2	11.078	13.446	2.368	21.4
3	12.562	14.865	2.303	18.3
4	11.848	13.614	1.766	14.9
5	11.056	13.597	2.641	22.9
Average	10.370	12.108	1.738	16.2

Fertilization $LSD_{5\%} = 0.4106^{***}$
Irrigation $LSD_{5\%} = 0.2371^{***}$

NPK	JX-97			
	Yield, t/ha		Yield surplus	
	non-irrigated	irrigated	t/ha	%
Ø	6.962	7.068	0.106	1.5
1	10.079	11.740	1.661	16.5
2	11.931	13.329	1.398	11.7
3	12.046	13.597	1.551	12.9
4	12.907	13.548	0.641	5.0
5	11.834	13.260	1.426	12.0
Average	10.960	12.090	1.131	9.9

Fertilization $LSD_{5\%} = 0.3392^{***}$
Irrigation $LSD_{5\%} = 0.1958^{***}$
*** P = 0.1%

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Li-CONTENT IN SOME MAJOR FORAGES AND Li-STATUS OF ANIMALS

ÁGNES RÉGIUS-MŐCSÉNYI, M. ANKE* and S. SZENTMIHÁLYI

ÁTK RESEARCH INSTITUTE FOR ANIMAL NUTRITION, HERCEGHALOM, HUNGARY
*KARL-MARX UNIVERSITÄT, LEIPZIG, GDR

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A discussion is presented partly on the basis of literary data, of the vital importance and biological value of lithium in livestock farming, the amount of Li-required, the nature of deficiency symptoms and methods of demonstrating the Li-status of animals.

According to the results of the examinations there is a close correlation ($r = 0.75–0.9$) between the Li-contents of plants and the amount of Li in the soil. The Li-status is best reflected by the blood serum, followed by the hair; in the latter case, however, there may be wide variations depending on the colour, since lithium is bound to a great extent to the pigment of the hair.

Studies carried out on various plant species grown under different soil conditions, throughout Hungary and the German Democratic Republic and on the organs of certain animal species kept in the given environment, prove that in Central Europe Li-deficiency is unlikely to occur in ruminants and horses fed on balanced diets. Li-deficiency will only occur in the case of one-sided grain consumption (e.g. in pigs and poutlry), since the grains are poor in Li and their Li-content does not reach the necessary quantity of 3 mg/kg or so in terms of dry matter.

Keywords: lithium, deficiency symptoms, forage, Li-status

Introduction

The silvery white alkali metal, atomic weight, 6.94, was discovered by Berzelius (Samuel and Gottesfeld 1974) in 1818. Many mineral springs contain lithium (7 mg/l on average), and since the 18th century it has been use in human neuropathology (Schön et al. 1970, Johnson 1979). Lithium may cause side effects, e.g. disorders of the thyroid and the carbohydrate metabolism, bone diseases, etc. (Voss et al. 1978, Müller-Oerlinghausen 1977, Baatsrup et al. 1978). The biological importance of Li in animal breeding was demonstrated by Anke et al. (1981a) in experiments with goats. The Li requirement was determined as 3 mg/kg feed dry matter, sincem if the feed contained 2 mg/kg, the body mass of newborn goats was significantly lower compared to the control, i.e. the Li-supply was deficient. The organism was also found to store smaller quantities of Li-than of other microelements (Mn, Mo); therefore, the body mass gain of Li-deficient animals in the course of development decrease within few days. Large quantities of Li may also lead to lower birth mass and

may cause a reduced rate of growth according to Rider et al. (1978), though contradictory results have also been published. Schön et al. (1970), Kerry et al. (1970), O'Connel (1971) and Vendsborg (1980) found an increase in body mass in patients given neurological treatment with Li; Voss et al. (1978) also found a body mass gain in rats consuming relatively large quantities of Li (0.55 g Li_2CO_3/kg feed dry matter). There conflicting results indicate the need for further investigations.

The role of Li-deficiency in conception seems to be less important that of Mn or Cu, though in the case of Li-deficiency conception creased by 25% compared to the control, and the sex ratio of the newborn animals shifted towards the females. The cause of the latter is unknown at present (Anke et al. 1981b). Fleischmann et al. (1974) found a correlation between the Li-supply and the lipid metabolism: in response to large quantities of Li the fat deposition in rats decreased.

Anke et al. (1981) made the first systematic determination of Li-content in forages and foodstuffs. The results showed the green plant parts to be rich in Li while the graines are poor in Li. The absorbable Li-content of the soil depends on the soil pH; the vegetation of acidic soils contains more Li than plants grown on neutral or alkali soils.

The blood serum is particularly suitable for determining the Li-status of the organism (Anke et al. 1981), in contrast to most microelements, where the quantity in the blood serum is not in close correlation with the quantity available from to by the organism (Mn, Zn, etc.). As mentioned above, it was Anke et al. (1981) who established the fast that both ruminants and pigs need more than 3 mg Li/kg feed dry matter, and that quantities lower than this may cause disorders.

To determine the soil-dependent Li-contents of forages examinations were carried out on indicator plants collected from various parts of the country.

Material and methods

For the analysis of the soil-specific Li-content in plants, lucerne, red clover, wheat and rye were collected. Hair and organ samples were taken to determine the Li-status on cows, sheep and horse (Régius-Mőcsényi et al. 1982).

The collection, drying and preparation of the samples for analysis and the evaluation of the results were carried out using the methods applied when examining the Ni-status.

Li was determined with an atomic absorption spectrophotometer (Jarrel-ASh 850) with an error of 5%. All the data are given in term of dry matter.

The statistical calculations were made after Weber (1972).

Results and evaluation

According to the literary data there is a close correlation between the Li-content of plants and the Li-status of the soil (Aldrich et al. 1955). Anke et al. (1981) found 50–70% differences in the same plant species. For example,

leafy fodder beet contained 14 mg/kg Li on a soil rich in Li and 3.6 mg/kg under Li deficient soil conditions. With the help of samples taken from plants grown on areas with different soil conditions a survey of the soil-specific Li-status of plants in Hungary was carried out. Table 1 shows the correlation of Li-contents in indicator plants grown within an area of 1 m^2; this figure is $r = 0.75–0.90$ for legumes and cereals. No correlation could be found between rye and wheat, probably due to the small number of samples and the only slight differences in Li-content between the two plant species.

Table 1

Relationship between Li-contents in plant species grown on the same soil type
(x = first, y = second plant species)

Plant species	*n*	*P*	*y*	*r*
Lucerne: red clover	24	< 0.001	0.23 + 78x	0.75
Red clover: rye	18	< 0.001	3.10 + 1.27x	0.75
Red clover: wheat	15	< 0.001	2.08 + 1.00x	0.90
Rye: wheat	10	> 0.05	—	—

According to Bradford (1966) and Bowen (1966) the Li-content in various soil-forming rocks and the specific pH value of the soil significantly influence the Li-content of the vegetation. This is further proof of the fact that the geological origin of the soil considerably influences the Li-contents of plants.

There is a relatively wide variation in Li-content among plants obtained from the same soil. The relative Li-contents of plants grown on different soils are shown in Table 2. The Li-contents of the plants was expressed as a percentage of the highest Li-content, as was done previously for other elements (Régius-Mőcsényi et al. 1982). When on a soil type all the examined plant

Table 2

Soil-specific Li-contents of rye, wheat and red clover as a percentage of Li-contents in plants grown on the soil type richest in lithium

Soil	Relative value	
	x	*s*
Andesite weathering soil	100	0
Triassic weathering soils	79	13
Alluvium	74	14
Loess	61	14
Alkali soil	52	16
Lowest significant difference	33	

species slow the highest Li-contents, then the relative value will be 100. Such a situation — which in the present case can be observed in the trend of the Li-content — only occurs in an ideal case; in practice this value is usually less than 100 (Régius-Mőcsényi et al. 1982). As seen from the data in Table 2, the vegetation of andesite and triassic weathering soils is the richest in Li, while that of loess and alkali soils is much poorer. Mitchell (1955) found 70–200

Table 3

Li-contents in indicator plants as compared to the corresponding GDR data (mg/kg dry matter)

Plant species	n	Hungary		GDR		P	%[1]
		$\bar{x}$	s	$\bar{x}$	s		
Low hop clover	20; 712	5.0	4.2	8.5	$6.0 < 0.05$		170
Red clover	54; 1212	6.1	4.8	9.6	$5.8 < 0.001$		157
Lucerne	84; 58	5.9	4.6	6.2	$3.8 > 0.05$		105
Rye	72; 286	12.0	9.4	7.0	$7.1 < 0.001$		58
Wheat	168; 341	13.0	8.5	11.0	$12.0 > 0.05$		85

[1] Hungary = 100%, GDR = x%

mg/kg Li in weathering soils, a value which agrees with the Li-content obtained for the indicator plants, i.e. on mineral soils rich in Li, two vegetation is also rich in Li.

The average Li-contents of the red clover, lucerne, rye and wheat samples used as test plants were compared to the corresponding data from the German Democratic Republic (Table 3). Legumes in Hungary contain less Li-than those in the GDR, while rye and wheat are richer in Li in Hungary. These data definitely prove that, in addition to the geological origin, the pH of the soil also influences the Li-contents of plants. No satisfactory explanation has yet been found for the fact that legumes contain less Li and cereals more Li in Hungary than in the GDR. Apart from the pH value, differences in variety and fertilization might also explain the opposite trend in Li-content in the two countries.

According to Anke et al. (1981) next to the blood serum the hair best reflects the Li-status of animals; therefore, parallel to collecting plant samples, hair samples were taken from cows on areas with identical soil conditions. Furthermore, on the basis of several hundreds of examinations, Anke et al. (1981) established that the colour of the hair had a decisive influence on the Li-content, presumably because Li is usually bound to the pigment of the hair (Table 4).

A comparison of the Li-content in the red hairs of Hungarian Simmenthal cows and in the black hairs of black-spotted cows revealed that black

Table 4

Li-contents in pigmented and white hairs of black-spotted and red-spotted cows (mg/kg)
(Anke et al. 1981)

Colour of hair	Black-spotted		Red-spotted		P	%[1]
	$\bar{x}$	s	$\bar{x}$	s		
Pigmented hair	4.1	2.5	1.7	1.1	0.005	41
White hair	1.8	1.6	1.8	1.1	0.05	100
P	<0.05		<0.05			
%[2]	44		106			

[1] Black-spotted = 100% Red-spotted = x%
[2] Pigmented = 100% White = x%

hairs contained significantly more Li than red hairs (Table 5). In addition, the deviation in the Li-content of red hairs exceeds the average value. A part from the colour of the hair and the soil-specific Li-content of plants this may also be due to differences in the system of feeding (confined housing, pasturing, etc.), since leafy forages are rich in Li while grains are poor in Li (the latter contain less than 3 mg/kg Li in terms of dry matter).

Table 5

Li-content in the red hairs of Hungarian Simmenthal cows as compared to the hair of black-spotted cows in the GDR (mg/kg)

n	Hungary		GDR		P	%[1]
	$\bar{x}$	s	$\bar{x}$	s		
73; 34	3.2	3.4	4.1	2.5	<0.05	125

[1] Hungary = 100%, GDR = x%

On the grounds of the above, the hair alone may occasionally be unsuitable for testing the Li-status, mainly because of its pigment-bound Li-content. Since, however in every case marker plants of different geological origin contained more than 3 mg/kg Li, the amount found by Anke et al. (1981) to be indispensable, primary Li deficiency in the feed of ruminants is unlikely to occur.

Subsequently, various organs of the animals were examined for Li-content, and the results were compared, with data from the GDR.

The Li-contents of various organs are shown in Table 6 for cattle, in Table 7 for sheep and in Table 8 for horses, in comparison to the corresponding GDR data.

According to the literary data (Anke et al. 1981), the amount of Li, contained in various animal organs unlike that of other elements (e.g. Cd), is not influenced by the age of the animal. In Tables 6, 7 and 8 the Li-contents of the organs show varying trends. The amount of Li found in the livers and cerebra of cows and sheep was larger compared to the GDR data, while in the organs of horses it was significantly less. When the Li contents of the hair and wool obtained in the present studies are compared to the "average" values given by Anke et al. (1981) it is found that the Li-contents in the manes

Table 6

Li-contents in various organs of cows as compared to GDR data (mg/kg dry matter)

Organ	n	Hungary		GDR		P	%[1]
		$\bar{x}$	s	$\bar{x}$	s		
Kidney	166; 143	18	17	18	18	>0.05	100
Liver	167; 137	19	14	17	18	<0.05	89.4
Cerebrum	144; 85	22	18	18	13	<0.05	81.8

[1] Hungary = 100%, GDR = x%

Table 7

Li-contents in various organs of sheep as compared to GDR data (mg/kg dry matter)

Organ	n	Hungary		GDR		P	%[1]
		$\bar{x}$	s	$\bar{x}$	s		
Kidney	25; 62	28	17	31	20	>0.05	111
Liver	27; 67	31	22	21	13	<0.01	68
Cerebrum	26; 57	40	24	27	16	<0.01	68
Wool	12; 44	1.1	0.8	1.2	0.9	>0.05	109

[1] Hungary = 100%, GDR = x%

Table 8

Li-contents in various organs of horses (mg/kg dry matter)

Organ	n	Hungary		GDR		P	%[1]
		$\bar{x}$	s	$\bar{x}$	s		
Kidney	32; 33	12.0	12.0	20	19	<0.05	167
Liver	49; 43	8.8	7.3	11	9.2	<0.05	125
Cerebrum	40; 41	12.0	11.0	19	8.9	<0.001	158
Mane	52; 27	1.9	1.8	1.4	1.4	<0.05	74

[1] Hungary = 100%, GDR = x%

of horses (1.9 mg/kg) and in the wool of sheep (1.1 mg/kg) agree with, or occasionally exceed, the values (1.4 and 1.2 mg/kg, respectively), established as "normal" by Anke et al. (1981), while the Li-content of cow hairs is lower, owing to the previously mentioned pigment-bound state of Li. The Li-contents in various organs of these cows, on the other hand, exceed the amounts demonstrated in the GDR, which again proves the effect of the pigment content on the Li-status.

In Central Europe primary Li-deficiency in the feed of domestic animals is unlikely to occur (Anke et al. 1981), though in the case of one-sided grain feeding (pigs and poultry) the amount of Li may be much below the necessary 3 mg/kg dry matter. Leafy forage can be expected supposed to meet the Li requirements of ruminants and the danger of Li-deficiency only arison if too much grains is fed. However, the possibility of secondary Li-deficiency, and the danger of overdosing when Li, is used as a sedative in human neurology may justify continued investigations.

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RELATION BETWEEN THE Ni-CONTENTS OF PLANTS AND THE Ni-STATUS OF ANIMALS

ÁGNES RÉGIUS-MŐCSÉNYI, M. ANKE* and S. SZENTMIHÁLYI

ÁTK RESEARCH INSTITUTE FOR ANIMAL NUTRITION, HERCEGHALOM, HUNGARY
* KARL-MARX UNIVERSITÄT, LEIPZIG, GDR

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The paper presents information on the relation between the Ni-contents of plants (wheat, red clover, rye, lucerne) grown on soils of different geological origin and the Ni-status of animals.

The analyses prove that there is a close ($r = 0.80$) correlation between the Ni-supply of the soil and the Ni-contants of the different plant species.

To determine the Ni-status of animals, liver, kidney and rib samples taken from dairy cows, horses and sheep were examined. According to the results the Ni-supply is satisfactory in Hungary; the plants and animal organs contain nearly twice as much Ni as was found in similar investigations carried out in the GDR.

Keywords: animal Ni-status, Ni-content, red clover, rye lucerne, wheat

Introduction

Ni, together with Fe and Co, belongs to subgroup 8 in the periodic system. The vital importance of Fe and Co was discovered long ago (Phillips 1934, Underwood 1977, etc.) while Ni has only been treated as a trace element for a relatively short time.

Over the last 15 years the chemical and physical similarity of Fe, Co and Ni has induced the effect of Ni supply on the production of various animal species (Nielsen 1974, 1980, Nielsen and Shuler 1979, Anke 1973, Anke et al. 1974, 1977, 1978, 1980, Hennig et al. 1973, Kirchgessner and Schnegg 1980, Schnegg and Kirchgessner 1975a, 1975b, 1976, 1978, 1980).

In spite of the rapidly widening knowledge on the subject, there are still a great many open questions in the field of Ni-research. The vital importance of Ni was demonstrated in goats and dwarf pigs, by Anke (1973) and Anke et al. (1974, 1977, 1978, 1980a, 1980b) in rats by Nielsen (1974), Schnegg and Kirchgessner (1975) and in sheep by Spears et al. (1978, 1979).

In agreement with other groups of researchers (Ni Symposium, Jena, 1980) Anke et al. (1980) established <500 μg/kg feed dry matter as the Ni requirement for man and animals.

For ruminants, which require Ni for the undisturbed functioning of the ruminal flora, since the activity of the urease enzyme is related to the Ni-

status (Spears et al. 1979), the necessary amount of Ni is 300–500 μg/kg, while for monogastric animals it is less (200 μg/kg).

The body mass gain for animals offered Ni-deficient feed decreases (Anke et al. 1981) and viability of the progeny is far lower than that of the control animals. Ni-decifient feeding may result in as much as 50% mortality. Ruminants are more sensitive to Ni-deficiency than pigs. As a consequence of Ni-deficiency the absorption of iron decreases, more iron is excreted (Schnegg and Kirchgessner 1976, Nielsen 1980) and the Ca and Zn metabolism is disturbed (Anke et al. 1981, Kirchgessner and Schnegg 1980).

The literary data reveal the important role of Ni in feeding, particularly in the case of ruminants, which consume roughages and are thus dependent to a great extent on the local conditions.

Material and methods

Experiments were carried out to determine the Ni-contents of fodder crops and the Ni-status of the livestock in Hungary.

The marker plants (wheat, rye, red clover and lucerne) were collected at the same stage of maturity from geologically identified soils (Balogh et al. 1956). Simultaneously with the collection of plant material, hair samples were taken from dairy cow herds kept on the same areas (Anke 1976, Anke and Risch 1979), and organ samples were taken when the cows, horses and sheep kept on the respective soils were slaughtered.

The samples were all prepared for analysis in an identical manner: the marker plants and organ samples were dried, first at 60 °C, then at 105 °C to constant weight, then reduced to ash at 450 °C. The ash was stored in hydrochloric acid until analysed. The hair samples were prepared for analysis according to the method of Anke and Risch (1979). The Ni-content was determined by colorimetry with dimethyl glyoxime (Oelschlager 1955a, b). Weber's (1972) method was used for the statistical evaluation.

Results and discussion

Prior to analysing the effects of soil conditions on the Ni-content of the plant, the way in which Ni is taken up by the plant must first be clasified. To this end, the trend in Ni-content was examined for two plant species grown in each case on the same area with the same Ni-supply in the soil (Table 1).

According to the data in the table, the Ni-contents of two plant species obtained from the same growing area showed a significant correlation ($r = 0.66$–0.88). This considerable relation between the Ni-contents of plant species grown side by side proves that their Ni in take is a function of identical and that their Ni-contents reflect the Ni-supply characteristic of the soil.

The Ni-status for the whole of Hungary was determined with the aid of the Ni-contents in common plants such as red clover *(Trifolium pratense)* in full bloom wheat *(Triticum sativum)* in the bud stage and rye *(Secale cereale)* during blooming takint the geological origin of each soil type into consideration (Table 2).

Table 1

Relationships of Ni-contents in two plant species on the same growing site
(x = first plant species, y = second plant species)

Species and number of plants	*P*	*y*	*r*
Lucerne: Red clover (21 : 21)	>0.01	358.1 + 0.71x	0.60
Rye : Red clover (12 : 12)	>0.01	308.8 + 0.71x	0.86
Rye : Wheat (11 : 11)	>0.01	125.7 + 0.65x	0.77

The plant species, show only slight variations in specific Ni-content, so it is in possible to draw conclusions on the Ni-status of a given area from the values of a single plant species. The highest Ni-content found on the given area was thus taken as 100 and the other values were compared to this. In this way plant species can be directly compared to one another when demonstrating the soil-dependent Ni-content.

In an ideal case, if the actual Ni-content of each plant species grown on the same soil had shown the highest value, the relative value would have been 100.

For the soil types examined this was not the case. The relative Ni-content of plants grown on andesite soils was 92: the fodder crops produced on these soils contain the largest quantities of Ni in Hungary. These are followed by the vegetation of alkaline, marshy and peat soils, while loess and calcareous sandy soils are poorest in Ni.

Table 2

Soil-specific Ni-content of the four indicator plants (lucerne, red clover, wheat, rye) as a percentage of the value measured on the soil richest in Ni

Geological origin of soils	$\bar{x}$*	*s*
Andesite soils	92	9
Alkali soils	87	19
Marshy and peaty soils	77	24
Sandstone, limestone marl soils	65	23
Acidic sandy soils	61	19
Alluvial soils	58	21
Loess soils	56	17
Calcareous sandy soils	54	9
Lowest marginal difference	42	

* $\bar{x}$ = middle of percentage

In Table 3 the Ni-contents of red clover, wheat and rye grown in Hungary are compared to the respective GDR data. The comparison shows that the vegetation in Hungary is generally richer in Ni-than that in the German Democratic Republic.

Table 3

Ni content in red clover (at blooming) wheat (in the bud stage) and rye (at blooming) in Hungary as compared to the GDR data

Plant species	n	Hungary		GDR		P	%*
		$\bar{x}$	s	$\bar{x}$	s		
Red clover	(57; 114)	2337	1371	1264	859	>0.001	54
Wheat	(192; 338)	940	383	400	203	>0.001	44
Rye	(76; 229)	800	361	399	208	>0.001	50

* Hungary = 100%; GDR = x%

According to the data in the table nearly twice as much Ni was found in the different plant species in Hungary as in the GDR, presumably due to the frequent occurrence in Hungary of basic volcanic soils, which are usually rich in Ni (Kowalsky 1977, Bergmann 1980). The case is probably similar for soils shaped by the wind and water; these are very frequent in Hungary and play an important role in fodder crop production and agricultural utilization. Loess, alluvium and sandy soils are of this type.

The average Ni-contents of red clover, wheat and rye grown on soils of the same geological origin show a close significant correlation ($r = 0.80$), (Table 4).

Table 4

Relationships of Ni-contents in three plant species grown on soils of identical geological origin
(x = one plant species, y = the other plant species)

Plant species	n	P	y	r
Rye : red clover	(15 : 15)	>0.001	579 + 1.73	0.76
Wheat : red clover	(17 : 17)	>0.001	644 + 1.48	0.81
Wheat : rye	(19 : 19)	>0.001	386 + 0.95	0.94

The data show that the Ni-content of forages is a characteristic specific soil. The vegetation of basic volcanic soils rich in Mg-contains the largest quantity of Ni, while the flora of soils rich in Ca is poorer in Ni.

The Ni-status of animals, and changes in the Ni-contents of various organs and of the hair in response to different Ni-rations were studied by

Anke et al. (1981) on goats; the authors found that the extent of the Ni-supply was best reflected by the ribs, followed by the liver and kidneys. Using these results as the starting-point an examination was made of the Ni-contents of the ribs, livers and kidneys of horses, cows and sheep kept on various soils, and these were compared to the corresponding GDR data. The ribs of animals in Hungary, in agreement with the values of plant analyses, contained significantly more Ni in each case than the ribs of GDR animals (Table 5).

Table 5

Ni-content in the ribs of certain domestic animals in Hungary and the GDR (μg/kg dry matter)

Animal species	n	Hungary		GDR		P	%*
		$\bar{x}$	s	$\bar{x}$	s		
Cattle	(106; 63)	724	388	416	203	>0.001	57
Sheep	(26; 30)	1266	501	441	423	>0.001	35
Horses	(26; 16)	1683	982	997	423	>0.05	59

* Hungary = 100%; GDR = x%

Of the three animal species examined the ribs of horses contained the largest quantities of Ni, while those of cows and sheep gave lower values. The reason for these differences between the species is not known as yet. There was some speculation that perhaps they were related with the age of the animals, since the horses tested were three times as old as the cows, on average. Human analyses, however, disproved this assumption (Anke et al. 1981).

The livers and kidneys of the three animal species were compared for Ni-content in the same way as the ribs (Tables 6 and 7).

The amount of Ni in the livers and kidneys of animals in Hungary, as the case of ribs, was nearly twice as much as in the respective organs of animals in the GDR.

Table 6

Ni-content of kidney of domestic animals in Hungary and the GDR (μg/kg dry matter)

Animal species	n	Hungary		GDR		P	%*
		$\bar{x}$	s	$\bar{x}$	s		
Cattle	(159; 238)	590	355	401	372	>0.001	68
Sheep	(23; 36)	940	410	666	567	>0.01	71
Horses	(15; 23)	1023	591	579	379	>0.05	57

* Hungary = 100%; GDR = x%

Table 7

Ni-content in the livers of domestic animals in Hungary and the GDR (μg/kg dry matter)

Animal species	n	Hungary		GDR		P	%*
		$\bar{x}$	s	$\bar{x}$	s		
Cattle	(164; 238)	779	499	451	288	>0.001	58
Sheep	(26; 39)	740	352	526	351	>0.05	71
Horses	(29; 34)	1632	3316	699	400	<0.05	43

* Hungary = 100%; GDR = x%

The Ni-contents of plants, in agreement with the analytical results for various organs of the three animal species, prove that yield losses caused by Ni deficiency are unlikely to occur in Hungary since Anke et al. (1980) found the Ni requirements of animals to be below 500 μg/kg dry matter. Moreover, according to the evidence of the contents in the ribs, liver and kidneys the Ni-status of the animals is far better in Hungary than in the GDR.

The results also show that the Ni-status depends on the specific Ni-supply of the soil, and that the Ni-contents of the individual organs vary with the Ni-supply.

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RELATION OF CRUDE FIBRE CONTENT AND CELL-WALL CONSTITUENTS TO DRY MATTER DIGESTIBILITY IN ROUGHAGES

ILDIKÓ VÁRHEGYI, S. SZENTMIHÁLYI, J. VÁRHEGYI and ZSUZSANNA SIMON

ÁTK RESEARCH INSTITUTE FOR ANIMAL NUTRITION, HERCEGHALOM, HUNGARY

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The authors analysed the in vivo digestibility and the cell-wall constituents (NDF, ADF and ADL) of a total of 53 grasses, meadow and lucerne hays using *van Soest's* (1963) detergent method. The digestibility of neutral detergent (NDF) and acid detergent (ADF) fibre was examined in 37 feeds. Considerable differences were found between the NDF, hemicellulose and ADL contents, of grasses and lucerne as well as for the digestibility of the cell-wall constituents.

In the case of grasses, meadow and lucerne hays a closer correlation was found between dry matter digestibility and acid detergent fibre content ($r = -0.94, -0.83, -0.77$) than between dry matter digestibility and Weende crude fibre content ($r = -0.88, -0.65, -0.58$).

Simple and multiple correlation coefficients were calculated between in vivo dry matter digestibility and the contents of different cell wall fractions. The most suitable predictors of digestibility were found to be the ADF or ADF-ADL contents in the case of grasses and meadow hays and the ADF-ADL or NDF-ADF-ADL contents in lucerne hays.

Keywords: cell-wall constituents, digestibility, dry matter, grasses, lucerne hay meadow hay

Introduction

Besides the Weende analysis developed in the 1800s the detergent method of analysing fibrous feeds has been gaining ground. The Weende analysis breaks down the dry matter of the feed in to crude protein, crude fat, crude fibre and ash, and registers the difference in the chemical components examined and in the dry matter as nitrogen-free extract. The detergent method breaks down the dry matter of the feed in to cell contents and cell-walls. The cell contents are easily digested by all animal species, while the cell-wall can only be utilized if intensive microbial zymosis takes place in the digestive system. The distribution of feed dry matter by the detergent method is shown in Table 1.

The present investigations covered the determination of in vivo digestibility and the cell-wall constituents of some important fibrous feeds and compared them to crude fibre. In addition, an answer was sought to the question of the extent to which the various fibrous components are related

Table 1

Distribution of dry matter in feeds (Analysis of feeds with detergents)
After Jorgensen (1971)

Fraction	Constituents	Digestibility	
		Ruminants	Monogastrics
(A) Cell content	lipids	good	good
(soluble in neutral detergent)	sugars	good	good
	organs acids	good	good
	starch	good	good
	NPN substances	good	good
	protein	good	good
	pectine	good	good
(B) Cell-wall content (fibre insoluble in detergent)			
(1) Soluble in acid detergent	hemicellulose	partial	very low
(2) Insoluble in acid detergent	cellulose	partial	very low
(acid detergent fibre)	lignin	indigestible	indigestible
	lignified N-compounds	indigestible	indigestible
	heat-damaged protein	indigestible	indigestible
	keratin	indigestible	indigestible
	silicates	indigestible	indigestible

with digestibility, i.e. which components are best suited for the calculation of nutritive value.

Literary review

Chemical factors which are related to digestibility are summarized by Minson (1982).

According to Rohweder et al. (1978) the acid and neutral detergent fibres are suitable predictors of the digestibility and feed intake of meadow and lucerne hays. Correlations of $r = -0.82$ and $r = -0.62$ were found for lucerne, and $r = -0.76$ and $r = -0.76$ for meadow hay between acid detergent fibre and digestibility, and between neutral detergent fibre and dry matter intake, respectively. Kronauer and Bickel found the detergent method to be more suitable for estimating the energy content of tropical grasses than the Weende analysis. Similarly, Ohlde and Becker (1982) proved the superiority of acid detergent fibre to crude fibre in examining by-products. Coppock et al. (1981) reported than the digestibility and energy content of feeds could be estimated directly from the acid detergent fibre content, while crude fibre was found to be unsuitable for this purpose. Barnes and Marten (1979) also

consider the detergent method suitable for examining feeds. At the same time, on the basis of investigations carried out by Van Es (1981), van Es and van der Meer (1981) and Jarrige (1980) reported only minor differences between the detergent fibre and crude fibre methods within the same group of feeds.

Material and methods

The apparatus for analysing the cell-wall constituents was constructed on the basis of a description given by Goering and Van Soest (1970). The analysis of cell-wall constituents in reed and excrement was carried out by the method of van Soest (1963, 1965, 1976) and Goering and van Soest (1970).

The in vivo digestibility of 8 fresh grasses, 30 meadow hays and 15 lucerne hays, each feed to 3 wethers, was determined. The feeds were subjected to Weende analysis, and the neutral detergent (NDF) and acid detergent (ADF) fibre and the acid detergent lignin (ADL) content were determined. The digestiblity of dry matter, organic matter, crude protein, crude fat, crude fibre and N-free extract was measured for each feed while for 8 fresh grasses, 15 meadow hays and 9 lucerne hays the digestibility of NDF and ADF was also measured.

A relationship was sought between the amounts of crude fibre and cell-wall constituents, on the one hand, the digestibility of dry matter on the other. The relationship was examined both for each component separately and for the cell-wall constituents as a whole, with the aid of single and quadratic and multiple linear regression. The calculations were made on an IBM Series/1 computer.

In the case of meadow hays the larger number of data made it possible to study the correlation between the starch equivalent of the feed, calculated with measured digestion coefficients, and the crude fibre and acid detergent fibre. The starch equivalent calculated using in vivo digestion coefficients was compared to that obtained with the standard coefficients established at the Research Institute for animal Nutrition and to that calculated on the basis of ADF.

Results

The average crude fibre, neutral detergent fibre, hemicellulose, acid detergent fibre and acid detergent lignin contents of grasses, meadow and lucerne hays, are summarized together with the standard deviation in Tables 2, 3, and 4 in terms of the in vivo dry matter digestibility of the samples

Table 2

Cell-wall constituents of fresh grasses

$\bar{x} + s$	Dry matter digestibility, %	
	above 68 ± 4.7	below 60% 57 ± 1.3
n	4	4
In 1000 g dry matter g, $\bar{x} \pm s$ crude fibre	235 ± 53.1	293 ± 22.5
Neutral detergent fibre (NDF)	598 ± 67.0	644 ± 27.4
Hemicellulose	282 ± 63.6	276 ± 9.0
Acid detergent fibre (ADF)	307 ± 43.8	368 ± 21.2
Acid detergent lignin (ADL)	37 ± 14.0	52 ± 2.9

Table 3

Cell-wall constituents of meadow hays

$\bar{x} \pm s$	Dry matter digestibility, %			
	above 61% 63 ± 2.3	60–56% 58 ± 1.8	55–51% 54 ± 1.8	below 50% 46 ± 3.4
n	5	9	10	6
In 1000 g dry matter, g $\bar{x} \pm s$ crude fibre	321 ± 26.7	323 ± 27.7	339 ± 29.1	387 ± 16.6
Neutral detergent fibre (NDF)	624 ± 46.5	641 ± 35.8	662 ± 31.8	712 ± 9.3
Hemicellulose	236 ± 30.2	239 ± 26.6	247 ± 25.9	259 ± 15.0
Acid detergent fibre (ADF)	388 ± 28.5	391 ± 31.3	415 ± 16.8	453 ± 13.0
Acid detergent lignin (ADL)	49 ± 10.0	52 ± 6.7	56 ± 7.1	67 ± 8.1

analysed. The quantity of hemicellulose is a calculated value, being the difference between neutral and acid detergent fibre.

There is a considerable difference between grasses and lucerne with respect to the amount of cell-wall constituents. A comparison of hays with similar dry matter digestibility shows that the cell-wall (NDF) and hemicellulose contents of grasses are higher, while lucerne hay contains more lignin (ADL). The correlation of the amount of crude fibre and cell-wall constituents to dry matter digestibility is obviously negative in grasses, meadow and lucerne hays alike. With an increase in the amount of fibrous components the digestibility of feeds decreases.

Table 4

Cell-wall constituents of lucerne hays

$\bar{x} \pm s$	Dry matter digestibility, %		
	above 61% 62 ± 1.2	60–56% 58 ± 1.0	below 55% 53 ± 1.7
n	3	7	5
In 1000 g dry matter, g $\bar{x} \pm s$ crude fibre	245 ± 9.9	298 ± 33.8	349 ± 53.8
Neutral detergent fibre (NDF)	399 ± 30.1	473 ± 46.3	548 ± 57.8
Hemicellulose	83 ± 12.3	104 ± 33.8	110 ± 22.7
Acid detergent fibre (ADF)	316 ± 19.9	369 ± 21.7	438 ± 39.8
Acid detergent lignin (ADL)	60 ± 9.1	76 ± 12.2	96 ± 11.3

In Tables 5, 6, and 7 the digestibility of crude fibre and neutral and acid detergent fibre in grasses, meadow and lucerne hays is expressed in term of dry matter digestibility categories. In the case of crude fibre two data are given for each type of feed with exception of grasses; the first refers to the samples as a whole, and the other to samples in which the digestibility of

Table 5

Digestibility of cell-wall constituents in fresh grasses

n	Crude fibre, g/kg dry matter	Crude fibre digestibility, %	Neutral detergent fibre (NDF), g/kg dry matter	NDF digestibility, %	Acid detergent fibre (ADF), g/kg dry matter	ADF digestibility, %
Dry matter digestibility above 60%						
4	235	77	589	75	307	64
Dry matter digestibility below 60%						
4	293	59	644	60	368	53

NDF and ADF was also examined. According to the analytical results meadow and lucerne hays show differences not only in the amount of fibrous components but also in their digestibility. The digestibility of the fibrous components is better in meadow hays. In lucerne hay the digestibility of crude fibre is similar to that of ADF, while the digestibility of NDF exceeds them both; in grasses and meadow hays the digestibility of crude fibre was found to be higher than that of acid detergent fibre.

Table 6

Digestibility of cell-wall constituents in meadow hays

n	Crude fibre, g/kg dry matter	Crude fibre digestibility, %	*n*	Neutral detergent fibre (NDF), g/kg dry matter	NDF digestibility, %	Acid detergent fibre (ADF), g/kg dry matter	ADF digestibility, %
Dry matter digestibility above 61%							
5	281	73	5	624	71	388	63
Dry matter digestibility 56–60%							
9	323	68					
4	323	67	4	634	66	405	56
Dry matter digestibility 51–55%							
10	339	65					
7	330	67	7	668	64	414	53
Dry matter digestibility below 50%							
6	387	56					
4	388	57	4	716	55	453	50

In Table 8 the correlation between the amount of cell-wall constituents in roughages and the digestibility of the dry matter can be seen. In the case of grasses and meadow hays the closest correlation, significant at $P<0.1\%$ ($r = -0.94$ and -0.83, respectively), was obtained for the acid detergent

Table 7

Digestibility of cell-wall constituents in lucerne hays

n	Crude fibre, g/kg dry matter	Crude fibre digestibility, %	*n*	Neutral detergent fibre (NDF) g/kg dry matter	NDF digestibility, %	Acid detergent fibre (ADF), g/kg dry matter	ADF digestibility, %
Dry matter digestibility above 60%							
3	245	57					
2	251	57	2	410	60	321	58
Dry matter digestibility 56–60%							
7	298	51					
4	282	52	4	458	57	361	53
Dry matter digestibility below 55%							
5	349	48					
3	336	50	3	540	53	427	49

Table 8

Correlation between the dry matter digestibility (y) and cell-wall constituents (x) of forages

n	Fresh grass 8	Meadow hay 30	Lucerne hay 15	Total 53
Crude fibre	−0.88**	−0.65***	−0.58*	−0.71***
Neutral detergent fibre (NDF)	−0.78*	−0.68***	−0.65**	−0.42**
Acid detergent fibre (ADF)	−0.94***	−0.83***	−0.77***	−0.81***
Acid detergent lignin (ADL)	−0.87**	−0.53**	−0.81***	−0.46***

* $P < 5\%$, ** $P < 1\%$, *** $P < 0.1\%$

Table 9

Correlation between dry matter digestibility (y) and cell-wall constituents (x) in fresh grasses. Regression models and equations

	1	2	3	4	5
x/x_1 x^2/x_2 x_3	Crude fibre	ADF ADF²	ADF ADL	NDF ADL	ADF NDF ADL
Correlation coefficient	−0.88	−0.94			
Multiple correlation coefficient			0.94	0.92	0.95
a	93.94	139.88	103.67	105.16	99.44
b/b_1	−0.117	−0.334	−0.106	−0.045	−0.158
b_2			−0.119	−0.329	0.030
b_3					−0.035
c		0.0003			
Standard error of estimation	±3.34	±2.64	±2.57	±3.02	±2.80

fibre content, and in the case of lucerne hays for the acid detergent lignin content ($r = -0.81$), but even for lucerne hay the correlation of dry matter digestibility was closer with ADF ($r = -0.77$, $P < 0.1\%$) than with the crude fibre content ($r = -0.58$, $P < 5\%$). When averaged for all the feeds examined, dry matter digestibility was found to be most closely correlated with the acid detergent fibre content, though this result was partly due to the fact that grasses made up more than 70% of the samples.

In Tables 9, 10, 11 and 12 various regression models and equations are shown. No. 1, is a single linear (crude fibre) model, No. 2 a single quadratic

Table 10

Correlation between dry matter digestibility (y) and cell-wall constituents (x) in meadow hays Regression models and equations

	1	2	3	4	5
x/x_1 x^2/x_2 x_3	Crude fibre	ADF ADF^2	ADF ADL	NDF ADL	ADF NDF ADL
Correlation coefficient	−0.65	−0.84			
Multiple correlation coefficient			0.84	0.72	0.84
a	92.09	44.99	124.38	113.70	122.96
b/b_1	−0.109	0.223	−0.155	−0.076	−0.166
b_2			−0.095	−0.155	0.010
b_3					
c			−0.0005		
Standard error of estimation	±4.55	±3.33	±3.28	±4.25	±3.33

Table 11

Correlation between dry matter digestibility (y) and cell-wall constituents (x) in lucerne hays Regression models and equations

	1	2	3	4	5
x/x_1 x^2/x_2 x_3	Crude fibre	ADF ADF^2	ADF ADL	NDF ADL	ADF NDF ADL
Correlation coefficient	−0.58	−0.80			
Multiple correlation coefficient			0.84	0.82	0.91
a	69.87	118.54	76.20	71.64	75.30
b/b_1	−0.042	−0.265	−0.024	0.0001	−0.084
b_2			−0.125	−0.184	0.055
b_3					−0.161
c		0.00027			
Standard error of estimation	±3.27	±2.53	±2.24	±2.40	±1.85

Table 12

Correlation between dry matter digestibility (y) and cell-wall constituents (x) in fresh grasses, meadow and lucerne hays Regression models and equations

	1	2	3	4	5
x/x_1 x^2/x_2 x_3	Crude fibre	ADF ADF²	ADF ADL	NDF ADL	ADF NDF ADL
Correlation coefficient	−0.71	−0.81			
Multiple correlation coefficient			0.84	0.72	0.82
a	83.79	97.31	76.20	91.43	96.49
b/b_1	−0.085	−0.105	−0.024	−0.037	−0.096
b_2			−0.125	−0.207	0.001
b_3					−0.046
c		0.000			
Standard error of estimation	±4.25	±3.64	±2.24	±4.24	±3.58

(ADF and ADF²) model, Numbers 3 and 4 are bivariant (ADF-ADL and NDF-ADL) linear equations and Numb. 5 is a linear equation with three variables (ADF-NDF-ADL). The tables give the values of the single and multiple correlation coefficients the regression constant (a), the regression coefficients (b), and the standard error of estimation. The closest correlation and smallest standard error were obtained with models 2 and 3 for grasses and meadow hays, and with models 3 and 5 for lucerne hays.

Figures 1 and 2 show the correlation between the strach equivalent, calculated with the digestion coefficients obtained in the in vivo experiments and the crude fibre and acid detergent fibre contents in meadow hays. In spite

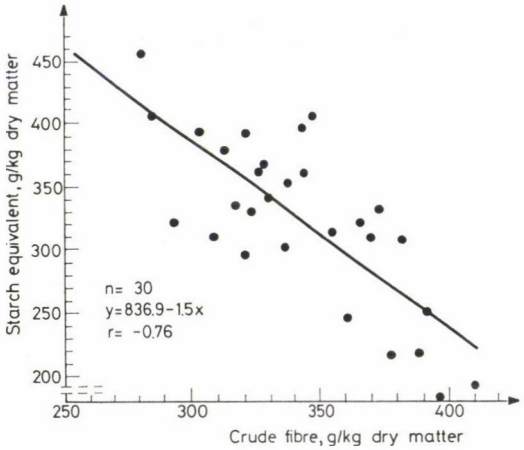

Fig. 1. Correlation between crude fibre content and starch equivalent in meadow hays

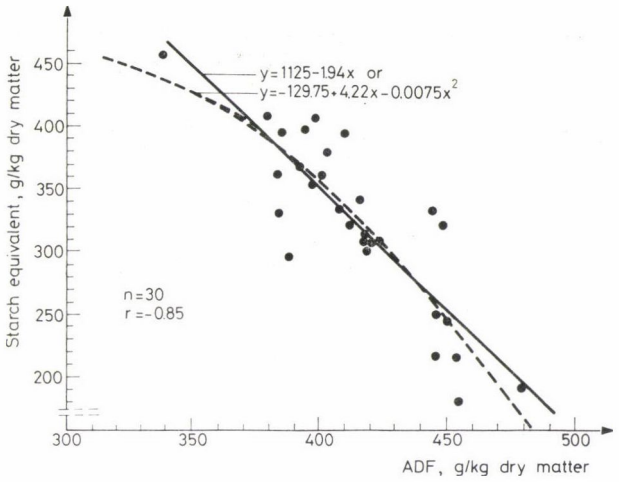

Fig. 2. Correlation between acid detergent fibre content and starch equivalent in meadow hays

of the key role played by the crude fibre in calculating the strach equivalent, the correlation between acid detergent fibre and starch equivalent is closer ($r = -0.85$) than between crude fibre and starch equivalent ($r = -0.76$).

Although few available data are as yet the starch equivalents calculated either directly on the basis of the ADF content ($y = -129.75 + 4.22x - - 0.0075x^2$), or using standard digestion coefficients or using the average digestion coefficients established at the Research Institute for Animal Nutrition were compared with starch equivalents calculated using digestion coefficients obtained in the in vivo experiments. The results, in the above order, were: $r = +0.86$, $r = +0.68$, $r = +0.74$.

Discussion and conclusions

In agreement with most of the literary data (Rohweder et al. 1978, Bernes and Marten 1979, Coppock et al. 1981, etc.), the cell-wall constituents of feeds, particularly acid detergent fibre either by itself or when analysed together with other components (neutral detergent fibre, acid detergent lignin), show a much clorer correlation with the digestibility of feeds than the crude fibre examined in the Weende method. There are considerable differences between grasses and lucerne in the amount and digestibility of cell-wall constituents.

The analytical results suggest that the cell-wall constituents may be suitable for the direct calculation of the digestibility and energy content of feeds. The analyses completed so far indicate that the ADF or ADF-ADL contents are best for this purpose in the case of grasses, and ADF-ADL or ADF-NDF-ADL contents in lucerne. The application of general equations

established for both grasses and papilionaceous crops may greatly lessen the accuracy of the estimation, owing to differences in the amount of cell-wall constituents.

The analysis of cell-wall constituents in forages and roughages should be continued and equations suitable for the direct calculation of the energy content of feeds should be evaluated on the basis of a larger number of data. This would facilitate a more exact, more objective estimation of the energy contents of feeds in laboratories engaged in feed analysis, where the energy values of feeds are currently estimated using a less exact method, on the basis of tabulated digestibility values.

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EFFECT OF SULPHATE SUPPLY ON THE NITROGEN, SULPHUR AND AMINO ACID METABOLISM OF ANGORA RABBITS

II. AMINO ACID METABOLISM

JOLÁN JÉCSAI, MÁRIA TELEKI and B. JUHÁSZ

RESEARCH INSTITUTE FOR ANIMAL NUTRITION, DEPARTMENT OF PHYSIOLOGY, HERCEGHALOM, HUNGARY

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Experiments were carried out to settle the question of what effect the sulphate supply exercised on the amino acid (AA) metabolism of Angora rabbits that consumed feeds of different protein and amino acid content.

According to the results, the protein and amino acid content of the feed had a greater influence on the parameters examined than the 0.2% sulphate added to the feed. When consuming a feed of lower (11%) protein content, the animals exploited the available protein and amino acid better than when given a feed of higher (17%) protein content. The apparent digestibility of sulphureous amino acids, cystin and methionine, as well as of arginine, was particularly higher when the lower protein content feed was consumed. The sulphate supplement best increased utilization of cystin of all amino acids. This tendency was the same at both protein levels, although at the lower protein level it was of a greater extent. With more protein consumed the free amino acid content of the blood increased. The inorganic sulphur supplement caused an increase in the cystin content of the blood in the first place.

We should like to carry out further experiments to examine the effect of sulphate on the metabolic processes of the Angora rabbit.

Keywords: Angora rabbit, nitrogen, suiphur, amino acid metabolism, sulphate supply

Introduction

The data published by Cheeke (1970), Gaman and Fischer (1970), Adamson and Fischer (1971, 1973), NRC norma (1977) on the amino acid (AA) requirement of the rabbit commonly agree that the methionine + cystin, lysine, arginine, leucine, isoleucine, phenylalanine, tryptophan, histidine, threonine, valine are amino acids indispensable for the rabbit. The meat-type and wool-type animals have different amino acid requirements, and the quantitative differences between them are considerable. According to Schlolaut et al. (1977) the Angora rabbit requires about 30% more sulphureous AA than the meat-type rabbits. This relatively high amount of sulphureous AA required for an optimum wool production must be all means be ensured for the animal, the more so because the profitable feeding of the rabbit can be solved only by using plant proteins generally poor in sulphureous AA.

Joshida et al. (1971) and Long (1981) describe a microbiological activity in the digestive tract of the rabbit. According to Kulwich et al. (1954) the

microorganisms living in the digestive tract are able to make use even of inorganic sulphates for their protein synthesis. With all this known, and on the basis of our earlier experiments (Teleki et al. 1984, Jécsai et al. 1984) we made a thorough investigation to find out to what extent feeds with different protein- and AA contents with sulphate added to the feed, would influence the AA metabolism and the other biological parameters of the Angora rabbits.

Material and methods

The detailed description method of the experiments was given in our previous publication (Teleki et al. 1985). The arrangement of the experiments was:

I. experiment (11% crude protein)		II. experiment (17% crude protein)	
Groups			
A (n = 4)	B (n = 4) +0.2% Na_2SO_4	C (n = 4)	D (n = 4) +0.2% Na_2SO_4

As seen above, the feed contained 11% crude protein in the first experiment and 17% in the second experiment. To the feed for groups B and D 0.2% Na_2SO_4 was added. The experimental animals were adult male Angora rabbits kept in metabolic cages.

In the course of the experiment the amount of the feed consumed and of the excreted faces were daily weighed and examined for their AA content. On the basis of the daily quantities of amino acid ingested and later excreted with the faces, we calculated the apparent digestibility of each AA. On the 5th day of both experiments, blood was taken from the auricular vein before morning feeding, always at the same time.

The feeds, faces and blood samples were examined for their AA content with an automatic AA analyser (Typ.: BC-200, Stein and Moor 1954).

The protein content of the blood was determined with the biuret method, while for its free AA-N content we used the *Folin–Danielson* method (Bálint 1962). The carbamide content of the blood was measured on the basis of the *Berthelot*-reaction (Klinisches Laborb. Merck, 1974).

Results

In Table 1 the amino acid composition of feeds used in the two experiments are shown in dry matter percentage.

In *experiment I* (11% crude protein) the amino acid content of the feed for groups A and B was low. This is particularly characteristic of the sulphureous AA the proportion of which was as low as 0.45% (methionine 0.22 + cystin 0.23%). The lysine content of the feed was 0.47%, the arginine content 0.56%. The quantitites of glutamic acid were relatively large (1.70%), aspartic acid (0.83%), proline (0.86%) and leucine (0.92%).

In *experiment II* (17% crude protein) the AA composition of feed for groups C and D was: methionine 0.33%, cystin 0.27%, further, 0.69% lysine, 0.99% arginine and 0.65% threonine were determined, and much leucine

Table 1

Amino acid composition of feed in dry matter, %

Amino acids	Experiment I		Experiment II	
	Group A	Group B	Group C	Group D
Aspartic acid	0.83		1.47	
Threonine	0.47		0.65	
Serine	0.45		0.68	
Glutamic acid	1.70		2.38	
Proline	0.86		1.12	
Glycine	0.48		0.81	
Alanine	0.51		0.79	
Cystin	0.23		0.27	
Valine	0.62		0.88	
Methionine	0.22		0.33	
Isoleucine	0.49		0.72	
Leucine	0.92		1.28	
Tyrosine	0.32		0.44	
Phenylalanine	0.58		0.80	
Lysine	0.47		0.69	
Histidine	0.27		0.38	
Arginine	0.56		0.99	
Crude protein	11.0		17.0	

Table 2

Apparent digestibility of amino acids, %

Amino acids	Experiment I		Experiment II	
	Group A	Group B	Group C	Group D
Aspartic acid	82.3	82.6	81.5	90.0
Threonine	80.3	78.8	75.8	79.8
Serine	81.0	84.1	75.8	79.6
Glutamic acid	84.5	87.0	82.5	85.5
Proline	84.2	92.5	83.3	84.9
Glycine	83.6	85.1	81.4	86.5
Alanine	84.5	84.5	76.1	75.0
Cystin	87.5	96.8	86.8	91.9
Valine	81.6	86.2	85.4	86.7
Methionine	93.4	93.4	84.4	86.4
Isoleucine	82.6	82.6	88.0	85.7
Leucine	82.2	83.7	91.9	89.1
Tyrosine	84.4	86.7	88.5	85.0
Phenylalanine	87.7	87.7	82.0	84.4
Lysine	80.3	81.8	83.3	81.2
Histidine	84.2	81.6	84.9	82.7
Arginine	93.6	92.3	84.8	89.6

(1.28%), proline (1.12%), aspertic acid (1.47%) and glutamic acid (2.38%) were found in the feed.

Table 2 shows the apparent digestibility of amino acids. According to the data of the table, in groups supplied with less protein (11%), the essential AA was digested in the following percentages: methionine 93.3%, cystin 87.5

Table 3

Blood parameters of experimental animals

	Experiment I		Experiment II	
	Group A	Group B	Group A	Group B
Total protein, g/l	72.2 ± 5.00	70.4 ± 3.20	67.7 ± 3.50	72.5 ± 5.00
Urea, μmol/l	5.0 ± 0.63	4.8 ± 0.22	6.7 ± 0.90	6.4 ± 1.31
AA-N, μmol/l	6.93 ± 0.40	7.11 ± 0.73	8.21 ± 0.91	8.94 ± 0.24

and 96.7%, arginine 93.6 and 92.3%, respectively. In the groups given more protein the digestibility of the same amino acids showed the following trend: methionine 84.4 and 86.4%, cystin 86.8 and 91.9%, arginine 84.8 and 89.6%.

As for the apparent digestibility of lysine and histidine the four groups showed no considerable differences. The digestibility of threonine, serine and proline was about 2% better in groups consuming less protein than in those consuming more. In the case of leucine and isoleucine, it was the other way round: these amino acids were digested in an average 88% in the latter, and 83% in the former groups.

In Table 3 the total protein, urea and AA-N contents of the blood are summarized. It can be seen that the groups showed no substantial variation in regard to the total protein content of the blood; the concentrations were within the normal range of fluctuation.

The lowest blood urea value (4.8–5.0 μmol/l) was measured with the animals of groups A and B (11% crude protein). For the animals of groups C and D (17% crude protein) 6.7 and 6.4 μmol/l values were obtained on the average.

The quantities of total AA-N were found to be 6.93 and 7.11 μmol/l for groups A and B, and 8.21 and 8.94 μmol/l for groups C and D, respectively.

The results concerning the free amino acid content of the blood are seen in Table 4.

In the blood of group A animals, 20.9 μmol/l methionine, 23.9 μmol/l cystin, 133.8 μmol/l lysine and 143.8 μmol/l arginine were measured.

In group B, the blood contained 22.3 μmol/l methionine, 29.1 μmol/l cystin, 136.2 μmol/l lysine and 152.5 μmol/l arginine.

In group C, 30.4 μmol/l methionine, 27.1 μmol/l cystin, 166.1 μmol/l lysine and 168.2 μmol/l arginine were determined.

Table 4

Free amino acid content in blood (μmol/l)

Amino acids	Experiment I		Experiment II	
	Group A	Group B	Group C	Group D
Glutamic acid	469.6 ± 23.6	478.8 ± 10.3	672.3 ± 51.5	672.6 ± 65.8
Proline	300.5 ± 16.4	298.2 ± 16.3	364.8 ± 36.9	341.8 ± 31.8
Glycine	477.9 ± 23.3	520.2 ± 47.5	579.0 ± 71.4	548.3 ± 35.8
Alanine	453.4 ± 27.5	481.0 ± 25.3	524.1 ± 54.6	502.4 ± 22.5
Cystin	23.9 ± 2.29	29.1 ± 10.8	27.1 ± 2.13	29.7 ± 12.2
Valine	153.9 ± 20.0	146.4 ± 14.5	164.7 ± 36.2	153.5 ± 37.8
Methionine	20.9 ± 11.8	22.3 ± 14.5	30.4 ± 3.62	30.8 ± 10.9
Isoleucine	44.8 ± 13.8	49.8 ± 21.5	51.1 ± 38.2	50.6 ± 11.6
Leucine	146.5 ± 13.6	161.7 ± 12.5	129.8 ± 23.2	137.8 ± 11.5
Tyrosine	32.4 ± 17.4	34.8 ± 16.5	38.6 ± 23.0	40.6 ± 17.5
Phenylalanine	34.2 ± 20.4	35.5 ± 17.2	31.9 ± 15.3	35.3 ± 14.1
Lysine	133.8 ± 8.1	136.2 ± 26.5	166.1 ± 31.2	165.6 ± 15.0
Histidine	138.5 ± 10.3	130.0 ± 23.5	130.1 ± 15.9	126.3 ± 10.9
Arginine	143.8 ± 11.8	152.5 ± 14.5	168.2 ± 38.2	165.5 ± 16.5

In group D, the following values were obtained for the AA composition of the blood: methionine 30.8 μmol/l, cystin 29.7 μmol/l, lysine 165.6 μmol/l, arginine 165.5 μmol/l.

Of the other AA, smaller quantities were present in the blood of the groups given less protein than of those that consumed more protein.

Conclusions

According to the latest literary data (DEGUSSA Informationdienst 1984) the sulphureous AA requirement in the dry matter content of feed is 0.90% for the Angora rabbit and 0.60% for meat-type rabbit. The AA analyses of our feeds revealed (Table 1) that even the higher protein content feed only contained 0.60% sulphur, a quantity sufficient for meat production but insufficient for wool production. The animals consuming the lower protein content feed were given 0.45% cystin + methionine, which is only 50% of the quantity of sulphureous AA required for wool production. These results of our preliminary experimental work made it reasonable to supplement the feed at both protein levels with inorganic sulphate. Instead of the expensive sulphureous AA, assuring that in the microbiological processes taking place in the digestive system of the rabbit, the sulphate would be partially or fully used up in the AA synthesis and protein formation (Kulwich et al. 1954, Inaba 1973).

Our experiments indicate that, in spite of their high protein content our, rabbit feeds are poor in sulphureous AA, so their completion with synthetic methionine and cystin is justified. The Na_2SO_4 is much cheaper than the synthetic sulphureous AA, and undoubtedly contributes to satisfying the sulphur needs of the animals Teleki et al. (1985): However, the sulphureous AA cannot be fully replaced by sulphates.

The exploitation of the available AA is suggested by the apparent AA digestibility calculated on the basis of the experiments. According to our investigations, the apparent digestibility of AA was somewhat better a feed relatively poor in protein is consumed than a feed richer in protein (Table 2). Wünsche et al. (1978) obtained similar results in their experiments with young pigs.

In our experiments the digestibility of cystin, methionine and arginine proved favourable in the low protein treatment above all.

The sulphate addition did not significantly influence the apparent digestibility of AA, though the apparent digestibility of several AA (cystin, aspartic acid, glutamic acid, proline, glycine) slightly improved at both protein levels, most markedly in the case of cystin.

The more favourable digestibility of AA on consuming less protein suggests the better exploitation of the available AA. This tendency was not, in essentials, influenced by the inorganic sulphur supplement.

As for the total protein and AA-N content of blood the groups showed suggests the better exploitation of the available AA. This tendency was not, in essentials, influenced by the inorganic sulphur supplement.

As for the total protein and AA-N content of blood the groups showed no significant differences. However, in the groups receiving more protein, about 1.5 μmol/l more AA-N was found in the blood than in those supplied with less protein.

The urea content of the blood was significantly ($P < 0.05$) greater in the high than in the low protein groups (Table 3).

As for the free AA content of blood (Table 4) most of the AA, first of all glutamic acid, proline, glycine and alanine, were present in the blood in larger quantities in the groups consuming more protein than in those given less.

The sulphate supplement did not significantly influence the AA-N content of the blood, although more cystin was measured in the blood of animals consuming feed completed with sulphate.

All in all, the blood analyses that, in the blood of animals consuming more protein a larger quantity of total AA-N was present beside the urea. Of the AA it is practically the non-essential AA that grew in quantity, while the sulphate supplement increased the cystin content of the blood.

On the basis of the results of our investigations into the AA metabolism, it can be established that the sulphureous AA requirements of Angora rabbits

was not satisfied by the AA content of either feed. However, for a high quality intensive wool production, it is not enough to provide much protein; the AA composition and proportions in the protein must also be considered.

We wished to make up for the sulphureous AA deficiency of our feeds by supplying sulphate. The 0.2% Na_2SO_4 added to the feed could not solve the problem, although the parameters examined were more favourable in the groups consuming sulphate than in the control at both protein levels. Teleki et al. (1985) pointed out that neither must the ratio of nitrogen and sulphur be left out of consideration. We should like to examine the effects of the organic and inorganic sulphur supplement by future investigations.

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CHEMICAL COMPOSITION OF MILK FROM RED DEER, ROE AND FALOW DEER KEPT IN CAPTIVITY

J. Csapó, L. Sugár, A. Horn and Zsuzsanna Csapó-Kiss

UNIVERSITY OF AGRICULTURE, FACULTY OF ANIMAL SCIENCE, KAPOSVÁR, HUNGARY

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The authors analysing the milk composition from the 5th–15th day to the 2nd–3rd month of lactation for five hinds, two roes and three fallow deer determined the drymatter, total protein, true protein, casein and NPN content of milk, the amino acid composition of milk and milk protein the ash, macro- and microelement (potassium, sodium, calcium, phosphorus, magnesium, zinc, iron, copper, mangabese) content, as well as the vitamin (A, D_3, E, K_3, C) content of milk, its fat content and the fatty acid composition (C_4–C_{22}) of the butterfat. The milk of hind contains much more protein, at and vitamin does cow's milk, while there is no substantial difference between them in the ratio of protein fractions, the amino acid composition of milk protein and the fatty acid composition of butterfat.

Keywords: A-, D_3-, E-, K_3-, C-vitamin content of milk, amino acid, fatty acid, macro- and trace element, major constituents, protein fractions, milk composition of red, roe and fallow deer

Introduction

At the Kaposvár Agricultural College we decided in 1984 to domesticate the hind, introducing thereby a new animal species in meat production, considering that, on the one hand, the Hungarian stock of hind was known for its outstanding meat production, and on the other hand, Transdanubia had optimum conditions for the establishment of this new branch of animal husbandry. Owing to its peculiar digestion the hind makes better use of the feed than do cattle or sheep. In March 1985 we set about elaborating a breeding and keeping method for hind, adjusted to the Hungarian conditions. The basic requirement for establishing the new livestock branch was to have a sufficient population of tame hinds. The best solution was to raise wild fawns artificially. Considering that up to the age of 3 months the mother's milk is the most important food of the fawn, one of the essential elements of artificial rearing is to give the fawns substitute milk. Since in the relevant literature very few reliable data were available on the composition of the deer milk, a thorough analysis of it was the first step in our research work.

In the course of our experiments we had opportunity to obtain milk from the roe and fallow deer as well. Therefore — while keeping to our main

targets, to substitute milk for fawns — we extended our studies to include analyses of roe and fallow deer milk, partly for the sake of comparison, and partly to supply data to others working in those fields of research. In this paper we wish to present the results of our analyses.

We did not find any reference to studies on the composition of the hind milk in the Hungarian literature, and even the international literature contains very few reliable data on the subject.

Silver (1961), analysing the milk of white-tailed red deer living in New Hampshire (USA), found that in the first month of lactation it was of practically steady composition. Then, up to the fifth month, its dry matter, protein, fat and ash content considerably increased, while its sugar content decreased.

Schubert and Giesecke (1972), studying the fatty acid composition of the butterfat of hind on the average of the 1st to 6th month of lactation, pointed out that the deer milk contained much myristic acid, palmitic acid, stearic acid and oleic acid. Arachidic acid, behenic acid and erucic acid were not found in deer milk.

Brüggemann et al. (1973) studied the composition of deer milk from the 60th to the 80th day of lactation. They found a slight increase in the fat content and some decrease in the lactose content. The dry matter, crude protein and ash content did not change in the period concerned.

Arman et al. (1974) determined the milk composition of hinds in various stages of lactation from milk samples collected up to and after the 100th day of lactation, with the following results: the dry matter content of milk increased from 21% to 28%, the fat content from 8% to 13%, the total protein content from 7% to 8.5%, while the lactose- and ash content remained unchanged during lactation.

Krzywinsky et al. (1980) analysed the milk of five hinds during lactation, and found that the deer milk contained about twice as much dry-matter as, and two to four times more fat and total protein than, the cow's milk; while in the ash, lactose and mineral content of milk and in its fatty acid composition, there was no substantial difference between the two kinds of milk. There was a slight difference in lower and higher saturated fatty acids of which the butterfat of hind contained more, and in unsaturated fatty acids which were present in larger quantities in the cow's butterfat.

The results obtained by the above authors for the first three months of lactation are averaged in Table 1. According to Ulmenstein (1965) the milk protein content in the milk of fallow deer is 6.3–7.9% the fat content 7.9–21.0% and the lactose content 4.6–6.1%.

Treichler et al. (1974) determined the composition of roe-milk samples collected from May to July 1973. The results of analyses between the 4th and 69th day of lactation are also contained in Table 1.

Table 1

Milk composition of red deer, jumping-deer and roe according to Silver (1961) (1), Schubert and Giesecke (1972) (2), Brüggemann et al. (1973) (3), Arman et al. (1974) (4), Krzywinsky et al. (1980) (5) and Treichler et al. (1974) (6) (g/100 g milk)

Component	Author					
	(1)*	(2)	(3)	(4)	(5)	(6)**
Drymatter	22.48		22.4	22.3	23.42	24.29
Total protein	9.87		8.61	7.39	7.54	9.40
Whey protein				1.18	0.78	1.485
NPN×6.38				0.27		
Casein				5.94	6.15	7.56
Lactose	3.22		4.02	4.45	4.93	3.51
Ash	1.55		1.26	1.15	1.10	
Potassium				0.13	0.10	0.149
Sodium				0.035	0.030	0.062
Calcium				0.22	0.28	0.331
Phosphorus				0.20	0.21	0.268
Magnesium				0.018	0.027	0.022
Fat	7.83		8.61	9.4	9.98	6.61
Percent proportions of fatty acids						
C_{10}		4.3				
C_{12}		4.9				
C_{14}		17.3			14.51	
C_{16}		30.1			29.65	
C_{18}		11.3			11.38	
$C_{14:1}$		0.7				
$C_{16:1}$		2.4				
$C_{18:1}$		20.6			18.67	
$C_{18:2}$		2.4			2.21	
$C_{18:3}$		1.2			0.69	
$C_{20:2}$		1.5				

* Data of the milk of the hind
** Data of the milk of roe-doe

We did not find literary data on the protein fractions and macroelement content of fallow deer milk, on the microelement content of milk from roe, red deer and fallow deer, on the fatty acid composition of milk from roe and fallow deer, on the vitamin and amino acid contents in the milk of the three species examined and on the amino acid composition of milk protein.

Material and methods

The experiments were carried out with 5 hinds of red deer, 3 hinds of fallow deer and 2 roe-does kept in the Zoological Garden of Pécs. The hinds of red deer were accommodated in a gently sloping pound of 400 m² and made comfortable by 2 concrete sheds of 20–25 m²

each. The 8 hinds and one stag living together in the pound were given the following daily feed rations in the period in question: 30–40 kg thin-stalked good quality lucerne hay abounding in leaf, 10 kg maize grain and 4 kg bread. In addition they received 15 kg apple or 15–20 kg melon or 10 kg pumpkin and 10 kg cucumber depending on the season, and once or twice a month for three or four days fresh lucerne and fresh grass instead of or parallel to lucerne hay. Owing to the above system of feeding the animals were in good condition during the experiment.

The eleven roe-does and three roe-bucks of the zoo were kept in a pound of 600 m^2, with several sheds made of reeds for shelter against the weather. The roes consumed a good quality lucerne hay ad libitum, and in addition received the following daily average feed ration: 8 kg cob-meal, 6 kg apple, 3 kg carrot, 2–3 kg cucumber, 1 kg cauliflower, 2 kg cabbage, 1 $^1/_2$ kg bread 1.5 kg kohlrabi, 1 kg pumpkin and 1/2–2 kg biscuit. Besides they were regularly given seasonal fruit (cherry, current, pear, gooseberry) and occasionally 2–20 kg elm-, oak-, thorn-bush-, *Evonymus-*, *Robinia-* and maple-leaves. In spring they ate hedge rose- and horn-beam buds as well as dandelion and fresh lucerne. On one or two occasions a month — in the same way as the red deer — they were given fresh lucerne and fresh grass besides lucerne hay over 3–4 days.

The fallow deer consumed practically the same food as the red deer, except that, instead of maize, ruminant concentrate was given the 11 animals kept in an about 400 m^2 pound. Both the roe and the fallow deer were in good condition during the experiment due to the careful tending and feeding.

From the animals included in the experiment milk samples were taken one week after dropping, then on the 30th and 60th day of lactation. Before the milk samples were taken the animals had been immobilized by means of a Telinject syringe containing "Fentanyl" solution or "Fentanyl-Rompun" combination. For the immobilization an improvised basic solution containing "Fentanyl citrate" (Janssen Pharmaceutica, Beersel, Belgium) and 5% "Rompun" (Bayer AG, Leverkusen, GFR) was used. The syringe containing 0.5–2 cm^3 solution was shot into the animal's haunch by means of a Telinject blow pipe or Telinject gun. The immobilized animals, lying on their sides, were given Oxtocin injection (Kőbánya Pharmaceutical Factory, Budapest) in the vena jugularis or in the muscleas of the haunch to promote or induce milking. At the same time blood was taken from the vena jugularis for haematological and serological examinations. This done, the udders of the animals were washed with lukewarm water, dried with a soft cloth, and then after half a minute of intensive massage milking began. Since the teats were very small, the animals were milked by a repeated pulling of teats. When milking, which lasted for some 10–15 minutes, care was taken to empty each udder-quarter completely. The about 150–175 cm^3 milk obtained on each occasion was cooled in cold water, then carried in cooling bags to the laboratory where it was immediately frozen to −25 °C. After the sample taking a "Nalorphin" (Chinoin, Budapest) "wakening" injection was given the animals intramuscularly. The quantity of agents used in the course of the experiment are shown in Table 2.

Table 2

Quantity of immobilizing and "awakening" agents used per animal species

Species	Number	Estimated live weight (kg)	Fentanyl citrate (mg)	Rompun (mg)	Oxytocin (cm^3)	Nalorphin (mg)
Red deer	5	100–140	50–60	50–75	4	15–25
Fallow deer	3	45– 60	50–60	—	4	15–25
Roe	2	18– 22	15–20	25–30	2	10

From the 5 red deer hinds milk samples were taken on three occasions, while from the 2 roe-does and 3 fallow deer hinds only twice. On the first occasion of sampling the red deers were 5–10 days, the roes and fallow deers 15–20 days, past dropping. With most animals the examinations took place in the second and third month of lactation.

In the course of processing the milk samples, the material of examination previously cooled down to −25 °C was melted in +35 °C water, homogenized, then determined for

composition. The drymatter content was determined by drying the samples to constant weight according to the standard No. MSZ-3744–67, while for the determination of the nitrogen content a *Kjel–Foss* quick nitrogen analyser (Foss Electric Denmark) was used. The milk protein fractions were separated as described in a publication by Csapó and Csapó (1983a). The amino acid composition of milk was determined from samples lyophilized then freed of fat by means of a LKB 4101 type (LKB Biochrom, England) amino acid analyser. The milk protein was hydrolysed with 6 ml hydrochloric acid according to Moore and Stein (1951), and the sulphur-containing cystine was determined in the form of cysteic acid with a quick method elaborated by us (Csapó 1982). For determining the tryptophan content of milk protein the photometric technique of Rékási et al. (1977) was used.

The fat content of the milk samples was determined by *Gerber*'s method according to the standard No. MSZ 3703–78; while, for the determination of the fatty acid composition of butterfat in the form of fatty acid methyl esters, a *Packard 419 type gas chromatograph*, a flame ionization detector and a *Hewlett–Packard 3390 type electronic integrator* were used. In the quantitative evaluation, the weight percentage proportions of the methyl esters were regarded as equal to the proportions of the corresponding peaks in the chromatogram.

The ash content was obtained by reducing the samples to ashes according to standard No. MSZ 3726/2–76. On determining the macro- and microelement contents of the milk samples, the metal oxides were turned with hydrochloric acid into chlorides, then the metals were determined from the solution with a UNICAM SP-191 type atomic absorption spectrophotometer. The determination of the phosphorus content took place by the photometry of the blue colour produced with ammonium molybdenate.

The A_1-, D_3-, E- and K_3-vitamin content in the milk samples was determined with a Pye Unicam LC-XP type high pressure liquid chromatograph, and the C-vitamin content by *Radeff*'s method (1938).

The mean value, standard deviation and significance of the results were established by means of a HT-PTK 1050 (Telecommunication Cooperative, Hungary) type pocket computer.

Results and conclusions

The dry matter content, protein content and protein fractions of milk from red deer, roe and fallow deer are contained in Table 3. The percentage distribution of protein fraction in total protein and whey protein is seen in Table 4. Table 5 contains the amino acid composition of milk from the above animal species, while the amino acid composition of milk protein is shown in Table 6. Table 7 gives information on the ash-, macro- and microelement content of milk; Table 8 on the fat content of milk and the fatty acid composition of the butterfat, and Table 9 supplies data on the milk's vitamin content. For the purpose of comparison the tables contain the results of our earlier analyses of cow's milk. The comparison can be safety made, since during the experiment the same preparatory and analytical operations were used in determining the milk composition of the animal species concerned.

The results of our analyses unambiguously show that, in the case of the milk components studied by us in the period in question (from the 5–10th day to the 2nd to 3rd month of lactation), changes depending on the lactation could not in most cases be indicated. For this very reason the averages and standard deviations, respectively, of the results obtained on three occasions of sampling are given in the tables. That is, for the red deer the data of the tables are the averages of 15; for the roe and fallow deer the averages of 6 measurings. Since the 6 measurings for the roe and fallow deer are, in our

opinion, insufficient to establish significance, only the averages are given in the tables. These, however, may give a true picture of the composition of milk in spite of the small number of samples analysed.

The data of Table 3 reveal that the milk of roe contains about 4 per cent more dry matter than that of red deer and fallow deer which do not much differ from one another. The milk of red deer contains more than one and a half times as much dry matter as the cow's milk.

Table 3

Drymatter and protein content, and protein fractions in the milk of deer, roe and fallow deer (g/100 g milk)

Component	Species			
	Red deer $\bar{x} \pm s$	Roe	Fallow deer	Cattle* $\bar{x} \pm s$
Dry matter	19.56 ± 0.39	23.96	19.62	12.01 ± 0.24
Total protein	7.05 ± 0.26	7.01	6.90	3.54 ± 0.18
True protein	6.69 ± 0.21	6.42	6.48	3.38 ± 0.17
Whey protein	1.42 ± 0.26	1.43	1.38	0.74 ± 0.06
True whey protein	1.06 ± 0.19	0.84	0.96	0.59 ± 0.05
Casein	5.63 ± 0.25	5.58	5.52	2.80 ± 0.14
Non-protein nitrogen × 6.38	0.36 ± 0.05	0.59	0.42	0.15 ± 0.03

* Csapó and Zs. Csapó (1983a)

The red deer, the roe and the fallow deer showed no substantial variation in the total protein content of milk and the quantity of various protein fractions. The difference is the greatest in the NPN content of which the roe milk contains more than one and a half times as much as the deer milk. A comparison of deer milk and cow's milk for total protein content and protein fractions shows that the milk of deer contains twice as much of the components concerned as does the milk of cow. In the percentage ratios of the different protein fractions to the total protein content (Table 4), no essential difference between red deer, fallow deer and cattle was found, while in the milk of roe the proportions of true protein and true whey protein were lower and accordingly that of NPN was higher than in the other species examined. With the true whey protein and NPN content examined as a percentage of the whey protein, these differences in milk between the species are still more conspicuous. The NPN content of whey protein is more than 40% in roe, more than 30% in fallow deer and about 25% in red deer; while the whey protein of the cow's milk only contains about 20% NPN. The difference in the NPN content of whey protein between deer and cattle is significant at $P = 1\%$.

Table 4

Distribution of total protein in the milk of red deer, roe and fallow deer

Total protein = 100%

Protein fraction	Species			
	Red deer	Roe	Fallow deer	Cattle
Total protein	100	100	100	100
True protein	94.89	91.58	93.91	95.85
Whey protein	20.14	20.40	20.00	20.96
True whey protein	15.04	11.98	13.91	16.75
Casein	79.86	79.60	80.00	79.04
Non-protein nitrogen × 6.38	5.11	8.42	6.09	4.21
Whey protein = 100%				
Whey protein	100	100	100	100
True whey protein	74.68	58.73	69.55	79.91
Non-protein nitrogen × 6.38	25.32	41.27	30.45	20.09

Table 5 shows the quantity of amino acids in the milk of red deer, roe and fallow deer in comparison to the cow's milk. As seen from the data, the milk of red deer, roe and fallow deer contains about twice as much of each amino acid as the cow's milk — in accordance with the total protein content of milk. On the quality of the milk protein, that is on the quantity of amino acids in 100 g protein, information is given in Table 6. A survey of the data in Table 6 reveals that there is no significant difference in the composition of milk protein between deer and cattle, as regards most amino acids, except the following:

Gly at P = 1%, Met at P = 0.1%, Tyr at P = 0.1% are significantly more in the milk protein of deer than in that of cow;

Ala at P = 5%, Val at P = 0.1%, Leu at P = 0.1%, Arg at P = 1% level are significantly less in the milk protein of deer than in that of cow.

The analysis of the amino acid composition of milk protein for the four species clearly shows that the milk protein of the cow contains less threonine and lysine than that of the deer, and the difference is even more remarkable — nearly 30% — in the case of the sulphur-containing methionine. In all the other cases the differences (even if significant) are not of such an extent as would require special attention when rearing fawns with the milk protein of cow's milk.

Table 7 contains the results obtained for the ash-, macro- and micro-element content of milk. According to the data the ash content (1.40%) of the roe milk is about 0.26% higher than that of the deer milk (1.14%) the ash

Table 5

Amino acid composition of milk of red deer, roe and fallow deer (g amino acid/100 g milk)

Amino acid	Species			
	Red deer $\bar{x} \pm s$	Roe	Fallow deer	Cattle* $\bar{x} \pm s$
Asparagic acid	0.47 ± 0.023	0.47	0.37	0.25 ± 0.011
Threonine	0.29 ± 0.021	0.30	0.26	0.13 ± 0.007
Serine	0.40 ± 0.015	0.37	0.35	0.19 ± 0.007
Glutamic acid	1.55 ± 0.068	1.51	1.33	0.71 ± 0.029
Proline	0.69 ± 0.046	0.68	0.77	0.33 ± 0.017
Glycin	0.16 ± 0.014	0.17	0.12	0.06 ± 0.006
Alanine	0.21 ± 0.013	0.20	0.20	0.11 ± 0.006
Cystine	0.051 ± 0.006	0.059	0.054	0.026 ± 0.003
Valine	0.37 ± 0.023	0.40	0.32	0.22 ± 0.010
Methionine	0.23 ± 0.013	0.23	0.20	0.09 ± 0.005
Isoleucine	0.29 ± 0.009	0.29	0.27	0.18 ± 0.005
Leucine	0.64 ± 0.044	0.64	0.58	0.33 ± 0.014
Tyrosine	0.37 ± 0.009	0.39	0.34	0.16 ± 0.004
Phenylalanine	0.31 ± 0.011	0.29	0.26	0.16 ± 0.006
Lysin	0.57 ± 0.035	0.55	0.49	0.27 ± 0.014
Histidine	0.20 ± 0.028	0.21	0.16	0.09 ± 0.008
Arginine	0.21 ± 0.010	0.17	0.18	0.12 ± 0.004
Tryptophan	0.11 ± 0.012	0.11	0.10	0.045 ± 0.004
Ammonia	0.11 ± 0.022	0.09	0.13	0.06 ± 0.009
Total	7.231	7.129	6.484	3.531

* Csapó and Zs. Csapó (1983b)

content in the milk of red deer is 0.18% higher than in that of fallow deer, and is significantly higher by some 0.4% (P = 0.1%) than in the cow's milk.

No essential difference in the potassium content of milk was found between red deer, roe and fallow deer. The potassium content of the red deer milk — 1546 mg/kg — is significantly higher than that of the cow's milk (P = 0.1%). As for the sodium content of milk, significant difference between red deer and cattle could not be found and the quantity of sodium in the milk was the same in the case of the fallow deer as well. The sodium content in roe milk (903 mg/kg), on the other hand, is almost twice as much as in the milk of these other three species.

The calcium content of milk is 900 — and its phosphorus content 400 mg/kg more for roe than for red deer. The calcium and phosphorus content of milk (2617 and 1774 mg/kg, respectively) is some 700–800 mg/kg higher for red deer than for fallow deer, and significantly higher (P = 0.1%) than for cattle. The roe milk contains about 60–80 mg/kg more magnesium than does

Table 6

Amino acid composition of milk protein in red deer, roe and fallow deer (g amino acid/100 g milk protein)

Amino acid	Species			
	Red deer $\bar{x} \pm s$	Roe	Fallow deer	Cattle $\bar{x} \pm s$
Asparagic acid	6.7 ± 0.33	6.7	5.8	7.4 ± 0.32
Threonine	4.1 ± 0.29	4.3	4.1	3.7 ± 0.21
Serine	5.6 ± 0.21	5.3	5.5	5.4 ± 0.19
Glutamic acid	21.9 ± 0.96	21.5	20.8	20.6 ± 0.84
Proline	9.8 ± 0.65	9.7	12.1	9.6 ± 0.48
Glycin	2.3 ± 0.20	2.4	1.9	1.8 ± 0.17
Alanine	2.9 ± 0.19	2.9	3.1	3.3 ± 0.16
Cystine	0.73 ± 0.09	0.9	0.9	0.75 ± 0.08
Valine	5.3 ± 0.33	5.7	5.0	6.4 ± 0.29
Methionine	3.2 ± 0.18	3.3	3.1	2.5 ± 0.15
Isoleucine	4.1 ± 0.13	4.1	4.2	5.1 ± 0.14
Leucine	9.0 ± 0.62	9.1	9.1	9.5 ± 0.41
Tyrosine	5.3 ± 0.13	5.6	5.3	4.5 ± 0.10
Phenylalanine	4.4 ± 0.16	4.1	4.1	4.5 ± 0.17
Lysin	8.0 ± 0.49	7.8	7.7	7.8 ± 0.39
Histidine	2.8 ± 0.40	3.0	2.5	2.6 ± 0.22
Arginine	2.9 ± 0.14	2.4	2.8	3.4 ± 0.11
Tryptophan	1.5 ± 0.16	1.4	1.4	1.3 ± 0.12
Ammonia	1.5 ± 0.31	1.3	2.0	1.7 ± 0.27

Table 7

Drymatter, ash, macro- and microelement content of milk in red deer, roe and fallow deer

Component	Species			
	Red deer $\bar{x} \pm s$	Roe	Fallow deer	Cattle* $\bar{x} \pm s$
Dry matter, g/100 g	19.56 ± 0.39	23.96	19.62	12.01 ± 0.24
Ash, g/100 g	1.14 ± 0.040	1.40	0.96	0.736 ± 0.024
Potassium, mg/kg	1546 ± 88	1606	1499	1268 ± 88
Sodium, mg/kg	454 ± 9.5	903	432	490 ± 38
Calcium, mg/kg	2617 ± 115	3513	1918	1193 ± 76
Phosphorus, mg/kg	1774 ± 120	2188	1151	947 ± 70
Magnesium, mg/kg	155.5 ± 18.6	220.8	167.9	133.7 ± 7.2
Zinc, mg/kg	12.9 ± 1.48	15.7	10.6	4.89 ± 0.76
Iron, mg/kg	1.78 ± 0.27	4.62	4.32	0.92 ± 0.12
Copper, mg/kg	0.338 ± 0.037	0.482	0.499	0.311 ± 0.046
Manganese, mg/kg	0.169 ± 0.041	0.301	0.168	0.081 ± 0.015

* Csapó and Zs. Csapó (1982)

the fallow deer and red deer milk. There was no significant difference in the magnesium content of milk between red deer and cattle.

Of the four species examined the roe has the highest zinc content in milk (15.7 mg/kg). The zinc content of red deer milk (12.9 mg/kg) is significantly higher than that of cow's milk. The iron content in the milk of red deer (1.78 mg/kg) is about one-fifth of that in the milk of roe and fallow deer, but nearly twice as high as in the cow's milk. The difference is significant at $P = 0.1\%$. The copper content in the milk of roe and fallow deer is almost one and a half times more than in the milk of red deer. While the latter has practically the same copper content as the cow's milk, no significant difference between them could be pointed out. The quantity of manganese in the roe milk is nearly one and a half times as much as in the milk of red deer and fallow deer, while the manganese content of the red deer milk is twice that of the

Table 8

Fat content of milk and fatty acid composition of butterfat in red deer, roe and fallow deer

Fatty acid (carbon number: double bond number)		Species			
		Red deer	Roe	Fallow deer	Cattle*
		Relative weight % of fatty acid methyl esters			
		$\bar{x} \pm s$			$\bar{x} \pm s$
Butyric acid	(4 : 0)	0.31 ± 0.107	0.15	0.72	0.52 ± 0.111
Capronic acid	(6 : 0)	0.29 ± 0.072	0.19	0.30	0.56 ± 0.094
Caprylic acid	(8 : 0)	0.86 ± 0.079	0.31	0.59	0.27 ± 0.022
Capric acid	(10 : 0)	2.51 ± 0.216	1.02	1.08	2.61 ± 0.219
Lauric acid	(12 : 0)	3.90 ± 0.356	1.43	1.47	4.35 ± 0.362
Myristic acid	(14 : 0)	16.45 ± 1.050	9.11	16.40	14.00 ± 0.998
Myristoleic acid	(14 : 1)	0.72 ± 0.231	0.08	0.71	1.41 ± 0.329
Pentadecanoic acid	(15 : 0)	0.99 ± 0.295	0.66	1.46	1.32 ± 0.194
Pentadecylic acid	(15 : 1)	0.33 ± 0.072	0.25	1.81	0.23 ± 0.050
Palmitic acid	(16 : 0)	34.88 ± 1.879	26.01	30.65	44.06 ± 2.100
Palmitoleic acid	(16 : 1)	2.78 ± 1.580	0.83	2.23	2.08 ± 1.009
Margaric acid	(17 : 0)	0.63 ± 0.271	1.03	1.33	0.60 ± 0.228
Heptadecylic acid	(17 : 1)	0.24 ± 0.049	0.40	0.75	0.46 ± 0.063
Stearic acid	(18 : 0)	11.81 ± 1.442	22.93	11.43	7.94 ± 1.001
Oleic acid	(18 : 1)	19.77 ± 1.773	27.25	25.58	17.25 ± 1.533
Nonadecanoic acid	(19 : 0)	0.035 ± 0.013	0.05	0.05	0.032 ± 0.009
Linolic acid	(18 : 2)	1.71 ± 0.262	2.65	2.56	1.72 ± 0.198
Arachidic acid	(20 : 0)	0.36 ± 0.059	0.57	0.34	0.19 ± 0.019
Linoleic acid	(18 : 3)	0.71 ± 0.052	2.02	0.10	0.09 ± 0.002
Behenic acid	(22 : 0)	0.11 ± 0.021	0.19	0.10	0.15 ± 0.019
Eicosatric acid	(20 : 3)	0.272 ± 0.042	2.40	0.31	0.20 ± 0.031
Erucic acid	(22 : 1)				
Fat content (g/100 g milk)		7.71 ± 0.53	11.90	8.36	3.72 ± 0.23

* According to our own experiment

cow's milk; the difference in the manganese content of milk between the two species is significant at P = 0.1%.

To summarize the above, it can be said that the milk of red deer contains significantly more ash, potassium, calcium, phosphorus, zinc, iron and manganese than the cow's milk (P = 0.1%), while in the case of sodium, magnesium and copper significant difference between the two species could not be discovered. With the exception of calcium and phosphorus content, no remarkable difference in the macro- and microelement content of milk was found between red deer and fallow deer. Apart from the amount of potassium and copper, the milk of roe contained substantially more macro- and microelement than the milk of the other three species examined. An analysis of milk from a larger number of animals would probably yield a statistical proof of the differences in mean value.

The fat content of milk and the fatty acid composition of butterfat are seen in Table 8. The data of the table show that the fat content of milk is nearly the same for red deer and fallow der, while the quantity of fat in the milk of roe is substantially larger than in the milk of the former two species. As to the fatty acid content of butterfat, the deer milk was found to contain significantly more caprylic acid, myristic acid stearic acid, arachidic acid and linoleic acid (P = 0.1%), less caproic, palmitic and heptadecylic acid (P = = 0.1%), and less butyric, myristoleic and behenic acid (P = 1%) than the cow's milk. In all the other cases examined significant difference in the fatty acid composition of butterfat could not be found between the two species. The most important of all differences proved by significance tests was the one in palmitic, and stearic acid, while the differences obtained in all the other cases — even if significant — need not be considered when rearing fawns with milk substitute prepared from cow's milk.

The fatty acid composition of butterfat in the fallow deer's milk does not much differ from that in the cow's milk. Of the four species the fallow deer's butterfat contains the largest quantity of butyric, pentadecylic, heptadecylic and oleic acid. Accordingly, the butterfat of fallow deer seems to be the richest in unsaturated fatty acids in the range of 14–18 carbon atomic number. In the range of 4–16 carbon atomic number the lowest while in the 18–22 range the highest quantity of fatty acid is contained in the butterfat of roe. Thus the butterfat of roe contains the largest quantity of multiply-unsaturated linolic, linoleic and eikosatric acid considered essential. The differences in the mean values of the latter three faty acids are so great between roe and deer, and roe and cow, respectively, that examinations performed with a larger number of animals could probably prove them significant.

The vitamin A content of the deer milk (0.588 mg/kg) is about 1.7 times higher than that of the cow's milk (0.352 mg/kg) (Table 9). The difference between deer milk and cow's milk is still greater in the quantity of vitamin D_3.

Table 9

Vitamin content in the milk of red deer, roe and fallow deer

Component	Species			
	Red deer $\bar{x} \pm s$	Roe	Fallow deer	Cattle* $\bar{x} \pm s$
Vitamin A (mg/kg)	0.588 ± 0.051	2.084	0.531	0.352 ± 0.044
Vitamin D_3 (mg/kg)	0.0139 ± 0.0014	0.0354	0.0122	0.0029 ± 0.0005
Vitamin E (mg/kg)	1.383 ± 0.285	2.182	1.271	1.135 ± 0.242
Vitamin K_3 (mg/kg)	0.057 ± 0.009	0.084	0.058	0.032 ± 0.006
Vitamin C (mg/kg)	22.4 ± 0.89	31.8	24.8	15.32 ± 0.29**

* According to our own experiment
** Csapó and Zs. Csapó (1984)

The deer milk contains almost five times as much vitamin D_3 (0.0139 mg/kg) as the cow's milk (0.0029 mg/kg). The deer milk contains some 1.2 times more vitamin K_3 and about one and a half times more vitamin C than the cow's milk. The above differences between the two species are significant a P = 0.1%. No significant difference between deer milk and cow's milk was found in the quantity of vitamin K_3. The vitamin content of milk from red deer shows high conformity to that from fallow deer; in several cases the mean values are almost the same. The milk of red deer contains slightly more vitamin A, D_3 and E, while the amount of vitamin K_3 and C is somewhat more in the milk of fallow deer. The similarity of the mean values suggests that the differences would not be statistically demonstrable even in the case of examinations with a larger number of animals. The milk of roe contains essentially more of all the five vitamins concerned than the milk of red deer and fallow deer. The milk of roe contained three and a half times more vitamin A, two and a half times more vitamin D_3, 1.6 times more vitamin E, one and a half times more vitamin K and 1.4 times more vitamin C than the milk of red deer and fallow deer. It is highly probable that examinations with a larger number of animals would prove the above differences significant.

Evaluation of the results

The percentage value (19.56%) obtained for the dry matter content of deer milk on the average of the months of lactation is about 1.5–2.5% lower than the results published by the reference authors.

The total protein content of deer milk determined by us (7.05%) is 1–1.5% lower than the values obtained by Brüggemann et al. (1973), but shows good agreement with the 6.77–7.14% pointed out by Arman et al. (1974)

and Krzywinsky et al. (1980). As to the protein fractions in the milk of deer, our results for casein, whey protein and NPN agree with the data obtained by Arman et al. (1974). The casein content of deer milk (5.37–6.93%) as determined by Krzywinsky et al. (1980) corresponds to our measuring data, while the value we obtained for whey protein (1.06%) is about one and a half times higher than the one they determined. The value we obtained for the total protein content in the milk of fallow deer (6.90%) corresponded to the 6.3–7% result published by Ulmenstein (1985), and a similar agreement exists between our measuring data of roe milk and those obtained by Treichler et al. (1974). Essential differences were only found in the total protein- and casein content for which the values they determined were higher by about 1.5–2% than the ones we obtained.

The 1.14% we pointed out for the ash content of deer milk on the average of the first 2–3 months of lactation was about 0.1% lower than the values obtained by Brüggemann et al. (1973), and practically agreed with the percentages (1.09–1.18%) determined by Arman et al. (1974) and Krzywinsky et al. (1980).

The quantity of potassium in deer milk (1546 mg/kg), as measured by us, somewhat larger than what Arman et al. (1974) and Krzywinsky et al. (1980) indicated. The 454 mg/kg value of sodium content is higher than the one obtained by Arman et al. (1974) and practically agrees with the data published by Krzywinsky (1980). The 2617 mg/kg value measured by us for the calcium content of deer milk is between the values of the mentioned two authors, while the value we obtained for phorphorus content (1774 mg/kg) corresponds to the lowest values that the mentioned authors determined as the phosphorus content of deer milk. The 155.5 mg/kg milk quantity of magnesium measured by us is slightly lower than the results obtained by the authors cited. Our data for the macroelement content of roe milk practically agree with those published by Treichler et al. (1974) with the difference that our values are slightly higher for sodium and theirs for phosphorus.

The 7.71% value obtained by us for the fat content of deer milk on the average of the first and second month of lactation is about 1.5–2.5% lower than those determined by the other authors cited. The value we obtained for the fat content of roe milk (11.9%) is almost twice that (6.61%) published by Treichler et al. (1974).

The fatty acid composition of butterfat in deer milk was analysed by Schubert and Giesecke (1972) and Krzywinsky et al. (1980). With their measuring results compared to one another and to ours it can be said that, considering the conditions (different methods of determination, sub-species, sampling), they are in agreement. Any remarkable difference is only found in the case of palmitic acid (our values are 4–5% higher) and linolic acid (our values are 0.3–0.7% lower), and compared to the results of Schubert and

Giesecke (1972) in the case of capric acid and lauric acid, for which we obtained 1.5–2% lower values than the authors cited. Measuring data for the low carbon number fatty acids (butyric acid, capric acid, caprylic acid), and for the 20–22 carbon number eikosatric acid (C = 20:3) and erucic acid (C = 22:1) were not found in the works of the mentioned authors, supposedly because the quantities concerned were very small, on the one hand; and the technics of gas chromatography has made a very great progress for 5 and 13 years, respectively, and than just reached the level where the analysis of substances difficult to find and identify can be carried out, on the other. On the fat content of the milk of fallow deer, the composition of the butterfat of roe and fallow deer, and the vitamin A, D_3, E, K_3 and C content of milk from red deer, roe and fallow deer, literary data are not availabe.

A comparison of the components of deer milk to those of cow's milk makes it clear that, on rearing fawns with cow's milk, attention must by all means be paid to mineral supplementing. Of the macro- and microelements emphasis should be laid first of all on calcium and phosphorus, and on zinc, iron and manganese, respectively. As for the fatty acid composition of butterfat, it can be established that in this respect no such differences exist between cow and deer as would affect the rearing of fawns. Vitamin supplements, however, are in any case needed. Special attention should be paid to supplementing vitamin D_3 of which the deer milk contains five times as much, while of all the other vitamins only about one and a half times as much as the cow's milk.

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LECTURE

SITUATION OF SHEEP FARMING IN THE WORLD*

D. LAKATOS and L. VERESS

UNIVERSITY OF AGRICULTURAL SCIENCE, DEBRECEN, HUNGARY

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Trends in sheep population

The role of sheep in animal farming on a global scale can best be judged if examined in juxtaposition with that of other livestock. Applying FAO's rates of conversion, we can establish that in 1982 the *productive livestock population of the world* amounted to 1.442, together with poultry to 1.476, million animals. Of this sum 69.7% was made up of cattle and other ruminants, 8.4% of draught animals; pigs came to 10.6%, goats, competing with sheep in many parts of the world to 3.3%, and sheep to 8%. With poultry included, the relative share of the sheep population was 7.8%.

Besides registering structural patterns, it is also expedient to survey the *dynamic of prevailing changes.* In these investigations the sequence of the years 1972–1982 will be presented against the background of the average values of the years 1961–1965. Figure 1 shows that the rate of growth in fodder-consuming poultry and pig breeds is considerable, and apart from the rather stagnant population of draught animals, it is the least spectacular in sheep. Nearly half the growth in the cattle, pig and poultry population took place in the years following 1972. In this period the annual rate of increase in the goat population was 2.15%, while in sheep it only came to 1.13%. For the past five years, the sheep population has increased more rapidly, with an annual growth rate of 2.24%.

In the average of the years 1961–1965, the world sheep population was around one billion, which grew to 1.158 billion by 1982, a growth rate of 15%. From a regional aspect, the rate of growth was highest in Asia (47.4%) and Africa (37.0%). In Europe this rate was 6.6%, in the Soviet Union 6.3%, in Oceania it was stagnant, whereas the rate of decline in the sheep population was 38.9% in North and Central America and 10.7% in South America. In the future, the sheep population in Asia and Africa is expected to show a more dynamic growth; in Europe and North America, a more moderate increase.

* Lecture held at the International Symposium On Sheep Production On Big Farms Debrecen, Hungary 14–16 August 1984.

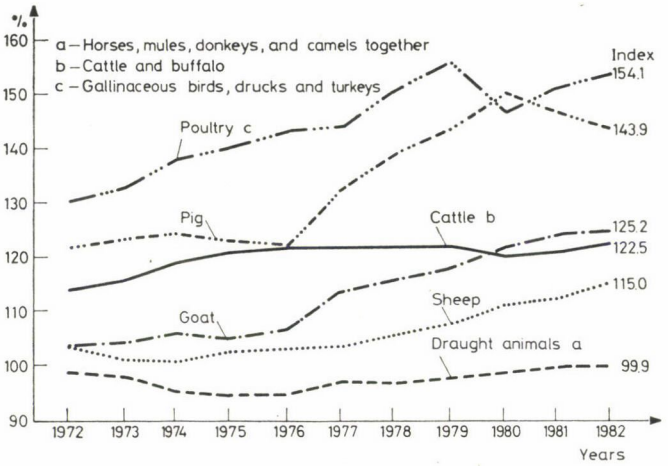

Fig. 1. Comparative changes in the volume of the major species of livestock, 1972–1982 (1961–1965 = 100)

The percentage share of sheep population and the production value of sheep produce of the *countries with the largest sheep populations in the world* is shown, on the basis of data for 1982, in Fig. 2. From these data and the trends inherent in them, certain conclusions can be drawn as to the general tendencies of the branch on a world scale. To the Soviet Union belongs 12.3% of the world's sheep population, China's share is 9.4%, that of New Zealand

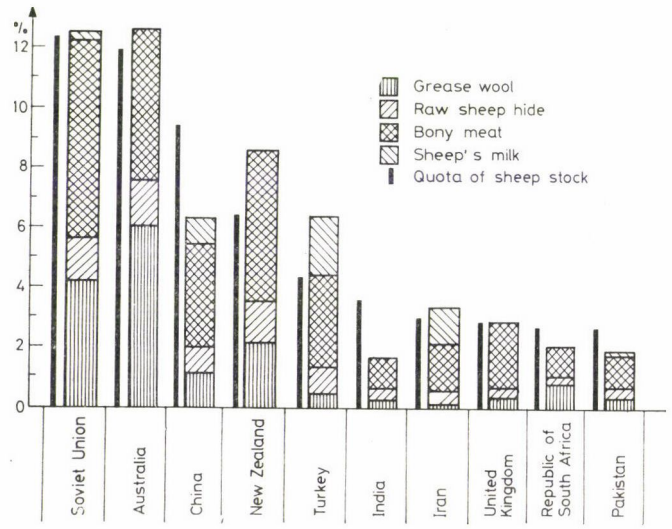

Fig. 2. The distribution of sheep stock and the production value of sheep products in the top ten sheep-farming countries

6.4%, while Turkey, India, Iran, the United Kingdom, the Republic of South Afrika and Pakistan — in a decreasing order — posses 2.7% to 4.3% of the total. In the period of time investigated, these 10 countries were responsible for a 17% increase: the relative proportion of their stocks rose from 58.3 to 59.2%. Pakistan achieved a growth of 170% China almost 70%, Turkey, New Zealand and Iran between 40 and 50% and only the Republic of South Africa experienced a decline.

The distribution of the sheep populations and the *intensity* of sheep farming in proportion to the size of land, grassy areas, and the size of population is rather heterogeneous. The first three columns in Table 1 provide an illustration of these indicators of density. The number of sheep related to 100 ha of land in Europe is 3.41 times, in Oceania 2.85 times as many as the world average, while in North and Central America this number amounts to merely 12% of the average. While in Europe 4.55 times, in Asia 1.45 times as many sheep belong to 100 ha of meadow in regard to the world average, in North

Table 1

Intensity indexes concerning the value of the sheep population and sheep products by regions in 1982

Regions	Sheep population (head)			Value of sheep products ($)		
	for 100 ha of area	for 100 ha of meadow-pasture	for 100 people of pop.	for 100 ha of area	for 100 ha of meadow-pasture	for 100 people of pop.
Africa	6.28	23.75	37.30	151	572	899
North and Central America	1.07	6.42	5.89	49	234	215
South America	6.17	23.81	42.98	107	411	742
Asia	12.81	52.85	12.84	421	1736	422
Europe	30.22	165.99	29.26	1575	8650	1 525
Oceania	25.18	45.13	910.91	949	1700	34 315
Soviet Union	6.39	38.10	52.75	217	1295	1 792
World Total	8.85	36.50	25.22	296	1221	844
*In percentage of World average**						
Africa	71	65	148	51	47	107
North and Central America	12	18	23	13	19	25
South America	70	65	170	36	34	88
Asia	145	145	51	142	142	50
Europe	341	455	116	532	708	181
Oceania	285	124	3612	321	139	4 066
Soviet Union	72	104	209	73	106	212

* Calculations from FAO data

and Central America the relative share is only 18% of the average. In especially sparsely populated Oceania, over 900 sheep are alotted to every 100 of the human population, which is 36 times more than the world average. At the same time, densely populated Europe and Asia, despite their more favourable sheep-per-area ration, lag behind in terms of the number of sheep per 100 of human population.

The considerable differences in territorial density indicators are simultaneously indicative of fundamental divergences in the climatic features, the fertility of the soil and, consequently, in the sheep maintenance capacity of the different regions of the earth. While, for instance, fertile plain areas with a sufficient level of nutritive capability and precipitation can maintain 15–20 ewes per 1 ha of pasture, in the African or Australian desert and semidesert areas, 20–25 ha could maintain a single sheep.

The economic importance and price conditions of sheep farming

The economic significance of sheep farming is well illustrated by the fact that it supplies 6% of the total bony meat production relative to cattle, pigs, poultry and sheep, 1.7% of milk, 5–6% of textile raw materials, and 11–12% of hides and skins as well as fur production (Hoffmann et al. 1981). Sheep production occupies and essential proportion of the national economies of a number of countries: in Australia, Mongolia, New Zealand and Iceland it provides tow-thirds of the production value of agriculture, in Greece 20%, and in Argentina, Bulgaria, Rumania and Spain over 10% is supplied by sheep products (Veress, Jankowsky, Schwark et al. 1982).

The international trade in sheep products is very active. Over 3/4 of fur production, 2/3 of wool, about 1/3 of mutton is sold on international markets. The output and trade of sheep products are a function of supply and demand as well as of cost and price relations. Of these two relations we shall emphasize the latter.

Table 2 illustrates *the average prices of sheep products on the European markets* in $/kg. It should be noted that in our calculations, with the exception of wool where we used the actual export prices of the regions and countries concerned, prices pertaining to the year 1982 have been applied.

Analysing the facts of Table 2, we find that the competitive position of pelt used by the fur industry in the 1970's significantly improved, despite the fluctuations in price, in comparison with wool used in the textile industries: in the whole period surveyed, its overall price index, depending on quality, multiplied by 3.5 to 4.5 orders of magnitude, while that of wool only rose 1.5 to twice as much. The prices of better quality products obviously rose at a more rapid rate, while poorer quality has recently undergone a decline in price. As shown in Table 2 the 1964 price ratio of 1 : 0.93 : 0.87 for wool of

different quality changed by 1983 to 1 : 0.88 : 0.68. As regards the size of furs, no similar correlation emerged, the value judgement of the market being rather unpredictable in this aspect.

The chief conclusion that can be drawn from Table 2 seems to be the fact that the *increase in the prices of all sheep products exceeded the increase in the price of wool.* Among the products hitherto not discussed, live slaughter sheep sold 4.6 times, slaughtered sheep 3.2 times, and ewe-cheese 4.4 times higher in 1983 than in 1964. It is worth mentioning that the price of ewe-cheese had a steady, uninterrupted rise between 1970 and 1980. According to the 1984 data of Ráki and Raskó, at Hungarian export prices 1 kg of wool in 1982 was equivalent to 0.9 kg of slaughter sheep or 2.4 kg of ewe's milk. The exceptional rise in the price of sheepskin and the added risk of marketing must have contributed to the favourable development of the price of live slaughter sheep. It can be observed that from 1981–1982 the prices of all sheep

Table 2

The formation on the prices of some important sheep products in European markets

Me: $/kg

Years	Grease combed wool[1]			Slaughter sheep[2]		Ewes cheese[2]	Sheepskin[3]	
	64's	58's	56's	live	slaughtered		7000–9000	3000–4000
							sg•cm	
1964	2.82	2.62	2.46	0.35	—	0.67	1.33	1.85
1965	2.57	2.24	2.07	0.34	0.93	0.70	1.05	1.86
1966	2.83	2.43	2.29	0.37	0.99	0.71	1.24	2.18
1967	2.53	2.06	1.93	0.40	1.26	0.67	1.20	2.12
1968	2.53	2.01	1.80	0.41	0.95	0.79	0.94	1.96
1969	2.38	1.82	1.70	0.44	0.94	0.71	0.84	2.14
1970	1.97	1.58	1.51	0.52	1.09	0.72	1.02	2.27
1971	1.78	1.58	1.41	0.54	1.12	0.88	2.72	2.13
1972	3.03	2.70	2.50	0.79	1.47	1.26	2.86	2.56
1973	6.99	6.10	5.13	1.07	1.66	1.46	4.13	4.08
1974	4.72	3.87	3.47	1.11	1.90	1.73	5.56	3.09
1975	4.35	3.57	3.08	1.20	1.88	2.04	5.21	3.74
1976	4.03	3.68	3.49	1.15	1.64	2.19	4.87	6.54
1977	4.31	3.92	3.60	1.28	2.05	2.44	7.37	6.57
1978	4.49	4.05	3.76	1.43	2.35	2.72	7.81	5.62
1979	5.24	4.43	4.37	1.55	2.71	2.89	7.83	6.33
1980	5.98	4.89	4.58	1.79	3.39	3.17	9.51	8.86
1981	6.36	5.53	4.39	1.84	3.91	3.14	8.59	7.80
1982	5.98	5.01	4.04	1.63	3.16	3.16	5.95	6.33
1983	5.39	4.76	3.64	1.61	2.99	2.94	.	.

[1] Price quoted in European markets
[2] Hungarian export price at border parity
[3] Air-dry: Hungarian import price

products have declined, which can be accounted for by the diminishing solvency and oversupply as a result of increased production.

On the basis of the data in Table 2, a clear picture can also be formed with respect to the changes in price rates. The quantity (in kg) of sheep products equivalent to 1 kg of combed wool of medium quality developed as follows:

	In 1964	In 1983
Live slaughter sheep	7.49	2.96
Slaughtered sheep	2.82	1.59
Ewe's cheese	3.91	1.62
Sheepskin, 3000–400 sq·cm	1.42	0.75

The general features of the production of sheep-produce

Figure 3 shows the parallel time sequences of sheep population and the production of sheep-produce. The sheep population increased by 15%, 4/5 of which has taken place in the past decade. Wool production showed a comparatively slower growth. The production of sheepskin, however, rose 48.9%, that of ewe's milk 33.9% and bony meat 21.8%, especially in recent years.

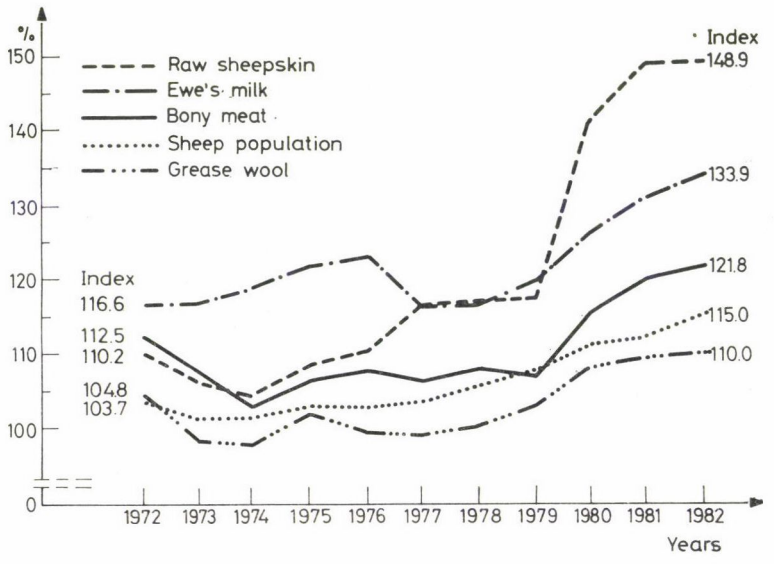

Fig. 3. World sheep population and sheep products output indexes for 1972–1982 (1961–1965 = 100)

The specific indexes are also indicative of the intensity of production. The wool production of an average sheep decreased by 4.3% (from 2.58 to 2.47 kg), while each animal produced 31.4% more sheepskin (0.86 versus 1.13 kg), 6.7% more of bony meat (5.05 vs. 5.39 kg), and 17.5% more of ewe's milk (6.00 vs. 7.05 kg). It should be noted that, according to market demands, there is a possibility of replacement between wool and sheepskin.

Table 3

*The value and percentage distribution of sheep products by regions in 1983**

Regions	Grease wool	Raw sheepskin	Bony meat	Ewe's milk	Total	Grease wool	Raw sheep-skin	Bony meat	Ewe's milk	Total
	million $					%				
Africa	573	1106	2 369	438	4 486	13	24	53	10	100
North and Central America	95	120	616	.	831	11	15	74	.	100
South America	689	323	834	23	1 869	37	17	45	1	100
Asia	1369	1563	6 002	2337	11 271	12	14	53	21	100
Europe	658	734	3 756	2296	7 444	9	10	50	31	100
Oceania	3314	1129	3 554	.	7 997	41	14	45	.	100
Soviet Union	1655	529	2 590	63	4 837	34	11	54	1	100
World Total	8353	5504	19 721	5157	38 735	22	14	51	13	100

* Calculations from FAO data

It should be noted at this point that in our further calculations on the basis of the available data in the FAO Yearbooks we could only use the values of mass-produced raw materials. Thus, they do not include the growth of the value of breeding animals and the value of special sheepskins as an economic performance. The differences in quality expressed as price differences could only be considered in the case of wool; in other products, the data pertaining to the respective regions and countries have been calculated at uniform prices.

Table 3 illustrates the relative contribution of the individual continents to the world production of sheep products and it also shows their characteristic product structure in terms of percentage. Africa excels in the production of sheepskin, North and Central America in that of bony meat, Europe in the production of ewe's milk, Oceania in that of wool, when related to the general pattern.

Oceania contributes to the production of grease wool with 38%, Asia and the Soviet Union with 16% each. In the production of raw sheepskin Asia's share is 28% Oceania's 21% and Africa's 20%. In the production of bony meat Asia leads the field with 31%, followed by Europe's 19% and Oceania's 18%. The joint share of Asia and Europe in the production of ewe's

Table 4

*The percentage share of the regions of world production in 1982**

Regions	Grease wool	Raw sheepskin	Bony meat	Ewes milk
Africa	7	20	12	9
North and Central America	2	2	3	—
South America	11	6	4	0.0
Asia	16	28	31	45
Europe	10	13	19	45
Oceania	38	21	18	—
Soviet Union	16	10	13	1
World Total	100	100	100	100

* Calculated from FAO data

milk is 90% while no ewe's milk is produced in North and Central America, Oceania (Table 4).

Figure 4 offers and illustration of the production standard in sheep farming on the basis of *production value* expressed in dollars and *related to a single average sheep*. The world average of this is $ 33.37, with Europe ($53.06) leading Oceania ($39.35) and Asia ($31.41). The world average sum is distributed thus: wool $7.13, sheepskin $4.75, bony mutton $17.04, and milk $4.45. In the same order, the leading regions as to the individual product-groups are Oceania, Africa, Europe, North and Central America, and again Europe. The values presented in Figure 4 are illustrated by percentages in Table 5.

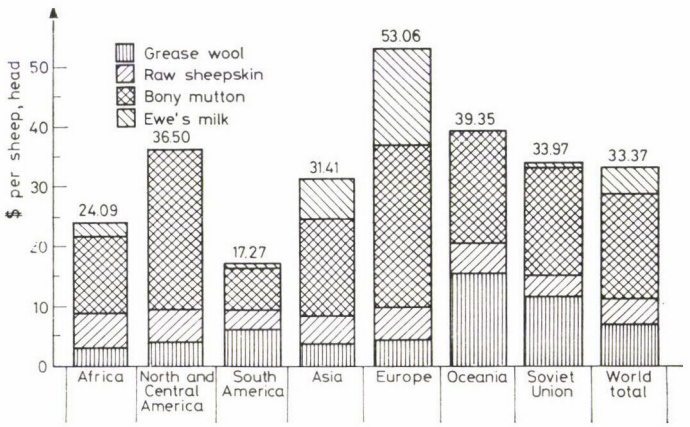

Fig. 4. The regional output of respective sheep products in 1982

Table 5

*The production of sheep produce per sheep by regions in the percentage of the world average**

Regions	Grease wool	Raw sheepskin	Bony mutton	Ewes milk	Total
Africa	43	125	75	53	72
North and Central America	58	111	159	—	109
South America	89	63	45	5	52
Asia	56	96	94	153	94
Europe	65	108	160	361	159
Oceania	219	112	108	—	118
Soviet Union	163	78	107	10	102

* Calculated from FAO data

The last three columns in Table 1 offer an opportunity to examine the *regional density indexes derived from production values.* It can be established that from a given unit of land area the output of sheep products shows the following pattern: Europe supplies 5.3 times, Oceania 3.2 times, the world average; while North and Central America provide 13%, South America 36%, of the mean world production. A similar pattern emerges in terms of the utilization of meadowlands, where the European relative figure is 7.1 times the average. The success of New Zealand in improving and increasing the carrying capacity of pastures is especially spectacular. The index pertaining to 100 people of population shows the absolute superiority of sparsely populated Oceania, where the output value of sheep products per inhabitant is over 40 times the world average figure.

The situation of producing individual sheep products

The overall production of grease wool showed a 10% increase by 1982, with the increase occurring in the last 4 years of the period. Its quantity increased from 2.60 to 2.86 million tons, but the wool yield from each average sheep decreased from 2.58 to 2.47 kg.

As regards *the volume of wool production*, Oceania excels, where one sheep produces 5.12 kg of grease wool, i.e. 107.3% above the world average, while Africa (1.11 kg/1 animal) shows a shortfall of 55%, Asia (1.37 kg), 45%, Europe (1.95 kg) 21% in relation to the mean value. In Europe this tendency is due to the lasting surplus output of wool.

In many parts of Australia there has been a new emphasis on selective breeding for meat production, which has contributed to the decline of the world's wool production. In the socialist countries, wool production has shown

a tendency of growth. In Hungary and the COMECON countries in general, price and other preferences create a favourable situation for the production of wool in relation to other products, causing hereby a considerable divergence from the price rates in world trade. In Hungary, this practice has led to erroneous policies in establishing category preferences which research and practice now attempt to correct.

The relative share of the *top ten wool-producing* countries in the world's total output decreased from 81.6% to 78.2%. Among them Australia (25.1%), the Soviet Union (15.8%) and New Zealand (13%) stand out. The most prominent countries in terms of specific wool yield are Australia (5.19 kg), New Zealand (4.98 kg), Argentina (4.92 kg), and the USA (3.94 kg). These countries produce, on he average, 3.16 kg of wool per sheep, which exceeds the world average by 28%. Almost one-third of the sheep population of the Soviet Union are mixed-wool breeds, which combined with the fact that the country is the breeds, foremost produced of karakul fur, tends to diminish specific wool production.

The *growth of wool yield* was most significant in Asia with 89.3%, while in the Soviet Union it amounted to 24.5%. In the other regions 2.3–11% more wool was produced than earlier, whereas South American showed a decline of 9.5%.

In the period surveyed, China stepped up its wool production by 228%, the increase in Pakistan and Turkey was 180% and 46%, respectively. Five of the top producers (USA, the UK, Argentina, Uruguay, Australia) showed a decline in wool output. The specific yield grew only in three countries: in Argentina by 1.08, in the Soviet Union by 0.46, in Australia by 0.36 kg per sheep. Wool production being place intensive and time consuming, wool tends to become a staple product only in sparsely inhabited areas.

Forty-one percent of the volume of grease wool is fine or Merino wool, 29% of crossbred quality, 30% mixed wool. Mixed wool provides the raw material for household textile products. The quick emergence of Asia and partly Africa in wool production has led to the growing rate of mixed wool (Veress, Jankowsky, Schwark 1982). In the international trade of wool contradictory trends can be observed: while the wool demand of the clothing industry keeps growing, low-priced synthetic fibres and other textile raw materials keep down the price of wool.

The years 1977 and 1980 saw a sudden *growth in the production of raw sheepskin on a world scale.* This led to a peak quantity of 1.3 million tons in 1982, which showed an increase of 48.9% in comparison to the basic period of time.

The production of fur should be examined within a framework of its competition with wool. Asia's relative share of 28.4% in global production approximates its proportionate share in sheep population (29.7%). Africa is

responsible for 20.1% of sheepskin production and 16.1% of sheep population. Oceania supplies 20.5% of sheepskin and 18.3% of the world's sheep stock. Within 20 years, Africa as good as tripled, Asia doubled its production of raw sheepskin, Oceania's increase is 1.6 times as much as previously. They availed themselves of the opportunity provided by the popular fashion in woolen furcoats and the price increase of sheepskin, as well as of the possibility that this product can be profitably manufactured at places remote from the market.

The *world average* of raw sheepskin production is 1.13 tons per 1000 sheep. In a regional framework Africa excels with 1.43 kg/head, and only South America and the Soviet Union are below the average level. The greatest increase was achieved by Africa with 0.76 kg/sheep.

Among the top ten producers of sheepskin, New Zealand (1.70 kg/head) and Turkey (1.59 kg) are prominent. The latter also leads the field in terms of growth, since it managed to increase its yield by 0.98 kg/head, i.e. 2.5 times as much as it was 20 years before. Among these ten countries, seven succeeded in stepping up their production, with Turkey achieving a fourfold increase, Pakistan 3.7, Iran 2.3, Australia and New Zealand over 1.5 times the previous output.

The growth dynamic of the production of raw sheepskin in the period of time concerned is almost five times as much as that of wool, which is due to a more active demand for the product. A lasting demand for small, mixed-wool, pigmented sheepskin (romanov) can be expected while furcoats are still in fashion. The production of bony mutton and lamb meat in the period investigated grew by 21.8%, and started its steady growth, after some fluctuation, in 1979. The year's total in 1982 was 6.2 million tons. Regionally, the production of Asia grew by 92.9%, that of Africa by 54.6%, Europe's output grew by 31.7%, while the joint production of North and Central America decreased by 48.3%.

The *growth in meat output* was mainly due to *extensive* production, as a result of increased stocks, because in 20 years the average output per sheep grew only by 0.30 kg, by which the 5.39 kg level was attained in 1982. North and Central America (8.57 kg/sheep) and Europe (8.32 kg/sheep) can boast the highest specific values, while South America was unable to surpass the 2.44 kg level. An average growth of 1.58 kg/sheep was recorded for Europe, 1.31 kg for Asia, while there was a decline of 1.72 in the Soviet Union and 1.55 kg/sheep in North and Central America. In Europe, where an attempt was made to increase the meat-producing capability of the various breeds, both the adult-age body weight and the specific production of meat showed a rapid increase (Wassmuth 1983).

The possibilities of a more intensive way of meat production are illustrated by the fact that a 50% rise in the annual prolificacy rate per ewe and

marketing lambs at a higher body weight (30–40 kg/lamb), the slaughter animal production of each ewe specialized for meat production would cover the import cost of the wool yield of 5 ewes specialized for wool production (Dobos 1984).

The *average slaughter weights* of sheep raised for mutton were 22 kg in North and Central America, 17 kg in Oceania, 13 kg in Africa, and in other regions it is 14–15 kg. The conditions of farming and, consequently, the live weight of ewes have a considerable effect on the weight of slaughtered animals, which is about 13–14 kg for 35 kg ewes and 28 kg for ewes weighing 100 kg. The consumption of mutton, which is 1.3 kg/person, shows with the exception of Europe, a declining tendency.

Among the *top ten sheep farming countries*, the production of bony meat declined only in the Soviet Union and Australia, while the following countries stepped up their production: Pakistan by 436%, Turkey by 182%, Iran by 94%, and China by 48%. It is significant that these latter countries are in Asia. Among them, a spectacular degree of increase is also shown with regard to the average yield per ewe: Turkey 3.41 kg, Pakistan 2.36 kg, and Iran 1.71 kg.

It is an important aspect of the world food situation that over half the quantity of mutton produced is consumed in developing countries. The per capita consumption is especially high in Mongolia, Iceland, Australia, New Zealand, in the South-East European and Arabic countries. By the year 2000, a rising supply of mutton is expected in Europe (Flamant et al. 1982).

In the Islamic countries the consumer demand for mutton and the expected rate of population growth being both considerable, the supply of mutton from native sources is less and less uncertain. The rapidly increasing price of mutton in the international market, however, conflicts with solvent demand. In the future, in markets demanding high quality, the meat of fast-fattened lambs is expected to be sought for, in which the ratio of bone and suet does not exceed the 20 : 20 rate (Kempster 1979, Schön and Schön 1980). In this way the optimum point in slaughtering age is reached at 50–55% of adult body weight (Veress 1984).

In 1982, the world total of *ewe's milk production* was 8.2 million tons, which corresponds to 7.05 kg per sheep. Milk production from 1976 underwent a temporary decline, then from 1980 on there began a rapid growth; in 1982 the output of milk exceeded the level of the period of reference by 33.9% its development surpassing that of the sheep population by more than twofold. As regards the possibility of obtaining more milk per sheep, a considerable degree of progress can be expected. In this respect the results achieved in Israel are most encouraging (Wassmuth 1983, ref., FAI 1981).

In North and Central America and Oceania the utilization of ewe's milk is not an economic objective. *About 90% of ewe's milk is produced in Asia and Europe*, the volume in the two regions being roughly the same. Asia attained

a faster growth (41.3%) of milk production than Europe (24.8%) when related to the world average; their average milk output indexes were 10.8 and 25.4 kg/ewe, respectively. With a more modest share, Africa and South America increased their production of ewe's milk by 56%.

In five of the *top ten countries with the largest sheep stocks*, namely Australia, New Zealand, India, the UK, and the Republic of South Africa, there is no interest in the production of ewe's milk. Only Turkey, Iran and China are among the top ten milk-producing countries, together with five European countries, of which France occupies the second, Italy the fourth, and Greece the fifth place. As regards global milk production, Turkey's share is 15.1%, that of France 13.9%, while the top ten countries increased their output from 68.6% to 75.5%, and they attained a 47.3% more rapid increase than the world average.

Concerning the *increase in milk production*, among the countries surveyed Iran leads with 99.7 before France (75.1%), Greece (62.4%) and Turkey (56.4%). The possibility of increasing specific milk yield — as well as the divergent course of utilizing stock — is indicated by the fact that while the average milk yields per ewe are 86.20 and 71.07 kg in France and Greece, respectively, in China and Afganistan these values come to 4.60 and 12.05, resp.

Ewe's milk can replace cow's milk in those regions where the more exacting demands of cattle raising cannot be satisfied. Owing to the fact that its production is labour intensive, ewe's milk is often considered to be a product of merely regional interest. Since, however, a considerable proportion of the ewe population is not milked, and because the genetic reserves of milk production are the largest among all the sheep products its potentials are great. The efficiency of live labour can be considerably enhanced by means of up-to-date milking machines. The international demand for ewe-cheese is active, and the world's production of ewe's milk has recently shown a spectacular growth. A further increase in yields can be expected, which is likely to raise the income and profit levels of sheep farming.

The situation of sheep farming in Hungary

Having taken stock of the world's sheep population, the situation of and changes in the production of sheep produce, we shall now offer a brief outline of the situation of sheep farming in Hungary.

In 1982, the sheep population in Hungary numbered 3.2 million, of which 61.1% was made up of the ewe stock. Against this background, 48.6 thousand tons of slaughter sheep, 12.2 thousand tons of wool, and 3.2 million litres of milk were produced, which corresponds to 25 kg slaughter sheep, 6.27 kg of wool, 1.65 litres of milk per ewe. The live prolificacy rate was 109.3/100 ewes. The sheep stock constitutes 8% of the overall cattle, pig,

horse and sheep population. The density index of sheep is 47.6 animals per 100 ha of agricultural area (Lakatos 1981).

Sheep production in Hungary is *export-oriented.* The home consumption of mutton is not significant. Seventy-eight percent of slaughter sheep and mutton are marketed abroad, the export of ewe-cheese is also significant. Wool is processed by the home industry.

The *gross production value* of sheep farming is 3.7 billion forints, which, using the exchange rate of 44 forints to the US dollar, corresponds to $84.1 million. Within the gross production of agriculture and animal breeding, the relative shares of the sheep branch are 2 and 4.1%, respectively. Its rate of growth is relatively slow. Between 1970 and 1980, while the production of plant cultivation grew by 43.1%, that of animal breeding by 40.2%, in sheep breeding the size of the ewe stock grew only by 27.4%, the production value of the branch merely attained a growth of 16.4%, which is indicative of the extensive character of development.

The role of the *merino breed is dominant* (98%), and in 1980 there was a cabinet decision in favour of maintaining "the merino breeding orientation". *The sheep enterprises in the country have a poor ecological and economic background*, and the area-exploiting quality of the branch is a decisive feature. The stock of building establishments is outdated, the accomodating facilities are overcrowded, the level of the branch's infrastructural and production technological state of supply occupies the last place among all the other animal breeding branches. Also its labour efficiency is low and stagnant.

In 1980, sheep-farming agricultural co-operatives kept on the average, 2 500, state farms 7 700 sheep. The effective methods of large-scale sheep farming have not become widespread, and the procedures of intensive development hardly exist even in model enterprises.

As shown in Fig. 5, in terms of production value per sheep, sheep production in Hungary lags somewhat behind the world average. Thus it is understandable that in both the supply of resources and the levels of yield and profitability the *sheep branch is at a considerable disadvantage in relation to the general development of Hungarian agriculture* other branches of animal breeding and especially the plant cultivation sector. The maintenance of the basically extensive sheep production branch has become especially contradictory within the framework of large-scale intensive agricultural enterprises. However, the lamb-fattening program is carried out by means of the most up-to-date methods available.

The *structure of returns* from sheep products has undergone a significant change over the past decade, owing to the new set of regulations. In 1981, 62.3% of the returns derived from mutton, 36.9% from wool, and 0.8% from milk and other sheep products. In comparison to 1964, the ratio of mutton production has risen 2.2 times, while that of wool has diminished to 60%,

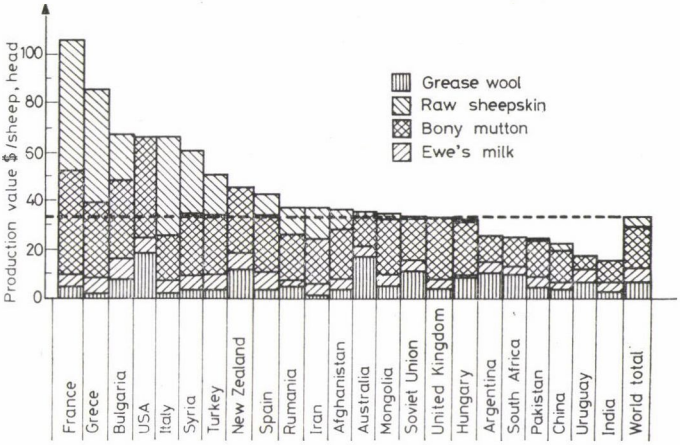

Fig. 5. The level and structure of sheep-product output in the top sheep-farming countries and Hungary in 1982

and that of milk to 10%. The average production price of slaughter sheep is 66.38 forints/kg (an increase of 7.5 times since 1964), the price of 1 kg of wool is 96.20 forints (a twofold increase), and that of ewe's milk is 18.31 forints per litre (a fourfold increase).

Wool has become considerably more valuable in terms of its home purchase price. To obtain 100 forints in returns, the producer has to offer 2.1 times more milk, 1.9 times more mutton and 1.5 times more meat lamb in relation to wool than the prices quoted at border parity in foreign markets.

Internationally, the competitive position of Hungarian sheep farming can be illustrated with a few relevant data (Table 6).

Table 6

Specification	New Zealand	France	Hungary
Agricultural land, ha/active agricultural worker	130	30	69
Raised lamb/1 active agricultural worker	1000	150	127
Raised lamb per ewe	0.8	1.2	0.9
Mutton production, kg/ewe	—	44.0	24.5
Distribution of production value, %			
wool	41.5*	3.4	30.8
mutton	58.5	87.4	67.3
milk	—	9.2	1.9

* Wool and sheepskin together
Source: Gecsei (1983), with additional data

It can be seen from Table 6 that the supply of land area makes Hungarian producers increase the intensity of the output of sheep produce. The productivity of labour should be raised by all means, in such a way that the inherent increase in cost could be integrated with the improvement of competence and social conditions. The unfavorable development of rearing rate and of reproduction indexes in general is a considerable handicap in improving the competitiveness of Hungarian sheep products. Specific meat production is merely about half of what has been achieved in France, in stocks bred for meat. In all three countries, the meat-wool production line is a characteristic feature, which, complemented with the utilization of milk, could lead to the improvement of results in this country.

With the current stock, according to the calculations of Ráki, Tóth (1983), the following export returns are achieved per ewe: bony mutton $28, wool $10, milk $0.7. In wool production we have been able to achieve only 40–45% of the yield of the top-ranking countries. The possibilities of diminishing our disadvantage in this field are meagre, for only a slow genetic progress can be attained. Some *improvements of the results* can be expected from restoring triple utilization, because a 20–30 litres/ewe level in milk production can be easily attained, which could secure an export return of $13–20. This trend could be supported by the extensive use of milking equipment, of which the rate of return can be less than three years. Further development could be achieved by the extension of the meat-milk or milk-meat mode of utilization.

The modernization of sheep farming, the further modification of the ways of utilizations and raising the standard, imply additional input and the improvement of the conditions of production, with attention to the criteria of economical feasibility. Emphasizing this latter criterion is justified by the fact that *sheep farming operates under a deficit in the majority of enterprises*. In accordance with the data of the Ministry of Food and Agriculture (MÉM STAGEK 1982), in 1981 a total production cost of 100 forints could only yield a production value of 88.30 forints, i.e. the deficit was 11.70 forints. 54.2% of the total cost was alloted to materials, 15% to wages, 7.3% to fixed assets and subcontractor services, and 3.8% to other expenses. It is worth noting that 19.7% was devoted to general costs, which not only eats up the slight returns of the immediate branch, but also serves as a source of deficit. It is a disquieting phenomenon that, while the cost of fodder shows a declining tendency, the unproductive ewe stock keeps growing; and, parallel with this, specific yields have also declined (Kenyeres 1984). Considering the total yield of the branch, one ewe produces, on the average, an exchange value of 17.85 kg of wool. (It should be noted that the production of mutton by itself is profitable, its production cost being 55.81 forints/100 Ft.)

The relationship between: direction of utilization and level of intensity

We have concluded the examination of the data contained in the production and trade yearbooks issued by FAO with a graded comparison of the top ten countries in terms of sheep population of the four staple sheep products.

It has been established that, as regards the production value deriving from the world's sheep population, the relative share of Australia is 12.6%, of the Soviet Union 12.5%, of New Zealand, Turkey and China from 8.6% to 6.3%, the other countries listed in Fig. 5 range between 3.6% and 1.1%.

There is, however, *a significant difference* among the 22 countries listed in terms of the *level of production value related to each average sheep.* The lowest value ($16.19 per number of sheep) belongs to India, the highest ($106.84) to France, a 6.6-fold divergence.

Ranking the countries listed, complemented with Hungary, according to the decreasing order of specific production values, as shown in Figure 5, the structure of production value is also illustrated. In the first seven countries the standard of production exceeds the world average by more than 50% (that of Hungary approximates the world average).

Placement in the ranking order is determined by the intensity of production, which, however, is never independent of the targets of utilization and the choice of type and breed. It is not accidental that the first seven countries — with the exception of the USA, which is characterized by a high standard of mutton and wool production — have specialized along the lines of the milk-meat or the meat-milk mode, while the majority of the countries in the last third of the list tend not to exploit the utilization of milk, and they score high in one product at the utmost.

Peak performances have been shown by the USA in wool ($18.65), Bulgaria in raw sheepskin ($8.86), and France in bony mutton and ewe's milk ($43.34 and $54.46). Concerning the joint values of wool, sheepskin and mutton, the performance of the USA is the highest ($66.17); in milk and bony mutton taken together France ($97.80) leads the field.

The relationships inherent in these figures give rise to the following *conclusions:*

— Where there is an intensive agriculture or a high density of population, sheep production can only be competitive under conditions of intensive allocation and yield. Therefore it is in these places that the effective realization of the intensive forms of farming can be expected (e.g. France, the Soviet Union, China, New Zealand, Israel, Cyprus, Bulgaria).

— In the case of the wool-sheepskin utilization mode, the demand for a high degree of performance cannot be attained; although with an abundant supply of grassy areas, high labour productivity, and a low input of assets

these patterns can also be productive (e.g. the Soviet Union, Australia, the Republic of South Africa). Effectiveness can also be increased by a gradual growth of meat production as related to wool (e.g. New Zealand).

— The maximum of production value can be attained by means of the meat-milk or milk-meat combination, which provides a margin of safety in returns for the branch (e.g. France).

— If the sheep branch produces — in order to supply — the home market, as in the developing countries, it undeniably utilizes pastures, and fulfills in area-protecting function (by grazing soil-protecting grass or areas occupied by constructive works). There is another motivation for maintaining it, and through preferential treatment as well as subsidies, it can be removed from the pattern of economic influences outlined above. Under extensive conditions of production, the aspect of a competitive ability is less significant.

— In the case of products that satisfy special, luxury needs (e.g. karakul), particular interest relations may exert their influence; although, for instance, the production of the karakul stock and fur shows no growth.

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CHRONICLE

Professor MIHÁLY MARÓTI, at seventy

Back in the fifties, a dim light used to be seen at the top of one of the buildings of the Museum boulevard in Budapest. In the sterile laboratory built in the loft of the Department for Plant Physiology of the Eötvös Loránd University, Mihály Maróti, the pioneer of plant tissue culture in Hungary worked. It was then the only laboratory of this kind in the country. Since then a new branch of science has come into existence: plant cell genetics and tissue culture, which has much to do with the present achievements and economic importance of plant biotechnology.

Professor Mihály Maróti was born at Lovasberény (Fejér county) 1917. For his secondary school studies he attanded the science grammar school of the Cistercian order in Székesfehérvár where he took his final examination in 1937. After that he first studied philosophy (1937–1940), then took courses in natural sciences at the Pázmány Péter University, Faculty of Arts (1940–1946) and received a teacher's diploma on biology and geography. In the meantime he did military service from 1944 and was a prisoner of war until 1946, when he returned home.

From then on professor Maróti's life and activity became inseparable from the Budapest University. Even as a university student, he did voluntary work at various departments, and from 1943 was first an unpaid then a salaried assistant to a professor at the Department for Plant Physiology of the Eötvös Loránd University, the legal successor of the Pázmány Péter University. Later he became a paid assistant lecturer (1950), then an assistant professor. In 1969 he was appointed professor to this university. In the meantime he organized in 1954 the University's Biological Station at Alsógöd, had its experimental objects erected, and was its director until 1977. Since his retirement in 1985 he has been scientific consultant to the Station's plant tissue development laboratory, which he had organized.

In the course of several decades of university work, he held main courses of lectures and conducted practical studies for special biologists, teacher trainees, pharmaceutists, geologists. As an invited lecturer, he also held special courses for agricultural engineers and horticultural university students.

Maróti delivered lectures on biology over a number of years in extension courses for general and secondary school teachers. He was regular lecturer on biological (botanical) subjects at the Radio School, the József Attila people's high school of the Society for Popular Science, the National Biologist Days, and at Itinerary Congresses of the Hungarian Biological Society.

The field of his scientific investigations was first plant cytology, cell biology, then he carried on comparative studies on the development of isolated plant organs on which he wrote his Ph.D. dissertation in 1957. For his research work done in this field he gained scholarships from the Ministry of Education (1952) and the Hungarian Academy of Sciences (1954). Later he dealt with the hormonal control of the growth and development of sterile plant tissue cultures, for which he took his Academic Doctor's degree in 1967.

At present professor Maróti deals with the induced organo- and embryogenesis of cells, tissues and organs of plants, and carries on histological testing of biologically active compounds and heavy metal environmental contaminants. He displays wide activity in the meristemic micropropagation of horticultural and agricultural crops and ornamental forest trees, in producing pathogen-free propagation material, and in a gene bank storage of plant tissues.

Maróti has published some 165 scientific papers in Hungarian and foreign journals, 85 educational works, and many newspaper articles. In addition, he is author or co-author to a number of technical books and lecture notes. His major works are:

— Plant cell, tissue, organ and embryo cultures. 563–575. In Sárkány S. Gondolat Kiadó, Budapest. 1969.
— Fundamentals of plant tissue culture. Akadémiai Kiadó, Budapest, 1976.
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— Fundamental and importance of plant tissue culture 3–22. In Dudits et al. Akadémiai Kiadó, Budapest, 1979.
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Professor Maróti was the initiator and first instructor of isolated plant tissue culture work in Hungary. His lecture notes, "Plant Tissue Culture" published in 1971, represent the first Hungarian information and guide on this field of science, in which he also gave account of his own experimental activities, and outlined the possibilities of utilization. This work has run to several editions. His work "Fundamentals of plant tissue culture", published ten years ago, in 1976 (348 p.), was the first Hungarian summarization of works published so far on plant tissue cultures.

In 1953 he organized and initiated the first up-to-date Hungarian laboratory for plant tissue culture at the Department for Plant Physiology of the Eötvös Loránd University, where the first test-tube plants produced, with a technique now considered a biotechnological method, were turned out. These mericlone plantlets (orchidea, carnation, strawberry, black nightshade, etc.) propagated pathogen-free form mostly were produced in co-operation with producing farms or research institutes (Sasad, Óbuda, Micsurin Co-operative Farms, Medical Plant Research Institute) which carried out their further propagation. From the time onward he received, educated and taught many Hungarian and foreign experts; some of them are today well-known experts in plant tissue cultures in Hungary. His pupils as well as research workers, teachers and those working in practice have asked and continue to ask for his assistance, as they know that Professor Maróti gladly helps and shares his knowledge and expertise unselfishly with others.

He has done study tours and participated at congresses in a number of countries: in England, Belgium, Czechoslovakia, German Democratic Republic, German Federal Republic, and Soviet Union. He has been National Correspondent to the International Association for Plant Tissue Culture (IAPTC) since its foundation (1972) and is still a member of it. He is also a member of the European Tissue Culture Society (ETCS) and of the Scandinavian Society for Plant Physiology (from 1960). He has been permanent contributor to the biological abstracting journal, Berichte, since 1977.

Parallel to his educational and scientific activity, professor Maróti has taken part in the work of many Hungarian scientific and educational organizations. He was secretary to the Thematic Committee on Plant Physiology of the Hungarian Academy of Sciences (1955–1958), has been active in the Hungarian Biological Society since its foundation (1948), was secretary to the Botanical Section of the latter (1954–1958), editor of its Botanical Publica-

tions (1965–1981), and remains today a member of its editorial board. He has been president of the Control Committee of the Hungarian Botanical Society since 1976; member of the editorial board for the journals "Élővilág" and "Búvár" since 1950; member of the Society for Popular Science since 1959, serving on its National Biological Committee since 1960 and was a member of its Control Committee from 1972 to 1977. Since 1977 he has been a member of the National Presidency of the Society for Popular Science, and President of its Pest County chapter.

Professor Maróti has received recognition for his scientific, educational, organization- and social work. He was awarded the ministerial certificate of merit (1966), the bronze medal of the Order of Labour (1967), the National Presidency Diploma of the Society for Popular Sciences (TIT) (1972), the TIT Gold Wreath badge (1977), the gold plaquette of the Eötvös Loránd University (1977), the gold medal of the Order of Labour (1980), the badge of honour for Social culture (1980) and the Herman Ottó-prize (1984). The latter was given him by the National Presidency of the Hungarian Biological Society, "for his pioneer work in introducing plant tissue cultures into Hungary, and for his results attained in this subject".

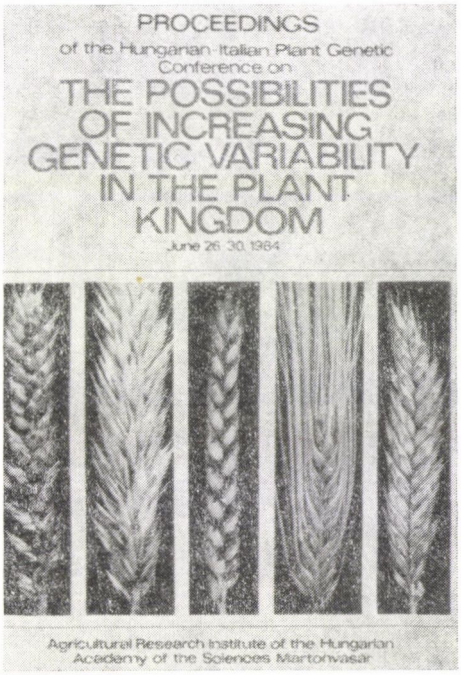
Professor Maróti works untiringly, in good health, even in these days. In addition to his duties at the Eötvös Loránd University, he is a guest lecturer at the Horticultural University and the Gödöllő University of Agricultural Sciences. With his skill in research, he is of assistance to several research institutes (ERTI, TAKI, etc.) and occupies many honourable posts in the Union of Hungarian Societies for Natural Sciences and in the Society for Popular Science.

On behalf of his pupils, colleagues and friends we offer our hearty congratulations on the occasion of his seventieth birthday and wish him to continue working among us in good health and strength for a long time to come.

L. HESZKY

BOOK REVIEWS

The possibilities of increasing genetic variability in the plant kingdom. (Proceedings of the Hungarian–Italian Conference on Plant Genetics, Martonvásár, Hungary, 1984)



By agreement between the Hungarian Academy of Sciences and the Italian Research Centre a scientific information exchange meeting was organized at Martonvásár between 26 and 30 June 1984, with the subject "Possibilities of increasing the genetic variability in the kingdom of plants" fixed in advance.

The material of the conference can be arranged in four categories (1) production of basic material for breeding by induced mutagenesis and polyploidy, (2) genetic variability and selection obtained by crossing, (3) cytogenetic studies on interspecific and intervarietal crossing, (4) perspectives of plant tissue culture and genetic variability.

At the conference, eight Italian genetists and breeders were present and gave lectures. On the Hungarian side, nine lectures were delivered.

C. Lorenzoni, from the University of Piacenza, gave an account of the situation and major lines of plant geneties and breeding as well as of the educational and research organization in Italy. G. P. Sorressi held a richly illustrated lecture on induced mutants of vegetable crops and their use in breeding, pointing out the results attained with EMS in resistances to the bean mosaic virus, and reporting on successful tissue and cell cultures of these mutant forms.

G. Borghi, research worker at the Cereals Research Institute, provided data on the mutation and selection work with cereals, with special regard to the improvement of the green mass, dry matter, protein and harvest index in semidwarf forms.

M. Sari-Gorka, E. Ottaviano and C. Frova, worker at the Genetic- and Microbiological Institute, Milano, delivered a joint lecture on "The possibilities of increasing the

efficiency of selection", mentioning their gamete selection work with maize.

P. Cardo, from the ENEA centre of Casaccia, dealt with the effect of X- and gamma irradiation on the pen and the horsebean, with special regard to cytogenetic changes in the chromosome.

A. Blanco, research worker at the Plant Breeding Institute of the Bari University, gave an account of "Cytogenetic studies on induced amphiploids and aneuploids" in durum wheat.

S. Arcioni, D. Mariotti, M. Pezotti and F. Damiani, from the Plant Genetic Centre of Perugia, reported on Lotus corniculatus plants started from callus culture and differentiated through embryogenesis. The variability of the progeny population provides a sound basis for selecting new forms.

E. Luppoto, also a worker at the Bergamo Institute, held a colourful lecture on the perspectives of genetic intervention, with regard to in vitro cultures of Zea mays and Medicago sativa.

The Hungarian lecturers' accounts matched their Italian colleagues' lectures.

Z. Barabás offered a survey of early, dwarf, rust and powdery mildew resistant wheats induced by quick neutron and gamma irradiation.

L. Magassy evaluated the role of polyploids in plant breeding, pointing out the applicability of auto- and alloploids.

L. Balla supplied finely illustrated information on the new martonvásári wheat variety breeding efforts and methods, with special regard to the importance of multiple and baek crossings.

T. Szundy analysed the possibility of making use of genetic variability is maize breeding. He outlined a programme for widening the genetic bases and carrying on progressive selection and heterosis breeding.

J. Sutka described the possibility of chromosome level interventions in winter wheat dwelling on the value of aneuploid, and mainly monosomic forms.

Andrea Belea held a lecture on intergeneric hybrids in wheat as a means of increasing the genetic variability, pointing out the applicability of *Triticum* and *Aegilops* crossings and their polyploid forms in breeding with cytogenetic and electrophoretic evaluation.

G. Vida discussed the problems, reservations and methodological difficulties related to the polygenic inheritance of genetic variability.

The conference supplied a good opportunity for our getting acquainted with one another's achievements in genetics and plant breeding, and made it possible for us to strengthen and widen our scientists' cooperation.

K. Mozsár

Keresztesi B. (red.): *Robinia*. 162 p. Akadémiai Kiadó, Budapest, 1984

The *Robinia* (*Robinia pseudacacia* L.) is a wide-spread, quickly growing tree species in the plains of the Carpathian Basin. In this book B. Keresztesi and co-authors: Z. Bujtás, Gy. Erdélyi, L. Halupa, Z. Járó, Gy. Lengyel, G. Madai, L. Márkus, L. Papp, K. Rédei, E. Sali, G. Temesi give an account of the propagation and practical utilization of robinia in the Hungarian part of the plains.

In the first chapter of the book, brief descriptions are given of the known *Robinia* species, and information is supplied of the occurrence, distribution, site conditions and sylvicultural characteristics of robinia — in its country of origin. Statistical survey is provided of the *Robinia* plantations in the main robina-growing countries of the world.

The work mostly deals with the distribution, sylviculture, breeding and utilization of *Robinia* in Hungary. This tree species occupies 268 thousand ha in Hungary, 18.27% of the country's forest area. The authors give detailed information on the age- and felling maturity conditions of *Robinia* plantations. A chapter of the book is devoted by the redactor to the results of *Robinia* breeding in Hungary, to the description and apicultural evaluation of cultivators, and to the variety maintenance.

The afforestation, forest cultivation, felling and timber utilization questions of the tree species are also discussed in detail.

A special chapter deals with the economic questions (output, cost) of *Robinia* cultivation. A great value of the book is that it also summarizes the results of investigations related to the nectar production of *Robinia* forests. At present, *Robinia* is the most important plant for commercial honey production in Hungary, as proven by the fact that, in years favourable for blossoming, 50–60% of the marketed volume of honey comes from robinia.

The topicality of the book is increased by its acquainting the readers with the role of robinia in afforestation for environment protion purposes, in the development of green fields for villages and towns, and in the establishment of protective forest belts.

A. TERPÓ

Amino Acid Composition and Biological Value of Cereal Proteins (Proceedings of the International Association for Cereal Chemistry, Symposium, Budapest, Hungary, May 31–June 1, 1983)
With supplemental invited contributions. Edited by: R. Lásztity and M. Hidvégi. Akadémiai Kiadó, Budapest, 1985. XV + 662 pages.

For their nutritive value, the cereals were earlier regarded as one-sided carbonhydrate sources. However, several thousands of years of using cereals as basic food, and up-to-date protein chemistry analyses, have equally proved that cereals are also important as protein sources. This book surveys the questions, methods and results of dietetic investigations concerning cereal proteins, in the form of lectures by eminent scientists. The contributors are biochemists, nutrition physiologists, plant breeders, plant growers, and process experts.

Scientific investigations into cereal breeding, cultivation and processing have great traditions in Hungary. The latest achievements are summed up by L. Lénárt in the book's introduction.

The past, present and future role and the importance of cereal proteins in nutrition are discussed in the introductory lecture of the *first part* by R. Lásztity. In this section, entitled "General Problems" Hungarian, and other European, American and African researchers deal with the outstanding importance of cereal proteins in human nutrition.

The *second part* of the lecture series surveys the methodological problems concerning the nutritive quality of cereal proteins. The large number of quantitative indices that express the biological value of the proteins describe the complex nature of these problems. The planning and evaluating of animal feeding experiments are complicated tasks alone. In this field Hungarian researchers also give accounts of remarkable results (Walger and Kunze).

With the elaboration of chemical indices *the methodology of evaluation* is approached from a different aspect (Hidvégi and Békés). The in vitro digestion methods may be advantageous from many points of view (Sarwar, Salgó). Since, in the cereal proteins, lysine is the limiting amino acid, the dye-binding methods of analysis suitable for a quick determination of lysine offer the breeders great help (Munck, Barát and Halász).

Part three contains lectures on the amino acid composition of cereal proteins and on biochemical questions related to it. For agriculturists the effects of plant-nutrition and agrotechnics on the amino acid composition are of interest (Német, Baudet, Huet and Mosée).

Among the lectures in *part four* that deal with the composition and nutritive value of protein preparations made from cereal proteins, the more interesting are those which discuss the grain germ (Tsen; Cerletti and Restani), and also the reports on analyses of protein products (Geervani, Hesser, Sarkki and Saarinem). The lecture on a comparative analysis of the proteins of maize varieties is also found in this part of the book (Juhász et al.).

Finally, *a special section* deals with the value of cereals as human and animal food. The problem of enrichment of foods with various plant nutrients is discussed by Sosulski, Fleming, and Lindner. In this section, *part five*, the subject of fodder mixtures is treated.

The book is conveniently completed by a list of contributors and a subject index.

The material of the symposium published in this book provides first hand information to all those researchers and professional representatives who are engaged in breeding, growing and processing cereals, or in studying the important matter of human nutrition.

The typography has been based on photoprints of the original manuscripts.

The fine light paper and the cloth binding render the book easy to handle.

K. VUKOV

I. BODÓ, J. DOHY, P. HAJAS, G. KELEMÉRI: *Beef-cattle breeding*. Mezőgazdasági Kiadó, Budapest, 1985. 350 p.

There are relatively few countries in Europe in which beef-cattle breeding has a long history. However, the idea of beef-cattle breeding is being considered in almost every country, if only because for economic reasons no one can ignore the question of increasing each cow's production of milk. This means, on the other hand, that fewer cows are required for producing the necessary amount of milk, and consequently the number of calves available for meat production will decrease. World-wide investigations are therefore underway to find the conditions that can realize an economically efficient means of beef-cattle production.

These briefly outlined views made it particularly important to publish a book that deals in detail with the breeding, economic, biological, genetic, meat production, marketing, etc., points of this topic, primarily stressing the European situation, though with an outlook to the world production of beef-cattle.

The authors discuss these matters of beef-cattle breeding with a wide international survey. This work may arouse interest not only in countries with developed cattle farming practices but also in the developing countries. The book has a special advantage in that its group of authors consists both of highly qualified theoretical experts and those with thorough practical experiences.

Certain questions are dealt with from different aspects. This is particularly important because, in the branch of production concerned, it is indispensable to have a comprehensive view of the whole process of production, to which a very large proportion of the professionals — at least in this branch — are not yet accustomed. Namely, it is difficult to make an integrated evaluation of the by-products utilized as feed, of the grazing areas, fertility, life performance, calf rearing, fattening and a final product (systems analysis).

Agriculture is undoubtedly humanity's greatest venture. Everything we eat or wear arises from it. In this global enterprise, with special regard to world population, a far from negligible branch is the beef-cattle farming for which this book supplies excellent information.

A. HORN

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