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Performance of watermelon (Citrullus lanatus L.) in response to organic and NPK fertilizers

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Abstract. The soil of North-Central Nigeria is home to many plant products that are used as industrial raw materials, and after processing their waste are often left in drainage channels, which ultimately find their way into rivers and streams where they pollute these water bodies, and sometimes some of these materials are burnt, which further aggravates global warming. In addition, the soil of the region is characterized by low organic matter content because of annual bush burnings, which reduce the low humus content of soils. Watermelon requires a fertile soil, which is high in organic matter content, while infertile soils yield an increased production of male flowers at the expense of female flowers, which results in low fruit set. Therefore, a study was carried out at the University of Ilorin Teaching and Research Farm, Ilorin, North-Central Nigeria, during the rainy seasons of 2013 and 2014 to assess the effect of different organic materials on the growth and yield of watermelon. The factors imposed were a control, NPK fertilizer and five organic materials (neem seed cake (NSC), jatropha seed cake (JSC), poultry manure (PM), compost manure (CM), and cow dung (CD)). The experiment was a randomized complete block design (RCBD) replicated thrice. Data collected on soil physico-chemical properties were: organic matter content, soil pH, organic carbon, total N, P, K, Ca, and Mg, bulk density (BD), micro porosity (MIP), macro porosity (MAP), and saturated hydraulic conductivity (K_S). Plant parameters evaluated include growth (vine length and number of leaves) and yield (number of fruits per plant, fruit weight per plant, and yield ha^{-1}). Results indicated that the organic matter content increased after the first year's cropping and declined at the end of the study. The amended plots showed significantly higher values ($P < 0.05$) with respect to most soil physical properties (MIP), (MAP), and (K_S), except the BD, where the values were lower. The bulk density particularly deteriorated on soils that were not organically amended. In addition, the soil chemical properties examined increased following the first year's cropping, and thereafter declined at the end of the second-year cropping season. The response of watermelon showed that the two years' yield data ranged between 334 and 402 t/ha, 306 and 390 t/ha, and 38.25 and 59.20 t/ha for NPK, poultry manure, and control treatments respectively. From the results, it was observed that the organic amendments were environmentally more friendly compared to the inorganic amendment (NPK fertilizer) in terms of positive effects on soil structural properties.

Keywords: watermelon, inorganic, organic materials, growth and yield

1. Introduction

Watermelon (Citrullus lanatus [Thunb.] Matsum. and Nakai), a member of the Cucurbitaceae family, is cultivated for its fruit and vegetative parts [1] and accounts for 6.8% of the global vegetable production [2]. The fruit is an important source of carotenoids and a precursor of vitamin A [3]. It ranks among the top five most frequently purchased and cultivated fruits globally with a per capita annual consumption of 7 kg [4]. The fruit can be served fresh in fruit salads, cooked and used as confectionary, and is becoming an everyday fruit like bananas, apples, and oranges [5]. Its seed is also considered an important dietary item [6] and contains a high amount of minerals and other nutrients [7, 6]. Lycopene in watermelon is an anti-carcinogenic compound found in red-fleshed cultivars [5]. In 2008, watermelon accounted for about 5.4% of the total area of land devoted to the cultivation of vegetables in Africa, and this contributed to about 4.6% of the world production of watermelon [8]. Most soils of North-Central Nigeria are inherently low in fertility [9] and soils used for the cultivation of watermelon should be well drained and rich in organic matter content [10]. In general, high-nitrogen fertilizer and high temperature promote the production of male flowers and lower the number of female or perfect flowers, resulting in low fruit set [11].

The major constraint to crop growth and yield is soil fertility, and peasant farmers in the north central zone of Nigeria depend on inorganic fertilizer for the restoration of lost nutrients, but its continuous use can lead to soil acidity. The long-term use of NPK fertilizer has a depressing effect on yield, and this can cause a decline in fruit number and delay in fruit setting, which subsequently delays ripening, and leads to the proliferation of vegetative parts [12]. Due to the use of NPK fertilizer, the identified production constraints can be ameliorated by the application of nutrient-rich organic amendments. Soil amendments are important in North-Central Nigerian soils because of its low organic matter content due to constant bush burnings and subsequent erosions. Harnessing the nutrient energy from biological wastes is very important in crop production. When these wastes are recycled as manure and utilized for agriculture, it reduces the pollution of streams and rivers [13].

The most common wastes which abound in the north central zone of Nigeria are jatropha (Jatropha curcas) and neem (Azadirachta indica) seed cakes, which are residues obtained after the extraction of oil from their seeds. [14] stated that the nutrient composition of jatropha is N (4.44%), P (2.09%), and K (1.68%). [15] also reported a high nutrient status of jatropha seed cake in soils, which led to a 179% and a 120% increase in the yield of maize and millet respectively. Neem seed cake, on the other hand, contains (2–5%) nitrogen, (0.5–1.0%) phosphorus, (0.5–3%) calcium, (0.3–1%), magnesium, and (1–2%) potassium [16], and it has pesticidal properties, especially in soils prone to nematode infestation [17]. The compost, which is a rich source of plant nutrients, is a mixture of decomposed organic materials, kitchen wastes, etc. The use of compost can reduce over-dependence on chemical fertilizers. The hazardous environmental consequences and the high cost of inorganic fertilizers make them not only undesirable but also uneconomical and beyond the reach of peasant farmers, who still dominate the Nigerian agricultural sector. The addition of compost improves the structure, texture, and tilth of the soil [18]. A good soil should have an organic matter content of more than 3%. The application of compost provides an alternative to the current methods of waste disposal and reduces the quantity of water and fertilizer applied to crops [19]. Poultry manure is rich in nitrogen and phosphorus, which can promote a good growth of plants [20]. [21] has earlier reported the use of organic materials such as rice hull, wood shavings, and kola husks as soil amendment in maize. The use of organic manures has been reported to have a comparatively higher advantage over inorganic fertilizers [22]. Many traditional farmers who cannot afford commercial fertilizers have resorted to the use of organic materials. Besides increasing soil fertility status, organic materials also help to improve physical condition, which in the long run increases crop productivity. The study was therefore aimed at determining the effect of different organic and inorganic material sources on the performance of watermelon.

2. Materials and methods

Experimental site

The study was conducted in the Teaching and Research Farm of the University of Ilorin, Ilorin – Nigeria (Latitude 8o 291 North, Longitude 4o 351 East and 307 metres above sea level), during the 2013 and 2014 cropping seasons. Ilorin is characterized by an annual rainfall of 1,186 mm, while mean annual temperature and relative humidity are 29ºC and 85% respectively. The soil is well drained, and the soil order is Alfisols belonging to the Tanke series [23]. The experimental site has been under fallow for two years before the commencement of this study.

Land preparation

The soil was ploughed, harrowed, and flat seedbeds measuring 6 m × 4 m were made. Each plot was separated from the other by a one-metre alley.

Soil sampling and analysis

Top soil (0–30cm) samples were collected in a 4 × 10 m^2 grid, bulked, and a composite sample was collected for physico-chemical characterization. Soil pH was determined (soil: water ratio 1: 2.5) using a glass electrode [24]; total N content was determined by micro-Kjeldahl method [25]; available phosphorus was determined following Bray No 1 method [26]; organic carbon was determined according to the Walkley–Black method [27]; exchangeable bases: calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were extracted with 1N ammonium acetate. Calcium and magnesium in the extract were analysed using Atomic Absorption Spectrophotometer (AAS), whereas K and Na were determined by flame photometry. Saturated hydraulic conductivity was determined by using a constant head permeameter [28] and the transposed Darcy's equation for vertical flows of liquid was used to calculate saturated hydraulic conductivity (Ks); thus, Ks = Q/At × L/H, where Q is the steady state volume of flow (cm^3). The cross-sectional area of core sample (cm^2) is A, the time elapsed (hr.) is t, the length of core sample (cm) is L, and the change in hydraulic head (cm) is H. Pore size distribution: the macro- and micropores were the two types of pores measured. Macroporosity (Map) was calculated thus: MaP = volume of water drained at 60 cm tension/volume of bulk soil, while microporosity (MiP) was determined after oven-drying the sample to constant weight at 1,050°C; MiP = volume of water retained at 60 cm tension divided by the volume of bulk soil. Total porosity was calculated as the sum of macro- and microporosities. Bulk density was analysed according to the method of [29]. Mean weight diameter of water-stable aggregates was estimated by the wet-sieving technique described by [30].

Experimental design

The design of the experiment was a randomized complete block (RCBD) replicated thrice. Treatments comprised control, NPK fertilizer, neem seed cake, jatropha seed cake, poultry manure, cow dung, and compost manure

Field layout

The organic manure was incorporated 14 days before planting at the rate of 15 t ha-1 and NPK fertilizer applied at the rate of 300 kg ha-1 at 21 days after planting, using the side-band placement method. Three seeds (Sugar baby cv.) were sown per stand at a spacing of 0.75 m by 0.75 m on 16 July 2013 and on 16 July 2014, which were later thinned to two seedlings per stand at 21 days after sowing. Weed control had been done manually using a traditional hoe at biweekly intervals before total ground cover was attained to ensure an adequate weed control. The crops were sprayed three times with lamdocyahalothrin as karate (2 litres per hectare) at 21, 35, and 49 days after planting to protect the plants from insect attacks.

Growth parameters

The growth parameters recorded were vine length and number of leaves per plant at 28, 42, 56, and 70 days after planting. Vine length was taken by measuring from the base of the plant at the soil level to the terminal bud with the aid of a measuring tape. The number of leaves was estimated by counting the green leaves.

Yield and yield component

Harvesting of the fruits commenced at 70 days after planting, when the fruits turned deep green in colour. Harvesting was done by carefully pulling off the matured fruits from the vine. After harvesting, the yield components were assessed [fruit diameter, number of fruit(s) per plant, and the weight of fresh fruits per plant at harvest]. Fruit circumference was measured with a flexible tape and fruit weight was measured by using a weighing balance.

Data analysis

The collected data were analysed via Analysis of Variance (ANOVA) using “GENSTAT” 17 statistical software package. Significant means were separated at 5% probability level (LSD 0.05).

3. Results and discussions

The pre-planting soil data (*Table 1*) indicated that in 2013 the soil was moderately acidic but decreased to slight acidity at the end of the first cropping season. There was, however, no change in soil acidity at the end of the second cropping season. The total organic carbon was moderate before and after the experiment in 2013, but it was very low at the end of the study in 2014. The total N content before and after the study was very low. The level of potassium and magnesium in the soil was low at the beginning and remained low at the end of the experiment in the second cropping season.

Table 1. Physical and chemical status of the soil before and after the experiment

Year	Soil pH	% org. Carbon	Org. Matter (%)	Total N (%)	P (ppm)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
2013a	5.9	1.02	1.76	0.03	1.63	0.12	2.15	0.9
2013b	6.1	1.12	1.94	0.05	0.76	0.6	9	1.8
2014	6.2	0.3	0.52	0.04	0.75	0.2	5	0.97

a. Prior to planting, b. After harvesting

Bulk density did not significantly respond to manure types in 2013, whereas the soil amendment (organic and NPK fertilizer) led to significant changes in the bulk density of treated soils in 2014 (*Table 2*).

Table 2. Effects of organic and inorganic materials on the physical properties of soil

Treatments	2013				2014			
	Bulk Density	Micro-porosity	Macro-porosity	Hydraulic Conductivity	Bulk Density	Micro-porosity	Macro-porosity	Hydraulic Conductivity
Control	1.31	15.82	1.90	34.29	1.47	12.29	2.06	38.00
NPK	1.40	12.07	2.29	32.15	1.42	14.39	2.47	40.05
Neem cake	1.36	15.87	2.93	38.44	1.29	16.43	3.11	48.56
Compost	1.37	13.13	2.35	42.14	1.33	14.56	2.99	41.29
Jatropha	1.36	15.61	3.41	44.67	1.33	15.56	4.24	49.47
Cow dung	1.35	14.51	3.34	35.55	1.35	15.36	4.06	51.30
Poultry ma	1.38	14.43	4.95	46.43	1.32	15.02	5.23	53.49
Mean	1.37	14.49	3.02	39.09	1.36	14.93	3.46	46.02
LSD (0.05)	Ns	0.146	0.090	0.373	0.042	ns	0.236	1.713

Generally, plots treated with organic amendments showed significantly lower bulk density values compared to the control and NPK-treated plots. Notably, there was an increase in the bulk density values in the control soil from 1.31 gcm^{-3} in 2013 to 1.47 gcm^{-3} in 2014, which translated to about 12% increment. In soils amended with inorganic manure (N.P.K.), the corresponding bulk density values ranged from 1.40 gcm^{-3} to 1.42 gcm^{-3}, translating to less than 2% increase. With bulk density values increasing at this rate in the control soil (unamended), the germination of most arable crops may be threatened in about six years of continuous cultivation, while it may probably take about 25 years for the same observation in soils amended with N.P.K. The results also indicated that although the microporosity of the treated soils significantly ($P < 0.05$) differed among treatments in the first year (2013) and showed no difference in the second year (2014), there was generally no established trend. There was a significant difference ($P < 0.05$) between the organic-amended and non-organic-amended plots in terms of macroporosity (MaP) and saturated hydraulic conductivity (K_s). Poultry manure consistently yielded significantly higher MaP and K_s on treated soils with values ranging from 4.95 to 5.23% and from 46.43 to 53.49 cmh^{-1} respectively, whereas the lowest values were generally obtained in control plots. It was generally observed that organic materials of animal origin significantly improved the measured soil physical properties more, when compared to observations made in soils amended with plant-based organic materials.

The data on rainfall, temperature, and relative humidity are presented (*Table 3*). The data in 2013 and 2014 indicated that the month of September had recorded peak rainfall. This rainfall comes in torrents, but sometimes for a short duration; temperatures and relative humidity were high. The meteorological data for the two years clearly indicated that the highest monthly rainfall and maximum temperature were experienced during the cultivating seasons for the two years (August–October).

Table 3. Meteorological data of the experimental site in 2013 and 2014

Months	Rainfall (mm)		Temperature °C (2013)		Temperature °C (2014)		Relative Humidity (%)	
	2013	**2014**	**Min.**	**Max.**	**Min.**	**Max.**	**2013**	**2014**
January	0.5	6.3	19.4	34.2	20.6	34.5	81	81
February	39.2	34.2	22.7	34.8	20.7	35.3	81	82
March	39.0	71.0	24.2	35.6	23.8	34.8	81	81
April	181.8	321.4	23.6	32.3	22.5	32.7	81	81
May	81.8	163.8	22.7	31.5	22.7	39.6	81	81
June	132.9	154.4	20.9	34.2	21.9	30.4	80	81
July	107.3	82.1	21.8	28.0	21.9	29.6	80	81
August	**17.7**	**94.9**	**21.4**	**27.8**	**21.3**	**27.5**	**80**	**80**
September	**202.5**	**391.6**	**21.5**	**29.2**	**21.2**	**28.5**	**80**	**80**
October	**154.3**	**259.4**	**21.7**	**31.0**	**21.7**	**31.6**	**80**	**81**
November	**0.0**	**0.0**	**23.4**	**31.5**	**22.7**	**32.5**	**83**	**81**
December	11.4	0.0	19.4	33.5	19.4	33.2	82	82
Mean	**969.0**	**1579.4**	**21.9**	**32.0**	**21.7**	**32.5**	**81**	**81**

The data on the vine length of watermelon in 2013 and 2014 is presented in *Table 4*. In 2013, NPK-fertilizer-treated plots produced plants with the longest vines, whereas the control plots produced the shortest vines. However, in 2014, the NPK- and poultry-manure-amended plots produced plants with vines that were on a par with each other but significantly longer than the other treatments.

Table 4. Effects of organic and inorganic materials on the vine length of watermelon in 2013 and 2014 at 28, 42, 56, and 70 days after planting (DAP).

	2013 Days after planting				2014 Days after planting			
Treatments	28	42	56	70	28	42	56	70
Control	47.54	77.12	120.31	126.29	30.41	70.30	107.85	114.19
NPK	67.95	112.53	147.54	155.12	45.48	100.17	149.72	161.48
Neem cake	64.72	95.97	141.95	146.63	43.81	94.90	146.74	159.28
Compost	62.93	94.89	140.54	148.85	42.98	90.25	144.28	157.47
Jatropha cake	64.20	93.21	142.10	149.13	44.95	98.91	147.77	155.21
Cow dung	64.88	97.58	144.60	148.96	44.26	90.71	147.54	157.80
Poultry manure	65.55	105.23	146.99	152.80	48.59	100.18	149.50	161.14
Mean	62.54	96.65	140.58	146.83	42.93	90.92	141.91	152.38
LSD (0.05)	Ns	13.625	2.088	6.066	1.898	4.024	3.494	4.589

Generally, in 2013 and 2014 (*Table 5*), results indicated that plants in plots treated with NPK and poultry manure produced the same number of leaves, these numbers ranging from 9.00 to 47.33 for NPK-treated plots, while in poultry-manure-treated plots values ranged from 7.67 to 47.00 between the 28th and the 70th day after planting in 2013, whereas in 2014 they ranged from 8.00 to 52.00 for NPK and from 8.00 to 53.33 for poultry manure over the same period. It was also observed that plants in organic-manure-treated plots showed higher number of leaves compared to the control. Furthermore, the increment in the number of leaves was the highest between the 56th and the 70th day after planting. For instance, the number of leaves produced by NPK, which was the most effective, increased by 59%, 44%, and 129% in the periods of 28 to 42 days, 42 to 56 days, and 56 to 70 days, respectively, after planting in 2013. Similarly, in 2014, the number of leaves increased by 75%, 60%, and 133% in the periods of 28 to 42 days, 42 to 56 days, and 56 to 70 days respectively.

Table 5. Effects of organic and inorganic materials on the number of leaves of watermelon in 2013 and 2014 at 28, 42, 56, and 70 days after planting (DAP).

	2013 Days after planting				2014 Days after planting			
Treatments	28	42	56	70	28	42	56	70
Control	6.00	10.33	13.00	31.67	6.00	8.00	12.67	24.67
NPK	9.00	14.33	20.67	47.33	8.00	14.00	22.33	52.00
Neem cake	6.33	13.00	15.50	44.00	7.67	11.67	18.00	42.33
Compost	6.00	12.67	14.33	42.67	7.33	10.00	16.00	42.33
Jatropha cake	6.33	14.00	18.33	42.33	7.33	12.33	19.00	49.33
Cow dung	7.00	12.67	17.33	45.33	7.67	12.00	19.00	44.67
Poultry manure	7.67	15.00	19.00	47.00	8.00	13.33	21.33	53.33
Mean	6.90	13.14	16.88	42.90	7.43	11.62	18.33	44.10
LSD (0.05)	1.569	Ns	1.565	1.238	Ns	1.616	2.085	4.178

The organic and inorganic amendments enhanced yield and yield components to a great extent in both years (*Table 6*). Generally, the NPK fertilizer had the most pronounced effect, whilst compost had the least. For instance, NPK increased yield by 580% and 776% in 2013 and 2014 respectively. Even the least effective organic manure (compost) increased yield by 312% and 344% in 2013 and 2014 respectively.

Table 6. Effects of organic and inorganic materials on the yield and yield characters of watermelon in 2013 and 2014

	2013					2014				
Treatments	Fruit diameter (cm)	Ave. wt. of fruit	No of fruits/ plant	Fruit wt/ plant kg	Fruit wt. t/ha	Fruit diameter (cm)	Ave. wt. of fruit	No of fruits/ plant	Fruits/ plant (kg)	Fruit wt. t/ha
Control	12.65	1.13	5.13	5.92	59.20	12.40	0.93	4.05	3.83	38.25
NPK	15.01	4.20	9.67	40.27	402.67	15.33	4.10	8.17	33.49	334..93
Neem cake	14.24	3.49	8.00	27.91	279.13	15.17	3.50	5.74	20.08	200.83
Compost	13.71	3.47	7.00	24.33	243.73	13.43	2.97	5.72	16.96	169.65
Jatropha	13.75	3.37	8.50	28.47	285.67	14.43	3.40	6.25	21.23	212.45
Cow dung	14.65	3.73	8.50	31.75	317.50	14.64	3.27	7.41	24.23	242.30
Poultry manure	14.51	4.10	9.50	39.03	390.30	15.27	3.90	7.85	30.63	306.26
Mean	14.08	3.36	8.04	28.24	282.40	14.39	3.15	6.46	21.49	214.95
LSD (0.05)	0.729	0.638	1.515	5.82	58.23	0.933	0.648	0.272	4.15	41.61

The low organic matter content of the experimental soil is characteristic of the soils in North-Central Nigeria (southern Guinea savannah) due to constant bush burnings and high temperatures leading to a high rate of organic matter decomposition. The low organic matter content invariably results in the fragility of soils in this environment. The foregoing necessitates organic amendment of soils in this area. Soil organic matter has been reported to improve soil microbial activities and soil-water-holding capacity, among other roles [31]. [32] had earlier reported organic matter content of 3% as the best for watermelon production in this area. The significant improvement observed in the physical properties, particularly in the bulk density of the organic-amended as against decline in NPK-amended and control soils over time, is indicative of the structural enhancement following soil organic amendment. Some researchers have reported either late emergence or complete germination failure as soil bulk density increased to 1.8 g/cm^3 in dry soil [33]. The comparative reduction of bulk density values in organic-manure-amended soils portrays its environmental friendliness, which is the reason for advocating its use for sustainable crop production [34, 31, 35]. The relatively higher improvement of soil physical properties observed with animal-based organic materials (poultry and cow dung) could probably be attributed to an advanced digestion/decomposition (bio-digestion) of the original materials in the digestive system of the animals and to the presence of faecal organisms. The released nutrients (including amino-acids) from the bio-digestion are likely to trigger off rapid multiplication of *in-situ* macro- and microorganisms in the soil pore spaces, which will subsequently increase soil total porosity. Furthermore, water and nutrient movement, rooting depth and density will be increased within the soil. In the same vein, improved water and nutrient absorption will ultimately translate to higher plant growth and yield. The soil pH of the experimental site was within the range for watermelon cultivation, which is 5.0–7.0 [36].

The increase in the vine length and number of leaves could be attributed to the presence of available nutrients in the poultry manure (15 tha^{-1}), which may be comparable to the one (300 $kgha^{-1}$) where NPK fertilizer was applied. The two weeks prior application of poultry manure with respect to planting may have resulted in fast mineralization and availability of the nutrients, which subsequently led to an increase in vine length and number of leaves comparable to those in the NPK-treated plots. The reason why the poultry-manure-treated plot outclassed the other organically amended plots may have been due to a comparatively faster decomposition rate and higher nutrient status. However, the vine length of watermelon in the two years of study was shorter and the number of leaves were less than what had been reported by [37] but similar to the findings of [38] using different rates of poultry manure in Asaba, Nigeria. The number of leaves produced were highest at 8 to 10 weeks; this period corresponded with the time of highest translocation of assimilates to the fruits.

The earlier reason adduced for the observation in the growth parameters may also have been responsible for that in the yield parameters. This is because the yield components followed a similar trend with the growth parameters. The number of fruits per plant obtained in this study is similar to that reported by [38] but lower than that of [39] using municipal wastes in Abakaliki, South-Eastern Nigeria. The yield experienced in this experiment was above what had been reported in a similar work by [40] (10–50t/ha) and [41], who reported a yield range of 10–20t/ha. [21] had reported yield increase in maize by using different agricultural wastes. The fruit weight per hectare using cow dung, poultry manure, and NPK fertilizer resulted in greater yield than the control plots in both years as compared to the plant-based manure components. Generally, animal-based manure produced superior growth and yield attributes than plant-based manure. This could be attributed to its ability to maintain more favourable physical conditions of the soil than discussed earlier.

Conclusion

It can be concluded from this study that the use of poultry manure at 15 tha^{-1} is equivalent to 300 $kgha^{-1}$ of NPK fertilizer in the cultivation of watermelon. However, NPK fertilizer is expensive and generally beyond the reach of peasant farmers. Therefore, the use of poultry manure is advocated, bearing in mind its beneficial effects on the soil.

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Damage caused by the small red-belted clearwing borer (*Synanthedon myopaeformis* Borkhausen) in cultivars grafted on different types of rootstocks

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Abstract. Considerable damage caused by the red-belted clearwing was observed in the biologically controlled apple orchard. In all cases, the larvae were found in the tumour-like tissue proliferations developing at the grafting point of the rootstock (M9) and scion, while no larva was found in crowns and cut surfaces. Samplings involving different cultivars were implemented in two apple orchards; in Bősárkány, where trees are grafted on M9 rootstocks and tumours were found at grafting points, and in Mosonmagyaróvár, where trees are grafted on M26 rootstocks and no proliferations were found at graft unions. During the aforementioned samplings, the numbers of larvae living in the tissue proliferations were counted, the sizes of tumours were measured, and the flight dynamic of adult clearwings was investigated. Research results reveal that damage caused by the clearwing larvae was only observed in trunks with tumour-like disorders (Bősárkány), where feeding larvae were found in 15.3% of the examined trunks in cultivar Royal Gala, 4.6% in Idared, 2.6% in Jonagold, and 1.3% in Florina. We investigated whether there is a correlation between the size of tumours and the degree of damage. The highest rate of proliferations was found on cultivar Florina, where only a minimum degree of damage was experienced. The lowest rate of proliferations was observed on cultivar Gala, which suffered the highest degree of damage done by clearwing larvae.

According to sex-pheromone trap catches, the flight period of male clearwings occurred simultaneously in both studied orchards from mid-May to mid-August. On the basis of scent trap catch results, however, it has to be highlighted that females were only present at the Bősárkány research site.

It is assumed that the absence of females in the Mosonmagyaróvár orchard can be attributed to the fact that they did not find such suitable oviposition sites as tissue proliferations. Hence, egg-laying and damage caused by the larvae did not happen there either.

Keywords: apple clearwing moth, rootstock–scion incompatibility, tissue proliferation, apple cultivars, flight dynamic

1. Introduction

The red-belted clearwing (*Synanthedon myopaeformis* Borkhausen) has not been regarded a pest of apple trees for a long period of time. Its occurrence is not mentioned in the works of Jablonowski [1, 2], Jenser [3], Bognár and Huzián [4]. Reichart [in Ubrizsy and Reichart 5] argues that its caterpillar feeds under the barks of trees weakened by illnesses or frost damages. Balás [6] points out that well-treated and healthy trees with intact bark are not exposed to damages caused by this pest. Its presence, and especially the rapid increase of its population, will only have to be reckoned with in trees with tumour-like disorders and injured barks. They both considered this species a secondary pest of apple trees.

Considerable damage caused by the red-belted clearwing in well-treated orchards was first observed in the 1970s in intensive orchards located in the region between the Danube and Tisza rivers [7, 8]. Chrestian and Lavy [9] reported damages done by the clearwing in France, which occurred on seemingly "healthy" trees. The common feature of the damages in France and in Hungary is that in both countries the high abundance of the clearwing moth was observed in regularly pruned but otherwise intact, healthy trees [10]. According to Balázs et al. [11], the rapid increase of the clearwing population and the occasionally large damage can be attributed to changes in apple production technology.

It has to be considered that apple orchards in their "modern" sense were first established in Hungary in the middle of the 1930s. Those plantations consisted of vigorously growing trees with medium-sized trunks, which were moderately pruned in the cropping phase and their barks were usually smooth.

From the end of the 1950s, mostly in orchards where trees were grafted on semi-vigorous M4 rootstocks and pruned in the form of the production arm spindle crown shape, as a result of intensive pruning, the trees have suffered a lot of cut injuries. Due to the lack of its natural enemies, the *S. myopaeformis* population increased rapidly, causing considerable damage in apple orchards. Ilovai and Szabó [12] claim that any factor that injures the bark (cut surface, hail, frost, etc.) will significantly contribute to the growth of the pest's population.

Since the 1980s – in favour of the dwarfing effect –, the dwarfing M9 has been the most widely used rootstock; its rate of propagation has increased nearly up to 50% during the last ten years. The main reason for its popularity is that this rootstock is perfectly suited to establishing high-density orchards. Apple trees grafted on M9 rootstocks begin producing fruit within a short period of time, their fruits grow bigger, and generally they can be harvested one week earlier than those grafted on M4 rootstocks. However, their disadvantages are that they require a support system (cordon) as well as intensive pruning and regular watering. The wound callus developing on the edge of the often 2–4-cm diameter cut surfaces caused by intensive pruning provides suitable conditions and environment for the egg-laying of *S. myopaeformis* and for the development of the larvae. Ateyyat and Al-Antary (2006) in Jordan concluded that out of the rootstocks M9, M26, and M106, the latter one proved to be the most resistant to the damage caused by the red-belted clearwing since the lowest number of eggs and larvae were found there.

In recent years, an additional factor has facilitated the growth of the pest's population. In order to create new crown forms and dwarf trees that correspond to current production requirements and to enhance the dwarfing effect, budding has been carried out at about 15–20 cm above the soil surface, which is different from the earlier practice. In the case of rootstock–scion incompatibility, a block of nutritive substances develops in the unit between the grafting point and the root collar, which proves to be appropriate for the insect's oviposition and the development of the caterpillars [14]. This damage might lead to the death of the host tree. One has to agree with Jenser [15], who suggested that views about the economic impact of the red-belted clearwing have to be modified on the basis of experience obtained in recent years.

Our samplings conducted in two different apple orchards provided an appropriate opportunity to investigate the question: to what extent will the rootstock–scion incompatibility lead to damage caused by the red-belted clearwing?

2. Materials and method

Data for analysis was taken within simultaneous samplings implemented in two different orchards used as research sites; one of them located in Mosonmagyaróvár, while the other one in the outskirts of Bősárkány, which is a small town near Mosonmagyaróvár. The studied orchard in Bősárkány is a biologically controlled plantation. It is a nearly one-hectare family-owned orchard, which was established in 1997, and since 2009 production has been carried out as biologically controlled. The main types of cultivars include Royal Gala, Idared, Florina, Pinova, and Jonagold, all grafted on M9 rootstocks. A remarkably big tissue proliferation can be found at grafting points on the three studied cultivars (Gala, Idared, and Florina). Pest control – primarily against the codling moth – is carried out by applying two substances: Dipel, which contains Bt toxin, and Madex, which contains granulosis virus.

The control evaluations were implemented in a 1,200 m^2 control area, which is the property of Széchenyi István University – Faculty of Agriculture and Food Sciences, Mosonmagyaróvár. This orchard does not receive any plant protection treatment at all. 18 different types of cultivars can be found there, of which the following five were studied during our research: Florina (M9 rootstock), Gala Must (M26 rootstock), Idared (M9 rootstock), Jonagold Wilmuta (M9 rootstock), and Golden B (M26 rootstock). Regarding the aforementioned cultivars, no tissue proliferations can be found at grafting points. It is important to mention that the orchard has not been cultivated on a regular basis for years; spring pruning was carried out in 2012; however, in 2013, not even that was performed. In the orchard, no pesticides or any plant health treatment are employed at all.

As for the methods, three different types of data-collecting instruments were employed in the form of samplings: examining the damage caused by the larvae per cultivar; measuring the size of tumours and counting the number of larvae in them per cultivar; observing the flight dynamic of clearwing adults and the change in the number of adults.

Samplings targeting to *examine the damage caused by clearwing larvae* were conducted on three occasions in 2012: on 23rd April, on 5th June, and on 20th September at both research sites, involving four cultivars: Royal Gala, Florina, Idared, and Jonagold. 50 trunks per cultivar were examined. Data concerning the number of damaged trees and the exact location of the damage was recorded.

In the Bősárkány orchard, the larvae were found in the proliferative disorders developing near the root collar. Hence, in order to study whether there is a correlation between the size of tumours and the degree of damage, we *measured the diameter of tumours and the diameter of trunks for each cultivar* at a height of 50 cm of the trunk above soil surface. 50 trunks per cultivar were examined on 3 November 2014.

The *flight dynamic of red-belted adult clearwings* was monitored by means of trapping. Three different types of lures were located inside both orchards:

- Sex pheromone traps: 5 pieces of “Csalomon”-type traps were placed at both experimental plots, and they were functioning from 25 April to 1 September; catches were controlled every other day.

- Scent traps: a home-made mash of apples cut into small pieces, yeast, apple juice, and beer was prepared. The fermented mixture was put in plastic bottles, which were cut in half and suspended on trees. 5 traps were located inside each research site, which were controlled every other day.

- **Pear-ester traps**: these traps were received from the Plant Protection Institute Centre for Agricultural Research for experimental purposes. We were to study its efficacy and to compare and contrast the number of catches with those of the sex pheromone and apple mash trap catches. 5 traps were employed as well, which were controlled every other day.

Statistical analyses were performed by using the software program Statistica (version 11; StatSoft, Inc. 1984–2012). A hypothesis analysis was performed involving three cultivars (Gala, Idared, and Florina) in order to justify whether the circumference ratio of tumours and trunks significantly differ from each other (t-test). The tendency of male catches in pheromone traps at both research sites was analysed by applying a quadratic trend function [16, 17].

3. Results and discussions

Damage caused by S. myopaeformis larvae

Research findings indicate that at the Bősárkány research site a total number of 36 S. myopaeformis larvae were found in the examined 600 trunks during three samplings conducted in April, June, and September. This figure reveals a 6% damage rate on average. The highest number of larvae was observed in June (21 pieces), which covered 58% of the total annual samplings. The recorded larvae number regarding each cultivar is presented in *Table 1*. We experienced a striking damage in cultivar Royal Gala, where feeding larvae were found in 15.3% of the studied tree trunks. In addition, 64% of the total larvae number was found in the aforementioned cultivar, which specimens were even present during the September sampling. Regarding the other three cultivars, the clearwing larvae damaged 4.6% of the trunks in cultivar Idared, 2.6% in cultivar Jonagold, while in cultivar Florina only a minimum of 1.3% damage was observed.

As for the exact place of damage, it has to be highlighted that larvae were only found in the tumour-like tissue proliferations developing at grafting points – M9 rootstock in Bősárkány –, whereas no larvae were found in crowns or in cut surfaces. Consequently, damage always occurred 10–20 cm above the root collar at graft unions. Among the studied cultivars, Royal Gala was found to suffer the most damage. It can be argued that the high degree of damage was facilitated by the fact that an inappropriate rootstock (M9) was chosen to the scion within the grafting process, which are not compatible with each other. Besides, budding was carried out rather high; so, it can be suggested that the loose-textured tumour developing at the grafting point is highly accessible and suitable for the females' oviposition and later for the development of the larvae, as it was also experienced by Balázs and Khanh [14].

Table 1. Damage caused by clearwing larvae and tissue proliferation sizes per cultivar in the Bősárkány orchard

Bősárkány	Date of sampling	**Gala**	**Idared**	**Jonagold**	**Florina**
Number of damaged trunks (pieces/50 trunks)	23 April 2012	0	5	0	0
	5 June 2012	13	2	4	2
	20 September 2012	10	0	0	0
Total number of damaged trunks (pieces/150 trunks)		23	7	4	2
Ratio of damaged trunks (%)		**15.3**	**4.6**	**2.6**	**1.3**
Mean diameter of damaged tumours (cm)		35.97	36.67	No data	38.57
Mean diameter of healthy tumours (cm)		33.97	34.90	No data	37.57
Mean circumference of damaged trunks (cm)		17.27	15.07	No data	14.77
Mean diameter of healthy trunks (cm)		16.43	16.43	No data	13.73

The size of tumours and the number of larvae

We measured the circumferences of tumours and the circumferences of trunks at a height of 50 cm of the trunk above soil surface, and their ratio were compared for each cultivar (*Figure 1*).

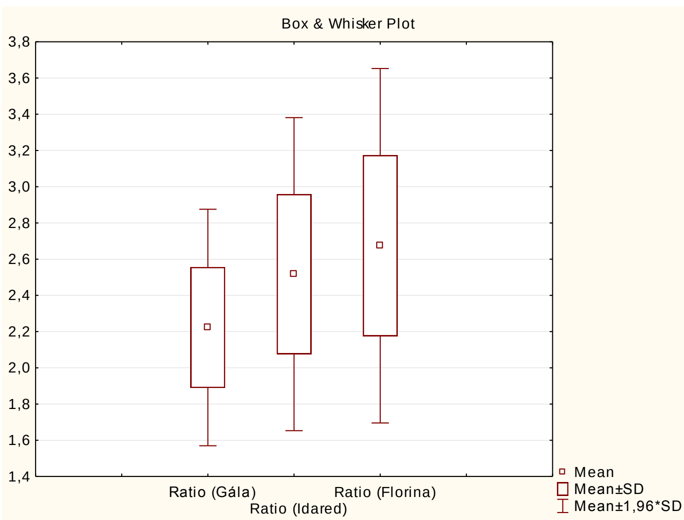

Figure 1. Tumour circumference and trunk circumference ratio of different cultivars (Gála, Idared, Florina)

As *Table 2* shows, the highest rate of tissue proliferation was observed on cultivar Florina, where the circumferences of tumours were 2.7 times the circumferences of trunks. The lowest degree of proliferation was observed on cultivar Gala, where the circumferences of tumours were 2.2 times the circumferences of trunks.

Table 2. Damaged tumour circumference and trunk circumference ratio per cultivar. Descriptive statistics (valid number, mean, minimum, maximum, standard deviation)

Descriptive Statistics					
Variable	Valid N	Mean	Minimum	Maximum	Std. Dev.
Ratio (Gála)	30	2.2	1.4	2.9	0.33
Ratio (Idared)	30	2.5	1.7	3.5	0.44
Ratio (Florina)	30	2.7	1.2	3.7	0.50

A hypothesis analysis was performed in order to justify that the ratio per cultivar does not differ with a 95% probability (null hypothesis). The result of the paired t-test reveals that the mean values of ratio only equal statistically when comparing the cultivars Idared and Florina ($p = 0.2017$, $p > 0.05$). When comparing cultivar Gala to those in the other two cases, mean values differ from each other significantly ($p = 0.005$ and 0.0001, $p < 0.05$).

The low ratio experienced in cultivar Gala differs significantly; however, it is lower than those experienced in the other two cultivars, as it is also confirmed by the statistical analyses presented in *Table 3*.

Thus, our hypothesis assuming that the extent of damage is higher in a bigger tissue proliferation has not been proved. On the contrary, damage reached its highest level in cultivar Gala, which showed the lowest ratio of tissue proliferation.

It is interesting to note that no larvae or any damage related to the red-belted clearwing were found at the abandoned control site, neither at cut surfaces nor at root collars regardless of the type of cultivar. It is true, however, that no tissue proliferations were found at grafting points; here, cultivar Gala was grafted on M26 rootstock.

Changes in the number of adult clearwings

Parallel to the evaluations targeting to investigate the damage caused by clearwing larvae, we also studied the changes in the number of adults at both research sites.

The sex pheromone traps caught a great number of flying males at both experimental plots; in the biologically controlled orchard, a total number of 296, while in the control Mosonmagyaróvár orchard a total number of 365 specimens were trapped (*Table 4*).

Table 3. Tumour circumference and trunk circumference ratio of different cultivars in paired comparison (hypothesis analysis with F and t- tests)

Group 1 vs Group 2	T-test for Independent Samples Note: Variables were treated as independent samples										
	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std. Dev. Group 1	Std. Dev. Group 2	F-ratio Variances	p Variances
Ratio (Gála) vs Ratio (Florina)	2.2	2.7	-4.1236	58	0.0001	30	30	0.33	0.500	2.247	0.033
Group 1 vs Group 2	T-test for Independent Samples Note: Variables were treated as independent samples										
	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std. Dev. Group 1	Std. Dev. Group 2	F-ratio Variances	p Variances
Ratio (Idared) vs Ratio (Florina)	2.5	2.7	-1.2915	58	0.2017	30	30	0.44	0.50	1.2822	0.5076

Figure 2 presents the flight dynamic curves created on the basis of catch results obtained at the research sites. The en masse occurrence of flying males was observed in June/July, when both experimental plots yielded more than 15 catches/2 days. The highest catches were recorded on 9th July in the biologically controlled orchard with a total number of 38 captured specimens/2 days, while at the control site peak numbers were counted on 20th June, when 68 adults flew into the traps. The last male adults were trapped on 14th August. It can be argued that swarming happened simultaneously at both research sites, as it is also confirmed by the statistical analysis (*Figure 3*).

After indicating the number of trapped male adults on the same graph, we installed quadratic curves through the obtained points. Calculating the maximum places from their equation, the researchers arrived to the conclusion that the maximum of swarming happened approximately on the 181st day of the year (29th July) in the biologically controlled orchard and on the 176th day of the year (24th July) in the abandoned orchard.

The flight dynamic curves justify the existence of a prolonged flight period of the red-belted clearwing, which corresponds to what Le Duc Khanh et al. [18] also suggest.

Table 4. Numbers of adults caught in different types of traps in Bősárkány and in Mosonmagyaróvár

Types of cultivars in **Bősárkány** bio-orchard	Gala	Idared	Jonagold	Florina	Pinova	all
Pheromone trap catches (pieces/ year)	85	60	66	30	55	296
Scent trap catches (pieces/year)	17	11	12	13	9	62
Pear-ester trap catches (pieces/year)	8	5	6	6	3	28
Types of cultivars in **Mosonmagyaróvá**r control orchard	Gala	Idared	Jonagold	Florina	Golden	all
Pheromone trap catches (pieces/ year)	76	83	81	65	60	365
Scent trap catches (pieces/year)	0	1	0	0	0	1
Pear-ester trap catches (pieces/year)	0	0	0	1	0	1

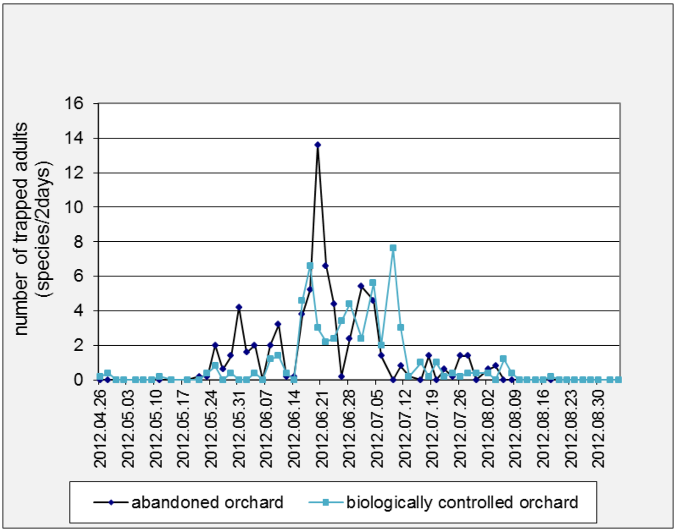

Figure 2. Changes in the number of *S. myopaeformis* males based on sex pheromone trap catches

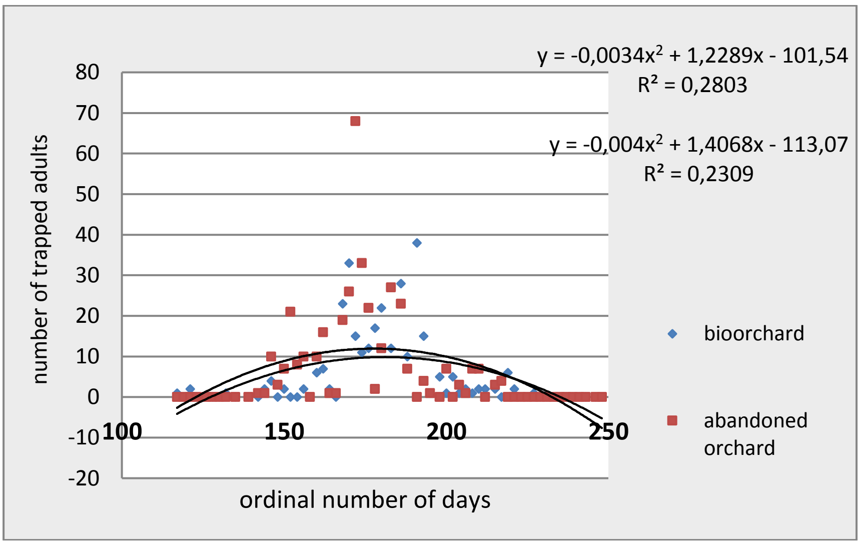

Figure 3. Flight curves based on sex pheromone trap catches

The reason why the red-belted clearwing is attracted to apple-juice-baited traps and fermenting fruit mashes is that this species requires maturation nutrition. Apple-juice-baited scent traps successfully attract flying moths, and therefore their flight dynamic can also be monitored. Both males and females are attracted to traps of this nature [19, 20].

The numbers of adults caught in scent traps are totally different at the two research sites. In the biologically controlled orchard, a total number of 62 adults were trapped between 16th June and 26th July, while at the control site only 1 specimen was found in the lures. Consequently, according to mash trap catch results, there was no flight to be recorded at the control research site, which indicates the total absence of female clearwings in the area. That might be the reason why no mating, egg-laying, and damage occured in the Mosonmagyaróvár control orchard. Nevertheless, the presence of males is justified by the continuous male catches in the sex pheromone traps. The question arises whether the reason for the lack of damage at the control site is the total absence of females, or the insects were present but could not find suitable places, that is injured surfaces for egg-laying since pruning was neglected in the orchard and no proliferations were experienced at grafting points.

The third type of lure we employed was the pear-ester trap, which attracts both male and female clearwing adults; however, it cannot be considered the most effective attractant of this species; in the biologically controlled orchard, only 28 adults were caught in the whole vegetation, while in the control orchard only one specimen was trapped (*Table 4*). The catch results of pear-ester traps confirm – in line with that of the scent traps – that no female moths were present in the control orchard.

Regarding pheromone and scent trap catches per cultivar (*Table 4*), the highest number of *S. myopaeformis* adults was collected in cultivar Gala in the Bősárkány orchard; 28.7 % of the flying males and 27.4 % of the total scent trap catches were found in Gala out of the 5 examined cultivars. Similarly, the largest damage was also observed in cultivar Gala, as it is presented in *Table 1*. In the control orchard, no remarkable difference in the number of trapped adults was observed among the different cultivars; however, only males were present there, and no damage caused by clearwing larvae was experienced.

4. Conclusions

Considerable damage caused by the red-belted clearwing larvae was experienced in those orchards where loose-textured tissue proliferations developed on the root collars of trees, which prove to be suitable for the egg-laying of females and provide excellent living conditions for the development of the larvae. Consequently, not only the existence of wound calluses caused by intensive pruning will increase the danger of larvae occurrence, but inappropriate rootstock choice and inadequate budding can also lead to damages, and at worse to the death of the host tree. It can be suggested that appropriate cultivar selection might also play an important role in preventing damages caused by clearwing larvae. Cultivar Gala was found to be rather susceptible. Conducting larvae control and management is especially difficult in biologically controlled orchards because of the larvae's "hidden" life and the prohibition of applying pesticides. Further research should be carried out to investigate which methods and techniques – apart from wound treatment right after pruning – could be applied in biologically controlled orchards to prevent the egg-laying of females. Such techniques as treating the trunks with substances containing oil, applying lime, or possibly taking advantage of the repellent effect of the powder made from fallen red-belted clearwings prove promising.

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Honey-bee production practices and hive technology preferences in Jimma and Illubabor Zone of Oromiya Regional State, Ethiopia

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Abstract: The study was conducted in two purposefully selected zones of Oromiya Regional State, namely Jimma and Illubabor. The objective of the study was to analyse the honey-bee production and to assess hive technology preferences in the study area. A total of 156 beekeepers were randomly and proportionately selected from four districts (Mana and Gomma from Jimma and Bacho and Yayo from Illubabor). Data were collected through formal survey and secondary sources. Accordingly, the average age of the beekeepers was 40.2 ± 8.13 years with an average of 13.5 ± 6.58 years of experience. The majority of the respondents (53.2%) in the study area got their colonies by catching swarms. Three hive types (traditional, transitional, and frame hive) were found in the study area. More than 70% of the respondents harvested once a year from traditional hives, while 25% of respondents harvested up to three times per year from frame hives. Moreover, an average of 22 ± 4.6 and 16 ± 4.1 kg of honey were harvested from frame and transitional hives per year, respectively. Compared to these two hives, a much lower (7 ± 1.6 kg) amount of honey was harvested from traditional hives. Various honey-bee floras were identified in the study area. Plants such as *Vernonia amygdalina*, *Croton macrostachyus*, and *Schefflera sp*. produce white honey. Half of the respondents' preferred transitional hive followed by frame hive (37.2%). Factors which affect the use of frame hives were lack of equipment (36.5%) followed by wax quality and availability problems (34%). That is why few beekeepers tried to modify the frame hive to solve the problems of wax in vertical frame hive. In order to adopt and sustain modern hive technology, the focus should be on honey-bee equipment as well as wax quality and availability.

Keywords: beekeeping, honey production, hive preference

1. Introduction

Ethiopia has huge potential for beekeeping production because of its endowment with diversity in climate and vegetation resources offering potentially favourable conditions for beekeeping. These have enabled Ethiopia to take around 23.58% and 2.13% of the total share of honey production on African and on a global level respectively [21].

The exact number of people engaged in the honey subsector in Ethiopia is not known. However, it is estimated that more than one million farm households are involved in the beekeeping business using the traditional, intermediate, and frame beehives [13]. It could also be observed that a large number of people (intermediaries and traders) participate in honey collection and retailing (at village, district, and zonal levels), and thousands of households are engaged in tej making in almost all urban areas, while also hundreds of processors are emerging, and exporters are flourishing [3].

Generally, about 4,601,806 beehives exist in Ethiopia, out of which about 95.5% are traditional, 4.3% transitional, and 0.2% frame beehives [3]. Based on the national estimate, the average yield of pure honey from movable frame beehive is 15–20 kg/year, and the amount of beeswax produced is 1–2% of the honey yield [12]. However, in potential areas, up to 50–60 kg of harvest has been reported [14].

Despite the high potentiality of the country for beekeeping and its extensive practices, beekeeping research conducted in the nation so far has not managed to characterize and document the apicultural resources and associated constraints of the sector for its proper intervention and utilization to specific potential regions [4]. Success in beekeeping primarily results from the utilization of improved beekeeping technologies that are suitable for local bee types and conditions [15]. These conditions may generally indicate the importance of considering the biology and ecology of the bees in the selection and adoption of technologies. Besides the technological and biological factors, the socio-demographic conditions of beekeepers were observed to play a significant role in the adoption of technologies. Thus, it was essential to assess the beekeeping production system as a whole and identify the determinants of hive technology preference and the major constraints of this subsector.

According to the Central Statistics Agency (2011/12), Oromia has the largest number of beehives followed by Amhara and SNNP. Jimma, Illubabor, and West Wellega were the areas of Oromia region with the highest number of hives (CSA, 2011/12) [5]. Different case studies and researches are being carried out concerning honey-bee production practices and honey-bee diseases and pests in different areas of the country. However, there is no compiled and tangible information on the preference of hive technology and management as well as constraints in the potential honey-bee areas (Illubabor and Jimma). Therefore, this research has been initiated with the objective of assessing honey-bee production and identifying the preference of hive technology in the Illubabor and Jimma zones.

2. Materials and methods

The study was conducted in the two neighbouring zones of Jimma and Illubabor, which are found in the south-western part of Ethiopia, having the highest number of hives (CSA, 2011/12) in the Oromia region. According to the zonal offices of Illubabor and Jimma (information from 2014), honey production is one of the most important sources of local earnings. Besides that, Jimma and Illubabor zones share many similarities in their agro-ecological conditions, cropping systems, vegetation types, and climatic conditions. In both zones, the dominant crops are maize, teff, coffee, sorghum, barley, wheat, different pulse crops, finger millet, fruits, vegetables, and spices. Annual precipitation ranges from 1,500 to 2,200 mm with 6 to 9 months of rainfall [5, 16].

Jimma and Illubabor zones have been selected purposefully because of their apiary potentials. A total of four districts (Mana and Gomma from Jimma and Bacho and Yayo from Illubabor) were selected based on the criteria of having large number of participants in beekeeping, beekeeper experience, potential area for beekeeping, abundance of honey-bee colonies, and availability of common bee forage. These were identified with the help of zonal agricultural and rural development offices and agents of the respective districts. A total of 156 beekeepers were randomly selected and interviewed proportionately from the districts. The sample size (N) was determined using the formula recommended by Arsham (2005) as N = 0.25/SE2, where N is sample size, and SE is the standard error at 4%. However, data was pooled and analysed into one zone because of the similarity of results across the districts.

Data were collected from September 2014 to June 2015 through formal survey, secondary sources, focus-group discussions, key-informant interviews, and field observations. Relevant information was further collected through discussions with representatives of the district and zonal office of Agricultural and Rural Development and Development Agents. Formal survey was conducted using semi-structured questionnaire with open-ended and closed-ended questions. The questionnaire was prepared to collect information as: age of the respondent, hive preference, beekeeping and/or management practices, placement of hives, honey-bee inspection, major bee floras, honey yield, and major constraints for adopting improved hives.

The collected data were analysed using appropriate statistical packages for social sciences (SPSS – software version 20). Descriptive statistics, such as mean, frequency, and standard deviation, were used.

3. Results and discussions

The study revealed that the average age of the beekeepers was 40.24 ± 8.13 years, with a range of 25–60 years. This result correlates with Chala et al. (2013) and Gebremedhin (2015), who report that the mean age of the respondents were 40.47 and 40.1 years respectively [4, 11]. The age distribution of beekeepers is generally within the active working age. Regarding their experience in beekeeping, the respondents had an average of 13.51 ± 6.58 years of experience, with a range of 5–28 years of working practice with honey-bees. This indicates that beekeepers have a good knowledge of apiary management and honey usage habits.

The majority of the respondents (53.2%) in the study area got their colonies by catching swarms or as a present from their parents (42.9%). This is in line with Addis and Malede (2014), who reported that 49.2% of the beekeepers started out by catching swarms. (This might be due to the fact that the area is endowed with species of plants that are favoured by bees.) Very few beekeepers (6.4%) were supplied by the government or NGOs. It was possible to buy a colony in the study area, even though only 17.3% of the respondents availed themselves of this opportunity (*Table 1*).

Table 1. Source of bee colonies

Sources	Number of respondents	Percentage
Catching swarms	83	53.2
Gift from parents	57	36.5
Given by Government or NGO	10	6.4
Buying	27	17.3

It can be clearly seen in *Table 2* that half of the respondents preferred transitional hives. However, the average honey-bee colony holding size (10.7± 4.3) for traditional was a little bit bigger than two hives. Contrary to the results of this study, Nebiyu and Messele (2013) found that 74.4% of the beekeepers in the Gamo Gofa zone, southern Ethiopia, preferred traditional hives over transitional (11.5%) and modern hives (14.1%) [18]. This might be related to an availability of local materials with the experience and knowledge gap of beekeepers for the preference of hive technologies in different areas of the country. Frame hive was preferred by

37.2% of the respondents next to transitional hive with the least average of colony holding size (6.08 ± 5.01). During group discussions with key informants and zonal offices of the study area, those having an experience in apiary preferred transitional hives for purposes of wax production. In addition, very few beekeepers tried to modify the frame hive – as shown in *Picture 1* –, giving evidence of a better management and obtaining higher earnings. This is consistent with Tessega's (2009) findings, who noted that experienced and skilful beekeepers could do many operations with less facilities [20].

Table 2. Respondents' hive preference and honey-bee colony holding size

Hive type	**Number of respondents**	**Percentage**	**Colony holding size in different hives (Mean± SD)**
Traditional	20	12.8	10.7± 4.3
Transitional	78	50	9.51 ± 9.9
Frame hive	58	37.2	6.08 ± 5.01
Total	156	100	

Picture 1. Horizontal frame hive with two and three compartments modified by a beekeeper in Bacho district

As shown in *Table 3*, an average of 22 ± 4.56 kilogram of honey per year from frame hives and 16.2 ± 4.12 kilogram of honey from transitional hives were harvested. Compared to these two types, a much lower (6.97 ± 1.58) amount of honey was harvested from traditional hives. The present result was in agreement with the result reported by Addis and Malede (2014) and Chala et al. (2013), who found that the average honey yield per year/colony was 7.20 ± 0.23, 14.70 ± 0.62, and 23.38 ± 0.73 kg for traditional, transitional, and moveable frame hives respectively [4]. However, the mean honey yield obtained from transitional hives in this study area is higher than the result indicated by Nebiyu and Messele (2013) in the districts of Gamo Gofa zone, southern Ethiopia, which is 14.07 kg per hive/year [18]. The productivity of frame hive and transitional in this study is more than triple than that of traditional hives, which is perhaps because of better management practices such as providing wax foundation sheets, recycling drawn-out combs after honey extraction, and a higher frequency of harvesting. A better honey storing of colonies in box hives with foundation sheet has been reported by [2]. Moreover, the possible advantages of increasing the overall average honey yield of colonies in box hives as compared to traditional hives has been well documented in Nigeria [9]. In this regard, to improve the output of beekeeping, the adoption of improved hives is important.

Table 3. Honey production (kg/hive /year) from three types of hives

Types of hive	Minimum (kg/hive/year)	Maximum (kg/hive/year)	Mean± SD
Traditional hive	4	8	6.97 ±1.58
Transitional hive	7	21	16.2± 4.12
Frame hive	12	32	22 ± 4.56

SD = Standard deviation

As shown in *Figure 1*, more than 70% of the respondents harvested honey once a year from traditional hive. In addition, respondents having transitional (33%) and frame hive (22%) also harvest honey once a year, even though the hive technology is improved. About 53% of the respondents having frame hive were able to harvest twice a year, which is slightly higher than noted for transitional hive (48%) and much higher than the traditional hive (27%).

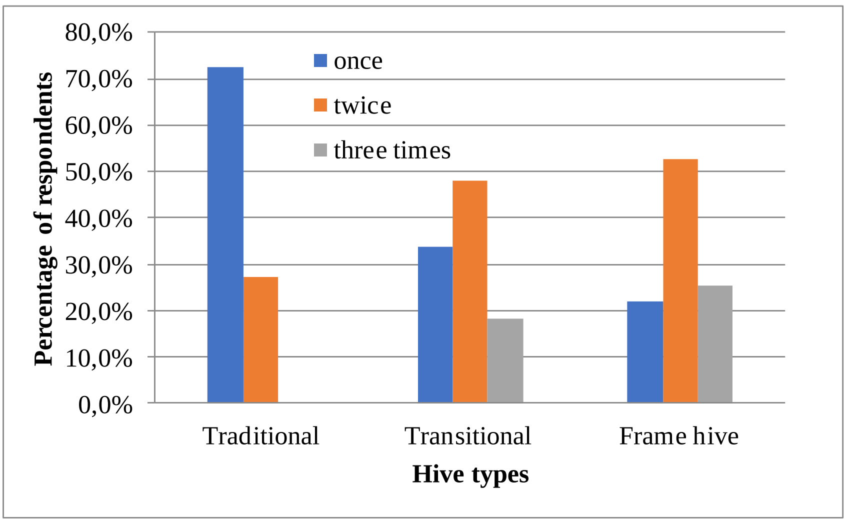

Figure 1. Honey-harvesting frequency for three hives

Moreover, 25% of the respondents' harvested honey three times a year in frame hives, while only 18% of respondents did it in transitional hive, and nobody experienced three times of harvesting a year in traditional hive. This research result was in line with Tessega (2009), who reported honey harvested once or twice, and in some cases even three times in Burie district [20]. This clearly indicates that harvesting frequencies differ within the same area but with different hive technologies. On the other hand, having three times of honey harvesting per year is an indication of the area being convenient for apiculture development.

More than 87% of the sample respondents who owned transitional and frame hive kept their colonies around their homestead (back yard) mainly to enable close supervision of colonies, whereas some of the respondents (12.5% and 6.6%) kept transitional and frame hive, respectively, hanging near their homestead. Besides, 58.9% of traditional bee colonies were kept in forests so that they might attract wild swarms. As mentioned during group discussions, when honey is harvested from traditional hive, absconding happens sometimes, and the hive has to return back, for which they use smoke to attract bees. Only 11% of respondents kept their traditional hive colony in the backyard, which is easier for harvesting as well as inspection than hanging nearby in the forests (*Table 4*). In some places, especially in the western and southern parts of the country, forest beekeeping by hanging a number of traditional beehives on trees is widely practised. In most other parts of the country, backyard beekeeping with relatively better management is common [19].

Table 4. Traditional, transitional, and frame hive placements

Hive type	Back yard (N)	%	Hanging near home stead	%	Hanging near in the forest	%	Total
Traditional	8	11.0	22	30.1	43	58.9	73
Transitional	91	87.5	13	12.5	0	0	104
Frame hive	85	93.4	6	6.6	0	0	91

Regular assessments and rapid detection of honeybee pests at their respective areas has paramount importance to prevent the loss of honey product due to pest attack [7]. However, in this study, both internal and external inspections were done sometimes by 48% and 46% of the respondents respectively. Unlike the external inspection, internal inspection was frequently done by about 29% of the respondents. Approximately 18% the respondents rarely inspect their hives internally. Below 5% of the respondents never inspect their hives, except visiting for harvesting.

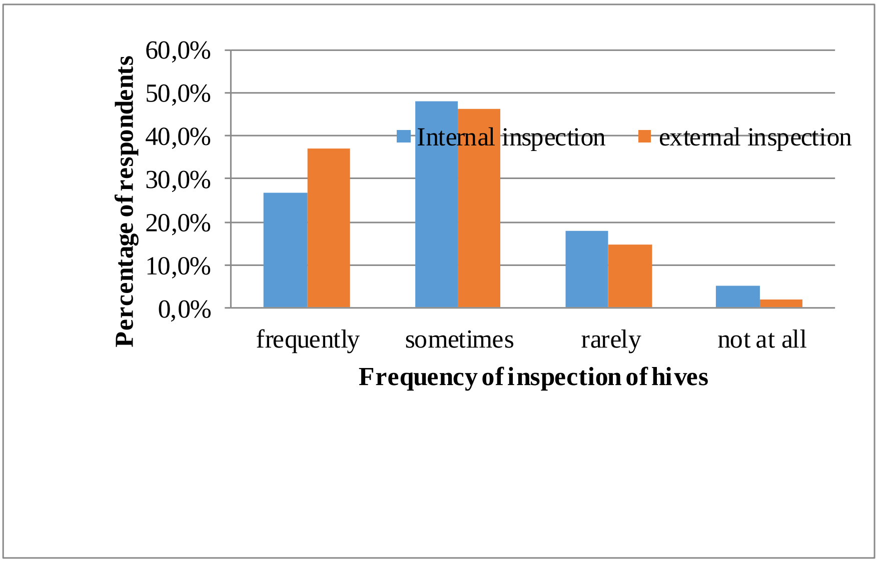

Figure 2. Internal and external honey bee inspections

According to the respondents, various honeybee plants exist in the area. In addition, respondents mentioned that different plants were responsible for the different colours of honey. Accordingly, plants like *Vernonia amygdalina*, *Croton macrostachys*, and *Schefflera abyssinica* produce white honey, while *Syzgium guineense* and *Bidens pachyloma* produce red honey. Similar plant species were identified as major pollen and nectar sources, for honeybees in Manasibu districts (Mathewos et al., 2004) and around the central low-land area (Amssalu 2000). Farmers reported that *Guizotia scabra* was a dominant honeybee forage in both Shashemene and Arsi Negelle districts, followed by *croton macrostachys.* Similarly, they argued that one of the critical factors that drive apiculture development is the availability of adequate quantities and the quality of bee forages.

About 72% of the respondents gave supplementary feed during the dry season, while 28% of the sampled beekeepers did not supplement. This might be due to lack of money to buy the supplementary feeds or may be due to lack of knowledge. Common feeds used as supplements during dry season were sugar, *berbre*, honey, *shiro*, maize powder, and chopped sugar cane.

Respondents gave varied reasons why they did not prefer frame hive technology (*Table 6*). Accordingly, lack of equipment was the first factor noted by 36.5% of the respondents, followed by wax quality and availability problem (34%).

Table 5. Honeybee forages reported by the respondents in the study area

No	Scientific names	Local name	Plant type
1	*Vernonia amygdalina*	Ebicha	Shrub
2	*Syzgium guineense*	Badessa	Tree
3	*Eucalyptus spp*	Bargemo	Tree
4	*Apodytes dimidiate*	Oda beda	Tree
5	*Acacia sibirana*	Lafto	Tree
6	*Prunus Africana*	Miessa	Tree
7	*Schefflera abyssinica*	Gatame	Tree
8	*Croton macrostachys*	Mokonissa	Tree
9	*Guizotia scabra*	Adala	Herb
10	*Cordia Africana*	Wodesa	Tree
11	*Schinus molle*	Turimanturi	Tree
12	*Agave sisalana*	Kancha	Shrub
13	*Allium cepa*	Shunkurti dima	Crop
14	*Vernonia amygadalina*	Girawa	Shrub
15	*Gizotia scabira*	Hadaa	Shrub/herb
16	Bidens pachyloma	Kelo	Herb

Discussants mentioned that affordability, availability, quality of materials – especially of the hives –, the inferior quality of wax, and lack of accessories were the major factors that hampered to use modern hives in the study area. That’s why a few beekeepers tried to modify the frame hive to solve the problem of wax in vertical frame hive, and these hives were made of quality timber, offering better conditions for opening and managing them more easily. Some related problems were identified, such as the lack of skill in modern bee management, which had contributed to colony absconding and low honey production [4].

Table 6. Factors which affect usage of frame hives as reported by respondents

Factors	Number of respondents	%
Lack of awareness	46	29.5%
Skill personnel	24	15.4%
Lack of equipment	57	36.5%
Durability of hive	45	28.8%
Wax quality and availability problem	53	34.0%

Respondents listed pests and predators which affect honey bee like ant, wax moth, birds, spiders, and lizards. According to the response of beekeepers, ant

(65.5%) attack was a serious problem in the study area, followed by wax moth (52.4%). Frequent cleaning of the apiaries, using ash, and killing of the predators were remedies done by some of the respondents. Bee lice were the least problem, mentioned by 6.3% of the respondents. Similarly, Adeday et al. (2012) in Wukro Tigray region noted similar pests and predators [1]. Moreover, according to the result obtained by Debassa and Belay (2015), in Walmara district, 75.4% of the sample respondents lost up to five colonies due to pests and predators [6].

Table 7. Major pests and predators reported by respondents

Factors	Beekeepers who consider pests and predators are important (%)
Ant	65.5%
Wax moth	52.4%
Birds	47.3%
Spiders	26.5%
lizards	7.8%
Bee lice	6.3%

Among the sampled beekeepers in *Table 8*, only 55.8 % had received some training in bee management for two and three days at Farmers Training Center (FTC), near the town and regional city. Of those who had been trained, 58.2% took their training at the nearby town, followed by FTC (26.9%), while the minority (14.9%) were instructed in a regional city with the help of governmental and non-governmental organizations. These results suggest that acquisition of technical skills and knowledge of bee farming were likely to influence the adoption of modern beekeeping technology.

Table 8. Respondents' experience on training of bee management

Training experience	**Number of respondents**	**Percentage**
Respondents took training	67	55.8
Respondents did not take training	89	44.2
Total	**156**	**100**
Place of traning		
At FTC	18	26.9
In a nearby town	39	58.2
In a regional city	10	14.9
Total	**67**	**100**

FTC = Farmer Training Centre

4. Conclusion

The productivity of frame and transitional hives is, more than triple than that of traditional hives. This is perhaps because of better management practices, such as providing wax foundation sheets, recycling of drawn out combs after honey extraction, and higher frequency of harvesting. Honey harvesting is done once, twice, or three times a year, and a variation among hive types can be clearly seen in the frequency of honey harvesting. Honey harvesting from frame hives and transitional hives takes place more than twice a year.

Half of the respondents preferred transitional hive, even though the average honey bee colony holding size for traditional was a little bit higher than the two hives. Major factors affecting choice of frame hive technology: lack of equipment, and wax quality and availability problems were mentioned as a first and second factors which affect the adoption of frame hive technology. In addition, pests and predators such as ants and wax moth were problems for honey bee colony in the study area.

Various honey-bee floras, such as Vernonia *amygdalina*, *Croton macro-stachyus*, *Schefflera abyssinica*, *Syzgium guineense,* and *Bidens pachyloma,* were identified, which plants are responsible for the different colours of honey. The majority of beekeepers have knowledge in colony feed supplementation during dry season, which has to be adopted by other beekeepers to sustain the colonies. More than half of the beekeepers took training in the study area for two to three days. This suggests that acquisition of technical skills and knowledge of bee farming were likely to contribute positively to farmers' adoption decision. In conclusion, in order to adopt and sustain the modern hive technology, the focus should be on honey bee equipment, hive and wax quality and availability.

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Genetic diversity study of sorghum (*Sorghum bicolor* (L.) Moenc) genotypes, Ethiopia

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Abstract. *Sorghum bicolor* is one of the most important cereal crops around the world, particularly in Africa, highly cultivated for dietary staple. For this reason, a good knowledge and usage of this genetic resource in sorghum accessions is highly vital for improving crop quality. Analysis of genetic variability among the accessions will enable accurate results in breeding. The research design used was augmented design, which is common in many gene banks. This research finding would be used later by plant breeders to select best performers for further evaluation of the crop and obtain a new variety of sorghum.

Keywords: genetic diversity, genetic variability

1. Introduction

Sorghum is ranked the fifth most produced food crop in the world, and it is a dietary staple for over half a billion people in over thirty countries, most of them being developing countries [1], [2]. It is also the second most cultivated cereal crop in Africa, where cultivation of farmer's variety of sorghum is the predominant form of agriculture next to maize [3]. Sorghum was domesticated in the African continent, particularly in East Africa, Ethiopia, from where it was believed to be introduced to other regions of the world with a wide agro-ecology [4]. It is one of most vital crops cultivated over a wide extreme ecological habitat in Ethiopia, in the range of low to high altitude (400–3,000 meters above sea level) [5]. It is well adapted to the range of environmental conditions in semi-arid Africa, with high variability [1], [6], [7]. Sorghum is the single most important cereal in the lowland areas because of its extreme resistance to water stress [8].

Sorghum bicolor contains both cultivated and wild relative races, and it provides a substantial amount of genetic diversity for traits of agronomic importance so as to develop the crop's different variety of interest for plant breeders [9].

Ethiopia is known to be one of the Vavilovian centres of origin, or diversity for many cultivated and wild species of crops, including sorghum [10], [11]. Sorghum is one of the cereal crops for which Ethiopia has been credited as being a centre of origin and/or diversity [10], [12]. In the high altitude areas, the landrace sorghum germplasm has often been the only well-adapted material that is easily accessible for use. There is a higher probability of genetic material exchange to occur between the wild (*Sorghum bicolor subsp. arundinaceum*) and the cultivated sorghum since both types mostly grow in sympathy with the wild and weedy relatives in most sorghum-growing parts of Ethiopia, mainly in the south-eastern and south-western part of the country [1]. A greater extent of genetic diversity existed within a species, often used as a measure of its ability to adapt to its new environment. Hence, biodiversity is like a wealth for coping with environmental fluctuations. Sorghum has one of the largest crop germplasm collections, consisting of more than 42,000 accessions worldwide [13], [14]. The largest diversity of the crop germplasm provides greater opportunities for improvement regarding its environmental adaptability and acquiring better agronomic traits from the crop species. Identifying and selecting the best varieties meeting specific local food and industrial requirements from this great biodiversity is of high importance for the food security assurance of any given country [14].

Having a good knowledge of the genetic diversity of a crop often enables the plant geneticist to select the desirable family for the breeding programme and gene introgression from distantly related germplasm. The more variable genotypes or accessions can be crossed to produce better varieties that can tolerate a range of environmental changes to abiotic and biotic stresses. Therefore, a better understanding of the genetic diversity in sorghum crop species will definitely facilitate the further improvement of this cereal crop concerning its genetic architecture [15].

Genetic diversity in the crop species is one of the precious gifts of nature to us, and it arises due to geographical isolation or genetic boundary to gene flow. Phenotypic traits are conventional tools to analyse the genetic diversity since studies of this type generally do not require complicated equipment and methodology. They are very simple and easy to score. These simple observable morphological characters are the useful tools for primary genetic diversity study as they provide a quick and useful approach for assessing the range of diversity in the crop species. Over the years, a number of studies have dealt with estimating genetic diversity in cultivated sorghum using morphological traits [16–22].

The use of phenotypic characters is the most advisable method most often used to estimate relationships between genotypes. The genetic variability of cultivated crops and their wild relatives together form a potential and continued source for breeding new and better crop varieties. A better understanding of the genetic diversity in sorghum would greatly contribute to crop improvement with a view to food quality and other important agronomic traits. Therefore, there is a need to evaluate the available accessions for genetic diversity and identify the best accessions according to their performance.

There are around 11,353 sorghum accessions collected and conserved in Ethiopian Biodiversity Institute gene bank, of which 8,913 accessions were characterized by plant breeders and other researchers, and further 2,440 sorghum accessions are yet to be screened for their potentially useful characters. For this reason, the main objective of this research was to determine the range of variation among sorghum accessions in general and to classify them into clusters based on their similarity features regarding the traits under study (quantitative characters) and also to generate data on their performance for plant breeders for further evaluation of the crop in particular.

2. Materials and methods

The study on sorghum was conducted in Oromia Regional State, Arsi Zone, Arsi Negale Research sub-centre in the summer of 2014/15, during the main cropping season. This region is located in the Western Oromia Regional State, with an altitude of 1,960 meters above sea level and 7°20'N latitude and 38°09'E longitude. 117 Sorghum accessions and two standard checks (Geremew and Baji), which were obtained from Melkasa Agricultural Research Centre (MARC), were used for yield and drought resistance traits comparison for the research, respectively. The research design used was augmented design with no replication among the sorghum accessions, except for the two standard checks replicated in every block due to insufficient seed availability. The sorghum genotypes were planted in two rows with a spacing of 75 cm × 30 cm between and within rows respectively, with a row length of 5m. DAP, Urea, and other management practices were applied as per recommended for the site.

Morphological data was recorded with the help of the International Plant Genetic Resources Institute (IPGRI), nowadays known as “Bioversity International”, based in Italy, Rome. The characterization descriptor list for sorghum (E and F, 1993) was used by randomly selecting and tagging 20 individual plants for diversity study research from each accession. For each selected plant, the quantitative trait to be studied in the accession was coded as Basal tiller (BT), Nodal tiller (NT), Leaf number at maturity (LN), Plant height (PH) in cm, Panicle length (PL) in cm, Panicle width (PW) in cm, thousand grain weight (GY) in gm, Days to 50% flowering (DF), and Days to 50% maturity (DM). The collected data were calculated by statistical analysis of variance using MINITAB (version 13.0) and SAS (9.2). Variances and coefficient variation were calculated as per formula, as it was suggested [23].

Table 1. List of the sorghum accessions and the two standard checks used for the study, obtained from the Ethiopian Biodiversity Institute

No	Acc. Number	No	Acc. Number	No	Acc. Number	No	Acc. Number	No	Acc. Number
1	9125	28	219976	55	233816	82	237778	109	241689
2	9161	29	219982	56	233819	83	237784	110	241690
3	9630	30	223513	57	233820	84	238379	111	241692
4	15817	31	223533	58	233821	85	238382	112	242029
5	15821	32	223581	59	233822	86	238384	113	242030
6	70940	33	226053	60	233830	87	238385	114	242034
7	71806	34	227098	61	233832	88	238387	115	242035
8	71889	35	227202	62	233835	89	238388	116	242038
9	73657	36	227203	63	233836	90	238392	117	69057
10	74788	37	227205	64	233837	91	238407	118	Germew (ck 1)
11	73957	38	227206	65	234056	92	238410	119	Baji (ck2)
12	200117	39	227208	66	234057	93	238438		
13	200646	40	227213	67	234067	94	238453		
14	200774	41	228091	68	234081	95	241197		
15	201444	42	228111	69	235468	96	241199		
16	201768	43	228544	70	235476	97	241218		
17	201817	44	228548	71	235597	98	241221		
18	201923	45	228741	72	235615	99	241235		
19	201936	46	228743	73	235624	100	241237		
20	201956	47	231201	74	235626	101	241240		
21	206944	48	233686	75	236728	102	241245		
22	206950	49	233689	76	237033	103	241246		
23	216827	50	233693	77	237037	104	241247		
24	217694	51	23699	78	237278	105	241248		
25	217697	52	233700	79	237281	106	241251		
26	217698	53	23707	80	237769	107	241273		
27	219974	54	233808	81	237771	108	241275		

3. Results and discussions

3.1 Analysis of variance

The analysis of variances (ANOVA) table revealed that there is diversity among the accessions of sorghum for all characters studied; in other words, there were significant differences ($p < 0.05$), as it was indicated in *Table 2*.

Table 2. The mean square of the tested sorghum accessions for the nine quantitative characters

Source of variation	Degree of freedom	Mean squares								
		BT	NT	LN	PH	PL	PW	GY	DF	DM
Between Groups	7	0.674	1.462	30.27	5.14	130.76	9.29	110.30	157.41	200.36
Within Groups	111	0.25	0.773	4.19	3.41	42.42	4.53	98.36	33.48	64.44
Mean		0.26	0.77	9.21	2.67	24.69	6.88	23.41	102.7	71.06
SE		0.48	0.08	0.22	0.17	0.63	0.20	0.56	0.99	0.78

3.2 Mean and range values

The mean values of the genotypes indicated that there are some genotypes performing better than the two standard checks, “Geremew and Baji”, for some of the traits studied. Only one genotype matured earlier than the two standard checks, which was ACC No 238453 (51 days), while some others matured at the same time as the two standard checks, e.g. ACC No 9161 (54 days) and ACC no 9630 (54 days), ACC No 237769 (59 days), ACC No 234056 (59 days), and ACC No 241275 (59 days), whereas the two checks matured after 54 days (Geremew) and 59 days (Baji) respectively.

Generally, a considerable mean range value was observed for all the traits (*Fig. 1*). Mean ranges of 0 to 2.5, 0 to 3.1, 4.75 to 14.66, 1.45 to 4, 11.34 to 45.6, 4.3 to 10.3, 12 to 36.4, 79 to 131, and 51 to 88 were recorded for BT, NT, LN, PH, PL, PW, GY, DF, and DM, respectively, which clearly shows genetic diversity in the sorghum accession for the studied traits.

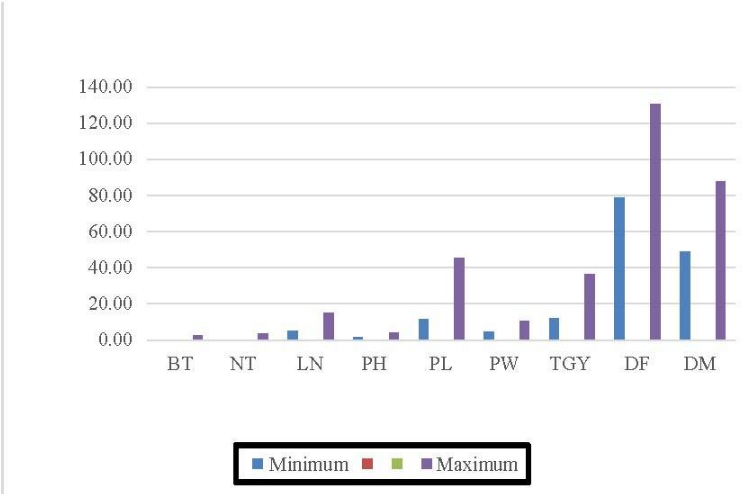

Figure 1. Minimum and maximum values of nine quantitative traits of 119 Sorghum genotypes

3.3 Phenotypic and genotypic coefficients of variation

Low PCV and GCV values were calculated for the traits considered according to [23]. This showed that there is no wide variation among genotypes for the traits considered, except for thousand grain yields (GY) and panicle length (PL), as it was illustrated in the bar graph (*Fig. 2*).

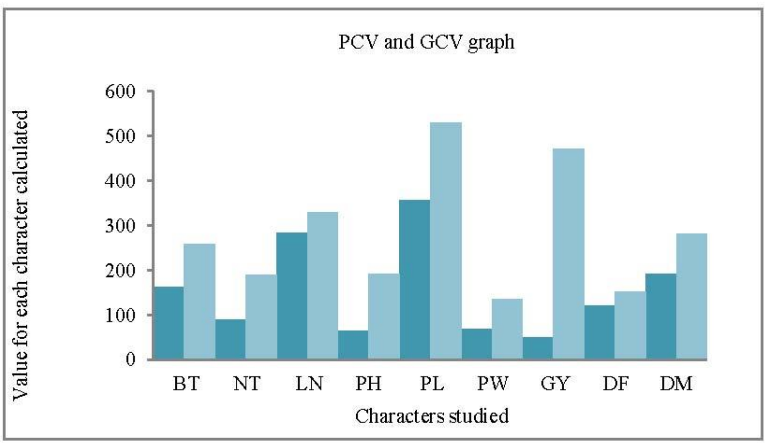

Figure 2. Phenotypic and genotypic coefficient of variation of all characters considered

3.4 Principal component analysis

Principal component analysis was performed in order to reduce a large set of phenotypic traits to a more meaningful smaller set of traits and to know which trait is contributing to maximum variability, because genetic improvement depends on the magnitude of genetic variation. The first four principal components (PCs), with eigenvalues greater than 1, explained about 71.9% of the total variation among accessions for all traits, as it was given in *Table 4*. The first principal component (PC1) obtained was 26.9% of total variance and had high contributing factor loading from LN and PH, which were the most important contributing traits for the relative magnitudes of eigenvectors for the first principal component, while the second principal component (PC2) had high contributing factor loading from PL, GY, and DF, which was 18.9%; thirdly, it had a high contributing factor loading from BT and NT for the third principal component (14.6%), and, finally, it had a high contributing factor loading from PW and DM for the fourth principal component (11.6%).

Table 3. Eigenvectors and eigenvalues of the nine principal components of the 119 sorghum accessions

Traits	Eigenvectors								
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
BT	0.214	0.416	-0.491	-0.134	-0.297	-0.139	0.199	-0.610	-0.042
NT	-0.041	0.405	-0.630	0.036	0.172	0.140	-0.078	0.614	0.064
LN	-0.589	0.147	0.010	0.181	0.080	0.007	0.045	-0.231	0.773
PH	-0.527	0.016	-0.123	0.398	0.252	0.099	0.206	-0.197	-0.627
PL	0.244	-0.504	-0.277	0.270	0.005	0.083	0.688	0.093	0.220
PW	-0.0372	-0.156	-0.101	-0.458	-0.056	-0.708	0.241	0.218	-0.086
GY	-0.026	0.490	0.446	-0.273	-0.018	0.285	0.611	0.171	-0.042
DF	-0.033	-0.177	-0.092	-0.044	0.829	0.356	-0.063	0.154	-0.080
DM	0.136	0.303	0.229	0.656	0.349	-0.485	0.042	0.221	-0.007
Eigenvalue	2.4174	1.6985	1.3098	1.0468	0.8261	0.6778	0.4942	0.4133	0.1161
% of total variance explained	0.269	0.189	0.146	0.116	0.092	0.075	0.055	0.046	0.013
% cumulative variance explained	0.269	0.457	0.603	0.719	0.811	0.886	0.941	0.987	1.000

The score plot of 119 accessions based on the first two principal components is presented in *Figure 3*. Accessions (arranged by their plot number) were distributed in different groups, which clearly showed genetic diversity among sorghum accessions.

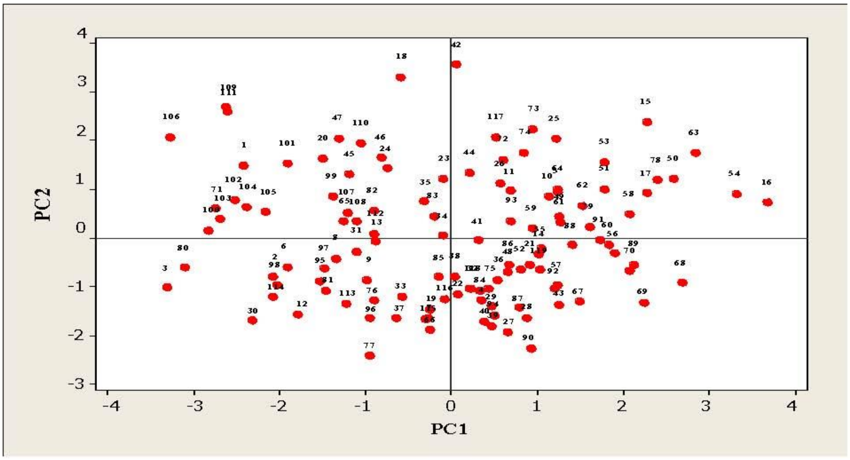

Figure 3. Distribution of sorghum accessions for the first two principal components (PC1 and PC2) based on nine quantitative traits given in their order of arrangement

3.5 Phenotypic and genotypic variation

Low phenotypic and genotypic values were calculated for the traits considered, as it was explained in *Figure 4* [23]. This indicated that there is no wide variation among genotypes for the traits studied, except for TGY, PL, and DM, which showed variability among the sorghum accessions for the traits considered.

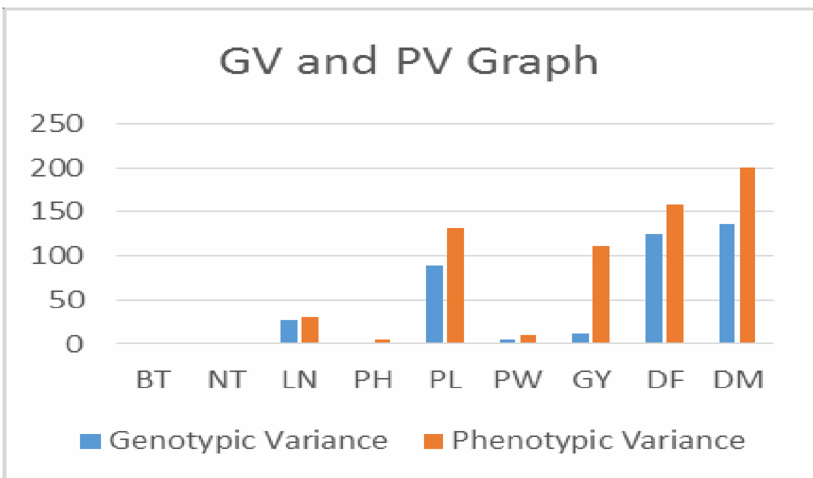

Figure 4. Genotypic and phenotypic variation bar graph of sorghum accessions considered for the nine quantitative traits

3.6 Cluster analysis

Cluster analysis was performed on the Euclidean distance matrix utilizing Ward's linkage method, and the resulting dendrogram is given in *Figure 5*, using MINITAB software version 14. The 117 sorghum accessions along with the two standard checks formed 13 clusters at a 40.88% similarity level. The result of the hierarchical cluster analysis indicated that 119 sorghum accessions were grouped into thirteen different clusters with a range of accessions that are categorized because of their similar performance for the trait under study (i.e. 5, 51, 4, 15, 8, 9, 13, 7, and 3 accessions per cluster respectively) from cluster number 1 up to 9, while the rest of the cluster numbers, 10, 11, 12, and 13, have only one accession per cluster. The clustering pattern indicated the existence of a significant amount of variability among the sorghum species. The two standard checks used were grouped into cluster 8 along with five other sorghum genotypes that performed in a similar way for the studied quantitative characters. Cluster 7 and 12 have the largest distance between them (56), while cluster 3 and cluster 5 have the smallest distance (13.5).

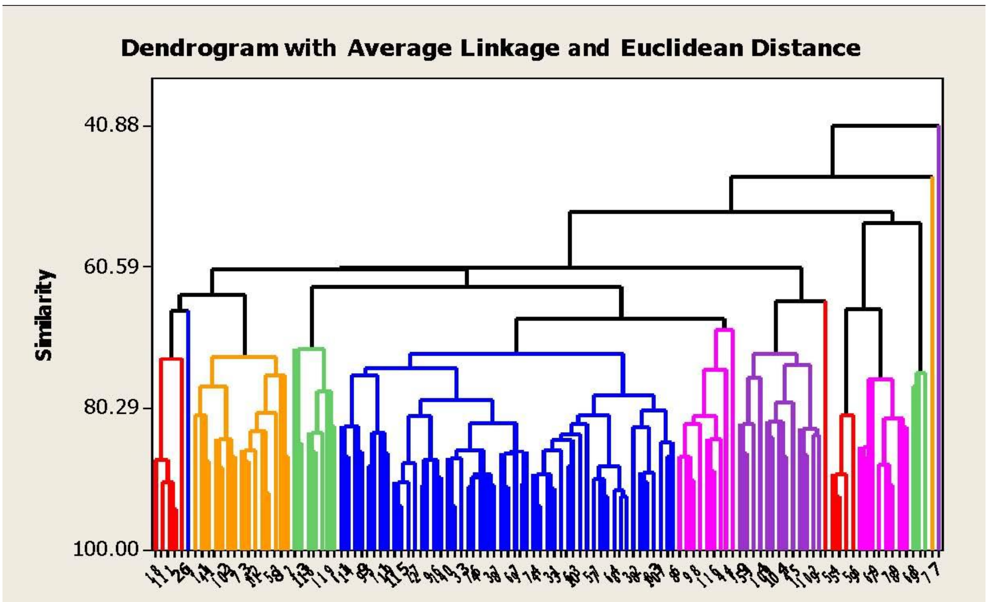

Figure 5. Cluster analysis of 119 sorghum genotypes

4. Conclusions

The diversity study of sorghum clearly indicates a diversity among the accessions. Landraces on a farm are acknowledged as the main source of genetic diversity for gene banks and breeding programmes, yet many studies have shown that genetic erosion is occurring on farmer varieties because of the utilization of high-yielding varieties. It has also been suggested, however, that only landraces which are not used for specific reasons are subjected to genetic erosion, while those which are (and have been for years) selected by farmers for certain desirable traits are likely to survive on a farm alongside improved varieties.

Based on all the parameters used to see if there was diversity among the sorghum accessions, the tested genotypes showed genetic variability for the traits considered. 119 genotypes are grouped into 13 cluster groups, which consists of 51 genotypes for the largest cluster and a single accession for four cluster groups (clusters 10, 11, 12, and 13), having different values of squared distance for each cluster group ranging from 13.5 to 56, which clearly shows that there exists a diversity of the sorghum genotypes.

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Specific horticulture therapy guidelines in the landscaping of Cluj-Napoca hospital facilities – improving mental and behavioural healthcare

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Abstract. In the beginning, nature was an irreplaceable environment for humans. The concept of horticulture therapy (HT) denotes the use of ornamental plants to improve people's health based on the connection between landscape architecture principles, design elements, and guidelines in healthcare facility gardens. In HT, people can improve and maintain health; so, gardens must provide only beneficial effects for users (patient, family, staff), testing design elements, which can be a scroll direction in garden, point of interest, connection with nature. This paper presents a case study analysis of the current landscape architecture standpoint: one of the Cluj-Napoca clinics, where HT can improve patients' well-being.

Keywords: design elements, therapeutic landscape, plants

1. Introduction

Horticulture therapy was mentioned in ancient Egypt, but the history of healing gardens goes back many centuries, as at one time nature was seen as intrinsic to healing – still, this important connection had been largely lost by the twentieth century [1]. In 1806, hospital staff in Spain began emphasizing the use of agricultural and horticultural activities in their programming for patients with mental disabilities. The favourable evidence encouraged other institutions to realize the benefits of working with the soil for people with mental disabilities [2].

The main concept of horticulture therapy of using nature (especially ornamental plants) in order to improve human health has been gaining ground since the 70s and 80s [1].

Based on this statement mentioned before, the main topic of this research is to study the connection between landscape architecture principles and design elements used as guidelines in healthcare facility gardens.

In order to provide a natural environment, horticulture therapy is an activity through which people can maintain and improve the health of their body, mind, and soul. The five senses of the human body (sight, smell, taste, touch, and hearing) are used to interact with plants by colour, flavour, and aroma and texture [3].

It was confirmed that when people come in contact with plants through a variety of gardening activities, such as planting and caring for plants, besides the aesthetic function, it generates feelings of comfort and improves the quality of life [3].

History and research made so far in the field of horticulture therapy show that contact with nature has beneficial effects on humans. From the theoretical point of view, using plants in constructed landscape significantly improves the patient's recovery period from any medical problems.

For example, the mental health benefits of interaction with landscape are actively and/or passively numerous and well-established. For this purpose, healthcare institutions in Europe and the United States of America make healing green spaces used for horticulture therapy such as: a garden at a crisis shelter for women and children survivors of domestic violence (Danner's Garden, Copenhagen, Denmark), Alnarp Rehabilitation Garden (Alnarp, Sweden), Rosecrance healing garden (Griffin Williamson adolescent treatment centre, Rockford, Illinois) [1].

In Romania, at the Mocrea Psychiatric Hospital in Arad, there was established the first therapeutic garden in 2014 for a Romanian healthcare facility, having an area of 1,500 square meters, where there are over 3,000 flowers and shrubs planted on site. In this green space, more than 40 hospitalized patients have the opportunity to be involved in horticulture therapy activities [4].

At this moment in Romania, horticulture therapy principles are insufficiently studied and applied in healthcare facilities, but the requirements for it are significant. The current Romanian laws have sufficient requirements for green space areas close to hospitals (10–15 square meters/patient), according to Decision No 525 of 27 June 1996 for approval of General Regulation – Urban Planning [5], but in many cases these are not complied with in practice. The benefits of interacting with nature for people with mental disorders have been various, well-documented, and historically certified from the beginning of the horticultural discovery. These conditions affect most people either directly or indirectly. One of four people is experiencing mental disorders, which in the most cases are not detected or judiciously treated. These conditions can affect people of all ages who are emotionally affected, including depression, attention deficit disorder (ADD), autism, suicide, bulimia, or addiction to narcotic substances.

The purpose of this study was to analyse the current landscape architecture standpoint in Cluj-Napoca – Child and Adolescent Psychiatry and Addiction Clinic, where, by using horticulture therapy principles, patients' wellbeing can be improved.

2. Materials and methods

In May 2016, the green area of Child and Adolescent Psychiatry and Addiction Clinic of Cluj-Napoca was the place for a therapeutic landscaping intervention. This clinic is located on Ospătăriei Street, in Plopilor neighbourhood, which covers an area of approximately 2,000 square meters. At this moment, the studied hospital is one of three paediatric psychiatric clinics in Romania which offer cure and medication for 25 patients, children and teenagers as well, and is the workplace for a teaching clinic for university and postgraduate programmes.

In the spring of 2016, at the initiative of School for Public Health Babeş–Bolyai University and a group of 3rd-year students taking part in this programme, a multidisciplinary team (researchers, doctors, psychologists, landscape architects, architects, and students) was formed to develop and implement the green area of the clinic mentioned before.

During the second semester of the academic year 2015–2016, students had to attend the course of project development for mental health. They studied alternative treatment of mental disorders, the use of horticulture therapy in the perspective of healing gardens. The practical part of the project consisted in the development of some main stages of the therapeutic garden elements.

The new landscape plan for the hospital green space aimed at having only beneficial effects on users (patient, family, and staff). Using the landscape architecture design elements, such as line, shape, colour, value, and texture in the green space of healthcare facility, this can provide for patients and also visitors a scroll direction of the garden (line and shape), a point of interest (colour and value), and a connection with the nature or character of the plants (texture) in the garden. The hospital's green space must have only beneficial effects on people.

At the start of the landscaping project proposal of the clinic's green space, the site was analysed according to the elements of the therapy through landscape: horticulture therapy and sensory arrangement – *Fig. 1*.

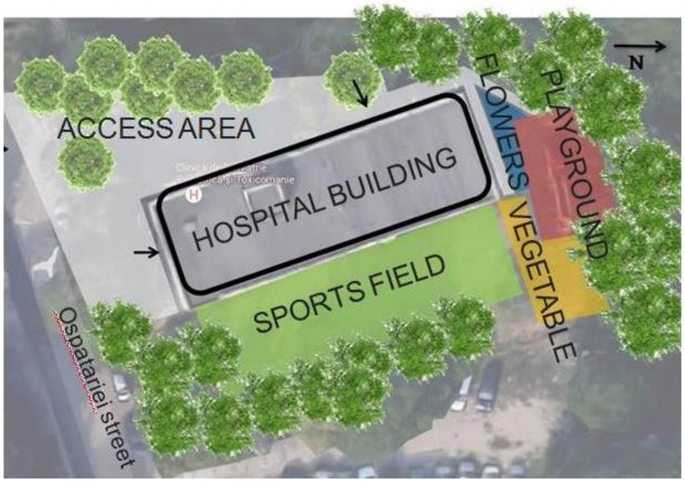

Figure 1. Land distribution of the landscaping plan – Child and Adolescent Psychiatry and Addiction Clinic of Cluj-Napoca

3. Results and discussions

To achieve the effect of horticulture therapy according to planning principles, it was absolutely necessary to make an analysis on how the landscaping projects need to be developed for this type of institution and also how they can be integrated for each type of illness that requires a specific design guideline in the garden.

According to Decision No 525 of 27 June 1996 for approval of General Regulation – Urban Planning [5], the green space area respects the required 10–15 square meters/patient, a ratio accomplished for the number of hospitalized people. A local case study analysed all project data such as location, addressability, profile, architectural programme, green space specifics, and user needs and requirements.

Being a sanitary facility with a paediatric profile, where diseases such as mental or chromatic disorders are treated, the purpose is to use blue or white shades of colour that have relaxing effects. In order to realize a surprise element and occupy the centre of attention, the use of ornamental plants with complementary colour inflorescences was proposed – they would use yellow (*Fig. 2*).

The ornamental plants proposed for the planting design are as follows: for its calming properties, *Lavandula augustifolia*, *Tropaeolum majus* for being an edible plant [6], installed together with groups of wild lily (*Hemerocallis sp.*). Due to their decorative colours, they mostly used perennial species to obtain a spring flower design – therefore, bulbous plantings are made each autumn (*Tulipa sp.*) [7]. Analysing the decorative plant species through the leaves, the plants already existing on the site (*Sedum sp.*) are proposed for reuse because of the specific texture and low-maintenance species in terms of green area sustenance [8].

A random, marginally flattened *Stachys* group can be positioned for the velvety foliage besides the autumn lily (*Hosta sp.*) [9]. From the group of ornamental grasses, the most suitable species is *Miscanthus sinensis* because, due to the shape of the leaf and the pendent port, it gives a feeling of comfort to the touch and, on the action of climatic factors such as the wind, presents an aesthetically unusual figure [10].

Figure 2. The sensory garden with perennial floral plants – Child and Adolescent Psychiatry and Addiction Clinic of Cluj-Napoca

Near this planting group, as part of the "sensory alley", rocks or gravels of different sizes and natural elements, such as bark, cones, or straw, were proposed.

The lack of sufficient seating generated the idea of using recycled briquettes and spread them through the garden (*Fig. 3*). And this way children would become curious to venture through the garden and would spot the centre of interest only to stay for a while.

In order to have some privacy and a place to stay, even if not arranged, it was proposed to use recycled wood pallets for the arrangement of this area.

For a more comfortable stay, people can enjoy the sitting spot. The corner already offers its own privacy due to its configuration, but with the help of vertical gardens in wood pallets presented in *Fig. 4* the place can be arranged more naturally. This way, ill children will be getting closer to nature. Clinical treatment also needs special psychotherapy features, the use of a vertical garden set-up, the application of HT principle, and to create a conducive environment to implement these activities.

Figure 3. Sitting area – Child and Adolescent Psychiatry and Addiction Clinicof Cluj-Napoca

Regarding the gardening area, raised beds, as shown in *Fig. 4*, can be planted with vegetable species such as tomatoes (*Solanum esculentum*), pepper (*Capsicum annuum*), parsley (*Petroselinum crispum*), and spinach (*Spinacia oleracea*) for the edible part of the garden [11]. Culinary herbs and edible species, such as *Mentha spicata*, *Thymus vulgaris*, and *Basilicum*, always provide a fresh flavour for a simple walk through the garden [12].

In the first phase of the project, the land was cleaned, arranged, and planted with vegetables, while the children were curious, interested, and eager to be involved in the planting or sowing stage. Similar results using horticulture therapy were reported by Marcus Cooper [1] all over the analysed healthcare green spaces addressing the mental health issue.

Figure 4. Raised beds for the vegetable garden – Child and Adolescent Psychiatry and Addiction Clinic of Cluj-Napoca

4. Conclusion

The sensory design aims for the Child and Adolescent Psychiatry and Addiction Clinic of Cluj-Napoca was to use natural, living, and inert materials. According to the aesthetic and therapeutic features, the landscaping project proposed decorative plants through leaves and flowers. For the planting design, it was set in the proximity of the access points, near the playground and the perennial plants composition. In this way, the green area will offer sustainable solutions for all user requirements, thus fulfilling its final aim: long-term physical and mental improvement. In conclusion, it is hoped that the green space will be exploited to the maximum of its therapeutic capacity in order to improve patients' health in a natural way.

Acknowledgements

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Assessment of nutrient content of tomato hybrids for processing

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Abstract. We have tested the refraction of 6 cultivars of open-field tomatoes. In our work, we have tested the nutritional values of tomato cultivars harvested at different times. Our aim was to answer the question as to which cultivar fulfils the requirements for processing under given circumstances. During harvest time, we also measured the ratio of yellow and red pigments. The trial was conducted in Kecskemét, Hungary, on the trial field of NAIK ZÖKO, in open-field conditions. The refraction measurement was done on weighted tomato, which was then ground to juice and then measured on a tabletop refractometer. The 6 tested cultivars Brix% were measured at 5 different harvest dates, and then the average refraction of the harvest was analysed. The most suitable cultivar for processing was found to be Solerosso.

Keywords: tomato hybrids, cultivars, pigment ratio

1. Introduction

Among vegetables, tomato has a huge importance. The yearly production of the world regularly exceeds 150 million metric tons. A significant part of this production goes to processing. Processed tomatoes have certain advantages compared to fresh market, such as the pulping and the possibility to store it for longer periods without the deterioration of nutritional values (Szuvandzsiev et al., 2013). The world's tomato consumption was determined at 12 kg per person per year. There are significant differences between countries: for example, in tropical countries, the average consumption is 4 kg per person, while tomato consumption in Greece or in Italy reaches or even exceeds 25 kg per person. Hungary is around the world average: in the last one or two decades, it recorded 10–12 kg per person per year (Helyes et al., 2006).

Tomato – like most of the vegetables – is not very high in calories. 100 gram of fresh tomato contains 92 J (22 Cal) of energy. The water content of the ripe fruit is around 93–96%. Both the minerals and chemicals found in the tomato fruit are responsible for the favourable effect it causes in the human body's metabolism (Helyes et al., 2005). Water-soluble carbohydrates give the soluble dry matter (Brix%), which is mostly made up of reducing sugars. The soluble dry matter of a ripe fruit is about 5–7.5% of the fresh weight. Most part of the dry matter is sugar and organic acids (Davies-Hobson, 1981), which are responsible for the taste of the fruit. The higher the average fruit size, the higher the water content and the lower the Brix% (Varga, 2002). The ripe tomato fruit contains 93–96% water, which dissolves carbohydrates, organic acids, minerals, vitamins, and pigments. This means that the soluble dry matter of a fresh tomato fluctuates between 4% and 7% (Brix°). The dry matter content depends on the cultivar, the growing technology, and the environmental factors during the growing season (Helyes, 2007). In cherry tomatoes, soluble sugars gave 62% of the soluble dry matter, while determinate cultivars for processing had only 46% of the Brix°. In regard to sugar–acid ratio, cherry types gave significantly higher values (Helyes, 2007; Helyes et al., 2013).

The type of harvest (manual or machine) also influences the dry matter content of the raw material we supply for the processing company. In the case of manual harvest, the Brix° is higher because the ratio of fully ripe fruit is higher (Jauregui et al., 1999). It is important to note that water quality also influences nutritional value and dry matter content (Doaris et al., 2008).

2. Materials and methods

2.1. Trial conditions

The trial was carried out on the NAIK ZÖKO's open field for vegetable trials. NAIK (Nemzeti Agrárkutatási és Innovációs Központ, English name: National Agricultural Research and Innovation Centre, acronym: NARIC) is an institute of national competence in Hungary. Processing companies' raw material need was supplied from tomato cultivars bred in Kecskemét till about the end of 1980s. By the turn of the millennium, processing capacities had been reduced just as production volumes, but using F1 hybrids had become general practice. The Hungarian Government wants to support the growth of the capacity of national processing companies, which requires high-yield cultivars with disease resistance and the ability for mechanical harvest. Breeders want to support the processing companies' research projects with new, early and mid-early cultivars with excellent parameters for processing. The work of Hungarian tomato breeders are praised by the fact that in Hungary tomatoes for processing are produced exclusively from their cultivars. Their latest cultivars are resistant to *Xanthomonas vesicatoria* – a bacterial disease of tomato. In their new projects, they are working on resistance to other diseases, creating doubled haploid lines, incorporating new sources of disease resistance, and applying new technologies under open field and glasshouse. The following determinate cultivars were used: Aragon F1, Solerosso F1, Mokka F1, Progress F1, Benito F1, and Albarossa F1. Plug production time was 5 weeks – plugs were planted on the field on 8 May 2015. The spacing was 120×40×40 cm (about 30,000 plants per hectare); plants were planted in twin rows. Irrigation and fertilization was carried out with drip tapes. Fertigation was carried out with 1.5% Yara Ferticare 10-5-26 once or twice a week, depending on the weather, with optimal water portions. Plant protection was carried out mechanically, row spacing was covered with agricultural fabric to keep them weed-free. Topping was an important plant manipulation technique for having as much fully ripe fruit as possible. It was carried out at a height that the top raceme could ripe at the designated harvest date. Harvest times are as follows: 1. 2015-08-17, 2. 2015-08-25, 3. 2015-09-02, 4. 2015-09-15, and 5. 2015-09-22.

2.2. Methods

From each plant, 5 biologically ripe fruits were collected. They were ground to juice in a laboratory. For refraction, we used Hanna HI 96801 digital refractometer and for pigments we used Hunter D25. The refraction results were collected in temperature-compensation mode (nD20) and in non-compensated (nD) mode. With the refraction, we were able to analyse the composition and density of liquids; so, this can be used in the food industry and environmental tests. Results can be viewed in Brix%. Brix tests are used for water-soluble dry matter measurement – the refraction –, which in the case of tomato is made up mostly of sugars, but it is not an exact equivalent. Refraction, also known as Brix, is an important parameter in food processing. Refraction, or soluble dry matter (total soluble substrate, TSS), is made up of soluble sugars in the case of tomato – with good approximation, it can be considered equivalent. Brix expresses the sugar content of tomato: 1 Brix° (or 1 Brix%) means there is 1 g of sugar in 100 g of tomato. Tomato values are between 4° and 7° – the higher the better. The sweetness of the fruit depends on the sugar content, but the allover taste depends on the ration of sugars and acids.

With the colour difference meter, we measured the light intensity of parts of the visual spectrum.

3. Results

3.1. Results of the refraction

Fruits were weighted and ground to juice, and then refraction (sugar content) was measured with Hanna HI 96801 refractometer. Results are shown in *Table 1* and in *fig-s 1, 2*.

Table 1. Sugar content of different tomato cultivars at 5 harvest dates

Harvest time	Aragon F1	Solerosso F1	Mokka F1	Progress F1	Benito F1	Albarossa F1
2015.08.17	6.98	6.95	6.33	7.07	6.04	6.57
2015.08.25	6.7	6.55	6.25	6.6	6.05	6.0
2015.09.02	4.93	5.75	5.25	5.75	5.35	5.55
2015.09.15	4.8	5.85	5.35	5.55	5.05	5.4
2015.09.22	4.5	4.5	5.15	5.15	5.55	5.25
Mean	**5.58**	**6.11**	**5.67**	**6.02**	**5.61**	**5.75**

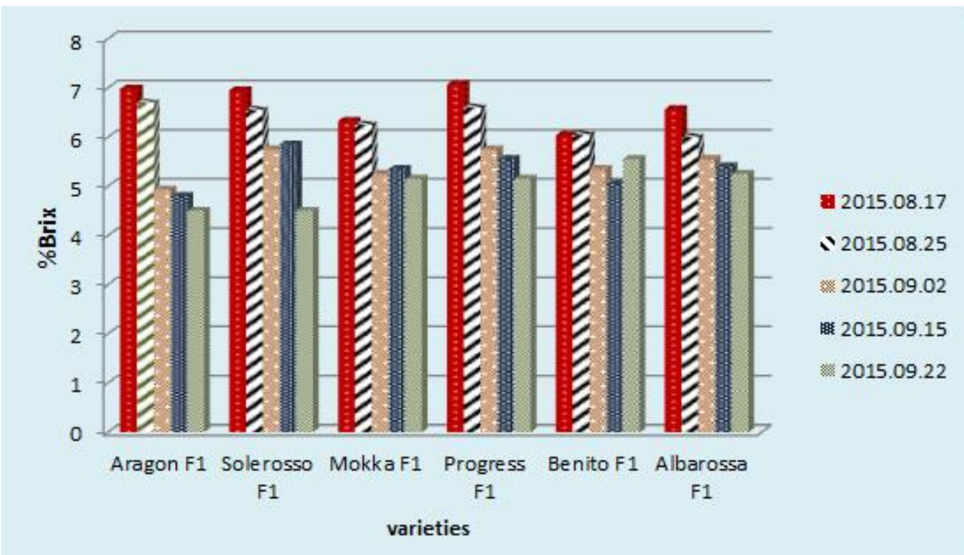

Figure 1. Dry matter content of different tomato cultivars by harvest date

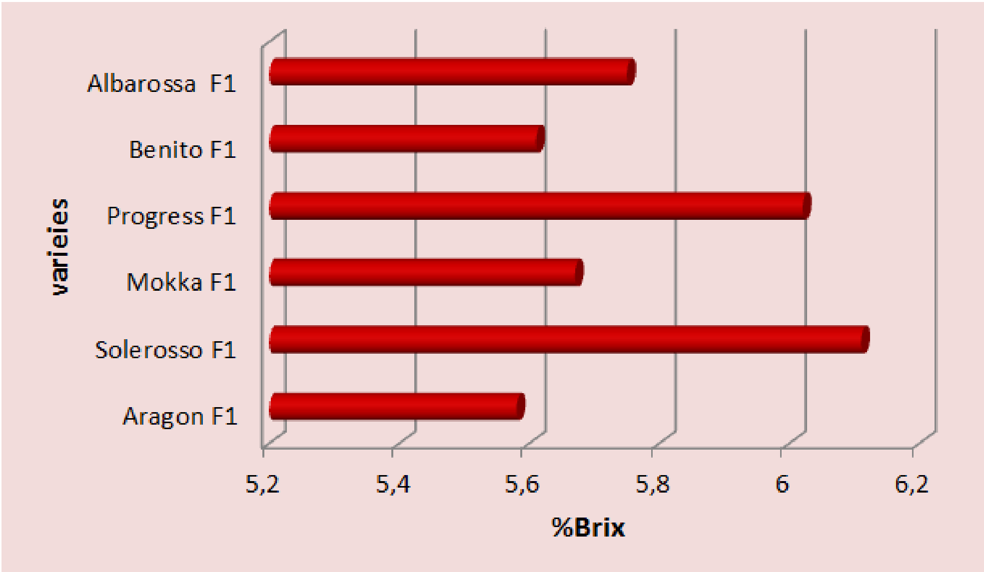

Figure 2. Graphic representation of mean Brix% of different tomato cultivars

Tomatoes for processing should have at least 4.5% Brix. Fruits for fresh market should have Brix between 3.5 and 5.5. Cultivars in the trial have the following results:

Aragon F1: This cultivar had the lowest Brix% in our trial. Although it had 6.7% at the second assessment, it was the lowest at the last 3 assessments.

Solerosso F1: It gave steadily over 6% for the first 2 assessments and had values near to 6% on later assessments.

Mokka F1: It had over 6% for the first 2 assessment dates but it gave a little bit over 5% for the last 3 times.

Progress F1: It had the highest refraction on 17th of August with 7.07% but results show a steady decreasing tendency, which reduced the season's average. Even this was enough for it to be the second best in our trial.

Benito F1: It gave fluctuating results; the 3rd and 4th assessments gave unexpectedly low values. Even if the last result was better, the season average was 5.61%.

Albarossa F1: This variety had a slow but steady decrease of sugar content throughout the assessment dates. Even so this was the 3rd best in the trial with 5.75%.

3.2. Colour measurement

For the first 3 harvests, we measured the red–yellow pigment ratio of the varieties with Hunter D25 spectrophotometer. The visual assessment resulted in well-coloured, intensive red fruits even at the September harvest. Results were in compliance with the expectations for processing.

4. Discussion

Water-soluble dry matter content is highly influenced by the cultivar and the harvest time. The means of Brix show a steady decreasing trend from mid-August to mid-September.

Cultivars have significant differences, but still, the decreasing of Brix values is prominent. Our trial is good for grouping these tomatoes into excellent, intermediate, and low Brix cultivars. These tomatoes cannot be categorized by one Brix measurement – obviously, reliability could be increased with more repetitions and more frequent harvest times.

Harvest time is crucial – as our results show: at the first 2 harvest times, sugar content decreases.

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Effects of land-use changes on soil properties based on reambulated soil profiles

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Abstract. In our study, by investigating reambulated soil profiles from the Nagy-Sárrét region in Hungary, we attempt to determine the extent of changes which have occurred due to effects which impacted the landscape in terms of the soil chemistry properties of soil profiles exposed during the Kreybig soil survey more than 70 years ago. Based on the results, in the areas used as grassland, we observed a decrease in pH and an increase in the humus content of the topsoil. The increased $CaCO_3$ following the chemical improvement of the soil which was used as cropland is still characteristic of the area. During the past decades, the investigated soils have been affected by significant changes with regard to water management, which have also modified the investigated parameters. We have classified the reambulated soil profiles among the Solonetz, Vertisol, and Gleysol reference groups based on the World Reference Base of Soil Resources (WRB) diagnostic system.

Keywords: archive soil data, land use changes, Kreybig, Solonetz, Vertisol, Gleysol, WRB

1. Introduction

Soils are constantly changing due to natural and anthropogenic effects [1]. When the landscape changes, the modification of one or more landscape factors leads to the modification of other factors, thereby altering the entire landscape [2]. As a result of soil recording attempts which date back more than 100 years on the national level, a large amount of soil data is now available. One of the most notable of the attempts mentioned above has been the Kreybig soil survey, which was the first large-scale Hungarian soil recording carried out on a national level and covering the entire country [2, 3]. During the last 70–75 years, however, both the land use and the nature of the landscape have undergone significant changes. We aim to determine the extent of changes which have occurred due to the effects on the landscape in terms of the soil chemistry properties of soil profiles. We have done this by investigating the reambulated soil profiles in the study area of Nagy-Sárrét, comparing them with the characteristic soil profiles of the Kreybig-mapping. Based on the field recordings, we have also attempted to classify the reambulated soil profiles according to the World Reference Base for Soil Resources (WRB) diagnostic system.

2. Materials and methods

Study area

The study area is located in the eastern part of the Nagy-Sárrét microregion of the Great Hungarian Plain (*Fig. 1*). The numbering of the soil profiles is in accordance with the Kreybig soil database available for the area. Profile no. 8 is located north-west of Biharnagybajom, profile no. 46 is located north of Biharnagybajom, while profile no. 37 can be found south of Biharnagybajom. Nagy-Sárrét is a recent alluvial plain interspersed with alkaline lands and flood-free areas [5]. Part of it has basin-like characteristics, where in the deeper, artificially drained areas, croplands and small fragments of natural vegetation can be found [6]. Other areas of Nagy-Sárrét are covered with soils characteristic of abandoned river beds, natural levees, and highlands. Dispersed afforestation (mainly pedunculate oak and black locust trees) can also be found. The majority of meadows are used as pastures and croplands. All the soils of the landscape have been developed under the influence of shallow groundwater and partially of temporary surface water cover, which is reflected in the topsoil but more frequently in the subsoil properties [7]. As a result of anthropogenic activities, these soils are mostly artificially drained, which is expressed in the lowering of the groundwater level and the retreat of surface water cover [8].

The most important changes regarding the development of the landscape occurred as a result of the water management in the 19^{th} century [9], which prevented the yearly water coverage, resulting in an increase in aridification and a decrease in the ground-water level. With regard to the flora, two main types can be identified. First, the agriculturally cultivated annual plant cultures and, second, the natural flora, which can be found sporadically throughout the area. In river basin locations which used to support the Sárrét saline soils, grasslands and swamps can be found, while the dead basins mainly feature croplands and borderlands. In the spring, another characteristic feature is the presence of wet-meadow-foxtail grasslands, which dry by the summer [10].

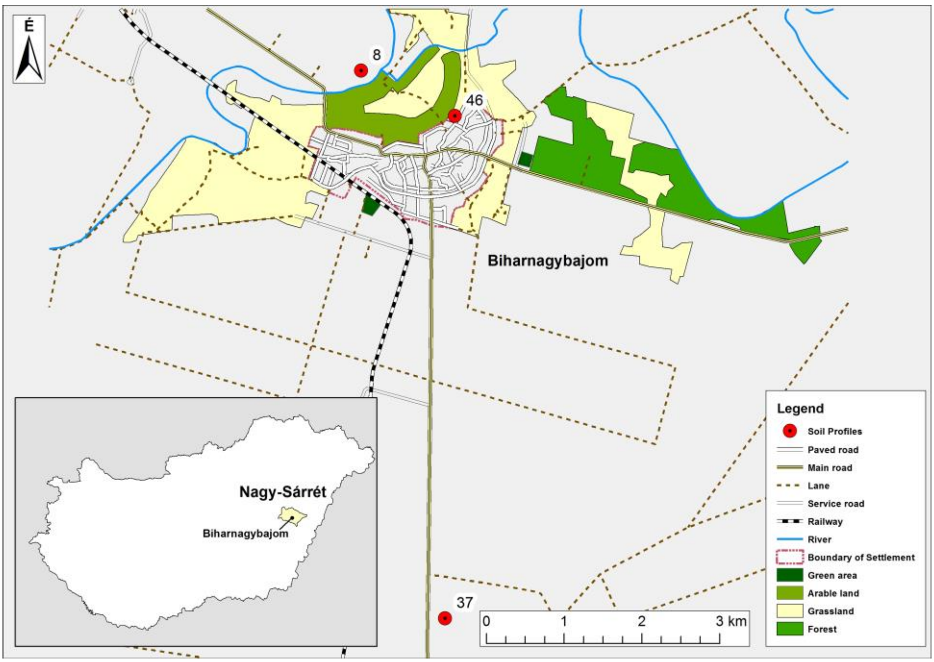

Figure 1. Location of study area.

Kreybig soil survey

In Hungary, Kreybig soil survey was the first national-level, large-scale local recording based on soil and laboratory investigations and was primarily intended to serve practical purposes [11, 12]. The comprehensive, national recording of soil types led by Lajos Kreybig started in 1934 and aimed to create a series of thematic soil maps which can be used to determine the soil properties by revealing the physiological conditions in terms of the animals living in the soil as well as the plants grown for crops. The recording work was performed on the basis of 1:25,000-scale topographic maps in accordance with the profile boundaries. Exposing drillings were performed for the recordings, some of which were up to 10 meters deep or as deep as the level of the ground-water [13]. Up to 1944, 108 map profiles were published, and more than 250 map profile recordings were performed. The missing profiles and the ones destroyed during the war were not completely replaced until 1951. The chemical properties of the soil for particular locations are depicted using colours, while its physical properties are indicated with surface-filling patterns. On the printed map profiles, the nutrition quantity and the ground-water depth of the given point were indicated with identification numbers. One of the characteristics of the Kreybig-method is that the soil spots of the maps are associated with one representative and several further soil profiles which can be found within the given point [14].

Soil description and classification according to WRB

The primary reason for creating the World Reference Base of Soil Resources (WRB) is the international contribution to the development of the FAO. The first version of the WRB was introduced at the 15th World Congress of Soil Science in Acapulco, Mexico in 1994. At the Congress, the researchers emphasized that by creating the WRB the goal was not the development of a new soil classification system but rather the harmonization of the different national systems [15, 16]. The system is based on the diagnostic approach to soil classification, using well-defined terminology and quantitative parameters. Currently, the fourth version of the WRB – published in 2015 and currently valid [17] – is based on principal and supplementary qualifiers rendered to the RSG.

Sampling and analysis

For the selection of representative profiles, we used Kreybig 1:25,000-scaled maps with the identification number 5166/2, which were made available to us by the Institute for Soil Sciences and Agricultural Chemistry of the Hungarian Academy of Sciences (MTA ATK, TAKI) [18]. We collected both undisturbed and disturbed samples from the horizons of the three soil profiles selected for investigation. Following the establishment of the soil pit, we performed the environmental description of the soil profiles based on the FAO instructions [19] and collected samples from every distinguishable genetic horizon as well as from the layers described in the Kreybig information sheets for the purposes of laboratory investigations [20, 21]. We determined the soil chemistry (based on Hungarian Standard 08–0206/2, 20135) and soil physics (based on Hungarian Standard 08-0205) properties from the collected disturbed samples. During the soil chemistry laboratory investigations, we measured the pH (H_2O), the carbonate and humus content (%) as well as the conductivity ($EC_{1:2.5}$). The texture class of the samples was determined using decantation (the Köhn-pipette method).

3. Results and discussions

Based on the Kreybig-database, we reambulated three exposed soil profiles in the study area (*Fig. 2*).

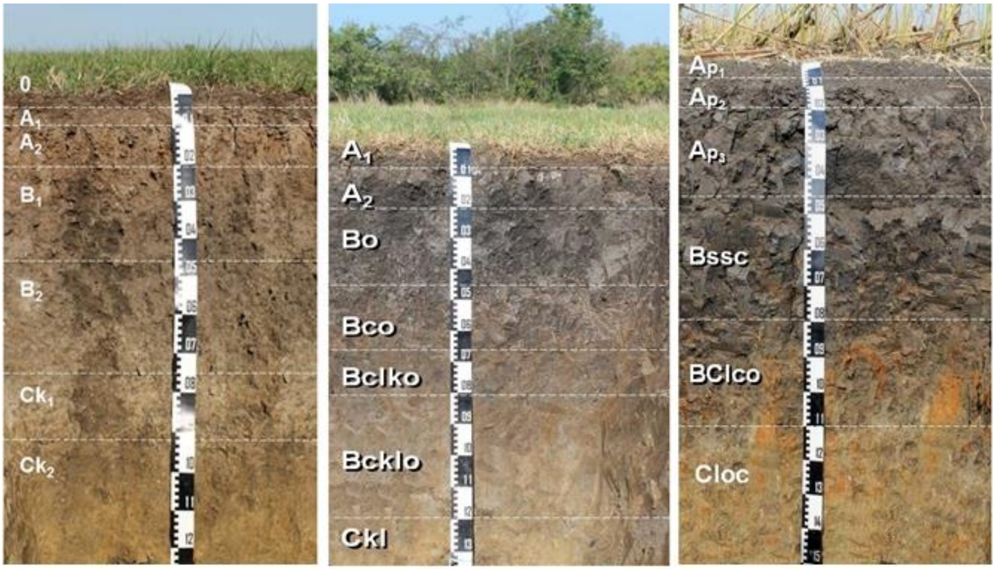

Figure 2. Soil profiles (8, 37, 46)

During the description of soil profile no. 8, we identified the following genetic horizons: *O horizon* ranging from 0 to 3 cm. Its humus content is high (7.5%) and has an acidic pH (pH (H_2O): 5.2). *A horizon* is located between 3 and 20 cm. We divided this horizon into an *A_1 subhorizon* (3–10 cm) (eluvial, or leaching topsoil layer) and an *A_2 subhorizon* (10–20 cm) (humus layers, which accumulate during the process of incomplete mineralization). Its humus content is lower than that of the horizon above, but in terms of pH there is no significant difference between the two horizons. *B horizon* is also classified into two subhorizons. *B_1 subhorizon* (20–45 cm) indicates an accumulation or transitional subhorizon, while *B_2 subhorizon* (45–75 cm) refers to a horizon where carbonates of pedogenic origin were accumulated. The reason for dividing *B horizon* into two separate subhorizons is that we observed carbonate precipitations in *B_2 subhorizon*, but since the two subhorizons are identical in terms of their texture and structure the introduction of another genetic horizon seemed unnecessary. *C_k horizon* can be found below a depth of 75 cm and ranges down to 92 cm. In this horizon, we can observe small amounts of carbonate precipitations; however, these precipitations are amplified in C_{k2} *horizon*, where iron concretion can be seen as well.

Within the *A horizon* of soil profile no. 37, both A_1 and A_2 *subhorizons* can be identified. The depth of A_1 *subhorizon* is 0–7 cm, and it is rich in humus and organic material. A_2 *subhorizon* is also rich is humus, but its structural elements show slight differences. Between 20 cm and 45 cm, we can find a transitional subsoil horizon (*B*); because here we can observe iron-oxide accumulations, we identified this horizon as B_o. Between 45 cm and 65 cm, we can find B_{CO} *horizon*, where the precipitation of iron-oxides is amplified and other carbonate precipitation can also be seen. Between 65 cm and 80 cm, B_{clko1} *horizon* can be found, where indications of gley processes can be observed in addition to the precipitations and the iron and carbonate concretions. The rate of conductivity is very high (3.48 mS/cm). The next one, B_{clko2} *horizon*, can be found between 80 cm and 120 cm, where carbonates of pedogenic origin, iron-oxide precipitations, and extensive gley processes can be observed. In terms of conductivity, differences can be observed from the previous horizon, although a relatively high value was measured here, as well (2.24 mS/cm). The high concentration of water-soluble salts can be explained by the raised ground-water level. C_{kl} *horizon* can be found between 120 cm and 135 cm, where the ratio of carbonates of pedogenic origin and the iron-oxide precipitations are high, and gley processes can be observed as well; however, the concentration of water-soluble salts is only 1668 µS.

The *A horizon* of profile no. 46 has been divided into three parts. A_{p1} *subhorizon* (between 0 and 5 cm) is a dark-coloured topsoil layer with humus accumulations and a great amount of organic material. It is a subhorizon disturbed by being used as cropland, as cultivated areas, or in other ways. This subhorizon is followed by A_{p2} *subhorizon* (between 5 and 20 cm), which is also rich in organic materials and characterized by a dark-coloured topsoil layer and also affected by agricultural activity. A_{p3} *subhorizon* can be found between 20 and 45 cm, and we can observe humus accumulation here, as well; however, it is only periodically disturbed by cultivation. The pH of all three subhorizons is slightly acidic or neutral. Between 45 cm and 80, we can find a B_{ssc} *horizon*, where "slickensides" can be observed. In addition, we also identified iron-oxide precipitations which formed due to decay. In terms of pH, the topsoil was slightly acidic, while the subsoil was slightly alkaline. Next, we identified a transitional horizon ranging from 80 cm to 110 cm (BC_{lco}), where *B* and *C horizons* overlap. The accumulation of 1.5 oxides and their hydroxides which formed due to decay is amplified, and carbonates of pedogenic origin also appear. Furthermore, signs indicating gley processes were observed. Between 110 and 160 cm, we can find C_{loc} *horizon*. This horizon is very loamy. The accumulation of iron-oxides and carbonates is more extensive compared to the above horizon. Its pH is neutral.

The results of the profile descriptions and the profile environment records are included in *Table 1* and *Table 2*.

Table 1. Environmental descriptions of investigated soil profiles

Profile ID	**8**	**37**	**46**
Location	Biharnagybajom	Biharnagybajom	Biharnagybajom
Elevation	90 m	86 m	86 m
Date of reambulation	2015.09.21	2015.09.22	2015.09.23
Type of soil climate	mesic	mesic	mesic
Type of soil moisture regime	ustic	ustic	ustic
Parent material	clay and silt	clay and silt	clay and silt
Geomorphology	plain	plain	plain
Land use and vegetation	Extensive grazing	Annual field cropping	Short grassland
Cultivated plants	-	wheat	-
Anthropogenic influences	organic fertilizer	organic fertilizer	organic fertilizer

Table 2. Main characteristics of investigated soil profiles

Profile ID	Depth (cm)	Genetic horizons	Colour (when moist)	Texture	Structure (Type)	Humus Content (%)	$CaCO_3$ (%)	pH (H_2O)	$EC_{1:2.5}$ (µS)
8	0–2–3	0	-	-	-	7.5	5.8	5.2	251
	3–10	A1	10YR 2/2	loam	granular	5.5	8.1	5.3	150
	10–20	A2	10YR2/2	silty clay loam	blocky/prismatic	4.1	9.1	5.5	135
	20–45	B1	10YR2/1	silty clay loam	prismatic	3.9	8.2	6.6	250
	45–65	B2	10YR 3/1	silty clay loam	blocky/subangular blocky	1.8	11.8	7.8	323
	65–105	C_{k1}	10YR 3/2	silty clay loam	subangular blocky	0.7	24.9	8.2	245
	105–130	C_{k2}	10YR 4/6	silty clay loam	subangular blocky	0.7	24.6	8.4	231
37	0–7	A_1	10YR 2/1	silty loam	subangular-blocky	4.9	9.4	7.5	588
	7–20	A_2	10YR 2/1	silty loam	blocky-prismatic	4.1	7.8	7.7	628
	20–45	B_o	10YR 2/1	silty loam	blocky-prismatic	2.8	8.9	7.9	1103
	45–65	B_{co}	10YR 2/2	loam	subangular-blocky	1.4	8.2	7.8	2480
	65–80	B_{clko}	10YR 2/2	silty clay loam	subangular-blocky	0.7	9.5	7.7	3480
	80–120	B_{clko}	2.5Y 3/2	clay loam	subangular-blocky	0.8	20.6	7.9	2240
	120–130	C_{kl}	2.5Y 4/2	clay loam	subangular-blocky	0.7	25.8	8	1668
46	0–5	A_{p1}	10YR 2/1	silty clay loam	subangular-blocky/granular	7.18	7.1	6.8	497
	5–20	A_{p2}	10YR 2/1	clay loam	subangular/ angular blocky	7.36	6.1	6.8	395
	20–45	A_{p3}	2.5Y 2/1	clay loam	massive	7.38	6.3	6.7	279
	45–80	B_{ssc}	10YR 3/2	clay	angular-blocky	2.19	6	6.7	251
	80–110	BC_{lco}	2.5Y 4/3	clay	subangular-blocky	1.67	13.3	7.9	391
	110–160	C_{loc}	5Y 4/4	clay	subangular-blocky	0.98	12.6	7.7	2250

Changes of soil properties

Based on the laboratory results and the data which can be found in the Kreybig information book, changes in soil chemistry properties could be detected in certain cases (*Fig. 3*). In terms of pH, significant acidification could not be detected, although the pH of the reambulated profiles decreased by at least 1 and in some cases 2 units. This is not regarded as a significant change considering the different measurement methods and the extent of the differences they produced.

In terms of $CaCO_3$ content, comparison was not possible in the case of profile no. 37 due to missing data, although in the cases of profiles no. 8 and no. 46 it showed a significant increase (*Fig. 3*). The primary reason for this is that, in order to improve the soil quality, attempts were made to increase the capacity of the soil by calcification.

The humus content showed an almost twofold increase in the layers close to the surface (*Fig. 3*). The increased humus content can be explained by the altered land use. Currently, profiles no. 8 and no. 46 are used as pastures; therefore, the litter accumulating under the grass coverage contributes to a large extent to the increase in the organic material content of the soil.

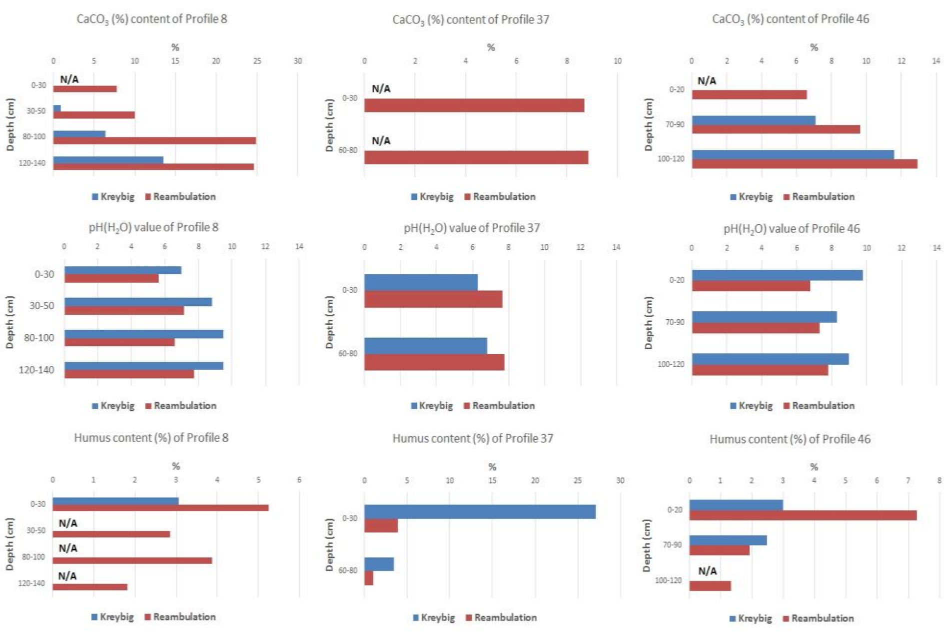

Figure 3. Changes of the chemical properties of the investigated soil profiles

Landscape changes as a result of land use

In the Nagy-Sárrét areas where the soil profiles were located, landscape changes of varying extent have occurred during the past seven decades, which indirectly affected the development of soils. At the time of the profiling, soil profile no. 8 was described as a saline soil, which can be used as cropland only to a limited degree or under specific conditions. Therefore, attempts were made to improve the soil capacity by calcification in order to make it suitable for agricultural activity. At the same time, the previously cultivated areas are now used as pasture or hayfield. Profile no. 46 was described as a predominantly neutral or slightly alkaline soil, and calcification was used in order to improve soil capacity. The traces of these activities can also be observed today, although these areas have since been built up. As a consequence of the drainage works performed in the past, ground-water level decreased, and due to anthropogenic effects this area is also currently used as pasture. Profile no. 37 was previously described as a wetland soil. However, during our field investigations, neither the thick peat layer nor any other organic-material-accumulating zone could be identified. This can be explained by the fact that following drainage it has been oxidized as a result of the increased soil ventilation due to agricultural activity and periodic crop burnings. Soil development is largely affected by the fact that the crop yields of the currently cultivated annual plant cultures are regularly irrigated by the irrigation canals, which can be found close to the area.

Results of WRB classification

Table 3 includes the soil profiles classified on the basis of the WRB criteria sets for 2014. Profile no. 8 was classified among the Solonetz reference soil group based on the morphological features (the mobilization of clay and humus materials is indicated by the accumulation in *B horizon*). Because of the high CaCO3 content (24.9%) and because it has a deep humic, base-saturated mollic horizon, the calcic and mollic principal have been rendered to the profile. The iron and rust spots found in the lower layer indicate capillary increasing water and periodic anaerobic conditions, based on which the principal gleyic has been rendered to the profile. As a supplementary, the loamic qualifiers have also been added because of its texture class.

In the case of profile 46, the requirements of the Gleysol reference soil group have been met. As a prefix, the calcic qualifier has been used because of the high CaCO3 content (25.56%). Furthermore, because it has a deep humic, base-saturated mollic horizon, the mollic principal has also been added. As a supplementary, the loamic qualifier has been added because of its texture class.

In the case of profile 37, the requirements of the Vertisol reference soil group have been met. The reason for this is the presence of the vertic horizon and the high clay content as well as the specific morphological features (slickenside, wedge-shaped structural elements, and shrink–swell cracks). As a prefix, we have used the grumic qualifier since a 7-cm-thick layer was observed on the surface, which was heavily structured, and the size of the structural elements was small. The iron and rust spots that can be found in the lower layer indicate capillary increasing water and periodic anaerobic conditions, based on which the prefix gleyic has been rendered to the profile. As a suffix, we have used the humic and pellic qualifiers. The humic qualifier has been added because of the fact that the profile had an organic carbon content higher than 1% on a weighted average down to a depth of 50 cm from the surface of the mineral soil layer in the fine earth fraction. The pellic qualifier has been used because down to a depth of 30 cm from the surface the wet Munsell colour score was lower than 3.5 and its colour saturation was lower than 1.5.

Table 3. Classified profiles according to WRB (2014)

Profile ID	**principal qualifiers**	**WRB RSG**	**supplementary qualifiers**
8	*Calcic, Gleyic, Mollic*	**Solonetz**	(*Loamic*)
37	*Grumic, Gleyic*	**Vertisol**	(*Humic, Pellic*)
46	*Calcic, Mollic*	**Gleysol**	(*Loamic*)

4. Conclusion

In our study, after investigating the reambulated soil profiles in the Nagy-Sárrét study area and comparing them to the data characterizing the profiles from the Kreybig mapping, we have come to the following conclusions. During the past seven decades, landscape and land-use changes of varying extent have occurred which indirectly impacted the state of soils and therefore their chemical and physical properties. In terms of pH, no significant change could be identified. Due to the improvement in soil quality (calcification), the lime content has increased in the agricultural areas. In the areas currently used as pastures, the humus content of the topsoil has increased. In the croplands which used to be characterized by wetland soil, however, the organic material content of the topsoil has decreased.

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Genotype-by-environment interaction and yield stability analysis in sorghum (*Sorghum bicolor* (L.) Moench) genotypes in North Shewa, Ethiopia

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Abstract. A multi-environment sorghum variety trial comprised of nine genotypes along with one standard check, “yeju”, was carried out in the main cropping seasons of the period of 2006–2008. The objective of this research was to identify a stable and better-yielding sorghum variety under the conditions of the sorghum-growing area of North Shewa, Ethiopia. The experiment was arranged in randomized complete block design replicated three times within an experiment. AMMI analysis based on grain yield data revealed that genotypes ICSV 1112BF, 82 LPYT-2 # 5x81ESIP 46, and PGRC/E #222880 were superior to the standard check both in grain yield and stability, and hence these genotypes have been verified, and the genotype PGRC/E #222880 has been registered by the national variety-releasing technical and standing committee by the given name “Chare” for commercial production for the North Shewa sorghum-growing areas.

Keywords: MMI, PCA1, variety development, wide adaptation

1. Introduction

Sorghum (*sorghum bicolor* (L.) Moench) is an important cereal crop of the semi-arid areas of the tropics and sub-tropics, including Ethiopia, after wheat, rice, and maize with over 80% of the crop in Africa and Asia. It is also the major cereal crop in Ethiopia following tef and maize in terms of area coverage [1]. Sorghum has been produced in more than five million households and its annual production is estimated to be 4 million metric tons from nearly 2 million hectares of land [1]. Sorghum covers a significant amount of cultivated land following tef in the lowland areas of North Shewa Zone of Amhara region. As it is native to Ethiopia, it has remarkable genetic diversity as evidenced by many landrace collections made in the country. It is well adapted to a wide range of environmental conditions in semi-arid Africa [2]. It is mainly produced in medium and lowlands of Ethiopia. It withstands hot and dry condition better than most cultivated crops in Ethiopia. Sorghum is grown for its grain used as food and local beverages; nowadays, its stalk has also become an alternate source of animal feed as well as fuel. However, the average yield trends are downwards.

In North Shewa, sorghum is the primary crop cultivated especially in the lowlands. It contributes to food security at household level. Notwithstanding the immense potential uses of sorghum in Ethiopia in general and in North Shewa in particular, several biotic and abiotic factors inescapably induce an absolute reduction of grain yield of sorghum, and consequently the gap between demand and supply is still wide. In recent years, in North Shewa, despite a preferable, good yielding, late-maturing local landraces producing sorghum has become a risky business. Presumably coupled with climatic changes, the rainfall becomes unpredictable. Rainfalls occur infrequently and start late. In addition to this, anthracnose disease infestation is a major yield-reducing factor of sorghum production in North Shewa. Thus, it is indispensable to look for relatively early maturing, drought resistance, moderate to high anthracnose-disease resistance, and better adapting varieties which will give a reasonable yield relative to the pattern and distribution of rainfall. Therefore, sorghum variety trial was started with the objective of developing a stable, early maturing, anthracnose-disease resistant, and acceptable yielding ability sorghum variety under conditions existing in the North Shewa sorghum-growing area.

2. Materials and methods

2.1 Experimental design

Eight promising sorghum genotypes along with the standard check "yeju" were arranged in randomized block design with three replications. Local checks of the respective locality were included in the experiment; however, due to terminal drought stress, the local checks did not produce seed, and finally the local checks were excluded from the analysis. The experiment was conducted in the lowland area of Shewa Robit and Alem Ketema for three years – 2006–2008 (*Table 1*). The experimental plots were fertilized with 100 kg/ha urea and 50 kg/ha DAP. All DAP and half of the urea were applied during planting, while the other half of UREA was added when the crop reached knee height. Seeds were drilled at the rate of 20 kg/ha in 75-cm spaced six rows, each of them being 5-m long. The agronomic practices were applied uniformly to all experimental plots as per the recommendation for sorghum. Data on days to heading, days to maturity, plant height, disease score, grain yield, and thousand-grain weight were recorded on plot basis.

Table 1. Description of the test environments of the field experiment

No	Locations	Altitude (m)	Latitude	Longitude	Soil type
1	Shewa Robit	1,680	12°01' 0.01"N	39°37' 59.99"E	Vertisols to Light soil
2	Aleme Ketema	1,450	10°3'24.63"N	38°59'43.79"E	Vertisols to Light soil

2.2 Statistical analysis

2.2.1 Combined Analysis of Variance

Combined analysis of variance was performed using the procedure outlined by Steel and Torrie [3] for each measured parameter using IRRISTAT for Windows ver. 5.0. [4]. The following model for the combined ANOVA was used:

$$Y_{ijkm} = \mu + b_i + l_j + y_k + (ly)_{jk} + b(ly)_{jk} + t_m + (tl)_{jm} + (ty)_{km} + (lyt)_{jkm} + e_{ijk},$$

where Y_{ijkm} = the yield observation from the t^{th} block, the j^{th} location, k^{th} year of m^{th} genotype μ is the experimental grand mean, b_i the random block effect; l_j is the random location effect, y_k the random year effect, t_m is the fixed genotype effect, $(ly)_{jk}$ is the random location by year interaction, $(tl)_{jm}$ is the random genotypes by location interaction $(ty)_{km}$ is the random genotypes by year interaction effect; $(lyt)_{jkm}$ is the random location, year and genotype interaction effect, and e_{ijk} is the random experimental error.

2.2.2 Stability analysis

The GEI sum square was done using the Additive Main and Multiplicative Interaction /AMMI/ model, as described in Nachit et al., 1992 [5, 6]. The AMMI model takes the following equation:

$$y_{ge} = \mu + \alpha_g + \beta_e + \sum \lambda_n \gamma_{gn} \delta_{en} + \theta_{ge} + \varepsilon_{ger},$$

where $y_{ge} =$ is grain yield of variety g in environment (e), μ is the grand mean, $\alpha_g =$ the variety mean deviations (the variety means minus the grand mean), $\beta_e =$ are the environment mean deviations (the environment mean minus the grand mean),

$\lambda n =$ the eigenvalue of n^{th} principal components analysis (PCA) axis n,

γ_{gn} = the variety eigenvector value for IPC axis n,

δ_{en} = is the environment eigenvector value for IPC axis n,

ε_{ge} = is the random error.

3. Results and discussion

3.1 Analysis of variance

The results of the combined analysis of variance across locations and over years revealed that location, year, location by year, genotypes, location by genotypes, year by genotypes, and location by year by genotypes showed a significant effect, while rep and rep by location by year had no significant effect on grain yield (*Table 2*). This shows the existence of GEI that affects the performance grain yield of the genotypes across location. GEI is the critical factor that discourages breeder and geneticist since it complicates the plant variety development programme for most crops to produce a stable variety across different seasons. Genotypes' mean agronomic performance is indicated in *Table 3*.

The combined analysis of variance of three years' data of Shewa Robit and Alem Ketema indicates that the grain yield performances of promising genotypes are significantly affected by year, locations, and GEIs. And these data considered for this experiment deviate from the already accepted analysis of variance assumption that it is additive in nature. And the information that is drawn from this analysis may mislead our result conclusion. Therefore, selecting the best genotypes based on mean grain yield is not recommended for this experiment. Hence, it is mandatory to split the contribution of individual sorghum genotypes to create the total GEI effect. And similar research results have been reported for most crops under Ethiopian conditions as, for example, Muhe and Assefa (2011) for bread wheat [7], Gedif and Yigzaw (2014) for potato [8], Adugna et al. (2011) for finger millet [9]. This calls for the use of another model that fits the proper evaluation of the tested genotypes, and several methods are used to analyse GEI [10, 11, 12]. This is because Ethiopia has diverse environmental conditions in terms of altitude, soil type, and climate variabilities, and developing stable varieties with wider adaptability is a difficult task for the plant-breeding programme in Ethiopia.

The grain yield change that is observed among genotypes is due to GEI, and GEI effect has to be considered during analysis. Hence, this urges us to use a more reliable and accurate method of analysis to increase the success of developing a stable variety. Several methods have been developed to select genotypes with greater stability for different ranges of environments, which also helps to estimate their performance under similar scenarios [10, 11]. Among these, the additive main effects and multiplicative interaction (AMMI) model is the choice of most breeders to analyse GEI [13].

Table 2. The combined analysis of variance of the genotypes tested at Shewa Robit and Alem Ketema, Ethiopia, in the 2006–2008 cropping seasons (three years)

No	Source of variation	d.f.	Sum of squares	Mean squares	F Ratio	Prob at 1%
1	Rep	2	814688	407344	0.64	0.537
2	Loc	1	232539000	232539000	362.54	0.000
3	Year	2	395924000	197962000	308.64	0.000
4	Year*Loc	2	39052900	19526400	30.44	0.000
5	Year*Loc*Rep	10	10601800	1060180	1.65	0.103
6	VC	8	36267100	4533390	7.07	0.000
7	Loc*VC	8	28258000	3532250	5.51	0.000
8	Year*VC	16	27372700	1710790	2.67	0.002
9	Year*Loc*VC	16	26850600	1678160	2.62	0.002
10	Residual	96	61575300	641409	-	-
11	Total	161	859256000	536990	-	-

Table 3. The mean performance of sorghum genotypes at Shewa Robit and Alem Ketema, Ethiopia, for three consecutive years (2006–2008)

Code	Variety	DTH	DTM	PLH	TSW	Grain Yield (Kg/Ha)
V1	ICSV 1112BF	69.22	109.94	143.81	2.93	4331.09
V2	82 LPYT-2 # 5x81ESIP 46	72.56	111.17	135.69	2.913	4288.99
V3	IS -777	74.17	113.11	179.36	2.43	3545.67
V4	Yeju (standarde ck)	70.11	107.44	174.10	3.69	3919.89
V5	IS 776	75.78	130.50	201.38	2.99	3779.20
V6	P- 898012 X 435124	75.00	113.22	165.69	2.70	4465.95
V7	148XE3541)-4-1XCS3541DRAIVE-5-4-2-1	70.89	110.39	216.73	2.90	3729.37
V8	PGRC/E #222880	70.50	112.50	184.20	3.43	4005.95
V9	PGRC/E #222878	75.44	114.94	203.50	2.34	2812.83
	Mean	**72.63**	**113.69**	**178.27**	**2.93**	**3875.44**
	SE(N= 18)	0.60	5.65	6.19	0.06	188.77
	5%LSD 96DF	1.67	15.86	17.39	0.16	529.86

3.2. AMMI analysis

GEI is very essential to be considered in a variety development programme to increase the chances of getting a stable variety that can fit into different environments with comparably constant performance in grain yield and also help in identifying the genotype that performs best in a given locality, as GEI affects the performances of genotypes in different environments and seasons. Those genotype that are not affected by GEI will be adapted to a vast area of environment, while those genotypes that are highly affected by GEI will have inconstant performances in different environments. In most cases, in Ethiopia, it is very difficult to develop varieties with a wider adaptation range because of the diverse nature of the environments. Therefore, an area-specific variety development is required in Ethiopia.

GEI can be analysed using the AMMI method, which is the most commonly used one in stability and adaptability analyses since AMMI can check for model efficiency as well as data analysis accommodates the influences of each environment, which improves the accuracy of analysis results [13]. The model also describes the pattern of adaptation of genotypes in relation to the tested environments [14, 15].

3.2.1 AMMI analysis of variance

The AMMI analysis of variance applied on sorghum genotypes for grain yield in six environments revealed that 85%, 4.61%, and 10.49% of the sum of squares were contributed by the environment, the genotype effects, and the GEI respectively (*Table 4*). It is clearly seen that the contribution of environmental variation to the sum of squares is considerable, and this means that the environment in which the experiment was undertaken is significantly different. In addition, the variation observed among genotypes for grain yield is largely due to environmental effects. Various authors also reported similar results for other sorghum genotypes tested at different locations and crop seasons [16, 17].

Table 4. Analysis of variance for grain yield of sorghum genotypes evaluated at Shewa Robit and Alem Ketema for three years (2006–2008), using the Additive Main effects and Multiplicative Interaction (AMMI) model, Ethiopia

SOURCE	**D.F.**	**S.S.**	**M.S.**	**F**	**F-prob**	**% explained**	**% accu-mulated**
Gentotypes	8	12089000	1511130		0.000	4.61	
Environments	5	222505000	44501000		0.000	85.00	
TreatmentXEnvironments	40	27493800	687344.0		0.000	10.49	
AMMI Compnent 1	12	20899700	1741640	7.395	0.000	76.02	76.02
AMMI Compnent 2	10	3373040	337304.	1.885	0.116	12.27	88.29
AMMI Compnent 3	8	2198940	274867.	2.689	0.073	8.00	96.29
AMMI Compnent 4	6	789085.	131514.	2.257	0.224	2.87	99.16
GXE Residual	4	233032.					
Total	53	262088000					

Table 5. AMMI estimates and the ranking of genotypes for the grain yield of 9 sorghum genotypes tested in each environment (Shewa Robit – 3 sites and Alem Ketema – 3 sites) in each year (2006–2008)

Code	Genotype Name/Site	Alem Ketema			Shewa Robit			T-ESTS	AMMI 1 trt	AMMI 2 trt	AMMI 3 trt
		A1	**A2**	**A3**	**S1**	**S2**	**S3**				
V1	**ICSV 1112BF**	1755.	4231.	2346.	5856.	8057.	3741	4331.	-23.46	-.07928	-11.11
V4	Yeju (standard ck)	695.0	3656.	1757.	6278.	7685.	3448	3920.	-38.40	-.1221	-.4141
V3	IS -777	1219.	4583.	2525.	2368.	6768.	3811	3546.	20.26	26.72	7.566
V7	148XE3541)-4-1XCS3541DRAIVE-5-4-2-1	2345.	4265.	2251.	2627.	8224.	2665	3729.	21.19	-17.78	-19.65
V6	P- 898012 X 435124	1945.	5156.	2977.	3605.	9486.	3626	4466.	14.27	-24.12	11.15
V2	**82 LPYT-2 # 5x81ESIP 46**	1369.	4271.	2359.	5911.	7874.	3949	4289.	-25.85	6.351	-2.208
V5	IS 776	1080	4683.	2528.	2826	7988	3569	3779	15.47	0.8351	16.71
V8	**PGRC/E #222880**	927.9	4458	2367	4377	8267	3638	4006	-6.565	-4.555	14.87
V9	PGRC/E #222878	1351.	3575.	1612.	1595.	6273.	2470	2813.	23.08	12.75	-16.91
Mean		1410.	4320	2303	3938.	7847	3435.	3875			
AMMI1 site		20.12	18.32	15.30	-59.73	5.366	0.623				
AMMI2 site		-.842	5.379	7.738	0.4198	-35.21	22.52				
AMMI3 site		-32.5	10.26	4.704	-5.494	11.02	12.05				

S_1 = Shewa Robit site 1; S_2 = Shewa Robit site 2; S_3 = Shewa Robit site 3; A_1 = Alem Ketema site 1; A_2 = Alem Ketema site 2; A_3 = Alem Ketema site 3

The AMMI analysis identified four principal component axes, and all contributed to 99.16% of the total variation observed among sorghum genotypes for grain yield due to GEI (*Table 3*). Of the four principal component axes, only AMMI Component 1 was significant at P < 0.01%. The first, second, third, and fourth interaction principal component (IPCA 1, IPCA 2, IPCA 3, and IPCA 4) axis explain 76.02%, 12.27%, 8.00%, and 2.87% respectively. Here, the AMMI model adequately explains the total GEI broken down into different components. The GEI components' values in this experiment using AMMI model are comparable with the reports from Nida et al. [16] and Adugna [17].

3.2.2 Biplot analysis

The AMMI model was used to analyse Biplot graph (*Figure 1*) using individual environments and mean grain yield performances of sorghum genotypes in XY plan. X-axis is designated for mean grain yield, while Y-axis for IPCA 1 scores. As indicated in *Figure 1*, each environment and variety main effect was plotted along the abscissa against their respective IPCA1 score as ordinate. The red vertical line that crosses through the centre of the biplot is represented by the experimental grand mean of grain yield derived from all varieties and environments, while the red horizontal line shows the point where IPCA1 score = 0. Those genotypes and environments that fall on the right side of the grand mean value of grain yield are rated as high-yielding genotypes and potential growing environments, and the remaining ones which fall on the left side of the grand mean are low-yielding genotypes and low-potential environments for sorghum production. Genotypes and environments located at the same side of the IPCA axis are interacting positively and produce desirable effects. Therefore, in this study, genotypes V1, V2, V4, V6, and V8 gave grain yield above the mean and are considered high-yielding genotypes, while V3, V5, V7, and V9 gave below the mean and are considered as low-yielding genotypes. Environments A2, S1, and S2 are high-potential environments, while A1, A2, and S3 are poor-yielding environments. Genotype V6 is best suited to environments S2 and A2, genotypes V3, V5, V7, and V9 to environments A1, A3, and S3, genotypes V1, V2, V4, and V8 to environment S1. AMMI adjusted and re-ranked the grain yield of each genotype by their respective IPCA axis score and environmental IPCA axis scores and thereby brought about a significant change in the ranks of genotypes when we compare them with the mean from combined analysis.

Genotypes and environmental contribution to the GEI were measured based on the magnitude of the corresponding IPCA 1 score, which is measured as the perpendicular distance from the benchmark, IPCA 1 = 0. Generally, the more genotypes or environments deviate from the IPCA1 = axis, the more they would contribute to the GEI variances and the more unstable they would be. Genotypes and environments at the extreme top or bottom edge of the biplot –*Figure 1* – are known to contribute more than their counterparts located closer to the IPCA1 axis = O [18]. Accordingly, genotypes V5, V6, and V8 had a very low contribution to the total GEI sum square, whereas their counterparts, V2, V3, V4, V7, and 'V9', highly contributed to the GEI sum square, suggesting that they are highly interactive with growing environments.

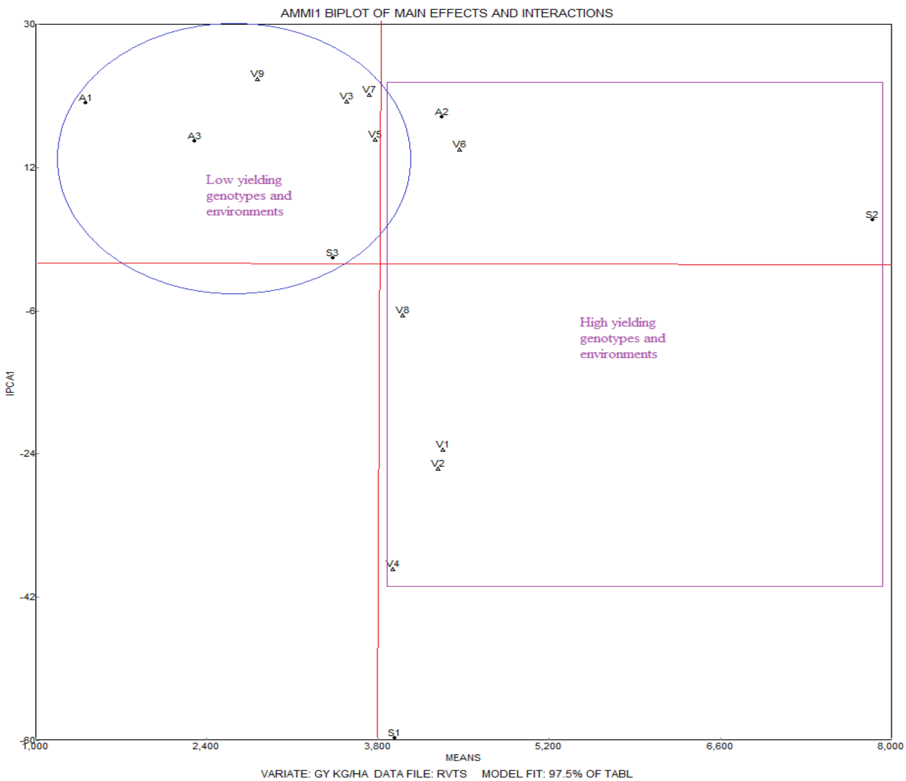

Figure 1. AMMI1 biplot for additive effects vs IPCA1 in nine sorghum genotypes evaluated for seed yield at two locations of North Shewa, Ethiopia during 2006–2008 S_1 = Shewarobit site 1; S_2 = Shewarobit site 2; S_3 = Shewarobit site 3; A_1 = Alem Ketema 1 A_2 = Alem Ketema site 2 A_3 = Alem Ketema site 3; V1–V9 = genotype 1 to genotype 9

AMMI2 biplot analysis using IPCA2 and IPCA1 is indicated in *Figure 2*. De Oliveira et al. (2014) pointed out that the stability information that is drawn using AMMI2 biplot is more precise than AMMI1 biplot because AMMI2 model contains information from IPCA1 and IPCA2 [19]. In AMMI2 model, those genotypes which are close to the nearby environment will perform better in that specific environments than those genotype which are far away [19]. AMMI2 also quantifies stability using AMMI stability value (ASV).

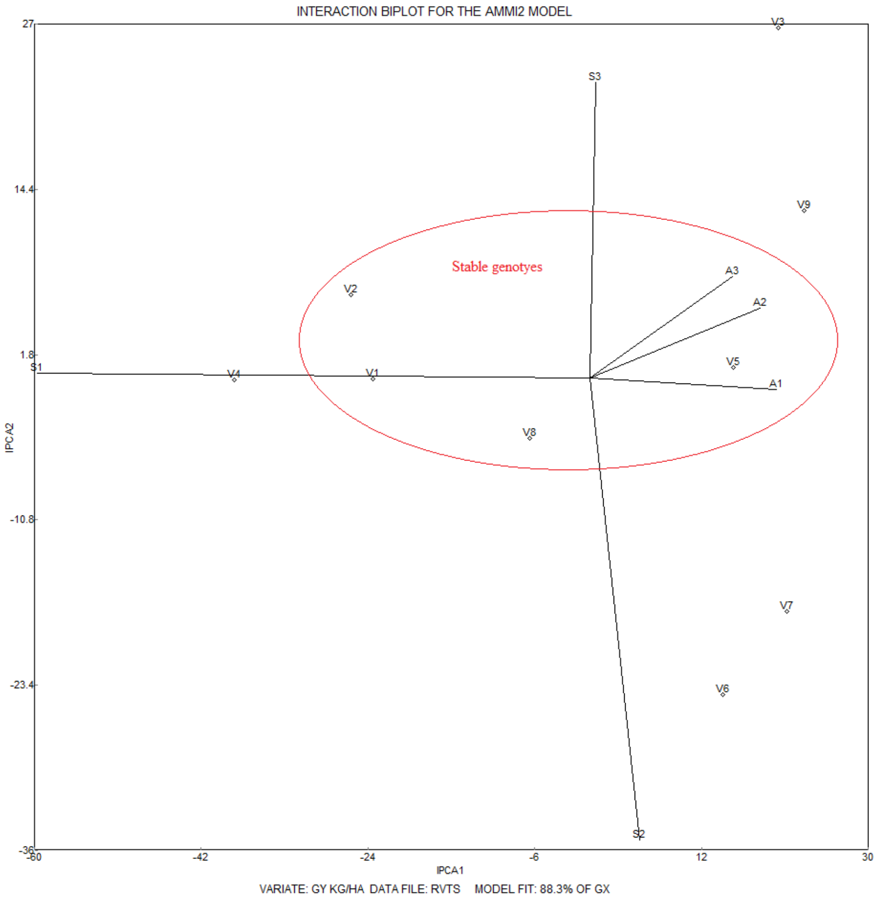

Figure 2. AMMI2 biplot showing the two main axes of interaction (IPCA2 vs IPCA1) in nine sorghum genotypes evaluated for seed yield at two locations of North Shewa, Ethiopia during 2006–2008

S_1 = Shewarobit site 1; S_2 = Shewarobit site 2; S_3 = Shewarobit site 3; A_1 = Alem Ketema 1 A_2 = Alem Ketema site 2 A_3 = Alem Ketema site 3; V1–V9=genotype 1 to genotype 9

ASV is the distance from the vertex of IPCA 1 and IPCA 2 to the genotypes or environments that fall in the AMMI2 biplot graph. This value is finally used to measure the grain yield stability of the genotype and cluster the genotypes and environments into different groups [20, 21]. Genotypes or environments which are very close to the vertex are more stable than those genotypes or environments away from the vertex. In other words, genotypes or environments that have less value of ASV score tend to be more stable than those genotypes or environments having high ASV score. Therefore, environment A1 (Alem Ketema Site 1), A2 (Alem Ketema Site 2), and A3 (Alem Ketema Site 2) are more stable environments for sorghum production compared to S1 (Shewa Robit Site 1), S2 (Shewa Robit Site 2), and S3 (Shewa Robit Site 3). With regard to genotypes, genotypes V1, V2, V5, and V8 are more stable than the remaining genotypes; however, only genotypes V1 (ICSV 1112BF), V2 (82 LPYT-2 # 5x81ESIP 46), and V8 (PGRC/E #222880) are high-yielding ones (*Figure 2*). Then these genotypes were promoted for verification trial in 2009, and only genotype V8 (PGRC/E #222880) was released by the national releasing committee, while the remaining two genotypes were rejected by the committee because farmers had disliked these genotypes. Finally, genotype V8 (PGRC/E #222880) was registered by the given name “Chare” in 2009. Similarly improved varieties have been released using AMMI model in Ethiopia as, for example, finger millet [9] and bread wheat [7].

4. Conclusions

GEI is an important factor for developing a stable variety that fits wider adaptation areas. In Ethiopia, GEI is vital for plant-breeding programmes where there is a diverse natural environmental, climatic and soil variability. In this study, nine promising genotypes were tested at Shewa Robit and Alem Ketema for three years to examine the grain yield performance and stability status of the genotypes and select the best genotype for variety release for commercial use. The combined analysis of variance is not appropriate for selecting a promising genotype to handle GEI. So, AMMI model is the most widely used technique to handle GEIs. In this experiment, AMMI Stability Value (ASV) and Biplot Analysis are effective and most appropriate tools to describe and identify stable and superior genotypes for most crops. In this experiment based on the AMMI analysis parameters, genotypes V1 (ICSV 1112BF), V2 (82 LPYT-2 # 5x81ESIP 46), and V8 (PGRC/E #222880) gave comparable yield in all the six different environments in North Shewa. And this genotype can be considered as stable in terms of grain yield performances and as well-adapted to the tested environments. However, genotype V8 (PGRC/E #222880) is therefore released to be used in North Shewa sorghum-growing areas and also for similar agroecological regions in Ethiopia.

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Current status, challenges, and prospects of biopesticide utilization in Nigeria

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Abstract. The toxicity, persistence, and non-biodegradability of chemical pesticides have increased calls for the adoption of sustainable and cost-effective pest control measures. Biopesticides present a sustainable alternative to synthetic pesticides. However, the biopesticide utilization in agrarian countries like Nigeria remains low, resulting in increased chemical pesticide utilization. Therefore, this paper seeks to examine the current status, challenges, and prospects of biopesticides in Nigeria. The findings revealed that biopesticide utilization in Nigeria is low due to high costs, poor infrastructure, skilled manpower alongside inconsistent field performance and government policies. The solution to these challenges will significantly boost crop protection, food security, and sustainable agriculture in Nigeria.

Keywords: pesticides, food security, pest control, crop disease, Nigeria

1. Introduction

The United Nations estimates the global population will exceed 10 billion by the year 2100 [1]. Currently, the population of Nigeria estimated at 140 million accounts for one-quarter of the population of sub-Sahara Africa or one in every 6 black persons in the world [2, 3]. However, these statistics are set to soar in the future, resulting in socioeconomic and environmental challenges for future generations [4]. As a result, analysts predict that energy, poverty, and food crises will become recurrent issues in the future [5, 6]. In view of the troubling state of things, countries with rising demographics urgently require sustainable strategies to address these issues, particularly the need to meet food requirements of growing demographics [7]. Currently, the dilemma facing human civilization is the capacity to enhance sustainable food production and address shortages and wastage [7, 8]. It is estimated that approximately 40% of the yearly crop production is destroyed by pests worldwide prior to harvest [9–11]. Likewise, nearly 20–30% of crops in Nigeria are damaged during post-harvest [12, 13]. Therefore, there is an urgent need for advanced food production, pest eradication, and disease management prior to harvest and post-harvest through the adoption of innovative, cost-effective agricultural practices. These efforts will ensure increased crop production and sustainable agriculture.

Over the years, conventional synthetic insecticides have been successfully utilized to control pests and boost crop production. Researchers around the globe have attributed the increased, albeit insensitive use of pesticides in the large-scale manufacturing processes to the increasing need for global food productivity [14]. However, recently, pertinent issues related to human health, safety, and the environment are threatening the continued use of synthetic pesticides [15]. Consequently, numerous researchers [16, 17] have reported the presence of different synthetic insecticides in various food products. In addition, the studies highlight the growing risks of agrochemicals to human health, the growing resistance to targeted pests and its unsustainable nature.

Hamilton and Ambrus [18] examined the effect of long-term and short-term (acute) dietary exposure to pesticide residues in food using a deterministic method or probabilistic methods. The results revealed that human exposure to, consumption or variability of pesticide residues in fruits and vegetables have considerably increased over the years [18]. As a result, the toxicity from short- and/or long-term exposure has become a growing concern among researchers.

Consequently, the study by Boobis et al. [19] examined the cumulative risk assessment of pesticide residues in food. The study highlighted various methods for assessing the cumulative toxicity of pesticides and the possible exposure scenarios using deterministic and probabilistic methods. In addition, the study revealed that exposure to pesticides can occur through food, water, residential or occupation pathways resulting in combined toxicological effects on humans and the environment [19].

Consequently, there is an urgent need to address the toxicological, socioeconomic, and environmental effects of increased pesticide utilization around the globe. This is critical to the sustainable food production and environmental protection, especially against the backdrop of appeals to mitigate the impending effects of climate change and global warming in vulnerable developing nations of the world. Hence, the development and adoption of innovative practices, process, and products are urgently required. This can be addressed by using eco-friendly, bio-based pesticides (known as biopesticides) as substitutes for synthetic insecticides for crop production, pest and disease management.

Biopesticide is a generic term for pest control measures that utilize bioactive microbes derived from plant and animal sources for sustainable crop protection [20, 21]. More importantly, biopesticides are biodegradable alternatives to the synthetic insecticides currently utilized for pre- and post-harvest control of crop pests and diseases. Their use has gained traction over the years due to technological advancements in pest control and management. In addition, the growing acceptability of biopesticides has been prompted by the search for eco-friendly, benign and Integrated Crop Management (ICM) strategies for pest control and management [20, 22]. According to Mazid and Kalita [15], biopesticide utilization is a sustainable agriculture technique with minimal, often harmless residues in harvested food crops and the environment [15]. As a result, there has been growth in global market penetration, although biopesticides still account for a small fraction of pest control products [21].

Despite global acceptance and utilization, biopesticide penetration remains low, particularly in developing agrarian countries like Nigeria. This is mostly due to widely reported issues such as the high cost, poor efficacy, and inconsistent field performance associated with biopesticide utilization [21]. In addition, lack of knowledge, cohesive advocacy, and other factors have conspired to limit biopesticide use in Nigeria – and Africa in general. Therefore, this paper seeks to review the current status, challenges, and prospects of biopesticide utilization in Nigeria. It is envisaged that the findings will avail the academia, industry, and other agricultural stakeholders with requisite knowledge on current developments in biopesticides in Nigeria. The long-term goal is to foster sustainable crop production and environmentally sustainable agriculture in Nigeria through pest control and disease management.

2. Overview of biopesticides – types and mode of action

In general, biopesticides are considered environmentally friendly alternatives to chemical pesticides derived from microorganisms, natural sources or processes [21, 23]. This unique class of bio-based pesticides is produced by genetic incorporation of DNA into agricultural commodities to prevent damage from pests or diseases [22, 23]. In principle, biopesticides can be classified into three categories [23, 24], namely: Microbial pesticides (MCP), Biochemical pesticides (BCP), and Plant-Incorporated-Protectants (PIPs).

Microbial pesticides (MCP). This class of biopesticides typically comprises one of many microorganisms, such as bacteria, fungi, viruses, protozoans, or algae, genetically adapted for crop pest control. For example, the proteins produced by the bacteria *Bacillus thuringiensis* (Bt) is reportedly used for pest control in vegetables and root crops [23]. This class of biopesticides makes up the largest percentage of the market today. Therefore, MCPs are designed to control a different class of pests, though each active element is meant for a specific target. This occurs by restraining pests either through the production of disease causing endotoxins or by hindering the reproduction of other microorganisms through antagonism [25].

Biochemical pesticides (BCP). This class of biopesticides is derived from naturally occurring living materials such as plant extracts or sex pheromones that attract pests to traps [15]. BCPs typically operate by interfering with the growth or reproduction of pests, thereby preventing damage to crops. In principle, BCPs are composed of mainly plant extracts such as: antifeedants, pheromones, fatty acids, potassium bicarbonate, and plant growth regulators. In contrast to conventional synthetic chemical pesticides that kill or inactivate pests, biochemical pesticides merely impede the growth or reproduction of the pests through plant growth regulators or pheromones. Examples of plants or plant products used as biopesticides include: limonene and linalool, neem (*Azadirachta indica*), pyrethrum, pyrethrins, rotenone, and sabadilla – typically used to deter pests such as fleas, caterpillars, ants, aphids, and ticks [15].

Plant-Incorporated-Protectants (PIPs). This class of biopesticides consists of genetically modified plants (or insecticidal transgenic crops) that produce chemicals (pesticides) that act as protection against pest infestation. In general, PIPs are typically extracted from the transgenes (protein-based cytotoxins) of the insect pathogenic bacteria *Bacillus thuringiensis* (Bt) [26]. In principle, PIPs, also termed semi-chemical pesticides, are also widely used for pest control. This is due to the minimal impact these class of biopesticides exert on humans and the environment [26, 27]. Consequently, significant research and scientific resources are dedicated to PIPs as natural pest control agents.

In practice, PIPs are transgenetically engineered into crops using recombinant DNA technology to control pests [28]. These comprise substances excreted by organisms to alter the actions of a body of a similar or a dissimilar species. These plant- or animal-based secretions can operate by inducing behavioural retort in organisms of the same or different species. As a result, semiochemicals are categorized into two basic groups, namely; allele-chemicals and pheromones. Allele-chemicals are chemicals created by one species which cause a reaction in the body of another species. On the other hand, pheromones are substances secreted by organisms to influence changes in the body of similar species. During pest management, pheromones are used as lethal pesticides to attract and trap insects, thereby interrupting mating. The deliberate disruption of pest reproduction is achieved by releasing proportionately large quantities of sex pheromones to confuse male pests. This ultimately reduces their ability to effectively locate females to mate. As a result, pheromones account for a sizeable percentage of the biochemical pesticides on the market.

Advantages and disadvantages of biopesticides. The use of biopesticides have numerous advantages such as low toxicity compared to conventional pesticides. In addition, biopesticides are biodegradable and decompose quickly upon application, minimizing exposure to humans, food, and the environment. This prevents bioaccumulation and, by extension, environmental pollution problems associated with synthetic pesticides. Biopesticides are also reportedly specific in action and operate by targeting only pests and closely related organisms which are a problem associated with chemical pesticides. As a result, biopesticides are environmentally benign and eco-friendly alternatives to chemical pesticides that can be effectively used for pest control and disease prevention.

In spite of its advantages, biopesticides reportedly have a short shelf life and field persistence, which may require a repeated application for the effective eradication of pests. As a result, this increases the cost of using biopesticides as a crop protection strategy. Furthermore, the specificity of biopesticides typically narrows down the target range of operation, which may require the use of many different types during intercropped or mixed cropping agriculture [29].

3. Biopesticides in Nigeria: historical overview

The synthetic chemical pesticide, lindane, was first introduced in Nigeria in the early 1950s. The influx of chemical-based pesticides was due to the need to boost agricultural productivity and crop yield due to rising urbanization and population. Therefore, pesticide use soared geometrically in 1960 after the country’s accession to independence [13, 30]. Over the years, the adverse effects resulting from excessive utilization of synthetic chemicals have become widely reported [31]. Numerous studies have highlighted the toxic and persistent effects of pesticide residues on crop and food contamination along with soil and groundwater pollution [16, 27, 30]. In view of the above, there have been increased calls to discontinue the use of synthetic chemical pesticides in agriculture. Hence, the use of biopesticides is now advocated particularly in developing countries like Nigeria.

3.1 The current status of biopesticides utilization in Nigeria

The current status of biopesticide utilization in Nigeria remains low despite its widely reported benefits for crop protection and disease management in agriculture

[32–34]. The study by Okwute [33] identified, examined, and highlighted the potential of several plant-based sources of pesticide in Nigeria. The authors demonstrated that the leaf, bark, seed, root, and fruits of over 30 plant species in Nigeria contain bioactive pesticide agents. The author identified the following plants as potential sources of bioactive agents for pesticides: *Azadirachta indica, Cannabis sativa, Eucalyptus globules*, *Gmelina arborea*, *Balanites aegyptiaca, Khaya senegalensis*, *Nicotiana tabacum*, and *Prosopis Africana* [33]. Likewise, the study by Ekefan and Eche [34] identified numerous indigenous biopesticides for use in pest management in Nigeria. *Table 1* presents selected botanical insecticides used to control field pests.

Table 1. Botanical insecticides and field pests controlled in crops [33]

SN	Plant name	Product/ trade name	Group/mode of action	Targets
1	*Lonchocarpus* spp. Derris elliptical	Rotenone	Insecticidal	Aphids, bean leaf beetle, cucumber beetles, leafhopper, red spider mite
2	*Chrysanthemum cinerariaefolium*	Pyrethrum/ Pyrethrins	Insecticidal	Crawling and flying insects such as cockroaches, ants, mosquitoes, termites
3	*Nicotiana tabaccum*	Nicotine	Insecticidal, antifungal	Aphids, mites, bugs, fungus, gnat, leafhoppers
4	*Azadirachta indica*	Azadirachtin/ neem oil, neem products, Bionimbecidine	Repellent, Antifeedant, Nematocide, Anti-fungal	Nematodes, sucking and chewing insects (caterpillars, aphids maize weevils)
5	Citrus trees	d-Limonene Linalool	Contact poison	Fleas, aphids, mites, paper wasp, house cricket
6	*Shoenocaulon officinale*	Sabadilla dust	Insecticidal	Bugs, blister beetles flies, caterpillars, potato leafhopper
7	*Ryania speciosa*	Ryania	Insecticidal	Caterpillars, beetles, bugs, aphids
8	*Adenium obesum (Heliotis sp)*	Chacals Baobab (Senegal)	Insecticidal	Cotton pests

Likewise, *Table 2* presents some selected indigenous botanical insecticides used for pest control.

Table 2. Indigenous botanical insecticides for pest control [34]

SN	Botanical insecticide	Pest controlled
1.	2% Hot pepper fruit extract	Foliar beetles, *Ootheca* sp., *Maruca vitrata*, *Heliothis armigera*
2.	“Fagara” root bark water extract	Cowpea flower thrips (*Megalurothrips sjostedti*), Pod borer (*Maruca vitrata*) and pod bug complex
3.	Neem leaf water extract	Okra leaf beetle (*Podagrica* spp)
4.	Chilli pepper	Aphids and other pests in vegetables
5.	Aqueous neem seed extract	Tomato fruit worm (*Heliothis armigera*), white fly, aphids
6.	Neem leaf	Nematodes in yam mini set termites and nematodes
7.	Neem seed cake	Stem borers in eggplant, nematodes in tomato
8.	Aqueous tobacco extract	Aphids, flea beetles, white flies, stem borers, caterpillars and mites

The study noted that natural pesticides can be extracted from fresh dried products, liquid secretions, powders, or cakes of indigenous plant species in Nigeria. In addition, the study highlighted that the low toxicity, eco-friendliness, and acceptability may account for the infancy of biopesticide utilization in Nigeria. This view is corroborated by Oruonye and Okrikata [32] and Okwute [33]. *Section 3.2* will highlight the challenges facing biopesticide utilization in the Nigerian agricultural sector.

3.2 Challenges of biopesticides utilization in Nigeria

The general consensus is that biopesticide use in Nigeria is plagued by numerous challenges. Chiefly, the poor enforcement of the country's pesticide regulation is hampering the development, adoption, and diffusion of biopesticides. Notwithstanding, various authors note that different field studies on indigenous biopesticides are still ongoing with follow-up tests, field work, and laboratory trials. It is envisaged that the success of research in this field will explore the thousands of plant resources, which, according to Ekefan and Eche, [34] abound in Nigeria. In their opinion [34], the low usage and patronage of biopesticides are hampered by numerous factors. In general, these factors can be broadly classified into political, technological, and socioeconomic.

Political. The political factors hindering biopesticide development, adoption and diffusion are centred on government policies in Nigeria. The role of the government is to stimulate, regulate, or supervise the development, distribution, and utilization of manufactured products in the country. The broad anthology of living and non-living entities present in biopesticides vary considerably in their properties, mode of action, fate, composition, and behaviour within their surroundings. As a result, the government needs to set strict health, safety, and environmental monitoring regulations before granting approval for the production and handling of biopesticides. To this effect, numerous government agencies, such as SON (Standards Organization of Nigeria) and NAFDAC (National Agency for Food and Drug Administration and Control), have been charged with ensuring public health and safety. However, Ekefan and Edge [34] note that the lack of governmental interest and clear policies on biopesticide development, regulation, and implementation in Nigeria has hampered progress. Furthermore, this has hampered investments in knowledge development, marketability, and accessibility to biopesticides in Nigeria. In addition, the lack of government support and advocacy for biopesticides has deterred farmers from patronizing biopesticides in Nigeria [32]. Hence, pest management technologies and strategies have been abysmally low.

Technological. The technological factors hindering biopesticide development in Nigeria are centred on the lack of solid research and development infrastructure in the country. The academia and industry lack the requisite scientific knowledge and technological skills to research, develop, and commercialize biopesticide products. This view that poor technological infrastructure is the faulty biopesticide application in Nigeria is corroborated by Lale [35]. The author further noted that the development and application of indigenous biopesticide products, such as oil and dust formulations, are poor. As a result, most biopesticide products on the Nigerian market today are not derived from standard clinical, laboratory trials or field data. This clear lack of research capacity presents significant risks to human health, safety, and environment. Furthermore, the lack of capacity severely hampers data-driven monitoring and assessment required to compare biopesticides with its synthetic derivatives. Hence, cutting edge scientific and industrial infrastructure is required to develop and test biopesticides in Nigeria. Furthermore, skilled personnel and modern equipment are required to monitor and assess the effects of biopesticides on human health, safety, and the environment. This will ensure that pertinent issues, such as toxicity, shelf life, and efficacy of bio-pesticides, are adequately addressed. This will reassure the generality of farmers who reside in rural areas to embrace the quest for sustainable agriculture.

Socioeconomic. The socioeconomic factors hampering biopesticide development and widespread utilization are centred on the cost and social acceptability. As earlier stated, low government promotion and patronage has severely impacted on the availability and acceptability of biopesticides in Nigeria. More importantly, the cost of producing and procuring biopesticide products remains high due to the lack of industrial production. Hence, biopesticides cannot favourably compete with their synthetic derivatives in terms of cost, resulting in low market penetration and availability. It stands to reason that the high costs will deter farmers, thereby hampering acceptability of such products in spite of their benefits. In the long term, this reinforces the first-mover advantage enjoyed by synthetic pesticides in pest management industry. However, the lack of technological leadership of biopesticides presents numerous opportunities for sustainable agriculture in Nigeria. Section 3.3 will briefly present the opportunities for biopesticide development in Nigeria.

3.3 Prospects of biopesticides utilization in Nigeria

As outlined, biopesticide development in developing countries is hampered by numerous challenges such as lack of awareness, confidence, and acceptability. Other factors include lack of data-driven standards and monitoring of field performance, which hampers marketability, product quality, and shelf life. Furthermore, lack of regulatory framework, health, and ecological risk assessment have all conspired to disadvantage biopesticides in comparison with chemical pesticides. However, these challenges also present numerous opportunities for biopesticide development in Nigeria.

The *political* challenges can be addressed by renewed government support of agriculture in the country. The policy objectives of the Agriculture Promotion Policy (2016–2020) [36] aimed at pesticide minimization in agriculture need to be enforced stringently. In addition, the implementation of APP must focus on the importance of biopesticides on sustainable agriculture in Nigeria. Hence, the redirection of the APP policy vis-à-vis government participation will spur the development, utilization, and acceptance of biopesticides in the Nigerian agriculture. This will increase private-sector participation, financial investments, and long-term growth – factors which are required to promote this valuable sector of the Nigerian economy.

Numerous *technological* opportunities can be derived from biopesticide development in Nigeria. The involvement of the government and industry will stimulate academic research and technological development in this sector. Over the years, R&D in Nigeria, particularly in the nation’s tertiary and research institutes, has experienced numerous challenges. The palpable lack of research funds (grants), modern equipment, and other bureaucratic bottlenecks have conspired to stifle

R&D efforts aimed at developing and commercializing home-grown technologies. The clear lack of synergy between the academia and industry has stemmed growth as well as the availability, acceptability, and abundance of biopesticide products in the Nigerian market.

The *socioeconomic* opportunities potentially accruable from implementing biopesticides in Nigeria are significant. Firstly, this will increase crop productivity and food security alongside health and safety in the country. It is estimated that about 40% of all harvested crops in Nigeria are lost due to pest damage [37]. Hence, the effective development and implementation of biopesticide initiatives will address the perennial problems of crop losses (wastage) and improve the profitability and sustainability of food production in Nigeria. In addition, the sector will – directly and indirectly – create jobs and improve the living standards of farmers – mostly composed of poor rural dwellers – in Nigeria. Lastly, biopesticides can improve the overall lifecycle of agriculture in Nigeria from pre-harvest to post-production required to ensure food security and sustainability in Nigeria.

4. Conclusions

The paper examined the current status, prospects, and challenges of biopesticide utilization in Nigeria. The aim was to identify and highlight knowledge required by government, industry, and other agricultural stakeholders to make informed decisions on the future of sustainable agriculture in Nigeria. The findings revealed that biopesticide development, acceptability, availability, and utilization are low in Nigeria. This is generally ascribed to numerous political, technological, and socioeconomic factors. However, the clear lack of government policy on biopesticides in Nigeria leaves a lot to be desired. Consequently, there is lack of motivation for investors to fund the technological infrastructure, R&D, and skilled manpower required for the economic growth and sustainable development of the sector in Nigeria. In view of this, the availability, marketability, and acceptability of biopesticides remain low. Hence, all stakeholders must work cohesively to stimulate growth and development in the sector. This will significantly boost sustainable crop production, food security, and environmental sustainability in Nigeria.

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Phenotypic characterization of Ethiopian finger millet accessions (*Eleusine coracana* (L.) Gaertn), for their agronomically important traits

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Abstract. Cereal finger millet (*Eleusine coracana* (L.) Gaertn) is one of the most promising vital crops of Asia and Africa in the face of climate change. It has a capacity to adapt to extreme environmental conditions and can be grown under a wide range of wider agroecology. It is believed to be originated in the highlands of Ethiopia and then disseminated across the globe. It is mainly cultivated as dietary staple food for humans, animal feeds and also used as medicinal crop. Though finger millet is recognized as the most important staple crop, particularly for the poor people in dry and semidry areas, it has been neglected and given little concern in mainstreaming the crop for its improvement research**.**

Keywords: blast diseases, agroecology

1. Introduction

Ethiopia is a country which is known for its rich biodiversity and being a centre of origins for many crop species and diversities due to its wide range of altitudes, temperature extremes, huge amounts of rainfall, and different soil characteristics. Therefore, due to this variation in the environment, it has evolved and gave a great opportunity for the existence of diverse vegetation types, crop species, and land race varieties of crops that have been used for generations, conserved by farmers in their fields [1].

Groups of crops, including finger millet (Eleusine coracana), were indicated as having their primary centre of diversity in Ethiopia; the local domesticates of the crop are known to have a wide genetic diversity, and in situ conservation mechanisms are applied, which is the best strategy to sustain the genetic integrity of the crop for generations [2]. Finger millet is a seasonal crop mainly cultivated as a grain cereal in most of the tropical and subtropical regions of the world, during the rainy season. Some archaeological findings also describe the crop species as being used in the ancient African agriculture in Ethiopia, which dates back 5000 years [3].

Finger millet is a dietary staple food crop in potentially drought-exposed regions of the world, and it is immensely considered as an important component in assuring food security. The crops grain posse's excellent storage quality, which can be preserved without any harm for years, confers it a perfect food grain quality. Crop leftovers are an excellent source of dry matter for the livestock, especially in dry seasons. After harvesting, the crop's residue makes good animal feeds and consists of up to 61% total digestible nutrients [4]. It has the capacity to produce a higher yield than other crops under multiple stresses such as drought, soil acidity, and land marginality [5], [6]. In addition to its drought resistance capacity, the crop has a high nutritional value and excellent storage qualities [7].

Germplasm is the sixth important crop in the country after tef, wheat, maize, sorghum, and barley. It accounts for 4.5% of the total cultivated land covered by cereals. It is widely grown in North Gonder, West Gojam, and Eastern Tigray. The Amhara Regional State Government is the first one considering the production area of the crop, which is around 242,894.74 ha of the total 453,909.38 ha of land, and it yields 4,902 tons, amounting to 53.55% of the total national production. The age-long trends of cultivation as well as the environmental and cultural diversity in the country have brought along a large number of finger millet landrace varieties. The grain is consumed in different forms as food and the straw serves as animal feed, fuel, and to make hats in rural areas. However, the national average grain yield of finger millet is low, 2.01 ton/ha, although it has a potential to yield up to 3 ton/ha [8], [9].

The production yield of the crop is low in Ethiopia due to numerous production obstacles, including mostly the unavailability of improved seed varieties of the crop germplasms, little research concern given to the crop, non-adoption of advanced technologies for the crop improvement programme by plant breeders, poor attitude towards the crop species on the part of researchers, diseases like blast – which is the most serious disease –, lodging and moisture stress in dry areas, thresh ability, and powdering problems – these are some the most serious production limitations in the crop production in Ethiopia [10], [11], [12].

The availability of agro-morphological genetic diversity among the crop species that ensures promising agronomic characters of the germplasm accessions, collected and conserved in the gene banks or via in-situ conservation in farmers' own fields would be of considerable importance in determining the best method needed to improve the yield of that crop [13]. Therefore, the degree of genetic variability present in the starting population of any crop species is also essential to crop improvement, which must be extensively studied by plant breeders to ensure its improvement, also taking into consideration the drawbacks of the genetic resource [14]. In other words, these diverse genetic resources are very essential for the genetic advancement of any given crop, including finger millet, for their effective use in the crop improvement programmes. So, the main objective of this research study was to conduct the phenotypic characterization of 58 finger millet germplasm accessions, which were gathered from different parts of the country and conserved ex situ at Ethiopian Biodiversity Institute gene banks (EBI) for their 9 agro-morphologically important quantitative traits, and also to analyse data of their performance for plant breeders for the further improvement programme of the crop in particular.

2. Materials and method

The study on sorghum was conducted in Oromia Regional State, Arsi Zone, Arsi Negale Research sub-centre of the Ethiopian Biodiversity Institute in the summer of 2016/17, main cropping season. This region is located in Western Oromia Regional State, having an altitude of 1,947 m a.s.l. (meters above sea level) and located at 7^{o}20'N latitude and 38^{o}09'E longitude. 58 finger millet accessions and two standard checks (Tadsse and Tessema), which were obtained from Melkasa Agricultural Research Centre (MARC), were used for yield and disease resistance traits comparison for the research.

Table 1. List of the accession numbers regarding the 58 finger millet germplasms and the two standard checks used for the research, obtained from the Ethiopian Biodiversity Institute

No	Acc. Number	No	Acc. Number	No	Acc. Number	No	Acc. Number
1	9341	16	215996	31	234152	46	241769
2	100013	17	216042	32	234154	47	25995
3	100015	18	216047	33	234157	48	26000
4	100020	19	216054	34	234259	49	26004
5	100032	20	216055	35	234160	50	26005
6	203060	21	219831	36	234161	51	26093
7	203061	22	222995	37	234170	52	26608
8	203446	23	223027	38	234171	53	26612
9	212462	24	228901	39	234193	54	237446
10	213228	25	229351	40	234205	55	237443
11	215017	26	229400	41	234208	56	9367
12	215829	27	229414	42	234210	57	9369
13	215887	28	229726	43	235830	58	241769
14	215968	29	230119	44	235831	59	Tadsse (check 1)
15	215973	30	230560	45	237447	60	Tessema (check 2)

The research design used was augmented design with no replication among the finger millet accessions, apart from for the two standard checks replicated in every block, as there was a shortage of seeds. All the accessions were assigned to plot a length of 5 meters in three rows and sown 0.75 meters between rows and with 30 cm spacing within the row length. Fertilizers (DAP and Urea) and other agronomic management practices were used as appropriate for the study site.

The data for the nine morphological characters were scored for 20 plants, randomly sampled from each accession, followed by the descriptor list of the crop [15]. Data scoring was done on plant and plot basis as follows: Pl, plant height (cm); BT, Basal tillers (in numbers); NE, number of ears per plant (in numbers); NF, number of fingers per ear (in numbers); FL, finger length (cm; GW, grain weight per ear (in gm); YPP, yield per plant (in gm). Also recorded on plant basis for the sampled 20 plants and for each accession: DF, days to 50% flowering, and DM, days to 50% maturity in number of days on plot basis. The collected data were calculated with statistical analysis of variance, Principal Component analysis, descriptive statistics, and clustering with the help of SAS (9.1) software.

3. Results and discussion

3.1 Analysis of variance

The ANOVA of the 9 quantitative traits of the finger millet genotypes is given below in *Table 2*. The mean square value of all the nine morphological characters under study suggested a significant difference (P < 0.05) between the tested genotypes, except for plant height, finger length, number of fingers per ear, and number of basal tillers among the accessions – elucidating the presence of genetic variability for the trait considered, which can be exploited through further selection.

Table 2. Mean square values of the nine quantitative characters of 60 finger millet accessions and the two standard checks

Mean square								
Character of study Df = 3	Block Df = 3	Entries Df = 59	Accessions Df = 57	Checks Df = 1	Checks vs Accessions Df = 1	Error Df = 3	Total Df = 65	CV
DF	5.79	63.79**	62.48**	78.12**	98.32**	2.12	74.0	1.3
DM	7.33	92.64**	94.7**	1.125**	46.9**	1.8	105.15	0.75
PH	14.57	212.22	176.85	737.47*	1577.3**	32.73	298.38	8.12
NE	3.64	159.5**	117.17*	169.74*	2285.6**	5.19	175.0	7.8
NF	2.29	4.02	4.05	0.877	7.05	0.93	6.55	12.26
FL	1.28	3.87	3.39	7.56*	22.69**	0.623	4.85	10.31
BT	2.94	11.16	8.83	0.525	146.31	1.5	13.65	11.93
GWE	0.24	3.75**	1.93**	5.18**	102.81**	0.13	4.03	8.69
YPP	10.57	166.94**	85.74*	229.17**	4574.41**	5.71	179.99	8.67

*Significant at < 0.05 and **significant at < 0.01. Df, Degree of freedom; CV, coefficient of variation (%)

3.2 *Mean and range values*

For each of the traits considered for this study, the descriptive statistics, including the maximum and minimum quantitative traits' mean values and the standard deviation of the means, were derived from the average data value for each of the accessions summarized in *Table 3*. The overall finger millet germplasms revealed a wide range of diversity for all of the traits under study, resulting in extreme values for the maximum and the minimum genotype mean values. For instance, days to 50% flowering ranged from 90 to 125 days with a mean of 112.12, while days to maturity was ranging from 166 to 200 days with a mean of 178.23. Similarly, the number of tillers per plant and ears per plant ranged from 4 to 23 cm and 6 to 62 cm respectively, whereas plant height ranged from 41 cm to 103.25 cm with a mean height of 70.5 cm. The number of fingers per ear ranged from 5 to 18 with a mean of 8 fingers per ear, and the finger length of the tested genotypes ranged from 3.15 to 12.335 cm with a mean of 7.66 cm.

Grain weight per ear ranged from 0.71 gm to 8.43 gm with a mean of 4.13 gm, and yield per plant of the selected 20 plants from each accession varied from 4.73 to 56.19 gm with a mean value of 27.55 gm. Eventually, it is possible to select the best-performing accessions for further improvement programmes by their grain yield capacity through direct selection.

Table 3. The minimum, maximum, mean, and standard deviation values for the 9 quantitative traits of the finger millet accessions

Trait	Minimum value	Maximum value	Average/mean value	Std
DF	90.0	125.0	112.12	8.3
DM	166.0	200.0	178.82	9.93
PH	41.0	103.25	70.5	15.81
NE	6.35	62.75	29.2	12.74
NF	5.05	18.45	7.85	2.32
BT	3.8	23.45	10.29	3.42
FL	3.15	12.35	7.66	2.02
GWE	0.71	8.43	4.13	1.93
YPP	4.73	56.19	27.55	12.90

Note: DF, days to 50% flowering; DM, days to 50% maturity; PH, Plant height (cm); NE, number of ears per plant; NF, number of finger; BT, Basal tillers per plant(cm); FL, finger length (cm); GWE, Grain Weight per Ear(g); YPP, yield per 20 plants; Std, standard deviation

3.3 Assessment of genetic variability, coefficients of variations, heritability in a broad sense, genetic advance, and genetic advance of mean among finger millet genotypes

The phenotypic and genotypic variances were estimated according to the method suggested by [16]. The phenotypic and genotypic coefficients of variations (PCV and GCV respectively) were also calculated using the formula as suggested by [17]. In order to ascertain which are the major traits contributing to the overall phenotypic variation among the accessions and estimate the broad-sense heritability, genetic advance and genetic advance as percentage of mean were computed following the method as per [18].

From the nine quantitative traits investigated in the current study, grain yield per 20 plants, plant height, number of ears per plant, days to 50% flowering, and maturity had shown high genotypic (GV) and phenotypic (PV) variances. In contrast, low values were recorded for NF, FL, BT, and GWE (*Table 4*).

In the current study, PCV and GCV values that were roughly above 20% were regarded as high, whereas values below 10% were considered to be low, and values between 10 and 20% were regarded as medium, as suggested by [19]. Based on this assumption, PCV values ranged from 5.43% for DM to 47.69% for GWE, while the genotypic coefficient of variability (GCV) varied from 5.32% for DM to 46.63% for YPP. PCV values were lower for DM and DF, medium for PH and FL, and higher percentage values were obtained for BT, NE, NF, GWE, and YPP. GCV values were minimal for days to 50% maturity and days to 50% flowering and medium for plant height and finger length. The current diversity research on finger millet is in agreement with previously conducted researches, considering the quantitative traits of maize and sorghum [20], [21], [22]. For all considered characters, the overall PCV values were higher than their corresponding GCV values. The higher the PCV and GCV values of these traits observed in the research study, the greater the chance to become mostly genetic in nature and provides a clue about their huge possibility of improving these traits via direct selection. The range of values between PCV and GCV was higher for the number of basal tillers and the number of fingers per ear, providing a hint at the negative impacts of the environment on these morphological characters, whereas this range was low for the rest of the characters studied for the current study, including DF, DM, NE, FL, GWE, and YPP. One of the main reasons behind this is probably the minimum influence of the environment on the gene expression of these agro-morphologically novel traits (*Table 4*).

Table 4. Computation of phenotypic and genotypic variance, phenotypic and genotypic coefficients of variation, heritability, genetic advance, and genetic advance as percentage of mean of 9 quantitative characters the finger millet accessions

Character	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM
DF	65.91	61.67	7.24	7.00	93.567	37.98	33.87
DM	94.24	90.84	5.43	5.32	96.35	46.76	26.15
PH	244.95	179.49	22.19	19.00	73.27	57.33	81.32
NE	164.69	154.31	43.95	41.3	93.69	60.11	205.8
NF	4.95	3.09	28.34	22.39	62.42	6.94	88.41
FL	4.49	3.253	20.59	17.527	72.5	7.68	74.63
BT	12.66	9.66	46.45	40.57	76.3	13.57	177.15
GWE	3.88	3.62	47.69	46.07	93.29	9.18	222.27
YPP	171.65	161.23	47.38	46.63	93.93	61.53	223.34

PV, Phenotypic variance; GV, genotypic variance; PCV, phenotypic coefficient of variation; GCV, genotypic coefficient of variation; h^2, broad sense heritability; GA, expected genetic advance; GAM, genetic advance as percent of the mean

Broad-sense heritability values were recorded as ranging from 62.42% for the number of fingers to 96.35% for days to 50% maturity, as indicated in *Table 4*. According to [23], if the heritability estimates of a character are 80% or above, the selection of genotypes for a given trait could be easy, which implies these characters' capability of responding to selection pressure. However, for characters with smaller percentage values of broad-sense heritability of 40% or less, the selection of character for further screening may be impractical because of the high environmental impacts on the genotypes, which suppress the gene expression for that particular trait. Based on this information, the heritability estimate was higher (> 80%) for days to 50% flowering and maturity, the number of ears, grain weight per ear, and yield per plant. It was medium (40 to 80%) for the rest of the quantitative characters.

Similarly, the estimates of genetic advance of mean (GA) for grain yield per 20 plants were calculated according to [18]. It was done with the assumption of selecting 5% of the high-yielding genotypes as parents; the mean grain yield of progenies could be improved by 61.53 gm. In other words, the mean genotypic value of the new population for grain yield will be improved from 27.5 gm to 89.00 gm per 20 plants. In the same way, the mean values for the rest of the morphological traits were estimated and given in *Table 5*.

Finally, for the estimation of genetic advance as percentage of mean (GAM) at 5% selection intensity, the recorded highest percentage values were for YPP (223.34%), GWE (222.27%), and NE (205.8%), followed by BT (177.15%), NF

(88.41%), and PH (50.95%). The lowest estimated values were for DF and DM (37.87% and 26.15%) respectively.

Table 5. PCA of the 9 morphological traits of the finger millet germplasms

Traits	Prin 1	Prin 2	Prin 3	Prin 4	Prin 5	Prin 6	Prin 7	Prin 8	Prin 9
DF	0.260103	0.071640	0.691629	-.250634	-.250634	0.572872	-.022657	-.109742	-.000023
DM	0.325636	0.362869	0.396422	-0.044991	0.274761	-.491380	0.284379	0.453092	0.000012
PH	0.386229	0.369373	-.119227	-.141421	0.163409	-.229949	-.100679	-.768414	-.000009
NE	-.387795	0.281964	-.035255	0.082213	0.275613	0.312533	0.740330	-.200954	-.000011
NF	0.277840	0.265051	-.155198	0.473041	-.728564	-.021137	0.270267	0.020060	0.000039
BT	-.223302	0.451473	0.189634	0.611130	0.246612	0.161456	-.498931	0.032384	0.000004
FL	-.045254	0.582225	-.421724	-.505664	-.109717	0.252898	-.182854	0.340571	0.000027
GWE	0.445896	-.130724	-.235752	0.166525	0.293981	0.307670	0.049890	0.131132	-.707112
YPP	0.445893	-.130760	-.235719	0.166509	0.294023	0.307695	0.049890	0.131096	0.707101
Eigenvalues	*4.004*	*1.51*	*1.08*	*0.868*	*0.6420*	*0.362*	*0.325*	*0.211*	*0.0004*
% of total variance	2.495	0.429	0.211	0.227	0.280	0.365	0.114	0.211	0.000
% Cumulative variance explained	0.4448	0.6125	0.7325	0.8290	0.9903	0.9404	0.9765	1.000	1.000

PCA, Principal Component Analysis; DF, days to 50% flowering; DM, days to 50% maturity; PH, Plant height (cm); NE, number of ears per plant; NF, number of fingers; BT, Basal tillers per plant; FL, finger length (cm); GWE, Grain Weight per Ear (g); YP, yield per 20 plants

3.4 Principal component analysis of the nine quantitative morphological characters

The principal component (PCA) analysis revealed that out of the nine characters, the first three having eigenvalues > 1 account for 73.25% of the total variation captured among the finger millet genotypes. The first component accounts for 40% of the total variability, whilst the second and the third for 15.1% and 10.8%, respectively, of the total variability among the genotypes for traits under study.

PCA 1 is more related to traits such as plant height, grain weight per ear, number of fingers per ear, and yield per plant. While the second principal component was positive for basal tiller, finger length and number of ears per plant were more related traits. The third and last principal component was positive for days to 50% lowering and days to 50% maturity.

3.5 Cluster analysis

Based on their similarity performance, the 60 finger millet genotypes were categorized into 4 clusters.

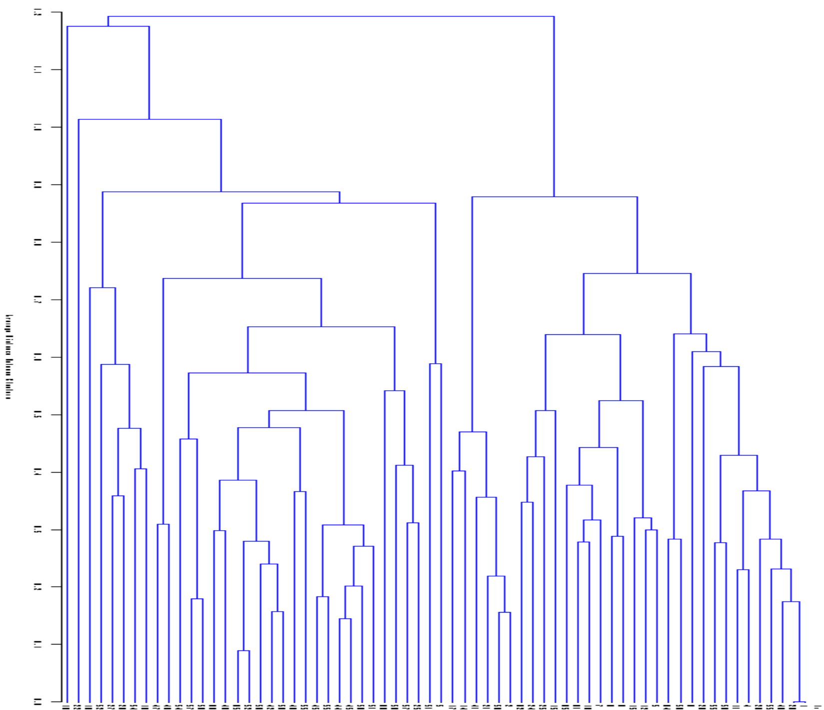

Figure 1. The cluster analysis of 60 finger millet accessions along with the two standard checks

The unweighted pair group method using arithmetic average (UPMGA) tree analysis was used for diversity study analysis, and the process grouped the 60 accessions into 4 clusters. Root-mean-square distance between observations was calculated at 37.85. The largest cluster distance observed was 1.29 and the smallest 0.088, which clearly showed the genetic diversity among finger millet germplasms.

Cluster I contained 32 accessions, which is the largest, Cluster II comprised 26 finger millet germplasms, including the two standard checks, while the last two clusters did not cluster with the rest of the group. Clusters III and IV were represented by only a single accession as a group.

Conclusion

The current study demonstrated a significant variation among the finger millet accessions for most of the studied quantitative traits. This indicates that the accessions used in this study are genetically diversified and offer an opportunity for plant breeders to conduct further breeding activities through selecting the most promising base populations of the crop accession numbers.

The PCA analysis depicted the contribution of each trait involvement of the individual genotype development to the total genetic variation observed among finger millet accessions. In this study, the first three PCA results were taken for the studied agronomically important characters with eigenvalues greater than unity and contributed to 71% of the total variation observed among the accessions. Significantly high positive results were obtained for ear yield and maturity traits in PC1 and PC3, which indicates the major character contributors to the overall genotype variations for yield-related agronomic characters among the finger millet germplasms. Thus, this shows that the finger millet accessions are highly diversified for ear and maturity traits, which could be further utilized as a basis for selecting parent germplasms.

Similarly, grain yield per 20 plants was found to be highly influenced by grain weight and the number of fingers per ear. Thus, this indicates that the finger millet accessions used in this study are genetically diverse and that each agronomic trait under study contributed to a varying degree to the overall morphological variability among finger millet accessions.

High heritability estimates along with a high genetic advance are usually more helpful in predicting gain under selection than heritability estimates alone. The current study suggests high heritability together with high expected genetic advance and genetic advance as percentage of mean for NE, NF, GWE, and YP, medium heritability with relatively higher genetic advance for plant height, number of fingers per plant, and number of basal tillers per 20 plants, and low heritability for values for days to flowering and maturity, which are 37.87% and 26.15%

respectively. Therefore, these agronomically important characters could be investigated further and more suitably improved than the other traits.

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Historical gardens of the Banat region

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Abstract. The aim of the article is the studying of a frequently seen phenomenon, which is the loss of value as far as some buildings and their surroundings are concerned, which, at the moment of their construction, held great historical and architectural value, but in time they have gradually lost their value due to political, social, and cultural changes. In the Banat region of the first half of the 19th century, we can remark the dominance of the neoclassical style. The parks of the Banat region, apart from their role of satisfying the visual aesthetic appearances, are very well adapted to the place. They are unique, but the pattern after which they were conceived is common, according to the fashion of the era in which they were created. The subject of the research develops around the historical gardens belonging to certain historical monuments. The aim of researching these landscape arrangements is the investigation of the present-day situation and their evolution that has led to their actual transformation.

Keywords: castle, neoclassical style, historical value, monument

1. Introduction

In Timiș County, there are more than 30 castles and mansions, most of which have their origins in the 18th–19th centuries, the period in which the nobility began to appear in the Banat region, who were enchanted by the beauty of the buildings of the Habsburg Empire.

Most of the Banat communes or small towns link their evolution to a nobleman from the old guard, a count that, through charity works, by diligence and perseverance, succeeded in motivating the locals to work together for the construction of the settlement, thus establishing the infrastructure of these settlements and of the buildings of the premises of institutions indispensable to a community.

After the sale of the Habsburg crown domains at the end of the 19th century and the emergence of large agricultural properties, the Hungarian, German, or

Croatian nobles built castles, mansions, and summer residences in the Banat area, following the model of the Viennese royal courtyards, with neoclassical parks stretching over tens of hectares with a beauty specific to that area and period.

Many of these castles and mansions were demolished during the First World War. Others remained as a relic of the past, as a vestige of the old times.

A new era was born and another one, hundreds of years old, was reaching its end. Few of the nobles in the Banat area were able to accept these changes and lamented that the old times with imperial fasting and feudal privileges had come to an end.

The castles and mansions of these noblemen began to change, to adapt to the times and regimes that rapidly faded in the first half of the century. Some of these buildings died along with the owners. Others remained to survive. The price of survival was, however, the change.

Landscaping also suffered in recent decades by deliberate destruction, sometimes through ignorance and carelessness or due to the lack of material means of maintenance.

2. Materials and methods

We studied the territories situated between the Eastern Carpathians and Crişana, territories that have been predominantly under Western influence over time. The study period is delineated between the 17th century and the 21st century, these periods being studied from the appearance of these castles and gardens to the present.

The studied sites are analysed, following aspects such as: general data regarding the owners, construction stages, architectural style and constructors, study of the site, of the local relief and of the order of major elements of the arrangement, of the residence and its relationship with the exterior arrangements as well as of the exterior arrangement itself.

The study and documentation of the historical gardens in Banat began by researching them from ancient documents, books, maps, articles, and postcards. With the help of written documents, such as the personal documents of the noble families kept in the state archives or the specialized books, we managed to outline the story of every noble family in the possession of a mansion, castle, and garden attached to it [1].

Postcards represented a significant visual insight into the past, which, in addition to the maps studied, were a great help for a more accurate understanding of the planimetry of the gardens [2].

Also, the maps documented at cadastral offices [3] and the military maps [4] have been of great help in identifying the initial planimetry of the locality and the evolution of the gardens corresponding to mansions within these localities.

All these documents underlie the study of these noble sites, which were finally outlined by a visit on the spot. The visitation of these sites was one of the most important steps of our research because the consultation of the present situation is decisive in the study of evolution of these gardens. But what we saw on the spot has had a negative and demoralizing impact in many cases, given the present state of these mansions, their castles and gardens, and what has remained from most of them.

The study was carried out on the architectural ensembles already classified as historical monuments as well as on those not classified but considered valuable based on the traces kept from the arrangement and/or its relation with the residence. So, we have visited 34 mansions and gardens, including 9 gardens classified as historical monuments and 25 gardens not included in the list of historical monuments.

The external arrangements and their related constructions were selected according to the coherent style, the current physical state, and the criteria of analysis such as historical analysis, stylistics, and the interventions carried out. The natural heritage assessment criteria have also influenced the selection of these gardens due to the valuable species of exceptional beauty discovered in situ, due to the evolutionary value, associative value, documentary, testimonial value, and landscape–land relationship [6].

Figure 1. Map of the gardens visited in Caraş Severin, Arad, and Timişoara

During the on-site visit, the following mansions and gardens were studied:

Parks ranked as historical monuments [7]: 1. Banloc – Timiş – Banloc Mansion Park; 2. Lovrin – Timiş – Lipthay Mansion Park; 3. Bulci – Arad – Mocioni Castle Park; 4. Căpâlnăş – Arad – Teleki Castle Park; 5. Fântânele – Arad – The Kövér-Appel Castle Park; 6. Macea – Arad – Cernovici-Macea Castle Park; 7. Mocrea – Arad – Solymosy Castle Park; 8. Odvoş – Arad – Konopi Castle Park; 9. Petriş – Arad – Salbek Castle Park.

Parks not classified as historical monuments:

10. Carani-Timis-Saurau Féger; 11. Rudna – Timiş – Nikolics Residence; 12. Folea – Timiş – Beniczky Residence; 13. Livezile – Timiș – Gyertyánffy Residence; 14. Sag – Timiş – Rónay Residence; 15. Jimbolia – Timiş – Csitó Castle of the Csekonics family; 16. Zagujeni – Caraș Severin – Jakabffy – Juhász Castle; 17. Delinești – Caraș Severin – Brody Residence; 18. Ghertenis – Caraș Severin – Hollósi Mansion Park; 19. Valeapai – Caraș Severin – Atanasievici Castle Park; 20. Comloşu Mare – Timiş – San Marco Mansion Park; 21. Sânnicolau Mare – Timiș – Nako Mansion Park; 22. Foeni – Timiș – Mocioni Mansion Park; 23. Beregsau Mic – Timiș – Damaszkin István Castle Park; 24. Cenei – Timiș – Uzbasich Mansion Park; 25. Giera – Timiș – Gyetsanffy István Mansion Park; 26. Granicerii – Timiș – Csávossy Castle Park; 27. Izvin – Timiș – Ottlik Péter Mansion Park; 28. Pesac – Timiș – Zichy Mansion Park; 29. Remetea Mare – Timiț – Ambrózy Castle Park; 30. Şimand – Arad – Kintyig Castle Park; 31. Şofronea – Arad – Purgly Castle Park; 32. Aradul Nou – Arad – Nopcsa Castle Park; 33. Zimandu Nou – Arad – Kintzig Castle Park; 34. Murani – Timiș – Manaszy Barco Mansion Park.

3. Results and discussions

The research of the historical gardens in the Banat area is performed for mansions and castles built in most cases during the known period of the neoclassical style in this area of the country. The neoclassical style requires a solemn image with an elegant refinement and exuberance of details and decorations. It is the favourite style of the aristocracy and of the bourgeoisie, offering an impressive image of the exterior and interior architecture, worthy of a social status, which also exposes its grandeur in this way.

The neoclassical period adopts the style of English landscapes with sinuous alleys, and the Banat castle parks are built in most cases in the neoclassical style. The layout is not geometric, and there are no rigorous lines or rules, strict alignments. The parks of these castles are characterized by trees and shrubs organized in a more relaxed style, with many exotic species brought to the liking of the owners, some arrangements reaching the appearance and character of the dendrological parks.

In addition to the importance of the building, the landscape architecture was equally important when it came to power and grandiosity. The arrangement of the grand entrance provided an impressive and important framework in order to bring the beauty of the building to the forefront [8].

Currently, most of these mansions and castles are left in a state of advanced degradation, most of which are abandoned, but some are used to shelter public functions, rarely private.

The gardens of these buildings, classified as historical monuments, are in most cases missing, without any specific landscaping. In the case of gardens classified as historical monuments, the only testimonies that could serve as a guide are the high vegetation elements, rare trees, which have been preserved in most gardens. The low and medium vegetation or architectural landscaping elements are in most cases unidentifiable.

All these gardens and mansions studied have a significant geographic significance because they have a noble family behind them, with the help of which these castles and gardens have emerged. In most cases, these nobles influenced the development of the locality in which they had built them by possessing these domains, and in some cases even the entire locality was under their control.

Figure 2. Case study – Banloc Castle Garden – a garden ranked as a historical monument – postal cards of the epoch [9], cadastral [3], military maps [4], and the author's photos

In the case of gardens not classified as historical monuments in most of the studied cases, we cannot observe a coherent landscaping because the traces of these gardens no longer exist. The planimetric existence according to a certain typology of settlement of these arrangements in relation to the castle can be ascertained, but the planimetry of the epoch garden is not noticeable.

The only footprint of the Epoch Park is in most cases the existence of high vegetation, positioned only in certain areas on the site, not necessarily having a visible logic, to present us a testimony of what used to be once.

Figure 3. Case studies – Gardens not classified as historical monuments: Ronay Castle Garden in Șag, Timiș County – Epoch Postcards [9]; Athanaszievich Castle Garden in Valeapai, Caraș Severin County – Epoch postcards [10]; Manaszy Barco Castle Garden in Murani, Timiș County – Epoch postcards [11] – the author's photos

Many of these gardens have been designed by specialists brought from outside the country, especially by Austrian craftsmen and architects, and in most cases these are based on Viennese gardens and courtyards.

On the cadastral maps, they appear as large landscapes with spectacular dimensions, which were located mostly behind the construction (the "back" being the main access façade), stretching spectacularly all along the alleys and long promenades, with a game of lines that give up any rigidity, rigour, and symmetry, leading the eye to oval shapes, thus giving the landscape image a planimetric freedom and a visual emotion when unravelling these unplanned paths.

The present situation is less readable in terms of frequency, rarity, and uniqueness due to the abandoned and wildlife situation of these gardens.

Of the number of gardens visited, 16 are made before and between 1775 and 1830, which offers membership to a limited series for a historical-geographic area and for a historical period, also offering a typicality for this area through the style of the adopted age.

According to the statistics adopted on these studied gardens, given their present condition as compared to their original image, we have made a diagram showing the following:

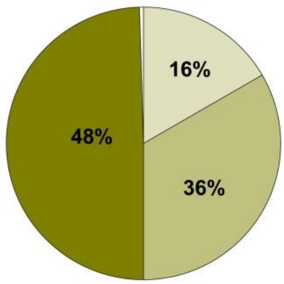

Figure 3. The original footprint of the existing historical gardens

The situation of the gardens of the mansions currently visited is demoralizing since 48% of the studied cases no longer show signs of landscaping of the original garden of the epoch. 36% of the gardens have landscapes with vegetal elements but only with high vegetation and currently existing landscape architectural elements of which less than 50% of the landscaping model of the original garden of the epoch.

In case of 16% of these gardens, landscaping with vegetal elements can be observed, namely with high vegetation and currently existing landscape architectural elements of which 50% according to the pattern of landscaping of the original garden of the epoch. According to the study carried out within our research, there is no entirely existent landscaping according to the landscaping model of the original garden of the epoch.

4. Conclusions

Focusing on the historical gardens of mansions, castles, and noble residences, the present study outlines an image of Banat sites selected from those already classified as historical monuments and from those not classified but considered valuable based on the traces kept in the arrangement and/or their relationship with the built residence.

Due to the fact that the information accumulated over time and the few and disparate studies on the historical gardens of the Banat area, the present study comes on a relatively free field, adding a supplement to the historiography of the problem, while leaving the possibility for further research on the topic.

The present study is an attempt to show the charm of rural residences, focusing on its landscaping, which, though humiliated by fate, proves that built history cannot be forgotten.

Today's specialists are interested in these gardens, which have been and are unmatched values and present a testimony of the historical past, being at least as valuable as the construction they are accompanying.

After years of ruin and forgetfulness, we hope that with the help of specialists in the field we can offer a new chance for the revitalization and continued survival of these gardens.

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The short- and long-term effects of changes of vegetation structure on isopod (Oniscidea) diversity and composition in Mátra Mountains

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Abstract. The aim of the present study was to examine the short- and long-term effects of changes in vegetation structure caused by shrub removal and mowing on isopod diversity and composition in Natura 2000 habitats of Mátra Landscape Protection Area. Species richness and isopod diversity increased in the short term as a result of annual changes in vegetation; however, the values of both indices were reduced in the long term. The changes in vegetation structure on a regional scale led to a reduced isopod diversity in the short and long term. The changes in vegetation structure caused alterations in community structure in the long term. We conclude that changes of vegetation structure have a negative effect on species richness and the diversity of isopod communities in the long term.

Keywords: Hungary, mowing, shrub removal, grasslands

1. Introduction

The formation of open habitats is a long-term process caused by deforestation; later on, mowing and grazing contribute to the maintenance of meadows. Changing or elimination of traditional management contributed to the re-formation of shrubs and forests [1], but this succession process can be reversed by treatments, namely shrub removal and mowing [2, 3]. Since 2000, the Bükk National Park Directorate has conducted a soil-zoological monitoring for the KEOP project (Restoration and treatment of lawns, meadows, and woody pastures) in the Mátra Mountains in order to reconstruct open habitats or maintain its current form. The protection of grasslands is important to the fauna as well because the arthropod species significant from a nature conservation point of view are attached to lawn plant species [4]. Grassland managements change the structure and composition of vegetation [5, 6], which affects the micro-climatic conditions of habitats, such as temperature, soil humidity, nutrient source, and lighting conditions. For example, mowing can create changes below the ground that have an effect on plant growth [7], such as decreasing of nitrogen mineralization in the soil [8]. Similarly, Turgeon [9] reported that mowing is detrimental from a botanical standpoint. Opposite to this, Ilmarinen and Mikola [10] concluded that mowing increased the areal cover of legumes, and it has less effect on the areal cover of individual woody species compared to the total cover of the woody plant group that is reduced. High floral diversity positively affects the diversity of flower-visiting insects [11] and therefore predatory arthropods such as spiders [12, 13, 14, 15] and beetles [16]. Opposite to this, some representatives of other trophic levels are affected by other conditions and the connection with the number of microhabitats. Terrestrial isopods are ground-dwelling crustaceans, members of the decomposer macrofauna [17, 18]. Isopods play an important role in decomposition processes through the fragmentation and mineralization of dead organic matter [19]. The food of isopods consists of fungi, bacteria, decayed wood, and leaf litter, as their weathering with conditioning by microorganisms improves their palatability for the isopods [20]. Isopods are considered the most successful crustacean colonizers of land habitats with wide ecological tolerance [21]. They were found in most mesic, xeric, and hydric habitats [22, 21] worldwide, with the exception of the poles and very high elevations [23]. Moreover, they tolerate high levels of copper and ammonia [24, 25, 26]. However, their dispersion ability is limited because the temperature and humidity of environment strongly influence their mortality and natality [27].

The main objectives of this study were to investigate the effects of changes in vegetation structure on isopod diversity. Firstly, we studied how the annual changes in vegetation structure impact isopod diversity in the short and long term. We examined changes in isopod diversity in relation to a sudden change of vegetation structure caused by shrub removal in the short term (between the years 2012 and 2013). Also in these created open habitats, we studied how isopod diversity changes in the long term (between the years 2012 and 2014). We hypothesized that changes in vegetation structure have a negative effect on isopod diversity in the short term. Moreover, we expected the further decreasing of diversity in the course of the previous year. Secondly, we explored how the changes in vegetation structure affect isopod diversity and composition on a regional scale. We analysed the differences between habitats (control shrubs, removal shrubs, and hay meadow) to examine the effect of vegetation structure changes in the short term (removal shrubs) and long term (hay meadow). We hypothesized that the highest isopod diversity will be in control shrubs, while the lowest will be in hay meadows because of defoliation.

2. Materials and methods

A. Sampling areas and methods

We sampled terrestrial isopods in three localities (Sár Hill Nature Reserve, Gyöngyössolymos, and Fallóskut) in the Mátra Mountains as shown in *Fig. 1*. Three sampling sites were selected in all localities, representing control shrubs (no removal), removal shrubs (cut once), and hay meadows (mown once a year), as shown in *Table 1*.

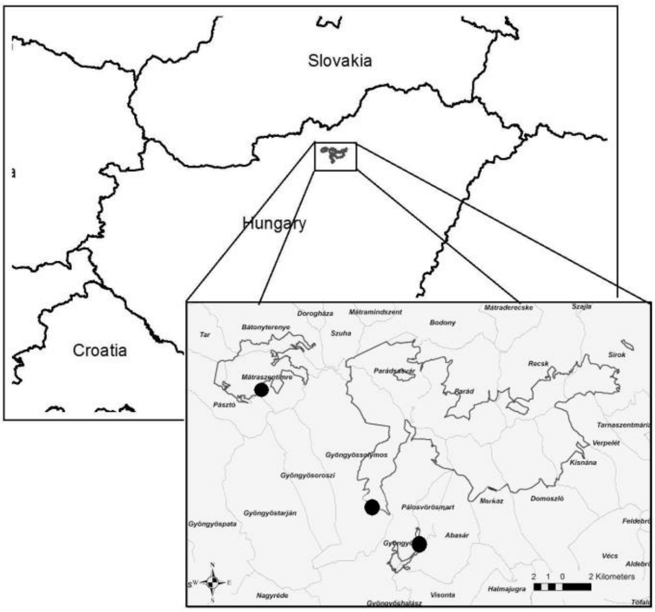

Figure 1. Map of sampling sites in Hungary

Double-glass pitfall traps filled with 65% ethylene glycol were established on the sampling sites between 2012 and 2014. Five traps were set at a distance of 4–5 m along a transect on every sampling site. Traps were deployed twice (May–July, September–November) over a six-week period each year. Grassland management was undertaken in those habitats with advanced succession. Shrub removal done manually was the first phase of the treatment process and occurred at the end of 2012, following sampling. Additional treatments during the following year (2013–2014) did not take place, but possibly following stem mashing and finally mowing would be necessary. The hay meadows were mown with a mowing machine in all years, in summer or autumn, depending on the weather conditions. The treatments were carried out in a rotational manner, reserving a small portion of intact (unmown) habitat each year. In order to analyse the effect of annual changes in vegetation, we compared data of different years: in the short term between 2012 and 2013 and in the long term between 2012 and 2014. To assess the effect of changes in vegetation on a regional scale, we considered data of different sampling sites: in the short term: between control shrubs and removal shrubs, in the long term: between control shrubs and hay meadows.

Table 1. Characteristics of the sampling sites

<table>
<tr><th>Sites</th><th>Altitude (m)</th><th>Land usage</th><th>Vegetation sturcture</th><th>Size (ha)</th><th>Vegetation</th></tr>
<tr><td rowspan="3">Gyöngyös-solymos</td><td rowspan="3">300</td><td rowspan="3">Sheep pastured</td><td>Hay meadow</td><td>5</td><td>Campanulo-Stipetum tirsae</td></tr>
<tr><td>Control shrub</td><td>1</td><td>Pruno spinosae-Crataegetum
with forest steppe items e.g. Acer tataricum</td></tr>
<tr><td>Removed shrub</td><td>1</td><td>Campanulo-Stipetum tirsae</td></tr>
<tr><td rowspan="3">Sár Hill</td><td rowspan="3">350</td><td rowspan="3">Vineyard</td><td>Hay meadow</td><td>3</td><td>Campanulo-Stipetum tirsae</td></tr>
<tr><td>Control shrub</td><td>1</td><td>Pruno spinosae-Crataegetum</td></tr>
<tr><td>Removed shrub</td><td>1</td><td>Pulsatillo montanae-Festucetum rupicolae</td></tr>
<tr><td rowspan="3">Fallóskút</td><td rowspan="3">700</td><td rowspan="3">Hay meadow and pastured</td><td>Hay meadow</td><td>1</td><td>Anthyllido-Festucetum rubrae</td></tr>
<tr><td>Control shrub</td><td>2</td><td>Pruno spinosae-Crataegetum with Quercus ceris, Carpinus betulus</td></tr>
<tr><td>Removed shrub</td><td>1</td><td>Pastinaco-Arrhenatheretum</td></tr>
</table>

B. Statistical analyses

We used the PAST Paleontological Statistic suite for data analysis [28]. The characterization of isopod communities was based on relative abundance (Ar) and frequency (F). Besides species richness (S) and the number of individuals (N), we computed Shannon-Wiener diversity (H), Simpson's diversity (1-D), and evenness (E) (Pielou's index). The Shannon-Wiener index is more sensitive to the frequency of rare species [29, 30, 31]. Species with the highest abundance have the greatest influence on the Simpson's index [29, 30, 31]. The Pielou evenness index expresses the evenness of the distribution of the species and is sensitive to the change of rare species [30, 31]. The value of species turnover between habitat types was evaluated with Wilson & Shmida's Beta diversity index (βT). The level of complementarity of habitats within the study area was characterized with Whittaker's β-diversity index (βW) [31]. Whittaker's β-diversity index depicts the relationship between alpha diversity and total number of species. We applied the Jaccard similarity index for pairwise comparison of similarities of habitats based on species composition. The Jaccard similarity index calculates the similarity based on the absence and presence of the species [32]. For better demonstration, community separation was represented with Detrended Correspondence Analysis. The Friedman test was applied to compare the ecological indices using XLSTAT 14.0.7188.5002 version software (https://www.xlstat.com). We used the keys of Hopkin [33], Schmidt [34], and Farkas and Vilisics [35] for identification of isopod specimens. Species' names were applied according to Schmalfuss [36].

3. Results

We collected a total of 5 isopod species composed of 675 specimens at 9 sampling sites, as shown in *Table 2*.

Table 2. Distribution of isopod species in sampling sites

Abbr	Species	Control shrubs		Removed shrubs		Hay meadows	
		Ar%	F%	Ar%	F%	Ar%	F%
	Trachelipodidae						
P. coll	*Porcellium collicola* (Verhoef, 1907)	5.2	100	3.8	33	2.2	66
T. rath	*Trachelipus rathkii* (Brandt, 1833)	14.8	66	84.6	66	95.5	100
T. ratz	*Trachelipus ratzeburgii* (Brandt, 1833)	0.39	-	3.8	33	-	-
	Agnaridae						
O. pla	*Orthometopon planum* (Budde-Lund, 1885)	3.39	66	3.8	33	2.2	66
	Armadillidiidae						
A. vul	*Armadillidium vulgare* (Latreille, 1804)	76.1	33	3.8	33	-	33

We did not find significant differences between the ecological parameters of communities relative to annual changes in vegetation structure, as shown in *Table*

3. We observed the highest species richness and diversity in the year following shrub removal; thus, changes of vegetation structure caused the increasing of isopod diversity and species richness in the short term. The values of both indices were reduced last year, as shown in *Table 4*.

Table 3. Differences between ecological parameters relative to changes in vegetation structure on annual and regional scales by the Friedman test

	Annual		Regional	
Change in vegetation structure	short term	long term	short term	long term
			Between control shrubs and	
	2012–2013	2012–2014	removal shrubs	hay meadows
Q (Observed value)	1	0	4	4
Q (Critical value)	3.841	3.841	3.841	3.841
DF	1	1	1	1
p-value	0.317	1.000	0.046	0.046
alpha	0.05	0.05	0.05	0.05

Table 4. Annual changes in the number of isopod species (S), number of individuals (N), Shannon-Wiener diversity (H), Simpson's diversity (1-D), and evenness (E)

Indices	2012	2013	2014
S	3	5	1
N	12	11	15
H	0.9184	1.16	0
1-D	0.,5694	0.562	0

On a regional scale, the ecological parameters of communities have differed significantly between habitats, as shown in *Table 3*. The lowest species richness and isopod diversity were observed in hay meadows, while we recorded the highest isopod diversity in control shrubs, as shown in *Table 5*. A negative correlation was observed between isopod diversity and the number of individuals in the short and long term. We did not find correlations between isopod diversity and number of individuals among the three habitats, as shown in *Fig. 2*.

Table 5. Number of isopod species (S), number of individuals (N), Shannon-Wiener diversity (H), Simpson's diversity (1-D), and evenness (E) at a regional scale

Indices	Control shrubs	Removed shrubs	Hay meadows
S	5	5	3
N	511	26	90
H	0.7814	0.6426	0.2126
1-D	0.3945	0.2781	0.08593
E	0.4369	0.3803	0.4123

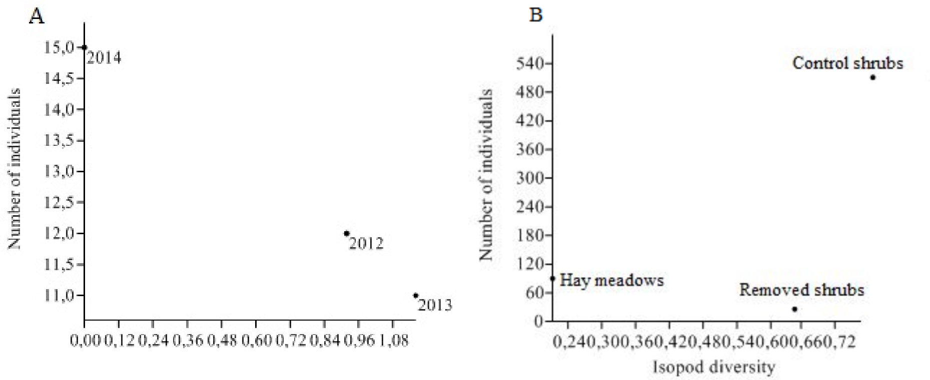

Figure 2. Correlation between isopod diversity and number of individuals in the period of 2012–2014 and in the different habitats (removal shrubs, control shrubs, hay meadows)

We found an increase in the species turnover between years in removal shrubs (2012–2013: 0.25, 2012–2014: 0.5). Between control shrubs and removal shrubs, the values of Wilson & Shmida's Beta diversity index is zero. Species turnover was the same in the hay meadows from removal shrubs (0.25) and control shrubs (0,25). There was a decrease in the Jaccard similarity index between the assemblages of removal shrubs (2012–2013: 0.6, 2012–2014: 0.33). Between control shrubs and removal shrubs, the values of Jaccard similarity index is 1. We found the same differences in hay meadows from removal shrubs (0.6) and control shrubs (0.6). The complementarity of isopods was especially low between these habitats. Whittaker's β species diversity was 0.15.

Examining the effect of annual changes in vegetation structure on isopods, we observed a low abundance in all years. In the first year, we found a generalist (*T. rathkii*) and two forest specialist (*T. ratzeburgii*, *O. planum*) species. The sudden change of vegetation structure resulted in the appearance of more generalist species (*P. collicola*, *A. vulgare*) in the second year. In the third year, only the *T. rathkii* tolerated the changed conditions in the long term, and its relative abundance increased continually as shown in *Table 2*. Examining the effect of changes in vegetation structure on a regional scale, we have not found significant differences between habitats. The highest number of collected individuals occurred in the control shrubs, where 3 generalist (*P. collicola*, *T. rathkii*, *A. vulgare)* and 2 forest specialist (*T. ratzeburgii*, *O. planum*) species were observed. In the removal shrubs, such species were presents, but their number was the lowest compared to control shrubs. In hay meadows, only 3 (*P. collicola*, *T. rathkii*, *O. planum)* species were observed, and the relative high isopod abundance was resulted by the high number of *T. rathkii*. The most abundant isopod was the cosmopolitan *A. vulgare*, but it was absent in hay meadows. The abundance of this species was quite high in control shrubs compared to the other two habitats. The abundance of *T. rathkii* was also high in all habitat types. The relative abundance of *T. rathkii* was the highest on hay meadows. The relative abundance of the 2 forest specialist species was the highest in removal shrubs as compared to control shrubs, but the relative abundance of generalist species changed adversely. The differentiations of assemblages are represented in the ordinations as shown in *Fig. 3*.

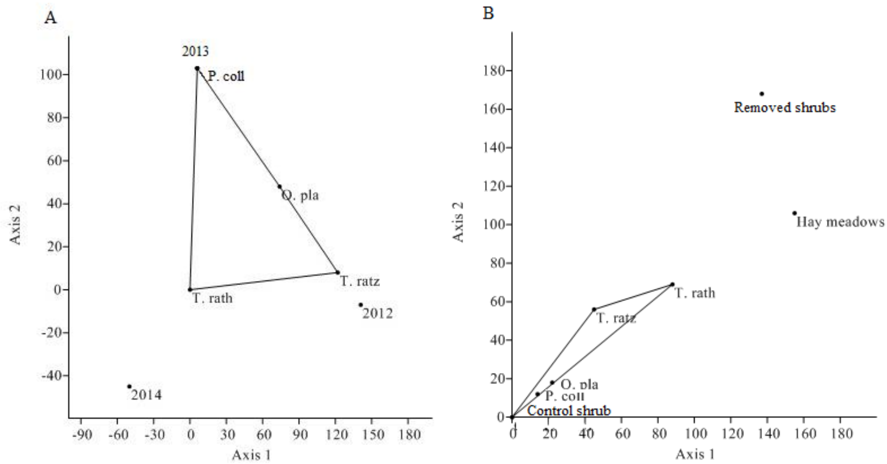

Figure 3. Annual (A) and regional (B) separation of isopod assemblages using Detrended Correspondence Analysis (see abbreviations of species in *Table 2*)

Grassland management can be considered as an intermediate disturbance [37], but it significantly changes the structure and composition of vegetation. It has positive effect on certain groups of arthropods [38, 39, 15, 39], but some animal taxa are affected negatively. For example, the high mortality of larvae, or pupae, of flower-visiting insects may be caused by mowing [40]. Grassland reconstruction treatments are composed of shrub removal followed by either mowing or grazing or burning [3]. Shrub removal can create changes in the vegetation structure of habitats in the short term, and it is followed by mowing, causing the changes in vegetation composition in the long term [10]. The alteration of habitats contributes to the changes in environmental factors, which affects food utilization, reproductive pattern [41], and the respiration of isopods. Isopods die in dry air because of the lack of O_2, not desiccation [42].

We hypothesized that annual changes in vegetation structure caused by shrub removal will have negative effects on isopod diversity in the short term and the decreasing of diversity will continue in the long term. Our hypothesis was partly confirmed and partly not. On the one part, our hypothesis was not confirmed in that isopod diversity will decrease in the short term. Isopod species richness was relative to the ecological conditions of their habitats [43]. The created open habitats following shrub removal provided suitable conditions for more homogenizing species that tolerate the arid and warm environments. This is supported by the observed negative correlation between the annual changes in isopod diversity and number of individuals. Our results compare well to Davis and Sutton [44], where isopods' abundance was higher in semi-natural grasslands than woodlands. This is an unexpected result because isopods preferring decayed fallen litter [20] and shrub removal lead to the decreasing of structuration of habitats and the reducing of underwood. Similarly, according to Hassall [45], the simplification of habitat structure and less shelter sites affect the mortality of isopods. On the other part, our hypothesis was confirmed because isopod diversity and species richness decreased in the long term. There was no treatment in the second year (2013), and so a succession process started in the removal shrubs. Open habitats have a relatively high temperature; thus, they are characterized by low isopod diversity [46, 47]. At high environmental temperatures and positive photoreaction, isopods may leave their habitats [48] because humidity is a limiting key factor in their distribution [21]. Moreover, defoliation reduces the mass of leaf litter, which is an important food source for isopods [49]. Our results demonstrate well that the annual changes in vegetation structure have positively affected isopod diversity and species richness in the short term but not in the long term. Thermal tolerance of isopods is affected by their genetic constitution, ability of acclimatization, and the ambient humidity [42].

The examination of isopod diversity on a regional scale showed different results for annual dynamics. Our hypothesis was confirmed, according to which the highest isopod diversity would be in control shrubs and the lowest in hay meadow because of defoliation. Similarly, Moss and Hassal [50] showed that the isopod community was the most diverse if grassland management had not taken place. According to Paoletti and Hassal [17], isopod diversity decreases because of a combination of direct and indirect effects of management. Comparing the isopod abundance between hay meadows and removal shrubs, there were differences. We found higher isopod abundance in hay meadows formed during the long-term process. Similarly, Ilmarinen and Mikola [10] reported that mowing increased the number of bacterial feeder decomposers. Opposite to this, according to Sankaran and Augustine [51], defoliation can decrease the abundance and activity of soil decomposers in the long term. In removal shrubs formed during the short-term process, isopod abundance was lower compared to hay meadows. On the contrary, Fu and Cheng [52] showed that in the short term defoliation leads to the increasing of the abundance of soil decomposers because of release of carbon-rich compounds. Our results compare well to Grandchamp et al. [38], where species of open habitats were dominant on mown meadows.

4. Conclusion

Consequently, our survey did not find high isopod diversity and species richness in this Nature 2000 area, compared to other habitats, such as highway verges, where we found the highest species richness [53, 54]. In addition to reducing the diversity in the long term, changes in vegetation structure did not alter adequately the composition of isopod communities based on habitat preference. This study demonstrates that grassland managements are important in order to save habitats of several significant arthropod taxa, such as beetles or spiders, but it may not be important for other arthropod groups. Thus, the correct selection of target groups for interventions is worth considering. It is true that isopods are not important arthropods from a nature conservation point of view, but their contribution to ecosystem processes may be significant [55]. Therefore, it is necessary to study the ecology of isopods.

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Investigation of thysanoptera populations in Hungarian greenhouses

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Abstract. Studies were performed on sweet pepper and on weeds in their surroundings from 2005 to 2007 in the Jászság region, on different vegetables and ornamentals from 2015 to 2016 throughout Hungary, and on some indoor ornamental plants in Budapest and Kecskemét in 2017. These studies were carried out in greenhouses. The main objectives of this work was to clarify the consistency of Thysanoptera populations in these greenhouses and, secondly, as part of the official monitoring of *Thrips palmi* Karny and *Thrips setosus* Moulton, the study also focused on the first appearance of these pests in Hungary. An important additional aim was to determine which reservoirs were significant in the risk of Thysanoptera species transmitting tomato spotted wilt virus (TSWV). Regarding the surveys conducted, the most frequent Thysanoptera species present in large numbers during the investigation period in every greenhouse was *Frankliniella occidentalis* Pergande. Also, a significant amount of *Echinothrips americanus* Morgan was found on ornamentals in southern Hungary, whereas on indoor ornamental plants only *Hercinothrips femoralis* O. M. Reuter was found.

Keywords: *Frankliniella occidentalis*, greenhouses, invasive, ornamentals, thrips, vegetables, TSWV transmission

1. Introduction

The abundance of invasive Thysanoptera species in Hungarian agricultural and horticultural crops is significant. These non-native pests can cause significant damage mainly in ornamentals. In the last century, polyphagous greenhouse thrips, such as *Heliothrips haemorrhoidalis* Bouché, *Hercinothrips femoralis* O. M. Reuter, *Parthenothrips dracaenae* Heeger, *Frankliniella occidentalis* Pergande, and *Thrips simplex* Morison (only on *Gladiolus* sp.) were observed in Hungary in high population densities (Ripka 2010). Since most of these species originate from tropical areas, they are not able to overwinter outdoors in Hungary. *Echinothrips americanus* Morgan and *Microcephalothrips abdominalis* D. L. Crawford were observed in Hungary in 2004. Since both thrips species can be present on many ornamentals without the plant showing any sign of damage, they can easily spread with plant material (Vierbergen et al. 2006). None of these two species were found to have significant population densities in Hungary (Jenser 2012). In 2007, in a glasshouse in the town of Érd, the appearance and damage of *Dichromothrips corbetti* Preisner was first reported on *Cattleya* orchid. The pest is native to the Far East and was introduced to Hungary most likely with imported orchids. No further data is available on the occurrence of this species in Hungarian greenhouses (Szénási & Marczika 2011).

The most important Thysanoptera pests of sweet pepper are the invasive western flower thrips (*Frankliniella occidentalis* Pergande) and the cosmopolitan onion thrips (*Thrips tabaci* Lindeman). Among affected vegetables, the most severe damage by *F. occidentalis* appears on sweet pepper, making the yield unmarketable. Furthermore, its hidden lifestyle and resistance to insecticides hinder the efficient protection of these vegetables. The indirect damage of *T. tabaci* and *F. occidentalis* by transmitting tomato spotted wilt virus (TSWV) is even more important than the direct damage in greenhouses. The vectors of TSWV are *F. occidentalis* in greenhouses and *T. tabaci* both under field and greenhouse conditions. The last decades witnessed an increase in the frequency of epidemics caused by the virus, with the most important damage occurring in Hungary in sweet pepper greenhouses (Jenser 1995). The spread of TSWV in Europe has coincided with the spread of *F. occidentalis*. Reservoir weed hosts play a significant role in the spread of TSWV because they can maintain the virus after harvest until the next sowing of sensitive crops (Bos 1981). Furthermore, reservoir weeds can help the development of vector thrips species and thereby the spread of the virus (Bitterlich & MacDonald 1993). Host plants are usually the same for both the virus and the vectors, and this can further aid the maintenance and spread of the virus (Cho et al. 1986).

The main objectives of this work were to clarify the stability of Thysanoptera populations in vegetable and ornamental greenhouses, and, secondly, as this work was part of the official monitoring of *Thrips palmi* Karny and *Thrips setosus* Moulton, we also focused on the first appearance of these invasive species in Hungary. Our additional aim was to determine the reservoirs that are significant in Thysanoptera species transmitting TSWV.

2. Materials and methods

Investigations into sweet pepper and their surroundings in the Jászság region (2005–2007)

Plant samples were collected from green pepper greenhouses with different cultivation techniques in Heves and Jász-Nagykun-Szolnok counties. Weed samples were collected from the surroundings of the greenhouses. A total of 51 greenhouses were tested in Jászfelsőszentgyörgy, Jászfényszaru, Szentlőrinckáta, Nagykáta, Pusztamonostor, Boldog, and Galgahévíz (*Fig. 1*). Farmers used chemical and biological control. There were several pesticide products, including Spintor SC 240, which were compatible with biological control, and, in addition, some of the commercially available natural enemies of thrips, namely *Amblyseius cucumeris* and *Orius laevigatus* from Biobest, were used. There were some greenhouses without any treatment during the investigation period. In the years of 2005–2007, 80% of the peppers were the Keceli variety.

Field studies were performed in the summers of 2005–2007. Greenhouses and their surroundings were sampled 3 times a year, for 2–3 days each, namely: from 21 to 23 June, from 27 to 30 July, and from 29 to 31 August in 2005; from 27 to 29 June, from 31 July to 2 August, and from 4 to 6 September in 2006; from 25 to 27 June, from 24 to 26 July, and from 4 to 5 September in 2007. In each greenhouse, 5 x 10 flower samples from different parts of the greenhouses were collected into plastic vials containing AGA solution (10 units of 60% ethyl-alcohol, 1 unit of glycerine, and 1 unit of glacial acetic acid). From flower samples, only 10–20 specimens of species found in high population and their larvae were mounted on the slide as specified in the standard method (Mound & Kibby 1998).

To investigate the surroundings of the greenhouses, weed samples (300 g/sample) were collected into textile bags at a frequency to represent the environment: plant species composition and their coverage. Weeds were determined to species level according to the diagnostic key of Ujvárosi (1973). From plant samples, arthropods were obtained by shaking the plants over a sheet of white paper. Thrips species were identified to species level. To identify adult thrips, the morphological keys of Jenser (1982) and zur Strassen (2003) were used. Males and females were separately identified only in the case of the TSWV vector species *T. tabaci* and *F. occidentalis*. Regarding Thysanoptera larvae, only the TSWV vectors *T. tabaci* and *F. occidentalis* were identified based on the work of Vierbergen and Nakahara (1998) and Vierbergen et al. (2010). Among larval stages, only the second was considered because microscopic diagnostic methods are not suitable to determine specimens in their first larval stage to species level.

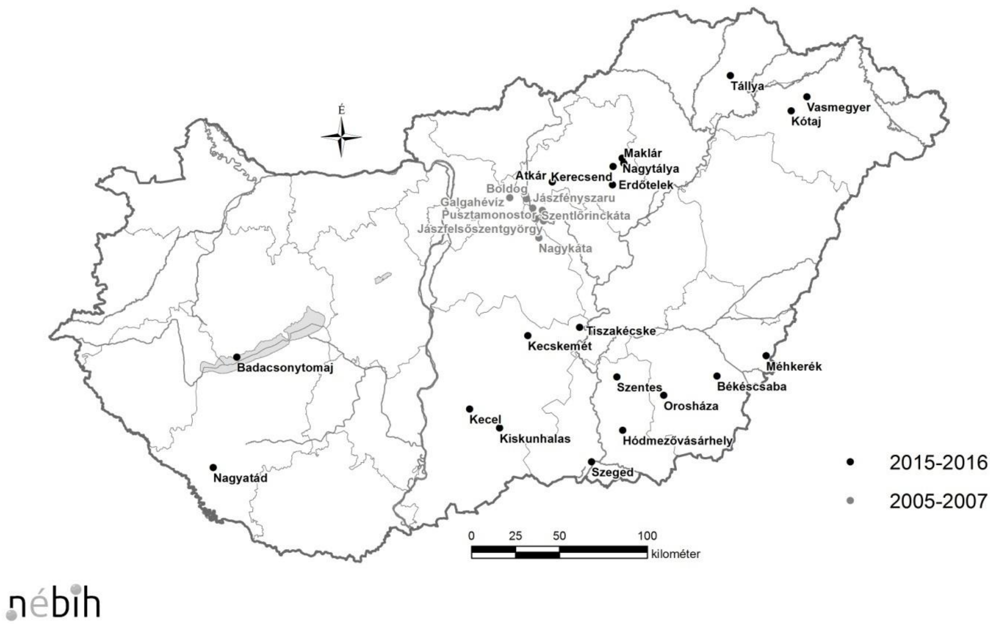

Figure 1. Greenhouse sampling sites, Hungary

Investigations into ornamental and vegetable greenhouses and indoor ornamentals (2015–2017)

Plant samples were collected from a total of 44 ornamental and vegetable greenhouses with different cultivation techniques throughout Hungary in Bács, Békés, Borsod, Csongrád, Heves, Somogy, Szabolcs, and Veszprém counties in the years of 2015–2016 (Fig. 1). The cultivated plants in these greenhouses were the following: Begonia sp., Callistephus chinensis, Capsicum annuum, Caryopteris sp., Chrysanthemum sp., Cucumis melo, Cucumis sativus, Cucurbita pepo, Cyclamen sp., Dianthus caryophyllus, Gerbera sp., Mandevilla sp., Pelargonium sp., Petunia sp., Rosa sp., Solanum lycopersicum, Verbena sp., and Viola tricolor. Almost all the examined greenhouses were well equipped, operated in enclosed spaces, and in the most cases there were nearly no weeds in their surroundings. Growers relied on chemical and biological control methods, and most of them used seedlings imported from countries, including the Netherlands and Germany. Sampling took place in 2015 from June to November two times a month; in 2016, from August to November, also two times a month, and each time a different location was sampled. From ornamental and vegetable plant samples, thrips were obtained by shaking the plants over a sheet of white paper. In each greenhouse, thrips were collected randomly from different parts of the greenhouses, and they were immersed into plastic vials containing AGA solution (10 units of 60% ethyl-alcohol, 1 unit of glycerine, and 1 unit of glacial acetic acid). All sampled thrips specimens were mounted on the slide according to the standard method (Mound & Kibby 1998). Adult thrips were identified using the morphological keys of Jenser (1982) and zur Strassen (2003).

In May and July 2017, the occurrence of and damage by Thysanoptera species were observed in some offices of the National Food Chain Safety Office, Directorate of Plant Protection on certain indoor ornamental plants, including Freesia sp., Iresine herbstii, Podophyllum sp., Impatiens walleriana, Alocasia polly, Orchidea sp., and one specimen of Monstera deliciosa, which arrived from Kecskemét in January. Sampling and identification followed the protocol as described above.

3. Results and discussion

Investigations into sweet pepper and its surroundings in Jászság (*2005–2007*)

In the Jászság region, 12,695 thrips adults were collected in the 51 green pepper greenhouses in the years of 2005 to 2007, from June to August. The most frequent species of the greenhouses were the following: *Frankliniella occidentalis* (4,120 adults), *Thrips tabaci* (3,460 adults), *Frankliniella intonsa* (2,747 adults), *Aeolothrips intermedius* (1,155 adults), and *Thrips atratus* (1,103 adults). The other Thysanoptera species that were found in minimal numbers within the greenhouses were probably looking for alternative food sources inside (tables 1, 2).

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Table 1. Thysanoptera species of sweet pepper greenhouses and their surroundings (Jászság region, 2005–2007)

Thysanoptera species	Number of specimens within the greenhouses	Number of specimens outside the greenhouses	Total number of specimens
Thrips tabaci (Lindeman 1888)	3,460	3,182	6,642
Frankliniella occidentalis (Pergande 1895)	4,120	365	4,485
Frankliniella intonsa (Trybom 1895)	2,747	1,511	4,258
Aeolothrips intermedius (Bagnall 1920)	1,155	880	2,035
Thrips atratus (Haliday 1836)	1,103	866	1,969
Haplothrips aculeatus (Fabricius 1803)	29	262	291
Haplothrips angusticornis (Priesner 1921)	8	103	111
Odontothrips confusus (Priesner 1926)	1	102	103
Taeniothrips spp.	1	75	76
Thrips nigropilosus (Uzel 1895)	25	33	58
Anaphothrips obscurus (Müller 1776)	8	46	54
Aeolothrips melaleucus (Haliday 1852)	3	37	40
Limothrips denticornis (Haliday 1836)	4	31	35
Chirothrips manicatus (Haliday 1836)	4	25	29
Thrips major (Uzel 1895)	4	18	22
Neohydatothrips gracilicornis (Williams 1916)	0	20	20
Thrips angusticeps (Uzel 1895)	4	14	18
Thrips physapus (Linnaeus 1758)	0	18	18
Thrips pillichi (Priesner 1924)	2	13	15
Scolothrips longicornis (Priesner 1926)	2	3	5
Thrips trehernei (Priesner 1927)	0	5	5
Frankliniella tenuicornis (Uzel 1895)	0	3	3
Limothrips angulicornis (Jablonowski 1894)	1	2	3
Thrips incognitus (Priesner 1914)	3	0	3
Aptinothrips rufus (Haliday 1836)	0	2	2
Haplothrips flavicinctus (Karny 1909)	0	2	2
Melanthrips spp.	0	2	2
Thrips dubius (Priesner 1927)	1	1	2
Bolothrips bicolor (Heeger 1852)	0	1	1
Thrips minutissimus (Linnaeus 1758)	0	1	1
Thrips validus (Karny 1910)	0	1	1
Total	12,685	7,624	20,309

Table 2. Thysanoptera species and their relative frequency in sweet pepper greenhouses (Jászság region)

Year 2005 (n =153)	Number of specimens	%
Thrips tabaci	1,871	29.4
Frankliniella occidentalis	1,286	20.2
Frankliniella intonsa	1,080	17
Aeolothrips intermedius	1,043	16.3
Thrips atratus	1,056	16.5
Other thrips species	40	0,6
Total	6,376	100
Year 2006 (n =153)		
Thrips tabaci	962	24
Frankliniella occidentalis	1,808	45
Frankliniella intonsa	1,132	28.4
Aeolothrips intermedius	23	0.7
Thrips atratus	41	1
Other thrips species	38	0.9
Total	4,004	100
Year 2007 (n =153)		
Thrips tabaci	627	27.1
Frankliniella occidentalis	1,026	44.3
Frankliniella intonsa	535	23.1
Aeolothrips intermedius	89	3.8
Thrips atratus	6	0.3
Other thrips species	32	1.4
Total	2,315	100

In 2005, *T. tabaci* was the dominant species with a frequency of 29.4% in the greenhouses. This polyphagous species is assumed to have invaded the greenhouses in large numbers from the weeds in the surroundings. However, in 2006 and 2007, *F. occidentalis* was the dominant pest in the greenhouses, with a relative frequency of 45% and 44.3% resp. This species was also found in weed species in the surroundings of the greenhouses. The number of *F. occidentalis* males in greenhouses is a factor worth monitoring. In 2005, 2006, and 2007, there were found 273, 326, and 189 male specimens resp. The ratio of males to females is approximately equal to the one stated by Lubinkhof and Foster (1977), that is: within a population, the number of females is usually four times higher than that of males. The polyphagous *F. intonsa* had a large number of individuals in the greenhouses during the investigated period. In 2006, its frequency (28.4%) was higher than that of *T. tabaci*. In our study, *F. intonsa* occurred in smaller numbers on the weeds of the surroundings than in the sweet pepper greenhouse. *Thrips atratus*, on the other hand, damages mainly the species of families Caryophyllaceae and Lamiaceae (Jenser 1998). In 2005, this thrips species had an extremely high number of individuals in sweet pepper (16.5%). However, the population collapsed in 2006 (1%), and in 2007 it completely disappeared (0.3%) from the greenhouses. The reason behind this phenomenon is yet to be discovered. In 2005, the predator *A. intermedius* was found settled within the greenhouses in a relatively large number (16.3%) from the weeds in the surrounding environment, and the appearance of this predator species probably also contributed to the decline in the number of phytophagous Thysanoptera species, especially *T. tabaci*, in the population of 2006. However, the following two years witnessed a decrease in the population of *A. intermedius*. In 2006, the relative frequency of this species was 0.7%, whereas in 2007 it was slightly higher, with a value of 3.8%. In 2007, the total number of the most frequent Thysanoptera species declined by 36.5% compared to the year 2005 (*Table 2*).

Our study investigated which weed species *F. occidentalis* occurred on during the vegetation period in the surroundings of the greenhouses (*Table 3*). In 2005–2007, the following weed species played important roles in maintaining colonies of *F. occidentalis* in the surroundings of the studied greenhouses: *Medicago sativa*, *Galinsoga parviflora*, *Convolvulus arvensis*, *Erigeron annuus*, *Trifolium pratense*, *T. repens*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, and *Chenopodium album*. Being the major elements of the plant assemblage of the surroundings of the greenhouses, these species were quite frequent and presented a relatively high coverage during the study – so, they played an important role during the vegetation period. According to literature, *F. occidentalis* does not occur in large numbers in the field on any of the following weed species: *E. annuus*, *T. pratense*, or *A. artemisiifolia*. During the study, *F. occidentalis* was found on these plants in small numbers and with low frequency. Furthermore, no literature mentions the following species as sources of *F. occidentalis* in the fields: *Calystegia sepium*, *Galium verum*, *Lactuca serriola*, and *Lamium amplexicaule*. The ratio of males in the weeds of the surroundings of greenhouses was approximately 50%. *T. tabaci* was found in high numbers within greenhouses and on the plants outside. The onion thrips was present in large numbers in the surroundings of the greenhouses.

This species occurred on almost all investigated weeds except the following: *Cirsium arvense*, *Cichorium inthybus*, and *Crepis rhoeadifolia*. However, these weeds were not frequent during the investigation period. *Convolvulus arvensis*, *Lamium amplexicaule*, *Anthemis arvensis*, and *Trifolium* species, on the other hand, were common during the years of the study and were present with a relatively high coverage, but *T. tabaci* had a relatively low population on these particular weeds. In summary, we found that large numbers of this pest may establish and propagate within the greenhouses from the weed composition of the surroundings. The species number and relative frequency of the polyphagous *F. intonsa* was lower on the examined weeds than those of *T. tabaci*. The most important sources for *F. intonsa* colonization in the study period were *Medicago sativa*, *Convulvulus arvensis*, *Trifolium repens*, *Trifolium pratense*, and *Melilotus officinalis*; and although the thrips was present in relatively high numbers also on *Calystegia sepium*, the weed was not so frequent and had a lower coverage. We found that *F. intonsa* had higher average number of individuals on certain plants as compared to *T. tabaci*. We also observed the presence of *T. atratus*, a polyphagous pest that mainly damages members of families Caryophyllaceae and Lamiaceae (Jenser 1998). *T. atratus* occurred in the highest numbers during the investigation years in the following plants: *Conium maculatum*, *Cytisus nigricans*, *Medicago sativa*, *Sambucus ebulus*, *Galium verum*, *Senecio vulgaris*, *Stellaria media*, and *Taraxacum officinale*. During our survey, *A. intermedius* was found on most plants; however, the most important sources for its establishment are probably the following species: *Melilotus officinalis*, *Medicago sativa*, *Conyza canadensis*, *Conium maculatum*, *Anthemis arvensis*, and *Erigeron annuus*. In 2005, *A. intermedius* adults were found in the vicinity of the greenhouses with a relative frequency of 75%, and the same species also had a high relative frequency (16.5%) within greenhouses that year (*Table 2*). In the following years, the population declined on greenhouse plants. According to Franco et al. (1999), *A. intermedius* is able to reduce the number of phytophagous Thysanoptera species mostly under field conditions, its predator role not being important in the greenhouses mainly because this species cannot complete its development on *F. occidentalis*.

Possibilities of transmitting tomato spotted wilt virus (TSWV) in the Jászság region (2005–2007)

Literature shows that out of the 43 weed species we found in the surroundings of the greenhouses 26 proved to be TSWV reservoir hosts (*Table 3*). During our study, the most important reservoir TSWV host plant was sweet pepper (*Capsicum annuum*) (Hausbeck et al. 1992, Bitterlich & MacDonald 1993). During the summers, TSWV reservoir weed hosts with relatively high frequency and coverage were: *Amaranthus retroflexus*, *Ambrosia artemisiifolia* (Stobbs et al. 1992), *Anthemis arvensis* (Chatzivassiliou et al. 2000), *Chenopodium album* (Cho et al. 1986; Stobbs et al. 1992, Latham and Jones 1997), *Conyza canadensis* (Stobbs et al. 1992), *Convolvulus arvensis* (Stobbs et al. 1992, Mertelik et al. 1996), *Galinsoga parviflora* (Cho et al. 1986, Mertelik et al. 1996), *Lamium amplexicaule* (Stobbs et al. 1992), *Sonchus oleraceus* (Cho et al. 1986, Stobbs et al. 1992, Bitterlich & MacDonald 1993), *Stellaria media* (Cho et al. 1986, Stobbs et al., 1992, Bitterlich & MacDonald 1993, Latham & Jones 1997), and *Trifolium repens* (Stobbs et al. 1992).

In Hungary, *F. occidentalis* and *T. tabaci* both play a special role in the transmission of TSWV in the greenhouses and in the fields resp. (Jenser & Gáborjányi 1998). The TSWV is acquired from reservoir plants by the vector Thysanoptera larvae, and the adults are responsible for its transmission (Sakimura 1960). Based on our study, the most important TSWV weed hosts with high frequency and cover in the surroundings of the greenhouses, on which mass population of *T. tabaci* adults and larvae occurred, are the following: *A. retroflexus*, *A. artemisiifolia*, *A. arvensis*, *C. canadensis*, *C. arvensis*, *G. parviflora*, *L. amplexicaule*, *S. media*, *T. officinale*, and *T. repens*. In the vicinity of the examined greenhouses, *S. media* occurred the whole year (spring, summer, autumn, winter) with a relatively large cover. On this plant, the number of *T. tabaci* larvae was the highest in the summer months (from June to August).

Table 3. Weed species in the surroundings of sweet pepper greenhouses (Jászság region, 2005–2007)

Weed species	TSWV reservoir (+)
Achillea millefolium	-
Amaranthus retloflexus	+
Ambrosia artemisiifolia	+
Anthemis arvensis	-
Artiplex tatarica	-
Calystegia sepium	-
Capsella bursa-pastoris	+
Capsicum annuum	+
Chenopodium album	+
Cichorium inthybus	+
Cirsium arvense	+

Weed species	TSWV reservoir (+)
Conium maculatum	+
Convulvulus arvensis	+
Conyza canadensis	-
Crepis rhoeadifolia	-
Cytisus nigricans	-
Erigeron annuus	-
Galinsoga parviflora	+
Gallium verum	+
Galium aparine	+
Lactuca serriola	+
Lamium amplexicaule	+
Lepidium draba	-
Lotus coeniculatus	-
Matricaria maritima	+
Medicago sativa	-
Melandrium album	-
Melilotus officinalis	+
Raphanus raphanistrum	-
Rumex obsutifolius	+
Sambucus ebulus	-
Senecio vulgaris	+
Sysimbrium sophia	-
Sonchus oleraceus	+
Stellaria media	+
Stenactis annua	-
Taraxacum officinale	+
Thalspi arvense	-
Trifolium pratense	+
Trifolium repens	+
Urtica dioica	+
Vicia villosa	-
Viola oleracea	-

Table 4. Occurrence of *Thrips tabaci* males (Jászság region)

Date of collection	Plant species	Number of specimens
28.07.2005	*Capsicum annuum*	1
30.07.2005	*Erigeron annuus*	2
31.07.2006	*Conyza canadensis*	1
02.08.2006	*Ambrosia artemsiifolia*	1
25.07.2007	*Medicago sativa*	1
26.07.2007	*Conium maculatum*	1
04.09.2007	*Capsicum annuum*	1
05.09.2007	*Galinsoga parviflora*	2

The arrhenotokous populations of *T. tabaci* – in which males are present – are efficient vectors of TSWV, while the thelotokous populations are not able to transmit the virus (Zawirska 1976, Chatzivassiliou et al. 1999). Since the presence of *T. tabaci* males was proven in the vicinity of our investigated greenhouses, we came to the conclusion that in our country *T. tabaci tabaci* populations also transmit TSWV. From June 2005 to September 2007, 10 male specimens were collected in the Jászság region. According to literature, the following plants have not yet been cited as potential hosts of *T. tabaci* males: *Ambrosia artemisiifolia*, *Capsicum. annuum*, *Conium maculatum*, *Conyza canadensis*, and *Erigeron annuus* (*Table 4*). From June 2005 to September 2007, 12 *F. occidentalis* larvae were collected from the following plants: *Amaranthus retroflexus*, *Chenopodium album*, *Gallinsoga parviflora*, and *Medicago sativa* (*Table 5*).

Table 5. Occurrence of *Frankliniella occidentalis* larvae (Jászság region)

Date of collection	Plant species	Number of specimens
28.07.2005	*Medicago sativa*	2
31.07.2006	*Medicago sativa*	3
25.06.2007	*Medicago sativa*	2
25.07.2007	*Medicago sativa*	1
25.07.2007	*Amaranthus retroflexus*	1
04.09.2007	*Chenopodium album*	1
05.09.2007	*Galinsoga parviflora*	2

We concluded that in the vicinity of the sweet pepper greenhouses in the Jászság region the risk of TSWV transmission is quite high since the number of TSWV reservoir host weed species present with large coverage in the surroundings was high. These plants can play a significant role in *T. tabaci* transmitting TSWV to sweet pepper during the vegetation period. This virus overwinters within Stellaria media or within other annual or perennial weeds (*Capsella bursa-pastoris*, *Lamium amplexicaule*, *Convolvulus arvensis*, and *Melilotus officinalis*). Certain TSWV reservoir weeds found present until late October/early November, such as *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Conyza canadensis*, and *Galinsoga parviflora* in our surveys, may play an important role in supplying TSWV to overwintering *T. tabaci* females. The most important TSWV reservoir hosts in the vicinity of the greenhouses are *Stellaria media* and *Galinsoga parviflora* (Zawirska et al. 1983, Mertelik & Mokra, 1996, Jenser et al. 2009). We found that in the vicinity of the greenhouses in the Jászság region there is a high risk of *T. tabaci* transmitting TSWV, as the number of adults and larvae was high, and a wide range of TSWV reservoir weed hosts had high large cover values in the vicinity of the greenhouses. *T. tabaci* males occurred on many weed species; so, *T. tabaci tabaci* populations can also transmit TSWV in Hungary. The frequency of *F. occidentalis* males on weeds in the vicinity of the greenhouses was approximately 50%. F. occidentalis males proved to be more efficient vectors than females within a population (van de Wetering et al. 1998). As *F. occidentalis* is a more efficient vector of TSWV than *T. tabaci* (Wijkamp et al. 1995, Chatzivasiliou et al. 2002) and, taking into account the extremely high number of males in the environment of greenhouses, *F. occidentalis* is safe to say to have a major role in the risk of developing TSWV epidemics in sweet pepper greenhouses. The presence of *T. tabaci* and *F. occidentalis* together poses a high risk for sweet pepper because, after overwintering, *T. tabaci* females can infest the crop in the spring, while the adults of *F. occidentalis* can infest the plants during autumn.

Investigations into different ornamental and vegetable greenhouses and indoor ornamentals (2015–2017)

Throughout Hungary, a total of 3,194 thrips adults were collected in the 44 different greenhouses in the years of 2015 and 2016, from June to November. The most abundant species within all greenhouses, with the highest number of individuals was *Frankliniella occidentalis* (2,330 females, 176 males), with a relative frequency of 78.45% (*Table 6*). It was found in large numbers in all the studied places, but the highest colonies of *F. occidentalis* were found on the following plants: *Callistephus chinensis*, *Capsicum annuum*, *Chrysanthemum sp*., *Dianthus caryophyllus*, and *Gerbera sp*. (*Table 7*). In 2015–2016, the number of *T. tabaci* was extremely low in the greenhouses; its relative frequency was only 1.6%. From the total catch of 51 *T. tabaci*, 31 specimens occurred in one particular sweet pepper greenhouse covered with weeds in its surroundings (23. 06. 2015, Vasmegyer). The remaining 20 *T. tabaci* specimens were found scattered in the other studied areas. The main reason of this situation was probably that almost all the examined greenhouses were well equipped and in most cases there were no weeds in their surroundings, and *T. tabaci* normally invades greenhouses from the environment. The polyphagous *F. intonsa* also had a low number of individuals within the greenhouses, yet the figures were higher than those of *T. tabaci* during the investigated period, with a relative frequency of 11%. From the total of 348 *F. intonsa* captured, 221 specimens were found on *Cucumis melo* (08. 07. 2015, Erdőtelek), and the remaining specimens were found in very low numbers in other studied areas. We believe *F. intonsa* was also unable to invade greenhouses in high numbers from outside for the same reason *T. tabaci* was not. Following the same reasoning, the predator *Aeolothrips intermedius* is also unable to colonize greenhouses from the environment. To support our assumption, a total of only 12 specimens were counted within the greenhouses during the entire study period. The additionally found Thysanoptera species of greenhouses (*Thrips atratus*, *Thrips timidus*, and *Taeniothrips spp*. with 1-1 specimen) were probably only seeking alternative food sources (*Table 6*).

Table 6. Thysanoptera species and their relative frequency in different ornamental and vegetable greenhouses

Years 2015–2016 (n = 44)	Number of specimens	%
Frankliniella occidentalis	2,506	78.45
Frankliniella intonsa	348	11
Echinothrips americanus	274	8.55
Thrips tabaci	51	1.6
Aeolothrips intermedius	12	0.3
Other thrips species	3	0.1
Total	3,194	100

Table 7. Occurrence of *Frankliniella occidentalis* on different ornamental and vegetable greenhouses (Hungary, 2015–2016)

Host plant	Total number of specimens	Total number of samples (n)	Number of specimens/ Sample units
Begonia spp.	102	3	34
Callistephus chinensis	104	1	104
Capsicum annuum	653	7	93
Caryopteris spp.	22	1	22
Chrysanthemum spp.	761	12	64
Cucumis melo	24	3	8
Cucumis sativus	110	1	55
Cucurbita pepo	1	1	1
Cyclamen spp.	24	2	12
Dianthus caryophyllus	122	1	122
Gerbera spp.	242	2	121
Mandevilla spp.	58	1	58
Pelargonium spp.	98	2	49
Petunia sp.	16	1	16
Rosa sp.	9	1	9
Solanum lycopersicum	102	3	34
Verbena spp.	41	1	41
Viola tricolor	17	1	17

Table 8. Occurrence of *Echinothrips americanus* on ornamental greenhouses (Southern Hungary, 2015–2016)

Host plant	Number of specimens	Location	Date of collection
Gerbera spp.	53	Szeged	27.08.2015
Begonia spp.	65	Hódmezővásárhely	27.08.2015
Pelargonium sp.	43	Hódmezővásárhely	27.08.2015
Petunia spp.	10	Hódmezővásárhely	27.08.2015
Verbena spp.	23	Hódmezővásárhely	27.08.2015
Gerbera spp.	45	Szeged	06.10.2016
Callistephus chinensis	35	Hódmezővásárhely	06.10.2016

Table 9. Occurrence of *Hercinothrips femoralis* on indoor ornamentals

Host plant	Number of specimens	Location	Date of collection
Monstera deliciosa	13	Kecskemét	24.01.2017
Freesia spp.	16	Budapest	09.05.2017
Iresine herbstii	18	Budapest	09.05.2017
Podophyllum spp.	23	Budapest	09.05.2017
Impatiens walleriana	11	Budapest	09.05.2017
Alocasia polly	15	Budapest	09.05.2017
Orchidea spp.	8	Budapest	03.07.2017

A relatively high number of *Echinothrips americanus* (274 adults) were found on ornamentals (*Gerbera* sp., *Begonia* sp., *Pelargonium* sp., *Petunia* sp., *Verbena* sp., and *Callistephus chinensis*) in Szeged and Hódmezővásárhely (southern Hungary) (tables 6, 8). Feeding on leaves, the invasive, polyphagous *E. americanus* is known to cause a direct damage to ornamentals in greenhouses. The favourite host families of this species are Araceae and Balsaminaceae. Being a Nearctic species with a native distribution area including the eastern parts of North America, *E. americanus* was first described as a greenhouse pest in the USA in 1984, with *Impatiens* spp. (Oetting 1987) as the most important hosts. It was first recorded in Europe within a tropical glasshouse in England in 1989. In France, the first author collected the species in 1997 on *Hibiscus* spp. The damage caused to infested plants was described as discoloured spots on leaves, a typical symptom caused by the sucking of thrips larvae and adults (Vierbergen 1998). Because of the lack of obvious damage on commonly cultivated hosts, such as *Syngonium* and *Dieffenbachia*, the species spread fast within Europe. The first appearance of *E. americanus* was recorded in 2004 in Hungary in August, when 14 specimens were found on an imported *Dieffenbachia* in Szeged, southern Hungary (Vierbergen et al. 2006). Till now, E. *americanus* has remained somewhat isolated around the original site, Szeged, and although the pest was found in the greenhouses in the neighbouring town of Hódmezővásárhely as well, in 2017, specimens of *Hercinothrips femoralis* were found with signs of their damage on some indoor ornamental plants, such as *Monstera deliciosa*, *Freesia*, *Iresine herbstii*, *Podophyllum*, *Impatiens walleriana*, *Alocasia polly*, and *Orchidea* (*Table 9*). Infested plants had spots of discolouration on their leaves. *H. femoralis*, a polyphagous species is native to tropical areas. In Europe, it damages both greenhouse and indoor ornamentals (zur Strassen 2003). The first appearance of *H.*

femoralis was recorded in 1938 in Hungary. In our country, the damage of *H. femoralis* is known mainly on *Cordyline*, *Dracaena*, *Aspidistra*, *Cyperus alternifolius*, and *Tradescantia virginiana* (Jenser 1988).

During our survey, there were observed no signs of some well-documented polyphagous invasive greenhouse thrips species such as *Helio-thrips haemorrhoidalis*, *Parthenothrips dracaenae*, *Microcephalothrips abdominalis*, *Thrips setosus*, or *Thrips palmi*.

Conclusions

During the study, the most abundant species within all greenhouses, with the highest number of individuals, was *Frankliniella occidentalis*. It was determined which reservoirs were significant in the risk of Thysanoptera species transmitting TSWV. During the official surveys, no signs of *Thrips palmi* and *Thrips setosus* were observed.

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The issues of urban green space in Baia Mare based on tree composition

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Abstract. Harmonious urbanization entails the creation of new green spaces and the rehabilitation of existing ones. Green spaces are not just spaces of psychic well-being but also social interaction sites. Present-day practice in redesign requires taking into consideration the ones using the spaces, in our case, the needs of urban residents, since space needs to have a crucial role in building and maintaining communities. This paper aims at drawing attention to conflicts regarding use mainly due to improper design and use of plant material and, in addition to the importance of green spaces, the need for quality green spaces.

Keywords: urbanization, green spaces, communities, quality green spaces

1. Introduction

The issue of urban green space (UGS) has become more and more common in research and planning as Europe and the United States play a leading role in the research on this topic [1]. This is not by chance as UGS has a great influence on the well-being of urban residents.

Rapid urbanization affects the spatial changes and influences the green spaces and historical spaces; the study and implementation of previous major planning strategies are essential to current planning. Furthermore, the availability of UGS is a crucial indicator of urban complexity, of improving the well-being of the residents, and of developing social and ecological relationships and interactions in towns and cities. The proportion of available surfaces and their quality is important in this process. According to Kabisch et al. [2], more than two-thirds of the inhabitants of Nordic countries and of the Western countries of the EU (Austria, North-West Germany) live less than 500 meters away from green spaces. While Poland, Slovakia, and the Czech Republic show good results in this respect, south-eastern European countries do somewhat worse: in Hungary, Romania, and Bulgaria, only 40% of the population lives up to 500 meters away from green spaces of at least 2 hectares large.

Baia Mare is a municipality located in the north-western part of Romania; it is the county seat of Maramureș. It has nearly 123,800 inhabitants, and it is the 17th largest town in the country based on this number. It is most commonly known as a mining town. Since the closure of the majority of mines, mining towns in developing countries have shown a gradual decline, mainly due to economic reasons: the lack of new investments, the demographic aging of the population, and lack of culture.

Unlike other industrial and mining towns, Baia Mare is in a fortunate position due to its geographical location and spectacular tourist destinations, although the economic development and expansion that is needed has affected the environment, the surrounding nature, and the landscape. Another important distinctive criterion is the result of the existence and maintenance of the local spirit and culture.

It is commonly observed (similar to other locations in the country) that the holiday-type proliferation of buildings has had a disastrous impact on the landscape, which is further exacerbated by the lack of local infrastructure networks. There is a tradition of urban and closed gardens, which are often characterized by chaotic design; there is also a lack of public green spaces, while the existing ones are unprofessionally designed and are less appealing.

Undeveloped lands play an important role in the development of the town's image: there are key areas that count as the town's "green reserves". Building on these areas must be prevented, and there is need for the creation of a green network based on aggregation. The lack of "urban green" results in social and psychological problems; nevertheless, their improper maintenance, the poor and neglected green spaces also lead to the previously mentioned problems.

Objectives

UGS is an indicator of urban quality of life, it quantifies the physical, social, and economic characteristics of urban environments. Its purpose is multifaceted (ecological, functional, aesthetic, settlement-structure-oriented), wherefore it is important to deal with their condition and development.

The role of green spaces was significantly trimmed by the inadequate maintenance of green spaces that were periodically outlined during the development of urban free space by the lack of new, 21st-century uses, functions, and modern objectives of the free spaces designed based on former visions and principles, by the incorrect choice and poor use of plant material as well as the bleak view of smaller social spaces such as the green spaces around residential complexes. In the case of developing countries, there is a need to promote the importance of man-centred existing and newly designed green spaces and the benefits of using a variety of plant species.

Whatever used to work well in 20th-century urban planning (especially regarding the distribution and creation of free spaces), it is likely not to meet present-day needs, sustainable development, and, last but not least, ecological development. During my work, I call attention to the identification of aesthetic and functional conflicts as well as the poorness of vegetation use that characterizes the green spaces of Baia Mare.

2. Materials and methods

The first stage of the research was the identification of research sites: *Fig. 1*. I decided to work with four locations of different categories of use and function; the element these areas share is that they gradually lost their original purpose, their man-centredness, and aesthetic values over time. I study the sites based on their original purpose, their current use (comparing old postcards, photographs, and descriptions with the current use as well as performing on-site observation) together with the analysis of the used plant material. My aim is to draw attention to the direct impact on humans of UGS as well as the importance of quality and man-centred design:

> Citizens contribute to the long-term management of urban green space. The activities and self-organization of citizens are highly dynamic over time. The adaptive capacity of citizen groups is essential in long-term place-keeping. Citizen groups can become institutionalized in order to ensure long-term continuity. Authorities are key in enabling and legitimizing place-keeping by citizens. [3]

The observation of green spaces was conducted between August 1, 2017 and September 15, 2017, during the weekdays and weekends.

3. Results and discussions

The taxonomy of UGS values is more complex: there are ecological, economic values (market value), social values (recreational value: utilization and function, aesthetic value, cultural symbolization value, historical value, therapeutic value, social interaction value, etc.), and the planning values. This value gives the scientific values (education function) and the policy value (financial and public function) [4]. The present study investigates the aesthetic, recreational effects of the research sites, values that affect quality of life, bearing in mind the taxonomical richness of the applied plant material increasing ecological diversity. In determining the quality of green spaces, the diversity of species is an important criterion and so is the proportion of built-up areas and green spaces, for which the highest value should be sought.

Three types of open-air activities are determined: necessary ones (throughout the year, in any circumstances, regardless of the external environment), optional ones (whenever external factors allow it), and social ones (quality environments have a great attraction value; thus, their use is intensive) [5]; at the same time, their distribution in the urban fabric is also important:

> Living in areas with green environments has also been found to be related to health in more general terms: populations exposed to the greenest environments have the lowest levels of health inequality related to income deprivation (Mitchell & Popham, 2008). The resurgent interest in ecologically rich urban green space has resulted in increased numbers of allotment tenants, the creation of community gardens and the active creation of green spaces through 'guerrilla gardening'. [6]

With the rapid development of the 1950s, the surface area of the town has been constantly growing: according to the General Urban Plan (PUG) from 2012 [7], there was a tenfold increase in the population between 1912 and 2002, which was followed by a downward trend. Based on the PUG, Baia Mare's administrative area is 23,262.81 ha, 3,170 ha of which is agricultural area, 18,599 ha is forestry area with mostly forests, while 1,804 ha are built in or have other functions. 76.83% of the periphery is made up of forests. The size of green spaces is close to 100 hectares.

Queen Mary Park | Săsar River
Central Public Park | Traian, Republicii and Gării districts (TRG districts)

Figure 1. Demarcation of research sites

Table 1. Presentation of locations based on usage

Name	Year of creation	Size	Purpose	Current use	Age-group
Queen Mary Park	Mid-19th century	50.350 m^2	urban public park	daily use of sports facilities, the rate of attendance increases in the weekends, when it is used for recreation and leisure	all age-groups
The banks of the Săsar River	the 1970s	45.650m^2	-	due to river regulations, it cannot be used for recreation in its full length	-
Central Public Park	2015	39.496 m^2	urban public park	strong playground orientation, intensive use in the afternoon	mostly parents with young children, senior population
Traian, Republicii and Gării districts	1950–1980	-	residential complex	amateur gardeners or people wanting to work out	senior population

a. Queen Mary Park (*RO: Parcul Regina Maria*)

The quality of town parks affects the frequency and length of visits. The town park contributes to and supports the development of social relations around the town centre [8]. Individual surveys [9], however, have also shown that in addition to the availability of green spaces the state of the park or public space is also important for the visitors. In the case of Baia Mare, we are talking about the oldest green space, the original function of which was to provide a space for entertainment and meeting for the citizens of the town. It is characterized by its functions it had at the end of the 19th and the beginning of the 20th century: it features a pub that was turned into a restaurant, space for dancing, a lake, shady park benches, flower house, shooting range, and then tennis courts, a small railway, playgrounds, newer restaurants, running tracks, and dog tracks. In the 19th century, the Liget ("grove") of Baia Mare was used both by noblemen and ordinary people (with different social status) at the same time [10].

Currently, the city park still has most of the old trees – it is in some way similar to a forest; the site seems functionally overloaded and overcrowded. From a utilization point of view, the playground and the small railway as well as the area around the improvised amusement park are highly popular among families with young children, while teenagers and those who prefer to work out use the northern part of the park, which is closer to the nature and is less structured, which, however, is more difficult or impossible to access during the rainy season and is even potentially dangerous.

b. The banks of the River Săsar

The town's hydrographic network is based on the River Săsar, flowing from east to west. It was a key element in the founding of the town: this is supported by the existence of mills built on the riverfront found in the first military survey. Later on, in the 20th century, the number of mills somewhat decreased, but the baths along the river occupied a growing area, while the different points of the river and the mill races were a cheaper option for bathing.

In the 1970s, the river was regulated throughout the town, and the population had no access to the river. Although sections of higher altitude have green areas (poor use of plants, unattractive), they are used for transit or for dog-walking, and the most important conditioning effect is not stressed.

c. Central Public Park (*RO: Parcul Public Central*)

The newly built public park opened in 2015 is located in the southern part of Baia Mare, somewhat peripheral but near the residential complexes. Its original purpose is to serve as a public park for the strengthening of social ties, resting and recreation, education. The most valuable element of the park is Géza Vida's cactus collection including 6,000 pieces, which extends the attraction of the park. The most important element of the park is the playground. Regardless of the size of the young trees, the park is rather museum-like and sterile. From the point of view of landscape design, plant placement, and use, it is poor; there are less used corners, such as the labyrinth, which is not suitable for public parks. A public park that does not apply a close-to-nature approach is rather a public space.

d. Green spaces of residential complexes

Collective housing in Baia Mare is grouped into the following districts: Traian, Republicii, Gării, Progresului, partly V. Alecsandri and Săsar. Collective housing is built on a total of 257.78 hectares, which is 7.23% of the total urban area. Most of the buildings in the town are P+3-4 floors, the highest ones do not exceed G+9 levels.

> After 1947, as the new Romanian socialist state engaged in large industrialization projects that ranged from enormous steel plants to mass housing estates for the newly urbanized workers, the problem of monotony and anonymity and overall foreignness of these new environments arose from the very start. Industrial work and its products (architecture being one of them) were seen at once as key to socialism, but also as potentially dehumanizing. [11]

The construction of large buildings to house the crowds moving to the town from villages was carried out in several stages in Baia Mare. While in the 1950s the buildings were concentrated around the city centre and were up to 2 floors, starting from the second half of the 60s, the effects of socialism could be felt throughout the nation: the airport, the new railway station, and the bus station were built. The massive and foreign destruction of the traditional image of the small town was carried out from the late 60s to the late 80s. The population of Baia Mare increased considerably during the industrialization period: between the 1966 and the 1977 census, this meant a 150% increase; and the same growth can be seen between 1977 and 1992. Typically, former village dwellers settled down in the town, bringing along their customs and traditions. As a result, the unique use of green spaces in the residential complexes built under the communist regime in Romania resembles that of the village gardens. However, the setting up of vineyards, the planting of fruit trees and vegetables do not bring any benefit to the owners, giving the complexes a decomposed, incoherent image. The rebuilding and transformation of residential complexes due to industrialization, the lack of social activities, and functional segregation entail the need for stimulation.

It is a common practice in Romania, and thus in Baia Mare, that the green spaces around apartment buildings are maintained and beautified by the inhabitants, which has led most frequently to constant bickering and a chaotic scenery (*Fig. 2*.), but to neglect as well, and the few green spaces that would make living in communist residential communities a bit more bearable are a nuisance for public administration itself. Another problem that is present across the country is the issue of the chaotically built garages, which are always located on free surfaces, typically on green spaces. The sight of residential complexes is a sad picture at the moment.

Figure 2. The issue of the use of green spaces in residential complexes. There are extremes, but not scattered, and they are typical of all Romanian towns. (photos by Tamás Hajdu)

“Residents in high-density neighbourhoods differ in two important ways from their lower-density counterparts: they live in much closer proximity to their neighbours and they are more likely to have to share built features and facilities (Easthope & Judd, 2010) such as open spaces and property maintenance services” [12]. It can be observed in the case of several residential complexes that if they have any type of public or even limited public free spaces, the atmosphere is more intimate, more homely, and it helps the inhabitants get to know each other better. At the same time, the spaces in the residential complexes are subject to a more strict supervision and collective responsibility, and that is why they are more protected [13].

3. The issue of plant usage

> The implications for urban greenspace design are considerable. Dramatic displays of flower colour enhance most people’s aesthetic experience in the short term, yet psychological restoration is more likely afforded by “background” green planting. This indicates that green planting has real value outside the relatively narrow flowering window of most species. [14]

Helen Hoyle and her colleagues found that moderate, and a design closer to nature has a more enhanced psychologically strengthening effect than over-designed, less natural spaces. At the same time, it is considered acceptable for the population of the UK to use natural, meadow-like designs, which would enhance the benefits of pollination; however, this kind of planning needs to be developed and promoted. Trees also have an interesting attraction value “[…] the presence of trees has an important impact on public housing residents’ use of outdoor spaces. Trees are an important variable in creating sociopetal outdoor spaces – spaces that attract people to them” [15]; this, however, needs the selection of the suitable species.

Another problem is the decrease of the proportion of decorative plantings occurring in public spaces and parks, including the lack of use of perennial ornamental plants, a practice that significantly depletes the ecologically possible plant selection [16]. In the case of urban green spaces in Baia Mare, but also in other towns in Romania, it can be observed that they prefer to use annual plants, creating a kind of tradition. Unfortunately, annual plants are preferred over perennials.

Table. 2. Tree composition in the examined green areas
(1. Queen Mary Park, 2. The banks of the Săsar river, 3. Central Public Park, 4.TRG districts)

Tree species	1	2	3	4
Abies sp				■
Acer sp.	■	■	■	■
Aesculus sp.	■		■	■
Betula sp.	■		■	■
Carpinus sp.	■			
Castanea sp.	■			
Catalpa sp.	■	■	■	■
Chamaecypari	■			■
Elaeagnus sp.		■		
Fagus sp.	■			
Fraxinus sp.	■	■	■	■
Juglans sp.	■			■
Maclura sp.	■			
Malus sp.	■	■		■
Morus sp.				■
Phellodendron		■		■
Picea sp.	■			■
Pinus sp.	■			■
Platanus sp.			■	
Populus sp.	■	■		■
Prunus sp.	■	■	■	■
Pyrus sp.				■
Quercus sp.	■	■		■
Rhus sp.				■
Robinia sp.	■	■		■
Salix sp.	■	■	■	■
Sorbus sp.				■
Syringa sp.				■
Thuja sp.	■	■	■	■
Tilia sp.	■	■		■
Tsuga sp.	■			
Ulmus sp.				■

The study of the plants in public areas of Baia Mare can be summarized as follows:

- the richness of species in green areas created in the past (in this case in the 19th century) is much higher, although ornamental trees are much easier to find now, and the choice is significantly larger;

- in the case of creating new green spaces, more emphasis is placed on constructed elements, while ornamental plants are secondary and are used only for decorative purposes with requirements of intensive maintenance;
- the residential complexes show a greater richness of species due to their private-garden character (the use of perennials and vegetables); these, however, are chaotically designed;
- the poorness of species results in low stimulation and a monotonous image of the town;
- it would be necessary to introduce new, mainly woody species suitable for urban settings by reforming the existing use of plants.

Solutions

a. Creative city

> Good city-making is about maximizing assets and what is considered an urban asset has broadened dramatically. Urban assets and resources can be: hard, material and tangible, or soft, immaterial and intangible; real and visible, or symbolic and invisible; countable, quantifiable and calculable, or to do with perceptions and images. [17]

Vitality is the energy of the town that is needed to achieve viability. Creativity works as a vitality catalyst. Through lasting, viable, and sustainable innovation, a town's vitality can be helped in the long run. Forms of vitality and viability: economic, social, environmental, and cultural; at the same time – in connection with the previous ones –, there are nine criteria that help a town to be viable from the point of view of creativity: critical mass, diversity, accessibility, safety and security, identity, innovation, cooperation, competitiveness, and organizational skills [18].

Animated cities have spaces that allow for the creation of lively social connections as opposed to cities where the stability of social activities could not be maintained despite brilliant architectural works [19].

Low-stimulus environments are bleak. Sustainability has social aspects (health, well-being), environmental aspects (the protection of biological diversity by improving ecological aspects), and economic considerations (asset value growth) [20].

b. Urban acupuncture and pocket gardens

Since the economic crisis, it has become increasingly difficult to create new spaces or to implement larger-scale plans that would provide a solution to revitalize a district of the town; thus, the role of smaller interventions, which are targeted primarily at public areas, has increased significantly. There is a big difference between various types of projects and problem solving; the smallest ones, such as the planting of trees in an open space, would increase the quality of life of the people in its immediate neighbourhood [21].

According to Jamie Lerner [22], small initiatives and quick interactions can invigorate certain abandoned or neglected parts of the town, make them people-centred and sustainable. These transformations are not only physical: they have psychological and cultural effects as well and can function as incentives for the different age-groups. In every case, the goal is the people-centred approach, and this is especially important regarding the towns that endured communism. Good acupuncture interventions help understand the town, can heal man-made wounds in the landscape, practically trying to find a cure for human errors. Its main aim is to restore the cultural identity of a place or community, to add missing urban functions, to strengthen national identity, and to transfer formal iconic places to contemporary urban life, but it does not necessarily require large structural interventions.

It is important to make public spaces dynamic, to encourage art and the young generation. However, the inclusion of a river or channel into the life of a town, the revitalization of an existing green space or the creation of new green spaces, or even planting trees in the streets can be considered urban acupuncture.

Another possible solution in Baia Mare is the Pocket Park as defined by Francesco Armato:

> Pocket Park, small areas that can make up for the emptiness, abandonment and no function of many spaces that are located within our cities, triggering processes of urban regeneration through the discovery of a new "life" and a new potentiality to accommodate. This must be rediscovered and brought to light so as to realize and perceive a different urban imaginary. [23]

This is a product that primarily plays a social role, strengthens relationships between people, or, depending on the nature of its design, it can emphasize the beneficial effects of nature on people (an oasis that provides the experience of being close to nature or pocket parks functioning as community gardens). The above mentioned park types would be the most ideal solution to the problems encountered in the residential complex in Baia Mare. Promoting correct gardening as recreational and social activity would covertly serve social purposes around apartment buildings. Many seniors choose to garden mainly for this reason and not for the products of cultivation. At the same time, the gardeners of apartment buildings are involved in shaping the street image *c. Promoting and establishing a forest park*

From existing forests, it is practical to create and cultivate areas that are close to natural forests, are diverse, mixed, and have a good traffic connection with the settlement. To this end, the northern part of Baia Mare, which is practically merged with the forest, would provide a perfect basis.

According to some studies, the amount of oxygen needed for daily respiration is produced by 10–20 trees (depending on the species) of grown foliage; if we break down this value to the size of the towns, it is incorrect to state that urban parks and gardens are "the lungs" of the settlement as the regeneration of air happens outside the town, and thus air exchange between the town and the neighbouring areas needs to be endured by the vegetation [24].

4. Conclusion

This work highlights the problems of green spaces of Baia Mare, problems that are not isolated but generally characterize the green spaces of Romania's settlements. As a solution, it is essential to create new open spaces that contribute to the socio-cultural development of green spaces so that it is not seen as a public space decorated with plants but as a public, reassuring, and attractive site. As urban ecosystems are labile and have little self-regulation capacity, social processes determine their development – so, they need proper and continuous regulation.

In Romania, and in Baia Mare too, urban green spaces have "grown up" to a stage where the arbitrary planning of the local government is replaced by a design that accommodates the needs of the population. It is important to utilize the power of green spaces to build human relations as well as a quality design, as "badly designed and badly managed public spaces are often blamed for uncivil behaviour and increased (fear of) crime" [25].

Other open space typologies that have a sociocultural perspective emphasize the potentials of interaction for different parts of society. Spatial typologies that include a more political economic perspective deal predominantly with aspects of ownership and the management of specific open spaces [26]. "In reality, physical form will impact decisively on the socio-economic potential of space, just as the socio-economic context should always inform any design solution adopted" [27].

Small-scale but effective interventions of civil initiatives are needed, but the design and maintenance of town planning and urban green spaces should be sufficiently open and collaborative so that competitive and sustainable green spaces can be created.

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