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First molecular identification of wheat seed gall nematode *Anguina tritici* races parasitized on wheat in Iraq

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Abstract. This study was conducted to identify races of wheat seed gall nematode *Anguina tritici* by using molecular identification for this nematode species parasitized on durum and bread wheat cultivars. Wheat seed galls of both cultivars were collected from two cities, Erbil and Duhok, from the Kurdistan Region and Iraq respectively. DNA was extracted from both nematode isolates (populations), and then PCR reactions were performed with Internal Transcribed Spacer (ITS) region using primers TW81/AB28 with 2 µl of template DNA of *A. tritici* for both nematode isolates on both wheat cultivars. The bands of both amplification products of PCR reactions were visualized in position about 800 bp on agarose gel, which indicates that both isolates of *A. tritici* belong to the same race. On the other hand, no nucleotide differences were observed between the two nematode isolations, as revealed by the sequence alignment of DNA of the internal transcribed spacer (ITS) region and phylogenetic tree, which emphasizes at the same time that both nematode isolates are of the same genetic structure or have the same identity and confirms their belonging to the same nematode race.

Keywords: molecular identification, *Anguina tritici*, races, wheat

1. Introduction

Ear-cockle disease is the oldest disease of wheat (*Triticum* spp.) [1], which was caused by the first recorded plant parasitic nematode in England by John Needham in 1743 – that is, wheat seed gall nematode *Anguina tritici* (Steinbuch, 1799; Filipjev, 1936) [2]. It is one of the major aerial diseases, and it causes sustainable losses in the wheat crop of tropical and sub-tropical countries [3]. It can be found in any place where wheat is grown, and this disease is still common in Eastern Europe and in parts of Africa and Asia [4]. Symptoms of nematode attack can be discerned at the seedling stage, but farmers generally fail to recognize the disease before harvesting and threshing of the plant [5]. Since its first record in Iraq by Rao in 1921 [6], *A. tritici* has remained an important nematode pest in Iraq, occurring in most wheat-growing areas, with a disease incidence from 22.9% up to 45% on the mexipac cv. of wheat [4]. *A. tritici* caused reduction in the wheat yield, reaching 57% in mexipak cv. [7], which increased to 75% on the same cultivar in Duhok Province in 1989 [8]. Ami et al. [9] reported that the percentage of infestation by galls reached its maximum value (50%) in bread wheat in Bashika, northern Iraq. Ear-cockle disease reduces the human consumption and market price of wheat [10], with significant reduction in the protein and gluten contents of the flour product of infested wheat with seed galls [11]. During the survey in Duhok Province in 2010–2011, it was shown that *A. tritici* was still one of the major problems in this region, reaching 50% in some wheat fields [12].

It is obvious from the previous studies that there are three races of *A. tritici* isolated from wheat plants that could not infect barley plants [11, 12, 13]. So, it was considered that there is another race on barely. Stephan et al. [14] stated that galls from durum wheat cultivars attacked only durum cultivars and from bread wheat infected only bread wheat to show the existence of durum wheat race and bread wheat race. In addition, another race of *A. tritici* was collected in 1998 and recorded for the first time by Stephan et al. [15] based on the differences of their obvious effects on wheat plants such as spike number and seed production. On the other hand, Taher [12] found that the *A. tritici* population from bread wheat has the ability to infect many durum cultivars. Therefore, this study aimed to clarify if there is any variation or similarity in the genetic structure of both populations of wheat seed gall nematode *A. tritici* parasitized on durum and bread wheat to verify – by using molecular identification technique – whether they belong to the same race or to two different races.

2. Materials and methods

A. Nematode samples

Two isolates (populations) of wheat galls were collected, involving galls of durum wheat from the Erbil silo in Erbil Province and galls of bread wheat from the Faydiyi silo in Duhok Province. These two different isolates were used as a source of *A. tritici* for nematode DNA extraction.

B. The extraction and purification of deoxyribonucleic acid (DNA)

DNA were extracted from several 2^{nd}-stage juveniles (*Fig. 1*) for each nematode isolate from Erbil and Duhok provinces, using worm Lysis buffer (WLB), which consisted of 10 mM Tris pH 8.2, 50 mM KCl, 0.45% Tween 20, 2.5 mM MgCl2, 0.05% gelatine, and 60 µg/ml Proteinase K. Nematode juveniles were crushed on the clean slide with 10 µl WLB under binocular microscopes and then transferred to a new PCR tube on ice with an extra 10 µl of WLB. The samples were frozen at -80 °C for 10 minutes, and then samples were warmed up to room temperature, after which incubated in water bath at 60 °C for 1 h and followed by a 95 °C incubation for 10 min to completely lyse the cells, digest the proteins, and inactivate proteinase K. Subsequently, the tube was cooled on ice and centrifuged at 6,000 rpm for 30 sec. [16]. The supernatant material containing the DNA was gathered and stored at -20 °C or directly used for PCR.

C. The amplification of target nucleic acid DNA

Two primers were used for the amplification of the ITS-rRNA gene, which were TW81 (5'-GTTTCCGTAGGTGAACCTGC-3') and AB28 (5'-ATATGCTTAAGTTCAGCGGGT-3') for both nematode populations. The amplification was performed in 25 µl reactions containing 12.5 µl Red MyTaq™ (Mix Master Mix), 1µl of each primer, and the 2 µl of DNA template with 8.5 µl of a double distilled water to obtain a final volume of 25 µl. The conditions of the PCR reaction were 95 °C for 4 min, followed by 35 cycles of 95 °C for 40 sec, 56.5°C for 40 sec, 72°C for 1 min, and a final extension of 72 °C for 10 min [17]. The amplified products and a phiX174 DNA / HaeIII marker were separated on a 1% agarose gel stained with Gel Red in 1 × TAE and then examined under UV light.

D. DNA sequencing

This process was performed in the laboratories of My TACG Bioscience Genomics BioSci and Tech Company in Malaysia, where samples of amplified

DNA products for both nematode isolations were sent to determine the order of the four nitrogenous bases, including: Adenine (A), Guanine (G), Cytosine (C), and Thymine (T) in a strand of DNA. The BioEdit program was used for alignment and a sequence scanner to check the sequence quality before the alignment (http://www.mbio.ncsu.edu/bioedit/bioedit.html).

After the submission sequences of *A. tritici* for both nematode isolates to GenBank in NCBI, the accession number was determined, which was for the Erbil isolate KT900694 while for the Duhok isolate KT900693.

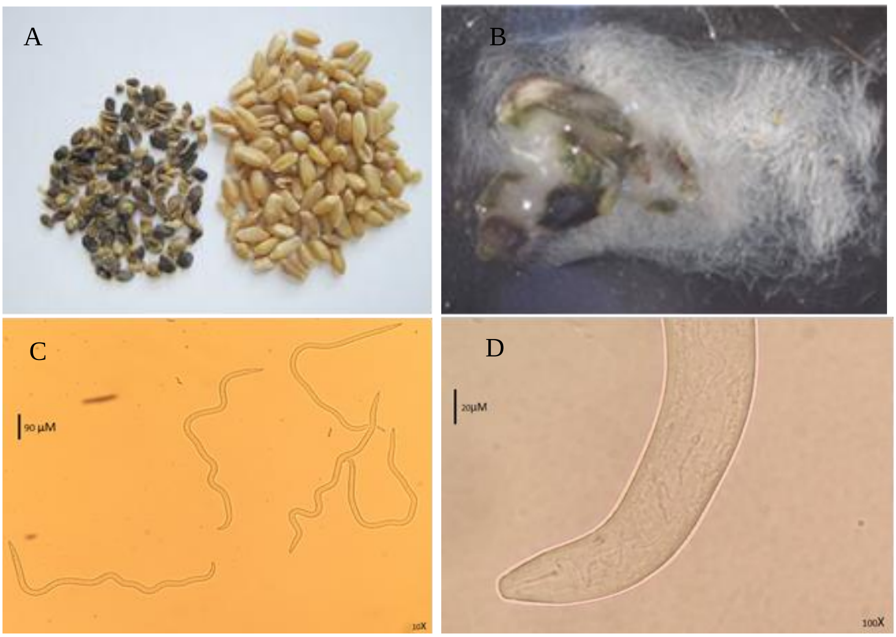

Figure 1. Healthy wheat seeds and galls (A), exiting of second-stage juveniles (J2) of *A. tritici* after opening the gall (B), free J2 of *A. tritici* (C), and anterior portion of J2 show stylet and esophagus (D)

E. Extraction of phylogenic tree

Phylogenic tree was extracted applying the NCBI BLAST program (https://www.ncbi.nlm.nih.gov/BLAST/) by which all nematode species that have the required percentage of genetic similarity with the studied nematode *A. tritici* can be obtained, and it is worth mentioning that those nematodes are in themselves species of the same genus or the same family, and by choosing some of them phylogenic tree was extracted.

3. Results and discussions

DNA sequencing of the Internal Transcribed Spacer ITS PCR-amplified product revealed a size of 800 bp among both isolates of wheat seed gall nematodes *A. tritici* from Erbil and Duhok provinces.

Fig. 2 illustrates the typical amplification products of PCR reactions with primers TW81/AB28, using 2 µl of template DNA of *A. tritici* for both isolates of Erbil and Duhok provinces. The bands of both amplification products of PCR reactions were visualized in position at about 800 bp on agarose gel, which indicates that both isolates of *A. tritici* from Erbil and Duhok provinces belong to the same race because they have the same size of bp. and genotype.

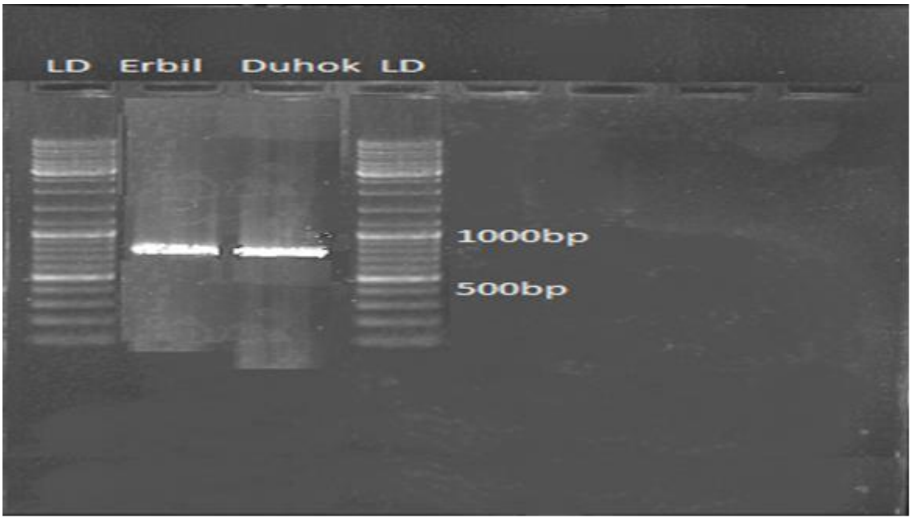

Figure 2. Agarose gel shows typical amplification products of PCR reactions with primers TW81/AB28, using 5 µl of template DNA of *Anguina tritici* of both isolates AE and AD from Erbil and Duhok provinces respectively.

On the other hand, no nucleotide differences were observed between either of the isolations by comparing the DNA sequence alignment of the internal transcribed spacer (ITS) region for both nematode isolates, as clarified in *Fig. 3* and *Fig. 4*. Their genetic similarity analysis, as illustrated by the phylogenetic tree (*Fig. 5*), revealed that both nematode isolates are of the same genetic structure or have the same identity, which also confirms their belonging to the same nematode race.

Score	Expect	Identities	Gaps	Strand
1338 bits(724)	0.0	724 / 724 (100%)	0/724(0%)	Plus / Plus

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Sbjct 1    ACCTGCTGCCGGATCATTACCGATCAACCTGAAAACTAGGGGGAGGACCTGGCTGGACCT  60
Query 61   CCTCTGTAGAATGACGACTTCTTCATTCCTACAGCCAATAGCTCAAGAGGGTGCCGTGAT  120
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Query 121  ATTGGCATGCTGCTTACAGGTGACGTCCCCACCGACTAGCAGGCTTATTCTTGGGCGAAA  180
Sbjct 121  ATTGGCATGCTGCTTACAGGTGACGTCCCCACCGACTAGCAGGCTTATTCTTGGGCGAAA  180
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Sbjct 181  AACGGCTTAGTTGGCTTCTAAGTTTCTCTGAGCAGTTGTATGCCTACGTCCGTGGCTGCG  240
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Sbjct 301  GCCGCCAACAAAACAACCATTTTTGAACTTTTTGAGAAATAACATTTCTAGTCTTACCGG  360
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Sbjct 361  TGGATCACTCGGTTCATAGATCGATGAAGAACGCAGCCAACTGCGATATATGGTGTGAAC  420
Query 421  TGCAGATATTTTGAACACCAAGAATTCGAATGCACATTGCGCCACTGGATATTTATCCTT  480
Sbjct 421  TGCAGATATTTTGAACACCAAGAATTCGAATGCACATTGCGCCACTGGATATTTATCCTT  480
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Sbjct 481  TGGCACATCTGGCTCAGGGTCGTAAACACTAAACGAAAGCTATTCGTTGTTTATGACAGA  540
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Sbjct 661  ATGGCTGTACCACATCGATTACATGTAGGCATGGATCTTCCGACCTGAGCTCAGGTGTGA  720
Query 721  TCAC  724
Sbjct 721  TCAC  724
```

Figure 3. Anguina tritici isolate AE Internal Transcribed Spacer1, Partial Sequence; 5.8S Ribosomal RNA gene, Complete Sequence; and Internal Transcribed Spacer 2, partial sequence. Sequence ID: KT900694.1; Length: 724; Number of Matches: 1

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Score            Expect    Identities          Gaps          Strand
1338 bits(724)   0.0       724 / 724 (100%)    0/724(0%)     Plus / Plus
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Sbjct 661  ATGGCTGTACCACATCGATTACATGTAGGCATGGATCTTCCGACCTGAGCTCAGGTGTGA   720
Query 721  TCAC  724
Sbjct 721  TCAC  724
```

Figure 4. *Anguina tritici* isolate AD Internal Transcribed Spacer1, Partial Sequence; 5.8S Ribosomal RNA gene, Complete Sequence; and Internal Transcribed Spacer 2, Partial Sequence. Sequence ID: KT900693.1; Length: 724; Number of Matches: 1

Phylogenetic tree (*Fig. 5*) was extracted to determine the amount of genetic change per time unit between both nematode isolates and some other isolates and species of *Anguina* as well as some nematode species belonging to the family Anguinidae such as stem and bulb nematodes *Ditylenchus* since they belong to the same ancestors.

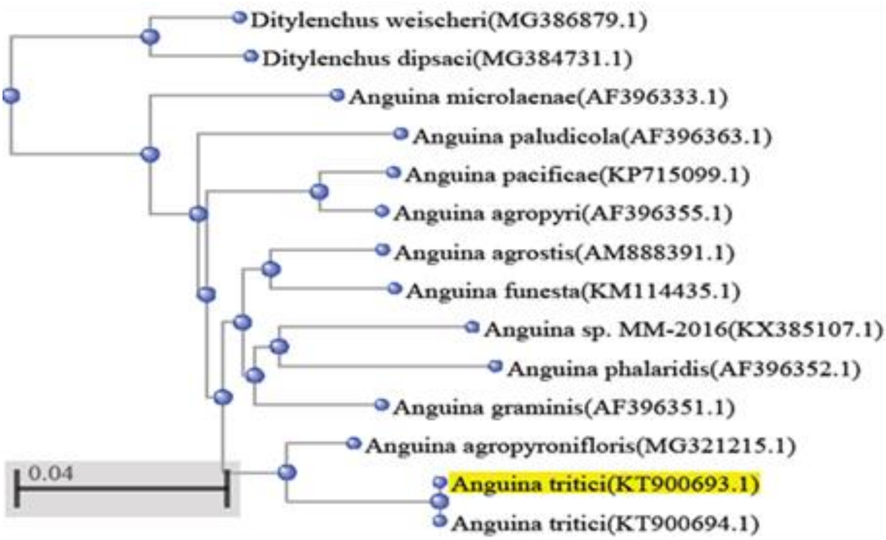

Figure 5. Best Maximum Likelihood Phylogenetic tree based on rDNA ITS sequences within isolates and some species of *Anguina* and two species of *Ditylenchus*. Branch lengths are proportional to the number of inferred changes.

The horizontal lines or branches in this tree represent an evolutionary pedigree that changes over time: the longest the branch in the horizontal dimension, the largest the amount of alteration. The scale bar at the base of the figure displays a scale for this. In this case, the line segment with the number 0.04 shows the length of branch that represents an amount of genetic alteration by 0.04. The units of branch length are nucleotide substitutions per site, which is the number of changes or substitutions divided by the sequence length. The vertical lines are used to lay out the tree visual, and therefore they simply show the connection of horizontal lines with each other and for how long they are unpertinent.

It seems from the phylogenetic tree that the closest species to both nematode isolates is *A. agropyroniflori* with a genetic similarity of 95%, while nucleotide differences increased with other nematode species where more nucleotide differences were observed with *D. dipsaci*, in which the genetic similarity between both isolates and this species reached 86% (*Table 1*).

Table 1. Genetic similarity percentage of isolates AE and AD of wheat seed gall nematode *A. tritici*, which have the accession numbers of KT900694 and KT900693, respectively, with some other nematode species composition [%] of the selected essential oils [13]

Nematode species	Accession number or sequence ID	Genetic similarity percentage with both isolates of *A. tritici*
A. agropyronifloris	MG321215	95
A. agrostis	AM888391	92
A. pacificae	KP715099	91
A. funesta	KM114435	91
A. obesa	KX385107	91
A. graminis	AF396351	92
A. agropyri	AF396355	91
A. phalaridis	AF396352	90
A. paludicola	AF396363	90
A. microlaenae	AF396333	90
Ditylenchus weischeri	MG386879	87
D. dipsaci	MG384731	86

This results clarified that all research related to wheat seed gall nematode *A. tritici* on wheat in Iraq which considered that both durum wheat isolate and bread wheat isolate of that nematode to be different races are not really accurate. Both isolates are the same, but the infection of durum or bread wheat by this nematode is due to the susceptibility of wheat cultivars, environmental circumstances, planting date, the application of both pesticides and herbicides by farmers, and the agricultural processes that one way or another affect the pathogenicity of *A. tritici* [11, 12].

Taher [12] rejected the idea that nematodes isolated from bread wheat invaded only bread wheat cultivars and those from durum wheat attacked only durum wheat cultivars. Thus, several races had been recorded by Stephan et al. [14] in addition to another new race of *A. tritici*, collected in 1998 and recorded for the first time by Stephan et al. [15] based on differences in their pathogenicity on wheat plants such as spike number and seed production.

These three races mentioned by previous studies do not resemble the J_2 population – used in the experiment carried out by Taher [12] – regarding its behaviour of infection, and this might indicate new races of *A. tritici* which have ability to infect different cultivars of durum and bread wheat but incapable of infecting barley cultivars. This result was obtained by Mustafa [11], who reported that *A. tritici* isolated from wheat plants could not parasite on barley plants. Al-Talib et al. [13] recorded a new race of barely plant named barley race. It is clear that there are two races of wheat and barley, but this molecular study emphasized for the first time that both nematode isolates from durum and bread wheat have the same genetic characteristics depending on the amplification products of PCR reactions. Therefore, we can say that *A. tritici* consists of two races, including wheat and barley races, while the pathogenicity of wheat race varies by different cultivars of wheat as well as the infection behaviour and severity may change in different regions and under different environmental circumstances. Also, we recommend the implementation of further molecular studies on different populations for the further clarification of these nematode races in Iraq. According to this result, *A. tritici* on durum and bread wheat belong to the same race or one race, which means that there are two races of *A. tritici* in Iraq: one on wheat and the other one on barley.

4. Conclusions

Molecular identification of wheat seed gall nematode *Anguina tritici* parasitized on durum and bread wheat cultivars which were collected from two cities, Erbil and Duhok, from the Kurdistan Region and Iraq, respectively, emphasized that both nematode isolates are of the same genetic structure or have the same identity and confirmed their belonging to the same nematode race.

References

[1] Bhatti, S., Dahiya, R. S., Dhawan, S. C. (1978), New record of tundu and ear-cockle incidence in barley. *Nematol*., 331–332.

[2] Perry, R. N., Moens, M. (2006), *Plant nematology*. British Library, London, UK: CAB International.

[3] Kort, J. (1972), Nematode diseases of cereals of temperate climates. In: J. M. Webster (ed.), *Economic Nematology*, 97–126.

[4] Al-Beldawi, A. S., Stephan, Z. A., Alwan, H. (1974), General survey of wheat gall disease in Iraq. *Iraq Agric. Bull.* 29, 48–69.

[5] Khan, M. R., Athar, M. (1996), Response of wheat cultivars to different inoculum levels of *Anguina tritici*. *Nematol. Medit*. 24, 269–272.

[6] Rao, R. S. R. (1921), A preliminary list of insect pest of Iraq. Dept. of Agric. Iraq, *Bull*. 7.

[7] Fattah, F. A. (1988), Effect of methods on incidence of ear-cockle and tundu on wheat under field conditions. *Plant and soil* 109, 195–198.

[8] Stephan, Z. A., Antoon, B. G. (1990), Biotypes of earcockle nematode *Anguina tritici* in Iraq. *Current Nematology* 1, 85–8.

[9] Ami, S. N., Mohammad, H. Y., Younis, S. A. (2004), Study on ear-cockle disease in some regions of Nineveh province – North of Iraq. *Iraqi J. for Agric. Sci*. 5, 95–100.

[10] Paruthi, I. J., Bhatti, D. S. (1988), Effect on consumption and marketing of wheat contaminated with seed gall of *Anguina tritici in Haryana. Agric. Uni. J. of Res*. 18, 173–176.

[11] Mustafa, S. A. (2009), Study on wheat and barley ear-cockle disease caused by nematode *Anguina tritici* in Erbil province. M.Sc. thesis, College of Agriculture, University of Salahaddin-Erbil.

[12] Taher, I. E. (2012), Pathogenicity, biology and control of wheat seed gall nematode *Anguina tritici*. M.Sc. thesis, College of Agriculture, University of Duhok, Duhok, Kurdistan Region, Iraq.

[13] Al-Talib, N. Y., Al-Taae, A. K. M., Nimer, S. M., Stephan, Z. A., Al-Beldawi, A. S. (1986), New record of *Anguina tritici* on barley from *Iraq. Int. Nemat. Net. Newsl*. 3, 25–27.

[14] Stephan, Z. A., Hammadi, A. I., Antoon, B. G. (1991), Races of ear-cockle nematode *Anguina tritici* in Iraq. Dept., State Board of Agric. Res. and Educ., Abu-Ghraib, Baghdad, Iraq. *Basrah J. of Agric. Sci.* 4, 1–2.

[15] Stephan, Z. A., Hassan, M. S., Hammadi, A. I., Antoon, B. G. (2000), New race of wheat gall nematode *Anguina tritici* and susceptibility of some cultivars to this race. *Iraqi J. of Agric*. 5, 1–5.

[16] Waeyenberge, L., Ryss, A., Moens, M., Pinochet, J., Vrain, T. C. (2000), Molecular characterization of 18 *Pratylenchus* species using rDNA restriction fragment length polymorphism. *Nematol*. 2, 135–142.

[17] Michel, L., Sikora, R. A. (2005), Plant parasitic nematodes in subtropical and tropical agriculture. 2nd Edition. CABI Bioscience, Egham, UK.

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Assessment of bio-agent (*Trichoderma Harzianum*) in the management of two pepper varieties infected with root-knot nematode (*Meloidogyne Incognita*)

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Abstract. Two field trials were carried out at the Teaching and Research Farm of the University of Ilorin in the 2012 and 2014 planting seasons to find out the effeciency of *Trichoderma harzianum* as a bio-control agent in controlling root-knot nematode (*Meloidogyne incognita*) in two pepper varieties (F1 Nikita and Gianfranco Fuscello). A 2×2 factorial design fitted into a randomized complete block design (RCBD) was used with 5 replications. The *T. harzianum* filtrate significantly increased plant height, number of leaves, and yield. The control showed higher root galling and soil nematode population. Varietal differences showed that F1 Nikita performed significantly better than G. Fuscello. The combination of *Trichoderma* and F1 Nikita appears effective for managing root-knot nematodes.

Keywords: F1 Nikita, Gianfranco Fuscello, bio-pesticides, nematology, susceptible, tolerant

Introduction

Pepper, *capsicum*, is one of the genus from flowering plants in the nightshade family, Solanaceae. Its species originated from the Americans. Some species of *capsicum* are used as spices, medicines, or vegetables. Depending on the place and type, the fruits of *capsicum* plants have a variety of names. They are often referred to as hot chilli pepper, or sweet pepper in Britain, red or green pepper and just *capsicum* in Australia, India, and New Zealand. Pepper is the world's second most important vegetable, ranking after tomato. Pepper is an essential agricultural product not because of its economic importance alone but also due to its medicinal and nutritional value; it is also a very good natural source of colour and antioxidants [1]. It is the most cultivated type of flavouring spice and food colouring, and it provides essential vitamins and minerals [2]. Both hot and sweet pepper contain larger amounts of vitamin C to prevent cold than any other vegetable [3]. Pepper is also used in the production of cosmetics, condiments, and medicine and functions as ornamental in gardens [4].

There are different pests and diseases which attack sweet pepper. The pests include aphids, cutworms, flea beetles, and hornworms, while the diseases are rot, blossom, anthracnose, tobacco mosaic virus, bacterial spot, mildew, and nematode diseases [5].

Root-knot nematodes are insidious, reduce yield and are silent enemies of most food, horticultural, vegetable, and fibre crops [6]. Indirect damages from nematodes of crop plants include their role in the plant disease complex by making plant roots more susceptible to secondary infection by fungi and bacteria and their role as vectors of many viruses [7], [8].

Nematode management is a practice of maintaining plant parasitic nematode below the economic threshold level, using chemical and non-chemical methods. The chemical method has been primarily used as the standard to achieve nematode control, but its hazardous and adverse effects on man and his biotic environment, phytotoxicity in plants, contaminations of water, and other forms of pollution have stimulated great interest in the search for alternative management methods.

Bio-pesticides possess a spectrum of properties from pesticidal to antimicrobial activities against pathogens. They are cheaper and more benign. In recent times, the use of bio-pesticides of microbial origin has been fast gaining ground in addressing the challenges posed by plant parasitic nematodes. *Trichoderma* species are fungi residing in almost all agricultural soils and are said to have more beneficial qualities. *T. virens* have been employed in the protection of cotton seedlings *Phythium ultinum* [9]. The metabolites secreted by some *Trichoderma* species exhibit fungistatic effects on the growth of *Ceratocytis paradoxa* [10]. There is a dearth of information on the bio-activity of *Trichoderma* against root-knot nematode infecting pepper.

Hence, the objectives of this study were to investigate the efficacy of *Trichoderma harzianum* against root-knot nematode, determine the effect of treatment on the growth and yield of the two pepper varieties, and evaluate the resistance or susceptibility of the crop to root-knot nematode.

Materials and methods

The experimental trial was performed at the University of Ilorin, Teaching and Research Farm in the 2012 and 2014 planting seasons.

Sources of root-knot nematode

The root-knot nematode was obtained from heavily galled roots of *Celosia argentea* collected from the Lao area of Airport Road, Ilorin. The root-knot nematode had been previously identified at the International Institute of Tropical Agriculture (IITA) as *Meloidogyne incognita* Race 2. The roots weighing about 100 kg were carefully washed to remove soil particles and cut into pieces with knife before incorporating evenly into the experimental field of 100 × $4m^2$ size. There was a two-metre alley between the two main plots.

Sources of sweet pepper and Trichoderma harzianum

The hybrid seeds were obtained at an agro-shop located at Mokola, Ibadan. Culture of filtrate *T. harzianum* was obtained at the Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo State, Nigeria. Thirty millilitres (30 ml) of *T. harzianum* was mixed with 15 litres of water and applied to the treated plots one week after the transplanting of seedlings.

Raising of nursery

Pepper seeds were planted at a depth of about 1.5 cm in nursery trays. Germination took place between 6 and 10 days. Seedlings were ready for transplanting at three weeks after planting.

Soil nematode sampling and identification

Twenty soil samples were randomly collected in a zig-zig pattern from each plot for initial soil nematode population and identification. Using the method of extraction as described by [11], the nematodes were extracted and counted, and identification was confirmed at the International Institute of Tropical Agriculture (IITA) in Ibadan.

Field layout and transplanting of pepper seedlings

The sandy loam experimental field was ploughed, harrowed, and formed into ridges. The field was divided into two main plots, each measuring 50 × 4 m (200 m^2). While one plot served as the control plot, the other served as the treated plot. Each main plot was divided into five blocks, and a block consisted of subplots, each containing 5 ridges with 0.5 spacing between the ridges. The chopped galled roots of Celosia argentea were incorporated equally into the two main plots to increase the initial soil nematode population in the soil. The experimental design was a 2 × 2 factorial design fitted into a randomized complete block design model (RCBD) and replicated five times. Pre-emergence herbicides (Paraquat and Glyphosate) were applied to the experimental plots one week before transplanting. After the transplanting of seedlings, subsequent weeding at three weeks and six weeks was done manually.

Data collection

The recorded parameters were plant height, number of leaves and fruits per plant, root gall index, and initial and final soil nematode population.

Data analysis

All numerical data obtained were subjected to analysis of variance, and means were separated using Duncan's multiple range test (DMRT) at $p = 0.5$

Results and discussion

Following the similar trends observed in the two years' trials, the results were pooled together. The statistical analysis revealed that all the *Trichoderma*-treated plants performed significantly higher ($p = 0.5$) than the control plants with respect to growth (height and number of leaves) and yield (number of fruits) as well as reduction of root galls and soil nematode population (tables 1–3). Though both varieties were susceptible to root-knot nematode infection, there were significant differences between them, especially in yield. F1 Nikita performed significantly higher than *G.* Fuscello in all the parameters measured. F1 Nikita in the presence of *Trichoderma harzianum* showed higher tolerance to nematode infection.

The findings in the present study have revealed the antagonistic and suppressive ability of the fungus against root-knot nematode by disabling them from multiplication that otherwise would have reduced yield as was evident in the control plot. Bio-control agents have been reported to improve the health of plants due to the control of seedling diseases [12] and thus contribute to overall productivity. They also exhibit self-propagation under unfavourable conditions and may thus remain in the soil for long [13]. Many findings suggest that *Trichoderma harzianum* strains strongly affect plant development and biochemistry. They have been reported to increase plant nutrient uptake and fertilizer utilization [14] to grow more quickly and improve plants' greenness, which may result in higher synthetic rates. [15] reported *Trichoderma* species to play a significant role as plant-promoting microorganism. It had also been reported that *Trichoderma* species found in close contact with roots contributed to plant growth [14]. However, it is still not confirmed if the benefits derived from *Trichoderma* occur because they directly attack and control disease-causing nematode or because they have direct effect upon plants. [6] reported inhibitions in most fungal plant pathogens by substances produced by *Trichoderma* spp. and suggested that controlling other soil-borne pathogenic fungi *Trichoderma harzianum* will further provide a better, enabling environment where plants will develop more vigorously without being suppressed by other microorganisms, which would otherwise affect or make it vulnerable to secondary infections pioneered by plant-parasitic nematodes. The study further revealed that, though the two pepper varieties were susceptible to root-knot nematode infection, varietal differences played a significant role in their performance. From the results obtained, F1 Nikita expressed its superiority in yield and nematode tolerance over G. Fuscello under *Trichoderma harzianum* treatment. The combination of F1 Nikita and *T. harzianum* in a nematode-infested field is therefore desirable.

Conclusions

Trichoderma harzianum proved effective and could be employed as a bio-agent against root-knot nematode. Increasing the naturally existing *T. harzianum* would be beneficial to farmers. Plant pathologists should isolate these organisms and culture them for farmers' use. Hybrid pepper variety F1 Nikita should be released to pepper farmers, especially those in zones that are endemic to nematodes.

Table 1. Effect of *T. harzianum* on the plant height of two sweet pepper varieties inoculated with root-knot nematode

Treatment	**5WAP***	**6WAP**	**7WAP**	**8WAP**	**9WAP**
F1 Nikita (Trichoderma)	9.1a	9.7a	10.1a	10.1a	10.7a
F1 Nikita (No Trichoderma)	3.1c	3.5c	4.6c	5.9c	6.2c
G. fuscello (Trichoderma)	4.9b	5.3b	6.5b	6.9b	7.1b
G. fuscello (No Trichoderma)	3.3c	3.6c	4.1c	5.5c	5.6c
SED	0.24	0.26	0.45	0.38	0.35
Level of significance	S	S	S	S	S

WAP* – weeks after planting

Means within the same column followed by the same letter(s) do not differ significantly at p = 0.5 according to Duncan's multiple range test.

Table 2. Effect of *T. harzianum* on the number of leaves of two sweet pepper varieties inoculated with root-knot nematode

Treatment	5WAP*	6WAP	7WAP	8WAP	9WAP
F1 Nikita (Trichoderma)	15.6a	16.8a	18.4a	19.8a	20.6a
F1 Nikita (No Trichoderma)	5.0c	6.0c	8.6c	10.0c	10.7c
G. fuscello (Trichoderma)	8.2b	10.0b	11.6b	12.8b	14.0b
G. fuscello (No Trichoderma)	4.4c	5.2c	7.2c	7.6d	8.0d
SED	0.42	0.66	0.75	0.52	0.55
Level of significance	S	S	S	S	S

WAP* – weeks after planting

Means within the same column followed by the same letter(s) do not differ significantly at p = 0.5 according to Duncan's multiple range test.

Table 3. Effect of *T. harzianum* on the mean number of fruits per plant, root gall index, and soil nematode populations

Treatment	Mean fruit no/plant	Root gall index	Soil nematode population	
			Initial	Final
F1 Nikita (Trichoderma)	26.0a	0.98a	155b	53.0a
F1 Nikita (No Trichoderma)	19.8b	2.04c	146a	348.0c
G. fuscello (Trichoderma)	23.4a	1.52b	168c	74.93b
G. fuscello (No Trichoderma)	16.8c	2.66d	159b	376.00d
SE	0.59	0.05	0.54	26.69

Means within the same column followed by the same letter(s) do not differ significantly at p = 0.5 according to Duncan's multiple range test.

References

[1] Howard, L. R., Talcott, S. T., Brenes, C. H., Villalon, B. (2000), Changes in phytochemical and antioxidant activity of selected pepper cultivars (*Capsicum sp.*) as influenced by maturity. *Journal of Agriculture and Food Chemistry* 48(5), 1713–1720.

[2] Sanusi, M. M., Ayinde, I. A. (2013), Profitability of pepper production in derived Savannah zone of Ogun State. *IJAFS* 4(2), 401–410.

[3] Bosland, P. W., Votava, E. J. (2000), *Pepper vegetable and spice, capsicum*. New York: CABI Publishing. 1–10.

[4] Rubatzky, V., Yomaguchi, M. (1997), *World vegetables*. 2nd edition. USA: International Thomson Publishing. 553–562.

[5] Schippers, R. R. (2000), *African indigenous vegetables. An overview of the cultivated species*. Chatham, U.K., NRI, CTA, DFID.

[6] Izuogu, N. B., Abiri, T. O. (2015), Efficacy of *Trichoderma harzianum* T_{22} as a bio-control agent against root-knot nematode (*Meloidogyne incognita*) on some soybean varieties. *Croat. J. Food Sci. Technol*. 7(2), 47–51.

[7] Archana, N. Singh, Prasad, D. (2014), Management of plant parasitic nematodes by the use of botanicals. *J. Plant Physiol. Pathol*. 2(1). DOI:10.4172/2329-955X.1000116.

[8] Izuogu, N. B. (2013), Seasonal abundance and distribution of nematode pests of Musa sp. in Ilorin, Kwara State, Nigeria. *Aspects of Applied Biology* 120, 77–83.

[9] Howell, C. R., Stipanovic, R. D. (1993), *Suppression of Gliocladium virens phytotoxin production with steroid inhibitors*. Available at: www.freepatentsonline.com/5268173.html.

[10] Eziashi, E. I., Uma, N. U., Adekunle, A. A., Airede, C. E. (2006), Effect of metabolites produced by *Trichoderma* species against *Ceratocytis paradoxa* in culture medium. *African Journal of Biotechnology* 5(9), 703–706.

[11] Whitehead, A. G., Hemming, J. R. (1965), A comparison of some quantitative methods of extracting small vermiform nematodes from soil. *Annals of Applied Biology* 55, 25–38.

[12] Howell, C. R. (1998), The roles of antibiosis in bio-control. In: Harman G. E., Kubiek, C. P. (eds.), *Trichoderma and Giliocladium* 2: 173–184.

[13] Sharma, P., Pandey, R. (2009) Biological control of root-knot nematode, *Meloidogyne incognita* in the medicinal plant: *Withania sominifera* and the effects of bio-control agents on plant growth. *African Journal of Agriculture Research* 4(6), 564–567.

[14] Harman, G. E. (2000), The myths and dogmas of biocontrol changes in perception derived from research on *Trichoderma harzianum* strain T¬22. *Plant Disease* 84(4), 377–393.

[15] Sharon, E., Spiegel Y., Solomon, R., Curtis, R. H. C. (2002), Characterization of *Meloidogyne javanica* surface coat with antibodies and their effect on nematode behaviour. *Parasitology* 125, 177–185.

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How grassland management methods affect spider diversity

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Abstract. The main objective of this paper is to report the effect of shrub removal, mowing, and grazing as grassland management methods on spider diversity. Sampling was conducted in the Mátra Mountains and four disturbed main road verges in Hungary. Shrub removal and mowing positively affected diversity. Moderate grazing caused increasing diversity, but intensive grazing reduced spider diversity. The intensity of mowing maintenance had various effects on diversity depending on the landscape impact. It is worth reducing the intensity of the application of mosaic treatments and considering the long-term maintenance of edge habitats in these areas.

Keywords: mowing, shrub removal, grazing, Mátra Mountains, main road verges

1. Introduction

Grasslands are valuable and endangered habitats across the world. From a nature conservational point of view, natural and extensive meadows are the most important, which are – due to their species composition – substantial in the maintenance of biodiversity [1]. The number of these habitats declined in the last decades [2], which is due to the expansion of the economic infrastructure and the fragmentation of grasslands or the disappearance of pasture management. The traditional grassland and pasture management has resulted in the appearance of valuable species, which have disappeared after the termination of management. Grassland management reduces the vegetation succession, creating mosaic habitats [3]. The aims of the treatments are to replace the traditional grassland and pasture management and thereby to preserve protected animal and plant species and maintain meadows as habitats.

Spiders have various life strategies and different habitat preferences due to their species richness. Thereby, they are considered to be ecological indicator organisms [4]: the composition of spider assemblages indicates the quality of the habitats. Various treatments, such as grazing and mowing, have a positive effect on plant diversity, creating diverse habitats where the number of species and the abundance of spiders increase [5].

The aim of our research was to investigate the effects of shrub removal, mowing and grazing intensity on the ground-dwelling spider diversity in Natura 2000 habitats of the Mátra Mountains as well as the effect of maintenance mowing intensity on roadside verges. Firstly, we examined what changes took place regarding the diversity of ground-dwelling spider assemblages after shrub removal, what differences are there between the spider assemblages of treated shrubs and of control habitats (Project 1), and how mowing affects the diversity of ground-dwelling spider species (Project 2). Moreover, we studied the optimal grazing intensity for ground-dwelling spiders in hay meadows and shrubs (Project 3). Finally, we assessed the effect of maintenance mowing on ground-dwelling species inhabiting Hungarian roadside verges. During assessment, we also considered the effects of vegetation structure and the naturalness status of habitats (Project 4).

2. Materials and methods

During our study, we used the results of four projects to examine the spider assemblages. Data collection was carried out in two parts of Hungary: the Mátra Mountains, situated in north-eastern Hungary, and four roadside verges in Central Hungary.

Project 1 for the effect of shrub removal

Four sites (1. Sár Hill Nature Reserve, 2. Gyöngyössolymos, 3. Fallóskút, 4. Parád) (*Fig. 1*) were selected in the Mátra Mountains between 2012 and 2015, and all sites contained a shrub, a treated shrub, and a hay meadow to research shrub removal. Two mountain sites were situated in the southern part of Mátra, and two in the high-altitude parts of Mátra (*Table 1*). Five Barber traps were set at a distance of 4–5 m along a transect and 10 m from the edge. The traps were placed twice (May–July, September–November) over a six-week period each year. Traps were emptied fortnightly [6].

Project 2 for the effect of moderate mowing

Data collection was done on three sites (1. Sár Hill Nature Reserve, 3. Fallóskút, 5. Bátonyterenye-Fallóskút) in the Mátra Mountains (*Fig. 1*). Two habitats were selected in all sites representing a hay meadow (mowed once a year) and a non-mowed meadow (*Table 1*). Live traps were established on the habitats between 2010 and 2012 due to the protected nature of this area and in order to save the protected species in these habitats. Twelve traps were set at random. The traps were placed three times (April–May, July–August, September–October) over a three-week period each year [7].

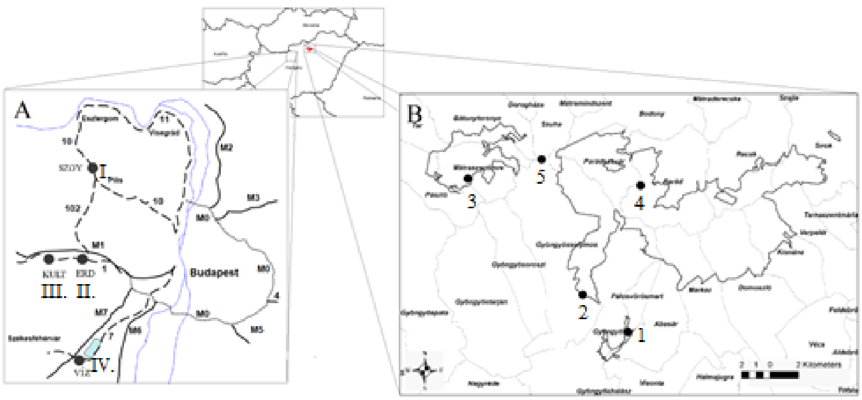


Figure 1. Sampling sites along roadsides (A) and in the Mátra Mountains (B) (for the number of sampling sites, see the *Material and methods* chapter)

Project 3 for the effect of grazing intensity

Data collection was done on the Somhegy-Bükk pasture (4) in the Mátra Mountains in 2014 (before grazing), 2015 (moderate grazing), and 2016 (intensive grazing). The reconstruction of habitats occurred by grazing (40 Hungarian Racka sheep and 20 Hungarian cattle). Two habitats were selected based on the mountain habitat attributes, representing grazing meadow and grazing shrub (*Table 1*). Five Barber traps were set at a distance of 4–5 m along a transect and 10 m from the edge. The traps were placed twice (May–July, September–November) over a six-week period each year. The annual data were compared against values of average temperature, and the average rainfall data of the Parádi-Recski Basin were requested from the National Meteorological Institute. Ascertainment of grazing intensity was on the basis of vegetation height, time of grazing, and number of grazing animals [8].

Table 1. Sampling sites of the Mátra Mountains

P	**L**	**T**	**S**	**Ve**
PA, SPA	GyS	SR	Control meadow	*Campanulo-Stipetum tirsae*
			Control shrub	*Pruno spinosae-Crataegetum*
			Treated shrub	*Campanulo-Stipetum tirsae*
PA, SAC	SH	SR	Treated shrub	*Pulsatillo montanae-Festucetum rupicolae*
			Control shrub	*Pruno spinosae-Crataegetum*
		SR/M	Control meadow	*Trifolio montanae-Danthonietum alpinae*
		M	Control meadow	*Pulsatillo montanae-Festucetum rupicolae – Pruno spinosae-Crataegetum*
PA, SPA	FK	M	Mowed meadow	*Anthyllido-Festucetum rubrae*
			Control meadow	*Anthyllido-Festucetum rubrae*
		SR	Mowed meadow	*Anthyllido-Festucetum rubrae*
			Control shrub	*Pruno spinosae-Crataegetum (Quercus ceris, Carpinus betulus)*
			Treated shrub	*Pastinaco-Arrhenatheretum*
PA, SPA	B-FK	M	Control meadow	*Anthyllido-Festucetum rubrae* and *Alopecuro-Arrhenatheretum*
			Mowed meadow	*Anthyllido-Festucetum rubrae*
PA, SPA	Parád	SR	Treated shrub	*Pastinaco-Arrhenatheretum* and *Pruno spinosae-Crataegetum*
		SR/ G	Mowed meadow (later grazed)	*Pastinaco-Arrhenatheretum* and *Festuco ovinae-Nardetum*
			Control shrub (later shrub removed and grazed)	*Pruno spinosae-Crataegetum*

Along the Hungarian roads, data were collected on verges besides four sampling sites representing the main types of verge habitats between 2014 and 2015 (*Fig. 1*). All sites (I. Pilisjászfalu, II. Herceghalom, III. Mány, IV. Agárd)

(*Table 2*) included three sections representing non-mowed, normal mowed (mowed once or twice a year), and enhanced mowed (mowed three or four times a year). The distance between two sections was 100 m. In each section, five pitfall traps were established 5 meters from each other, and they were located 1.5 m from the roads. Double-glass pitfall traps filled with ethylene glycol were used, which were left in the field for three weeks and three times a year in different seasons (April–May, July–August, October–November) [9].

Table 2. Characterization of main road verges

Road section	Location	Vegetation of adjacent area
Pilisjászfalu (I.)	Road number 10 (Budapest-Esztergom)	dry dolomite grassland with shrubs
Herceghalom (II.)	Road number 1 (Budapest-Győr)	installed tree line with Robinia pseudoacacia, Populus sp., Ulmus minor
Mány (III.)	Road number 1 (Budapest-Győr) between two roads	arable, corn and cereal plantation
Agárd (IV.)	Road number 7 (Budapest-Székesfehérvár)	Populus sp. plantation next to the Velencei Lake. Grass height is sometimes 1 meter on the verges.

We used the PAST Paleontological Statistics Software Package for data analyses [10]. Besides the average number of species and individuals, we also calculated Shannon diversity. For the comparison of values in the case of more samples, the one-way ANOVA whereas for the investigation of more treatments or factors the two-factor ANOVA was used.

3. Results and discussions

Project 1

Examining shrub removal, the median value of the number of species and individuals was higher in the year following shrub removal compared to the pre-treatment values – similarly to control habitats –, but differences were significant only in treated habitats (number of species: $p = 0.03$, number of individuals: $p = 0.01$) (fig-s 2–3). Microclimate changed by shrub removal influences spider abundance [11] and could explain why average species richness and number of individuals increased directly after shrub removal. The higher abundance of rare and protected species in mowed habitats represents the regional differences (*Table 3*), but we found no significant differences between abundance values (p = 0.75). Based on our results, shrub removal had a positive influence on ground-dwelling spider diversity.

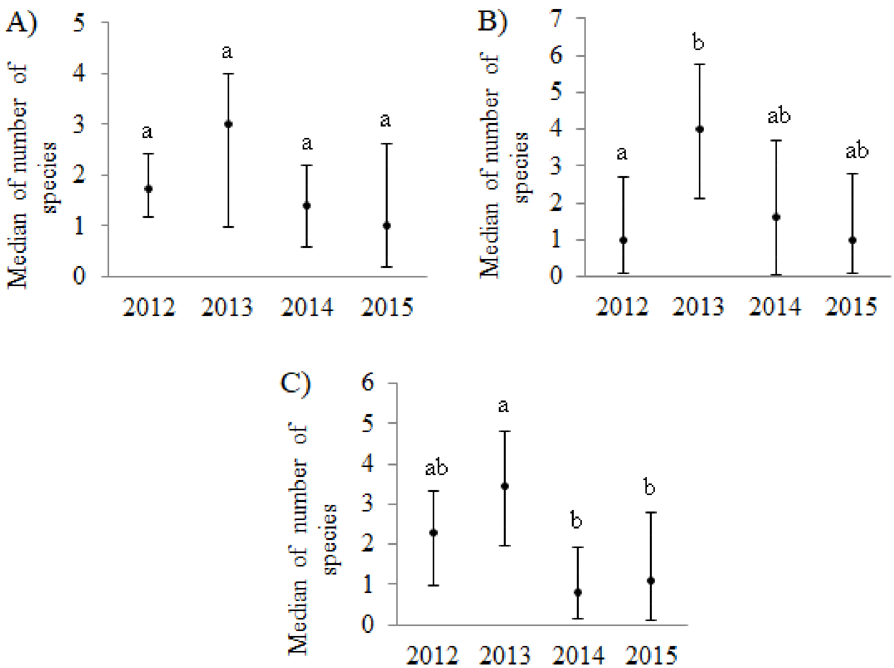
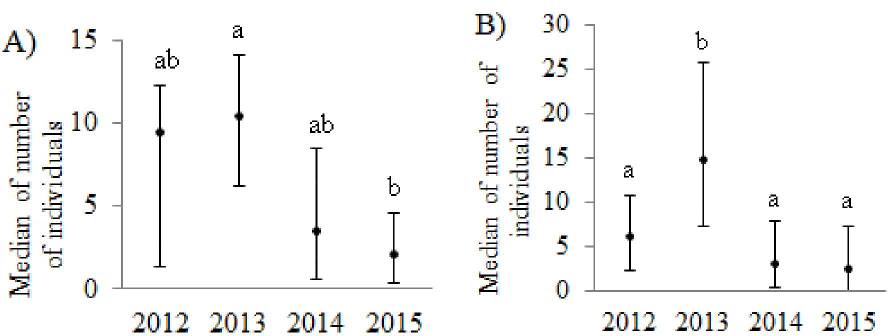


Figure 2. The median values of the number of species per traps in the case of control shrubs (A), treated shrubs (B), and control meadows (C). The different letters note the significant differences (p < 0.05).



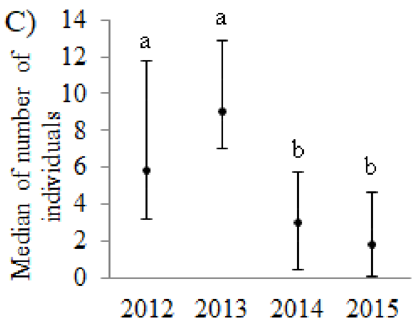


Figure 3. Median values of the number of individuals per traps in the case of control shrubs (A), treated shrubs (B), and control meadows (C). The different letters note the significant differences ($p < 0.05$).

Table 3. Abundance of protected and rare spider species (Ar %) – TS: Treated shrub, CS: Control shrub, CM: Control meadow

Species		Ar (%)			
		TS	CS	CM	Total
Protected species	*Nemesia pannonica* (Herman, 1879)	0.60	0.10	1.10	1.90
	Eresus kollari Rossi, 1846	0.01	0.01	0.03	0.07
	Atypus affinis Eichwald, 1830	0.03	0.09	0.05	0.19
	Geolycosa vultuosa C. L. Koch, 1838	0.01	0	0	0.01
Rare species	*Arctosa figurata* (Simon, 1876)	0	0	0.05	0.05
	Zelotes aurantiacus Miller, 1967	0	0.01	0	0.01
	Drassodes cupreus (Blackwall, 1834)	0.01	0	0.01	0
	Gnaphosa modestior Kulczyński, 1897	0.10	0.50	0.20	0.20

According to the two-way ANOVA, the differences between the diversity of treated and control habitats were significant, but between years differences were not significant (*Table 4*). Spider diversity was lower after shrub removal compared to pre-treatment species diversity and was higher in the second year after shrub removal. There was a decrease in the diversity in the final year of the study caused by the absence of additional treatments (*Table 5*). This is the first phase of the grassland management process and can change the coverage of vegetation [12]. It may explain why the assemblages had a relatively low diversity in the year following shrub removal, which was the highest in the second year. It was caused by the presence of neighbouring refuge habitats that supported the survival of species. The shrubs were homogeneous habitats where diversity was lower and the abundance was higher compared to the heterogeneous hay meadows, where the diversity was higher and the abundance was lower. Since additional treatments were not applied, these habitats are threatened with succession. It was presented by a reduction in species richness that was observed in the last year when shrubs appeared in grassland habitats [6].

Table 4. Results of the two-way ANOVA for the effect of shrub removal (shrubs, treated shrubs, hay meadows) on diversity in the Mátra Mountains and in the examined years (2012–2015)

	Sum of sqrs	df	Mean square	f	p
Years	0.27841	3	0.09280	1.201	0.3866
Treatments	1.50178	2	0.75089	9.71736	0.01313
Error	0.46363	6	0.07727		
Total	2.24383	11			

Table 5. Values of Shannon diversity in treated shrubs and control habitats during the examined years (2012: before shrub removal, 2013–2015: after shrub removal)

Shannon diversity	Examined years			
	2012	2013	2014	2015
Control shrubs	2.164	2.011	2.568	1.792
Treated shrubs	2.791	2.250	2.906	2.239
Control meadows	2.929	3.114	2.847	3.106

Project 2

When examining mowing, we did not find significant differences between the examined values of spider assemblages of mowed and non-mowed meadows, but the median values of abundance and species richness (Fig. 4) and diversity (Table 6) were higher in the mowed meadows. Mowing has a positive effect on floral diversity, which increases the species richness of spiders [13]. According to the two-way ANOVA, differences between diversity of mowed and non-mowed meadows were not significant, but between three different sites these were significant (Table 7).

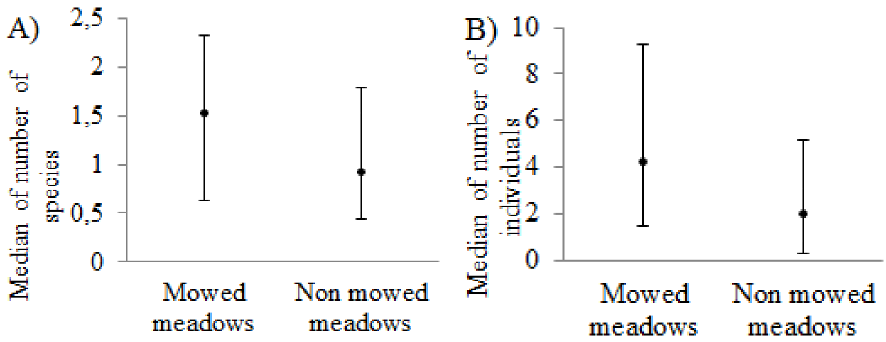


Figure 4. Median values of number of species (A) and number of individuals per traps (B) in mowed and non-mowed meadows. The differences were not significant ($p > 0.05$).

During our research, hay meadows had diverse spider assemblages, which can be maintained by controlled mowing management. In hay meadows, the number of herbivore species is high due to rich vegetation. In more open habitats, the sward often includes more dicotyledonous than monocotyledonous species, thereby explaining the correlations between arthropod and flower diversity [14]. Mowing has similar direct influences compared to shrub removal. To preserve shelters and resources for many species, we applied rotational management in the meadows. The relative abundance of rare and protected species illustrates well that most such species prefer open to semi-open habitats (*Table 8*). Our results corroborated that hay meadow could be conserved with mowing, and thus spider and floral diversity could be maintained. Similarly to shrub removal, mowing can be considered to act as an intermediate disturbance [15]. The annual treatments can be considered as a low-intensity disturbance that produces a higher diversity of spider assemblages than in untreated habitats, where grassland and forest species occur [6].

Table 6. Values of Shannon diversity in mowed and non-mowed meadows

Shannon diversity	Treatment	
	Mowed meadows	Non-mowed meadows
Location 1	1.750	1.459
Location 2	2.091	1.966
Location 3	1.781	1.643

Table 7. Results of ANOVA for the effect of mowing (mowed meadows and non-mowed meadows) in the Mátra Mountains and locations on diversity

	Sum of sqrs	df	Mean square	f	p
Locations	0.19426	2	0.09713	22.7572	0.04209
Mowing	0.05170	1	0.05170	12.1148	0.07355
Error	0.00853	2	0.00426		
Total	0.25450	5			

Table 8. Abundance of protected and rare spider species (Ar %) – MM: Mowed meadow, NM: Non-mowed meadow

Species		Ar (%)	
		MM	NM
Protected species	*N. pannonica*	3.50	1.30
	A. piceus Sulzer, 1776	0.10	0.20
	E. kollari	0.30	0.10
	G. vultuosa	0.10	0
Rare species	*A. figurata*	0.05	0
	D. cupreus	0.10	0
	G. modestior	0	0.10

Project 3

According to our results, there was a negative correlation between grazing intensity and spider diversity, but significant differences were not found (*Table 9*). In the case of meadows, diversity (*Table 10*) as well as the median value of species richness (*Fig. 5A*) and abundance (*Fig. 6A*) increased during moderate grazing despite decreasing average temperature compared to pre-treatment diversity and decreased during intensive grazing. In meadows, moderate grazing resulted in a lower vegetation height and an increased amount of sunlight reaching the ground, which positively affected grassland species.

Contrarily, spider diversity (*Table 11*) and the median value of species richness (*Fig. 5B*) and abundance in shrub (*Fig. 6B*) decreased during moderate and intensive grazing as well; this is inversely related to average rainfall values. Increasing diversity in shrub can be expected in the following year when colonization may take place from the neighbouring natural meadows.

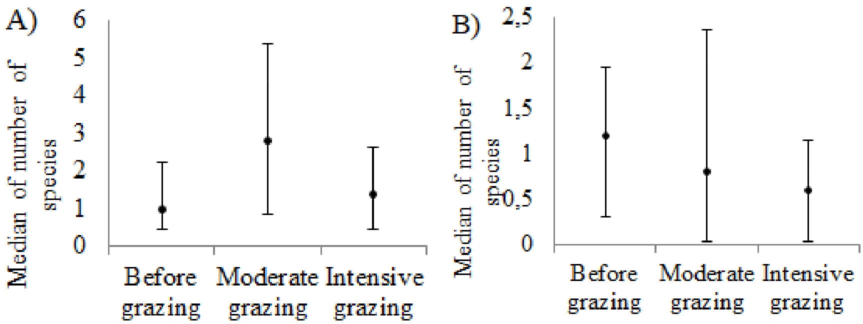


Figure 5: Median values of the number of species per traps in the case of mowed meadow (A) and shrub (B) before grazing, during moderate grazing, and during intensive grazing. The differences were not significant (p > 0.05).

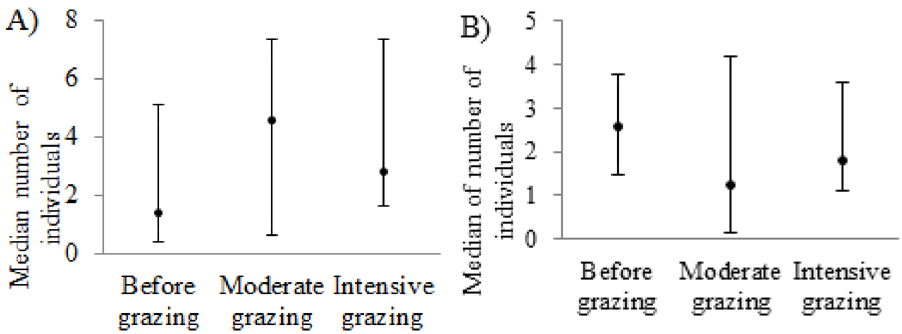


Figure 6: Median values of the number of individuals per traps in the case of mowed meadow (A) and shrub (B) before grazing, during moderate grazing, and during intensive grazing. The differences were not significant (p > 0.05).

Table 9. Results of the two-way ANOVA for the impact of grazing intensity (examined years: 2014: before grazing, 2015: moderate grazing, 2016: intensive grazing) in the Mátra Mts. and vegetation structure (meadows and scrubs) on diversity

	Sum of sqrs	df	Mean square	f	p
Vegetation structure	0.30165	1	0.30195	7.8937	0.106
Years	0.15823	2	0.07941	2.076	0.325
Error	0.07650	2	0.38252		
Total	0.53728	5			

Table 10. Values of Shannon diversity in grazed habitats during the examined years (2014: before grazing, 2015: during moderate grazing, 2016: during intensive grazing)

Shannon diversity	Before grazing	Moderate grazing	Intensive grazing
Mowed meadow	2.404	2.652	2.19
Shrub	2.236	1.931	1.733

However, this year, besides intensive grazing, shrubs were extensively removed, causing a higher level of disturbance for spider assemblages, wherefore their diversity decreased. Based on these results, moderate grazing is an effective grassland management type to increase spider diversity on the Somhegy-Bükk pasture, but intensive grazing influences the assemblages negatively. Moderate grazing is regarded as intermediate disturbance [15], which causes high diversity [8].

Project 4

Based on our results, the mowed verges had diverse spider fauna similarly to semi-natural habitats [9]. As ecological corridors, these verges have homogeneous vegetation, but due to the diversity of adjacent areas these verges can provide habitats for several animals. On roadside verges, we did not find significant differences between the investigated sections (*Table 11*), but the highest median value of the number of species was in normal mowed sections (*Fig. 7A*), while the highest median value of abundance was in non-mowed sections (*Fig. 7B*). Our results showed that the different verge types influenced optimal maintenance intensity. In the case of forest and wet verges, the normal mowed sections were the most diverse. In contrast with this, other verges became more diverse due to enhanced maintenance (*Table 12*).

Table 11. Results of ANOVA for the effect of maintenance mowing (no mowing, normal mowing, enhanced mowing) and habitat types of roadside verges (dry grassland, agricultural habitat, forest, wetland)

	Sum of sqrs	df	Mean square	f	p
Maintenance	0.039835	2	0.019917	0.93523	0.443
Habitat types	1.225065	3	0.750216	3.52267	0.08857
Error	0.127781	6	0.021296		
Total	2.392681	11			

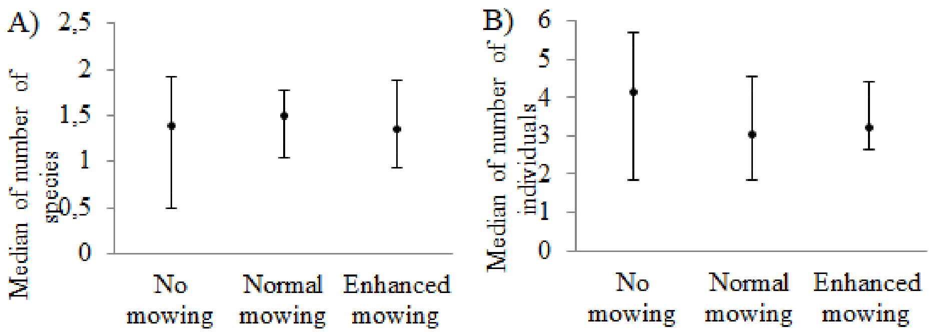


Figure 7. Median values of the number of species (A) and individuals (B) per traps in the case of no mowing, normal mowing, and enhanced mowing on roadside verges. The differences were not significant ($p > 0.05$).

The results supported the intermediate disturbance hypothesis [15] in the case of wetland and forest habitats because in these verges next to shaded habitats grassland and forest species found suitable circumstances due to moderate mowing. Our results showed that the verges could provide refuges for grassland spiders influenced by suitable intensity mowing. Furthermore, in the case of disturbance-tolerant species, mowing extends to the borders of adjacent areas. Based on these results, we suggest considering the structure and naturalness of verge habitats when selecting the appropriate degree of mowing intensity.

Table 12. Values of Shannon diversity of the habitat types on main road verges by maintenance mowing (no mowing, normal mowing, enhanced mowing)

Shannon diversity	Habitat types			
	Dry grassland	Agricultural habitat	Forest	Wetland
No mowing	2.107	2.417	2.458	2.406
Normal mowing	2.261	2.405	2.729	2.554
Enhanced mowing	2.276	2.691	2.546	2.21

4. Conclusions

We concluded that shrub removal is an effective grassland management action to increase spider diversity in Natura 2000 habitats. Consequently, shrub removal is not enough to maintain spider diversity. It is necessary to continue the grassland management process if we are to maintain diverse spider communities and assist the overall recovery of these valuable habitats [6]. Based on our results, we suggest the application of moderate mowing to maintain the Natura 2000 habitats for spiders [7]. It can also be concluded that moderate grazing is an optimal grassland management to maintain meadows as habitats for several spider species and preserve the high spider diversity. Moreover, when deciding on grazing intensity, it is important to consider the structure of habitats and to avoid the use of more treatments simultaneously [8]. Besides Natura 2000 habitats, the maintenance of disturbed areas is important, as well. We concluded that maintenance mowing does not have major influence on spider diversity, but it is necessary to preserve the spider species. Furthermore, the type of verge habitats has to be considered when selecting the appropriate degree of mowing intensity.

Acknowledgements

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References

[1] Déri, E., Lengyel, S., Lontay, L., Deák, B., Török, P., Magura, T., Horváth, R., Kisfali, M., Ruff, G., Tóthmérész, B. (2009), Természetvédelmi stratégiák alkalmazása a Hortobágyon: az egyek-pusztakócsi LIFE-Nature program eredményei. *Természetvédelemi Közlemények* 15, 89–102.

[2] Bérces, S. (2011), A biodiverzitás monitorozása homoki élőhelyeken a Duna-Ipoly Nemzeti Park Igazgatóság területén. *Rosalia* 6, 447–471.

[3] Gerner, G., Biró, É., Bódis, J., Kun, R., Nagy, T., Molnár, Zs., Biró, M. (2015), Élőhelytípusok és tájhasználat Sztána és Zsobok határában. In: Molnár. K., Molnár., Zs. (eds.), Élet és rend a határban. Etnoökológiai Kutatótábor Kalotaszegen. *Sztánai Füzetek 19*. Kolozsvár-Sztána: Művelődés Egyesület–Szentimrei Alapítvány. 79–101.

[4] Blandin, P. (1986), Bioindicateurs et diagnostic des systèmes écologiques. *Bulletin d'écologie* 17, 215–307.

[5] Jeanneret, Ph., Schüpbach, B., Pfiffner, L., Walter, T. (2003), Arthropod reaction to landscape and habitat features in agricultural landscapes. *Landscape Ecology* 18, 253–263.

[6] Szmatona-Túri, T., Vona-Túri, D., Magos, G., Urbán, L. (2017), The effect of grassland management on diversity and composition of ground-dwelling spider assemblages in the Mátra Landscape Protection Area of Hungary. *Biologia* 72(6), 642–651.

[7] Szmatona-Túri, T., Vona-Túri, D. (2016), The effect of grassland management on diversity of spider assemblages in the Mátra Mountain. *Ecologica Monenegrina* 7, 291–297.

[8] Szmatona-Túri, T., Vona-Túri, D., Urbán, L., Magos, G. (2018), The effect of grazing intensity on ground-dwelling spiders of grassy and shrubby habitats. *Acta Zoologica Bulgarica* 70(2), 195–202.

[9] Vona-Túri, D., Szmatona-Túri, T., Kádár, F., Kiss, B., Weiperth, A., Gál, B. (2016), Ground-dwelling arthropod (Araneae, Coleoptera: Carabidae, Isopoda: Oniscidea) assemblages on Hungarian main road verges. *Acta Universitatis Sapientiae Agriculture and Environment* 8, 98–113.

[10] Hammer, O., Harper, D. A. T., Ryan, P. D. (2001), PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1).

[11] Kohyani, P. T., Bossuyt, B. Bonte, D., Hoffmann, M. (2008), Grazing as a management tool in dune grasslands: Evidence of soil and scale dependence of the effect of large herbivores on plant diversity. *Biological Conservation* 141, 1687–1694.

[12] Berlow, E. L., D'Antonio, C. M., Swartz, H. (2003), Response of herbs to shrub removal across natural and experimental variation in soil moisture. *Ecological Applications* 13, 1375–1387.

[13] Malumbres-Olarte, A., Vink, C. J., Ross, J. G., Ruickshank, R. H., Paterson, A. M. (2013), The role of habitat complexity on spider communities in native alpine grasslands of New Zealand. *Insect Conservation and Diversity* 6, 124–134.

[14] Noordijk, J., Delille, K., Schaffers, A. P., Sýkora, K.V. (2009), Optimizing grassland management for flower-visiting insects in roadside verges. *Biological Conservation* 142, 2097–2103.

[15] Connell, J. H. (1978), Diversity in tropical rain forests and coral reefs. *Science* 199, 1302–1310.

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Institutional changes in Hungarian environmental policy between 1998 and 2018

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Abstract. A country's economic situation, its political establishment, and the prevailing environmental conditions have a significant impact on the institutional system required for efficient environmental protection measures. During our work, we reviewed the institutional changes and legislation regarding environmental protection which have occurred over the past 20 years as well as the role of changes in the government. In summary, it can be concluded that significant changes occurred during the past two decades. The names, organizational structures, operations, and scopes of ministries have undergone regular changes over the years. In Hungary, there has been no separate ministry of the environment since 2010, and this area is regulated only on the state secretary level. In contrast, in the V4 countries and the Carpathian Basin, environmental protection is regulated on the ministry level.

Keywords: environmental ministries, environmental legislation, law

1. Introduction

In Hungary, several studies have been conducted over the recent years regarding environmental protection policies on the settlement and local government level [1, 2, 3, 4]. We also found studies demonstrating the state of national environmental protection and its organizational system [5, 6, 7, 8]; however, it is difficult to keep track of the rapid changes which have occurred with regard to the operation of the organizational system of environmental protection. During the recent years, several changes have occurred, highlighting the relevance of our study.

In Hungary, the organizational and institutional conditions of environmental protection have improved since the change of regime following the end of the

Cold War [1]. Among the countries of the Eastern Block, Hungary was the first to establish environmental protection laws since, as a consequence of the centrally planned economy, environmental damage was more severe in comparison to countries with a similar level of economic development [9, 10]. In Hungary, laws regarding environmental protection were established during the mid-1990s. Then, following a 3–4-year period with practically no legislative action, the rate at which new laws were passed increased disproportionately primarily because of the upcoming EU accession [6]. Following the trend of the 2000s regarding international environmental policies, climate change and waste management became central issues in Hungary, as well [1]. The establishment of a separate environmental protection ministry may help to enforce environmental interests [11]. The aim of this study is to review the organizational changes and laws passed over the last 20 years regarding environmental protection and the role of changes in government in Hungary, thereby providing a comprehensive analysis of the current situation.

2. Materials and methods

In order to review the hierarchy of laws, we reviewed the effective Fundamental Law and environmental acts of Hungary as well as the role played by laws, government decrees, and local government decrees regarding environmental protection. To investigate the administrative changes occurring in environmental protection, we reviewed the scope, structure, and establishment of responsible ministries, institutions, and organizations.

3. Results and discussions

A. Hierarchy of environmental protection laws

At the top of the hierarchy, there are the provisions of the Fundamental Law of Hungary [12]. The new, modified Law came into effect on 1 January 2012. It has five articles (Article P, Article Q, Article XX, Article XXI, and Article 38) on environment and environmental protection. This specifies the tasks and regulatory responsibilities of the government with regard to environmental protection.

Environmental laws also refer to the Fundamental Law of Hungary; its general framework is outlined in the laws of environmental protection [13]. Among other things, it stipulates the terms and principles of the regulation, its general requirements, the tasks of the state and local government as well as the specific institutions responsible for the operation of environmental protection. Several laws were established based on its provisions. There are nonenvironmental laws concerning soils, forests, mining, and nuclear energy, for instance. Furthermore, there are other, specifically environmental laws on issues such as waste as well as nature, landscape, and animal protection.

At the next level of the hierarchy, there are the government and ministry decrees. These decrees can be established only with legal permission, which is granted by the Environmental Act and other acts.

At the lowest hierarchical level, there are the local government decrees. These decrees, issued by local authorities, must be in accordance with national specifications [7]. They also play an important role at the settlement level in the fields of local environmental and nature protection, built environment, and waste management [14, 2].

B. Changes in the organization of environmental protection administration between 1998 and 2018

Act VII of 1987 elevated environmental protection in Hungary to a ministry level [15]. Initially, the operative tasks of environmental protection were managed in combination with water management; subsequent to this – during the 8 years following the change of regime –, they were integrated into regional development. The names, organizational structures, operations, and scopes of the ministries have undergone regular changes over the years, which is, in part, related to changes in government. In the following, we will review the changes that took place over the past two decades, taking each governmental cycle in turn.

The first Orbán Government (*1998–2002*)

After the change of government in 1998, the first Orbán Government was established. At that time, the name of the existing Ministry of Environment Protection and Regional Development was changed to Ministry of the Environment (ME) under Act XXXVI of 1998, while water management remained under the remit of the Ministry of Transport, Telecommunications and Water Management [16, 17]. On 8 July 1998, Dr Pál Pepó was appointed Minister for the Environment at the new ME, and he was followed by Dr Ferenc Ligetvári on 20 June 2000. As of 1 December 2000, the position was filled by Béla Turi-Kovács.

The Medgyessy Government (*2002–2004*)

After the parliamentary elections of 2002, in the governmental organization led by Péter Medgyessy, water management and environmental issues were assigned to one portfolio, under the name of the Ministry of the Environment and Water (MEW) [18], which was the legal successor of the Ministry of Environmental Protection and Water Management established by the Parliament in 1987 [19]. From that point on, from 27 May 2002, the leader of the ministry was Dr Mária Kóródi as Minister for Environment and Water, followed by Miklós Persányi from 19 May 2003 [8]. The structure of the MEW is shown in *Figure 1*. With the establishment of the National Environmental Protection and Nature Conservation and Water Management Inspectorate, a "green authority system" was formed in 2005, integrating environmental protection, nature conservation, and water management tasks.

The first and the second Gyurcsány governments (*2004–2006 and 2006–2009*)

The position of prime minister was filled by Ferenc Gyurcsány in 2004, who was later elected as Prime Minister in the parliamentary election of 2006. From that point on, the MEW continued to operate under the same name and with the same responsibilities. Its leader remained Miklós Persányi, followed by Dr Gábor Fodor from 7 May 2007. From 5 May 2008, the position was filled by Imre Szabó. Under Governmental Decree No 347/2006 (XII. 23.), a directorate was created to manage environmental and water management issues [20].

The Bajnai Government (*2009–2010*)

No changes were made to the measures taken by the former administration.

The second Orbán Government (*2010–2014*)

After the parliamentary elections of 2010, the position of prime minister was once again filled by Viktor Orbán. Under the Act XLII of 2010, the legal successor to the MEW was the Ministry of Rural Development (MRD) [21]. Therefore, in 2010, the issue of environmental protection was stripped of its ministry-level independence [6]. On 27 May 2010, Sándor Fazekas was appointed as the leader of the MRD as Minister for Rural Development. The scope of the MRD covers the areas of forest management, cartography, land administration, environmental protection, nature conservation, and water management [22]. The issue of environmental protection was managed only on the state secretary level. The state secretary for the environment was Dr Zoltán Illés.

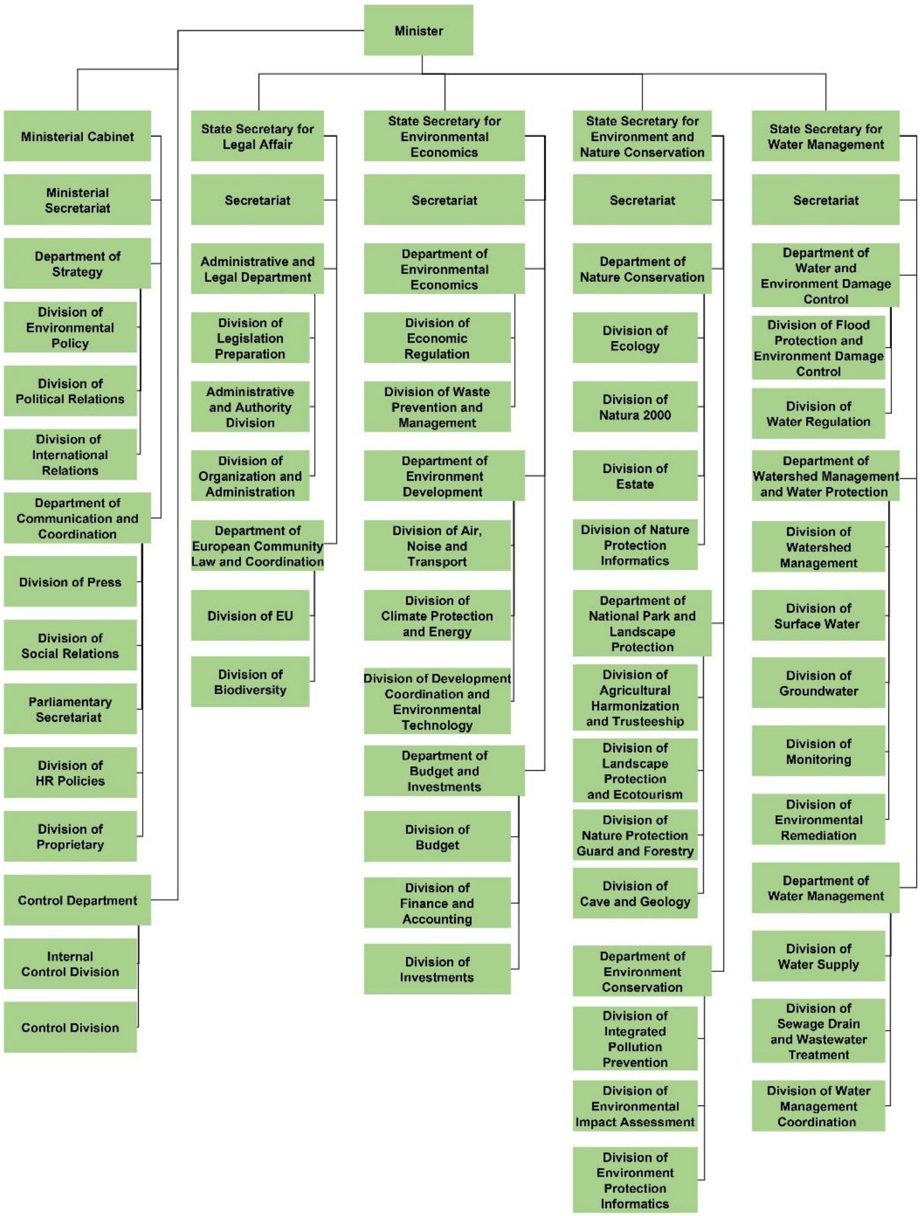

Figure 1. The structure of the Ministry of Environment and Water

The structure of the MRD is demonstrated in *Figure 2*. At that time, development and climate policy, energy policy, mining, and waste management were under the responsibility of the Ministry of National Development [21, 23, 24]. At this point, the Inspectorate, which was responsible for environmental, nature, and water protection, became a central agency led by the minister [20, 25]. In 2012, the organizational structure of the administration changed. From that point on, management tasks involving water management became the responsibility of the Ministry of the Interior; however, the technical administrative tasks remained within the remit of the MRD. With the dissolution of the organization, based on Government Decree No 300/2011 (XII. 22.) as the legal successor of the VKKI, the National Environmental Protection Institute (NEPI) operated by the MRD, which managed environmental protection and water management tasks, as well as the National Water Management Directorate (NWMD) managed by the Ministry of Interior were established to coordinate the activity of the water management directorates with the 12 water management directorates formed in accordance with the prevailing hydrographic conditions [4, 6, 7, 8, 26]. Under OGY Decision No 23/2010 (V. 14.), the Hungarian Parliament's Committee on Sustainable Development was established [27]. It became responsible for the management of activities of the MRD, including environmental protection, nature conservation, and water management meteorological tasks. The committee was also responsible for issues which are technically under the scope of other ministries but are connected to environmental protection, such as protection against radioactive contamination, energy efficiency and renewable resources, chemical safety, environmental health affairs, environmental safety, and issues of transport related to environmental protection [28]. As of 1 January 2011 and 2013, the county-level and district-level government agencies, respectively, started their activities as the official regional state administration bodies of the government.

The centres of county-level government agencies are in the county seats, while the capital's government agency and the government agency of Pest County are located in Budapest [29].

Government agencies are responsible for the harmonization and facilitation of the regional implementation of governmental tasks in accordance with the law and with the decisions of the government. At the time they were set up, the scope of government agencies was in accordance with the environmental authority county borders. In certain cases, two or more county-level government agencies cooperated to manage specific environmental authority tasks from one centre. In accordance with the above, a total of 11 combined government agencies are responsible for the management of environmental authority tasks.

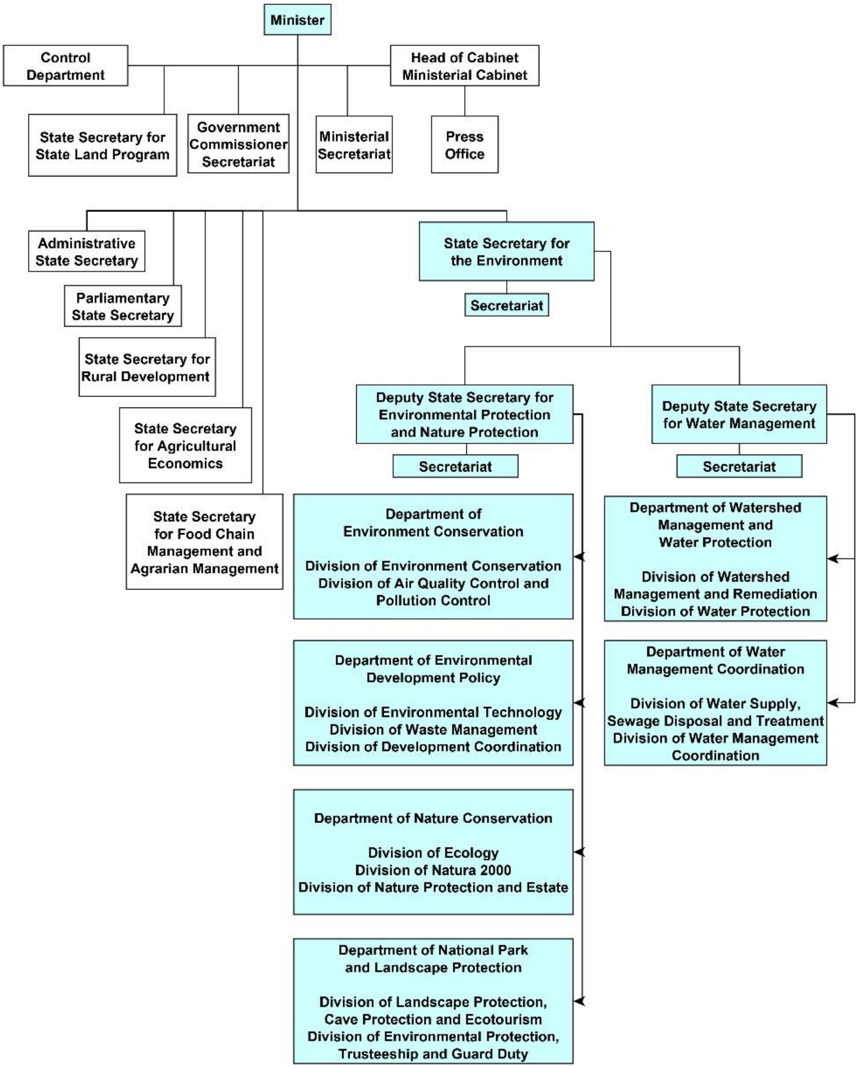

Figure 2. The structure of the Ministry of Rural Development between 2010 and 2014

The third Orbán Government (*2014–2018*)

After the election of 2014, Viktor Orbán remained the Prime Minister. Under Act XX of 2014, the Ministry of Rural Development (MRD) continued to operate under the name Ministry of Agriculture (MA) [30].

The structure of the MA is shown in *Figure 3*. At that time, the position of Minister for Agriculture was held by Sándor Fazekas. The scope of the MA covers the areas of forest management, land administration, environmental protection, nature conservation, and cartography [31]. For protection against catastrophes, water management, water protection, and the management of water administration bodies, the responsible organization is the Ministry of the Interior [31, 32].

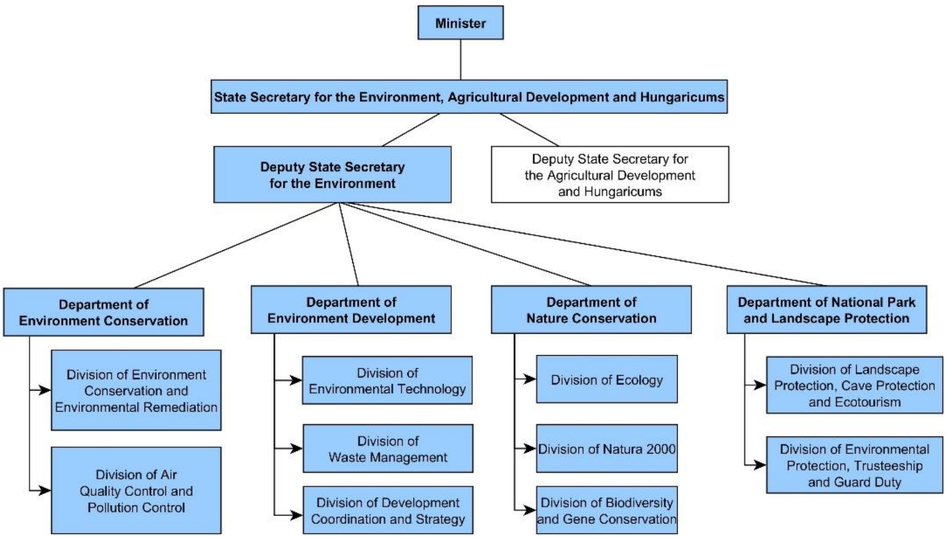

Figure 3. The structure of the Ministry of Agriculture between 2014 and 2018

Mining, waste management, and energy policy are under the scope of the Ministry of National Development [31, 33]. Energy policy covers the non-military use of nuclear energy, the utilization of biofuels and other renewable fuels for transport purposes, the utilization of renewable resources for the purposes of heat and electricity production as well as creating the necessary conditions for climate policy, sustainable economic development, and energy efficiency. The issue of environmental protection was managed only on the state secretary level by Zsolt Németh, who held the position of State Secretary for the environment, agricultural development, and hungaricums (unique Hungarian products) [34].

Compared to the measures taken by the second Orbán Government, a few significant changes occurred with regard to environmental protection. Under government decrees no 223/2014 (IX. 4.) and no 71/2015 (III. 30.), water management and authority tasks were completely decoupled from the environmental protection and nature conservation authority and administrative tasks [35, 36]. The government designated a Directorate of the Interior Ministry (which was responsible for the disaster management) as the national water management authority [35]. As of 1 April 2015, the environmental protection and nature conservation departments of county-level government agencies were responsible for managing the regional environmental protection and nature conservation tasks, instead of the former environmental protection and nature conservation directorates. As of 1 January 2017, the National Environmental Protection and Nature Conservation Directorate was integrated into another organization and terminated with legal succession. Its general legal successor is the Pest County Government Agency, which functions as a national-level environmental protection and nature conservation authority [37]. The district offices of county-level government agencies are responsible for regional environmental protection and nature conservation. Formerly, there were 11 combined authorities, aligned with river basin regions; however, as of 2017, they were aligned with administrative (county) borders [36]. In 2015, a new directorate, named the Environmental Sustainability Directorate, was established as part of the Office of the President of the Republic. Its main task was to monitor national and international activities related to environmental sustainability [38].

The fourth Orbán Government (*2018–*)

After the elections of 2018, the fourth Orbán Government was established. As per Act V of 2018, the Ministry of Agriculture (MA) (in Hungarian: Földművelésügyi Minisztérium) continues to operate under a modified name (in Hungarian, Agrárminisztérium) [39]. The leader of the ministry is István Nagy, holding the position of Minister for Agriculture. The scope of the Ministry of Agriculture (MA) covers the areas of forest management, land administration, environmental protection, nature conservation, and cartography [40]. The issue of environmental protection is managed only on the state secretary level by Zsolt Németh, who holds the position of State Secretary for the Environment, Agricultural Development and Hungaricums [41]. The structure of the MA is shown in *Figure 4*. As per Act V of 2018, the Ministry of National Development was terminated, and from that point on the fields it was responsible for (mining, waste management, energy policy, and climate policy) were managed by the newly established Ministry for Innovation and Technology. For protection against catastrophes, water management, water protection, and the management of water administration bodies, the responsible organization is still the Ministry of the Interior [40].

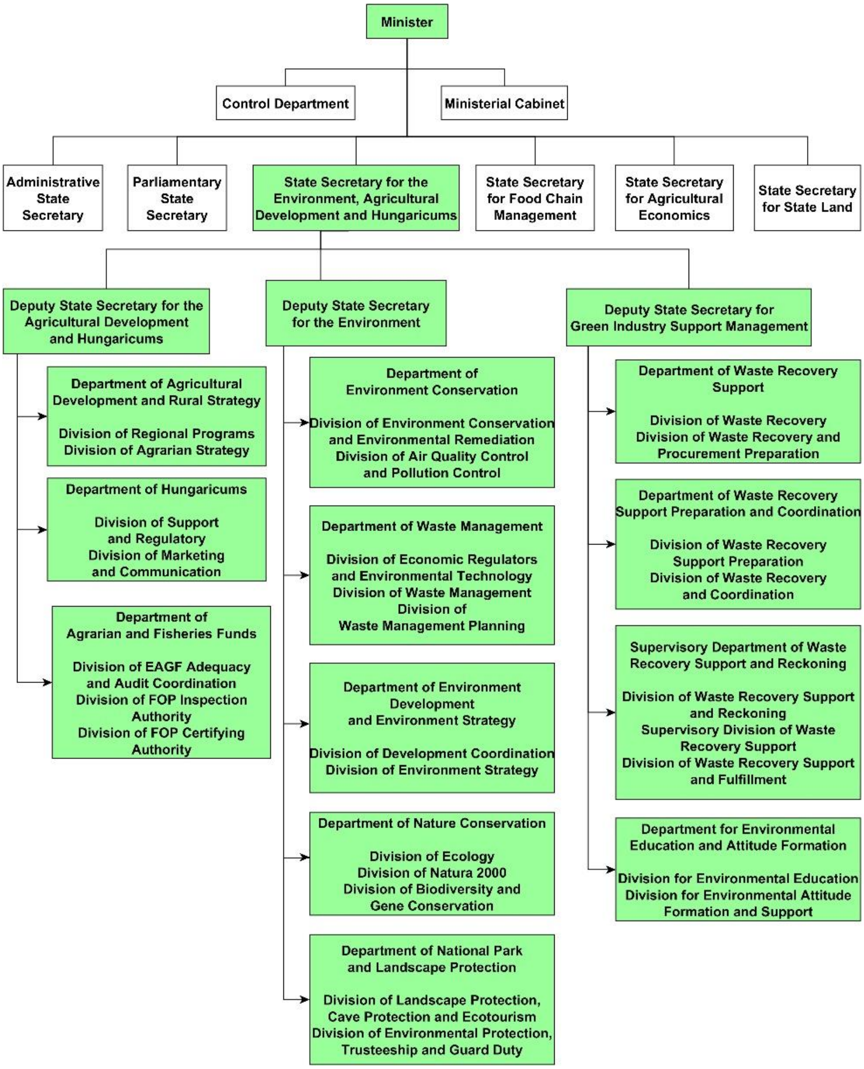

Figure 4. The structure of the Ministry of Agriculture in 2018

4. Conclusions

In Hungary, the last time there was a ministry responsible exclusively for environmental protection was between 1998 and 2002.

Between 2002 and 2010, there were environmental and water management ministries; since 2010, there has been no independent environmental protection ministry, and the field is represented only on the state secretary level (*Figure 5*).

First Orbán Government 1998-2002	Medgyessy Government 2002-2004	First Gyurcsány Government 2004-2006	Second Gyurcsány Government 2006-2009	Bajnai Government 2009-2010	Second Orbán Government 2010-2014	Third Orbán Government 2014-2018	Fourth Orbán Government 2018-
Ministry of Environment (ME)	***Ministry of Environment and Water (MEW)***				***Ministry of Rural Development (MRD)*** assign of MEW	***Ministry of Agriculture (MA)*** former MRD	***Ministry of Agriculture (MA)*** former MA
Dr Pál Pepó **Dr Ferenc Ligetvári** **Dr Béla Turi-Kovács**	**Dr Mária Kóródi** Dr Miklós Persányi	Dr Miklós Persányi	Dr Miklós Persányi **Dr Gábor Fodor**	**Imre Szabó**	**Dr Sándor Fazekas**	**Dr Sándor Fazekas**	**Dr István Nagy**
Minister for the Environment	Minister for the Environment and Water				Minister for the Rural Development	Minister for the Agriculture	Minister for the Agriculture
					Dr Zoltán Illés	**Zsolt V. Németh**	**Zsolt V. Németh**
					State Secretary for the Environment	State Secretary for Environment, Agricultural Development and Hungaricums	State Secretary for Environment, Agricultural Development and Hungaricums

Figure 5. Institutional changes in Hungarian environmental policy

The attempt to integrate water management and environmental protection issues into a joint administrative and authority organization was unsuccessful.

In the countries of V4 and the Carpathian Basin, environmental protection is regulated on the ministry level [42–50].

References

[1] Varjú, V. (2010), *A környezeti politika fejlesztéspolitikába történő integrációja – a stratégiai környezeti vizsgálat*.

[2] Bányai, O. (2018), A helyi önkormányzatok környezetvédelmi szabályozása – elmélet és gyakorlat kettőssége. In: Bányai-Barta (ed.), *A települési környezetvédelem elméleti és gyakorlati megközelítései*. Budapest: Gondolat Kiadó. 45–68.

[3] Fodor, L. (2018), Települési környezetpolitika komplex megközelítésben. In: Bányai-Barta (ed.), *A települési környezetvédelem elméleti és gyakorlati megközelítései*. Budapest: Gondolat Kiadó. 69–89.

[4] Pénzes, F. (2018), Helyi szintű döntéshozatal és helyi szintű politikák kialakítása – különös tekintettel a környezeti kérdésekre. In: Bányai-Barta (ed.), *A települési környezetvédelem elméleti és gyakorlati megközelítései*. Budapest: Gondolat Kiadó. 138–154.

[5] Láng, I., Faragó, T., Schmuck, E., Zoltai, N. (2003), *Környezetvédelem Magyarországon és az Európai Unióban* [Environmental protection in Hungary and in the European Union].

[6] Bándi, Gy. (2011), *Környezetjog*. Budapest: Szent István Társulat.

[7] Fodor, L. (2012), *Környezetvédelmi jog és igazgatás*. Debrecen: Debreceni Egyetemi Kiadó.

[8] Faragó, T. (2013), *A hazai környezetügy az elmúlt negyedszázadban*. Budapest: Országgyűlés Fenntartható Fejlődés Bizottsága.

[9] Berg, M. M. (1999), Environmental protection and the Hungarian transition. *The Social Science Journal* 36(2), 227–250.

[10] Miklós, L., Špinerová, A. (2009), The environmental conditions in [the] Carpathian Basin and the environmental policy of [the] European Union. *Acta Universitatis Sapientiae, Agriculture and Environment* 1, 83–92.

[11] Csutora, M., Kerekes, S. (2004), *A környezetbarát vállalatirányítás eszközei*. KJK Kerszöv.

[12] *Magyarország Alaptörvénye* [Fundamental Law of Hungary].

[13] *1995. évi LIII. törvény a környezet védelmének általános szabályairól* [Act LIII of 1995 on the General Rules of Environmental Protection].

[14] *2011. évi CLXXXIX. törvény Magyarország helyi önkormányzatairól*.

[15] *1987. évi VII. törvény a Magyar Népköztársaság minisztériumainak felsorolásáról*.

[16] *1998. évi XXXVI. törvény a Magyar Köztársaság minisztériumainak felsorolásáról*.

[17] *1994. évi LVI. törvény a Magyar Köztársaság minisztériumainak felsorolásáról szóló 1990. évi XXX. törvény módosításáról*.

[18] *2002. évi XI. törvény a Magyar Köztársaság minisztériumainak felsorolásáról*.

[19] *17/2006. (MK 94.) KvVM utasítás a Környezetvédelmi és Vízügyi Minisztérium Szervezeti és Működési Szabályzatáról*.

[20] *347/2006. (XII. 23.) Korm. rendelet a környezetvédelmi, természetvédelmi, vízügyi hatósági és igazgatási feladatokat ellátó szervek kijelöléséről*.

[21] *2010. évi XLII. törvény a Magyar Köztársaság minisztériumainak felsorolásáról*.

[22] *Vidékfejlesztési Minisztérium alapító okirata 2010*.

[23] *Nemzeti Fejlesztési Minisztérium alapító okirata 2010*.

[24] *24/2013. (VII. 12.) NFM utasítás a Nemzeti Fejlesztési Minisztérium Szervezeti és Működési Szabályzatáról*.

[25] *Az Országos Környezetvédelmi, Természetvédelmi és Vízügyi Főfelügyelőség módosításokkal egységes szerkezetbe foglalt alapító okirata 2010*.

[26] *300/2011. (XII. 22.) Korm. rendelet a vízügyi igazgatási szervek irányításának átalakításával összefüggésben egyes kormányrendeletek módosításáról*.

[27] *23/2010. (V. 14.) OGY határozat az Országgyűlés bizottságainak létrehozásáról, tisztségviselőinek és tagjainak megválasztásáról*.

[28] http://www.parlament.hu/internet/plsql/ogy_biz.keret_frissit?p_szerv=&p_ckl=39&p_biz=A345&p_fomenu=10&p_almenu=10&p_rec=&p_egys=&p_nyelv=HU

[29] *2010. évi CXXVI. törvény a fővárosi és megyei kormányhivatalokról, valamint a fővárosi és megyei kormányhivatalok kialakításával és a területi integrációval összefüggő törvénymódosításokról*.

[30] *2014. évi XX. törvény Magyarország minisztériumainak felsorolásáról*.

[31] *152/2014. (VI. 6.) Korm. rendelet a Kormány tagjainak feladat- és hatásköréről*.

[32] *Belügyminisztérium alapító okirata 2014*.

[33] *Nemzeti Fejlesztési Minisztérium alapító okirata 2014*.

[34] *3/2014. (VIII. 1.) FM utasítás a Földművelésügyi Minisztérium Szervezeti és Működési Szabályzatáról*.

[35] *223/2014. (IX. 4.) Korm. rendelet a vízügyi igazgatási és a vízügyi, valamint a vízvédelmi hatósági feladatokat ellátó szervek kijelöléséről*.

[36] *71/2015. (III. 30.) Korm. rendelet a környezetvédelmi és természetvédelmi hatósági és igazgatási feladatokat ellátó szervek kijelöléséről*.

[37] *378/2016. (XII. 2.) Korm. rendelet egyes központi hivatalok és költségvetési szervi formában működő minisztériumi háttérintézmények felülvizsgálatával összefüggő jogutódlásáról, valamint egyes közfeladatok átvételéről*.

[38] *A Köztársasági Elnöki Hivatal I-1/ 05931/2014. számú szervezeti és működési szabályzata*.

[39] *2018. évi V. törvény Magyarország minisztériumainak felsorolásáról, valamint egyes kapcsolódó törvények módosításáról*.

[40] *94/2018. (V. 22.) Korm. rendelet a Kormány tagjainak feladat- és hatásköréről*.

[41] *Az Agrárminisztérium Szervezeti és Működési Szabályzatáról 2018*.

[42] https://www.vlada.cz/en/clenove-vlady/ministerstva/

[43] https://www.premier.gov.pl/en.html

[44] https://www.vlada.gov.sk//current-members-of-the-government/

[45] https://www.federal-chancellery.gv.at/ministries

[46] https://vlada.gov.hr/clanovi-vlade/66

[47] http://gov.ro/en/government/the-cabinet-of-ministers

[48] http://www.uzzpro.gov.rs/english/ministarstva.html

[49] http://www.vlada.si/en/about_the_government/ministries/

[50] https://www.kmu.gov.ua/en/team

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Lettuce production in aquaponic and hydroponic systems

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Abstract. Besides soil cultivation, there are other alternative methods such as the aquaponic and the hydroponic technology.

In our research, four lettuce varieties (‘Edina’, ‘Május királya’, ‘Lollo Rossa’, and ‘Lollo Bionda’) were compared by the use of different systems. In hydroponics, the direct nutrient supply resulted higher leaf weight. In addition, multiple values of nitrate (269.50–406.50 mg kg-1) were measured in this system compared to the aquaponic system (23.25–170.00 mg kg-1). The ‘Lollo Rossa’ stood out with higher element content (Zn, B, and Mg) in both cultivation methods.

In conclusion, it can be stated that higher nutrient content in hydroponics resulted higher leaf weight, but nitrate values were also higher in this unit. Aquaponic technology can be used to produce high-quality (low-nitrate) lettuce with the ‘Lollo Rossa’ and ‘Lollo Bionda’ varieties.

Keywords: soilless cultivation method, variety, nitrite, nitrate

1. Introduction

Lettuce (*Lactuca sativa* L.) is a well-known plant among leaf vegetables. It belongs to the family of *Asteraceae*. The lettuce is rich in nutrient elements for it contains essential elements such as minerals and organic substances [3]. The leafy green vegetables also contain vitamin C, beta-carotene, fibre, folate, and phytonutrients. It can be part of a well-balanced diet since it does not contain cholesterol and is naturally low in calories [2].

Earliness in vegetable forcing has a great importance due to the advantages of high sale prices in the early season. The length of the growing season is determined primarily by the characteristics of the variety, the environmental factors (light, temperature), and the cultivation technology [6].

Besides traditional soil cultivation, there are other alternative methods such as aquaponics and hydroponic gardening (soilless cultivation). Aquaponics is a closed recirculation ecosystem, which is a combination of aquaculture and hydroponics [7]. It is an integrated bio-system where the plants and the fish live in a symbiotic relationship. Wastewater from fish farming contains nitrogenous compounds, especially ammonia, which could be hazardous for fish, even in paucity. Additionally, toxicity depends on the temperature and pH of the water [5]. Therefore, it is a sustainable vegetable farming technique which uses natural biological cycles to supply nitrogen and minimizes the use of non-renewable resources.

Several mediums exist for producing hydroponic crops, for instance: floating raft, nutrient film technique (NFT), rockwool, perlite, or pine bark. On the other hand, there are some critical management requirements to maintain the water quality and the bio-filter nitrification [8]. In hydroponic systems, fertilizers are used to provide nutrients for the vegetables. The root of the plant takes up nutrients from the water in the tank [1].

This cultivation method is able to provide vegetable crops in good quality throughout the year. Furthermore, using this method, the vegetation period can be shortened to 30 days compared to conventional cultivation, which needs to match a longer period (nearly 60 days) for production. These alternative methods are widely used for growers who have limited growing field for vegetable production [4].

2. Materials and methods

The experiment was conducted at the University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Horticultural Science. The aquaponic system belongs to the Department of Animal Husbandry.

For the evaluation, two head-forming (‘Edina’ and ‘Május királya’) and two leaf-forming (‘Lollo Rossa’ and ‘Lollo Bionda’) lettuce were examined in two different soilless cultures (hydroponic and aquaponic).

Sowing into seed tray took place on 14 March 2017. Clay balls were used to fix the root of the plants in both systems. *Pétisol* nitrogen plus fertilizer (18:9:12 NPK + 0.1% microelement) was applied in 0.1% concentration into the Intermediate Bulk Container (IBC) by hydroponic technology. At that time, the pH of the water was 8.05, the temperature was 20.3 °C, and the EC value was 0.96 mS/cm.

In aquaponic production, catfish (*Ameiurus nebulosus*) were cultivated as they adapt to harsh environmental conditions, and they have the ability to tolerate the low oxygen concentration and the range of water salinity.

At the time of transplanting (20 April 2017), the water parameters were the following in the aquaponic system: the temperature of the water was 20.5 °C, the pH was 7.99, and the EC value was 1.01 mS/cm. The transplants were with 5–6 leaves, and the spacing was 25 × 25 cm in the growing area. For the experiment, we used 25 plants/variety.

3. Results and discussions

In springtime cultivation, the head weight (g/plant) and the root weight (g/plant) of the lettuce were measured 5 weeks after transplanting. The head weight of the lettuce is an important factor from the aspect of profitability.

It can be clearly seen in *Table 1* that in the hydroponic system the head weights of varieties were higher than in the case of the aquaponic cultivation method.

Table 1. The head weight (g/plant) and root weight (g/plant) of different varieties

Growing method	Variety	Head weight (g/plant)	Root weight (g/plant)
Aquaponic system	'Edina'	109.04 ± 13.13	20.93 ± 0.81
	'Lollo Rossa'	128.98 ± 15.23	44.13 ± 2.39
	'Lollo Bionda'	97.28 ± 13.59	50.27 ± 9.06
	'Május királya'	131.32 ± 16.79	61.36 ± 6.75
Hydroponic system	'Edina'	190.13 ± 10.09	39.84 ± 4.93
	'Lollo Rossa'	170.77 ± 10.22	54.32 ± 6.41
	'Lollo Bionda'	185.59 ± 19.36	70.31 ± 8.47
	'Május királya'	152.99 ± 22.17	56.13 ± 5.55

In the hydroponic system, one of the head lettuce, 'Edina', showed the highest value (190.13 ± 10.09 g), while the two leaf lettuce ('Lollo Rossa' and 'Lollo Bionda') showed nearly equal values (170.77 ± 10.22 g and 185.59 ± 19.36

g). In the aquaponic system, again one of the head lettuce (‘Május királya’) showed the highest value (131.32 ± 16.79 g).

Evaluating the nitrate and mineral element content in water (*Table 2*), we can state that there was a higher nitrate and nitrite content (31.20 and 1.43 mg l^{-1}) in the hydroponic system. In both growing systems, high calcium (191.00 and 231.00 mg l^{-1}) content was measured. Potassium and sulphur content were several times higher in the aquaponic than in the hydroponic system.

Table 2. Nitrate, nitrite, and mineral element content (mg l^{-1}) in water samples

Parameter mg l^{-1}	**Hydroponic**	**Aquaponic**
Nitrate	31.20	0.14
Nitrite	1.43	0.06
B	0.26	0.10
Ca	191.00	231.00
Cu	0.80	0.08
Fe	0.32	0.19
K	95.10	195.00
Mg	53.50	49.40
Na	27.40	29.80
P	9.70	5.11
S	30.70	87.10
Zn	0.10	0.09

There was no significant difference between the technologies in the dry matter content (*Table 3*). Regarding the varieties, we can state that the ‘Lollo Rossa’ (leaf lettuce) showed the highest dry matter content (87.48 ± 0.08% and 8.51 ± 0.36%) in both systems. The variety and the cultivation method can influence the dry matter content. The chemical composition of the plants influences the quality of the products, and so the quality is determined by both organic and mineral components.

The higher nitrate and nitrite content in leaf vegetables can result lower quality. The nitrate content was several times higher in the hydroponic cultivation method than in aquaponics, which difference was also measured by water samples. For both gardening methods, the ‘Edina’ (head lettuce) showed the highest value of nitrate (170 ± 48.08 mg kg^{-1} and 406.50 ± 4.95 mg kg^{-1}).

Table 3. Nitrate and nitrite (mg kg^{-1}) and dry matter content (%) in the raw material

Growing method	Variety	Dry matter content %	Nitrate mg kg^{-1}	Nitrite mg kg^{-1}
Aquaponic system	**‘Edina’**	5.76 ± 0.74	170 ± 48.08	1.39 ± 0.04
	‘Lollo Rossa’	7.48 ± 0.08	23.25 ± 4.31	0.53 ± 0.02
	‘Lollo Bionda’	6.52 ± 0.06	73.40 ± 5.52	0.81 ± 0.01
	‘Május királya’	6.99 ± 1.49	53.55 ± 0.49	0.68 ± 0.03
Hydroponic system	**‘Edina’**	5.62 ± 0.11	406.50 ± 4.95	4.91 ± 0.11
	‘Lollo Rossa’	8.51 ± 0.36	325.50 ± 16.26	2.95 ± 0.28
	‘Lollo Bionda’	6.55 ± 0.66	299.00 ± 16.97	3.10 ± 0.08
	‘Május királya’	5.42 ± 0.39	269.50 ± 28.99	2.43 ± 0.03

A similar tendency was also measured among the genotypes and the systems by nitrite. The ‘Edina’ variety produced the highest value in the aquaponic (1.39 ± 0.04 mg kg^{-1}) and in the hydroponic system (4.91 ± 0.11 mg kg^{-1}) as well.

Boron can help the nutrition uptake of plants. There was no significant difference between the various technologies for this microelement supply. However, differences were found in the boron content between the varieties (*Table 4*), considering that the highest boron content was detected in leaf-forming varieties (‘Lollo Rossa’ and ‘Lollo Bionda’) in both systems.

Magnesium is one of the most important mineral elements as it is necessary for many biochemical processes. It also has to be mentioned that the magnesium is the central atom of the chlorophyll, which plays a key role in photosynthesis.

Concerning the magnesium content, we measured higher values in the hydroponic system – with the exception of ‘Május királya’, where this value was lower. The varieties with an open head (‘Lollo Rossa’ and ‘Lollo Bionda’) have higher magnesium content (293.50 ± 10.61 mg kg^{-1} and 264.00 ± 28.28 mg kg^{-1}) than head-forming varieties (‘Edina’ and ‘Május királya’) in the hydroponic system (215.00 ± 1.41 and 178.50 ± 13.44 mg kg^{-1}).

Table 4. Boron and magnesium (mg kg^{-1}) content in the raw material

Growing method	Variety	B mg kg^{-1}	Mg mg kg^{-1}
Aquaponic system	**'Edina'**	1.63 ± 0.11	200.00 ± 32.53
	'Lollo Rossa'	2.25 ± 0.05	231.50 ± 0.71
	'Lollo Bionda'	2.17 ± 0.21	204.00 ± 4.24
	'Május királya'	1.65 ± 0.44	203.00 ± 38.18
Hydroponic system	**'Edina'**	1.67 ± 0.01	215.00 ± 1.41
	'Lollo Rossa'	2.97 ± 0.09	293.50 ± 10.61
	'Lollo Bionda'	2.28 ± 0.25	264.00 ± 28.28
	'Május királya'	1.51 ± 0.08	178.50 ± 13.44

Copper as a constituent of enzymes participates in the respiratory metabolism and electron transport. It is also involved in photosynthesis and carbohydrate as well as protein synthesis. The copper content of the water in the hydroponic system was ten times higher than in aquaponics, which clearly appeared in the copper supply of plant samples. It can be stated that leaf lettuce varieties have a higher mineral content (*Table 5*).

In addition, the iron content also confirms this as the genotypes showed higher value in the hydroponic system, which partly appeared in the iron content of the hydroponic water. Moreover, the iron is essential for the processes of assimilation, photosynthesis, and protein synthesis.

Regarding the zinc supply, the 'Lollo Rossa' (1.63 ± 0.09 and 1.68 ± 0.01 mg kg^{-1}) had the highest zinc content among the varieties by the growing methods.

Table 5. Copper, iron, and zinc element content (mg kg^{-1})

Variety	Growing method	Cu mg kg^{-1}	Fe mg kg^{-1}	Zn mg kg^{-1}
'Edina'	**A**	0.73 ± 0.05	47.95 ± 5.15	1.43 ± 0.17
	H	7.34 ± 0.17	51.20 ± 1.00	1.02 ± 0.05
'Lollo Rossa'	**A**	0.62 ± 0.02	64.00 ± 0.90	1.63 ± 0.09
	H	10.80 ± 0.30	77.70 ± 1.40	1.68 ± 0.01
'Lollo Bionda'	**A**	0.43 ± 0.01	59.20 ± 0.90	1.18 ± 0.04
	H	12.50 ± 1.00	78.90 ± 4.50	1.03 ± 0.05
'Május királya'	**A**	0.46 ± 0.03	61.30 ± 8.80	1.10 ± 0.16
	H	9.99 ± 0.21	52.30 ± 1.70	0.80 ± 0.04

A – Aquaponic system
H – Hydroponic system

Sulphur and phosphorus are important components of organic compounds. According to the data, it can be concluded that the sulphur content of leaves was almost two times higher in the aquaponic than in the hydroponic system (*Table 6*).

There was no noticeable tendency for the phosphorus content.

Table 6. Sulphur and phosphorus (mg kg^{-1}) content in the raw material

Variety	Growing method	S mg kg^{-1}	P mg kg^{-1}
'Edina'	**A**	106.75 ± 10.25	317.50 ± 33.50
	H	58.60 ± 2.70	278.00 ± 2.00
'Lollo Rossa'	**A**	18.30 ± 1.60	330.00 ± 1.10
	H	8.69 ± 0.19	388.50 ± 11.50
'Lollo Bionda'	**A**	55.50 ± 2.80	289.50 ± 10.50
	H	27,15 ± 1,25	233.50 ± 20.50
'Május királya'	**A**	77.80 ± 11.30	289.50 ± 35.50
	H	43.25 ± 1.15	329.50 ± 16.50

A – Aquaponic system
H – Hydroponic system

4. Conclusions

In the experiment, two head-forming (‘Edina’ and ‘Május királya’) and two leaf-forming (‘Lollo Rossa’ and ‘Lollo Bionda’) lettuce were examined in two different soilless cultures (hydroponic and aquaponic).

It can be stated that the head weights of the varieties were higher in the case of the hydroponic growing method than in the aquaponic system. The ‘Edina’ (head lettuce) showed the highest value (190.13 ± 10.09 g), while the two leaf lettuce (‘Lollo Rossa’ and ‘Lollo Bionda’) showed nearly equal values (170.77 ± 10.22 g and 185.59 ± 19.36 g) in the hydroponic system.

Furthermore, in this system (hydroponic), a higher nitrate content (31.20 mg l^{-1}) was measured compared to the aquaponic one. The nitrate content was several times higher in the plants in the hydroponic system, which difference was also measured in water samples. Regarding dry matter content, the ‘Lollo Rossa’ (leaf lettuce) produced the highest content in both aquaponic and hydroponic systems (7.48 ± 0.08% and 8.51 ± 0.36%). Moreover, varieties with an open head (‘Lollo Rossa’ and ‘Lollo Bionda’) contain higher amounts of iron compared to those head-forming (‘Edina’ and ‘Május királya’) by hydroponic cultivation. Regarding the other mineral elements (Zn, B, Mg), the ‘Lollo Rossa’ stood out with higher element content in both cultivation methods.

Finally, we can conclude that the production in the hydroponic system is more profitable (higher head weight) than the aquaponic system. The use of wastewater with the aquaponic system is more favourable for lettuce growing due to the non-chemical production. The productivity can be a bit lower, but the raw material is healthier and without any harmful compound.

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References

[1] Ako, H., Baker A. (2009), *Small-scale lettuce production with hydroponics or aquaponics*. College of Tropical Agriculture and Human Resources (CTAHR). University of Hawaii at Manoa. SA-2. pp. 1–7.

[2] Bunning, M., Kendall, P. (2012), Salad greens: Health benefits and safe handling. *Food and Nutrition Series, Health*. Fact Sheet No. 9.373. Colorado State University Extension. 5/07. Revised 06/12.

[3] Noumedem, J. A. K., Djeussi, D. E., Hritcu, L., Mihasan, M., Kuete, V. (2017), Lactuca sativa. In: *Medicinal spices and vegetables from Africa. Therapeutic Potential Against Metabolic, Inflammatory, Infectious and Systemic Diseases*. 437–449.

[4] Pattillo, A. D. (2017), An overview of aquaponic systems: Hydroponic components. *NCRAC Technical Bulletin Series*. USDA. 123/10 p.

[5] Salam, M. A., Asadujjaman M., Rahman, M. S. (2013), Aquaponics for improving high- density fish pond water quality through raft and rack vegetable production. *World Journal of Fish and Marine Sciences* 5(3), 251–256.

[6] Slezák, K., Jezdinsky, A. (2013), A zöldséghajtató berendezések hasznosítása. *Agrofórum* 24(2), 22–24.

[7] Turkmen, G., Guner, Y. (2010), Aquaponic (integrating fish and plant culture) systems. In: *International Symposium on Sustainable Development*, Science Book. 657–666.

[8] Tyson, R. V., Treadwell D. D., Simonne, E. H. (2011), Opportunities and challenges to sustainability in aquaponic systems. Reviews. *Hort. Technology* 21(1), 6–13.

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Critical approach to landscape-ecological mainstream topics

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Abstract. Nowadays, changes in environment have become characteristic of notorious mainstream political topics, with a corresponding moral, political, and financial support. The presented article deals with the landscape-ecological scientific aspects of climatic changes and of ecosystem services. The research of both phenomena is based on the complex investigation of the geosystem and, as a second step, on the scientifically-based interpretation of the obtained results. The problem resides in the question concerning the capability of scientific institutions and teams to deal with these topics with scientific profoundness, taking into account intensive public pressure and high expectations.

Keywords: science, governance, geosystems, climatic changes, ecosystem services

1. Introduction

The recent practical requirements towards environmental and landscape sciences drive scientists to define the object of interest – the **landscape** – as well as to establish its **structure and functions** in conformity with the forms acceptable by the policy, decision-making, planning, and projecting practice. Utmost consideration should be devoted to the interpretation of objective properties of the material reality of this object towards their application to current topics, guarding the scientific aspects of this application in any trendy challenges.

During the development of landscape sciences, several definitions of landscape were formulated. Nowadays, we can differentiate between two groups of considerations on the term landscape. The first group is represented by geographers and landscape ecologists and can be characterized as a geosystem-based approach. The second one is popular among highly different groups of landscapers but also of social scientists, architects, and others who perceive the landscape as a cultural-historical phenomenon, a value of the environment. Such a differentiation is nothing new; several authors pointed out that the landscape can be understood in two ways: as a hard material entity and as a perception of the reality [27]; even as a *genre de vive* [35].

The definition of the landscape as a geosystem was promoted by scientific centres in Central Europe [28], where the main trend was presented by German landscape ecologists and geographers and by the Soviet landscape sciences school: the "landshaftovedenyje" [32]. Another group of scientists, mostly from Western Europe and North America, developed another significant landscape ecological school, based on the research of the spatial pattern of the land cover [7, 34]. Of course, those schools were never separated and never expressed any opposition. The third considerable stream – at the same time, the newest one – of the friends and lovers of the landscape prefers the understanding of the landscape as a picture, a "scape" of the land, its cultural heritage, beauty, and values on the basis of perception [15].

This diversity of approaches also shows somehow a kind of an "identity crisis" of the landscape ecology at the turn of the millennia [36] and a considerable shift of the popularity of the understanding of the landscape concept from a material approach towards its understanding as picture, aspect, and values on the basis of perception.

Considering the legacy of all above mentioned approaches to the landscape, the basic question concerning the topic of this paper reads as follows: which approach could serve as a real scientific basis for two selected mainstream topics – climatic changes and ecosystem services? It is to be underlined that both topics, without any doubt, are of high complexity level.

Of course, we prefer the material – geosystem – approach.

2. Materials and methods

The article has a theoretical-methodical character. The method of the work is a critical comparison of theoretical studies on geosystems and ecosystems with a recent series of works dealing with mainstream topics [4], [5], [30]. The methodical procedure is based on the knowledge of a vast literature in this field as well as on own methodical and practical experiences in this field [17], [22]. The absolute theoretical-methodical basis of the work is the definition of the main aspects of the **landscape as a geosystem** concerning the climatic changes and ecosystem services as follows:

The geosystem-based definition of the landscape is anchored on the general system theory [1], universally explained with very simple words as the set of the components of the geosphere and their mutual relations (e.g. [19], [28], [29] and also Act No. 50/1976 Zb. on territorial planning and building code as amended by Act of NC SR No. 237/2000 Z.z.). This theory ranks among the elements of the geosystem, the geological substratum, the soils, the georelief, the waters, the atmosphere, the land cover, and the man-made objects. These elements are in permanent interrelation and interaction as an integrated system, never isolated. In spite of this obvious fact, the elements of the same material object are subjects to particular sciences and also to particular sectoral managements. Of course, we insist on integrated research, management, planning, and assessment, including the concept of the ecosystem services [9].

The integrated approach is actually not a novelty. Chapter 10 of Agenda 21 from Rio Summit 1992 named "Integrated approach to the management of land resources" stated that the only space we had must be accepted by each sector. On the other hand, it is to be mentioned that not too much has happened since the Rio Summit. In reality, the above mentioned theory – the landscape as integrated entity and the need for integrated management – is generally accepted, but the analytical management of elements and the sectoral approach still prevail.

The decisive aspect of the geosystem approach for the evaluation of climatic changes, ecosystem services, and other topics is the definition of the different content and role of the primary, secondary, and tertiary landscape structure for this evaluation. Landscape is also considered as a complex natural resource which has a potential to fulfil different functions and meet different needs of the humans exactly because of its complex character – never as isolated elements of this system [10].

Considering the physical character and the role of the elements for the land use, **three substructures** of the landscape can be defined for the landscape management and planning [21], [22]:

- Primary landscape structure as a set of material elements of the landscape and their relations, basically the abiotic elements as the geological base and subsoils, soils, waters, georelief, and air.
- Secondary landscape structure is created by 3 groups of elements, the human-influenced, reshaped, and created material landscape elements that currently cover the Earth's surface.
- The tertiary (socioeconomic) landscape structure consists of a considerable number of socioeconomic factors/phenomena, which have very specified intangible and non-material properties such as the protection and other functional zones of nature and natural resources protection, hygienic and safety zones of industrial and infrastructure

objects, declared zones of specific environmental measures, administrative boundaries, etc.

All these structures have decisive influence on all functions and utility values of the landscape, including the climatic changes, the realization of ecosystem services, and other topics, but in different ways.

From the point of view of environmental care, including the adaptation to climatic changes and the utilization of ecosystem services, the most important are the primary and secondary/current landscape structures because their disruption causes all the ecological problems.

3. Results and discussions

3.1 The geosystem approach to the evaluation of climatic changes

Slovakia produces less than 1% of EU's total GHG emissions but suffers the same amount of the impacts of the climatic changes as the big emitters. Therefore, it might be obvious that the adaptation policies should be more emphasized than the struggle against emissions. How to approach this problem?

In our conditions, the crucial factor of climate changes is the system of water circulation. In this respect, the geosystem as a whole and its elements (see above) plays the role of "vessel" for the water. This vessel is the river basins for surface water, and the geological substratum creates the aquafer for underground water.

This vessel decides where and how much water is present in or absent from the landscape.

In respect to climatic changes, the most dangerous factor of climatic changes in Slovakian natural conditions is the frequent sudden intensive rains and the subsequent **quick and heavy run-off**. The run-off then activates the whole chain of disastrous consequences such as:

- physical disasters as: flash floods on small rivers → soil erosion → accumulation → silting the reservoirs → less water capacity of the watershed and other damages to the human environment;
- ecological consequences as: unbalanced water system → overwhelming irrigation

  or the opposite: draught → unfavourable changes of ecosystems.

Thus, the basic questions should be formulated as follows:

a) What causes the initial problem? Is it the rain?

Of course, the amount of run-off is done by rain. But the problems mentioned above are strongly conditioned by the "vessel", by the natural properties of all elements of the geosystem. These are the texture and structure of the geological substratum, the grain size of the soils, the topographic position, the slope, the vertical and horizontal curvature of the georelief, the shape of the watershed, the vegetation, the land cover, land-use, and anthropic objects – virtually the whole geosystem.

b) The other side of the question is: Are researches oriented towards this complex direction? Or, with other words: how many projects are oriented towards research on the whole geosystem and how many are oriented towards single components of the landscape, e.g. to atmospheric issues, rain, surface waters, subsurface waters, floods, draught, erosion, accumulation, etc.? Unfortunately, the last mentioned case is more common. And what is the situation with support provided by different granting systems? E.g. there are numerous projects with very different approaches concerning the waterlogging of agricultural territories as well as other projects targeting drought; or even both, waterlogging and drought may happen in the same territory, on the same fields, within the same geosystem, both problems being conditioned by exactly the same elements of the geosystem.

c) What is the routine management of these problems – an integrated approach or a sectoral one? Unfortunately, in spite of the positive development in legislation and methods, practice shows that sectoral approach still prevails.

A very specific symptomatic example is the management of the rivers and floods. Nobody doubts that floods and their management is an integrated issue *par excellence*. Nevertheless, the rivers and floods are assigned to the competence of water management authorities and companies. But these authorities dispose over the waters alone and neither over the territory around them nor the river basins nor the "vessel"! The territories of basins are in the ownership of most diverse entities – they mostly belong to forest and agricultural land owners; so, water managers are many times powerless in enforcing the measures that would lead to actual results.

We could mention numerous similar examples of problems concerning river basin management, water reservoir management, water pollution, and lake and wetland silting.

3.2 The geosystem approach to the evaluation of the ecosystem services (hereinafter as ESS)

This problem area is very different from the previous ones. The common feature of both is that the ESS concept is a complex problem just as climatic changes, and it would also need an integrated approach to research as well as to management. The basic problem is also similar, namely that the integrated approach is lacking.

Let us clarify scientifically the content of two basic terms related to this mainstream topic:

- what is the object of the studies on **"ecosystem"** services?
- what are the **"services"** of ecosystems?

3.2.1 Is the object of the ESS really the "ecosystem"?

There cannot be any objection against the fact that the spatial-material-functional bearer of the ecosystem services is the landscape as a geosystem. What is then the relation between geosystems and the ecosystem with respect to the ESS?

Since its introduction by Tansley [33], the definition of the ecosystem has been unaltered: the ecosystem is the system of the "house" and its "inhabitants". Its material components are the abiotic surroundings (physiotop) and the biocenosis. Looking at the definition of the geosystems (see above), the elements of both the ecosystems and geosystems are the same. The difference is only the approach towards their investigation. The ecosystem approach centralizes one element – the biota – and analyses the relation of the biota to other elements, whereas the geosystem approach – theoretically – considers all elements as having equal ranks, without centralizing any one of them [29], [30].

So, the first crucial fact to be underlined is that both systems include **all abiotic and biotic elements**.

Another important aspect of the ecosystem concept is that it is an open system of the circulation of materials, energy, and information. This open system means also that the ecosystem does not have any borders within the landscape space since this circulation is present everywhere up to the limits of the geosphere.

So, the second crucial aspect concerns exactly the limits of the ecosystems. The ecosystem is an **open system without limits**, but the definition of the ESS should practically relate to concrete demarcated spatial segments of the landscape.

Respecting the above mentioned definition, when analysing the concrete content of numerous present studies on ESS, a few basic problems are to be highlighted:

a) In the majority of the present studies – including the basic publications [3] as well as the results of a broadly scoped international project on ESS, which included 27 case studies [4], [5], [30] –, the objects of the ESS are not really the ecosystems! In most cases, these are the highly simplified elements of land cover; in better cases, the simplified types of vegetation formations [2]. All these are only the elements of the secondary landscape structure.

b) Of course, each element of land cover is at the same time also an ecosystem; nevertheless, the mentioned works evaluate only the physiognomic or the simple biotic characteristics of the selected spatial elements. But the decisive component of the ecosystems for the "production" of the ESS – the most stable structure of the ecosystem – is the abiocomplex (primary landscape structure), creating the permanent condition for all ESS, including the conditions for the renewal of the biota and thus the ESS that these studies have many times completely ignored [9].

So, from a scientific point of view – considering the goals of the ESS concept –, the most correct setting as for the object of the ESS would be the **ecotop** [10], [28], [29], which is defined as the physiotop + biocenosis. Ecotops respond to both major requirement towards the object of the ESS – they have a complex content and exact borders. Landscape-ecological complexes are also suitable operational units for the ESS, being spatial projections of the geosystem types [19], [22].

Nothing new! The definitions of the basic terms as ecosystem and geosystem have not changed for decades; they are still valid. However, the important thing is to recognize them and apply them in the right way in new mainstream topics as well [25].

3.2.2 What are the "services" of ecosystems? When do the properties of the ecosystems become "services"?

The ESS are divided in most of the cases according to the commonly accepted subdivision of CICES – Common International Classification of Ecosystem Services [12], [24]. According to the theoretical imaginings, the conception of ESS should be achieved as the final result of the economic evaluation of the services [3], [24]. The final practical goal is to define the complex economic value of the ecosystem as an argument by the decision-making process [8].

If we look at the real material-energetic matter of the ecosystems, this subdivision shows several discrepancies. Also, the real studies on the ESS display the same problems [4], [5], [16], [31], [32]. According to the material-energetic properties of ecosystems and to the functions of ecosystems, the results of the evaluations in the studies on ESS – which were entitled as ecosystem "services" – can be ranked at least into 4 groups:

a) **"Products"** of natural functions of ecosystems. They depend on the circulation of material, energy, and information through the geosystem as a whole. These are in constant operation – humans and other components of the ecosystems "consume" them without any action of their own [6][18].

According to CICES, they are marked as regulatory and supporting ESS, e.g. production of oxygen, absorption of CO2, regulation of run-off, geosystems, hygienic properties of ecosystems, non-productive function of the forests, support of ecological stability, bearing capacity of the landscape, or biodiversity [18], [13], [14].

b) **Potentials** of the ecosystems as utility values of ecosystems for humans. In CICES, these are marked as productive ESS. They depend crucially on abiotic conditions – geological substratum, georelief, soils, waters, and climate [10] based on the bonity of the soils, relief, waters, and climate. The concrete delivery of production is secondary; it depends on how the primary landscape structure is utilized, what the current land cover/land is, and how the current ecosystem as a whole functions, e.g. bioproductive potential for crops, melliferous potential, pharmaceutical potential, or air-cleaning potential [18]. It means that the same abiotic conditions can "produce" – have potential – for very different productions. Nevertheless, potentials should be considered just as preconditions for whatever utilization, not service.

c) **Suitability** of landscape-ecological complexes for utilization by humans. This is based on both previous concepts: natural functions and the utility potentials of ecosystems. The utility values of the ecosystems can be considered for technological-localizing criteria of suitability, mostly based on abiotic properties (primary landscape structure), whereas the natural function of ecosystems for selective criteria of suitability. E.g. a certain soil type may present high potential for the production of both food crops and timber, but its final suitability for such production is defined selectively, according to land cover or biota (secondary landscape structure). In cases when the same productive soil type is in forests, meadows, or fields, its final suitability depends also on evaluation if the non-productive function of the whole ecosystem is more or less valuable than the production of biomass [24].

d) **Offered and realized benefits** of ecosystems for humans. These benefits become reality when humans start to utilize them. They can issue from all the properties, functions, and potentials of ecosystems as an "**offer**" of the ecosystems. They become "services" in cases when humans express the "demands" towards these benefits. These types of the ESS are ranked in CICES among cultural-societal and supporting ESS, e.g. offer of landscape properties for recreation, science, education, and intellectual services. The realization of these services also needs – besides the ecological/ environmental values – the appreciation of the realization criteria based on the tertiary landscape structure such as the legal provisions on nature conservation areas and protected monument zones [22]. The character of the cultural-societal services of ecosystems displays also the so-called importance of ecosystem for human needs [18], [19].

Another type of these services are used natural resources such as products of the material elements of geosystems for humans, e.g. water supply, mineral resources – in CICES, these are ranked among productive ESS. Nevertheless, until these resources are not utilized, they remain just potentials. Another issue is their protection by legal provisions by declaration of protective areas and zones. These zones are considered for realization criteria (based on the tertiary landscape structure).

We might conclude that in practical case studies on the ESS there are several discrepancies and scientific problems in defining the main concepts of the ESS: the "ecosystem" and the "services".

4. Conclusions

As it has become obvious, the central question is quite complex. Therefore, it is inevitable to define the character and content of the assessed ESS for each concrete work on the basis of deep knowledge of the geosystem, its elements, and the various properties of primary, secondary, and tertiary landscape structure. According to our experiences based on ESS assessment in concrete territories, we consider as most correct the approach of evaluation of the suitability of landscape ecological complexes for human use since this procedure includes the evaluation of all three landscape structures according to all technological (abiotic), selective (biological-ecological), and realization (socioeconomic) criteria [23].

The diversity of understanding the object of evaluation of the ESS as well as the diversity of the definition of ESS also presume a big diversity of the methods of the evaluation of ESS. Actually, there is no generally accepted method of the ESS evaluation but very different methods of the assessment of the utility functions and values of the nature and landscape – older or newer –, which results are renamed as ESS [20], [26], [16], [4], [5], [30]. However, the potential of older methods is not yet exhausted – they are well elaborated and are many times much more accurate than present-day methods that use just the estimates of the obvious functions of landscapes. Anyway, the presented article does not deal with these problems.

As a general conclusion, we underline the following basic aspects:

The source of **all** above mentioned – seemingly different – consequences of climatic changes from floods to drought as well as the provision of ecosystem services is the circulation of material, energy, and information through the **geosystem as a whole.** This conditions the behaviour of the system and the consequences of the interconnections and interrelations of the elements of the geosystem. Therefore, the scientifically based solution of these problems needs:

– a complex, scientifically based geosystem approach to **basic research**;
– scientifically based procedures for the **application** of the results of basic science;
– scientifically based **interpretations** of the purpose-oriented characteristics also in cases of much pressure on the part of the public regarding the results in mainstream topics;
– **integrated** – not sectoral – **management** of the landscape as a whole in all mainstream problems.

All above mentioned preconditions have sufficient theoretical-methodical basis, legal support, good planning and projecting tools. The only insufficiency concerns their integration.

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References

[1] Bertalanffy, L. von, (1968), *General system theory. Foundations, development and applications*. New York: George Brazileer. Penguin Books.
[2] Burkhard, B., Kroll, F., Müller, F., Windhorst, W. (2009), Landscapes' capacities to provide ecosystem services – A concept for land-cover-based assessments. *Landscape Online* 15, 1–22.
[3] Costanza, R. et al. (1997), The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260.
[4] Dick, J. et al. (2014), Ecosystem services: A rapid assessment method tested at 35 sites of the LTER-Europe Network. *Ekológia (Bratislava)* 33(3), 217–231.
[5] Dick, J. et al. (2018), Stakeholders' perspectives on the operationalisation of the ecosystem service concept: Results from 27 case studies. *Ecosystem Services* 29, 552–565.
[6] Eliáš, P. (2010), Od funkcií vegetácie k ekosystémovým službám. *Životné prostredie* 44(2), 59–64.
[7] Forman, R. T. T., Godron, M. (1981), Patches and structural components for landscape ecology. *BioScience* 31, 733–740.
[8] Gomez-Baggethum, E., Barton, D. (2013), Classifying and valuing ecosystem services for urban plannig. *Ecological Economics* 86, 235–245.
[9] Grunewald, K., Bastian, O. (eds.) (2015), Ecosystem services – Concepts, methods and case studies. Berlin–Heidelberg: Springer-Verlag.
[10] Haase, G. (1978), Zur Ableitung und Kennzeichnung von Naturraumpotentialen. *Petermanns Geogr. Mitt*. 122(2), 113–125.
[11] Haase, G. (1980), Izučenie topičeskich i choričeskich struktur, ich dinamiki i razvitija v landšaftnych sistemach. *Structura, dinamika i razvitije landšaftov.* Moskva: Institut geografii AN SSSR. 57–81.

[12] Haines-Young, R., Potschin, M. (2013), *Common International Classification of Ecosystem Services (CICES), consultation on version 4*. August–December 2012, EEA Framework Contract No EEA/IEA/09/003.

[13] Halada, Ľ., Topercer, J., Kartusek, V., Mederly, P. (1995), Systém ekologickej kvality krajiny – ďalší prístup k manažmentu krajiny. *Životné prostredie* 29(5), 271–273.

[14] Hrnčiarová, T. (1998), Ekologická a kultúrna významnosť krajiny vyplývajúca z legislatívnych predpisov. In: Izakovičová, Z., Kozová, M., Pauditšová, E. (eds.), *Implementácia trvalo udržateľného rozvoja*. Bratislava: ÚKE SAV. 99–103.

[15] Hynek, A. (2010), Krajina: objekt, nebo konstrukt? In: Herber, V. (ed.), Fyzická geografie a kulturní krajina. *Fyzickogeografický sborník* 8, 138–142. Brno: Masarykova Univerzita.

[16] Izakovičová, Z. et al. (2012–2017), Funkčnosť prírodných kapitálov a ekologických služieb: od konceptu k reálnej aplikácii (OpenNESS), Projekt EK 308428, Ústav krajinnej ekológie SAV Bratislava, SYKE Helsinki.

[17] Izakovičová, Z., Świader, M. (2017), Building ecological networks in Slovakia and Poland. *Ekológia (Bratislava)* 36(4), 303–322.

[18] Jurko, A. (1990), *Ekologické a socioekonomické hodnotenie vegetácie*. Príroda, Bratislava.

[19] Krcho, J. (1968), Prírodná časť geosféry ako kybernetický systém a jeho vyjadrenia v mape. *Geografický časopis (Bratislava)* 20(2), 115–130.

[20] Lamarque, P., Que-Tier, F., Lavorel, S. (2011), The diversity of the ecosystem services concept and its implications for their assessment and management. *Comptes Rendus Biologies* 334, 441–449.

[21] Miklós, L., Izakovičová, Z. (1997), *Krajina ako geosystem*. Bratislava: VEDA.

[22] Miklós, L., Kočická, E., Izakovičová, Z., Kočický, D., Špinerová, A., Diviaková, A., Miklósová, V. (2019), *Landscape as a geosystem*. Springer.

[23] Miklós, L., Špinerová, A. (2019), Landscape-ecological planning LANDEP. Springer.

[24] Millennium Ecosystem Assessment. (2005), Ecosystems and human well-being: Synthesis. Washington, DC: Island Press–World Resources Institute.

[25] Mizgajski, A., Markuszewska, I. (eds.). (2010), *Implementation of landscape ecological knowledge in practice. The problems of landscape ecology, vol. XXVIII*. Poznań: Polish Association for Landscape Ecology, Wydawnictvo Naukowe, Adam Miczkiewicz University.

[26] Nahlik, A. M., Kentula, M. E., Fennessy, M. S., Landers, D. H. (2012), Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. *Ecological Economics* 77, 27–35.

[27] Naveh, Z., Liebermannn, A. (1994), *Landscape ecology – Theory and application*. Second edition. New York–Berlin–Heidelberg: Springer-Verlag.

[28] Neef, E., Richter, H., Barsch, H., Haase, G. (1973), Beitrage zur Klärung der Terminologie in der Landschaftsforschung. Beitrag'd. Institut d. Geographie and Geoökologie d. Akad. d Wiss. d. DDR. *Beilage zu Práce a materiály z biológie krajiny* 20.

[29] Preobrazhensky, V. S. (1983), A system orientation of landscape research in geography and its present-day realization. In: Drdoš, J. (eds.), *Landscape synthesis, geoecological foundations of the complex landscape management*. Bratislava: VEDA. 31–36.

[30] Saarikoski, H. et al. (2018), Institutional challenges in putting ecosystem service knowledge in practice. *Ecosystem Services* 29, 579–598.

[31] Šedivá, A., Izakovičová, Z. (2015), Assessment of representative landscape types of Skalica district. *Ekológia (Bratislava*) 34(4), 329–338.

[32] Sochava, V. B. (1977), *Vvedenje v učenije o geosystemach* [in Russian]. Novosibirsk: Nauka.

[33] Tansley, A. G. (1935), The use and abuse of vegetational concepts and terms. *Ecology* 16, 284–307.

[34] Turner, M. (1990), Spatial and temporal analysis of the landscape patterns. *Landscape Ecology* 4(1), 21–30.

[35] Vidal de la Blache, P. (1922), Principes de géographie humaine. Source: *Encyclopaedia Britannica* – http://www.britannica.com/EBchecked/topic/627886/Paul-Vidal-de-la-Blache.

[36] Wu, J. (2013), Key concepts and research topics in landscape ecology revisited: 30 years after the Allerton Park workshop. *Landscape Ecology* 28, 1–11.

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Investigation of the possibility of green bean production under unfavourable agro-ecological conditions in lysimeters

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Abstract. There are extended agricultural areas in the world that can be utilized only with irrigation for crop production. Improper irrigation may induce unfavourable processes in the soil (e.g. secondary salinization). To investigate this problem existing in Hungary as well, 12 simple drainage lysimeters – which are useful equipment for the investigation of the water and salt balance of the soil – were used in an irrigation experiment in the Research Institute of Karcag. The basic goal was to investigate the possibility of the production of a salt-sensitive crop (green bean) in areas with unfavourable agro-ecological conditions. 6 lysimeters were irrigated with deionized water, while the other 6 with saline water of 1,600 mg/l salt content. We also used a soil conditioner (Neosol) during the experiment. Analysing the effect of the irrigation quality on the plant height of green beans, it can be established that the plants irrigated with deionized water were averagely 5.3 cm taller than the plants irrigated with saline water. Similar tendencies were characteristic of the average biomass (deionized: 93.5, saline: 62.5 g), the average root mass (deionized: 9.5 g, saline: 8.2 g), the number of pods (deionized: 17.1, saline: 11.9), and the pod yield (deionized: 137.9 g, saline: 85.9 g) values. However, all these values can be improved by soil conditioning combined with the optimization of irrigation.

Keywords: irrigation, secondary salinization, vegetable production

1. Introduction

Nowadays, the presence of weather extremes is becoming more and more frequent. Climate is the primary determinant of agricultural productivity; therefore, understanding and estimating the effects of climate change on food production and supply are the responsibility of humans [1].

For cropping systems, one of the most important tasks to maintain the quality of producing is perhaps changing varieties/species to those which can adapt to changes more efficiently (e.g. better resistance to heat shock and drought). Furthermore, instead of using "water-waste" technologies, conserving soil moisture could result in a more productive agricultural system in spite of the unfavourable agro-ecological conditions [2].

In Hungary, especially on the Great Plain (which is the central area of crop production in the country), climate changes affect agricultural production negatively as well. Unfortunately, drought is more and more frequent in the summer period, and thus irrigation is essential for the vegetables with high water demand. Beyond the unfavourable ecological conditions, the frequency of weather extremes (extra-dry or -wet periods) is higher compared to the other regions of Hungary.

Irrigation makes agricultural production safer and more intensive, though it is well known that it can also have negative effects on the soil. Improper irrigation practice can cause soil degradation such as decrease in fertility. This is an extended problem in Great Cumania (a subregion in Hungary in the Trans-Tisza region) as half of its territory is covered primarily by salt-affected soils, while the other half is covered by better soils (chernozems); however, these soils are susceptible to secondary salinization induced by irrigation. According to Szabolcs et al. [6, 7], secondary salinization has two reasons: salt accumulation due to the application of saline water or the rise of the salty groundwater transporting salts up to the upper soil layers.

Our research work is based on a previous review which focused on the importance of irrigation in the droughty periods; however, the quality of water used for irrigation in the hobby gardens around Karcag can cause secondary salinization by the application of inappropriate irrigation techniques.

On the basis of our preliminary survey, it could be concluded that the water quality of the aquifers (well waters) is not suitable for irrigation due to their high salt content.

If we take all these conditions given, the question arises as to whether sustainable plant production can be carried out in the region. In order to answer this question in a scientifically established way, an experiment was set up with a salt-sensitive vegetable (green bean) at the lysimeter station of the Research Institute of Karcag (RIK), University of Debrecen. Lysimeters are suitable tools to investigate the possibility of green bean production under unfavourable agro-ecological conditions in a well-defined environment. Practically, we simulated the typical agro-ecological conditions and vegetable production of the investigated area.

There has been an increased green bean production in Hungary recently, and this cannot be done successfully without irrigation due to its high water demand and the low amount of natural rainfall in its growing areas in the vegetation period. Therefore, it is important to investigate the problems arising during green bean production under irrigation with saline waters as high-quality irrigation water is not available everywhere.

The main goal of our investigations is to determine the correlations in a soil-water-plant system in order to understand the processes taking place during secondary salinization and to find solutions for this problem to mitigate the harmful effects, mainly by means of prevention.

2. Materials and methods

In order to reach our research goals, a lysimeter experiment was set up, where we wanted to determine the effect of irrigation frequency, water quality, and soil conditioning on the soil and, through that, on the water supply of the indicator plant that can be manifested in the morphological parameters and the yields of the plants.

The simple drainage lysimeters

The research work was carried out in 12 simple drainage lysimeters *(Fig. 1)*. The wall of the lysimeters is made of plastic, the depth of the soil columns in the vessels is 120 cm, and the surface area is 0.8 m^2 each.

The leachate from the lysimeters is regularly collected and quantified. The amount of precipitation is measured in the meteorological station of RIK, near the lysimeter station [3].

By means of the simple drainage lysimeters, it is easy to quantify the amount of salts leached from the soil columns as only the salt concentration of the leachate must be determined. Furthermore, exact soil sampling can be carried out from the lysimeters at different depths.

Figure 1. The simple drainage lysimeters involved in the experiment

The lysimeters were filled with Solonetz soil, whose main properties are summarized in *Table 1*.

Table 1. Some parameters of the soil of the lysimeters

PARAMETER	UNIT	LAYER	LAYER	LAYER
		0–20 cm	20–40 cm	40–60 cm
$PH_{(KCL)}$		7	7.23	7.41
TOTAL SOLUBLE SALT CONTENT	%	0.13	0.12	0.13
HUMUS CONTENT	%	2.31	1.43	1.07
NO_3-N	mg/kg	68.6	14.6	9.6
P_2O_5	mg/kg	1072	653	307
K_2O	mg/kg	444	247	207

Treatments and indicator crop

The effect of two treatments was studied in the experiment in a complex way: irrigation with two different qualities of water and soil conditioning. All the lysimeters were irrigated with the same weekly amount of water (15 litres per week), 6 with saline water (1,600 mg l^{-1} salt content), and the other 6 with deionized water. According to Zsembeli et al. [9], the quality of groundwater and other water sources used for irrigation (from the aquifers at 12–40 m depth) can be characterized by 1,600 mg l^{-1} salt content.

Taking the surface area of the lysimeters into account, 1 litre of irrigation water equals 1.25 mm water input. During the vegetation period of green bean, altogether 192 mm water was irrigated by simple sprinkling. The soil of 6 lysimeters was treated with *Neosol*, and the other 6 did not get any chemical amendments. Hence, 6 replications were applied for irrigation water quality as well as for soil conditioning. The combinations of the treatments are summarized in *Table 2*.

Table 2. Treatments of the lysimeter experiment

Lysimeter no.	**Soil conditioner application**	**Irrigation water quality**	**Irrigation frequency**	**Dosage of irrigation per day**
1–3	Neosol (PRP)	deionized	5 times a week	3.0 l
4–6	Neosol (PRP)	salty well (1,600 mg/l)	2 times a week	7.5 l
7–9	–	deionized	5 times a week	3.0 l
10–12	–	salty well (1,600 mg/l)	2 times a week	7.5 l

The applied indicator crop was green bean (*Phaseolus vulgaris* L. var. *nanus*), the cultivar *Budai piaci*. The sowing date was 20/05/2018, and the final harvest (plants removed) took place on 10 July.

NPK fertilizers were added to the soil of the lysimeters in early spring: N (27% substance content) 35 g, P (19%) 67 g, K (60%) 23 g for each lysimeter.

Seedbed was created directly before sowing, and then six of the twelve lysimeters were treated with a soil conditioner (*Neosol*) at the dose of 50 g per lysimeter. According to the producer, the microbiological activity of the soil can be boosted by *Neosol* (distributed in pellet form) and thus also its fertility [10]. Through the application of *Neosol*, the soil characteristics can be improved by unblocking the nutrients in the soil [5].

Four seeds per lysimeter were sown at the depth of 4 cm in the arrangement illustrated in *Fig. 2*.

Figure 2. Arrangement of bean seedlings in a lysimeter

During the vegetation period, the pods were harvested five times; the last harvest (on 10th July) meant the removal of the plants (including the roots).

3. Results and discussions

Effect of the treatments on the morphological parameters of the indicator crop

Differences due to the irrigation with saline and deionized water could be spotted even at the beginning of the growing period as the seeds irrigated with the salty well water germinated 5 days later, and this delay remained until blooming.

Table 3 contains the quantified effect of the treatments on the average height of the indicator crops.

Table 3. Effect of the complex treatments on the average plant height (Karcag, 2018)

		Average plant height (cm)
Water quality	deionized	48.53 ± 5.00
	saline	43.21 ± 4.50
Irrigation frequency	2 × 7.5 l	46.13 ± 0.06
	5 × 3 l	45.62 ± 0.57
Soil conditioning	PRP (Neosol)	46.41 ± 0.79
	control	45.33 ± 0.27

On the basis of the data, it can be established that plants irrigated with deionized water were 5.3 mm taller on average than plants which were treated with salty well water. The effect of the irrigation frequency was not significant; plants irrigated two times a week were minimally (0.5 cm) taller than those irrigated five times a week. Soil conditioning had a positive effect on plant height; treated plants were 1.1 cm taller than non-treated ones.

Plant height is a central part of plant ecological strategy because this morphological parameter is strongly correlated with not just life span but the time to maturity as well [4]. The canopy area, which is characteristic of the genotype too, has a major role in the photosynthetic activity of the plants and also determines transpiration capacity. In order to quantify the canopy of green bean, we weighed the total overground biomass of the indicator crops for each individual plant in the lysimeters after the final harvest (*Table 4*).

Table 4. Effect of the complex treatments on the overground biomass of green bean (Karcag, 2018)

		Overground biomass (g/plant)
Water quality	deionized	93.47 ± 10.91
	saline	62.50 ± 8.27
Irrigation frequency	2 × 7.5 l	83.33 ± 0.27
	5 × 3 l	72.64 ± 2.36
Soil conditioning	PRP (Neosol)	85.14 ± 1.19
	control	70.83 ± 3.83

Comparing the average biomass values of the plants, we found that 31 g less weight was characteristic of the plants irrigated with salty well water. This difference cannot be considered high taking the salt sensitivity of green bean into account. The irrigation frequency resulted in a 10.7 g per plant higher biomass in the case of the lysimeters irrigated two times a week. The positive effect of soil conditioning was manifested in a biomass 14.3 g higher compared to the control plants.

It is of great importance that the biomass of green bean be as high as possible since the amount of nitrogen fixed by the plant depends not only on the genotype but on the growing ability of the plant too. The annual amount of nitrogen fixed by the plants is also important when green bean is integrated in a crop rotation. In the nodules of beans, *Rhizobium phaseoli* bacteria can fix the atmospheric nitrogen; therefore, green bean is considered a good forecrop.

The effect of the complex treatments was studied on the root mass too as roots highly determine the success of bean production. Only the nutrients close to the root system of the plants can be taken up; therefore, the underground biomass and the extension of the root system are very important factors. A larger extension of roots results in higher water uptake, and hence the root biomass has an important role not only in nutrient utilization but in drought tolerance as well. The effect of the complex treatments on the root mass is summarized in *Table 5*.

Table 5. Effect of the complex treatments on the root biomass of green bean (Karcag, 2018)

		Root biomass (g/plant)
Water quality	deionized	9.55 ± 1.54
	saline	8.18 ± 1.53
Irrigation frequency	2 × 7.5 l	8.88 ± 0.03
	5 × 3 l	8.85 ± 0.04
Soil conditioning	PRP (Neosol)	9.10 ± 0.24
	control	8.63 ± 0.25

On the basis of the data, it is obvious that the treatments had no significant effects on the root biomass of green bean. The only considerable difference could be observed in the case of irrigation with saline water resulting in the lowest root mass per plant, but even this stress factor did not inhibit root growth to a harmful extent. These results are in harmony with the statement that the root systems of plants are highly plastic in their development [8].

Effect of the treatments on the yield of the indicator crop

The effect of the complex treatments on the yield of green bean was partly determined by counting the number of the pods grown on each plant in the lysimeters (*Fig. 3*).

Regarding water quality, we counted 5.2 less pods per plant when saline well water was used for irrigation than in the lysimeters irrigated with deionized water. Irrigation frequency of two times a week with higher doses was more effective than more frequent irrigation. We could observe the positive effect of soil conditioning too, but more effective treatments were those where the irrigation with saline water was combined with favourable frequency and soil conditioning: two times a week irrigation frequency and soil conditioning resulted in 14.1 pods per plant on average, while only 9.7 pods per plant were counted for five times a week irrigation frequency with no soil conditioning. These results led to the conclusion that the application of treatment combinations positively influencing the moisture and salt profile of the soil, the harmful effect of secondary salinization can be mitigated regarding the number of pods of green bean.

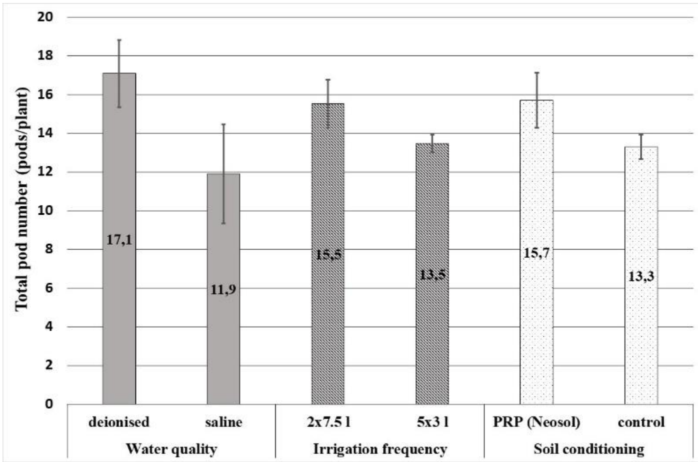

Figure 3. Effect of water quality, irrigation frequency, and soil conditioning on the total pod number of green bean (Karcag, 2018)

As the number of pods alone is not enough for the full assessment of the yield of green bean, the total weight of pods was also measured (*Fig. 4*).

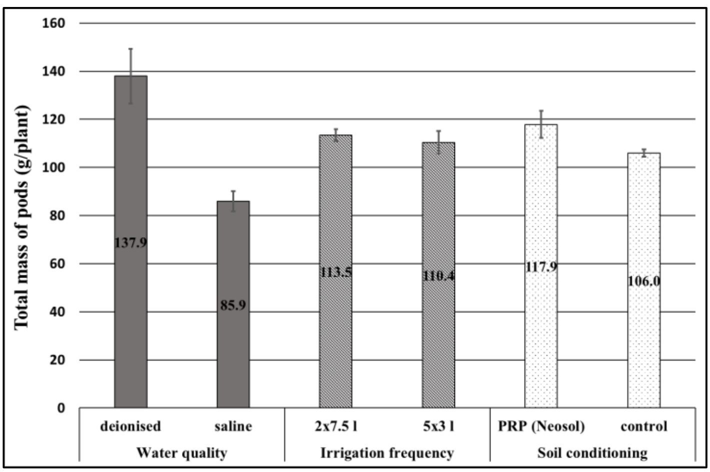

Figure 4. Effect of water quality, irrigation frequency, and soil conditioning on the total weight of pods of green bean (Karcag, 2018)

The negative effect of the application of saline water for irrigation could be observed in the case of the yield of green bean too. The best treatment combination with saline water (two times a week irrigation frequency and soil conditioning) resulted in a 93.4 g per plant average pod weight, which is 14.9 g higher than the average pod weight in the lysimeters irrigated five times a week with saline water without soil conditioning (78.5 g per plant). Nevertheless, irrigation with saline well water decreased the potential yield, 137.9 g per plant pod weight could be reached by irrigation with deionized water. We established that the yield-declining effect of secondary salinization can be mitigated by the application of soil conditioner and proper irrigation frequency.

4. Conclusions

On the basis of our results, it can be established that in the case of irrigation with saline water the amount of water must be limited to the demand of the crop; over-irrigation increases the risk of secondary salinization. The mitigation of this unfavourable process is possible by proper irrigation frequency and soil conditioning taking the given soil conditions (texture, infiltration rate, etc.) into consideration.

The treatments having positive effect on the physical and hydrological (hence on the chemical) soil status (lower irrigation frequency with soil conditioning) resulted in higher yields and better morphological properties of the green bean.

In areas with unfavourable agro-ecological conditions, soil conditioning combined with the optimization of irrigation (control of quantity, frequency) is highly recommended as the safety of crop production can be increased in a soil-protective way.

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References

[1] Adams, R. M., Hurd, B. H., Lenhart, S., Leary, N. (1998), Effects of global climate change on agriculture: An interpretative review. *Climate Research* 11(1), 19–30.

[2] Howden, S. M., Soussana, J. F., Tubiello, F. N., Chhetri, N., Dunlop, M., Meinke, H. (2007), Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences* 104(50), 19691–19696.

[3] Szűcs L., Tuba G., Czimbalmos R., Zsembeli J. (2015), A PRP-SOL talajkondicionáló szer hatása a talaj hidraulikus tulajdonságaira hagyományos és redukált talajművelési rendszerekben. In: Madarász, B. (ed.), *Környezetkímélő talajművelési rendszerek Magyarországon*. Budapest: MTA–CSFK–FTI. 111–121.

[4] Moles, A. T., Warton, D. I., Warman, L., Swenson, N. G., Laffan, S. W., Zanne, A. E., Leishman, M. R. (2009), Global patterns in plant height. *Journal of Ecology* 97(5), 923–932.

[5] Sulewska, H., Koziara, W., Szymańska, G., Niewiadomska, A., Panasiewicz, K., Ratajczak, K. (2016), Response of spring barley to PRP SOL application as a complex of mineral inducer process (MIP). *Nauka Przyroda Technologie* 10(2), 17.

[6] Szabolcs I., Darab K., Várallyay GY. (1969a), A tiszai öntözőrendszerek és a Magyar Alföld talajainak termékenysége. II. A talajvíz „kritikus” mélysége a kiskörei öntözőrendszer által érintett területen. *Agrokémia és Talajtan* 18, 211–220.

[7] Szabolcs I., Darab K., Várallyay, Gy. (1969b), A tiszai öntözőrendszerek és a Magyar Alföld talajainak termékenysége III. Az öntözés lehetőségeit és feltételei ábrázoló 1:25000 léptékű térképek készítésének módszerei. *Agrokémia és Talajtan* 18, 221–234.

[8] Williamson, L. C., Ribrioux, S. P., Fitter, A. H., Leyser, H. O. (2001), Phosphate availability regulates root system architecture in Arabidopsis. *Plant Physiology* 126(2), 875–882.

[9] Zsembeli, J., Szűcs, L., Blaskó, L. (2011), Secondary salinization by irrigation from drilled wells in [the] Karcag area. *Növénytermelés* 183(3), 305–308.

[10] http://www.prp-technologies.eu/en/products-and-services/our-products/neosol (12/03/2019).

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Changes in germination parameters of seven sweet basil (*Ocimum basilicum* L.) varieties due to treating with gibberellic and ascorbic acids

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Abstract. During the study, the seeds of seven sweet basil cultivars were treated with 100 ppm solutions of gibberellic acid or ascorbic acid prior to a 14-day germination experiment. Values of the first day of germination, germination energy, germinability, mean time and rate of germination, and uncertainty and synchrony of germination were calculated. The results show that both of the substances altered the measured parameters, priming with gibberellic acid proving to be a more effective way to enhance the germination of basil seeds. Also, they revealed major differences among the germination parameters of the examined cultivars.

Keywords: enhance, germinability, priming

1. Introduction

Sweet basil (*Ocimum basilicum* L.) is an aromatic annual herb belonging to the *Lamiacieae* family [1], subfamily *Nepetoideae*, genus *Ocimum* [2]. It is native to Asia (India, Pakistan, Iran, and Thailand) [3]. It is cultivated in the tropics and also in temperate climate in Europe and the Americas [4].

Some species, such as *Ocimum americanum* L, have insecticidal properties, while others have ornamental qualities with a particular leaf shape, size, and colour: e.g. the Purple Ruffles variety of *O. basilicum* [5, 6]. *Ocimum gratissimum* and *Ocimum sanctum* are also cultivated worldwide [7]. Apart from these uses, basil has been utilized in traditional medicine for curing headaches, diarrhoea, and constipation [8, 9].

The common sweet basil is of high economic importance because of the essential volatile oil derived from its leaves [10–12]. The composition of the essential oil determines the specific aroma of the plant [13], making it a widely used substance in the perfume industry and against several diseases [7, 14]. The essential oil composition varies among different cultivars [15].

Basil has antioxidant [9, 16], antifungal [17], anticancer [18, 19], and antiviral activities [20].

The pharmaceutical, aromatic, and culinary properties of sweet basil are due to its content of different valuable active substances [21, 22]. Basil is a source of phenolic acids such as rosmarinic, caffeic, or cichoric acid and derivatives of lithospermic acid and lithospermic acid B, which help in healing certain renal diseases [16, 23]. Anthocyanins are also highly valued substances with antioxidant activity [24–26].

Low temperature values occurring at the time of germination negatively affect both the germination process and seedling growth [27]. The optimal germination temperature of sweet basil varies between 20 and 30 °C [28–30]. Different treatments and substances can compensate the negative effects of abiotic stress [31]. The effects of gibberellic acid (GA3) on germination parameters of sweet basil were studied. Priming the seeds with GA3 solution prior to germination can reduce the negative effects of drought [32] and salinity [33]. It was reported to have positive effect on the low-temperature germination of different plant species [34]. Ascorbic acid (AsA) is a well-known antioxidant that affects plant growth in many ways such as germination, seedling growth in suboptimal situations [35], or in the case of salinity stress [36].

Therefore, two main objectives were defined: 1. to compare the effect of GA3 and AsA on seven different sweet basil varieties (‘Aromat de Buzău’, ‘Serafim’, ‘Busuioc Dulce’, ‘Italiano Classico’, ‘Dark Opal’, ‘Genovese’, and ‘Grand Verte’) germinating on different temperature values and 2. to compare the germination of the mentioned basil cultivars.

2. Materials and methods

Plant material

The seeds of the seven sweet basil cultivars were obtained from the Buzău Research Station for Legumiculture (SCDL Buzău) in the case of ‘Aromat de Buzău’, ‘Serafim’, ‘Busuioc Dulce’, and ‘Grand Verte’ varieties; the seeds of ‘Italiano Classico’ and ‘Dark Opal’ varieties from S.C. Morami S.R.L. and in the case of the ‘Genovese’ variety from S.C. Agrosem Impex S.R.L.

Priming materials/substances

The gibberellic acid (GA3) was purchased from Duchefa Biochimie.
The ascorbic acid (ASA) was purchased from VWR, part of Avantor.

Experimental design

The experiment was carried out at 15 C° using four replications of each 100 seeds from the seven basil varieties. The seeds were counted out and immersed in the priming solutions (control – containing distilled water, 100 ppm GA3 solution, 100 ppm ASA solution) for 24 hours. After the 24 hour-period, the seeds were placed in Linhardt-dishes using blotting paper as substrate. The lower compartments of the dishes were filled with distilled water and covered with a glass lid to ensure a high and constant relative humidity throughout the germination process.

The dishes were then placed in a growth chamber (Fitotron Poleko, Model: HKK240) for 14 days at a constant temperature and humidity level, without illumination. The batches were verified during data collection, and additional distilled water was administered if needed.

Data collection

The following parameters were recorded during the experiment:

- Time elapsed until the emergence of the first seedling, also called Tindicator of the velocity of the initiation of germination (during the first part of the process) [37].
- Germination energy of the seeds (GE), expressed in %, measured at the halftime of the study (on the 7th day), the same way as in the case of germinability.
- Germinability (G), expressed in %, measured at the end of the study (on the 14th day); it indicates the capacity of the batches to germinate under proper circumstances [38].
- Mean germination time, used to evaluate seedling emergence [39], [38]. The lower the mean germination time, the faster is the germination of a population of seeds completed [37].
- Mean germination rate (MR) is calculated as the reciprocal of mean germination time (MT) [38].
- Uncertainty (U) of the germination process: low values indicate a high synchrony of the germination and vice versa [39].
- Synchrony (Z) value ranges from 0 to 1, 0 meaning that at least two seeds germinated at separate times, while 1 means that all seeds germinated at the same time [38, 39].

The seed batches were verified on a daily basis, and the emerged plantlings were counted. Germination was considered successful if the radicle of the plant has penetrated the seed husk.

Statistical analysis

The collected data were subjected to one-way ANOVA (analysis of variance) carried out with the Paleontological Statistics (PAST) statistical software, version 3.25. After the normality of the data sets had been verified, Tukey pairwise test was carried out in the case of normally distributed data and Mann-Whitney pairwise test in the case of non-normally distributed data (marked with an * in the tables). P values are in the majority of the cases less than 0.001; otherwise, the values are displayed in the tables.

3. Results and discussions

The first day of germination (FDG), or, more precisely, the emergence of the first seedling was positively affected by treating the seeds with GA3, which reduced the time needed until FDG with 1–2 days. AsA treatment also reduced the time of FDG at a smaller scale in the case of 'Aromat de Buzau', 'Busuioc Dulce', and 'Dark Opal'; its values exceeded the control groups' values in the rest of the cases. Due to the lack of variation among the repetition values, no statistical analysis was conducted. For results, see *Table 1*.

Due to invariances among the data collected from 'Aromat de Buzau' in the case of germination energy (GE), statistical analysis could not be run. Priming the seeds with GA3 had positive effect on the GE of the lots. In the case of 'Dark Opal' seeds, none of the priming treatments had significantly different results than the others. Seed lots of 'Serafim', 'Busuioc Dulce', and 'Italiano Classico' varieties responded positively to GA3 priming, the differences being significant. Likewise, control and AsA treatments did not differ from each other. The seeds of the 'Grand Verte' variety responded positively to both GA3 and AsA treatments, having the same results regarding GE, while the control group produced significantly lower results. The 'Genovese' variety was the only case where the AsA treatment had significantly lower results than the control group (*Table 1*).

'Serafim' and 'Dark Opal' varieties showed no significant differences among the treatments regarding germinability. In the cases of 'Aromat de Buzau' and 'Busuioc Dulce' varieties, the GA3 treatment had a significantly positive effect in comparison to the control treatment. 'Italiano Classico' and 'Genovese' responded negatively to AsA treatment, the differences being significant; these varieties also showed no differences between control and GA3 treatments. Only the seeds of the ‘Grand Verte’ variety germinated at a significantly higher rate under AsA treatment. Results are shown in *Table 1*.

Studying the results of the mean time of germination reveals a relative similarity in the way how the different seed lots reacted to the treatments. In all of the cases, except the ‘Italiano Classico’ and ‘Grand Verte’ varieties, the results indicate that the AsA treatment was not significantly different from the control group, lots treated with GA3 germinating in a significantly less time. In the case of ‘Italiano Classico’ and ‘Grand Verte’ seedlots, it can be said that both treatments resulted in the reduction of the time needed for germination (*Table 1*).

A relative similarity can be observed when comparing the results of the rate of germination, too. The obtained data of the rate of germination are similar to the results of the mean time of germination. The seeds of all varieties responded positively to the GA3 treatment, the rate of germination values being significantly higher than in the case of the control group and, except the ‘Italiano Classico’ and ‘Grand Verte’ varieties, upon AsA treatment. Results are shown in *Table 1*.

Comparing the results of uncertainty, differences occur between the ways how the varieties responded to the different treatments. There are no significant differences between the treatments in the case of the ‘Aromat de Buzau’, ‘Serafim’, and ‘Dark Opal’ varieties. Priming with GA3 or AsA, the ‘Busuioc Dulce’, ‘Genovese’, and ‘Grand Verte’ seeds resulted in a significant reduction of uncertainty values compared to the control group. The analysis of the uncertainty values of ‘Italiano Classico’ seed lots reveals that priming with AsA has reduced them significantly compared to the control group; results from seeds treated with GA3 do not differ from the other two treatments (*Table 1*).

The treatments had different effects on the synchrony of germination, the seeds reacting to them in alternative ways. In the case of ‘Busuioc Dulce’, ‘Genovese’, and ‘Grand Verte’ seeds, priming with AsA resulted in higher synchrony values, the differences being significant in comparison to the control group; at the same time, ‘Genovese’ seeds treated with GA3 also produced significantly higher results than the control group, while in the case of ‘Busuioc Dulce’ and ‘Grand Verte’ the synchrony of seeds primed with GA3 did not differ from the other two treatments. The synchrony of ‘Serafim’, ‘Italiano Classico’, and ‘Dark Opal’ seeds showed no significant differences. In the case of the ‘Italiano Classico’ variety, the synchrony of germinating seeds was the highest in the lot belonging to the control group (*Table 1*).

Table 1. The results of the one-way ANOVA analysis and the Tukey post-hoc test, the treatments being compared (in the case of the * Mann-Whitney test)

'Aromat de Buzau'	**FDG (day)**	**GE (%)**	**G (%)**	**MT (day)**	**MR (day^{-1})**	**U (bit) ***	**Z $p< 0.05$**
Control	8	0	24.25^{b}	10.751^{a}	0.093^{b}	2.428^{a}	0.181^{ab}
GA3	6	8	46^{a}	9.133^{b}	0.109^{a}	2.556^{a}	0.212^{a}
AsA	7.75	0.25	17^{b}	10.731^{a}	0.093^{b}	2.527^{a}	0.128^{b}
'Serafim'	**FDG (day)**	**GE (%) $p<0.01$**	**G (%)**	**MT (day)**	**MR (day^{-1})**	**U (bit)**	**Z**
Control	4.5	51^{b}	83.4^{a}	7.448^{a}	0.134^{b}	2.539^{a}	0.208^{a}
GA3	3.75	74.5^{a}	89.75^{a}	5.838^{b}	0.171^{a}	2.551^{a}	0.199^{a}
AsA	5	38^{b}	82.5^{a}	8.320^{a}	0.120^{b}	2.616^{a}	0.188^{a}
'Busuioc Dulce'	**FDG (day)**	**GE (%) $p<0.01$**	**G (%) $p<0.05$**	**MT (day)**	**MR (day^{-1})**	**U (bit) $p<0.01$**	**Z $p<0.01$**
Control	5.5	39.5^{b}	84.25^{b}	8.163^{a}	0.123^{b}	2.720^{a}	0.171^{b}
GA3	3	90.75^{a}	98.25^{a}	5.682^{b}	0.176^{a}	2.299^{b}	0.231^{ab}
AsA	5.25	61.75^{b}	88^{ab}	7.376^{a}	0.135^{b}	2.216^{b}	0.272^{a}
'Italiano Classico'	**FDG (day)**	**GE (%) * $p < 0.05$**	**G (%)**	**MT (day) $p < 0.05$**	**MR (day^{-1}) $p<0.05$**	**U (bit)**	**Z $p<0.05$**
Control	4.5	25^{b}	52.75^{a}	8.2450^{a}	0.122^{b}	2.777^{a}	0.164^{a}
GA3	3	53.75^{a}	63.75^{a}	5.895^{c}	0.170^{a}	2.453^{ab}	0.218^{a}
AsA	5	19.5^{b}	25.75^{b}	6.949^{b}	0.144^{ab}	2.308^{b}	0.222^{a}
'Dark Opal'	**FDG (day)**	**GE (%)**	**G (%)**	**MT (day)**	**MR (day^{-1})**	**U (bit)**	**Z**
Control	4.5	44^{a}	67.75^{a}	7.190^{a}	0.139^{b}	2.468^{a}	0.211^{a}
GA3	3.5	51.5^{a}	67.75^{a}	5.742^{b}	0.174^{a}	2.185^{a}	0.257^{a}
AsA	4	50.5^{a}	66.75^{a}	6.931^{a}	0.144^{b}	2.600^{a}	0.197^{a}
'Genovese'	**FDG (day)**	**GE (%)**	**G (%) * $p<0.05$**	**MT (day) * $p<0.05$**	**MR (day^{-1}) * $p<0.05$**	**U (bit) $p<0.01$**	**Z $p<0.01$**
Control	3.25	76^{b}	92^{a}	6.083^{a}	0.164^{b}	2.508^{a}	0.197^{b}
GA3	3	91.25^{a}	94.5^{a}	4.763^{b}	0.210^{a}	1.976^{b}	0.295^{a}
AsA	5	52^{c}	61^{b}	6.201^{a}	0.161^{b}	2.0434^{b}	0.306^{a}
'Grand Verte'	**FDG (day)**	**GE (%) ***	**G (%) $p<0.05$**	**MT (day)**	**MR (day^{-1}) $p<0.01$**	**U (bit)**	**Z**
Control	3.5	40.75^{b}	72^{b}	7.414^{a}	0.135^{b}	2.518^{a}	0.200^{b}
GA3	3.25	71.5^{a}	77.25^{ab}	5.292^{b}	0.191^{a}	1.883^{b}	0.317^{ab}
AsA	4	71.5^{a}	82.75^{a}	5.815^{b}	0.172^{ab}	1.841^{b}	0.343^{a}

FDG – first day of germination, GE – germination energy, G – germinability, MT – mean time of germination, MR – mean rate of germination, U – uncertainty, and Z – synchrony of germination. Different letters denote significant differences; in the case of the lack of statistical analysis, no letters appear.

Comparing the values of germination parameters of the sweet basil varieties

The seeds of the 'Aromat de Buzau' cultivar stand out by needing almost twice as much time until FDG as the rest of the cultivars regardless the treatment applied to them. Among the untreated lots, 'Genovese' and 'Grand Verte' seeds had the lowest FDG values: they needed only 3.25 and 3.5 days until the first seedlings appeared. After priming them with GA3, none of the sweet basil varieties' seeds had differences among them; AsA treatment had a slight effect on 'Aromat de Buzau', 'Dark Opal', and 'Genovese' seeds, and it had no positive effect on the rest of the cultivars (*Table 2*).

Among the untreated seed lots, the 'Genovese' variety had the highest GE, followed by 'Serafim' and 'Dark Opal'. Among the lots treated with GA3, the top three cultivars were 'Genovese', 'Busuioc Dulce', and 'Serafim'; in the case of AsA treatment, the 'Grand Verte', 'Busuioc Dulce', and 'Genovese' cultivars had the highest values. The germination energy (GE) of the cultivars changed in a positive way in the case of both priming materials, the number of seed lots with GE values exceeding 50%, rising to 4 in the case of the AsA treatment and to 6 in the case of GA3 treatment, from an initial 1 in the case of the control group. 'Busuioc Dulce' and 'Genovese' seed lots had GE values over 90% after being treated with GA3; on the other hand, the seeds of 'Italiano Classico' variety's GE values were lower than the control groups. Again, 'Aromat de Buzau' differs from the other cultivars by having GE values under 10% (*Table 2*).

The varieties from the untreated group with the highest G values are the following: 'Genovese', 'Busuioc Dulce', and 'Serafim'; from the GA3-treated group: 'Busuioc Dulce', 'Genovese', and 'Serafim'; from the AsA-treated group: 'Busuioc Dulce', 'Serafim', and 'Grand Verte'. The priming of seeds with GA3 resulted in the growth of germinability values in all of the varieties except 'Dark Opal', where absolutely no change occurred. On the other hand, treating the seeds with AsA had a different effect on them, 'Aromat de Buzau', 'Italiano Classico', 'Dark Opal', and 'Genovese' responding to the treatment with lower G values. The varieties having the lowest germinability in all cases were 'Aromat de Buzau' followed by 'Italiano Classico' (*Table 2*).

Table 2. The results of the one-way ANOVA analysis and the Tukey post-hoc test, the varieties being compared (in the case of the * Mann-Whitney test)

Control	FDG (day)	GE (%)	G (%)* $p<0.05$	MT (day)* $p<0.05$	MR (day^{-1}) $p<0.01$	U (bit)	Z
Aromat de Buzău	8	0	24.25^{e}	10.752^{a}	0.093^{c}	2.428^{a}	0.181^{a}
Serafim	4.5	47.75	80.5^{abc}	7.571^{bc}	0.132^{b}	2.612^{a}	0.197^{a}
Busuioc Dulce	5.5	39.5	84.25^{ab}	8.163^{b}	0.123^{b}	2.720^{a}	0.171^{a}
Italiano Classico	4.5	25	52.75^{d}	8.245^{b}	0.122^{b}	2.777^{a}	0.164^{a}
Dark Opal	4.5	44	67.75^{c}	7.190^{c}	0.139^{b}	2.468^{a}	0.211^{a}
Genovese	3.25	76	92.00^{a}	6.083^{d}	0.164^{a}	2.508^{a}	0.197^{a}
Grand Verte	3.5	40.75	72^{bc}	7.414^{bc}	0.135^{b}	2.518^{a}	0.200^{a}
GA_3	**FDG (day)**	**GE (%)* $p<0.05$**	**G (%)* $p<0.05$**	**MT (day)* $p<0.05$**	**MR (day^{-1})* $p<0.05$**	**U (bit) $p<0.01$**	**Z $p<0.05$**
Aromat de Buzău	6	8^{d}	46^{d}	9.133^{a}	0.109^{c}	2.556^{a}	0.212^{bc}
Serafim	3.75	74.5^{b}	89.75^{b}	5.838^{b}	0.171^{b}	2.551^{a}	0.199^{bc}
Busuioc Dulce	3	90.75^{a}	98.25^{a}	5.682^{b}	0.176^{b}	2.299^{ab}	0.231^{abc}
Italiano Classico	3	53.75^{c}	63.75^{c}	5.895^{b}	0.170^{b}	2.453^{a}	0.218^{bc}
Dark Opal	3.5	51.5^{c}	67.75^{c}	5.742^{b}	0.174^{b}	2.185^{ab}	0.257^{abc}
Genovese	3	91.25^{a}	94.5^{ab}	4.763^{c}	0.210^{a}	1.976^{b}	0.295^{ab}
Grand Verte	3.25	71.5^{b}	77.25^{c}	5.292^{bc}	0.191^{ab}	1.883^{b}	0.317^{a}
AsA	**FDG (day)**	**GE(%) $p<0.05$**	**G (%)* $p<0.05$**	**MT (day)* $p<0.05$**	**MR (day^{-1}) $p<0.01$**	**U (bit) $p<0.05$**	**Z $p<0.05$**
Aromat de Buzău	7.75	0.25^{e}	17^{c}	10.731^{a}	0.093^{e}	2.527^{a}	0.128^{d}
Serafim	5	48.2^{c}	84.6^{a}	7.384^{b}	0.151^{d}	2.578^{a}	0.196^{cd}
Busuioc Dulce	5.25	61.75^{b}	88^{a}	7.376^{c}	0.135^{cd}	2.216^{ab}	0.272^{abc}
Italiano Classico	5	19.5^{d}	$25.7^{c}5$	6.949^{d}	0.144^{c}	2.308^{ab}	0.222^{bc}
Dark Opal	4	50.5^{b}	66.75^{b}	6.931^{d}	0.144^{bc}	2.600^{a}	0.197^{cd}
Genovese	5	52^{b}	61^{b}	6.201^{de}	0.161^{ab}	2.043^{b}	0.306^{ab}
Grand Verte	4	77.5^{a}	82.75^{a}	5.815^{e}	0.172^{a}	1.841^{b}	0.343^{a}

FDG – first day of germination, GE – germination energy, G – germinability, MT – mean time of germination, MR – mean rate of germination, U – uncertainty, and Z – synchrony of germination. Different letters denote significant differences; in the case of the lack of statistical analysis, no letters appear.

The varieties from the untreated group with the highest G values are the following: 'Genovese', 'Busuioc Dulce', and 'Serafim'; from the GA3-treated group: 'Busuioc Dulce', 'Genovese', and 'Serafim'; from the AsA-treated group: 'Busuioc Dulce', 'Serafim', and 'Grand Verte'. The priming of seeds with GA3 resulted in the growth of germinability values in all of the varieties except ‘Dark Opal’, where absolutely no change occurred. On the other hand, treating the seeds with AsA had a different effect on them, ‘Aromat de Buzau’, ‘Italiano Classico’, ‘Dark Opal’, and ‘Genovese’ responding to the treatment with lower G values. The varieties having the lowest germinability in all cases were ‘Aromat de Buzau’ followed by ‘Italiano Classico’ (*Table 2*).

Comparing the mean time for germination (MT) of the different groups, it can be said that the ‘Aromat de Buzau’ variety’s seeds needed the longest time to germinate in all cases, the differences being significant. On the contrary, ‘Genovese’ MT values were the lowest (its seeds germinated at a faster rate) among the untreated and GA3-treated groups, while in the AsA-treated group ‘Grand Verte’ had the lowest values. Results show that both GA3 and AsA decreased the MT values of all of the varieties, GA3 treatment exerting a more powerful effect (*Table 2*).

Similar to the MT are the mean rate (MR) values of the seed lots, ‘Aromat de Buzau’ having the lowest and ‘Genovese’ as well as ‘Grand Verte’ the highest MR values. GA3 treatment enhanced the mean rate of germination among all varieties, priming with AsA being less effective, in the case of ‘Genovese’ seeds producing even lower values than the untreated group (*Table 2*).

The comparison of the uncertainty of germination (U) of the cultivars showed no significant differences in the untreated group, ‘Aromat de Buzau’ seeds having the lowest and ‘Italiano Classico’ seeds the highest values. In the group treated with GA3, ‘Genovese’ and ‘Grand Verte’ seeds had significantly lower values than ‘Aromat de Buzau’, ‘Serafim’, and ‘Italiano Classico’ seeds; ‘Busuioc Dulce’ and ‘Dark Opal’ did not differ significantly from the other varieties. After the AsA treatment, seeds with lowest U values were ‘Genovese’ and ‘Grand Verte’, differing significantly from the seeds with the highest U values, which were ‘Dark Opal’ and ‘Serafim’ (*Table 2*).

Comparing the synchrony (Z) of the untreated seeds shows no significant differences, ‘Italiano Classico’ having the lowest and ‘Dark Opal’ the highest values. Priming the seeds with GA3 resulted in a growth of Z values of all varieties, ‘Aromat de Buzau’, ‘Serafim’, and ‘Italiano Classico’ seeds having a lesser and ‘Grand Verte’ a significantly higher value. After treating the seeds with AsA, the ‘Aromat de Buzau’, ‘Serafim’, and ‘Dark Opal’ varieties had the lowest and ‘Genovese’ and ‘Grand Verte’ the highest Z values (*Table 2*).

4. Conclusions

After the analysis of the obtained data, it can be said that GA3 applied in a 100 ppm concentration at 15 °C has a positive effect on the germination parameters of sweet basil. On the contrary, seeds of the different cultivars treated with AsA responded in adverse ways, AsA enhancing the germination of some of the cultivars and reducing it in other cases.

Comparing the sweet basil varieties shows differences among them, too, 'Aromat de Buzau' seeds having inferior results in most aspects. The 'Serafim', 'Busuioc Dulce', and 'Genovese' varieties had the highest values on average.

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References

[1] Asghari, F., Hossieni, B., Hassani, A., Shirzad, H. (2012), Effect of explants source and different hormonal combinations on direct regeneration of basil plants (Ocimum basilicum L.). http://search.informit.com.au/documentSummary;dn=339277382874316;res=IELENG (accessed on: 14 August 2014).

[2] Paton, A., Harley, M. R., Harley, M. M. (1999), The Genus Ocimum. In: *Basil*. The Netherlands: Harwood Academic Press. 1–38.

[3] Makri, O., Kintzios, S. (2008), *Ocimum* sp. (Basil): Botany, cultivation, pharmaceutical properties, and biotechnology. *Journal of Herbs, Spices & Medicinal Plants* 13, 123–150. DOI: 10.1300/J044v13n03_10.

[4] Klimánková, E., Holadová, K., Hajšlová, J., Čajka, T., Poustka, J., Koudela, M. (2008), Aroma profiles of five basil (Ocimum basilicum L.) cultivars grown under conventional and organic conditions. *Food Chemistry* 107, 464–472. DOI: 10.1016/j.foodchem.2007.07.062.

[5] Kintzios, S., Kollias, H., Straitouris, E., Makri, O. (2004), Scale-up micropropagation of sweet basil (Ocimum basilicum L.) in an airlift bioreactor and accumulation of rosmarinic acid. *Biotechnol. Lett.* 26, 521–523.

[6] Phippen, W. B., Simon, J. E. (2000), Shoot regeneration of young leaf explants from basil (Ocimum basilicum L.). *In Vitro Cell. Dev. Biol. Plant* 36, 250–254. DOI: 10.1007/s11627-000-0046-y.

[7] Pandey, A. K., Singh, P., Tripathi N. N. (2014), Chemistry and bioactivities of essential oils of some Ocimum species: An overview. *Asian Pacific Journal of Tropical Biomedicine* 4, 682–694. DOI: 10.12980/APJTB.4.2014C77.

[8] Grayer, R. J., Vieira, R. F., Price, A. M., Kite, G. C., Simon, J. E., Paton, A. J. (2004), Characterization of cultivars within species of Ocimum by exudate flavonoid profiles. *Biochemical Systematics and Ecology* 32, 901–913. DOI: 10.1016/j.bse.2004.04.002.

[9] Politeo, O., Jukic, M., Milos, M. (2007), Chemical composition and antioxidant capacity of free volatile aglycones from basil (Ocimum basilicum L.) compared with its essential oil. *Food Chemistry* 101, 379–385. DOI: 10.1016/j.foodchem.2006.01.045.

[10] Saha, S., Dey, T., Ghosh, P. (2010), Mincropropagation of Ocimum kilimandscharicum guerke (Labiatae). *Acta Biologica Cracoviensia* 52(2), 50–58.

[11] Siddique, I., Anis, M. (2009), Morphogenic response of the alginate encapsulated nodal segment and antioxidative enzymes analysis during acclimatization of Ocimum basilicum L. *J. Crop Sci. Biotechnol.* 12, 233–238. DOI: 10.1007/s12892-009-0131-7.

[12] Sudhakaran, S., Sivasankari, V. (2002), In vitro flowering response of Ocimum basilicum. *Journal of Plant Biotechnology* 4(4), 179–181.

[13] Loughrin, J. H., Kasperbauer, M. J. (2003), Aroma content of fresh basil (*Ocimum basilicum* L.) leaves is affected by light reflected from colored mulches. *Journal of Agricultural and Food Chemistry* 51, 2272–2276. DOI: 10.1021/jf021076c.

[14] Chalchat, J.-C., Özcan, M. M. (2008), Comparative essential oil composition of flowers, leaves and stems of basil (Ocimum basilicum L.) used as herb. *Food Chemistry* 110, 501–503. DOI: 10.1016/j.foodchem. 2008.02.018.

[15] Carović-Stanko, K., Liber, Z., Politeo, O., Strikić, F., Kolak, I., Milos, M., Satovic, Z. (2011), Molecular and chemical characterization of the most widespread Ocimum species. *Plant Systematics and Evolution* 294, 253–262. DOI: 10.1007/s00606-011-0471-x.

[16] Kwee, E. M., Niemeyer, E. D. (2011), Variations in phenolic composition and antioxidant properties among 15 basil (Ocimum basilicum L.) cultivars. *Food Chemistry* 128, 1044–1050. DOI: 10.1016/j.foodchem.2011.04.011.

[17] Barcelos, R. C., Jham, G. N., Dhingra, O. D., Mendonca, F. A., Valente, V. M. M. (2013), Identification and quantification of the major fungitoxic components of the Brazilian basil (Ocimum basilicum L.) essential oil. *Journal of Food Research* 2, 124. DOI: 10.5539/jfr.v2n5p124.

[18] Arshad Qamar, K., Dar, A., Siddiqui, B. S., Kabir, N., Aslam, H., Ahmed, S., Erum, S., Habib, S., Begum, S. (2010), Anticancer activity of Ocimum basilicum and the effect of ursolic acid on the cytoskeleton of MCF-7 human breast cancer cells. *Letters in Drug Design & Discovery* 7, 726–736. DOI: 10.2174/1570180811007010726.

[19] Behbahani, M. (2014), Evaluation of in vitro anticancer activity of Ocimum Basilicum, Alhagi Maurorum, Calendula Officinalis and their parasite Cuscuta Campestris. *PLoS ONE* 9, e116049. DOI: 10.1371/journal.pone.0116049.

[20] Chiang, L.-C., Ng, L.-T., Cheng, P.-W., Chiang, W., Lin, C.-C. (2005), Antiviral activities of extracts and selected pure constituents of Ocimum basilicum. *Clinical and Experimental Pharmacology and Physiology* 32, 811–816. DOI: 10.1111/j.1440-1681.2005.04270.x.

[21] Gopi, C., Ponmurugan, P. (2006), Somatic embryogenesis and plant regeneration from leaf callus of Ocimum basilicum L. *J. Biotechnol.* 126, 260–264. DOI: 10.1016/j.jbiotec. 2006.04.033.

[22] Sahoo, Y., Pattnaik, S. K., Chand, P. K., In vitro clonal propagation of an aromatic medicinal herb Ocimum basilicum L. (sweet basil) by axillary shoot proliferation. *In Vitro Cell. Dev. Biol. Plant* 33, 293–296. DOI: 10.1007/s11627-997-0053-3.

[23] Rady, M. R., Nazif, N. M. (2005), Rosmarinic acid content and RAPD analysis of in vitro regenerated basil (Ocimum americanum) plants. *Fitoterapia* 76, 525–533. DOI: 10.1016/j.fitote.2005.04.001.

[24] Kong, J.-M., Chia, L.-S., Goh, N.-K., Chia, T.-F., Brouillard R. (2003), Analysis and biological activities of anthocyanins. *Phytochemistry* 64, 923–933. DOI: 10.1016/S0031-9422(03)00438-2.

[25] Phippen, W. B. (2000), Anthocyanin inheritance and instability in purple basil (Ocimum basilicum L.). *Journal of Heredity* 91, 289–296. DOI: 10.1093/jhered/91.4.289.

[26] Phippen, W. B., Simon, J. E. (1998), Anthocyanins in Basil (*Ocimum basilicum* L.). *Journal of Agricultural and Food Chemistry* 46, 1734–1738. DOI: 10.1021/jf970887r.

[27] Fu, J. J., Liu, J., Yang, L. Y., Miao, Y. J., Xu, Y. F. (2017), Effects of low temperature on seed germination, early seedling growth and antioxidant systems of the wild Elymus nutans Griseb. *JAST* 19, 1113–1125.

[28] Fallahi, H.-R., Mohammadi, M., Aghhavani-Shajari, M., Ranjbar, F. (2015), Determination of germination cardinal temperatures in two basil (Ocimum basilicum L.) cultivars using non-linear regression models. *Journal of Applied Research on Medicinal and Aromatic Plants* 2, 140–145. DOI: 10.1016/j.jarmap.2015.09.004.

[29] Nadjafi, E., Tabrizi, L., Shabahang, J., Mahdavi Damghani, A. M. (2009), Cardinal germination temperatures of some medicinal plant species. *Seed Technology* 31, 156–163.

[30] Zhou, D., Jacob, B., Ponder, M. A., Welbaum, G. E. (2016), Germination response of six sweet basil (Ocimum basilicum) cultivars to temperature. *Seed Technology Journal* 37(1), 43–51.

[31] Rakshit, A., Singh, H. B. (eds.) (2018), *Advances in seed priming*. Springer Singapore: Singapore. DOI: 10.1007/978-981-13-0032-5.

[32] Bagheri, A., Bagherifard, A., Saborifard, H. Ahmadi, M., Safarpoor, M. (2014), Effects [of] drought, cytokinin and GA3 on [the] seedling growth of basil (Ocimum basilicum). *International Journal of Advanced Biological and Biomedical Research* 2, 489–493.

[33] Liopa-Tsakalidi, A., Zakynthinos, G., Varzakas, T. H., Xynias, I. (2011), Effect of NaCl and GA 3 on seed germination and seedling growth of eleven medicinal and aromatic crops. *Journal of Medicinal Plants Research* 5(17), 4065–4073.

[34] Adhikary, P., Tarai, P. (2013), Effects of temperature and gibberellic acid (GA3) on seed germination of *Vicia sativa, Chenopodium album and Physalis minima*. *International Journal of Agriculture, Environment and Biotechnology* 6, 629. DOI: 10.5958/j.2230-732X.6.4.042.

[35] Akram, N. A., Shafiq, F., Ashraf, M. (2017), Ascorbic acid – A potential oxidant scavenger and its role in plant development and abiotic stress tolerance. *Frontiers in Plant Science* 8. DOI: 10.3389/fpls.2017.00613.

[36] Zehra, A., Shaikh, F., Ansari, R., Gul, B., Khan, M. A. (2013), Effect of ascorbic acid on seed germination of three halophytic grass species under saline conditions. *Grass and Forage Science* 68, 339–344. DOI: 10.1111/j.1365-2494.2012.00899.x.

[37] Kader, M. A. (2005), A comparison of seed germination calculation formulae and the associated interpretation of resulting data. *Journal & Proceedings of the Royal Society of New South Wales* 138, 65–75.

[38] Ranal, M. A., Garcia de Santana, D., Ferreira, W. R., Mendes-Rodrigues, C. (2009), Calculating germination measurements and organizing spreadsheets. *Revista Brasiliera Botanica* 32, 849–855.

[39] Ranal, M. A., Garcia de Santana, D. (2006), How and why to measure the germination process? *Revista Brasiliera Botanica* 29, 1–11.

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From tradition to landscape architecture – Planting design concept using perennials and bulbs

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Abstract. “Tradition and Modernity”, two aspects the University of Agriculture Sciences and Veterinary Medicine of Cluj-Napoca lives by. The current paper presents a case study analysis of a landscape architecture design, combining tradition with modernity. Through the use of traditional Transylvanian patterns, this concept design is based on the use of different plant species and flowering periods. It measures 500 sq. m and is situated on the campus of the UASVM. Today, there is an increasing interest for bulbs and *Lavandula* species in landscaping. This is the reason why *Lavandula* is popular in the design concept presented below. Designed with the use of Romanian traditional patterns and specific colours, two types of ornamental plants are combined: perennials and bulbous plants. This proposal attempts to provide a way of approaching the Romanian landscape, specific to the region it belongs to.

Keywords: *Lavandula*, landscaping, pattern, ornamental plant

1. Introduction

“Tradition and Modernity”, two aspects the University of Agriculture Sciences and Veterinary Medicine lives by. Celebrating its 150th anniversary [20], a statement is needed to enhance and spread the message of tradition, pride, and heritage. Designed by using the Romanian traditional patterns and specific colours, the proposal is based on combining two types of plants, perennials and bulbous plants. Traditionally, these well-balanced, geometrical shapes were used either as architectural decorations – rectangles, circles, and triangles – or in a wide range of colours – yellow, red, white, black, blue, or green – embroidered into the folk clothing. Design elements, such as line, shape, colour, value, or texture, can enhance and accentuate the aesthetic quality and value of a landscape design.

Tradition represents a set of concepts, customs, and beliefs that historically settle within social or national groups, passed on from generation to generation, defining a specific feature for each social group. The traditional landscape architecture design is a mixture between features used in the systematization of lands. Throughout history, traditional gardening in landscape architecture was present in three main categories of garden types: farms and utilitarian spaces, private gardens where the emphasis fell primarily on the quality of life, and the gardens of the upper classes, noblemen, designed to express their power and status. The characteristics of these landscapes varied according to the geographical region, the cultural influences of the neighbouring peoples, and the already existing traditions [9].

Some general guidelines should be established analysing the most representative historical (traditional) gardens – namely, the geometry of the space, preservation of an easy-to-understand landscape frame, and the accent of the constructed structures. Globally, the art of aesthetics in landscape architecture has influenced the way of thinking and perception about beauty of the people we now consider being influential. In Romania, the approach of beauty and the use of style began only at the end of the 18th century [13]. Until then, the Romanian gardens were composed mainly of medicinal and edible plants [8]. It can be said that Wilhelm Meyer was the first person who brought gardening practice in Romania at a European level [17].

Today, there is an increasing interest for the *Lavandula* species in the health and beauty industry, academic science but also in landscaping architecture design. These plants are giving a little more beauty to the world, lavender being a beauty for every garden and also a favourite perennial plant for gardeners owing to its colour, fragrance, and versatility.

In landscape architecture design, the Hungarian Pharmacy Society chose lavender to be the medicinal and aromatic plant of the year 2018 [19]. This plant was first mentioned and used as a healing plant by Dioscorides in the period of c. 40–90 AD [11]. The botanical name of the Lavender is *Lavandula*, which was given by Linnaeus. The genus name comes from the Latin term *lavare* – washing –, referring to the cosmetic uses of the plant. The *Lavandula* is part of the order *Lamiales*, family *Lamiaceae*, subfamily *Nepetoideae*, tribe *Ocimeae* [18]. Lavender is a herbaceous perennial plant which grows best in a climate with a cool winter and a warm, sunny summer [14]. For ornamental purposes, lavender is used for landscape architecture planting design, on curbs and in parks, being an unpretentious plant, which does not require much care. This plant embellishes the garden through the blue-violet flowers, and is also preferred near garden alleys or planted near the fences for the specific perfume released by the inflorescence during summer. The aim of the current paper is to present a proposal for a specific landscape design, a Transylvanian traditional pattern concept, to achieve a flowering period around the vegetation period, using current species of bulbous and lavender.

2. Materials and methods

The present paper outlines a case study analysis of a landscape architecture proposal, a green space measuring 500 sq. m, situated on the campus of the University of Agriculture Sciences and Veterinary Medicine of Cluj-Napoca. The green space chosen for this landscape architecture design concept is divided into two zones of almost symmetrical shape. More specifically, the site is situated in front of the main entrance for the university rectorate building founded 145 years ago. This green area is a north-facing space with enough sunshine for plants to fully develop throughout the year.

For this purpose, a planting combination between perennials and spring-flowering bulbs, such as *Allium*, *Crocus*, *Hyacinthus*, *Narcissus*, or *Tulipa*, were planted in association with shrubs and species that bloom generously at the beginning of the growing season (spring-summer). Based on the *Lavandula* layout in the summer time, some bulbous plants, such as *Dahlia*, *Canna*, *Eremurus*, *Fritillaria*, or *Gladiolus*, the late bloomers, fill an important colour path in the landscape until the end of the decorative season of a garden. Figures 1 and 2 below provide information on certain parameters of the plants under study, such as height, habitat, flowering period, and ornamental plant characteristics.

Lavandula are small aromatic evergreen shrubs with usually narrow, simple, entire, toothed, or lobed leaves and small tubular inflorescences. The 'Dwarf Blue' variety is a low-growing shrub, native to the Mediterranean region.

This evergreen shrub can grow up to 20–30 cm, and it has deep blue flowers during the summer. The 'Nana Alba' variety is a bushy, compact, evergreen shrub that grows up to 30 cm with white flowers appearing on tall spikes in the summer that are in contrast with the narrow grey-green leaves. The table below (*Table 1*) includes certain flowering plants in order to create the traditional landscape-architecture-patterned floral combinations:

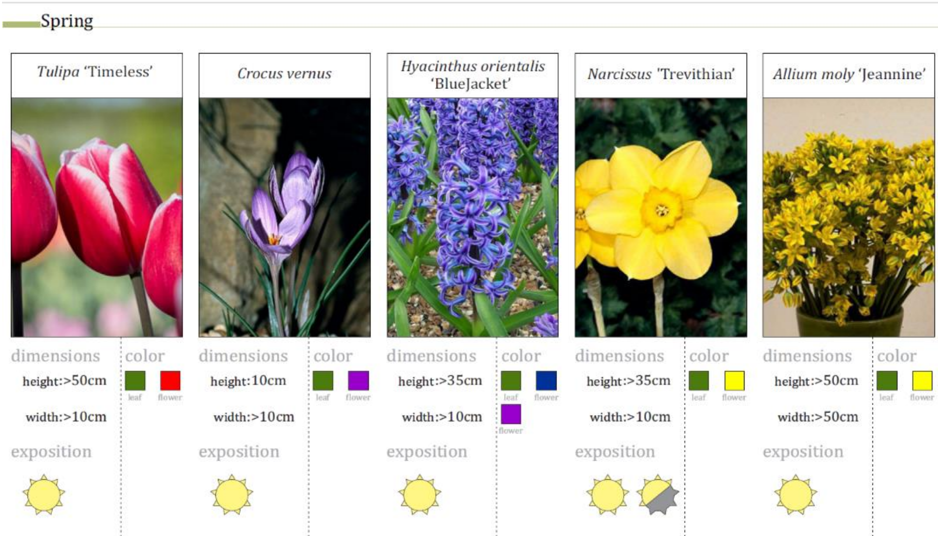

Figure 1. Characteristics of the bulbous species proposed in the spring layout of the landscape (original)

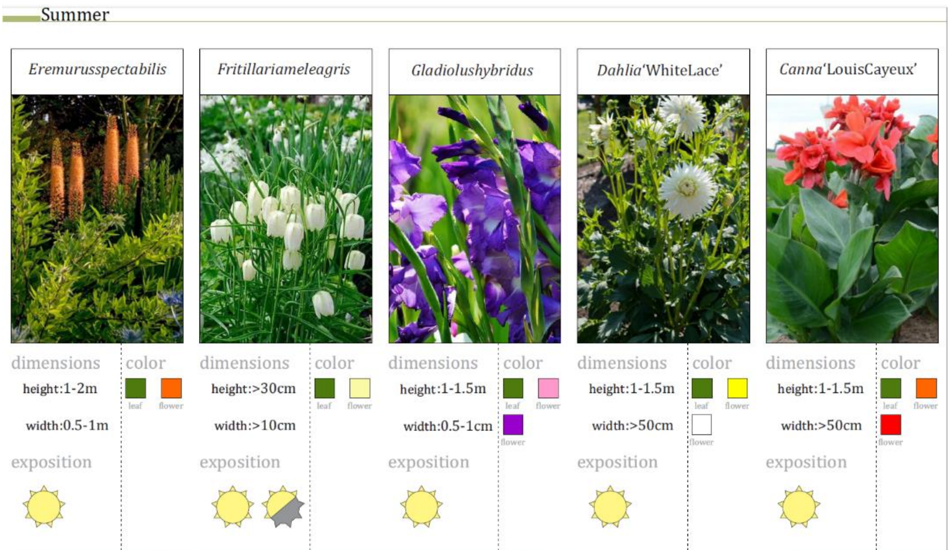

Figure 2. Characteristics of the bulbous species proposed in the summer layout of the landscape (original)

Table 1. Ornamental plants used in the planting design combinations

No.	SPECIES	Planting material	Planting plan
		Quantity	Unit
		(pieces)	(pieces/square meter)
Spring decoration time			
1	*Allium moly* 'Jeannine'	60	10/m^2
2	*Crocus vernus*	600	600/m^2
3	*Hyacinthus orientalis* 'Blue Jacket'	845	65/m^2
4	*Lavandula angustifolia* 'Dwarf Blue'	608	8/m^2
5	*Lavandula angustifolia* 'Nana Alba'	232	8/m^2
6	*Narcissus sp.* 'Trevarthian'	130	65/m^2
7	*Tulipa gesneriana* 'Timeless'	5330	65/m^2
Summer decoration time			
1	*Canna sp.* 'Louis Cayeux'	54	10/m^2
2	*Dahlia sp.* 'White Lace'	16	10/m^2
3	*Eremurus spectabilis*	820	10/m^2
4	*Fritillaria meleagris*	130	10/m^2
5	*Gladiolus hybridus*	130	10/m^2
6	*Lavandula angustifolia* 'Dwarf Blue'	–	8/m^2
7	*Lavandula angustifolia* 'Nana Alba'	–	8/m^2

These ornamental plants were arranged in the form of a heterogeneous mosaic. The design layout of the proposed vegetation combinations was in accordance with the planting plans and shall consider the way in which they are placed. The planting method differs for each plant, depending on the ornamental species used. In accordance with the various plant sizes [1], the following planting plans are used to achieve a proper spread. For example, in the case of *Lavandula angustifolia*, eight plants are proposed for each square meter (*Fig. 3*). In the case of the bulbous plants [2] (*Fig. 4*), *Tulipa gesneriana*, *Crocus vernus*, and *Hyacinthus orientalis* were arranged from 65 to 600 pieces of bulbs in one square meter. In the same manner, 10 pieces of bulbous plants are arranged per square meter [10] for the following species: *Allium moly* 'Jeannine', *Eremurus spectabilis*, *Fritillaria meleagris*, *Gladiolus hybridus*, *Dahlia sp.* 'White Lace', and *Canna sp.* 'Louis Cayeux', highlighted in *Fig. 6*.

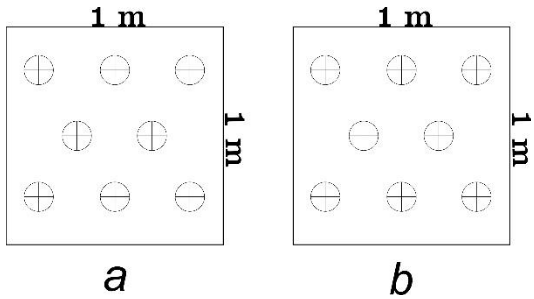

Figure 3. Planting plan for *Lavandula angustifolia* ‘Dwarf Blue’ (a) and *Lavandula angustifolia* ‘Nana Alba’ (b) (original)

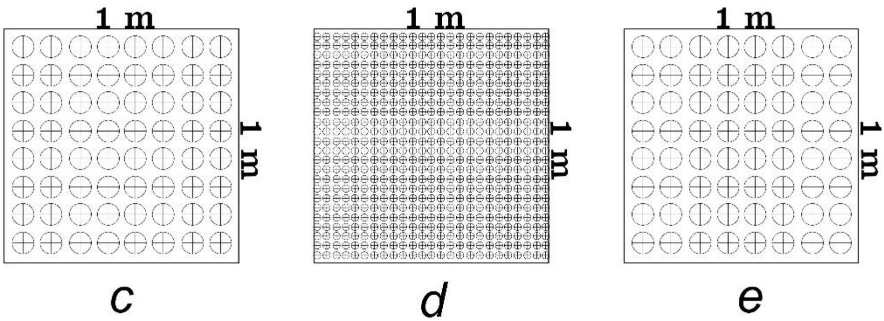

Figure 4. Planting plan for *Tulipa gesneriana* ‘Timeless’ (c), *Crocus vernus* (d), and *Hyacinthus orientalis* ‘Blue Jacket’ (e) (original)

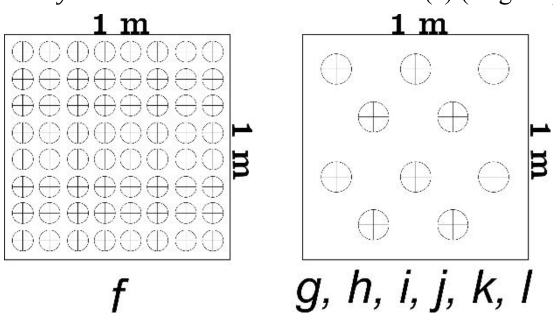

Figure 5. Planting plan for *Narcissus sp.* ‘Trevarthian’ (f), *Allium moly* ‘Jeannine’ (g), *Eremurus spectabilis* (h), *Fritillaria meleagris* (i), *Gladiolus hybridus* (j), *Dahlia sp.* ‘White Lace’ (k), and *Canna sp.* ‘Louis Cayeux’ (l) (original)

In creating the concept design, 3D modelling and rendering software were used such as SketchUp 2018, Lumion 6, and CorelDraw 2017. After the topographic plan had been processed and correlated with the existing green area, the 3D model and the following plan were created as shown in fig-s 6 and 7.

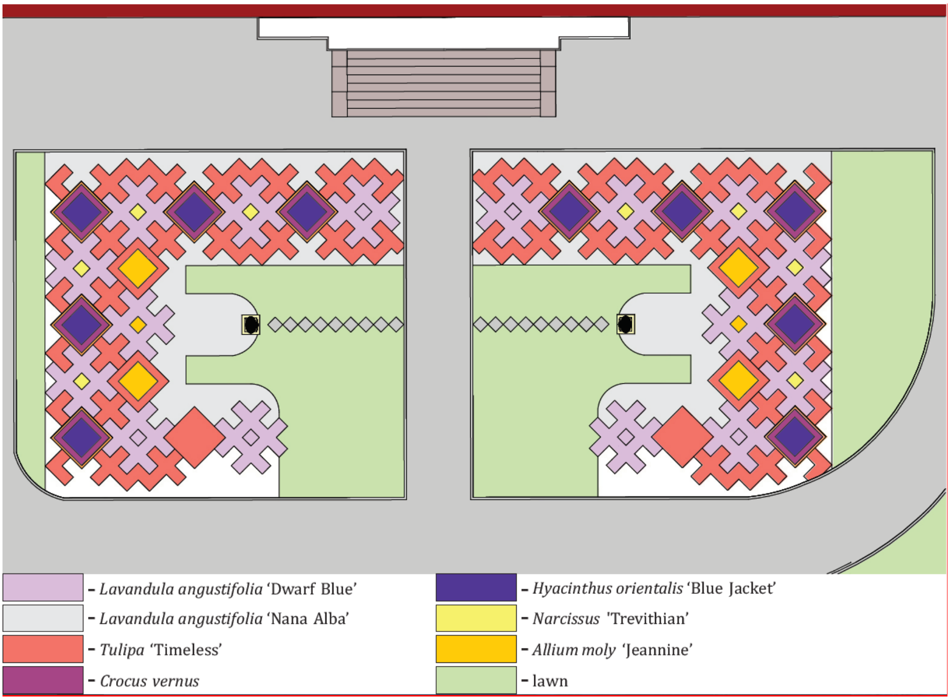

Figure 6. Landscape architecture planting plan for spring decoration (original)

In order to create detailed renders, images were taken on-site and imported into specialized programs to create the virtual world and implicitly the concept design – in this context, the Lumion 6 program, a 3D render software was used to create lifelike representations. Following a sketch as a general guideline, a zoning based on a traditional Transylvanian concept was made, and the floral vegetation placement was chosen according to the decoration period, flowering, colour, texture, size [1,2], and shape. In this case, the decorative transition from spring to summer was eventually achieved.

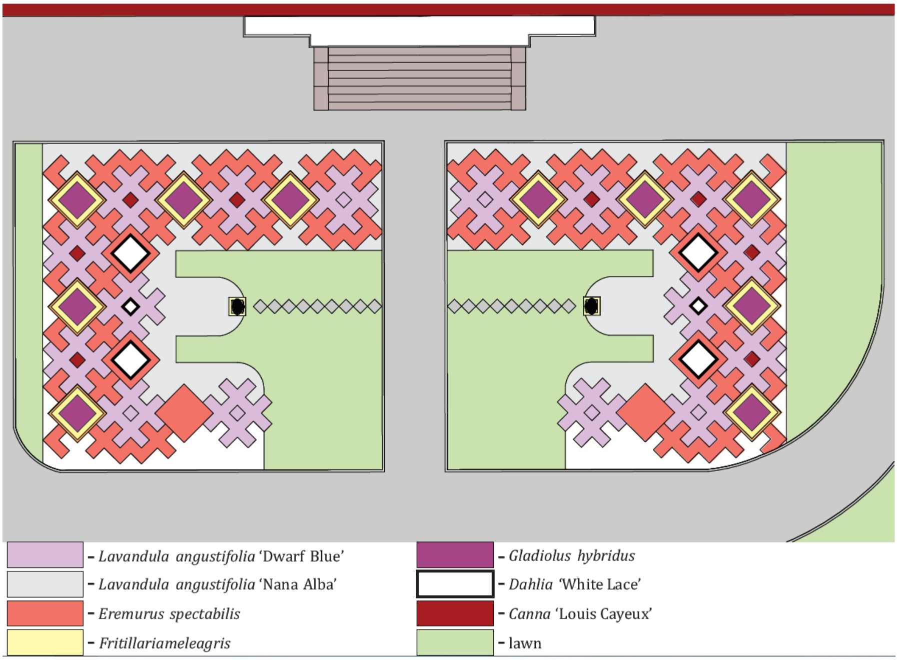

Figure 7. Landscape architecture planting plan for summer decoration (original)

3. Results and discussions

Results regarding height and the decoration period of the plants: in order to be able to describe in detail each bulbous and lavender species, observations were made on the important characteristics and properties of ornamental plants. Therefore, proposals will be made for a landscape design concept according to these aesthetic characteristics. In this case, the purpose of our project will be to obtain plant combinations for a great overall effect such as form, colour, contrast, and texture. The height and blooming period of the plants described in *Table 2* contribute to the general appearance of the selected species that decorate the proposed landscape [7]. Also, regarding the plant habitat, it can be seen that *Crocus vernus* is smaller (10 cm) compared to *Eremurus spectabilis*, which is the highest bulb species (200 cm) [5]. Additionally, the *Lavandula* species have a medium height among the selected ornamental plants.

The flowers are small, blue-violet or white; they are arranged in terminal spiciform inflorescences supported by long, rigid peduncles [6]. It can be seen from *Table 2* that the two lavender varieties used for the landscape design have similar habitats. The *Lavandula angustifolia* 'Dwarf Blue' is 20–30 cm tall, and its spread is 30–40 cm, while the *Lavandula angustifolia* 'Nana Alba' has almost the same size – height: 30–40 cm, spread: 45 cm. Both lavender varieties' flowering period is almost the same, and, of course, this depends on the weather conditions, flowering typically occurring in June or July and decorating at least for 3–4 weeks.

Table 2. Blooming time and habitat of the studied ornamental plants

No.	SPECIES	Decoration time												Habitat
		Spring			Summer			Autumn			Winter			Height
		J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	(cm)
	Bulbs													
1	*Allium moly* 'Jeannine'													50
2	*Canna sp.* 'Louis Cayeux'													100–150
3	*Crocus vernus*													10
4	*Dahlia sp.* 'White Lace'													100–150
5	*Eremurus spectabilis*													100–200
6	*Fritillaria meleagris*													20
7	*Gladiolus hybridus*													100–150
8	*Hyacinthus orientalis* 'Blue Jacket'													15–25
9	*Narcissus sp.* 'Trevarthian'													35
10	*Tulipa gesneriana* 'Timeless'													40
	Perennials													
11	*Lavandula angustifolia* 'Dwarf Blue'													20–30
12	*Lavandula angustifolia* 'Nana Alba'							**x**	**x**	**x**				20–30

Table 2 presents the selected bulb and lavender species' flowering phenology [5, 7, 12, 18] because, designing with ornamental plants, a landscape architecture project must be in accordance with the decoration period, shape, colour, and blooming time. It can be seen that the predominant colours are the complementary shades, such as yellow or purple, combined with white flowers.

Analysing the planting period of the bulbs, it is important to achieve the proposed planting design by respecting the specific time frame as shown in *Table 3*. For example, bulbs such as *Allium moly*, *Crocus vernus*, *Fritillaria meleagris*, *Hyacinthus orientalis*, *Narcissus sp.*, and *Tulipa gesneriana* have to be planted in the autumn in order to obtain the expected spring blooming layout [5].

Lavender (*Table 3*) can be planted in two time periods of the year, in the spring-summer and autumn. In the spring-summer period, it is recommended to plant the lavender from March to May, and in the autumn period it is best to plant it in September or October, depending a lot on the climate conditions for the specific region. The planting distance between plants depends on the cultivated lavender varieties. In landscape planting design, there have been no reliable data until now; the lavender plants surely need to be planted at least 50 cm apart from each other to have a well-developed and -formed lavender shrub.

Table 3. Planting period in landscape design layout

No.	SPECIES	Planting period											
		Spring			Summer			Autumn			Winter		
		J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
	Bulbs												
1	*Allium moly* 'Jeannine'												
2	*Canna sp.* 'Louis Cayeux'												
3	*Crocus vernus*												
4	*Dahlia sp.* 'White Lace'												
5	*Eremurus spectabilis*												
6	*Fritillaria meleagris*												
7	*Gladiolus hybridus*												
8	*Hyacinthus orientalis* 'Blue Jacket'												
9	*Narcissus sp.* 'Trevarthian'												
10	*Tulipa gesneriana* 'Timeless'												
	Perennials												
11	*Lavandula angustifolia* 'Dwarf Blue'												
12	*Lavandula angustifolia* 'Nana Alba'												

The design proposal aims were to create a green space consisting of spring and summer using ornamental plants to create a floral mosaic carpet with a design specific to the traditional Romanian concept. The traditional pattern used in this case comes from the Transylvanian region of Romania. It is mainly composed of straight lines forming squares and rectangles perpendicular on each other.

To achieve balance, two equal parts were created thus, resulting in the continuous symmetry of the studied area. The repeated placement of the ornamental plants, both in the foreground and in the background, in right-angled shapes, links the space with the rest of the composition, creating unity and harmony. As unifying elements of the design concept, light-coloured gravel and lawn were used to further enhance the contrast with the surroundings.

Two scenarios are presented in the following figures for the spring and summer design concept arrangements. The first one (*Fig. 8*) was composed mainly by bulbous floral species and as a perennial unifying element such as lavender. The second arrangement presented in *Fig. 9* was composed of perennial floral species, their decoration period starting in early summer.

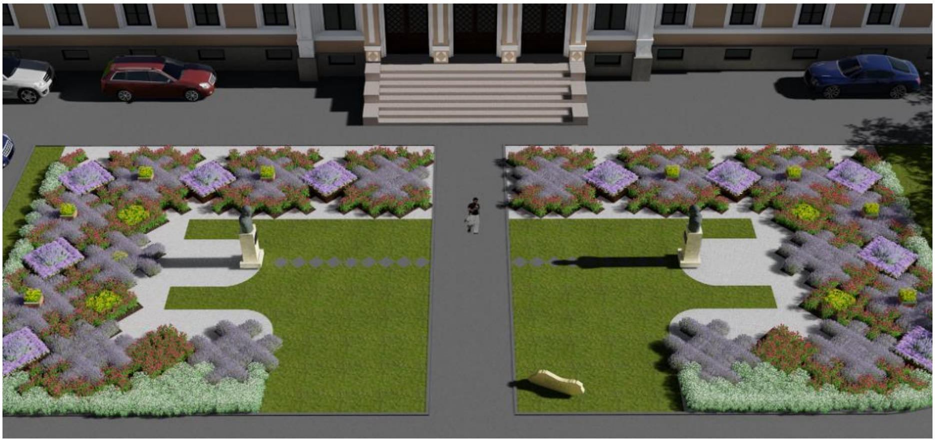

Figure 8. Spring decoration representation of the proposed landscape design (original)

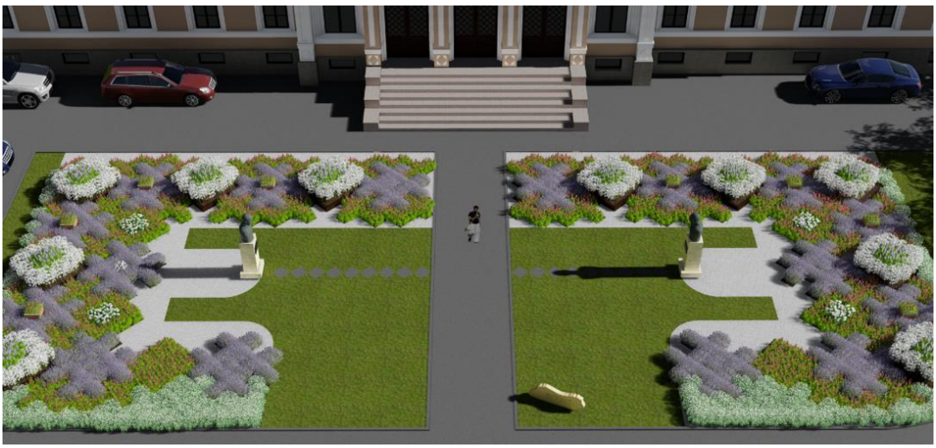

Figure 9. Summer decoration representation of the proposed landscape design (original)

Due to the shape of the existing green area, the zone in divided into two parts. The north-eastern zone is almost the same as the north-western one but smaller is size. In the next part, following the planting plan and using a 3D rendering software, we can observe the ornamental plant arrangement during spring and summer time (*Fig. 10*). In the spring layout, bulbous species, such as *Allium moly*, *Crocus vernus*, and *Tulipa gesneriana*, were proposed in the combination of the *Lavandula angustifolia* 'Dwarf Blue' and 'Nana Alba' species in summer.

Figure 10. Spring and summer decoration in the north-eastern view (original)

The north-western area is bigger in size than the previously presented one. The planting plan layout of bulbous species accomplish the traditional pattern by using *Narcissus sp.* and *Hyacinthus orientalis* for the spring time decoration and *Canna sp.* ‘Louis Cayeux’, *Dahlia sp.* ‘White Lace’, and *Fritillaria meleagris* in the summer design (*Fig. 11*).

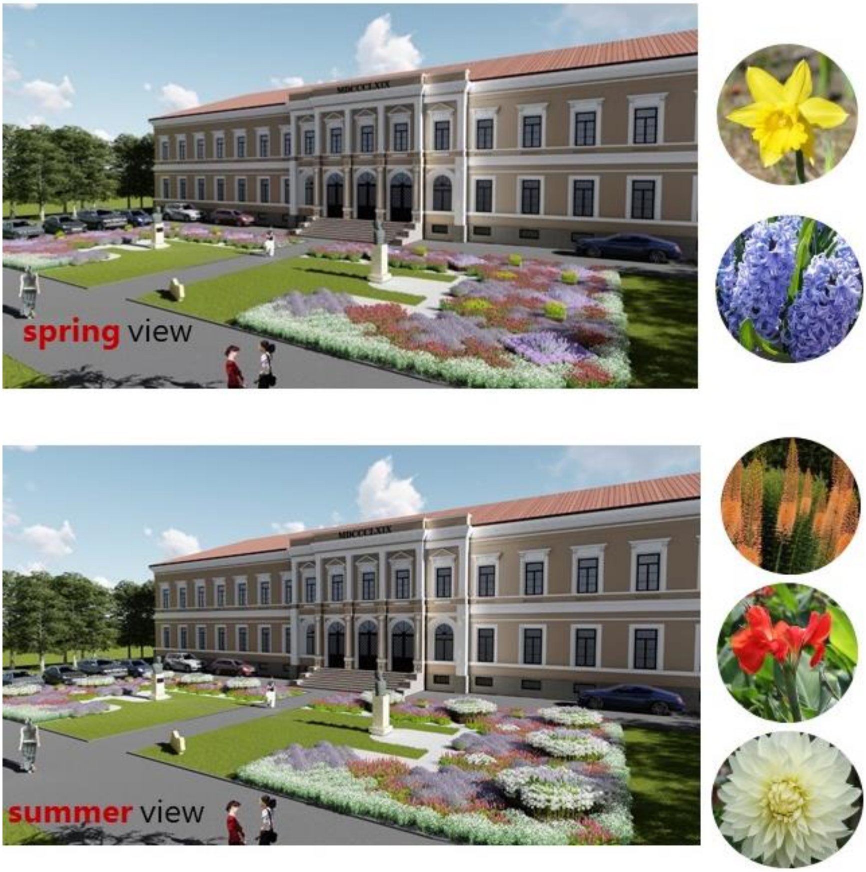

Figure 11. Spring and summer decoration in the north-western view (original)

The proposed vegetation layout gives passers-by an effect of movement and a certain amount of dynamism in the shape of a floral mosaic composition. This colourful and rigorous use of plants gives a clear picture of the whole design concept and a degree of unity in the landscape at the same time.

4. Conclusions

In landscape design, the human mind will always find well-balanced, regular shapes such as circles, squares, or rectangles more appealing than other, asymmetrical shapes. Introducing new bulbous varieties in local planting design can increase variety in terms of colour, shape, blooming, and decoration period. Also, perennials, such as lavender, in a planting design composition can be valuable ornamental plants with a permanent decorative element during de vegetation period. Traditional Transylvanian patterns are one of the most representative elements in our local history, and by using landscape architecture one can place emphasis on local identity and heritage.

Whenever someone hears the word lavender, it certainly flashes in their mind an image of a big field full of blue/violet flowers and that very specific *Lavandula* fragrance. So, thanks to these features, lavender plants are required more often by garden owners, or they are used by the landscapers in Romania for landscaping designs.

References

[1] Addai, I., Scott, P. (2011), Influence of bulb sizes at planting on growth and development of the common hyacinth and the lily. *Agriculture and Biology Journal of North America* 2, 298–314.

[2] Ahmad, I., Ahmad, T. Asif, M., Saleem, M., Akram, A. (2009), Effect of bulb size on growth, flowering and bulbils production of tuberose. *American-Eurasian J. Agric. & Environ. Sci.* 25(3), 391–397.

[3] Bernáth, J. (2000), *Gyógy- és aromanövények*. Budapest: Mezőgazda Kiadó. 384–389.

[4] Cantor, M. (2016), *Floricultură specială – Manual didactic*. Cluj-Napoca: AcademicPres.

[5] Cantor, M., Dumintras, A., Zaharia, D. (2007), *Plante bulboase utilizate în amenajări peisagistice*. Editura Todesco.

[6] Draghia, L., Chelariu, E. L. (2011), *Floricultură*. Brad, Iași: Ion Ionescu.

[7] Dumitraş, A., Singureanu, V., Sabo, G. (2008), *Principii generale de proiectare şi amenajare a spaţiilor verzi*. AcademicPres.

[8] Glăman, G., Vlăduț. M. (2003), *Floricultura și arta grădinăritului la Români*. Bucharest: Ceres.

[9] Iliescu, A. F. (2003), *Arhitectura peisageră*. Bucharest: Ceres.

[10] Kumar, K., Singh, C. N., Beniwal, V. S., Pinder, R. (2016), Effect of spacing on growth, flowering and corn production of gladiolus (*Gladiolus sp.*) cv. American Beauty. *International Journal of Environment, Agriculture and Biotechnology (IJEAB)* 1(3), 550–554. ISSN: 2456-1878.

[11] Lis-Balchin, M. (2004), *Lavender. Handbook of herbs and spices*. Vol. 2. Peter KV, Woodhead Publishing Ltd & CRC Press.

[12] Lord, T., Lawson, A. (2012), *Encyclopedia of planting combinations: Over 4000 color and planting schemes*. Firefly Books.

[13] Marcus., R. (1958), Parcuri și grădini din România. Bucharest: Ed. Tehnică.

[14] Mason, J. (2014), *Growing and knowing lavender*. ACS Distance Education.

[15] McCoy, J. A. (2001), *Lavender: History, taxonomy, and production*. North Carolina State University.

[16] Roman, G. V., Morar, G., Robu, T., Ștefan, M., Tabără, V., Axinte, M., Borcean, I., Cernea, S. (2012), *Fitotenie. Vol. II. Plante tehnice, medicinale și aromatice*. Bucharest: Ed. Universitară. 375–377.

[17] Toma, D. (2001), *Despre grădini și modurile lor de folosire*. Iași: Polirom.

[18] Toma, F. (2009), *Floricultură și artă florală. Vol. IV. Specii utilizate pentru decorul parcurilor și grădinilor*. Bucharest: Invel Multimedia.

[19] *** http://www.mgyt.hu/hu/mgyt-hirek/387-ev-gyogynovenye-2018.

[20] *** https://www.usamvcluj.ro/.

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Evaluation of industrial tomato genotypes in open-field production

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Abstract. Recently, industrial tomato production in Hungary shows an increasing tendency after a weak processing period. However, to maintain the cultivation profitable, the use of proper technology and genotype is indispensable.

In the experiment, five hybrids and one variety were evaluated in a plot experiment design on open field. The main objective was to evaluate the fruit quality of different genotypes and to determine the suitability for mechanical harvest.

According to the results, *Heinz 1015* F_1 and *Heinz 9478* F_1 had the best fruit quality for industrial processing.

Nowadays, the use of hybrids with good adaptability and resistance properties is important for a profitable production.

Keywords: economic value, quality examination, sensory, profitable production, evaluation

1. Introduction

At present, tomato has one of the largest producing areas worldwide, and it is indispensable not only for fresh market but for the industry as well [3]. It is an especially fast-developing sector: in a little more than a decade, it has grown by 49% [1]. According to the statistics, the total growing area is more than 4.8 million hectares worldwide, of which a little more than 182 million tons were harvested [2]. Tomato is important not only worldwide but in Hungary as well.

In Hungary, the total production area of industrial tomato was 2,200 hectares in 2017, of which nearly 185 thousand tons were harvested [4]. All produced tomato is processed in Hungarian factories [5]. Univer, which is the principal tomato-processing company in Hungary, was the 37th in the world ranking in 2018 [7].

Currently, the main problem is the low takeover price and the rise of production prices. The minimum production value is 70 tons per hectare. Thereby, to make production profitable, the yield has to reach 100 tons per hectare [6].

2. Materials and methods

The experiment was carried out at the University of Debrecen, Farm and Regional Research Institute, Botanical and Exhibition Garden, on an open field in 2017. The soil type was lowland chernozem. After the harvest, different quality parameters were examined on the berries.

Experiment progress

In order to have representative results, the following six genotypes were evaluated: *Heinz 1015 F_1*, *Heinz 9478 F_1*, *NUN 254 F_1*, *Prestomech F_1*, *Rustico F_1*, and *Kecskeméti 407*. The planting date was 5 May 2017. The parcel size was 80 × 45 cm with 21–30 plants. Harvesting was carried out on 30 August 2017.

Conducted measurements

The measurements were conducted immediately after the harvest. The following physical parameters were evaluated: fruit shape index (length/ diameter), weight of berries (g/piece), yield of plants (g/plant), water-soluble dry matter content (Brix%) with hand refractometer (PAL-BX/RI), and firmness of the berries (g cm^{-2}) with Magness-Taylor pressure tester. Furthermore, skin thickness was calculated – measuring the force needed to tear the skin (kg^{-1}) – with TA.XT Plus Texture Analyzer. The sensory evaluation was carried out for 12 properties, which were rated from one to five, by 15 persons.

3. Results and discussions

The berries were evaluated for different quality parameters right after the harvest. The main objective was to select the proper genotypes for the Hungarian growing conditions.

Fruit shape index

The shape of the berries during mechanical harvest is of utmost importance. The fruit shape index is the length of the berry divided by its diameter. If the result equals one, the berry is spherical. When the result is less than one, the berry is flat, and when the result is more than one the berry is oval. For mechanical harvest, the best shape is oval, with a fruit shape index between 1.0 and 2.0.

The fruit shape index of the evaluated genotypes is shown in *Figure 1* and the evaluated berries in *Figure 2*.

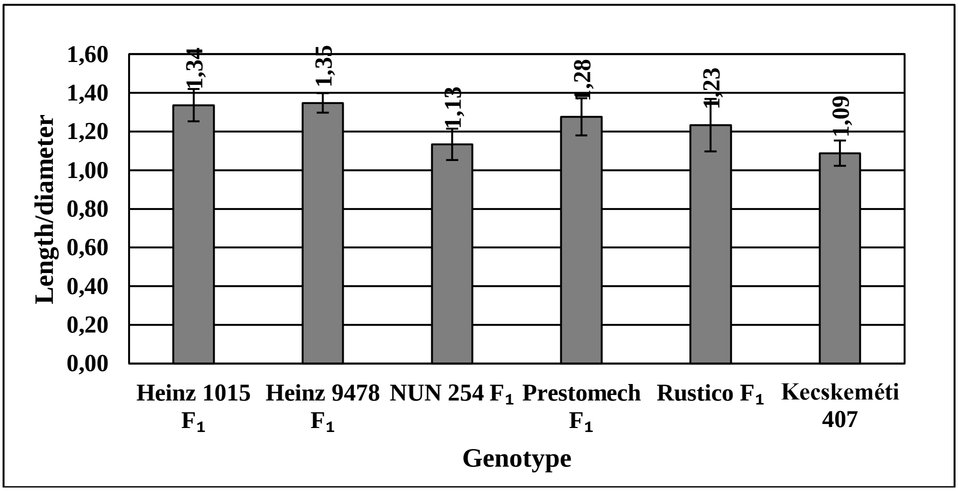

Figure 1. Fruit shape index of the evaluated genotypes

Figure 2. Fruit shape index of the evaluated genotypes

Heinz 1015 F_1 and *Heinz 9478 F_1* had the highest values, the average of the two genotypes showing no statistical difference. *NUN254 F_1* and *Kecskeméti 407* had the lowest values (1.13 and 1.09). *Kecskeméti 407*, the only examined open-pollinated variety, can also meet the requirements with its barely oval shape.

According to the results, all the examined genotypes are suitable for the industry, with a fruit shape index between 1.0 and 2.0.

Weight of the berries and yield per plant

Uniform berry weight plays a major role in harvesting: the key of successful mechanical harvesting is the similar shape and size of the berries, which is highly influenced by the weight of the berries. The other important parameter, which should be examined together with berry weight, is the yield of the plants.

Presently, the main goal is to reach 100 t ha^{-1} yield to make the production profitable. To reach this objective, it is important to use proper genotypes, which have not only unified berry weight but proper yield as well.

In the last few years, the number of plants per hectare has decreased from 50 thousand to 35–38 thousand according to farmers' reports. This increases the need to choose genotypes with higher yield per plant.

The evaluated genotypes have different values, which are presented in *Table 1*.

Table 1. Marketable yield of the evaluated genotypes

	Berry weight (g per piece)	***Marketable yield per plant (g per plant)***
Heinz 1015 F_1	56.80 ± 8.02	2,712
Heinz 9478 F_1	64.08 ± 5.94	3,016
NUN 254 F_1	68.20 ± 5.22	1,636
Prestomech F_1	69.20 ± 4.96	1,587
Rustico F_1	62.70 ± 4.72	1,239
Kecskeméti 407	77.70 ± 9.35	560

Even though *Kecskeméti 407* had the lowest marketable yield per plant due to sunburnt foliage, it yielded the highest berry weight. However, the high standard deviation shows the non-uniformity of the variety, which can influence the mechanical harvest.

Regarding to berry weight, *Heinz 1015 F_1* had the lowest mean, and the standard deviation was rather high (56.80 ± 8.02 g). Meanwhile, the yield of the plants was especially good, the marketable yield being a little more than 2.7 kg per plant.

Concerning yield per plant data, the best result belongs to *Heinz 9478 F_1*, which produced a little more than 3 kg of marketable yield per plant (3,016 g).

Water-soluble dry matter content

One of the most important quality parameters of industrial tomato is the water-soluble dry matter content, which was evaluated after the harvest. This parameter and the proper harvesting time (before 20 August) determine the purchase price. The mentioned two parameters can alter the price both in a positive and in a negative way.

For the food industry, the required value is 5.0 Brix degree, above which the recipient raises the acceptance price. The other important value is 4.7 Brix degree: below this, the acceptance price decreases. The results of the evaluated genotypes are shown in *Figure 3*.

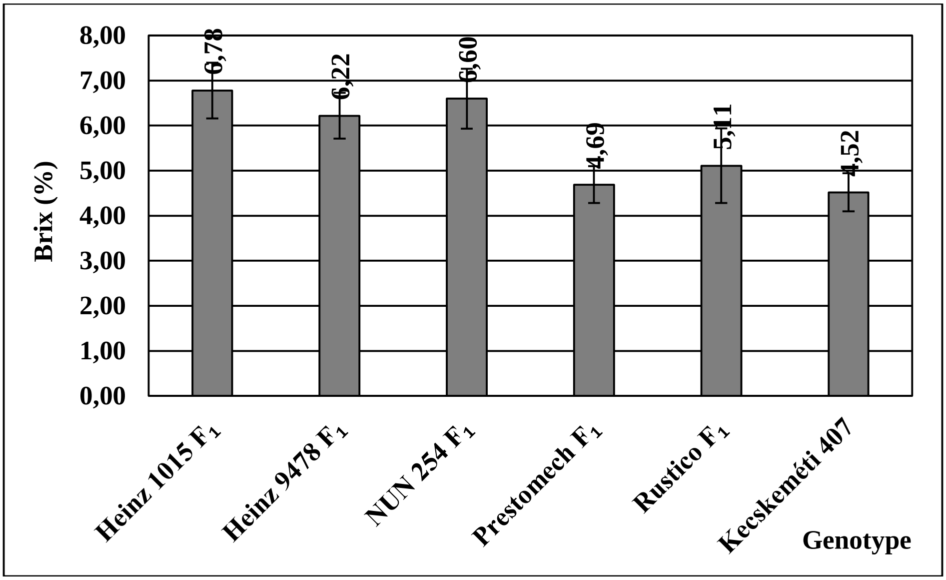

Figure 3. Water-soluble dry matter content (Brix%) of the evaluated genotypes

According to the results, the examined genotypes can be divided into two groups. In the first group, there are three hybrids: the firmly good *Heinz 1015 F_1*, *Heinz 9478 F_1*, and *NUN 254 F_1*, with high water-soluble dry matter content and higher than 6.0 Brix degree. In our growing circumstances, these hybrids were the most prosperous considering industrial production.

The other group was composed of the other three genotypes, *Prestomech F_1*, *Rustico F_1*, and *Kecskeméti 407*. The Brix values of these three genotypes are close to 5.0, only the *Rustico F_1* exceeding this value.

Firmness and skin thickness

Besides water-soluble dry matter content, firmness and skin thickness are two of the main quality parameters of industrial tomato. The berries have to be resistant against injuries during mechanical harvest and transport because injured berries begin to deteriorate very quickly. The results for the examination of these quality parameters are shown in *Table 2*.

Firmness must be at least 1,200 g per cm^{-2} to fulfill the requirements of the industry. All of the evaluated genotypes meet this value. However, there is no significant difference between the results of each hybrid.

The other important quality parameter is skin thickness, which can be measured by the force needed to tear the skin. It is at least as important from the viewpoint of damages as firmness. Skin thickness is the main quality parameter, which determines the resistance of the berries to mechanical injuries during the harvest and transport.

One of the evaluated genotypes had outstanding results: the *Kecskeméti 407* needed extremely high (0.680), nearly eight times stronger force to tear the skin compared to the evaluated hybrids. The hybrids needed nearly equal force to tear the skin, but none of them reached the value of 0.100 kg.

Table 2. Firmness and skin thickness of the evaluated genotypes

Genotype	***Firmness (g cm^{-2})***	***Skin thickness (kg^{-1})***
Heinz 1015 F_1	1,601.9 ± 179.45	0.089 ± 0.018
Heinz 9478 F_1	1,458.0 ± 204.33	0.071 ± 0.015
NUN 254 F_1	1,333.0 ± 183.49	0.085 ± 0.022
Prestomech F_1	1,320.0 ± 115.95	0.067 ± 0.018
Rustico F_1	1,243.0 ± 107.61	0.083 ± 0.018
Kecskeméti 407	1,291.1 ± 118.04	0.680 ± 0.017

Sensory evaluation

As part of the experiment, sensory evaluation was carried out with 12 quality parameters.

Nowadays, the utilization of industrial tomato is becoming more and more widespread. In some cases, farmers can target the fresh market. In such cases, the detectable parameters are more important: costumers choose based on appearance; it is not possible to taste the products.

However, during industrial production, the quality parameters are more important because using less additives means better product quality and higher prices (additive-free and bio-products are more expensive).

According to our results, *Heinz 1015* F_1 and *Heinz 9478* F_1 had the proper quality parameters to fulfill the needs of the fresh market. Meanwhile, for industrial utilization, *Heinz 9478* F_1 had the best results in all but two parameters (*Table 3*).

Table 3. Sensory evaluation of the examined genotypes

	Heinz 1015 F_1	***Heinz 9478*** F_1	***NUN245*** F_1	***Prestomech*** F_1	***Rustico*** F_1	***Kecskeméti 407***
Appearance	4.40±0.52	4.70±0.48	3.70±0.67	3.80±1.03	4.00±0.67	4.00±0.47
Colour	4.60±0.52	4.80±0.42	3.40±0.70	4.30±0.48	4.60±0.52	4.00±0.67
Firmness	4.00±1.05	4.40±0.70	3.80±0.92	3.70±0.67	4.30±0.67	4.10±1.10
Sweet taste	3.50±0.71	3.60±0.84	2.90±0.57	3.00±0.67	3.00±1.15	2.80±1.32
Acidity	4.00±0.67	4.10±0.74	3.60±0.97	3.40±0.70	3.30±1.16	3.30±1.25
Tomato taste	4.20±0.63	4.00±0.82	3.10±0.74	2.90±0.57	3.40±0.84	2.70±1.06
Skin thickness	3.00±1.33	3.40±1.17	2.70±1.06	2.90±1.37	3.00±1.41	2.80±1.03
Consistency	4.00±0.82	4.50±0.71	3.70±0.95	3.90±1.20	4.20±1.03	3.90±0.74
Juiciness	3.20±1.14	3.50±0.97	3.50±1.08	3.40±1.17	3.30±1.06	3.40±1.07
Sour taste	3.90±1.60	4.00±1.63	3.40±1.58	3.20±1.48	3.40±1.43	3.00±1.63
Unpleasant aftertaste	4.70±0.48	4.80±0.42	3.90±1.45	4.40±0.70	4.10±0.74	3.90±1.20
Overall impression	4.10±0.74	4.40±0.52	3.30±0.95	3.60±0.97	3.50±0.71	3.10±1.29

4. Conclusions

Tomato has one of the largest producing areas worldwide. In the last few years, its growing area and yield have been increasing in Hungary as well.

Nowadays, the purchase price is rather low; therefore, the yield has to reach or exceed 100 t ha^{-1} for a profitable production.

In the experiment, six genotypes were evaluated on open field. The measurements verified different quality parameters: fruit shape index (length/ diameter), weight of berries (g/piece), yield of plants (g/plant), water-soluble dry matter content (Brix degree), firmness of the berries (g cm^{-2}), skin thickness, and sensory evaluation.

Finally, we can state that the *Heinz 1015 F_1* and *Heinz 9478 F_1* hybrids were the most suitable ones for industrial production in our circumstances. These hybrids stood out with rather high water-soluble dry matter content (6.22–6.78 Brix degree), optimal fruit shape index (1.34–1.35), yield of plants (2,712–3,016 g), proper firmness (1,601.9 ± 179.45 and 1,458.0 ± 204.33 g cm^{-2}), and skin thickness (0.089 ± 0.018 and 0.071 ± 0.015 kg^{-1}).

Acknowledgements

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References

[1] XXXX (2016), 88 million tons of fresh Tomatoes! *Eurofresh Distribution* 144, 42.
[2] FAO (2019), http://www.fao.org/faostat/en/#data/QC.
[3] Gould, W. A. (2013), *Tomato production, processing and technology*. Third edition. Baltimore, USA: CTI Publications Inc.
[4] KSH (2019), https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_omn004f.html.
[5] Rimóczi, I. (2018), Százezer tonna ipari paradicsom. *Kertészet és szőlészet* 65(38), 6–9.
[6] Takácsné Hájos, M., Vas, F. (2016), Termesztési mód hatása az ipari paradicsom jövedelmezőségére. *Gradus* 3(2), 268–273.
[7] http://www.univer.hu/hu/aktualis/hirek/paradicsomfeldolgozok_vilagrangsora_az_univer_a_37_helyen.html.

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The behaviour of some hyacinth varieties in forced culture

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Abstract. This paper presents the behaviour of five hyacinth varieties: 'City of Haarlem', 'Blue Jacket', 'Miss Saigon', 'Jan Boss', and 'Double Prince of Love' in forced culture under the influence of different culture substrates. For this purpose, the following parameters were monitored concerning the main characteristics: number of flowers from inflorescence, length of stem flower, earliness of flowering period, and the flowers' blooming period. The results of this work show that in culture substrate garden soil and sand (1:1) the best results were obtained regarding the length of the floral stem, number of flowers from inflorescence, and flowering period, and less favourable results were obtained for bloom precocity.

Keywords: flowering, morphological characteristics, potted plants, substrate

1. Introduction

Hyacinths are popular garden flowers, but they can also be found in markets, flower shops, as cut flowers, or in pots.

The genus *Hyacinthus* brings together approximately 30 bulbous rustic species [1]. The current Dutch cultivars have been imported in the middle of the 16th century, and they are descended from a blue species of *Hyacinthus orientalis* [2].

In the recent years, the floricultural greenhouse industry produced potted plants and cut flowers in Romania from a variety of bulbous species such as tulips, daffodils, Dutch iris, or lilies. According to Janse [3], in the early 18th century, the forcing of hyacinth bulbs was already known.

At the beginning of this century, temperature treatments were introduced for hyacinths plants to produce high-quality flower and sufficient stem length [4].

According to Selaru [5], the thermal treatments to which the bulbs are subjected during storage aim at forming and preserving the floral bud until the bulb is planted. For example, bulbs intended for flowering in December-January are harvested in the first part of June and kept for two weeks at 30 °C, after which the temperature is lowered to 25.5 °C for three weeks, and then it is maintained at 23 °C until the flower is fully formed. Following this phase, storage is kept at 17 °C until the bulbs are planted, which takes place in September (*Table 1*).

Table 1. Calendar of forcing hyacinths with thermally treated bulbs

Planting period	Flowering periods	Temperature in rooting room	Preservation temperature in the month before planting
15–30 Sept.	20–25 Dec.	9 °C	13 °C
1–10 Oct.	25–15 Jan.	9 °C	17 °C
15 Oct.	15 Jan.–15 Feb.	9 °C	17 °C
15 Nov.	15 Feb.–15 Mar.	9 °C	17 °C
15 Dec.	15 Mar.–15 Apr.	9 °C	17 °C

Source: [5]

Planting bulbs for forced cultivation is done in pots with a diameter of 9–11 cm or on rails, in a light, well-drained substrate. The planting distances are very small, 2–3 cm, ensuring a density of 300–350 plants per square meter. The depth of planting should be such that the leaf cone remains at the surface of the substrate [1]. Bulb size for culture in pots should be more than 16 cm in circumference [6].

Immediately after planting, bulbs need 8–12 weeks of low temperature, 4–5 °C, according to [1], or 9 °C for a good rooting [5].

The need for low temperature duration varies depending on the variety and the finished product at recovery. In the case of cut flowers, the period of cold is longer in order to obtain longer flowering rods. For two weeks from planting, a maximum temperature of 13 °C can be permitted because it would otherwise damage the normal growth of the plant. Towards the end of the rooting period, the temperature may drop to 7 °C.

In the case of untreated bulbs, the temperature must be between 5 and 9 °C.

In the case of late forces, shoots grow too much in the rooting room (this must exceed 8–10 cm). In this situation, as soon as the bulbs have rooted at 9 °C, the temperature must be lowered to 2–0 °C. These plants will no longer need dark conditions for the elongation of the stem [5, 7].

After the bulbs rooted and benefited from the necessary cold, the pots are transferred to the greenhouse where the forcing itself occurs by increasing the temperature gradually to the level of 22–23 °C. This thermal threshold is maintained until the buds begin to colour when temperature drops to 20 °C, and when they are all coloured, it decreases and remains at 15 °C until it is recovered [1, 5].

Regarding the light within the first 6–7 days from the beginning of the forcing itself, the plants intended for use as cut flowers will be covered with a black foil for the elongation of the floral stem, after which light is ensured at the minimum intensity of 10,000 lux [8].

Hyacinths may also be forced to flourish earlier in their cultivation in greenhouses [9]. Planting bulbs is done by the end of October under natural environmental conditions. In January-February, the plastic material is installed – using heating as well if necessary – for the plants to benefit from the warmth needed for early flowering.

Considering the importance of this bulb flower crop, studies were focused on the behaviour of some *Hyacinthus orientalis* L. varieties in forced culture. Based on the observations and the measurements carried out for the morphological characteristics, the best varieties can be promoted on Romanian market as pot plants.

2. Materials and methods

The forcing of hyacinth bulbs was accomplished in the didactical greenhouses of the University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca (UASMV), during the period of 15 November 2017–30 March 2018.

The experiment consists in analysing the influence of culture substrate on the main morphological characteristics of the flower of some hyacinth varieties. The biological materials used to achieve this research were five of the most cultivated cultivars of *Hyacinthus orientalis*: 'City of Haarlem' (*Fig. 1*), 'Blue Jacket' (*Fig. 2*), 'Miss Saigon' (*Fig. 3*), 'Jan Bos' (*Fig. 4*), and 'Double Prince of Love' (*Fig. 5*). The cultivars are planted on pots in three culture substrates: garden soil, garden soil + peat (1:1), and garden soil + sand (1:1).

The combination of the two experimental factors with three and five graduations resulted 15 experimental variants. In the experiments, a completely randomized design and 3 replications were used. Five bulbs were used for each variant/replication with a total of 15 plants per variant.

Throughout the storage and until planting, the hyacinth bulbs were kept in a dry storage place at a temperature of 18 °C.

In the rooting chamber, the bulbs in the pots were kept at a temperature of 5–9 °C, and during the forced period in the heated greenhouse the temperature was kept in the range of 21–25 °C during the day and between 15 and 16 °C at night.

Figure 1. ‘City of Haarlem’ [10]

Figure 2. ‘Blue Jacket’ [11]

The experiment consists in analysing the influence of culture substrate on the main morphological characteristics of the flower of some hyacinth varieties (length of stem flower, number of flower/inflorescences, precocity of flowering, and flowering period).

[12]

[13]

Prince of Love’ [14]

The data were statistically analysed using analysis of variance test [15].

3. Results and discussions

Figure 6 shows the average data recorded for the average height of floral stems in the five studied varieties under the influence of the culture substrate.

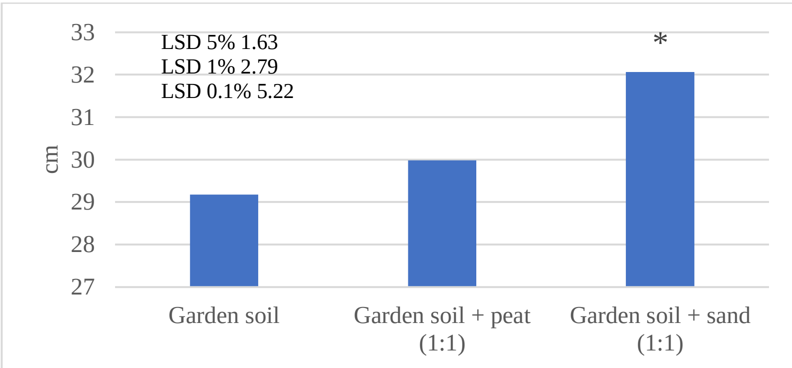

Figure 6. The average length of the floral stem under the influence of the culture substrate

By analysing *Figure 6*, we can see that the highest average height of the flower stem was recorded in the garden soil + sand (1:1) (average height: 32.06 cm), followed by the garden soil + peat substrate (29.98 cm). In the case of the mixture of garden soil and sand, there was an increase in the average plant height of 1.65 cm, which is a statistically significant positive difference.

The length of the stem flower for the 15 experimental variants was between 22.70 cm and 36.65. In *Figure 7*, which shows the combined influence of the culture substrate and the variety regarding the height of the flowering of the floral stem of hyacinths, it can be noticed that the highest plants with an average height of 35.65 cm were recorded for the 'City of Haarlem' in the combination with garden soil + sand, followed by the combination of 'Blue Jacket' and garden soil. In this case, the average plant height was 35.20 cm. In both experimental variants, the difference compared to the control of the experiment (mean height, with a value of 30.41 cm) was very significantly positive.

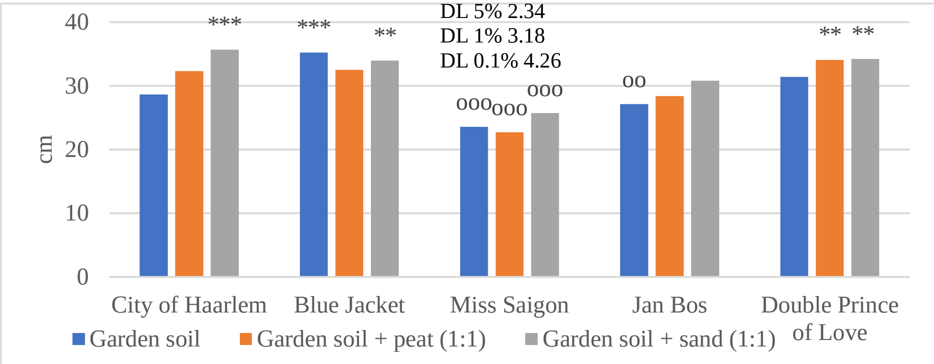

Figure 7. Length of stem flower under the combined influence of the substrate and the variety (cm)

The results are in accordance with the results achieved by Toma et al. [16], who obtained a length of stem flower between 23.2 cm for the 'Peter Stuyvesant' cultivar and 33.4 cm for the 'Delft Blue' forced in pots placed at a forced temperature of 8–9 ^{o} C. On the other hand, the plants with the lowest average height were those from the 'Miss Saigon' variety, which recorded minimum values of this parameter in all three substrate types; the height of the plants decreased with 20% compared to the average of the experience.

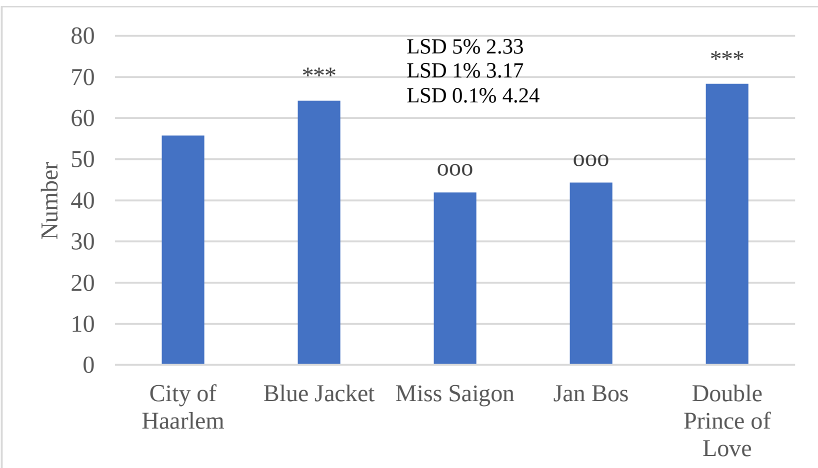

Figure 8. Number of flowers in inflorescence under the influence of variety

The varieties 'Blue Jacket' and 'Double Prince of Love' showed the largest number of inflorescence flowers with 64.25 and 68.35 flowers, respectively, and with 17.0% and 24.5% more, respectively, than the average of the experience. In both varieties, differences compared to the control, the average of the experience, were very significantly positive (*Fig. 8*). Concerning the number of flowers in inflorescence, the results are superior to those obtained by Toma et al. in 2012 [16].

The 'Miss Saigon' and 'Jan Bos' varieties had a smaller number of flowers – on average: 41.93 for the 'Miss Saigon' variety and 44.30 for the 'Jan Bos' variety –, the differences of 12.98 and 10.61 flowers/inflorescence compared to the average being very significantly negative results.

From the analysis shown in *Figure 9*, it can be noticed that the best results were recorded in the case of garden soil + sand (61.36 flowers/inflorescence), followed by garden soil + peat (55.18 flowers/inflorescence) and garden soil (48.20 flowers/inflorescence). Compared to the average experience of 54.91 flowers/inflorescence, the substrate composed of garden soil + sand (1:1) recorded a plus of 6.45 flowers/inflorescence, which is distinctly significant in statistical terms. On the other hand, in the case of culture substrate composed only of garden soil, inflorescences had 12.2% less flowers than the control of the experiment, the difference of 6.71 flowers/inflorescence being significantly negative. Results are in accordance with those obtained by Sabo et al. [17].

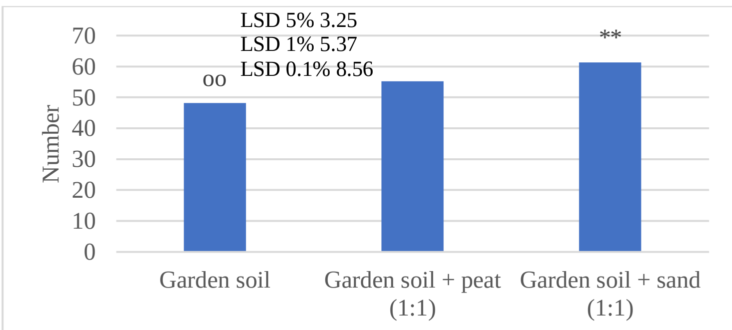

Figure 9. The number of flowers in inflorescences under the influence of the culture substrate

In the case of the below-mentioned variants (*Fig. 10*), there were positive, highly significant differences, compared to the control, the average of the experience having a value of 54.91 flowers/inflorescence.

The lowest number of flowers in inflorescence was observed with 'Miss Saigon', cultivated in all three substrates, as well as with 'Jan Bos', cultivated in garden soil and garden soil + peat. In the case of these variants, the average number of flowers in the inflorescences ranged from 34.75 to 47.55, all cases showing highly significant negative differences from the average of the experience.

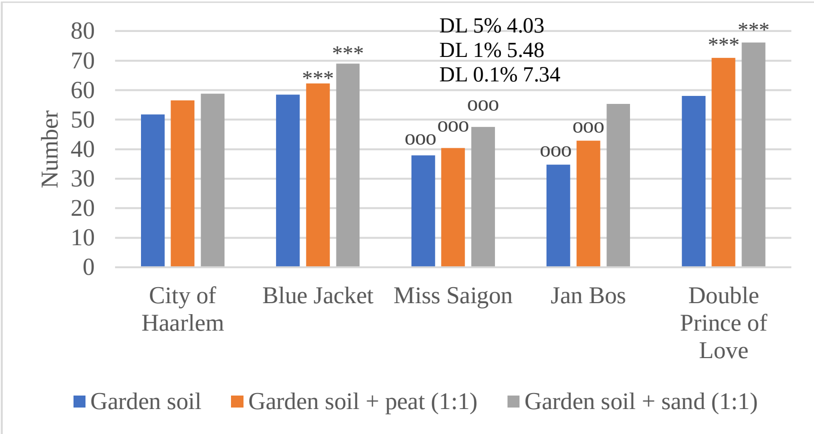

Figure 10. Number of flowers/inflorescences under the combined influence of substrate and variety

The 'Jan Bos' was the earliest blooming variety because it flourished in 12.44 days after being introduced into the greenhouse, while the 'Double Prince of Love' variety needed not less than 17.46 days of heat, making it the slowest in terms of flowering (*Fig. 11*).

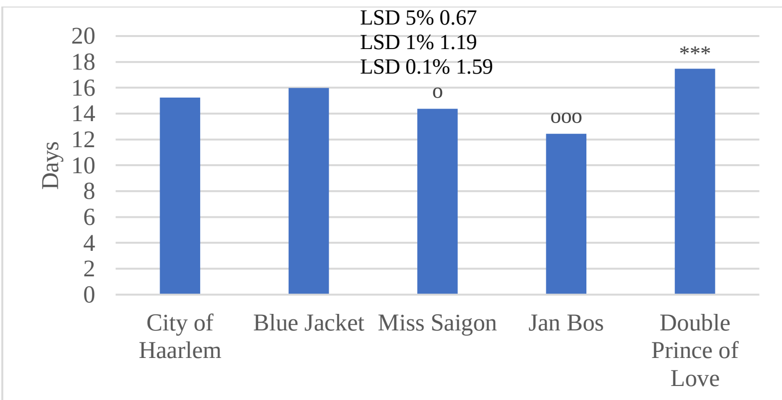

Figure 11. Precocity of flowering under the influence of the variety (days)

The analysis illustrated in *Fig. 11* shows that 'Jan Bos' needs the fewest days to flourish from the time of introduction into the greenhouse, averaging 12.44 days, 17.6% less than the average experience of 15.10 days, thus recording a difference of 2.65 days, which is significantly negative. With a significantly negative difference from the control, the 'Miss Saigon' variety, which took an average of 14.37 days to flourish, was 4.8% less than the average.

The 'Double Prince of Love' needed the longest period to flowering (17.46 days), with 2.37 days longer than the average experience; so, the difference was very significantly positive.

Even if the variety used had a strong influence on bloom precocity, this is not valid for the substrate used as well, the data presented in *Fig. 12* showing that only the substrate made up of garden + sand soil led to a small delay in flowering.

Thus, it can be noticed that only the substrate made up of garden soil + sand had a significant influence on the analysed character, a variant in which blooming occurred 1.18 days later than the average of the experience.

Using the other two substrates, garden soil and garden soil + peat, the plants flourished in about 14.5 days from the date of introduction into the greenhouse.

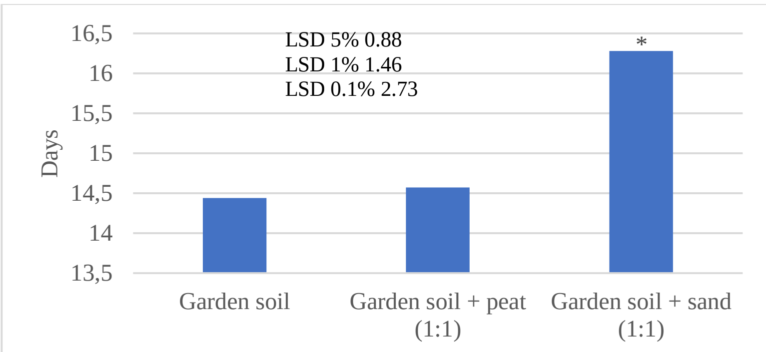

Figure 12. Precocity of flowering under the influence of the variety (days)

Analysing *Fig. 13*, we can observe that the number of days required for the plants to flourish from the date of introduction into the greenhouse was between 11.12 days for 'Jan Bos' cultivated in the garden and 18.45 days for the 'Double Prince of Love' cultivated in a mixture of garden soil + sand.

Determinations carried out for bloom precocity demonstrate that the variant that can be characterized as the earliest in terms of blooming is the combination of the 'Jan Bos' variety and the garden soil substrate. In this case, the plants bloomed – on average 11.12 days – by 26.36% fewer days than the average of the experience. The difference between this variant and the average of the experience is 3.98 days, which is very significantly negative (*Fig. 13*). Also, the 'Jan Bos' variety cultivated in garden soil + peat (1:1) shows a significantly negative difference, in which case the flowering took place in approximately 12 days, almost 3 days earlier than the calculated average.

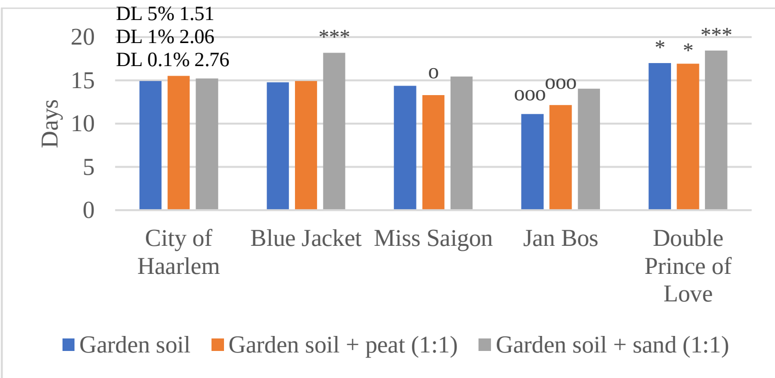

Figure 13. Precocity of flowering under the combined influence of culture substrate and variety (days)

On the other hand, we can mention the following experimental variants: ‘Blue Jacket’ and ‘Double Prince of Love’, grown in garden soil + sand. In both variants, blooming took place after 18 days kept in forced culture.

The flowering period of the five studied varieties of hyacinth is presented in *Fig. 14*. The results of this work show that the variety had an influence on this character. Sabo et al. [17] also found similar results with hyacinths.

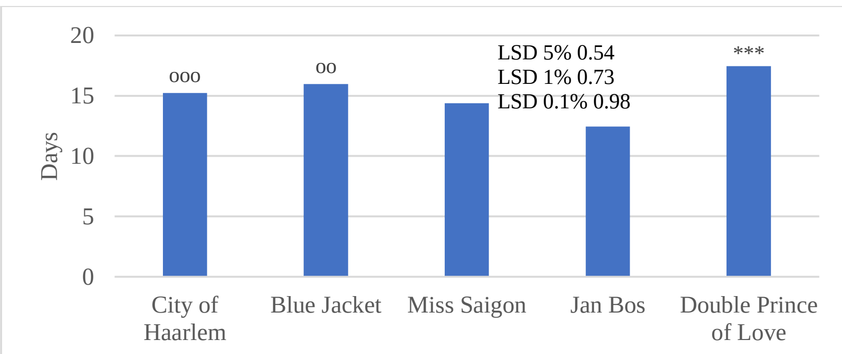

Figure 14. Flowers’ flowering period under the influence of variety (days).

Thus, the flowering period varied between 12.44 days for the ‘Jan Bos’ variety and 17.46 days for the ‘Double Prince of Love’ variety, while the other varieties yielded values close to 14–15 days.

For ‘City of Haarlem’, the difference from the average of experience of 9.94 days was 1.87 days, which is very significantly negative. For the ‘Double Prince of Love’ variety, the difference from the average was 2.17 days, which is a significantly positive difference.

Also, with long flowering period are the varieties ‘Miss Saigon’ and ‘Jan Bos’, which flourished for more than 10 days, but the differences from the control are statistically insignificant.

As can be seen in *Fig. 15*, the substrate of culture had a great influence on the flowers’ flowering period of the hyacinths.

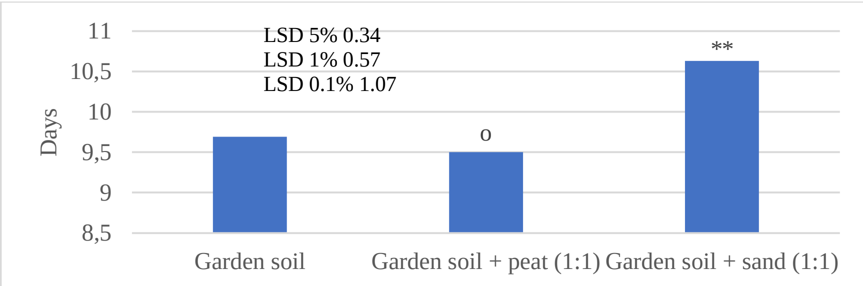

Figure 15. The flowers’ flowering period under substrate influence (days)

Thus, the longest flowering period (10.63 days) was registered for plants grown in a mixture of garden soil + sand – 6.9% longer than the average of experience. The difference from the control of the experiment was in this case 0.69 days, which is distinctly positive.

When cultivating plants in a substrate consisting of garden soil + peat, the flowering period is only 9.50 days, 4.4% days less than the average of the experience, the difference of 0.44 days being significantly negative.

The combined influence of the cultivar substrate and the variety used on the flowering period of the hyacinths shows that the ‘Double Prince of Love’ variety was the best one. Cultivating this variety in a substrate made up of garden soil + peat and garden soil + sand, the duration of the flowering period exceeds 12 or even 13 days. Remarkable results were also obtained in the ‘Jan Bos’ variety, in plants that were planted in the garden soil + sand, in which case the flowers had a blomming period of about 12 days. From a statistical point of view, the differences from the average experiences of 9.94 days were significantly positive in all the variants presented above (*Fig. 16*).

The experimental variants with a short flowering period are represented by the ‘City of Haarlem’ variety, cultivated both in garden soil + peat and garden soil + sand. Plants from these variants recorded blooming periods of 7.14 days and 7.66 days, with differences of 2.80 and 2.28 days compared to the average of experience – both variants were statistically significantly negative.

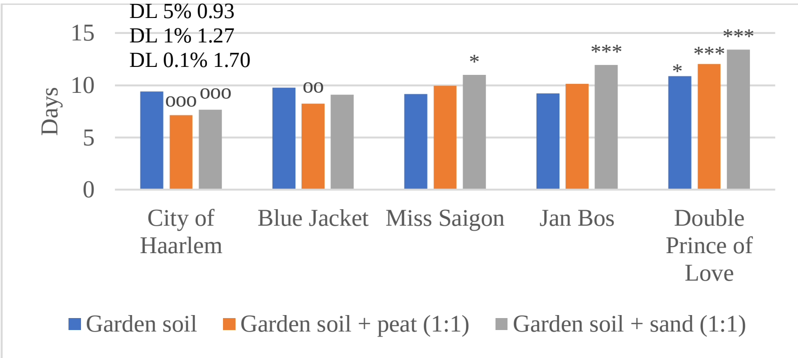

Figure 16. The flowering period of hyacinth under the combined influence of the culture substrate and the variety (days)

4. Conclusions

Regarding the substrate of culture formed by garden soil + sand, there were very good results regarding the height of the plants, the number of flowers in the inflorescences, and the flowers' blooming period, but less favourable results were obtained in terms of flowering precocity. Satisfactory results were also obtained for the substrate culture consisting of garden + peat (1: 1) with insignificant differences regarding the studied morpho-decorative characteristics.

Garden soil yielded less favourable results in the flowering period, the height of the floral stem, and the number of flowers in the inflorescence.

The study also demonstrated that the varieties 'Double Prince of Love' and 'Blue Jacket' achieved the best results in the same substrate and can be promoted on the Romanian market as pot plants for forced culture.

References

[1] Toma, F. (2009), *Specii utilizate ca plante în ghivece pentru decorul interioarelor*. Vol. 3. Bucharest: INVEL.

[2] *** https://www.steenvoorden.nl/bestanden/Forcing_Guide_Hyacint_English.pdf.

[3] Janse, J. A. (1966), *In Geuren en Kleuren, een Geschiedenis van de Hollandse Bolgewassen*. Utrecht: Oosthoeks' uitgeversmaatschappij.

[4] De Hertogh, A. (1974), Principles for forcing tulips, hyacinths, daffodils, Easter lilies and Dutch irises. *Scientia Horticulturae* 2(1974), 313–355. Amsterdam: Elsevier Scientific Publishing Company.

[5] Şelaru, Elena (2002), *Cultures for cut flowers*. Bucharest: Ceres. 258–266.

[6] Băla, Maria (2012), Floricultură generală și specială. Timișoara: Editura Partoș. 247–249.

[7] Buzatu, Mihaela (2001), Plante floricole cu bulbi rezistente la îngheț. Timișoara: BRUMAR.

[8] Cantor, Maria (2016), Floricultură specială. Cluj-Napoca: AcademicPress.

[9] Teresa, M. (2007), *Plante de balcon și grădină*. Bucharest: ALLFA.

[10] *** https://www.suttons.co.uk/Gardening/Flower-Bulbs/All-Bulbs/Hyacinth-Bulbs-City-of-Haarlem_290554.htm.
[11] *** https://www.highcountrygardens.com/flower-bulbs/hyacinth-flower-bulbs/hyacinth-blue-jacket.
[12] *** https://www.highcountrygardens.com/flower-bulbs/hyacinth-flower-bulbs/hyacinth-miss-saigon.
[13] *** https://www.bluestoneperennials.com/BHYJB.html.
[14] *** https://gardenseedsmarket.com/hyacinthus-double-prince-of-love-hyacinth-double-prince-of-love-3-bulbs.html.
[15] Ardelean, M., Sestraș, R., Cordea, Mirela (2007), *Tehnică experimentală horticolă*. Cluj-Napoca: AcademicPress.
[16] Toma, F., Petra, Sorina, Zamfir-Vasca, Diana, Tanase, Oana (2012), Research on the behavior of some hyacinth varieties in different types of forcing for blooming in out of season. *Scientific Papers, Series B, Horticulture* LVI, 197–202.
[17] Roxana Alexandra, Sabo, Buta, Erzsébet, Moldovan, Ioana, Cantor, Maria (2018), Research regarding the influence of the cultivar and culture substrate on hyacinths forcing culture. *Current Trends in Natural Sciences* 7(13), 176–186.

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Children–plant interaction using therapeutic horticulture intervention in a Romanian school

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Abstract. Nature, childhood, and ecopsychology can to be connected in the landscape of a schoolyard. The landscape architecture of the natural environments serves as a wide-open green space for outdoor activities, creating imaginative and inventive urban environmental layouts and connecting natural elements. School-based green experience, either indoor or outdoor, can be a physical and mental activity for children. In the case of individuals, it makes` easy to access a natural, green environment and to be actively involved in a natural setting, developing either social and/or cognitive functions and improving concentration and creativity. Therapeutic horticulture activity, such as planting indoor plants, can be a good experience for developing team work, the proprioceptive (kinase) receptors, affectivity, socialization, permanent care, and responsibility. The potential benefits of ornamental plants for children involved in public education include spending time in outdoor spaces, fresh air and sunshine, experiencing a sense of control, and being exposed to sensory stimulations. Physical and psychological education based on therapeutic horticulture activities in Romanian schools, such as planting and green care, can provide important opportunities for children to develop their attachment to nature, offering sustainable education solutions to an active part of the natural environment.

Keywords: landscape, indoor plants, nature-based intervention

1. Introduction

Therapeutic horticulture activities have been mentioned since the ancient Egypt, and the main concept is to use nature (especially ornamental plants) as a tool to enhance human health and well-being [1]. Based on the results obtained upon people–plant interactions while attending horticultural therapy sessions, green spaces are a real field in which humans can contribute to their healing, rehabilitation, education, and training. Nature, childhood, and ecopsychology can be interconnected in the landscape of a schoolyard.

Current Romanian legislation requires a specific percentage of land use to provide enough green area inside school perimeters (for example: 22 square meters/children). As stipulated in the legislation in force, urban planning rules must be in accordance with HG 525/1996- 2.2; 2.2.2; however, these conditions are not fully met.

In order to achieve the nature-based education, ornamental indoor plants can be a solution in the education-integrated therapeutic horticulture activities to provide opportunities for children to connect with nature. According to this, the purpose of the present research study was to analyse the interaction between children and indoor ornamental plants, combined in the national educational system as alternative guidelines for the children's long-term development. According to Piaget and Inhelder (1971), playing is necessary for the development of intelligence [2].

School-based green experience – Physical and mental activity with children

In accordance with the environmental design in schools, the playtime site and placement influence the academic activities. Green spaces and natural surroundings serve as a large open area where various creative activities and games can be played in an urban environment. People surrounded by natural landscapes and with free access to green infrastructure are more active [3], and they also demonstrate well-developed social, cognitive, and increased concentration capacity. For children, learning environments in the educational institutions can contribute to achieving a permanent contact with nature. Outdoor activities, such as learning and playing, which involve green areas are closely connected with children's state of health, mental and physical well-being [4]. Although, to play outside, children use frequently only playground infrastructures [5], which is the cause that they have insufficient connection with green areas inside schools [6].

Compared to the past decades, young people are less involved in nature-related interactive activities nowadays [7] – analysing the constant connection with natural environments, only 10% of the children are involved as compared to

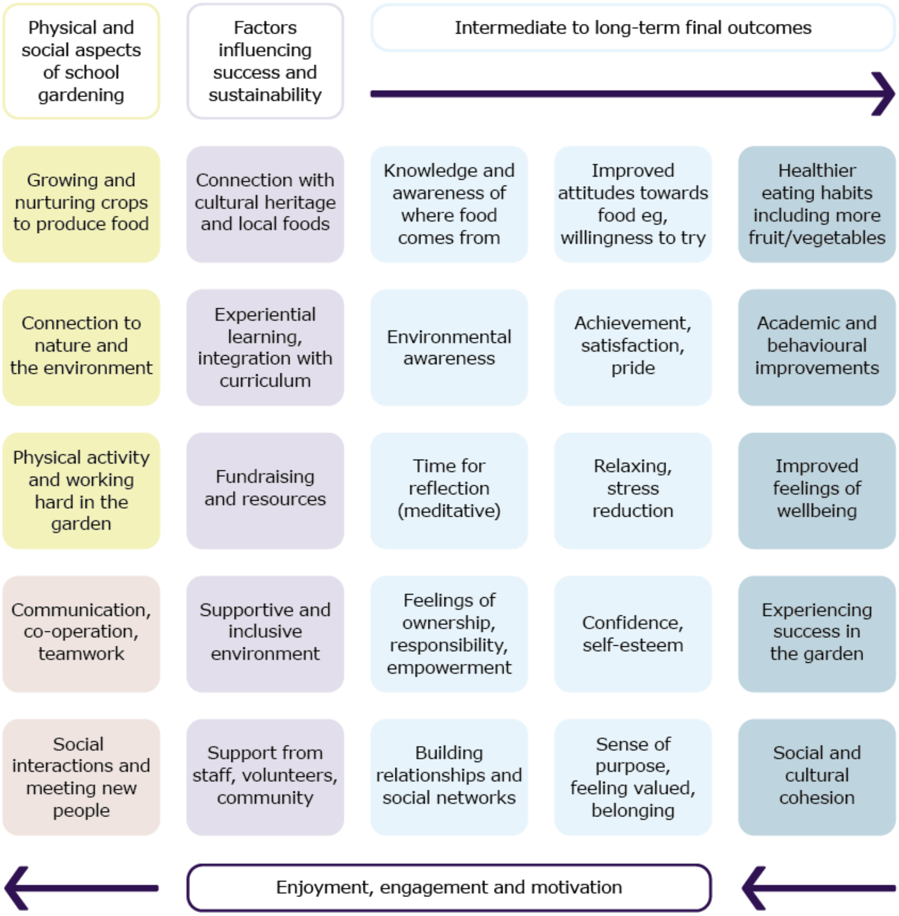
40% registered in the 80s [8]. Activities in their case carried out predominantly indoor may cause loss of attention and concentration in children [7].

Generally, natural environments used to be where childhood playing activities took place, whereas current research results have shown that fewer children have an interest in spending time in nature nowadays. A study published in 2016 by Natural England found that 1 of 10 children across England had not been in nature for the last 12 months. Because people are surrounded by nature, both in rural and urban environments, different nature-based activities can be developed to experience human–nature connection. In this context, the green space heritage – public and private gardens – which surrounds communities should be used for the benefit of children.

In the last few years, gardening workshops have become very popular. In their article, Christian et al. (2014) highlight the obtained results of the *Campaign for School Gardening* (RHS – Royal Horticultural Society), emphasizing the increase in fruit and vegetable consumption among children [9]. Consequently, different measurements were proposed to be integrated in order to obtain a sustainable gardening experience:

- gardening activities included in curriculum,
- connection between children, culture, and gardening,
- involving volunteers and local community in the teaching process,
- presenting gardening as a profession, and
- join with local plant retailers or nurseries and public green spaces.

The landscape design of a school yard is an important aspect which is directly correlated to everyone's well-being. Moreover, according to several research studies, green space could affect children's health. According to the figure below, a conceptual model shows potential health and well-being effects of gardening activities integrated in schools [10]. Therapeutic horticulture makes a positive contribution to the development of the children and helps them in their lives. Several possibilities can be highlighted for integrating nature-based activities, including horticulture therapy programmes, such as gardening, to enhance children's well-being in schools. The psychical and social aspects of school gardening include connection with the nature, interaction with other children, improved sense of well-being, and better school performance (*Fig. 1*).



Source: [*11*]

Figure 1. Conceptual model showing the potential health and well-being impacts of school gardening

2. Materials and methods

The present study was an experimental research based on the impact of an educative therapeutic horticulture activity – indoor ornamental plant potting and maintenance recorded as a post-test assessment and conducted among volunteer subjects in a Romanian school. The selected participants were 20 children, each of whom was asked to plant an indoor pot plant named spider plant –

Chlorophytum comosum (*Fig. 2*) – during an organized and indoor therapeutic horticulture session.

(a) (b)

Figure 2. Seedlings: (a) of *Chlorophytum comosum* prepared for rooting
(b) in fresh water

Often called spider plant but also known as airplane plant, this indoor species was chosen based on its air purification qualities, morphological characteristics, growing range, and low maintenance needs [12]. It is one of the most popular room plants, supple and graceful, and a little pretentious, which explains its prevalence [13]. The sensory elements, such as form, leaf texture, and colour, are the main elements included for examination during the programme.

The main objective of this research study was to archive a long-term longevity of the plants throughout a year, in which each student was responsible for providing the necessary elements (light, water) and proper growing conditions. After this period, children were asked to bring back the plant to be able to compare the morphological characteristics such as leaf number and dimension. Also, they completed a questionnaire, developed according to all the levels of Maslow's pyramid of human needs, thus analysing the quality of life following human–plant interaction. The Romanian form of the questionnaire was adopted from the English version described in a research article regarding the benefits of community gardening for the quality of life [14].

During this process, the physiological, safety, social, self-esteem, and self-actualization statements were measured for each child. In the end, 95% of the plants survived and had a good aesthetic development.

3. Results and discussions

Based on the investigations made by measuring the effects of the therapeutic horticulture investigation with a view to achieve a long-term belonging to a natural element, such as indoor ornamental plant, this evidence-based research can have a possible effect on physiological, safety, social, self-esteem, and self-actualization statements. According to the data obtained for the experimental group, 19 questionnaires were completed. Based on the 15 questions, the obtained results are presented in the charts below.

Analysing the **physiological** effect (*Fig.* 3) of this research study (1–4), ten subjects "like to work in the soil" during the planting and maintenance processes. The majority (18 children), 94.7% "enjoy working outside" during the planting period. 17 students declared that they could identify the sensory elements of *Chlorophytum* (colour, texture, fragrance), and only one of them thought that this therapeutic horticulture activity was not "working with nature".

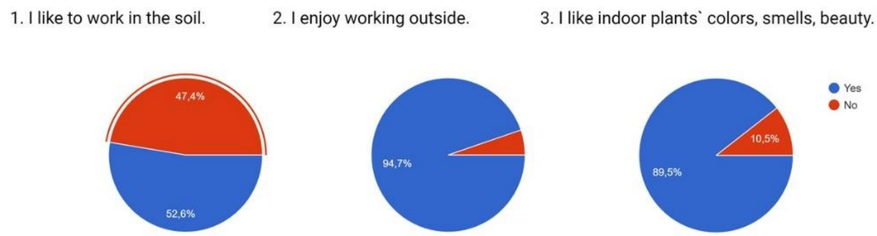


Figure 3. Data about quality of life statements on physiological issues during gardening

Evaluating the safety issue (5), only ten children "feel safe" (52.6%) compared to the other nine (47.4%) who were not so comfortable (*Fig. 4*).

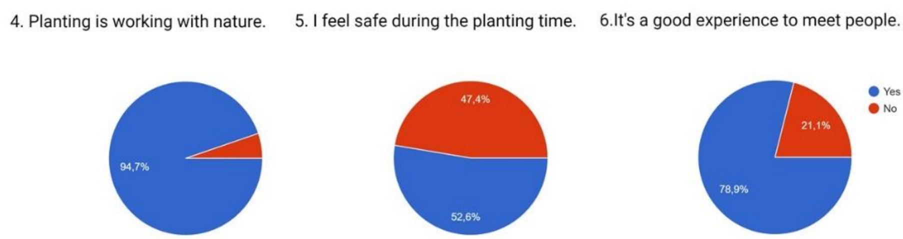


Figure 4. Data about quality of life statements on safety issues during gardening

Testing the **social** aspects (6–10), the majority of them (73.7%) consider that they "enjoy helping others in the planting activity", ten of them say that "gardening experience helps others", 100% of the involved students "care" about the plant and class community, and the majority does not "enjoy working alone" (*Fig. 5*).

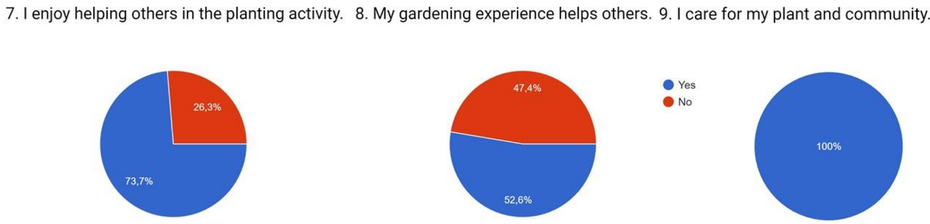


Figure 5. Data about quality of life statements on social issues during gardening

Concerning self-**esteem** (11–13), more than 13 identify beauty (78.9%), feel proud (89.5%), and handle the necessary effort for this activity (*Fig. 6*).

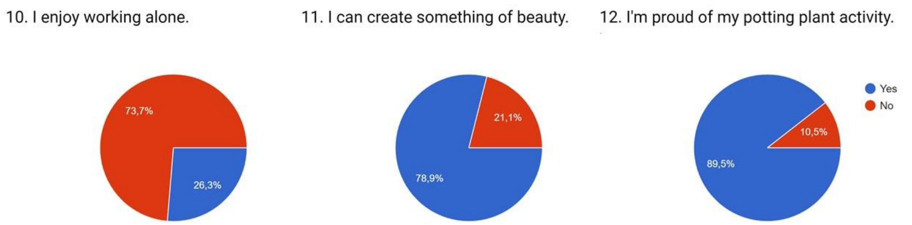


Figure 6. Data about quality of life statements on self-esteem issues during gardening

Analysing the self-actualization statements, 94.7% "feel peaceful" due to the direct interaction with this the plant during the experimental period, and 15 of them intend to take part in other therapeutic horticulture-based activities (*Fig. 7*).

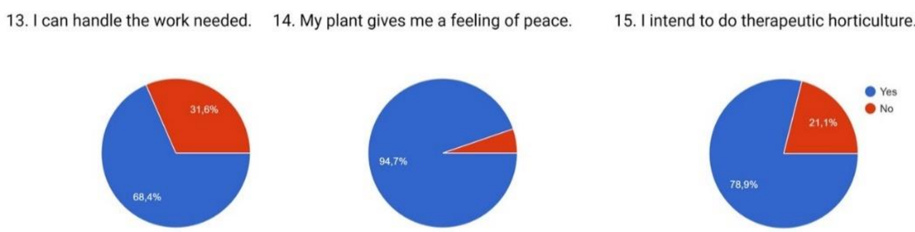


Figure 7. Data about quality of life statements on self-actualization issues during gardening

4. Conclusions

In landscape design, the sensory elements, such as texture, colour, and fragrance, have an important role in the spatial perception of the users. Children feel good when they can take part in their environmental design on which they spend their time. The contributions of the presence of indoor ornamental plants can have an influence on children's physical and mental development. The activities with indoor plants are very important because plants can contribute to children's intellectual development and increase their level of creativity. Based on the horticulture therapy intervention, gardening activities specially designed for children can be easily integrated into indoor spaces, influencing their emotional and social developments.

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References

[1] Marcus, C. C., Sachs, N. A. (2013), *Therapeutic landscapes: An evidence-based approach to designing healing gardens and restorative outdoor spaces*. John Wiley & Sons.

[2] Piaget, J., Inhelder, B., (1971), *The child's conception of space*. 4th edition. London: Langdon, Compton Printing Ltd.

[3] Wells, N. M., Ashdown, S. P., Davies, E. H. S., Cowett F. D., Yang Y. (2007), Environment, design, and obesity. Opportunities for interdisciplinary collaborative research. *Environ. Behav*. 39, 6–33.

[4] Ward Thompson, C., Aspinall, P., Montarzino, A. (2008), The childhood factor: Adult visits to green places and the significance of childhood experience. *Environ. Behav*. 40, 111–143.

[5] Ridgers, N. D., Stratton, G., Fairclough, S. J. (2006), Physical activity levels of children during school playtime. *Sports Med*. 36, 359–371.

[6] Barton, J., Sandercock, G., Pretty, J., Wood, C. (2015), The effect of playground-and nature-based playtime interventions on physical activity and self-esteem in UK school children. *International Journal of Environmental Health Research* 25(2), 196–206.

[7] Bird, W. (2007), *Natural thinking: Investigation [of] the links between the natural environment, biodiversity and mental health*. Bedfordshire: Royal Society for the Protection of Birds.

[8] Natural England (2009), *Childhood and nature: A survey on changing relationships with nature across generations*. Cambridgeshire: Natural England.

[9] Christian, M. S., Evans, C. E., Cade, J. E. (2014), Does the Royal Horticultural Society Campaign for School Gardening increase intake of fruit and vegetables in children? Results from two randomised controlled trials. *Public Health Research* 2(4), 1–162.

[10] Buck, D. (2014), Gardens and health: Implications for policy and practice. London: The King's Fund.

[11] Ohly, H., Gentry, S., Wigglesworth, R., Bethel, A., Lovell, R., Garside, R. (2016). A systematic and qualitative evidence. *BMC Public Health* 16(1), 286.
[12] Cantor, M. (2016), *Floricultură specială – Manual didactic*. Clujk-Napoca: AcademicPres.
[13] Șelaru, E. (2004), *Plante de apartament*. 2nd ed. Bucharest: Ceres.
[14] Waliczek, T. M., Mattson, R. H., Zajicek, J. M. (1996), Benefits of community gardening on quality-of-life issues. *Journal of Environmental Horticulture* 14(4), 204–209.

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