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Contents

K. Halász, Cs. Borbély, V. Pós, L. Gáspár, N. Haddadderafshi, Zs. Winter, N. Lukács
Effect of crop management and cultivar on colonization of *Capsicum annuum* L. by Endophytic Fungi 5

Sz. Orosz, Á. Szénási, J. Puskás, R. Ábrahám, A. Fülöp, G. Jenser
Observations on the flight pattern of some Phlaeothripidae (Thysanoptera) species by using suction trap in Hungary 16

D. Balla, T. J. Novák, M. Zichar
Approximation of the WRB reference group with the reapplication of archive soil databases 27

K. Demény, Cs. Centeri, D. Szalai
Analysis of land stability and land-use change processes in the 19–20th centuries: a case study in Gödöllő Hillside, Hungary 39

A. Buna, E. Domokos, L. D. Donescu, E. M. Ianoși
Analyzing quality deficiencies of three potato cultivars during the storage period 50

E. Józsa
Detailed hydrogeomorphic analysis in the Gerecse Mountains, Hungary 62

M. Mehrparvar, S. M. Mansouri, B. Hatami
Some bioecological aspects of the rose aphid, *Macrosiphum Rosae* (Hemiptera: Aphididae) and its natural enemies 74

A. I. Henning
The importance of protecting unique Romanian landscape values, illustrated by examples of problem solving in other countries 89

D. Vona-Túri, T. Szmatona-Túri, F. Kádár, B. Kiss, A. Weiperth, B. Gál
Ground-dwelling arthropod (Araneae, Coleoptera: Carabidae, Isopoda: Oniscidea) assemblages on Hungarian main road verges 96

D. Aminu, O. B. Bello, B. A. Gambo, A. H. Azeez, O. J. Agbolade, A. Iliyasu, U. A. Abdulhamid
Varietal performance and correlation of okra pod yield and yield components 112

L. Kovács
Joint overview of the Rhédey Castle and Park in Sângeorgiu de Pădure based on maps resulting from military measurements 126

A. Kovács, L. Szappanyos, H. Ledó Darázsi, Z. Felföldi, Cs-T. Szabó
Short evaluation of eggplant production and variety usage in Romania – short overview and perspectives 131

W. C. Njuguna, H. W. Kamiri, J. R. Okalebo, W. Ngetich, S. Kebeney
Evaluating the effect of plant population densities and nitrogen application on the leaf area index of maize in a reclaimed wetland in Kenya 139

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Effect of crop management and cultivar on colonization of *Capsicum annuum* L. by Endophytic Fungi

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Abstract: Due to their importance as biological control agents, we analysed the colonization of two pepper (*Capsicum annuum* L.) cultivars by culturable endophytic fungi in natural sandy soil in the open field and under soil-free conditions in the greenhouse, respectively. In natural soil, we observed a significant difference in colonization rates between the cultivars 'Hó' and 'Kápia'. Colonization rates were always lower in the greenhouse than in the open field. Colonization was enhanced towards the end of the growing period and organ-specific differences were also observed. On the basis of colony morphology, 15 separate groups were identified for future sequence-based identification.

Keywords: soil-free culture, culturable endophytes, colonization rate, organ specificity

1. Introduction

In the last few decades, it has become generally known that practically all plants studied so far host endophytic microorganisms, among them endophytic fungi. Endophytic fungi are defined as fungi that colonize plant tissue for a considerable period of their life cycle without causing any symptoms in the host plant. Their interaction with the host is intriguingly complex, ranging from mutualism to commensalism and parasitism [1, 2]. Many publications demonstrate that endophytes can influence the biosynthetic pathways of the host and even contribute to the synthesis of secondary metabolites or plant hormones, possibly indicating mutual adaptation during the evolutionary process [2–6]. Nevertheless, many aspects of the plant–endophyte interaction remain unresolved: it is not clear what genetic and biochemical features are responsible for colonization and for the type of interaction. It is not even known whether plants would be fit enough to survive in their natural environment without their microbial endophytes [3, 4].

Answering these questions is of great practical importance since mutualistic endophytic fungi can stimulate plant growth, enhance tolerance to abiotic stressors, such as drought, and may confer resistance against pathogens or herbivores [5–9]. Moreover, it is now widely recognized that the use of selected endophytic fungi as biological control agents could open new approaches in crop management. Biological control offers an attractive, environmentally friendly approach to reduce the use of chemicals, and it can be incorporated into an effective integrated pest management system [9–11]. Biological control is especially desirable for those horticultural plants that are continuously harvested and are consumed unprocessed. In these cultures, the use of fungicides and pesticides interferes with regular harvest, while the toxic products of pathogenic organisms present a health risk to consumers.

Bell pepper (*Capsicum annuum* L.) belongs in this latter category of vegetables. It is an economically important cash crop grown in greenhouses or open fields worldwide. It is consumed either raw or in processed form, chili powder and paprika being some of the most frequently used spices.

Unfortunately, the growth conditions of bell pepper (hot weather, especially when combined with the climatic conditions of tropical and subtropical regions) strongly favour mould contamination and mycotoxin production, the most important and most dangerous of which are aflatoxins produced by multiple *Aspergillus* species [12–14]. In addition, production and yield of pepper are strongly influenced by fungal infections that induce wilting, stunted growth, chlorosis, and blotch. Hussain et al. isolated *pathogenic fungi* from the roots of pepper plants growing on infected sites, and found that *Aspergillus flavus, A. niger*, *Penicillium commune*, and *Trichoderma harzianum* were able to confer protection against them [15]. Similarly, Bae et al. [16] were also able to protect pepper against *Phytophtora capsici* by using various *Trichoderma* species. At the end of their experiments, 26–60% of the *Trichoderma*-treated plants were free of symptoms, while in the control only 0–10% stayed healthy. In yet another study, the presence of endophytic fungi has been shown to inhibit the growth, virility, and reproduction of the aphid *Aphis gossypii* [17]. Some fungal strains even seem appropriate for biological protection, as demonstrated by Martinuz et al., who induced systemic resistance to *Aphis gossypii* using *Fusarium oxysporum* Fo162 and *Rhizobium etli* G12 strains [18]. Others have described protection of chili pepper against *Meloidogyne incognita* by the combined use of *Pasteuria penetrans* and *Paecilomyces lilacinus* [19]. Amongst the natural endophytic fungi of pepper plants, *Penicillium resedanum, Cladosporium cladosporioides,* and *Paraconiothyrium sp.* have been shown to improve plant growth and confer protection against pathogenic attack and environmental stresses [20, 21].

Because of their potential importance, there have been some studies to identify endophytic fungi in *C. annum*. Amongst these, the most systematic analysis was carried out by Paul et al. in Korea [20]. They collected samples from *C. annuum* leaves, stem, and root in 3 different phenophases during the year. Out of 900 organ samples, they obtained about 480 fungal isolates belonging to 21 genera. By sequencing the ITS regions, the authors established that the *Colletotrichum* genus could be found most frequently (18.92%), followed by *Fusarium* (18.71%), *Alternaria* (7.48%), and *Penicillium* (6.24%). The occurrence and frequency of individual fungus species varied by the phenophases, but *Alternaria*, *Fusarium*, and *Cladosporium* species were present in all developmental stages of pepper [20].

However, most datasets on *Capsicum* endophytes come from Asia, and it is unknown how representative these results are for peppers grown elsewhere since fungal community structure changes dynamically and is strongly influenced by environment and cultivar [1, 2, 22]. Therefore, due to its importance as a horticultural plant in Hungary, we decided to analyse colonization rates in different organs of pepper and to find out how many fungal morphotypes exist in the plants. Changes were followed from April to October 2013 in the cultivars ‘Hó F1’ and ‘Kárpia F1’ cultivated soil-free in greenhouse or in open field. Here we present the results of this analysis.

2. Materials and methods

Plant material

We investigated two pepper (*C. annum*) cultivars, ‘Hó F1’ and ‘Kápia F1’, starting at seedling stage.

Plants were grown in the Research and Experimental Farm of Corvinus University of Budapest (19° 03’ 01’’ LE and 47° 28’ 19’’ LN) in Soroksár, Central Hungary.

Seeds were sown in February 2013, and all seedlings were grown under greenhouse conditions till the 5th of May. Then, they were transplanted either to an unheated greenhouse to be grown under soil-free conditions in rockwool in double rows (60 and 90 cm distance) or to an open field in sandy soil in double rows spaced at 40 and 100 cm. The distance between plants was 33 cm in each row.

Plants were drip-irrigated. Fungicide treatment was not applied at all in the greenhouse and only once (in July) in the open field.

Sample collection

Samples were collected at the seedling stage in April and May and from fruiting plants in August and October 2013. We collected young leaves (the topmost fully differentiated leaf), old leaves (the 6–8th leaf counted from top to bottom), young fruits having yellow or green pericarps, biologically ripe, fully coloured fruits, and peduncles of ripe fruits. In addition, young roots and stem samples were also analysed, the latter being taken 15 cm below the top. Samples were placed in plastic bags and pre-cultivation of potential endophytic fungi was started within 6 hours of collection.

Cultivation of endophytic fungi

Surface sterilization of the samples was achieved by soaking them in 70% ethanol for 1 min, then in 20% hypochlorite solution for 10 min, followed by a final rinse in 70% ethanol for 1 minute. Finally, samples were washed in sterile distilled water.

Surface-sterilized samples of about 5x5 mm were prepared under sterile conditions. Nine pieces of tissue from each organ were placed on PDA (Potato Dextrose Agar) pre-culturing medium completed with chloramphenicol (1 g/l). The plates were kept in the dark at room temperature until the fungal colonies appeared (about 2 weeks).

We analysed the frequencies of colonies to evaluate the fungal colonization in the plants. Then, we selected representative colonies and transferred them to new PDA plates.

In order to isolate homogenous strains, cultures were monosporated or, the non-sporulating ones, monohyphated [23]. We grouped the isolated colonies according to their morphological characters.

Morphotyping

Fungal colonies were inspected after 1 week, and were then put in morphological groups according to colony appearance, mycelium colour structure, the shape of conidiomata, conidia, and conidiophore.

Statistical evaluation

To decide whether the observed differences in colonization rates were statistically significant ($\alpha \leq 0.05$), we used χ^2 test when more than 2 samples were compared and z-test for pairwise comparisons.

3. Results and discussions

Colonization rate is influenced by crop management and cultivar

To find out how soil and growth conditions influence the fungal colonization of bell pepper, we compared two frequently used crop management systems, namely cultivation in natural soil under open field conditions and soil-free cultivation in greenhouse. In both locations, two widely used Hungarian pepper hybrids, 'Hó F1' and 'Kárpia F1' were grown, and we cultivated endophytic fungi from tissue samples (leaf, fruit, root, and stem) from both locations and cultivars. To assess the effect of open field versus greenhouse, we only included the isolates from August and October since the seedlings for both sites had been reared together under greenhouse conditions. For these two time points, we started with a total of 1,607 samples, i.e. with nearly 200 samples per combination (site, cultivar, sampling time), and the number of outgrowing colonies was 436 and 218 from field and greenhouse samples, respectively. As shown in *Figure 1A*, colonization rates were lower in greenhouse-grown plants.

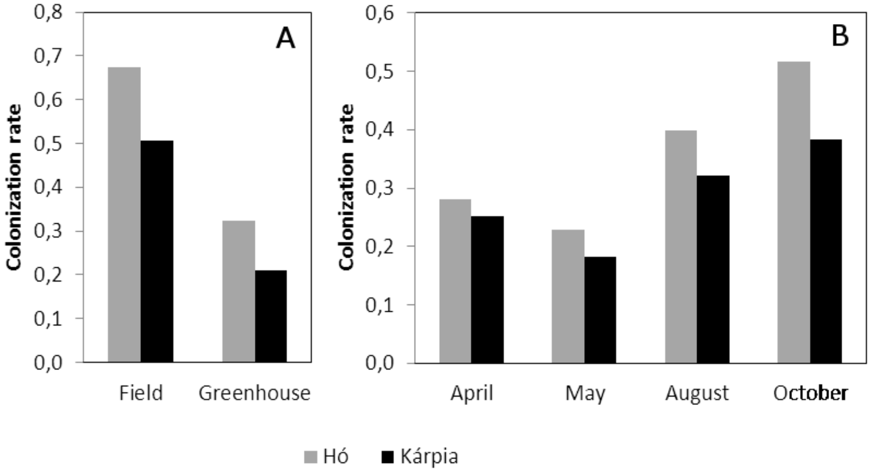

Figure 1. Cultivar, production site, and time-dependent variations of colonization rate

(A) The effect of the production site on fungal colonization was analysed in the samples collected in August and October. Samples from all organs were included in the analysis. Colonization rates in the open field are significantly higher than those in greenhouse-grown peppers. *(B)* Although there were no changes in colonization rate at the seedling stage (cf. columns for April and May), the colonization rates increased towards the end of the growing season in August

and peaked in October. There was a difference between the two cultivars in the second half of the year with colonization rates being consistently higher for ‘Hó’ than for ‘Kárpia’.

Statistical evaluation resulted a significant difference between production sites at $\alpha<0.1\%$ and also between the two cultivars under field conditions, but not in the greenhouse.

Increased colonization rate during the vegetation period

We also investigated the temporal progression of the overall colonization rate. All samples (2,260) were included in this analysis: in April and in May, they were collected from roots, stems, and leaves; in August and in October, fruits were also included. At the seedling stage, i.e. in April and May, we did not observe any difference in fungal colonization rates, except for a slight decrease in May, which may be a result of extremely fast growth observed at this time (*Fig. 1B*). The colonization pattern, however, significantly changed in August and October. In these months, we observed a continuous increase in colonization.

To our knowledge, the fungal colonization of *C. annuum* at different developmental stages (seedling, flowering, and fruiting stage) has only been described by Paul et al. [20] to date. For the first two developmental stages, the data we obtained are similar to their results. However, at the fruiting stage, they had observed a considerably more increased colonization rate in all organs than we did. Several explanations are possible. First, the Korean team analysed only field-grown plants, under climatic conditions that were different (higher temperature and humidity) from the climatic conditions in Hungary. These factors are known to stimulate fungal infection [13]. Secondly, we included more organs in our studies (e.g. young fruits) that show low colonization, and therefore diminish overall colonization rates. An interesting finding of Paul et al. was the observation that different fungi dominate at different developmental stages [20]. With respect to our morphological groups (see below), we did not observe such association up to now.

Organ-specific differences in colonization rates

It is known from the literature that many endophytic fungi are specialized to interact with specific organs [3, 4, 20]. Understanding the organ-specific dynamics of fungal community structure might help unravel the physiological role of individual fungal taxa. It is also important because of the health risks connected to infection on the fruits by mycotoxin-producing endophytes [12–14]. This is why, in addition to root, leaf, and stem samples, we have also included in our analysis pedicles, young and old pericarps as well as seeds.

The results shown in *Fig. 2* illustrate that colonization rates of most organs, except for roots and young pericarps, are significantly higher at the end of the vegetation period in October than in August, as expected based on the overall colonization rates. Old leaves and pedicles represent the most strongly colonized organs at the fruiting stage. High colonization of pedicles is possibly interconnected to its porous tissue structure that may accommodate hyphal growth better.

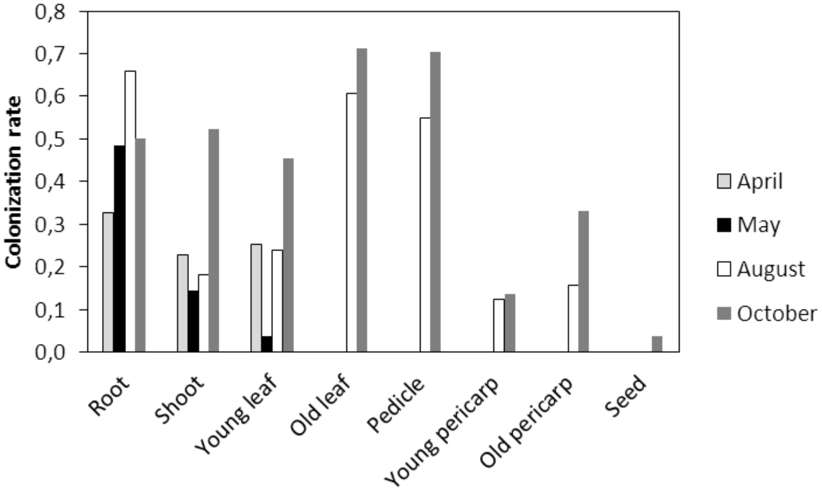

Figure 2. Differences in colonization rates between individual organs

Colonization rates of young and old pericarp tissues were relatively low, although a strong enhancement was observed in the pericarp of fruits nearing biological ripeness in October. Fungal infection of pepper pods, especially that of pericarps, has been reported in *Capsicum*, and the cancerogenic aflatoxins produced by *Aspergillus* species are considered a major health risk in chili powder [12–14]. In Hungary, *Alternaria* sp. was most frequently isolated from mouldy pepper pods [24]. At present, we have no information about the fungal taxa infecting the pericarp of our cultivars. Further analysis, first of all, ITS sequence-based identification of individual endophytes, will be carried out to collect more information about the fungal community structure in bell pepper pods.

Of all investigated organs, roots seem to be the most highly colonized at all sampling times. Although we do not differentiate between production sites in *Fig. 2*, it is one of the major goals of our future studies to find out whether and how species composition and richness differ between pepper plants grown in natural soil and pepper plants grown in artificial, soil-free culture, since data in literature show that soil conditions may have an effect on the community structure of endophytes [3, 25].

Morphotypes of pepper-colonizing endophytic fungi

During our investigation, we obtained 809 independent fungal colonies needing taxonomical identification by DNA barcoding. To reduce the amount of samples, we morphotyped our cultures and divided them into groups after each sampling period (eg. into 31 and 29 groups in August and October, respectively). Finally, at the end of the experiment, we classified again all colonies into only 15 larger groups and unique morphotypes. Two of the groups were inhomogeneous, consisting of minor morphological groups with only a few representatives each or of just single, morphologically distinct colonies.

As an example, now we show the morphological diversity of the isolated fungal endophytes in autumn (*Fig. 3*).

The diagram shows the quantitative distribution and the macromorphological features of the 11 major groups originating from the October sampling. Obviously, the individual groups are not equally represented. Group DA is the largest, making up more than 50% of the colonies. This is followed by groups DG, DB, DE, and DC, which together with group DA include more than 80% of isolates. The remaining 20% is highly heterogeneous. Two segments of the diagram indicate colonies classified into minor morphological groups (18 of the 29) or colonies not classified into any of the groups. Although we are well aware of the pitfalls of morphological classification of microfungi, we believe that our results indicate a relatively large species richness of endophytic fungi with a few dominating taxa. Some preliminary sequencing data seem to confirm this belief.

For further molecular analysis, 118 representative colonies were chosen. They were monosporated/monohyphated and will be classified on the basis of their ITS (internal transcribed region sequence) [26] in experiments that are currently under way. Since the presence of mycoviruses can alter colony morphology as well as the pathogenicity of fungi, several colonies will also be screened for viruses by using a universal, dsRNA-based method for virus detection [27, 28].

Taken together, the results presented in this paper form the basis of the ongoing molecular identification of endophytic fungal taxa and describe the quantitative features of fungal community structure under different culturing conditions during the vegetation period.

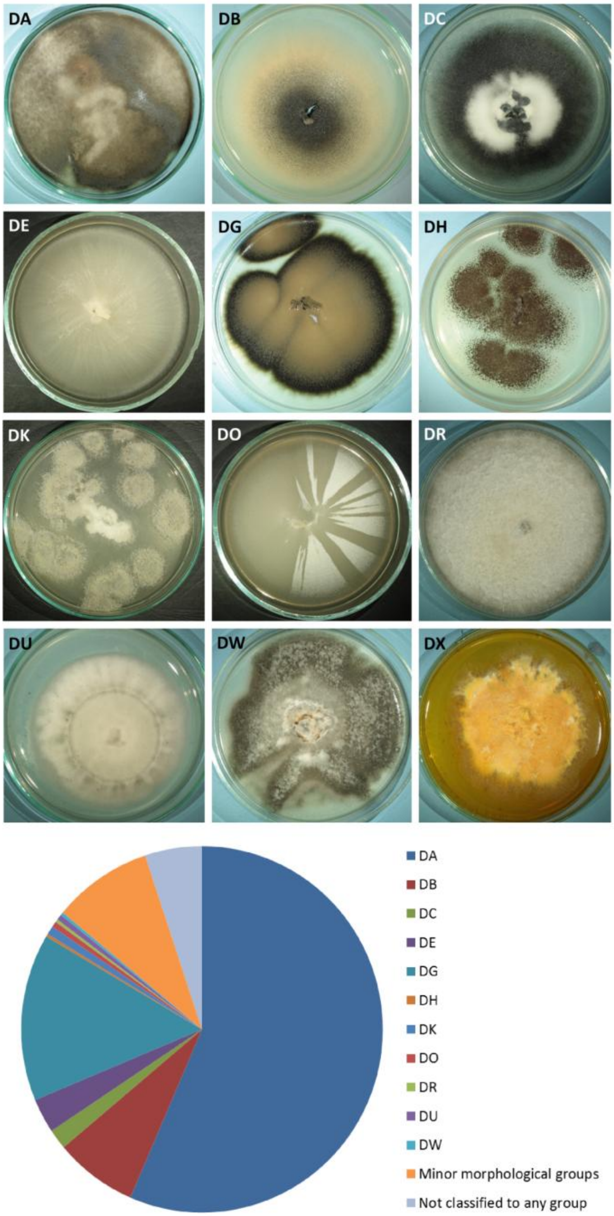

Figure 3. Colony morphology and quantitative representation of fungal morphotypes of colonies from the October sampling period. The colony nominated as DX was arbitrarily chosen from the “Minor morphological group”. The endophytic fungal community seems to be dominated by 5 major morphotypes.

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Observations on the flight pattern of some Phlaeothripidae (Thysanoptera) species by using suction trap in Hungary

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Abstract: In this study, the seasonal flight activity of the Phlaeothripidae (Thysanoptera) species was studied by using suction trap, in South-East Hungary, in the years 2000 and 2004 from April to October. The flight period of two dominant species, namely *Haplothrips angusticornis* Priesner and *Haplothrips aculeatus* Fabricius (Thysanoptera: Phlaeothripidae), was observed in high number in Europe. Also, it was the first record of mass flight observation of *H. angusticornis.* In addition, the effect of meteorological factors, such as temperature, sunshine duration, relative humidity, air pressure, and their influences, were evaluated.

Keywords: suction trap, mass flight, Phlaeothripidae, *Haplothrips angusticornis, Haplothrips aculeatus*

1. Introduction

Thysanoptera is one of the most migratory insect orders because its measured air density could be the highest among the other insect orders. Most winged species have a flight period lasting a few weeks each year. Within this period, some thrips fly on most days, but there are usually a few days when sudden mass flights occur [1]. In Europe and Central Asia, the most noticeable mass flights occur in the case of cereal and grass thrips, such as *Limothrips cerealium* Haliday, *Limothrips denticornis* Haliday, and *Chirothrips manicatus* Haliday (Thysanoptera: Thripidae), when they leave ripening crops to fly towards other host plants at the end of the growing season [2]. Mass flights occur sporadically within the flight period and in many species are reputedly associated with thundery weather. Indeed, in many parts of Europe, thrips are called as “Thunder Flies” or “Storm Flies” as right before storm or thunder their presence in the air increases to a very high number [3]. It is remarkable that the link between thrips and thunder is current in the common names used in so many countries and dates back at least 150 years [4]. However, [2] showed that the occurrence of mass flights of cereal thrips in Germany depended to a greater extent on temperature than on atmospheric pressure or humidity. On the other hand, [1] showed that there was no correlation between thunder and mass flights of thrips in southern England.

Worldwide, the situation of mass flight and migration of Phlaeothripidae species is not clarified yet. According to [1], Tubulifera migration is uncommon in Britain. Glick [5] found that Tubulifera species are more common than Terebrantia in Lousiana (USA) and, by contrast, *Haplothrips aculeatus* Fabricius (Thysanoptera: Phlaeothripidae) were observed in low numbers in the air in Germany [6].

According to [7], the suitable height for collecting flying Thysanoptera is around 6 m. In an earlier study of [8], a suction trap was used in this height for the autumn mass flight observation of *Frankliniella intonsa* Trybom (Thysanoptera: Thripidae). [9] used the suction trap at the height of 7.5 m to determine if suction traps could be useful for monitoring the diversity and flight activity of some Thripidae species. [10] investigated the long-distance dispersal for onion thrips (Thysanoptera: Thripidae). To address these questions, *T. tabaci* adults were collected using transparent sticky card traps in commercial onion fields at varying heights above the canopy (0.5–6 m above soil surface) and with trap-equipped unmanned aircrafts (UAVs) flying 50–60 m above onion fields during August sampling periods in 2012 and 2013. Otherwise, there are no data regarding the mass flight of Phlaeothripidae species.

Our current study aims at clarifying the mass flight potentials of Phlaeothripidae species under Hungarian climatic conditions and at determining the correlation between the mass flight and meteorological factors such as temperature, sunshine duration, relative humidity, air pressure, and their influences.

2. Materials and method

A Rothamsted-type suction trap was operated by the Csongrád County Plant Protection and Soil Conservation Service at Hódmezővásárhely in South-East Hungary in the years 2000–2005 from April to October. It was drawn in 3,000 m^3 of air in one hour, at a height of 12 m. The diameter of the collecting tube was 20 cm. The collecting jar was changed daily in the morning at seven o'clock during the experiment. The collected specimens were preserved in 70% ethanol. Because of the enormous numbers of the collected Phlaeothripidae adults, we selected them in only two years, 2002 and 2004. Each of the studied Phlaeothripidae specimens was mounted according to Schliephake and Klimt [11] for identification.

From the catching data of the examined species, relative catch (RC) data were calculated for each night. The RC is the quotient of the number of individuals caught during a sampling time unit (1 day) per average number of individuals of the same generation falling to the same time unit. In the case of the expected average individual number, the RC value was 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and in different traps [12]. Data on environmental factors, such as temperature, sunshine duration, relative humidity, and air pressure, were arranged into classes according to Sturges' method [13]. The relative catch values were assigned into the classes of the environmental factors belonging to the given day, and then they were summarized and averaged.

All graphics were prepared using *Microsoft Excel 2010*. The results were characterized by third-degree polynomials. The significance level (the coefficient of determination) was determined according to Manczel [14], by using the following formula:

$$t = r/\sqrt{1-r^2} * \sqrt{n-2} \qquad (1)$$

3. Results

Species diversity in suction trap for the two years is shown in *Table 1*.

In the experiments, high numbers of *H. angusticornis* were collected by the suction trap in both years. There were 962 specimens in 2002 and 1,309 specimens in 2004. As for *H. aculeatus*, in 2002 there were 393 individuals captured by the suction trap and by 2004 its number decreased to a very low level, and only 31 specimens were found. Besides these dominant species, only a few numbers of other Phlaeothripidae species were captured in both of the investigated years (*Table 1*).

Table 1. Individual number of Phlaeothripidae species collected by suction trap (Hódmezővásárhely, 2002 and 2004)

Species	No of specimens (2002)	No of specimens (2004)
Haplotrips angusticornis Priesner 1921	962	1,309
Haplothrips aculatus Fabricius 1803	393	31
Haplothrips hukkineni Priesner 1950	0	1
Haplothrips leucanthemi Schrank 1781	2	1
Hoplothrips semicaecus Uzel 1895	0	2
Bolothrips bicolor Heeger 1852	1	0
Liothrips setinodes Reuter 1880	2	1

The effect of meteorological elements for the mass flight of *H. angusticornis* was evaluated. Regarding the influence of the minimum, maximum, and daily mean temperatures, the higher temperature caused higher numbers of migrating specimens, i.e. 19 °C minimum (*Fig. 1*), 29 °C maximum (*Fig. 2*), and 23 °C mean temperature (*Fig. 3*). Concerning the effect of sunshine duration, the more sunny hours had positive influence on the migration of *H. angusticornis*; in the case of 12 hours/day, the flight was maximum, and they did not fly at night (*Fig. 4*). The optimal level of relative humidity for the collected individual numbers was about 62% (*Fig. 5*). Higher level of relative humidity caused negative effect on the mass flight and migration. The effect of air pressure brought about very contradictory results (*Fig. 6*) because when the pressure was higher than 1000 hPa the number of migrating specimens steadily declined until 1008 hPa, and then started again to increase above this level.

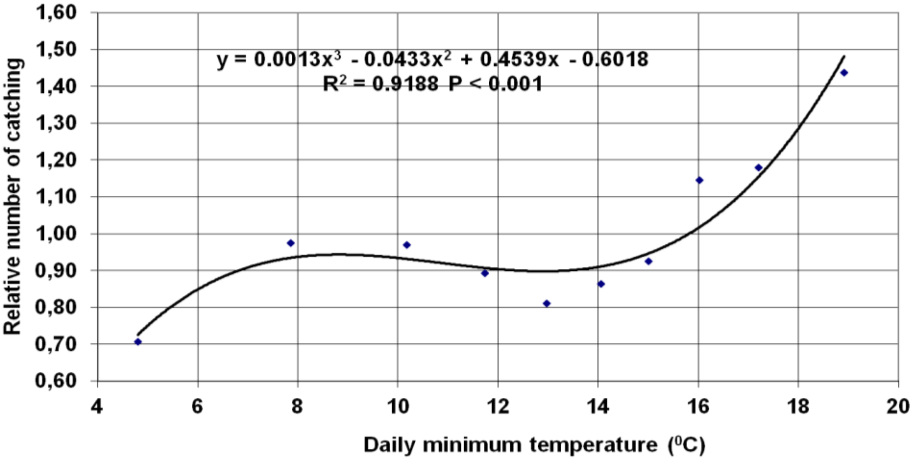

Figure 1. Catching results of *Haplotrips angusticornis* by the suction trap depending on the daily minimum temperature (Hódmezővásárhely, 2002 and 2004)

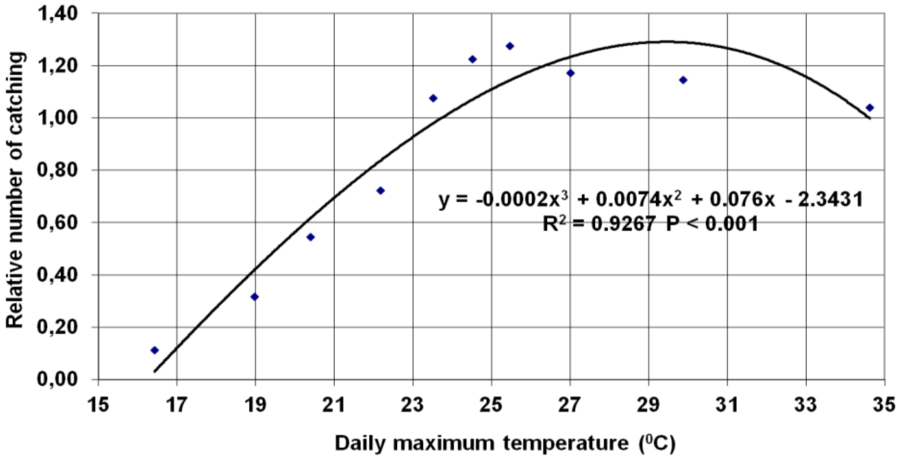

Figure 2. Catching results of *Haplotrips angusticornis* by the suction trap depending on the daily maximum temperature (Hódmezővásárhely, 2002 and 2004)

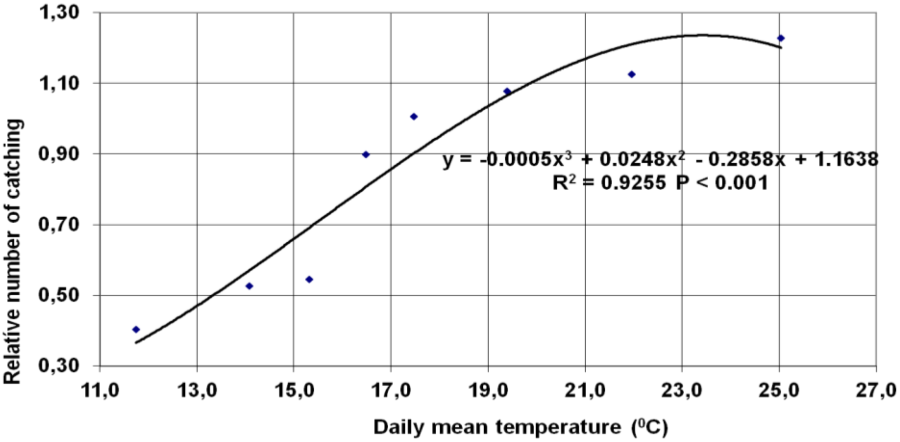

Figure 3. Catching results of *Haplotrips angusticornis* by the suction trap depending on the daily mean temperature (Hódmezővásárhely, 2002 and 2004)

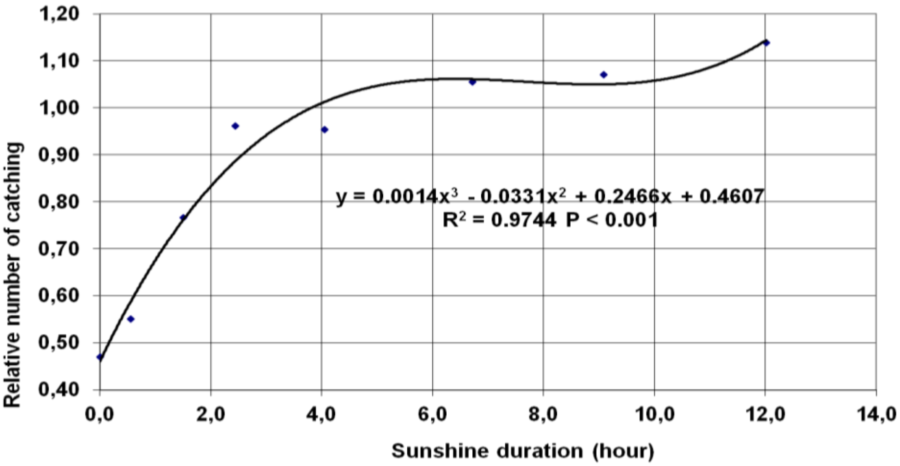

Figure 4. Catching results of *Haplotrips angusticornis* by the suction trap depending on the sunshine duration (Hódmezővásárhely, 2002 and 2004)

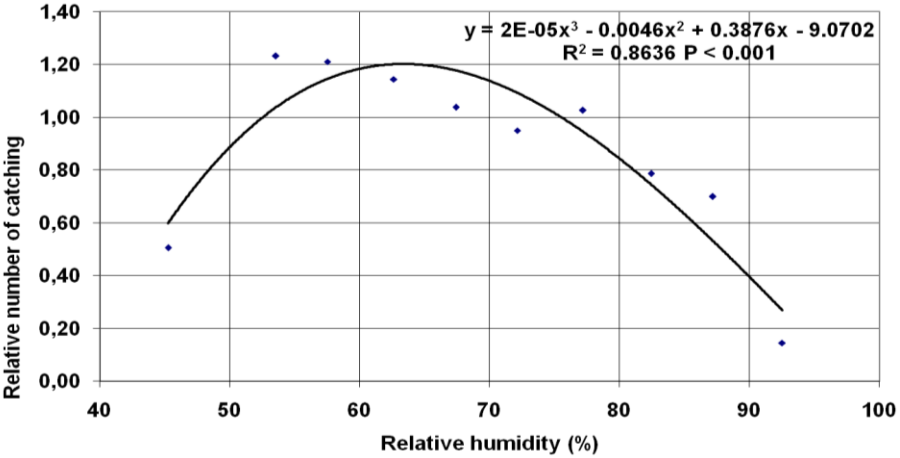

Figure 5. Catching results of *Haplotrips angusticornis* by the suction trap depending on the relative humidity (Hódmezővásárhely, 2002 and 2004)

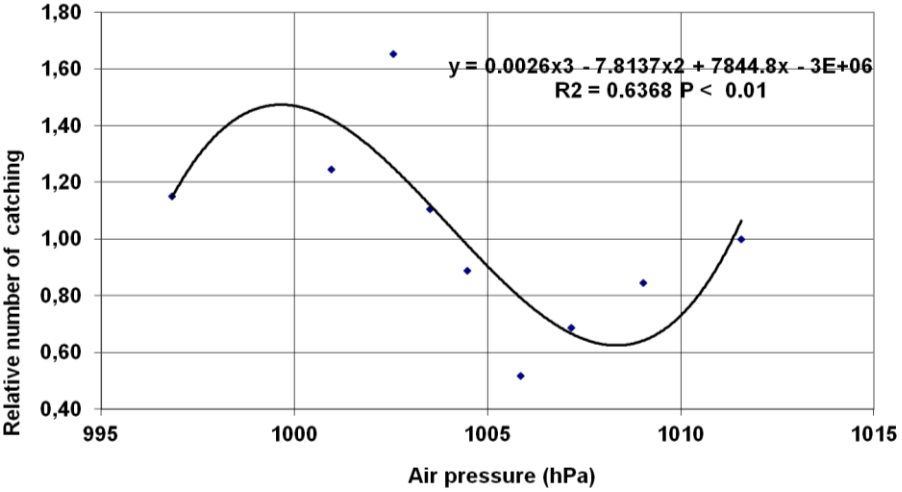

Figure 6. Catching results of *Haplotrips angusticornis* by the suction trap depending on the air pressure (Hódmezővásárhely, 2002 and 2004)

H. angusticornis migrated from April to late September in both years, while *H. aculeatus* started to migrate from late May to early November in 2002. The catching number of *H. angusticornis* was the highest on 26 May 2002 and on 22

July 2004. The mass flight of this species was observed in 2002 from mid-May to late June and in 2004 at the end of July (*Fig. 7, 8*).

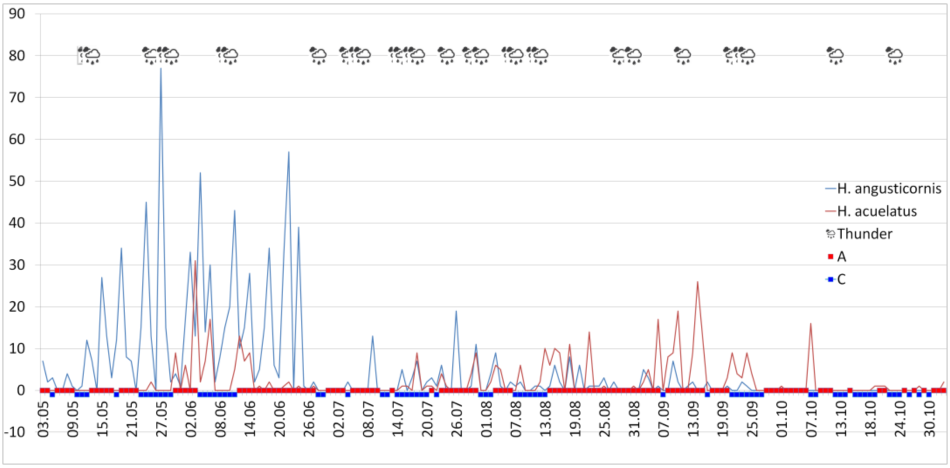

Figure 7. Seasonal flight activity of *H. angusticornis* and *H. aculeatus* observed by the suction trap in 2002 (A = anticyclonic climatic conditions; C = cyclonic climatic conditions) (Hódmezővásárhely, 2002) (On the X axis of the graph, together with the date, the changing of cyclonic and anticyclonic periods are shown, according to the data of the Hungarian Meteorological Service, regarding the studied area. On the top part of this graph, there are small cloud signs, referring to the stormy days.)

In 2002, the anticyclonic climatic conditions were prevalent. During the investigated period of this year, there were 67 days under cyclonic and 117 days under anticyclonic climatic conditions (*Fig. 7*). Probably, this circumstance could also have a role in the continuous migration of both species. According to our experiences, the storm or thunder had no direct influence on the numbers of the migrating adults. In 2004, the same situation was observed. According to the data of the Hungarian Meteorological Service, during this whole vegetation period, the anticyclonic climatic condition was also prevalent. The number of migrating *H. angusticornis* was even much higher in July than in the previous investigated year (*Table 1*, *Fig. 8*).

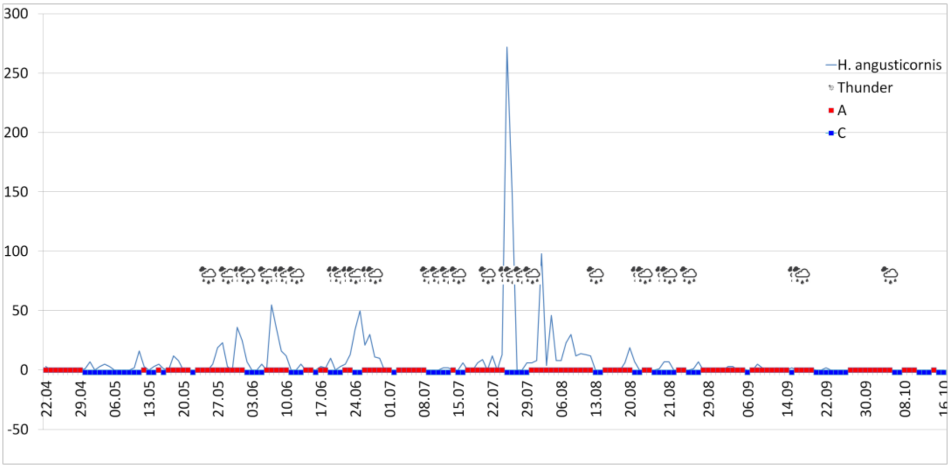

Figure 8. Seasonal flight activity of *H. angusticornis* observed by the suction trap in 2004 (A = anticyclonic climatic conditions; C = cyclonic climatic conditions) (Hódmezővásárhely, 2004) (On the X axis of the graph, together with the date, the changing of cyclonic and anticyclonic periods are shown, according to the data of the Hungarian Meteorological Service, regarding the studied area. On the top part of this graph, there are small cloud signs referring to the stormy days)

4. Discussion

The migration and the mass flight of thrips species depend on the meteorological conditions, the spatial composition of the host plants, and their ripening time [3].

This study is the first report concerning the mass flight of *Haplothrips angusticornis*. Although this species sporadically occurs in Central and Southern Europe, it is widespread in Hungary [15]. *H. angusticornis* was primarily found in the flower of weeds belonging to the family Asteraceae (*Achillea* spp., *Anthemis* spp., *Matricaria* spp., etc) [6]. The main cause of the mass flight of this species could be that *H. angusticornis* was breeding in temporary habitats, after which it must migrate to survive on overwintering weed species or in other hidden places. This tendency for species living in temporary habitats could be more migratory than for species from permanent ones. According to [1], cereal and grass-feeding thrips, belonging to the Thripidae suborder, are predominant in mass flight. Though *H. angusticornis* is neither a cereal nor a grass-feeder species, in 2002 and 2004, they occurred in surprisingly high numbers in the air (*Table 1*). However, the life habits and flight activity of this species still need to be clarified. There is no data available on the biology of *H. angusticornis*.

Haplothrips aculeatus is widely spread in Europe, and also a common species in Hungary [16]. This species is mostly a cereal and grass feeder [1]. It leaves the hibernation sites very late, when the maximum temperature is more than 20 ^{0}C for many days [16]. According to our results, this species started to migrate in late May (*Fig. 7*). It can migrate continuously during the vegetation period [6]. The migration depends on the host plants' (Poaceae or Asteraceae species) ripening time. In the present study, *H. aculeatus* migrated continuously during the whole vegetation period of 2002 (*Fig. 7*). [17] indicated that this species was found in higher numbers on *Anthemis arvensis* L., *Erigeron annuus* L., *Matricaria maritima* L., *Taraxacum officinale* F. H. Wigg, *Galinsoga parviflora* Cav., *Ambrosia artemisiifolia* L. (Asteraceae), *Medicago sativa* L. (Fabaceae), and *Amaranthus retroflexus* L. (Amaranthaceae). According to [6] and [1], *H. aculeatus* was observed in low numbers in the air. Our study confirms these experiences because there were 393 and only 31 specimens captured in the air by the suction trap during the whole vegetation period of 2002 and 2004, respectively (*Table 1*).

According to our data, under anticyclonic meteorological conditions, there is a stronger possibility for an increased number of migrating *H. angusticornis*. The meteorological elements of anticyclonic climatic conditions are the followings: higher temperature, stronger sunshine duration, and higher air pressure. Under cyclonic climatic condition, the meteorological elements are the opposite: lower temperature, less sunshine duration, and lower air pressure. According to [2] and [18], the temperature has the most important effect on the migration of the thrips. As for the influence of the minimum, maximum, and daily mean temperatures, the higher temperature caused the higher numbers of migrating specimens in this study. According to our investigation, the more sunny hours have positive influence on the migration of *H. angusticornis* (*Fig. 4*) and the optimal level of relative humidity was about 62% (*Fig. 5*). The higher level of relative humidity has a negative effect on the mass flight and migration. The effect of air pressure proved to be very contradictory in this study (*Fig. 6*). The concrete effect of this element needs to be clarified in the future.

The thunder had no influence on the flight of the studied *Haplothrips* species. Basically, during the storm or thunder, none of the thrips species could fly [1]. Therefore, the wind can also cause a lower number of migrant Thysanoptera adults.

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Approximation of the WRB reference group with the reapplication of archive soil databases

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Abstract: In our study, we tested the existing and freely accessible soil databases covering a smaller geographical region surveyed and classified according to the Hungarian classification in order to approximate the WRB soil reference groups (RSG). We tested the results and applicability of approximation for the RSG with three different methods on 12 soil profiles. First, RSGs were assigned to Hungarian soil taxa based on results of previous correlation studies, secondly, a freely accessible online database of ISRIC was applied furthermore, and an automated reclassification developed and programmed by us was used, which takes the original soil data as input.

Keywords: soil classification, Solonetz, Vertisol, WRB correlation, WRB algorithmization

1. Introduction

As a result of the soil survey works during the past 100 years in Hungary, there are enormous amounts of soil data available for meta-analyses. However, due to their different approaches of soil profile description and laboratory methods, it is often difficult to imply them for present-day application in researches with novel approaches. Furthermore, because of the limited options and financial resources, the requirement for the reuse, reclassification, and harmonization of these data with later databases is constantly increasing [1]. Several difficulties emerge in this process since these data are based on different methodology and classification systems.

Currently, the most commonly used soil classification system in Europe is based on the diagnostic approach of World Reference Base for Soil Resources (WRB). It provides well-defined terminology and quantifiable conditions [2]. During the recent years, numerous results were published regarding the mapping of soil databases converted from different sources into WRB [3-10] and the classification of soils with simplified automated algorithms [11].

Láng et al. (2010, 2013) used the taxonomical-distance-based comparison to perform the numerically controlled harmonization of the Hungarian soil classification with the WRB. In their study, they investigated the correlation possibilities between the national and the WRB classification in the case of brown forest soils (cca. Luvisols, according to WRB), using the method for classification purposes for the first time. Based on their results, the numeric comparison of the Hungarian soil types to the similar units of WRB became possible [12-13].

The differences and connections between WRB and the Hungarian soil classification were first summarized by Michéli et al. (2006) and Krasilnikov et al. (2009) who also established correlation keys which are primarily based on field experiences and the definitions of the classification units [14].

This study investigates data of soil profiles from an area which was previously mapped and classified based on the Hungarian classification system in order to identify whether it is possible to classify the soil profiles characterized by the archive data according to WRB and, if it is, to define the degree of accuracy. The comparison was used to answer the question if we can only acquire the data recorded according to the different methodology and taxonomy, whether the (unambiguously inaccurate and in some cases impossible) reclassification using the data ill-suited to WRB could provide more accurate identification of RSGs than the automatic assigning based on the system-level correlation or the acceptance of the RSG predicted by the ISRIC database. Since data about the taxonomical status of soils assigned properly to WRB in field are available in low spatial density, approximation could be useful in WRB soil mapping and reapplication of archive data as well.

Study area

The investigated profiles are located on the Hortobágy, Dél-Hajdúság, and Nagy-Sárrét regions in Eastern Hungary (*Fig. 1*). Hortobágy is an abandoned alluvial plain. It is the largest continuous area with alkaline soils on the continent. Approximately 3/4 of the area is covered by alkaline and in deeper soil horizons also by salt-affected soils. As a consequence of shallow alkaline groundwater, diverse alkaline soil complexes were formed on the silty loess deposits with characteristical mosaic spatial pattern [15].

Dél-Hajdúság is a fossil alluvial plain covered by silty loess. In lower topographic positions, alkaline meadow chernozem soils can be found with significant clay content, which are used predominantly as croplands, but in smaller extent also pastures or forests. At higher elevations, more fertile typical carbonatic chernozem soils are dominant. Alkaline and salt-affected soils are just in subordinate extent in this landscape, which has great importance from agricultural point of view [16].

Nagy-Sárrét is a recent alluvial plain interspersed with alkaline lands and flood-free areas. Part of it has basin-like characteristics, where in the deeper, artificially drained areas dominantly croplands and in small fragments natural grassland vegetation can be found. All soils of the landscape have been developed under influence of shallow groundwater and partially of temporary surface water cover, which is reflecting in topsoil, but more frequently in the subsoil properties. As a result of anthropogenic activities, these soils are mostly artificially drained, which is expressed in the lowering of groundwater level and the retreat of surface water cover [17].

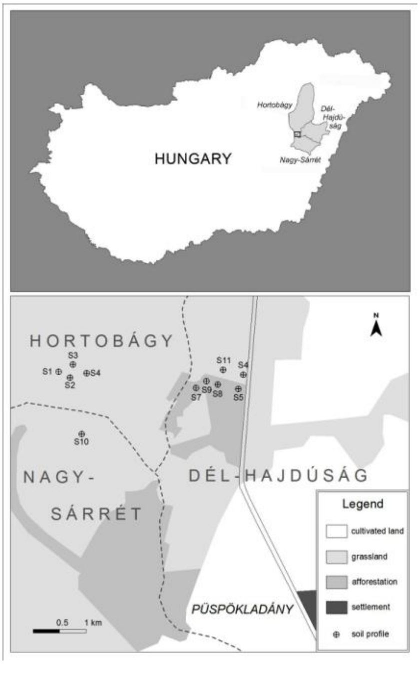

Figure 1. Location of the study area and the sampling sites in Hungary

2. Materials and methods

Twelve soil profiles (S1-S12), 1 on the Nagy-Sárrét, 4 on the Hortobágy, and 7 on the Dél-Hajdúság, were investigated (*Fig. 1*). The profiles represents the spatial variability of soils within the three neighbouring regions [18]. The preparation, analysis, and classification according to the Hungarian taxonomy of the profiles took place between 1999 and 2002. To compare the results and applicability, three methods for the approximation of WRB RSGs were used (*Table 1*): 1) assigning the profiles to WRB according the correlation databases between WRB and Hungarian classification's soil taxa, 2) prediction of RSGs based on ISRIC database, and 3) results of automatized WRB classification and the prediction of RSGs. In the first case, we assign to the profiles two or more RSGs. These were given as possible equivalents according to the correlation table (Michéli et al. 2006) [11]. In the second case, we used the coordinates of profiles in order to predict the RSG using the ISRIC web services [19–20]. These methods we used to associate the profiles with RSGs and give the probabilities that the database stored in each location. In the third case, we carried out the reclassification based on the available data from the soil profiles with automated algorithms which were designed in accordance with the WRB diagnostics.

Table 1. Overview of the input and output data of the three applied methods for the approximation of WRB RSG

Approximation method	Input data	Output data
System-level correlation between Hungarian and WRB soil taxa	Hungarian soil type	WRB RSG(s) one or more
Prediction of RSGs based on ISRIC database	Coordinates of the location	WRB RSG(s), several, each with probability (%) of occurence
Automatized reclassification according to WRB-based algorithms	Soil horizon data from profiles	WRB RSG, one only in case it fits entirely

Possibilities and uncertainties of automatized classification

The possibilities for reclassification of soil data acquired from different sources are limited for a number of reasons. Basically, missing data or the sampling method can be the reason why a given soil profile cannot be classified and assessed with an adequate degree. The automatable method suggested by Eberhardt and Waltner (2010) is different from the previous ones, being primarily the correlation and harmonization of existing soil taxa [5]. The essence of the suggested method is using the original soil survey data to identify the WRB units instead of harmonizing each national classification unit. This requires to design the necessary algorithms separately for every database applying different methodologies [11]. But this is rather time consuming and errors occurring due to the different methods can be corrected only to a limited degree. Nevertheless, after the initial setup of the system, a practically unlimited amount of soil units can be classified automatically; therefore, it makes possible the process of large databases.

Automatization of the classification process

The specification is a development of a plug-in, which is able to classify soils based on the archive data in accordance with the WRB. As a preparatory step, our soil data need to be integrated into a processable data structure [21]. Therefore, it is advisable to store the data in relational data tables so that the later processes can be automatized more easily [22]. The first table includes field and laboratory results and further computed data such as diagnostic levels, attributes, and soil materials [23]. The second table records the geographical location of the soil profiles and the result of the classification.

The next phase of the work is the algorithmization of the level verifying, attribute calculating, and the main group’s specifying components. Since the WRB classification system has fixed criteria and in most cases the archive data do not follow the structure of the idealized system, the method of this process also has to be taken into account.

Decision process of soil RSG

Since the heavily textured soils with high clay content usually form a separate WRB RSG, which directly follows the Solonetz soils in the WRB (2014) system, we assumed that some of them belong to either the Solonetz or the Vertisol reference groups based on the available data, references, soil maps, and the topographic characteristics of the profiles. In order to reach this conclusion, the possibility of belonging to one of the previous five groups had to be excluded (*Fig. 2*).

The classification as ***Histosol*** group could be excluded since our profiles do not have organic soil material (>20% C_{org}):

1. at least 10 cm thick if it starts at the surface and the soil climate is cryic or pergelic, or the underneath soil level is coherent rock, technical solid material, or rough debris the cracks of which are filled with organic material, or
2. at least 60 cm thick for 100 cm from the surface, if it starts within 40 cm from the surface and at least 75% of its volume is made up of fibrous peat moss, or
3. at least 40 cm thick for 100 cm from the surface, if it starts within 40 cm from the surface, if it is made up of other material.

The classification can be keyed out at ***Anthrosols*** if the soil does not have a horizon of ≥50 cm thickness which is ploughed, cultivated, or changed due to irrigation (hortic, irragric, terric).

The classification keys out at ***Technosols*** if in the top 100 cm layer of the soil the amount of artefacts does not reach 20% by volume or there is no technic hard material or artificially established impermeable geomembrane. Since the examined databases are originated from cultivated or pasture sites, this RSG can be excluded in the case of all the investigated profiles.

Cryosols can be excluded in the examined geographical region due to the different soil climate (they do not have cryic horizon), because this RSG cannot be found under the Hungarian climate conditions.

The classification as ***Leptosol*** can be excluded if in the soil:

1. there are no continuous hard rock or technic hard material within 25 cm starting from the surface, or
2. within 75 cm starting from the surface, or if the soil is shallower, down to the surface of the continuous hard rock or technic hard material the fine earth part makes up ≥20% by volume of the entire soil.
3. The parent materials of the study area are unconsolidated sediments, where rough debris or technical solid material can be found only under urbanized conditions due to anthropogenic influence. In this case, however, the soils could be keyed out among Technosols, therefore this RSG could be excluded as well based on the land-use characteristics of the investigated area.

The soil can be classified as ***Solonetz*** if it has a natric horizon within 100 cm starting from the surface, and cannot be classified into any of the previous RSGs. If this condition is met, the investigated profile keys out into Solonetz. The next step of the process is the identification of the natric horizon if it presents.

The soil can be classified as ***Vertisol*** if

1. it has a vertic horizon starting within 100 cm from the surface and
2. if the vertic horizon does not start at the surface, the clay content is ≥30% throughout between the surface and the vertic horizon,
3. the surface is articulated by seasonally opening–closing shrink–swell cracks.

Therefore, in order to decide whether the soil belongs to the Vertisol, not only the proving of the vertic horizon was necessary but the clay content above the vertic horizon (if present) and the presence of cracks within the horizon should also be checked. If based on the established criteria, the investigated profile cannot be assigned to any of these RSG-s; the RSG of the profile will be considered as unknown.

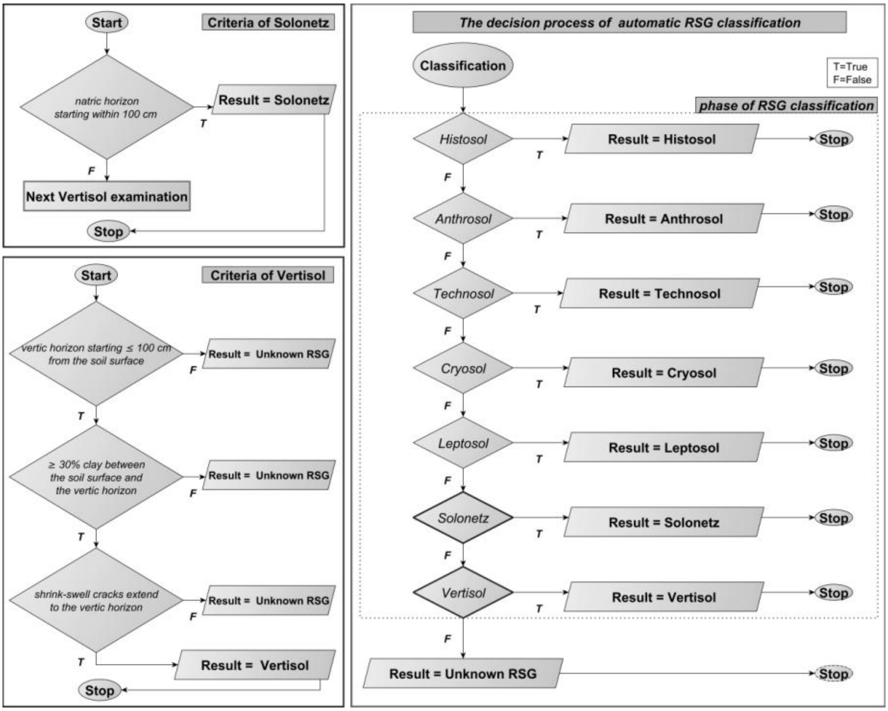

Figure 2. The process of automatic soil classification.

3. Results and discussions

The profiles were classified as meadow solonetz (S1, S2, S3, S4, S10, S11, and S12), typical meadow soil (S5, S9), meadow chernozem (S7), and solonetzic meadow soil (S6, S8) categories according to the Hungarian classification system (*Table 2*). Due to the correlation project, the result of the classification could be compared to the results published by Michéli et al. (2006). The following RSGs were established for the types identified by us according to the Hungarian taxonomy: meadow solonetz – Solonetz, Vertisol; typical meadow soil – Phaeozem, Chernozem; Vertisol; meadow chernozem – Chernozem, and solonetzic meadow soil – Vertisol, Cambisol.

The estimation of RSG based on the ISRIC database provides more information as far as the probability of RSGs associated with a given location is also predicted nevertheless, these data can be considered only as an approximation.

The last column of *Table 2* includes the RSG as results of the automatized classification carried out by the software developed by us. Five profiles were classified as Solonetz, 4 were classified as Vertisol, and 3 were considered as RSG unknown. In the case of profiles which were considered as belonging to unknown

RSG, the available data were not sufficient for the automated classification, or the profile could not even provisionally be classified into any of the RSGs, because the classification requirements were not met. In the first case, the missing ESP (Exchangeable Sodium Percentage) values of S1 and S2 excluded them being classified as Solonetz. In the case of S7, either the available data were not sufficient or it was placed behind the Vertisol in the WRB system, and in this study we have not dealt with the classification of those RSGs.

Table 2. Soil type (Hungarian classification) and identification of RSGs based on system-level correlation (Michéli et al. 2006), soil map data based on approach (ISRIC), and soil profile data based on automatized reclassification

Profile ID	Hungarian soil type	Results of Michéli et al. (2006) correlation	RSG according to ISRIC	RSG according to automatic classification
S1	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Unknown
S2	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Unknown
S3	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Solonetz
S4	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Solonetz
S5	typical meadow soil	Phaeozem/Chernorem/Vertisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Vertisol
S6	solonetzic meadow soil	Vertisol/Cambisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Vertisol
S7	meadow chernozem	Chernozem	Solonetz (13%), Solonchak (13%), Vertisol (10%)	Unknown
S8	solonetzic meadow soil	Vertisol/Cambisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Vertisol
S9	typical meadow soil	Phaeozem/Chernorem/Vertisol	Solonchak (19%), Solonetz (17%), Vertisol (11%)	Vertisol
S10	meadow solonetz	Solonetz/Vertisol	Solonchak (19%), Solonetz (14%), Vertisol (9%)	Solonetz
S11	meadow solonetz	Solonetz/Vertisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Solonetz
S12	meadow solonetz	Solonetz/Vertisol	Unknown coordinates	Solonetz

Based on the results, it can be seen that in some cases the archive soil data sources do not contain sufficient information to identify unambiguously the diagnostic horizons of the profiles according to WRB. In accordance with the methodology of WRB, this excludes the classification of soil profiles according to WRB since it requires the information about the present diagnostic horizons to assign or exclude any RSGs; therefore, the result of the automated classification led to unknown result. The vertical position of identified diagnostic horizons in the studied 12 profiles based on the available data are presented in *Figure 3*. Because of the lack of data, not only the positive identification of certain horizons are difficult but also frequently the exclusion of them (*Table 3*).

In some cases, the specific data types were not available, and there were other soil data (categorical or derived data) based on the given feature (e.g. surface cover, soil moisture household, and soil climate type) that could be inferred (however not in a numerical way). For example, the presence of shrink-swell cracks is a diagnostic criteria to identify vertic horizon, but earlier databases do not contain information concerning that, with the exception of mentioning deep, wide cracks at the description of structure. The most frequent problem out of the ones associated with the data was the limited number of data regarding depth. The established database managed some of its data with a topsoil/subsoil distinction, which in a lot of cases makes it more difficult or excludes entirely the possibility of precise examining of the depth criteria according to the WRB. Since the data collection and the division of the profiles to horizons were not carried out in accordance with the guidelines of WRB, the indication of diagnostic horizons conforms to the sampled layers and is not necessarily in accordance with the boundaries of diagnostic horizons which could be observed and identified in the field.

The applied three methods to estimate WRB RSGs lead to different results. In the case of the classification based on types of the Hungarian taxonomy applying the results of former correlation studies, there was not possible to assign to just one RSG, but two, or even three RSGs were given as possible equivalents, without estimation of probability. Therefore, the unambiguous reference group identification is not possible in this way. The approximation of RSG using the ISRIC database is more useful because the probabilities of possible RSG-s were associated to a given profile. The spatial resolution of this database, however, is not adequate to precisely describe the heterogeneity of the area. Based on the coordinates of the investigated profiles, the ISRIC database predicted Solonchak and Solonetz RSGs. In addition, in one case, RSG prediction was not possible due to missing coordinates. In the case of automated data classification, five profiles were classified as Solonetz, four as Vertisol, and three were keyed out as RSG unknown or impossible to predict due to missing data. The most relevant question in our study – in addition to missing data – was the uncertainity of identification of diagnostic horizons (natric, vertic, calcic, and mollic) based on the archive data. Since the data collections were not carried out in accordance with the guidelines of WRB, the indication of diagnostic horizons conforms to the sampled layers (diagnostic horizons calculated from the layers), which are not definitely in accordance with the boundaries of horizons which can be identified in the field, therefore it can only serve as a basis for the identification. However, regarding the assessment and application of decision-making rules of the established RSGs, it should be noted that these only mean a “best approximation” for the studied archive soil data and do not substitute the field data collection, description, and classification process according to the detailed WRB methodology.

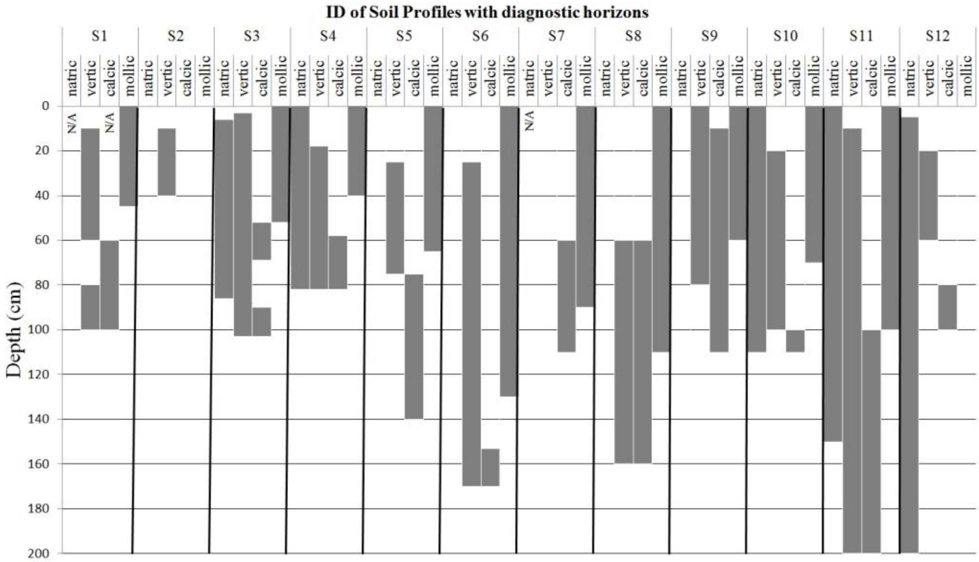

Figure 3. Data based on the estimation of diagnostic horizons in investigated profiles

Table 3. Soil characteristics of the profiles representing the most typical soil conditions within the study area (S7–S9–S11)

Profile ID	Horizon depth	Texture of fine earth (<2 mm)	Grain size distribution in fine earth (%)			pH_{H2O}	pH_{KCl}	$CaCO_3$	Organic carbon	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	ESP
	(cm)		(<2 mm)					% (m/m)	%	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	%
			Clay (0.002 mm <)	Silt (0.002-0.063 mm)	Sand (0.063-2 mm)										
			%	%	%										
S7	0-10	*silt loam*	15.4	71.5	13.1	7.33	6.79	1.34	3.33	N/A	N/A	N/A	N/A	N/A	N/A
	10-25	*silt loam*	18.1	73.6	8.3	7.35	6.86	1.72	2.35	N/A	N/A	N/A	N/A	N/A	N/A
	25-40	*silt loam*	22.1	69.7	8.2	7.37	6.92	2.44	2.69	27.10	2.50	3.30	0.16	33.06	0.48
	40-60	*silt loam*	26	67.1	6.9	7.74	7.21	7.25	1.50	N/A	N/A	N/A	N/A	N/A	N/A
	60-75	*silty clay loam*	29.8	65.6	4.6	8.04	7.44	17.13	1.12	N/A	N/A	N/A	N/A	N/A	N/A
	75-90	*silty clay loam*	27.8	64.3	7.9	8.22	7.66	26.18	0.60	19.50	3.00	3.30	0.18	25.98	0.69
	90-105	*silt loam*	26.7	64.8	8.5	8.32	7.68	26.41	0.09	N/A	N/A	N/A	N/A	N/A	N/A
	106-110	*silt loam*	26	65.1	8.9	8.39	7.76	19.85	0.45	N/A	N/A	N/A	N/A	N/A	N/A
S9	0-10	*silty clay loam*	35.1	61.5	3.4	4.95	4.12	0	2.28	24.00	5.15	1.00	0.19	30.33	0.62
	30-40	*silty clay*	43.1	50.2	6.7	7.2	6.88	16.33	1.06	44.38	4.66	0.95	0.21	50.20	0.42
	50-60	*silty clay loam*	39.6	51.3	9.1	7.42	7.01	21.96	1.65	38.43	4.31	0.83	0.27	43.83	0.61
	70-80	*silty clay loam*	34.6	56.8	8.6	7.67	7.1	25.63	0.45	26.95	3.61	0.59	0.52	31.67	1.65
	100-110	*silty clay loam*	28.1	59.6	12.3	7.72	7.22	23.22	0.19	23.16	4.13	0.58	0.67	28.53	2.36
S10	0-10	*silt loam*	13.5	77.5	9	7.57	6.74	4.03	1.99	5.76	1.03	0.20	7.81	14.79	52.79
	10-20	*silt loam*	21.7	68.6	9.7	9.42	8.33	1.9	0.83	6.53	1.45	0.50	23.68	32.16	73.63
	20-30	*silty clay loam*	31.8	60.1	8.1	9.45	8.55	1.98	1.30	6.27	1.88	0.60	31.76	40.50	78.41
	30-40	*silty clay*	41.5	52.6	5.9	9.78	8.84	1.96	0.69	6.03	2.45	0.66	32.48	41.61	78.06
	40-50	*silty clay loam*	39.3	55.7	5	9.76	8.85	2.14	1.45	5.99	3.17	0.58	32.36	42.09	76.88
	50-60	*silty clay*	41.9	51.5	6.6	9.73	8.74	1.57	0.81	5.19	3.26	0.56	32.24	41.24	78.17
	60-70	*silty clay loam*	36.2	55.8	8	9.73	8.89	7.9	0.88	12.10	3.33	0.44	30.50	46.36	65.79
	70-80	*silty clay loam*	36.7	52.1	11.2	9.62	8.9	14.37	0.42	14.00	3.50	0.34	27.98	45.82	61.06
	80-90	*silty clay loam*	33.1	56.3	10.6	9.62	8.86	13.38	0.10	10.59	2.64	0.40	25.20	38.83	64.90
	90-100	*silty clay loam*	30.2	58	11.8	9.69	8.8	11.29	0.28	11.16	2.55	0.36	22.64	36.71	61.68
	100-110	*silty clay loam*	28.6	59.6	11.8	9.69	8.86	15.63	0.26	16.52	3.26	0.33	20.28	40.38	50.22

The results of reclassification also highlight the fact that the types/main types of the Hungarian soil classification system and the reference groups of WRB system cannot be completely corresponded to each other. However, until data collected by the WRB methodology are not available in large number and with adequate spatial frequency, the estimation carried out by the reclassification of archive data provides a good alternative for the field identification of WRB RSGs.

4. Conclusion

Using the automated WRB soil classification based on our own developed algorithms, five profiles could be classified as Solonetz, four as Vertisol, and the remaining three profiles were keyed out as unknown reference soil group from the 12 investigated profiles. According to the correlation studies, the types of the Hungarian taxonomy could be assigned not to one but sometimes to three RSGs with unknown probability. This did not allow the unambiguous reference-group-level WRB classification based on the archived soil data. The approximation carried out with the help of ISRIC database also indicates more than one RSGs associated with a distinct location, but it predicts the probability of their occurrence. However, the spatial resolution is not adequate to draw an accurate map of the heterogeneity of soils. In the case of the proved profiles, Vertisol, Solonchak, and Solonetz RSG-s could be identified.

The results of the automatized reclassification of the archive data suggested that the RSG-s of WRB cannot be unambiguously approximated as a consequence of the different field-surveying approaches and methods. The different data collection structure strongly limits the reclassification possibilities as well, but at least it provides more accurate results compared with the estimation of the RSGs by simple assigning according to general correlation rules or prediction based on location and ISRIC database.

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Analysis of land stability and land-use change processes in the 19–20th centuries: a case study in Gödöllő Hillside, Hungary

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Abstract: The manuscript presents land-use change processes based on former military map analyses. Military maps were derived from the 1770s until the 1890s and later from the CORINE Land Cover map. I observed the transition direction of areal distribution of various land uses. Digitalized maps showed 19–20th century land-use conditions; besides them, we created a grouping system which is based on the intensity of land use. We distinguished six land-use types, ranking them according to the anthropogenic influence (1. built-up areas; 2. arable fields; 3. orchards and vineyards; 4. meadows and pastures; 5. forests; 6. wetlands).

Keywords: historical maps, land stability, land use

1. Introduction

In the past few decades, several studies have been written about the research on landscape change [1, 2, 3, 4, 5], which help to understand the rapid changes in the spatial structure of the landscape. They are also trying to provide a starting point for landscape planning by means of using different approaches and aspects.

Not only the structure of the landscape has changed rapidly but also the methods used for the description of such changes. Besides simple, descriptive studies – and often complementing them –, there have been studies using landscape metrics [6, 7, 8, 9, 10, 11, 12], which help to understand social, economic, and environmental issues. Among other things, they are useful in assessing the naturalness and anthropogenic alteration of landscapes [13], thus revealing the fragmentation of the landscape. The primary causes for the fragmentation of the landscape is increasing land usage [14, 15], but the development of transport infrastructure (roads, railways) and the expansion of human settlements also contribute largely to the break-up of habitats, causing severe fragmentation [9, 16, 17, 18, 19, 20].

Besides studies using landscape metrics, the primary analysis of research findings concerning the presentation of changes in the landscape and in land cover is based on the examination of historical maps [21, 22, 23, 24, 25, 26, 27, 28], aerial photography [29, 30, 31, 32], as well as (GIS-based) satellite images [33, 34, 35, 36]. The advantage of such approaches is that they make it possible to understand current events and to explore future possibilities. They can provide a basis for exploring the differences and similarities or the stability and changes between two or more points in time, even in terms of land-use categories. They may also help to resolve disputed land ownership issues.

This study applies the latter direction, i.e. out of the different approaches we have chosen the method that utilizes historical maps. We will present the locations and intensity of land use during the past 200 years.

2. Materials and methods

The region we explored is the area of Gödöllő Hillside, which is situated to the east of the capital (Budapest); it is rich both in nature and landscape values. It belongs to the Northern Mountain Ranges according to the micro-region classification. The area of Gödöllő Hillside is 550 km^2 and it consists of 16 settlements. The landscape varies between 130 and 344 m.a.s.l., which reduces towards the south-east [37]. The highest point of the hillside is Margita (344 m), which is situated near the village of Szada, located in a suburban region, and the lowest point is near Gyömrő (130 m). It is a diverse micro-region with twofold natural characteristics. Due to its landscape characteristics, the micro-region is a transitory area between a plain terrain and medium-height mountain ranges from the aspect of geological, climatic, botanical, and soil features. Besides the natural conditions, the land use in the micro-region is determined by its role in the country's economy, good accessibility, and ecological conditions. The change in land use happened in parallel with the transformations in the population number [38].

In this study, we have analysed only the area delineated by the four central towns (Veresegyház, Szada, Gödöllő, and Isaszeg) of the 16 settlements belonging to Gödöllő Hillside (*Figure 1*). The administrative boundaries of 12 settlements extend beyond the border of the hillside; therefore, we narrowed down the area to the settlements the outer boundaries of which are entirely within the hillside. Our previous observations [39, 40] have also confirmed that this is the area where the scope of changes requires further analyses.

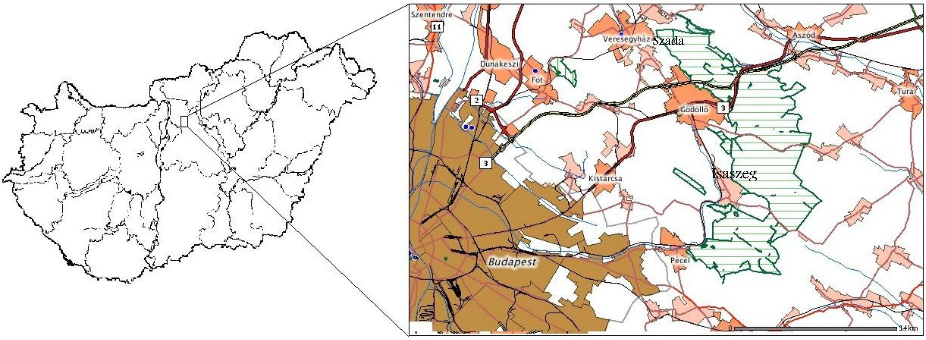

Figure 1. Location of surveyed areas [41]

The changes in land use have been studied by the aid of the 1st and 3rd military maps, as well as the CORINE Land Cover (CLC 50) maps. Our aim, besides presenting the 19–20th century conditions, was creating a category system which is based on the intensity of land use, i.e. on changes in the “natural environment” caused by anthropogenic influence. We digitized available maps, carried out a comparative study between adjacent time periods, and then we displayed the results on a map.

We distinguished six different land-use methods: built-up areas, orchards and vineyards, meadows and pastures, forests, wetlands, and arable fields. The various land-use categories have been ranked according to anthropogenic influence, primarily from the nature conservation point of view, as follows: 1. built-up areas; 2. arable fields; 3. orchards and vineyards; 4. meadows and pastures; 5. forests; 6. wetlands.

Next, maps from earlier periods have been projected on later maps (the First and Second Military Survey as well as the Third Military Survey and the CLC 50 survey), which resulted in a change map. The polygons have been recoded, and then ranked according to the above aspects, after which the direction of the change (positive, negative, no change) was identified.

As a result, we received an 11-member scale: from (-5) to (+5), where the section between -5 and -1 denotes a negative change, the section between 5 and 1 shows positive change, while 0 means that the area of the given polygon was stable and free of change (*Table 1*).

Table 1. Evaluation of different land-use types based on historical maps

	After	**Built-up area**	**Arable land**	**Orchard, vineyard**	**Meadow, pasture**	**Forest**	**Wetland**
Before	Code	1.	2.	3.	4.	5.	6.
Built-up area	1.	**0**	+1	+2	+3	+4	+5
Arable land	2.	-1	**0**	+1	+2	+3	+4
Orchard, vineyard	3.	-2	-1	**0**	+1	+2	+3
Meadow, pasture	4.	-3	-2	-1	**0**	+1	+2
Forest	5.	-4	-3	-2	-1	**0**	+1
Wetland	6.	-5	-4	-3	-2	-1	**0**

After this, the categorization was refined according to negative changes, since our aim was to determine anthropogenic alterations,
where: -0 = stable area,

– (-1) – (-2) = denote minor alterations. We agreed on labelling a change which is one or two value points a minor change (in any category). Any change greater than this indicates a higher intervention, therefore larger figures, i.e.:

– (-3)-(4)-(-5) = denote major alterations for the purposes of our study.

We prepared the area of land cover maps using the following sources:

1. 1st (1763–1787) Military Survey Map (Scale = 1:28,800) (Arcanum Ltd),
2. 2nd (1806–1869) Military Survey Map (Scale = 1:28,800) (Arcanum Ltd),
3. 3rd (1869–1885) Military Survey Map (Scale = 1:25,000) (Arcanum Ltd),
4. CORINE Land Cover maps (2003) (Scale 1:50,000).

ESRI ArcView 3.2 was used for digitizing the maps, to prepare spatial statistics and layouts for presentation.

3. Results and discussions

The structure of the land has changed significantly in the past 200 years. Due to intensive land use (farming of lands, building up of areas, developing roads), the average size of habitats has diminished, the previously homogeneous land-use methods have become greatly fragmented. The huge increase of patches indicates the same tendency.

The towns we have chosen (Veresegyház, Szada, Gödöllő, and Isaszeg) belong to the core of Gödöllő Hillside, covering 1/3 of the area. In the late 1700s, after the end of the Ottoman rule, their population was insignificant, but by the end of the 1900s and the beginning of the 2000s population had boosted significantly, which greatly increased the proportion of developed environments (23.7%) and the intensity in land use (*Table 2*).

Table 2. Land-use changes between 1763 and 2003 (%)

Land-use type	1st Military Survey Map	2nd Military Survey Map	3rd Military Survey Map	CLC 50
Built-up area	0.74	1.09	1.27	23.72
Forest	33.30	33.66	27.09	46.76
Wetland	7.77	5.26	4.86	1.46
Pasture, meadow	48.23	41.94	25.31	5.18
Arable land	4.59	12.23	34.13	22.28
Orchard	0.90	1.22	1.26	0.59*
Vineyard	4.47	4.60	6.09	

*orchard + vineyard

3.1. The 1st and 2nd military maps

Comparative analysis based on the 1st and 2nd military maps revealed that during the 19th century the area of 65.79% stayed unchanged, which indicates a large stability in land use. Negative changes, however, are more dominant than positive ones: they affected 22.35% of the land.

No major restructuring occurred during the 1st (1763–1787) and the 2nd (1806–1869) military survey; the two dominating land-use methods were meadow/pasture management and forestry. Larger contiguous forests can be found in the middle and eastern parts of the hillside (around Gödöllő and Isaszeg), which retained their original functions. It should be noted that viticulture had a great significance relative to the size of the inhabited area, providing a major way of living in the region for about 100 years (*Table 2*).

Based on the ranking of sensitivity, forests proved to be stable land-use methods (*Table 3*), while wetlands were the most affected by changes. Wetlands were primarily transformed into meadows and pastures or became used as arable fields. Disregarding wetlands, stability distribution is above 60%.

Table 3. Ranking of sensitivity according to the land-use methods between the 1st and 2nd military maps (%)

Land use /code	**Built-up area (1.)**	**Arable land (2.)**	**Orchard/ Vineyard (3.)**	**Meadow/ pasture (4.)**	**Forest (5.)**	**Wetland (6.)**
-5	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.55
-4	*0.00*	*0,00*	*0.00*	*0.00*	0.22	16.34
-3	*0.00*	*0.00*	*0.00*	0.50	1.03	3.63
-2	*0.00*	*0.00*	5.01	14.74	2.07	39.08
-1	*0.00*	0.00	2.48	2.88	19.31	13.37
0	**62.92**	**73.48**	**61.79**	**64.04**	**77.03**	**27.04**
+1	0.24	0.02	19.81	13.08	0.34	*0.00*
+2	19.35	11.25	9.72	4.76	*0.00*	*0.00*
+3	1.25	1.03	1.19	*0.00*	*0.00*	*0.00*
+4	12.46	14.22	*0.00*	*0.00*	*0.00*	*0.00*
+5	3.77	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Typical transformations: built-up area → orchard/vineyard; arable field → wetland; orchard, vineyard → built-up area; meadow, pasture → arable field; forest → meadow, pasture; wetland → meadow, pasture. The area is characterized by minor transformations (*Figure 2*) although changes affected wetlands the most, which are the most sensitive areas in terms of nature conservation.

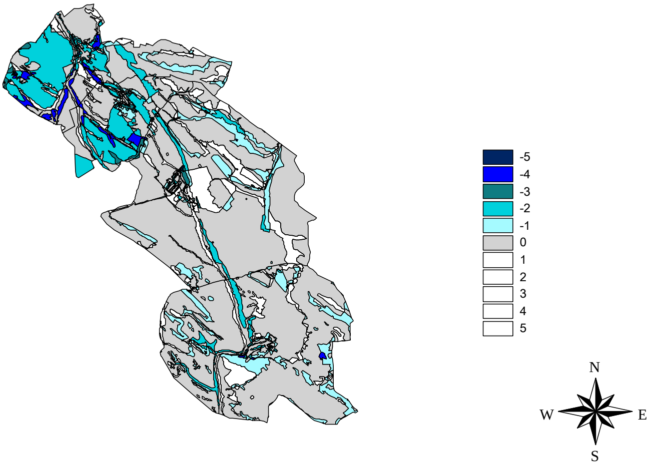

Figure 2. Degree of transformation between 1st and 2nd Military Map

3.2. 3rd Military Maps and CLC50 Maps

By the end of the 1800s, in the period of the 3rd Military Survey (1872–1885), the main land-use methods were arable field (34.13%) and forestry (27.09%). The proportion of meadows, pastures, and forests further decreased by ploughing up grasslands, and thus resulting in more arable fields (*Table 2*).

The abovementioned two farming methods remained dominant at the end of the 1900s and the beginning of the 2000s, but in a different order. The proportion of forests is exceptionally high, forestry being, as seen below, one of the most stable land-use methods. The role of forestry was greatly influenced by the fact that the area was first a royal pasture and then a hunting ground.

40.44% of the studied area remained stable, while nearly one third (32.34%) was transformed negatively. Negative changes affected primarily orchards, vineyards; meadows/pastures and wetlands; in all three cases, they were predominantly transformed into built-up areas (*Table 4*).

Two land-use methods are especially notable: built-up areas and forests. Following the rapid population growth of the 20th century and the suburbanization after the political changes in 1989, the area of built-up areas increased significantly. A large number of home gardens and much of the wetlands was also built up or filled in and became used as arable land.

Table 4. Ranking of sensitivity according to the land-use methods as to the 3rd Military Map and the CLC 50 Map (%)

Land use/code	**Built-up area**	**Arable land**	**Orchard/ vineyard**	**Meadow/ pasture**	**Forest**	**Wetland**
	(1.)	**(2.)**	**(3.)**	**(4.)**	**(5.)**	**(6.)**
-5	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	26.78
-4	*0.00*	*0.00*	*0.00*	*0.00*	7.94	25.16
-3	*0.00*	*0.00*	*0.00*	27.54	6.93	0.03
-2	*0.00*	*0.00*	65.68	14.06	0.06	15.28
-1	*0.00*	21.50	11.06	0.00	1.20	18.24
0	**85.02**	**41.92**	**0.00**	**4.71**	**83.61**	**14.51**
+1	10.26	1.70	0.03	52.66	0.25	*0.00*
+2	0.00	6.95	23.22	1.02	*0.00*	*0.00*
+3	0.58	26.57	0.00	*0.00*	*0.00*	*0.00*
+4	2.41	1.36	*0.00*	*0.00*	*0.00*	*0.00*
+5	1.73	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

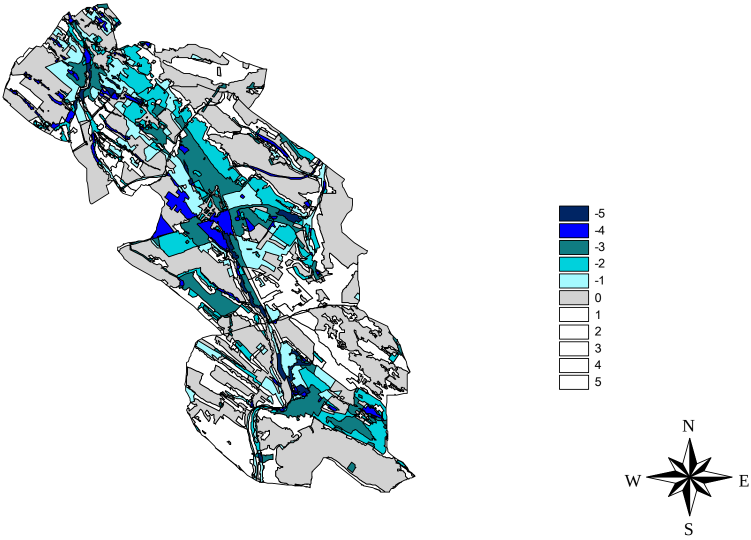

Figure 3. Degree of transformation between 3rd Military Map and CLC 50 Map

Typical transformations: built-up area → arable fields; arable fields → forest; orchard, vineyard → built-up area; meadow/pasture → forest; forest → built-up area; wetland → built-up area (*Figure 3*).

4. Conclusion

The methodology is capable of revealing numerous and obvious changes in land use. Areas with no changes between two snapshots of the land use (two mapping periods) provide good information about land stability that can be further analysed again as we approach the next mapping period.

The first period we investigated shows high landscape stability (65.79%), which is not characteristic of the second period (40.44%). The study focused mainly on changes in nature conservation areas, and we can also conclude that the introduced categorization was useful and indicated a decrease in landscape stability. These changes are caused by the fragmentation of previously contiguous areas (increasing number of polygons) and the increasing role of anthropogenic alteration (primarily, e.g. the areal changes due to the effects of suburbanization).

It is clear that negative effects predominate over positive changes in both time periods. Although we showed minor transformations in both cases, stability indicators varied on a wider scale in the second time period. According to our calculations, the stability percentages vary between 0 and 85.05%.

We have clearly proved that transformations in the first period had multiple causes, such as demographic changes or changes in the structure of agriculture. Transformations during the second period were primarily caused by population growth, which resulted in more built-up areas in the region. For the most part, this can be explained by the proximity of Budapest. Changes in the 19th century affected more of the northern, more densely populated part of the region, which may have been caused by the construction of the Veresegyház railway line. By the 20th century, these changes spread equally to the southern parts as well, which may be explained by the building of the suburban railway line.

Analysis of landscape stability based on historical maps can greatly contribute to predicting the future changes in the landscape structure of Gödöllő Hillside. The tendencies we have observed are probably valid in the medium term, as well. The current analysis may be further complemented, e.g. by a sensitivity ranking with economic considerations. Such a study would offer a more precise and broader set of criteria to be used in the assessment of the tendencies in landscape stability.

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Analysing quality deficiencies of three potato cultivars during the storage period

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Abstract: The aim of this work was to assess quality deficiencies in three potato cultivars (Christian, Roclas, and Cumidava) during the storage period. According to the results, the Roclas presented the highest level of susceptibility to pathogens; this, however, can be attributed to the dry rot that causes greater damage in this cultivar. No significant positive correlations between the plant's vegetative parameters and the most dangerous diseases and pests in Christian were detected. There was a significant positive correlation between the biomass of the tubers and the silver scurf blemish disease, respectively between tuber numbers and dry rot in Cumidava and significant positive correlations between tuber numbers and the silver scurf blemish disease, between biomass of the tubers and dry rot, respectively between tuber numbers and wireworm larvae at Roclas. Altogether, we can conclude that the most susceptible cultivar was Roclas followed by Cumidava, while the least susceptible was the Christian cultivar.

Keywords: Cultivar Christian, Cumidava, Roclas, susceptibility, vegetation, pests

1. Introduction

Potato is a high-value crop with complex production, storage, and utilization, and therefore, adequate prevention practices are necessary to obtain a healthy product [1]. It belongs to crops infected by many diseases that severely affect both above- ground and below-ground plant organs [2]. The development of more effective methods of controlling potato pests and diseases remains an important task facing agricultural scientists today [3].

Quality deficiencies on potato tubers are on the increase and several reasons have been suggested to explain these deficiencies [6]. One reason can be the continuous increase in the use of ecological products (with much lower amounts of pesticides), leading to an increasing occurrence of pests and diseases [7, 8]. The increasing quality standard of markets may also influence tuber deficiencies: in 1980, around 70% of potatoes were sold unwashed; today, over 90% are washed [6]. The use of resistant varieties is probably the cheapest and the most effective method against diseases and pests. However, it is not always necessary to breed for a very high level of resistance. Incomplete resistance has often given an adequate level of control in the field [7], [9]. Although many potato cultivars have been produced world-wide, there is a continuing need for new improved cultivars with high level of durable disease and pest resistance, acceptable yield quantity, and superior quality demanded by processors and supermarkets [10].

The aim of this work was to assess the quality deficiencies that appear on three potato cultivars during the storage period. This is the first step in the development of potato breeding aimed at addressing the present and future requirements for healthier, higher-quality food, while addressing suitability for ecological agriculture [11].

2. Materials and methods

The experiment was carried out on the research field of the National Institute of Research and Development for Potato and Sugar Beet, Brașov, Romania, Central Europe. The following three cultivars were tested: Christian, Roclas, and Cumidava, all developed at the above mentioned Institute. All cultivars were cultivated under the same field conditions and within a 50 ha area. The soil was chernozem with pH 6, containing 30% loam and 4.5% humus. The soluble phosphorus content was 50 ppm, while the soluble potassium content exceeded 100 ppm. Fertilization was applied uniformly to all cultivars with 700 kg/ha NPK (nitrogen, phosphorus, and potassium).

Cultivar description

Samples were collected at the seedling stage in April and May and from fruiting plants in August and October 2013. We collected young leaves (the topmost fully differentiated leaf), old leaves (the 6–8th leaf counted from top to bottom), young fruits having yellow or green pericarps, biologically ripe, fully coloured fruits and peduncles of ripe fruits. In addition, young roots and stem samples were also analysed, the latter being taken 15 cm below the top.

Cultivar Christian

Genealogy: KE. 53 x CLEOPATRA
Maturity: medium early variety.
Tubers: oval tuber, red skin, yellow flesh.
Plant: medium developed stems, well-developed foliage, semi-erect; medium sensitive to late blight on leafs and tubers; medium resistant to PVY; sensitive to PLRV; resistant to wart disease (*Synchytrium endobioticum*).
Starch content: 17.0%, good cooking quality; cooking type B; suitable for early and summer-autumn consumption.
Biological yield capacity: 70.6 t/ha [11, 12, 13].

Cultivar Cumidava

Genealogy: ROESLAU x DESIREE
Maturity: medium late variety.
Tubers: round-oval tuber, red skin, yellow flesh.
Plant: thick stems, well-developed foliage, erect; medium sensitive to late blight on leafs and tubers; very resistant to PVY; resistant to PLRV; resistant to wart disease.
Starch content: 20.0%, good cooking quality; cooking type A/B; suitable for autumn-winter consumption.
Biological yield capacity: 70.6 t/ha [11, 12, 13].

Cultivar Roclas

Genealogy: HB 8 x GRANDIFOLIA
Maturity: medium early variety.
Tubers: oval tuber, yellow skin, yellow flesh.
Plant: thick stems, semi-erect, robust; medium resistant to blight on leafs and tubers; medium resistant to PVY; resistant to PLRV; resistant to wart disease.
Starch content: 17.0%, good cooking quality; cooking type B; suitable for early and summer-autumn consumption and processing (chips).
Biological yield capacity: 65.9 t/ha [11, 14].

All cultivars were planted on March 31, 2013, with 38,000 plants/ha, 35 cm between plants and 75 cm between rows. The first plantlets appeared on May 03 and the full flowering period was between June 13 and 23. No extremities in temperature and precipitation were detected during the 2013 vegetation period in the area. The overall climate conditions were ideal for potato cultivation in 2013. The storage of tubers was processed under new and modern storage system conditions with all parameters controlled. Storage phases of equalization, wound healing, cooling, holding, and reconditioning were followed, with optimal conditions of 7–10ºC temperature, 95–98% relative humidity and CO_2 maintained at the lowest possible level.

Data collection

Analyses were made on plants during the 2014 vegetation period in July–August in order to determine the relationships between the possible pests, diseases, and physiological problems that may infect cultivars in storage after harvest.

For each cultivar, four blocks of 40 m^2 study area each (a total of 12 blocks) were selected randomly, in the middle of the field, to avoid the possibility of side effects from field margins. All plants from each 40 m^2 area were then measured. Observations on foliage and shoots were repeated 3 times until July 31 for each cultivar. Plant height, total shoots, total leaves and foliage, and the plants' green biomass were assessed. Infection with *Phytophthora infestans* was assessed on green parts.

After July 31, all plants from the 12 blocks were collected and carried to a laboratory where the following data were collected: dry shoot numbers, dry leaves number, and tuber numbers; biomass of the upper parts of the plants, biomass of the roots and stolons, and biomass of the tubers. All collected tubers were examined on the basis of the eleven external and nine internal signs used under storage conditions. These observations were carried out until all plants from the experimental blocks were assessed (the total study surface being 480 m^2).

From each cultivar, 1000 tubers/month were randomly selected and examined during the storage period (December 2013–February 2014). Data from eleven external signs were collected and noted: three diseases (bacterial ring rot (*Clavibacter michiganensis* ssp. *sepedonicus*), common scab (*Streptomyces scabies*), and silver scurf blemish disease (*Helminthosporium solani*)), one pest (wireworms (larvae of *Agriotes* ssp.)), six physiological problems (the growing of small tubers on the main tuber (secondary growths), green colour, sprouting, drying, tuber distortion, exfoliation)), and mechanical injury.

Besides external signs, the data of nine internal symptoms were also collected: bacterial ring rot, late blight (*P. infestans*), potato gangrene (*Phoma exigua* var. *exigua*, *P. exigua* var. *foveata*), dry rot (*Fusarium* ssp.), bacterial soft rot/blackleg (*Erwinia* ssp.), wireworms, black and brown spots, and mechanical injury. This process was repeated 3 times for each cultivar during the entire storage period.

Data analysis

For the data assessed, the ANOVA test was used, and to determine statistically significant differences the Duncan post-hoc test was performed. First, all factors provoking damage were compared separately (i.e. damages caused by silver scurf at Roclas compared with damages caused by the same pathogen at Christian and Cumidava). Then, accumulative analyses were made, in which symptoms were classified and analysed according to their provoking factors: pathogens (bacteria, fungi), pests (wireworms), physiological phenomena, and mechanical injuries. The average proportions of diseases and pest and the average values of data on 1,000 tubers were considered for analysis. Pearson correlations between the plants' vegetative parameters and the most common and dangerous diseases and pests infecting particular plant organs during storage were calculated. These were: correlations between tuber numbers, biomass of the tubers, and the silver scurf blemish disease (*H. solani*); correlations between tuber numbers, biomass of the tubers, number of leaves and shoots per cultivar at full vegetation, the biomass of the green parts of the plants, and late blight (*P. infestans*); correlations between tuber numbers, biomass of the tubers, and dry rot (*Fusarium* ssp.); also correlations between tubers number, biomass of the tubers, and wireworms (larvae of *Agriotes* ssp.). Significant positive correlations between plant parameters, diseases, and pest were calculated and significances computed in SPSS Statistics. Average values of vegetative data and average proportions of diseases and pest on 1,000 tubers/assessment data/cultivars were considered for the analyses, and results were presented in the table.

3. Results and discussions

The studied cultivars did not present significant external signs of bacterial ring rot disease. There were also no signs of secondary growth, green colour, or exfoliated tubers. The mean proportions of the affected tubers per cultivar observed on the base of external signs are presented in *Table 1*. It can be observed that the common scab affected all cultivars to a very high level, sometimes up to 100%. ANOVA revealed that there were significant differences between cultivars regarding the appearance of quality deficiencies (*Table 2*). Roclas presented a significantly lower proportion of infected tubers with silver scurf than Christian and Cumidava (Duncan test, $p = 0.006$). Wireworms, however, preferred, in a significantly higher proportion, the Roclas tubers to the Cumidava (Duncan test, *p* = 0.04) and the proportion of dried tubers was also significantly higher in Roclas than in Christian (Duncan test, *p* = 0.05) (*Table 2*).

Table 1. The proportions of affected tubers per cultivar observed on the base of external signs during the storage period

Observed external signs	Cultivars		
	Christian	Cumidava	Roclas
	Mean proportions of affected tubers (%)		
Common scab	100 SD: 0.0	86.6 SD: 11.5	93.3 SD: 11.5
Silver scurf	80 SD: 0.0	76.6 SD: 5.7	16.6 SD: 28.8
Wireworms	22.5 SD: 4.3	10 SD: 0.0	46.6 SD: 23.0
Sprouting	0.6 SD: 1.1	5.6 SD: 3.7	1.6 SD: 1.5
Dried tubers	0 SD: 0.0	1 SD: 1.0	5.6 SD: 3.7
Tuber distortion	14.1 SD: 22.3	4.1 SD: 5.0	4.3 SD: 1.1
Mechanical injury	5.6 SD: 3.7	8.3 SD: 10.1	18.3 SD: 10.4

Table 2. ANOVA and Duncan test (between groups) of differences in external sings at Roclas compared with the other two cultivars during the storage period. Arrows after "p" value show the direction of the main effects: ↑ indicates higher, ↓ indicates lower effect.

External signs		Sum of squares	df	Mean square	F	*p*
Silver scurf	Between groups	7622.22	2	3811.11	13.19	0.006↓
Roclas	Within groups	1733.33	6	288.88		
	Total	9355.55	8			
Wireworms	Between groups	2084.72	2	1042.36	5.66	0.04↑
Roclas	Within groups	1104.16	6	184.02		
	Total	3188.88	8			
Dried tubers	Between groups	54.88	2	27.44	5.37	0.05↑
Roclas	Within groups	30.66	6	5.11		
	Total	85.55	8			

Considering the internal symptoms, statistics revealed that tubers did not present most of the pathogens causing severe diseases: bacterial ring rot, late blight, potato gangrene, bacterial soft rot, and blackleg were present in very low proportions, much below the infection level. Other problems caused by dry rot, wireworms, black spots, brown spots, and mechanical injuries were present in various proportions (*Table 3*).

Table 3. The proportions of affected tubers per cultivar observed on the base of internal signs during the storage period

Observed internal signs	Cultivars		
	Christian	Cumidava	Roclas
	Mean proportions of the affected tubers (%)		
Dry rot	1.6 SD: 2.8	3.3 SD: 5.7	15 SD: 10.0
Wireworms	13.3 SD: 7.6	28.3 SD: 20.2	33.3 SD: 17.5
Black spots	1.6 SD: 2.8	5 SD: 5.0	5 SD: 5.0
Brown spots	1.6 SD: 2.8	3.3 SD: 2.8	11.6 SD: 2.8
Mechanical injury	5.5 SD: 5.5	8.3 SD: 10.4	11.6 SD: 12.5

ANOVA revealed that dry rot causes significantly higher damage in cultivar Roclas (between groups Duncan test, $p=0.01$). The Roclas also has a significantly higher proportion of brown-spotted tubers than the other two cultivars (Duncan test, $p=0.05$). Considering the cumulative data comparisons of external signs, differences in pathogen susceptibility were detected as a significant factor, and the cultivar Roclas presented significantly lower damage. The cultivar Cumidava was less infected by wireworms than Roclas (*Figure 1A*).

According to the internal signs cumulative comparisons, Roclas presented the highest level of susceptibility to pathogens; this, however, can be attributed to the dry rot that causes higher damage in this cultivar. Wireworms also preferred, in a significantly higher proportion, the Roclas to the Cumidava. Physiological damage was again significantly more frequent in Roclas (*Figure 1B*).

No significant positive correlations between the plants' vegetative parameters and the most common and dangerous diseases and pests infecting particular plant organs at cultivar Christian were detected (*Table 5*). There was a significant positive correlation between the biomass of the tubers and the silver scurf blemish disease, between tuber numbers and dry rot in cultivar Cumidava (*Table 5*). There were again significant positive correlations between tuber numbers and the silver scurf blemish disease, between biomass of the tubers and dry rot, and between tuber numbers and wireworm larvae at cultivar Roclas (*Table 5*).

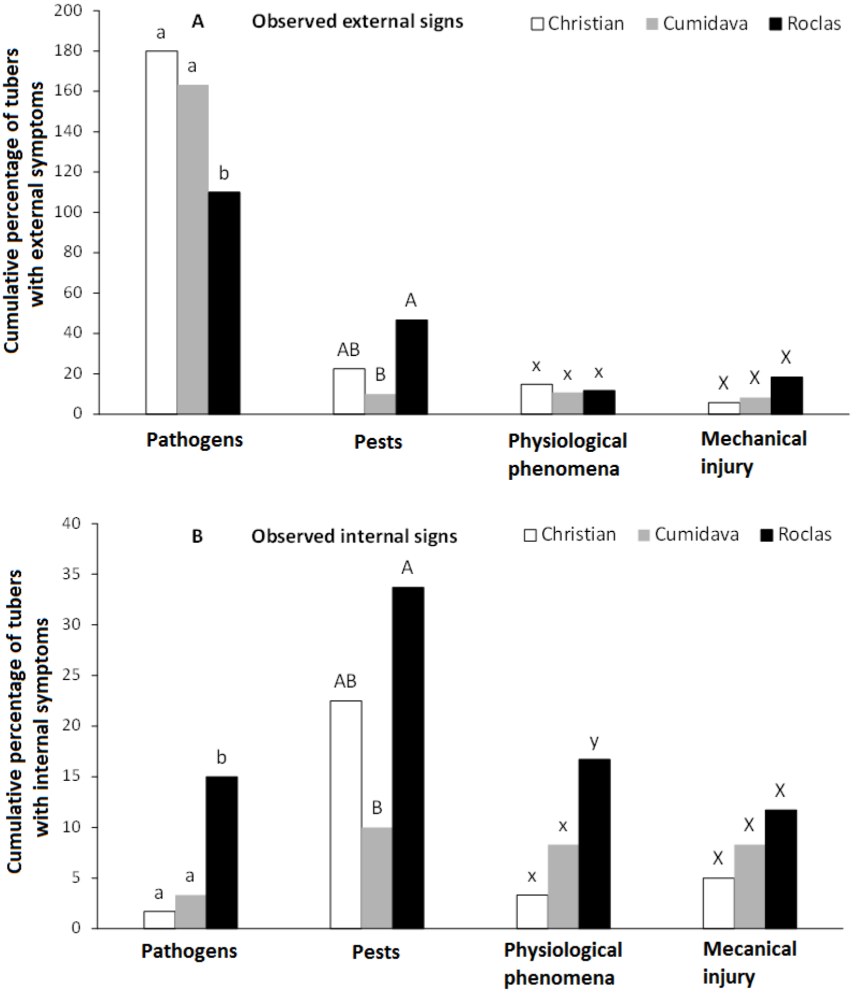

Figure 1. The cumulative sensitivity of the three potato cultivars to pathogens, pests, physiological phenomena, and mechanical injuries by external (*A*) and internal (*B*) signs. Different letter $p < 0.05$ (ANOVA).

Table 5. Pearson correlations between the plants' vegetative parameters and the most common and dangerous diseases and pests infecting particular plant organs during storage and vegetation period. Significant differences (rho and *p* values) are bolded. Plants' vegetative parameters: 1. Tubers number; 2. Biomass of the tubers; 3. Nr of leaves at full vegetation; 4. Nr of shoots at full vegetation; 5. Biomass of the green part of plants

Diseases and pest	Potato cultivars	Plants' vegetative parameters				
		1.	2.	3.	4.	5.
		rho and *p* values				
Helminthosporium solani	Christian	0.73 0.47	0.81 0.39	-	-	-
	Cumidava	0.59 0.54	**0.9** **0.01**	-	-	-
	Roclas	**0.9** **0.05**	0.89 0.25	-	-	-
Phytophthora infestans	Christian	0.89 0.19	0.09 0.94	0.31 0.79	0.51 0.65	0.16 0.89
	Cumidava	0.39 0.73	0.5 0.66	0.46 0.69	0.63 0.56	0.1 0.93
	Roclas	-0.38 0.74	0.12 0.92	0.79 0.41	0.35 0.76	0.89 0.30
Fusarium ssp.	Christian	0.89 0.19	0.88 0.94	-	-	-
	Cumidava	**0.99** **0.05**	0.49 0.67	-	-	-
	Roclas	0.88 0.25	**0.98** **0.05**	-	-	-
Larvae of *Agriotes* ssp.	Christian	0.22 0.85	0.82 0.27	-	-	-
	Cumidava	0.39 0.73	0.5 0.66	-	-	-
	Roclas	**0.9** **0.05**	0.82 0.25	-	-	-

According to our study, common scab affected most of the stored tubers (in a proportion of 86–100%) regardless of cultivar. Although common scab did not affect the yield, it greatly reduced tuber quality. Silver scurf was the second disease that appeared in high proportion on the stored tubers. Analysis of external symptoms showed that the quality of tubers was mostly affected by pathogens. The stored tubers were mostly destroyed in a proportion of 13.3–33.3% by wireworms. If not properly managed during the early growth stage of the crop, wireworms may adversely affect the quantity and quality of the potato yield. The presence of wireworms inside tubers increases the susceptibility to different diseases [15]. Studies have shown that the percentage of injured tubers damaged by wireworms was higher in small tubers than in large ones [16]. In our cases, wireworms were present with no significant differences in all cultivars although tuber biomass was significantly higher in Roclas than in Cumidava. The risk of wireworm damage can be reduced by the rotation of the field, with increasing the number of years between grass clover leys and potatoes [6]. Measuring beetle activity in a given locality should indicate the presence of an established local population, thus contributing to an assessment of the overall risk of wireworm damage [17]. Considering the cumulative data comparisons of external signs, the cultivar Roclas presented significantly lower damages. According to the internal signs cumulative comparisons, Roclas presented the highest level of susceptibility to pathogens; this, however, can be attributed to the dry rot that causes higher damage in this cultivar. Wireworms also preferred, in a significantly higher proportion, the Roclas to the Cumidava. Physiological damage was again significantly more frequent in Roclas. Plant resistance to pathogens and pests can be attributed to physical mechanisms such as skin colour or skin hardness [15]. The results of this study suggest that the two red-skinned cultivars, Cumidava and Christian, show promise as wireworm-resistant potatoes.

The three cultivars presented similar characteristics in the growth and development of the above ground vegetative organs at the first two observations. The two medium-early cultivars were advantaged by their shorter vegetation period. There were differences in foliage and tuber reactions to late blight. Considering data from the vegetation period, statistics revealed that potato cultivars present significant differences in susceptibility to late blight disease. Cultivar Cumidava at the first observation period showed a significantly higher proportion of foliage and shoots infected with *P. infestans* than Christian and Roclas. This is because the late-maturing Cumidava was the most exposed to foliage and shoot infection with late blight. Similar studies [18] have noted that the early maturing varieties are more susceptible. Other studies have also reported that the medium and late maturing varieties varied in their resistance levels to bacterial soft rot [19]. These, however, were not demonstrated entirely in our research because, except for late blight, no other differences in susceptibility under field conditions have been detected. Using correlations as methods, significant positive relationships between factors (in our case, vegetative parameters and frequency of diseases and pests) can be predicted. In our cases, no significant positive correlations between the plants' vegetative parameters and the most common and dangerous diseases and pests infecting particular plant organs at cultivar Christian were detected. There was, however, a significant positive correlation between the biomass of the tubers and the silver scurf blemish disease, between tuber numbers and dry rot at cultivar Cumidava, between tuber numbers and the silver scurf blemish disease, between biomass of the tubers and dry rot, and between tuber numbers and wireworm larvae at cultivar Roclas. In summary, we can conclude that the most susceptible cultivar was Roclas followed by Cumidava and the least susceptible was the cultivar Christian. Further research, however, is needed to detect if these variations are stable under other climate conditions than Central Europe.

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Detailed hydrogeomorphic analysis in the Gerecse Mountains, Hungary

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Abstract: The northern foreland of the Central Gerecse Mountains is a complex landscape with a moderate relief and the presence of terrace remnants. To explore the hydrogeomorphic settings, the characteristics of the drainage network, several basin metrics, and geomorphometric maps were interpreted, which are the outputs of a semi-automated algorithm. Based on the results, the small catchments of the area were divided into two groups with diverse topographic characteristics and the presence of 7 terrace levels was revealed.

Keywords: geomorphometry, DEM, semi-automated landform mapping, fluvial geomorphology, GRASS GIS, R

1. Introduction

Exploring the evolution of fluvial landscapes by analysing the hydrogeomorphic signatures of the topography has interested many Hungarian geomorphologists since the 19th century [1, 2, 3, 4, 5]. As significant watercourses of the hilly and mountainous ranges of the Pannonian Basin are accompanied by terrace remnants, the key to understand the development of the Danube valley and its tributaries is to compile a scientific synthesis of the terrace system [2, 3]. The complex geomorphological and geological settings require objective and detailed mapping projects to distinguish between landforms of different origin and recognize the effects of neotectonics.

During the past decades, new data sources and terrain-analysing tools led to novel opportunities in earth sciences and geomorphometry is now one of the most prosperous subdivisions of modern geomorphology [6]. Deriving morphometric parameters and interpreting the resulting maps has become a common practice to explore the geological [7], topographical [8], and hydrological [9] characteristics of a given area. Furthermore, GIS-based algorithms have proved to be suitable for the paleo-profile reconstruction and mapping of terrace remnants as well [10].

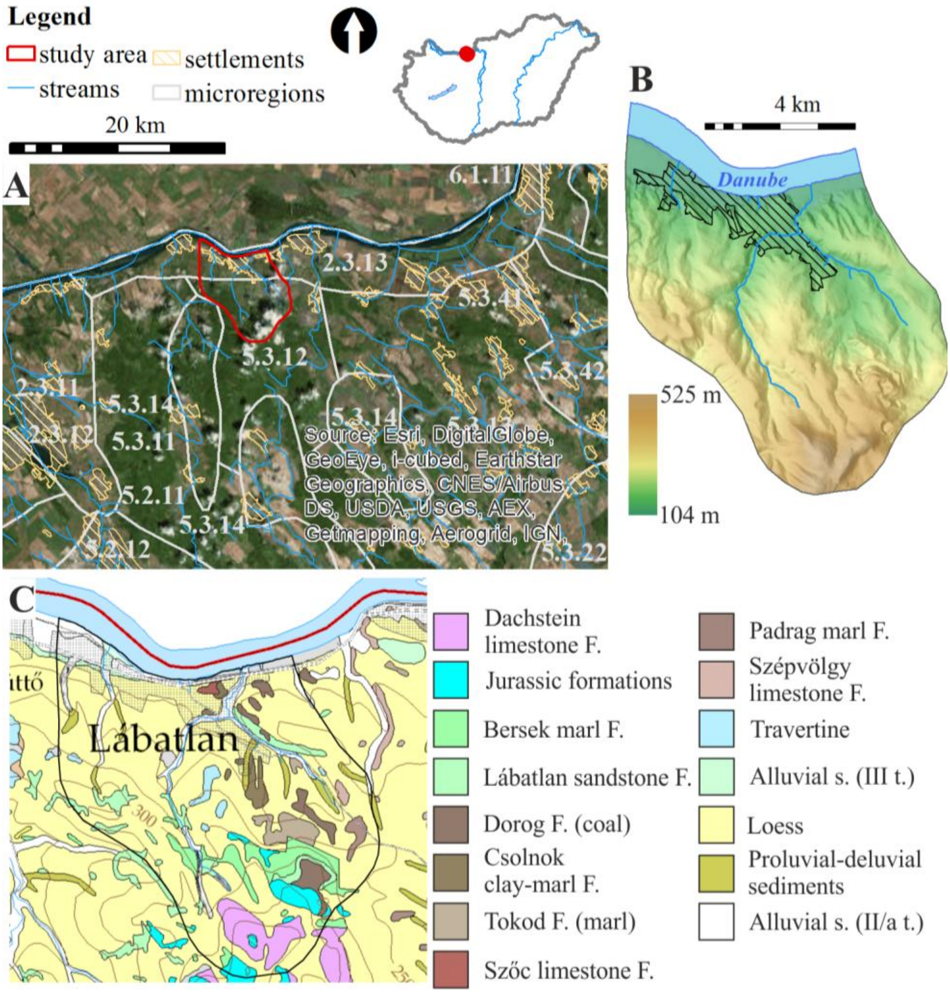
The wider environment of the study site is thoroughly studied in the geologic and geomorphologic literature in Hungary. The main topics relevant for the current study are the terrace levels of the Danube valley [2, 11], the travertines [3, 12], and the mass movements [13] in the region.

The aim of this study was to carry out a detailed DEM-based morphometric analysis of a small area in the Gerecse Mountains. Due to the complex evolution of the region, it is challenging to draw conclusions about the topographic configuration using only traditional geomorphological research methods. The compiled semi-automated algorithm allows the objective mapping of the hydrogeomorphic characteristics with low time and cost requirements. Exploring the spatial pattern and anomalies of the stream network and delineating landforms, especially terrace remnants, provide new insights into the landscape. The new results obtained with this unified procedure can be integrated with former researches about the surface development. As mentioned above, the area has a wide literature, and thus the GIS-based results can be compared to findings of previous studies and the available geomorphological map.

Table 1. Terrace levels in the Gerecse Mountains according to Pécsi, M. (1959)

Right bank settlement	**Distance from mouth (km)**	**0 level of Danube (m a.b.s.l.)**	**m above Danube level**								
			FLP (low)	**I**	**II/a**	**II/b**	**III**	**IV**	**V**	**VI**	**VII**
Szőny	*1,753*	*103.18*		5	10	23		78			
Dunaalmás	*1,751*	*103.13*	3	5	10	27	47	78	120	170	210
Neszmély	*1,749*	*103.05*	3	5	9	22	37	72	120	150	210
Süttő	*1,743*	*102.58*			8		43			170	170
Lábatlan	*1,737*	*102.11*	3	5	7			72		160	200
Nyergesújfalu	*1,733*	*101.95*		5	9	20	46	68		140	170
Tát	*1,727*	*101.61*						80			
Esztergom	*1,718*	*100.92*	2.5	6	10	18	48	78			

Over the more than 100 years of the Hungarian terrace-morphological researches, there has not been a satisfactory synthesis of the spatial arrangement and chronology of the terrace levels. The most widely accepted terrace system for the Hungarian stretch of the Danube valley was published by Pécsi, M. in 1959 (*Table 1*). As these results involve a number of uncertainties due to the demanding field work and lack of detailed geomorphological maps, the overview of the Danube valley and its tributaries with suspected terraces using DEM-based, quantitative surface analysis algorithm could provide new insights into the topic.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN,

Figure 1. Location (A), topography (B), and geology (C) of the study area.
(Source of geological map: http://map.mfgi.hu/fdt100/)

The studied area is located on the northern slopes of the Gerecse Mountains, in Northern Transdanubia, along the Hungarian-Slovakian border (*Fig. 1*). The 25 km^2 region comprises several small catchments directly draining to the Danube. The area belongs to the Central Gerecse Mountains (*5.3.12 on Fig. 1A*) and the Almás-Tát Danube Valley (*2.3.13 on Fig. 1A*) microregions [14]. The 0 level of the Danube varies between 103.88 m (at Komárom) and 100.92 m (at Esztergom). The minimum elevations are found on the lower floodplain level from 104 m, while the highest peak is the Nagy-Eménkes with 525 m. For the presented study, the catchment area of Piszke, Fuchs, and Lábatlan streams was selected.

The mountain is mostly built up of well-karstified Triassic and Jurassic limestones, while the majority of the surface is covered by Quaternary clastic sediments and alluvial materials [15]. The loess and travertine deposits have a great importance for the terrace chronology [3, 16].

From a geomorphological point of view, the area can be divided into two distinct landscape types. Under 150 m a.s.l., the undulating surface is the terraced valley slope of the Danube. The northern foreland of the Gerecse Mountains is the first section in Hungary where the river has a defined, antecedent valley. The low mountainous area is well-dissected, it comprises a series of horsts, while its slopes are also characterized by the landforms of fossil and recent mass movements. The stream network has a general S–N flow direction though some valley sections reflect the influence of neotectonics.

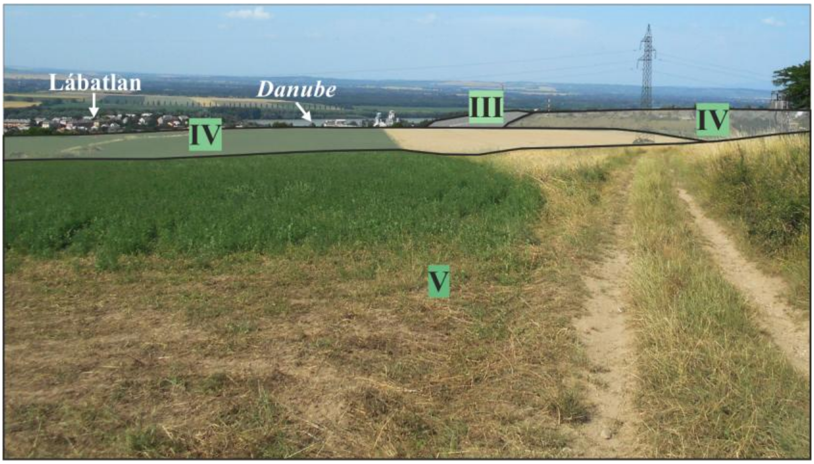


Figure 2. Terrace levels in the study area (Photo by author, 2016)

Terrace researches identified the presence of up to 7-8 terrace levels in this marginal zone of the Transdanubian Range [2]. Several authors [1, 2, 11] reported the occurrence of multiple terrace surfaces in Lábatlan and its surroundings, which were also well recognizable during the field survey (*Fig. 2*).

2. Materials and methods

Research objectives required a high-resolution digital elevation model to create detailed maps of the hydrogeomorphic parameters. The terrain analysis was based on a contour-based DEM with 5 m horizontal resolution, distributed by FÖMI (National Institute of Geodesy, Cartography and Remote Sensing). Based on previous research by the author [17] and considering the price and quality of the available DEMs for Hungary, it is highly recommended to purchase contour lines dataset from FÖMI and interpolate hydrologically correct models for catchment analyses. Geological and geomorphological map on a 1:100,000 scale, auxiliary information from literature, and field survey were also analysed to interpret and validate the GIS-based results.

Table 2. List of generated morphometric parameters

Parameters	Description	Tools
topographic grain	characteristic ridgeline – valley bottom distance	*script by author*
slope, aspect	basic topographic derivatives	*r.slope.aspect*
relative relief, slope variability	range of elevation and slope values calculated per unit area	*r.neighbors*
stream/valley network	map of streams/valleys based on flow accumulation	*r.threshold,* *r.stream.extract*
length-direction plot	general direction of valley network	*r.stream.segment*
normalized long profile	comparable plot of longitudinal profile – it indicates differences in valley development	*r.stream.order,* *r.stream.distance*
hypsometry	comparable plot of catchment topography – it indicates differences in surface evolution	*r.stream.basins*
basin metrics	shape indices of catchment	*r.basin*
landform elements	geomorphometric map of the 10 most common landforms	*r.geomorphon*
terrace-like surfaces	plots and map of possible terrace remnants	*script by author*

GIS techniques provided the opportunity to analyse the different catchments in a consequent and comparable way. *Table 2* gives a summary of the generated morphometric parameters and the necessary tools to create the maps. The selected methods are mostly part of the *r.stream.** hydrological GRASS GIS module by [9]. The R statistical software was used for the calculation of several indices and the display of diagrams (ggplot2 package). A more detailed description of the methods is given with the resulting maps presented.

It is important to emphasize that all steps were carried out using GNU GPL (General Public License), open-source software including GRASS GIS 7.0.3 (http://grass.osgeo.org) to create and process the maps and R (http://r-project.org) to perform the statistical analyses.

3. Results and discussions

The quantitative analysis of the topographic configuration started with the definition of the so-called *topographic grain* value, which refers to the characteristic ridgeline-to-valley bottom distance [18]. As the search window has a great influence on the scale and characteristics of the generated morphometric parameters, the topographic grain value was used for neighbourhood size parameter in the GIS-based terrain analysis. The calculation of the topographic grain is implemented as a bash shell script for GRASS GIS and R. By calculating the relative relief values with nested neighbourhood matrices, it is possible to define a break-point where the increase rate of local relief encountered by the sample is significantly reducing. The results suggested 310 m as the topographic grain value, which was used later to calculate the relative relief and slope variability per unit area and to create the landform map of the study site.

The spatial variability of the relief energy and the slope values (*Fig. 3*) suggests a lower, gently sloping region, where the terrace surfaces and the settlement are located, while the higher region is characterized by the flat horst top surfaces surrounded by steep slopes and deeply cut valleys. The highest relative relief and slope values are found around the open-pit mine. Furthermore, as the surroundings of the mine are covered by loess, the high relief is also a result of mass movements.

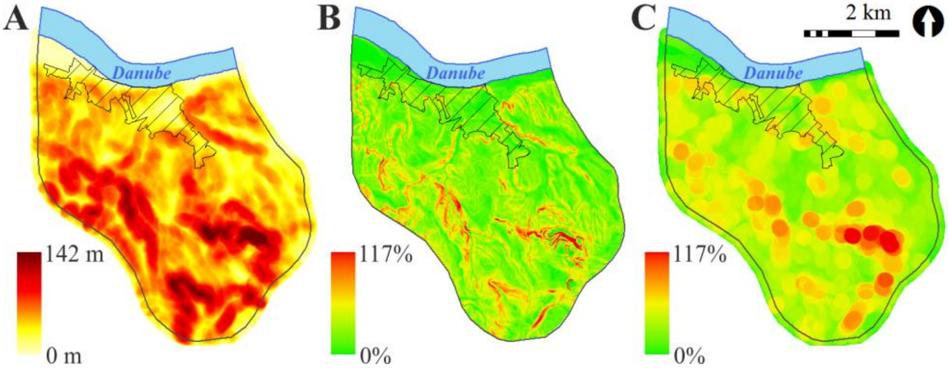


Figure 3. Relative relief (A), slope (B), and slope variability (C) map

The derivation of the stream network was completely based on the DEM data. The drainage area suggested by the software is 0.035 km^2, without considering the geology or the climatic conditions in the area; thus, the result is rather interpreted as the extended valley network. The generated map and the length-azimuth rose diagram (*Fig. 4*) visually and numerically confirm that the typical valley orientation is SSE–NNW, S–N.

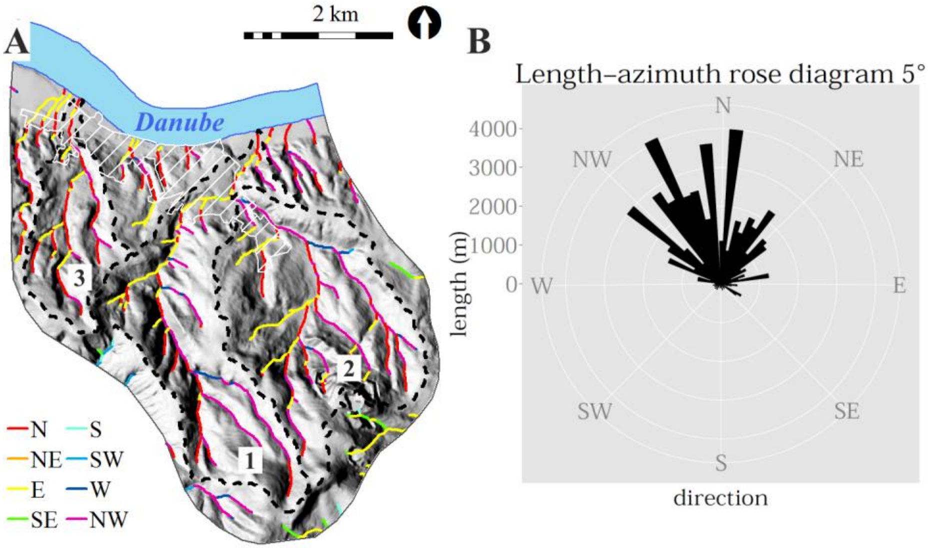


Figure 4. Valley network and area of catchments (A), length-azimuth rose diagram (B) [1 – Lábatlan stream basin, 2 – Fuchs stream basin, 3 – Piszke stream basin]

The direct comparison of the analysed 3 streams was accomplished by generating the dimensionless normalized longitudinal profiles and calculating concavity parameters. They can highlight the effects of lithological changes and tectonic events on the valley development [8, 19]. The profiles and concavity values show a strong similarity between the Lábatlan and Piszke streams. The maximum concavity is modest, reaches close to the midpoint of the watercourses, suggesting that these streams have a less graded profile. Deviations of the Fuchs stream can be explained by topographic characteristics (slope break at pediment), lithological changes, and the tectonically predicted lower valley section. As a result, there is a significant break on the Fuchs stream and its valley has an asymmetric shape on the lower sections.

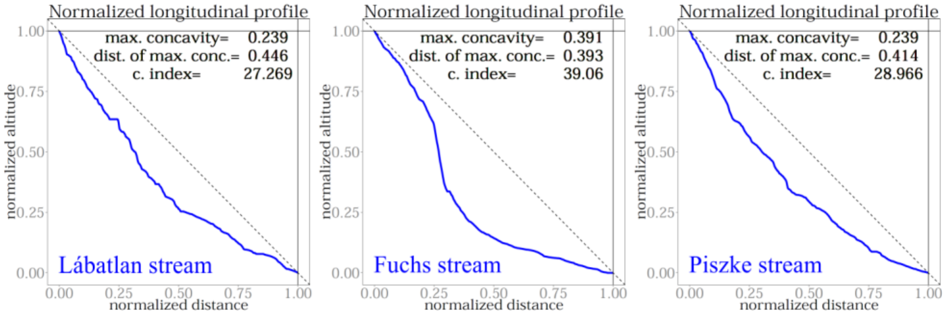


Figure 5. Normalized longitudinal profiles.

Several parameters were calculated for the analysis of the selected basins (*Table 3*). The hypsometric curve and integral (Ihyp) enabled the comparison of the elevation distribution, thus providing auxiliary information about the stage of landscape evolution and the dominant geomorphic processes [8, 18]. The elevation distribution confirms the presence of terrace-like surfaces, as overrepresented altitude values occur on the plots. The higher values of the hypsometric integral suggest a well-dissected area, while the lower value is representative for low relief with extensive flat regions.

Table 3. Basin metrics of the analysed small catchments

	Lábatlan stream basin	**Fuchs stream basin**	**Piszke stream basin**
Ihyp	0.408	0.297	0.480
Catchment area	5.3 km^2	6.4 km^2	2.3 km^2
Elevation difference	396.9 m	368.5 m	255.3 m
Length of main channel	6.0 km	4.9 km	3.5 km
Elongation ratio	0.43	0.62	0.49
Shape factor	0.88	1.38	0.67

Analysing the basin metrics was also part of the research; the calculation was easily feasible with the r.basin add-on specifically developed for this purpose [20]. The basins of the Lábatlan and Piszke stream are more elongated and, accordingly, the possibility of the formation of higher-order tributaries is low [21]. The Fuchs stream shows different characteristics in this case as well, as it has an important right-bank tributary.

The GIS-based geomorphological map of the study area was created by the geomorphons approach, a robust cell-based method for the identification of landform elements at a broad range of scales by using line-of-sight-based neighbourhoods [22]. The characteristics of the geomorphons map depend on the value of lookup distance defining the maximum scale of mapping, the skip radius to eliminate forms that are too small to be of interest, and the flatness threshold to prevent the analysis of flat areas. The topographic grain value was selected as lookup distance parameter, while other parameters were chosen to fit the basic rules of the geomorphological mapping concepts adopted in Hungary. The resulting map (*Fig. 6B*) shows strong similarity to the traditional geomorphological map (*Fig. 6A*), the valley networks are mostly coherent, and the landforms are not generalized.

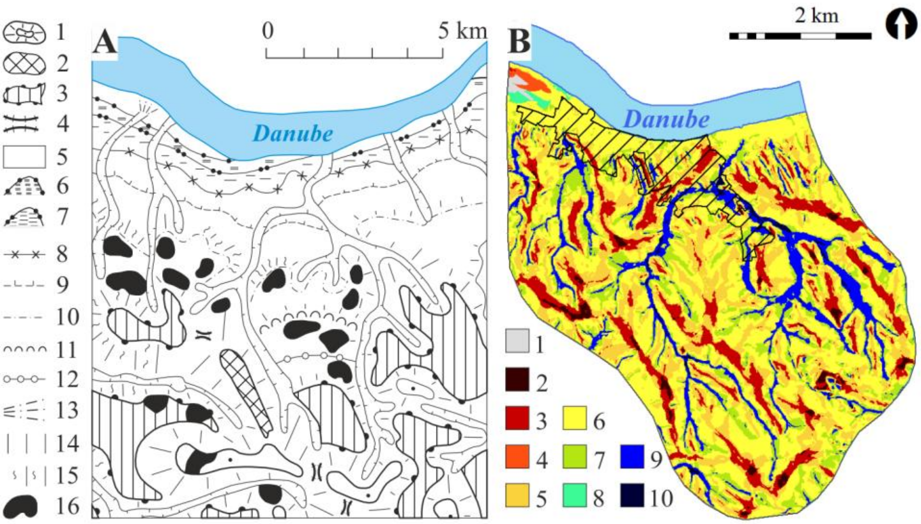


Figure 6. Geomorphological map after Pécsi, M. – Schweitzer, F. [1980] (A) and geomorphometric map (B). [Legend A: 1 – horst, 2 – ridge, 3 – pediment, 4 – saddle, 5 – low floodplain, 6 – II/a terrace, 7 – II/b terrace, 8 – III. terrace, 9 – IV. terrace, 10 – V. terrace, 11 – VI. terrace, 12 – VII. terrace, 13 – alluvial fan, 14 – stable slope, 15 – temporarily stable slope, 16 – travertine; Legend B: 1 – flat, 2 – summit, 3 – ridge, 4 – shoulder, 5 – spur, 6 – slope, 7 – hollow, 8 – foot-slope, 9 – valley, 10 – depression]

The GIS-based terrace mapping methodology largely builds on the work of [10]. Further improvements of the method were carried out in the form of an R script using GRASS GIS functionality. The algorithm cuts up the studied area into parallel sections in the flow direction and determines cells potentially belonging to terrace surfaces based on local slope characteristics. The output report contains a histogram of altitudes, a swath-profile of the landscape (*Fig. 7A*), scatter plots to represent the relation of the relative elevation and slope values, and a final plot showing the longitudinal profile of the river with the determined height ranges of terrace levels. The algorithm also produces a raster map containing the cells of terrace top-surfaces (*Fig. 7B*).

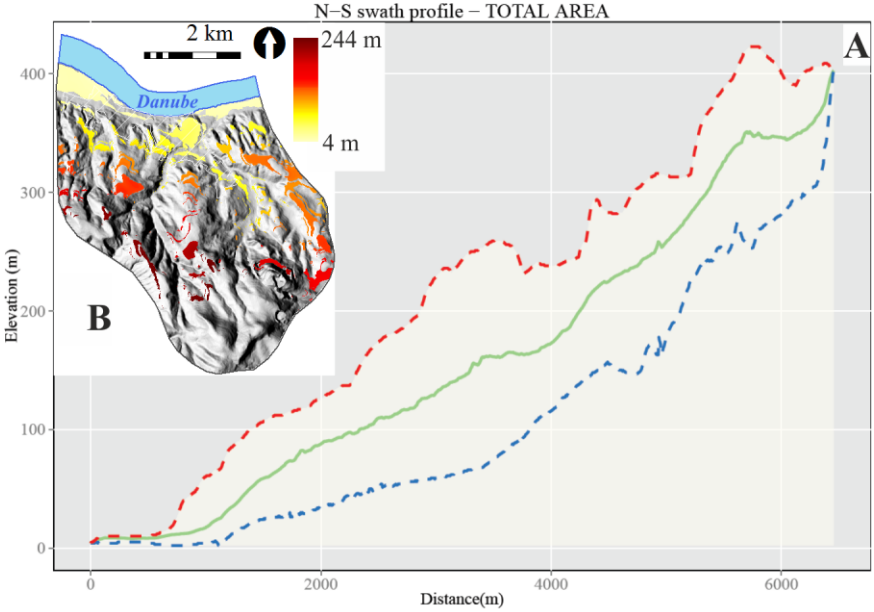


Figure 7. Swath profile (A) and map of terrace-like surfaces (B). [Legend A: blue – minimum curve, green – mean curve, red – maximum curve]

On the minimum and maximum curve of the swath-profile, multiple flat regions can be observed, not only in the lower elevations. The map of terrace-like surfaces is in good agreement with the geomorphological map (*Fig. 6A*), although in some cases the method selected cells belonging to pediment surfaces as well. In the central section of the map, terrace-top surfaces shown on the photo above (*Fig. 2*) can also be identified. Based on the results produced by the compiled algorithm, 7 terrace levels could be distinguished, similar to the findings of [2, 16]. However, the altitude ranges of the terrace levels differ with 5–10 meters from the values defined by M. Pécsi, especially in the case of higher terrace levels.

4. Conclusions

The current study explored the potentials of the novel DEM-based geomorphological research, on the example of the detailed hydrogeomorphic analysis of a small study area in the Transdanubian Range. The selected morphometric parameters provided objective and quantifiable information on the topographic configuration and the spatial pattern of hydrological network; therefore, they are useful to reveal insights into landscape evolution.

Based on the analysed parameters, the small catchments could be divided into two categories. The Fuchs stream basin shows different characteristics in every aspect, which can be explained mainly by the geological conditions and it is clearly visible in the appearance of the landforms as well.

The methodological assessment of the selected open-source software was also an important part of the study. Both the GRASS GIS and R proved to be suitable to compile a semi-automated algorithm for such a detailed geomorphic research. The scripts developed for the computation of the topographic grain value and the delineation of terrace-like surfaces are also considered as significant scientific output.

The presented work is a good example that the joint analysis of a wide range of morphometric parameters can reveal new information even in well-studied regions by producing objective, reproducible, and comparable results.

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Some bioecological aspects of the rose aphid, *Macrosiphum rosae* (Hemiptera: Aphididae) and its natural enemies

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Abstract: The rose aphid, *Macrosiphum rosae*, is one of the most important pests on roses in the world and it causes economic damage. In this study, biology, seasonal population dynamics, and status of natural enemies of the rose aphid were studied. Seasonal population dynamics was studied by randomly sampling 10 shoots every week in two locations of Isfahan, Iran. Rose aphid with a high population density, both in spring (April and May) and in autumn (November), was observed on roses. The results showed that the rose aphid overwinters as parthenogenetic females and nymphs. This aphid migrates to a secondary host, *Dipsacus fullonum* (Dipsacaceae), in summer due to poor food quality of rose plants. Since sexual form and egg of the rose aphid were not observed in Isfahan, it is probably anholocyclic species with host alternation in this area. Natural enemies of the rose aphid include four species of Coccinellidae, three species of Syrphidae, two species of Chamaemyiidae, one species of Chrysopidae, a few species of Anthocoridae and Miridae, and one species of Cantharidae. One species of ectoparasite mite of Erythraeidae was also collected. In addition, four species of parasitoid wasps, Braconidae, were collected.

Keywords: seasonal fluctuations, population dynamics, predator, parasitoid, pest

1. Introduction

Rose is one of the most beautiful ornamental flowers in the world, and as such it can be found in many houses and gardens in cities due to its especial characteristics such as stability, long period of floral initiation, different varieties, and, of course, its beauty [1]. Rose as a plant is found everywhere and is cultivated widely in most parts of the world. Furthermore, cut rose flower is regarded as one of the best cash crop ornamental flowers. Rose is attacked by numerous pests; amongst them, aphids are considered as a major pest. Aphids have a very successful worldwide distribution [2, 3]. Their damages to plants may be direct or indirect: direct damage is due to aphids' intense feeding on plant sap, which will wilt the plant and decrease the yield; indirect damage comes as a result of honeydew excretion and virus transmission. Excretion of honeydew promotes the growth of sooty mould on the plant surface, so photosynthesis will be disturbed and crop yield will be decreased [2, 4].

The rose aphid, *Macrosiphum rosae* (Linnaeus, 1758) is a cosmopolitan species due to the world-wide cultivation of roses [4–7]. This aphid is the most important pest of roses and is probably native to Eurasia and it causes significant economic damage [6, 8]. This aphid has been distributed in all parts of Iran with high economic importance [9]. There is little knowledge on the biology and ecology of this pest in Iran. In other countries, several studies have been performed in this field [e.g. 6, 10–15], but according to the climatic conditions of the given regions different results were obtained. Three life cycles have been observed for this aphid [4–6]: A) Holocyclic: its sexual morphs are produced in autumn and overwintering occurs in the egg stage. In summer, the aphids emigrate from roses as primary host plants to secondary host plants and aestivate on them. In early autumn, they return again to the primary host plants to produce sexual morphs. Migration of this aphid to secondary host plants of Dipsacaceae in summer is unavoidable [16]. B) Holocyclic: in this case, the rose aphid remains on the rose bushes during the whole year without any migration, and overwinters as eggs on the roses. C) Anholocyclic: there are no sexual morphs or egg stage, and it overwinters as parthenogenetic females on the roses.

Eastop and Hodjat [17] observed that rose aphid activates in Khuzestan province (southern part of Iran) from March to June on the terminal buds and leaves of different roses. They mention that rose aphid is observed in the mountainous and cold regions of Iran on roses from April to November with a high population in early spring. There is no report about the oviparous females of this aphid in Iran. Eastop and Hodjat (1980) reported that probably this aphid overwinters in egg stage in the Alborz Mountain and in very cold regions of Iran. In addition, in hot and dry regions of Iran, such as Khuzestan, *M. rosae* reproduces parthenogenetically throughout the whole year [17].

Since rose aphid is of particular importance because of its economic damage, investigation and bioecological studies on this aphid and those factors affecting its population dynamics are fundamental and very significant steps in gaining better knowledge to control it. Therefore, this study was designed to investigate the population fluctuations of *M. rosae* on roses under field condition in Isfahan, central part of Iran, and determine its natural enemies.

2. Materials and methods

Sampling regions

Two locations in Isfahan, a central region of Iran, were selected for studying the bioecology and seasonal changes of the rose aphid population. The first location was Ghadir Park in the eastern part of Isfahan with the perennial rose bushes. The altitude of this region was about 1,570 m, with a latitude of 32° 38' and a longitude of 51° 42'. The numerous rose bushes were available and most of them were hybrid tea variety of rose. In this area, there were also numerous ornamental trees such as elm, pine, plane, varnish, and locust trees. Sampling began on April 30, 2003.

The second location of sampling was the Campus of Isfahan University of Technology (IUT). The altitude of this region was about 1,600 m, with a latitude of 32° 42' and a longitude of 51° 32'. There was a rose garden with 130 rose bushes. There were various fruit trees such as grape, pomegranate, apple, pear, almond, berry, fig, and some ornamental trees as pine, elm, and plane trees. Furthermore, various vegetables and summer crops were cultivated in this area. The IUT weather station, close to the garden, provided us with the climatic data.

The water logging method of irrigation of rose plants was used in both places of sampling to avoid any impact on the population of aphids.

Sampling method and counting the aphids

Seasonal fluctuation of the rose aphid population was determined by weekly sampling for 19 months from April 2003 to November 2004. Every week, at each place of sampling, 10 rose bushes were selected randomly; one twig of each rose bush was cut at random as sampling unit. Since most of the rose aphid colonies are located along a length of 10–15 cm on the terminal part of twigs, 15 cm of the terminal portion of twigs was selected and cut off. In laboratory, the nymphs and adults were counted separately using stereomicroscope. Data from each collection date were transformed into $\mathrm{Log}_{(n+1)}$ to stabilize variance and three-point moving averages were used to visualize seasonal trends. The graphs were produced using Microsoft Excel 2010.

Determining secondary host plants

According to the reports of other researchers, *M. rosae* in other regions of the world migrates to secondary host plants in summer [4–6]. So, in this study, from early June, when aphid populations are decreasing, different plants in Isfahan and around the sampling locations, especially those plants mentioned as secondary host plants in the literature [e.g. 4–6, 18, 19], were identified and thoroughly examined (at least three times per month) as to whether there is rose aphid or not. Since the rose aphid may have spent the summer furtively on the rose plant, especially inside the collar, some parts of the plant, especially the collar and top levels of the roots were also checked carefully in addition to the weekly sampling of twigs. If an aphid was found on these plants, it was collected by a paint brush in a vial of 80% ethanol, and then identified in the laboratory.

Determining place and stage of overwintering

To do so, rose bushes in both sampling places were visited and examined by weekly sampling from mid-September. Since rose plants were the primary hosts of the rose aphid, there were two possibilities for the overwintering of the rose aphid on this plant; it either spends the winter as egg on the rose bushes or overwinters as viviparous female. To determine the existence of the sexual form of the aphid and the existence of egg on the plant tissues, plant sampling was done in a way that different parts of the plant, including twigs, branches, upper parts of root, and collar, were cut with pruning shears and put in a plastic bag to be examined by stereomicroscope in laboratory. Female sexual morphs are easily recognizable for their swollen hind tibia with pseudorhinaria on it [5].

Collecting and identifying natural enemies

Natural enemies of rose aphid were collected in different regions of Isfahan, especially in designated sampling regions. Since rose aphid, like other aphids, has many natural enemies from various orders and families of insects, a special method was used for collecting each group. Ladybirds and predatory bugs were collected using paint brush, insect net, and aspirator, and kept in 80% ethanol. Other rose aphid predators, such as the larvae of Syrphid flies, the larvae of Chamaemyiid flies, and the larvae of green lacewings, were collected with paint brush from the rose bushes, and then transferred to laboratory. For identifying these predators, they were reared until maturity. To rear these larvae in laboratory, they were put in glass petri dishes with a diameter of 11 cm and a height of 2 cm with a filter paper on its bottom. Then, they were fed with rose aphids. The petries were kept in an incubator at 25±1°C. 2–3 days after the emergence of adults, they were transferred to vials with 80% ethanol. Afterwards, they were identified at the family level and were sent to specialists for identification at the species level.

Collection of the rose aphid parasitoids was quite different from its predators. To do so, at first, the available aphid colonies on the roses in nature were examined, and after observing some parasitized aphids the twigs having these aphids were cut off, and they were reared until the emergence of parasitoids. At the laboratory, twigs were kept in small vials of water in incubator at 25±1˚C. The emerged parasitoids were kept in small vials containing 80% ethanol and identified at the family level. These parasitoids were also sent to specialists for identification.

3. Results and discussions

Biology and seasonal fluctuations

Seasonal fluctuations of the rose aphid in two sampling regions, the Campus of IUT and the Ghadir Park, are shown in figures 1 and 2 respectively. Weather information during our study (2003 and 2004) is presented in figures 3 and 4. When the cold weather of winter is over, and it gets warmer in the early growing season, the rose aphid population increases considerably, and thus in April and May very large and dense colonies can be observed on roses. The increase of population continued until mid-May. One of the reasons of population increase in spring is the suitable quality of the rose plant sap. Since in spring the vegetation growth of the rose plant begins and at this time it has tender and delicate tissues, this condition is very suitable for the growth of aphids [20]. The quality of aphid food (plant sap) is an important factor that can result in the increase of aphid population and acceleration of their growth [21, 22].

A large number of biological agents play an important role in the natural control of aphids [3, 21, 23]. At the beginning of the season, with the increase of the rose aphid population, some predators, such as ladybirds, predatory bugs, green lacewings, and also parasitoids, are active and play a considerable role in controlling the rose aphid population. On the whole, the role of natural enemies in reducing the population of this aphid in May cannot be denied since after the activity of natural enemies has begun the population of rose aphids is reduced.

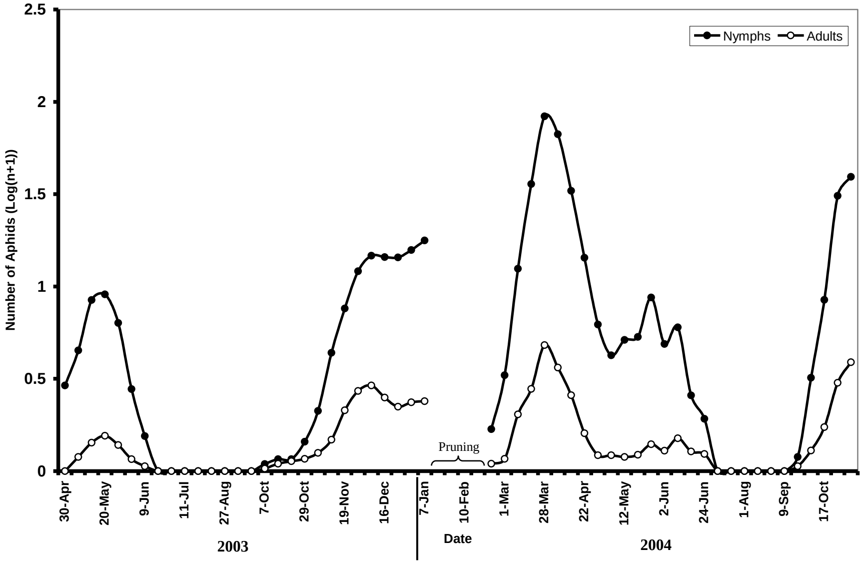

Figure 1. Seasonal fluctuations of the rose aphid, *Macrosiphum rosae*, in IUT Campus. Data from each collection date were transformed into $\mathrm{Log}_{(n+1)}$ to stabilize variance and three-point moving averages were used to visualize seasonal trends.

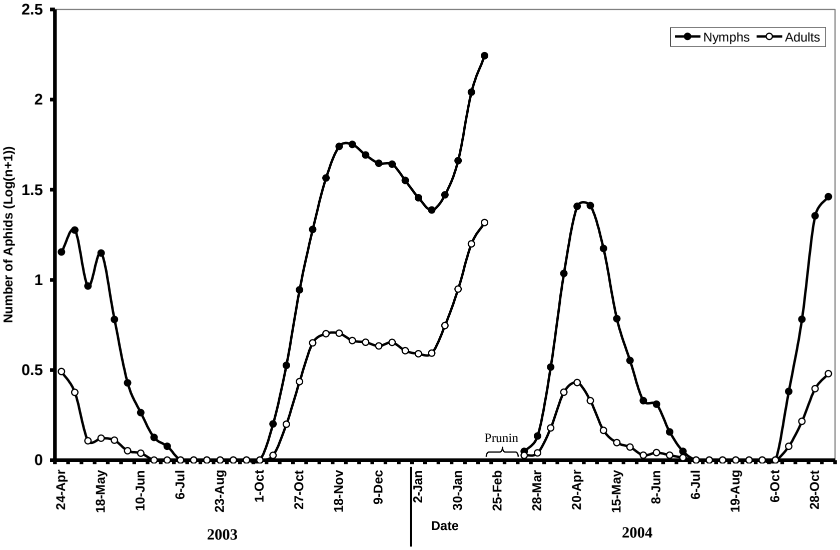

Figure 2. Seasonal fluctuations of the rose aphid, *Macrosiphum rosae*, in Ghadir Park. Data from each collection date were transformed into $\mathrm{Log}_{(n+1)}$ to stabilize variance and three-point moving averages were used to visualize seasonal trends.

By late May, with the increase of temperature, the growth of the rose aphid and also its fertility decrease, which results in the decrease of the aphid population on the rose plants. The author's studies on the biology of the rose aphid at different temperatures [24], and also studies of Maelzer [6] on South Australia, demonstrated that the optimum temperature for the growth of the rose aphid is about 22 °C. At temperatures higher than 22 °C, the growth and fertility of the rose aphid is reduced severely. Temperature curves in the two years of study (fig-s 3 and 4) show that the average daily temperature is going up almost from the end of May from 22 °C and it drops under 22 °C at the end of September. These changes of temperature are exactly synchronized with the fluctuation of the population of *M. rosae*, meaning that at the end of May, when the average daily temperature goes above 22 °C, the population of the rose aphid starts decreasing and also in early October the temperature drops under 22 ºC, and the rose aphid population increases again.

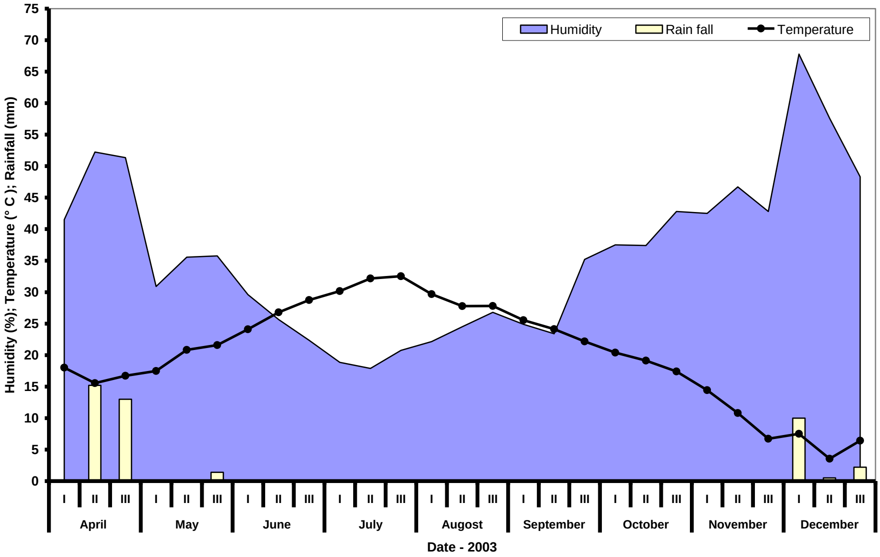

Figure 3. Weather information (mean of daily temperature, rainfall, and humidity) of Isfahan city in 2003

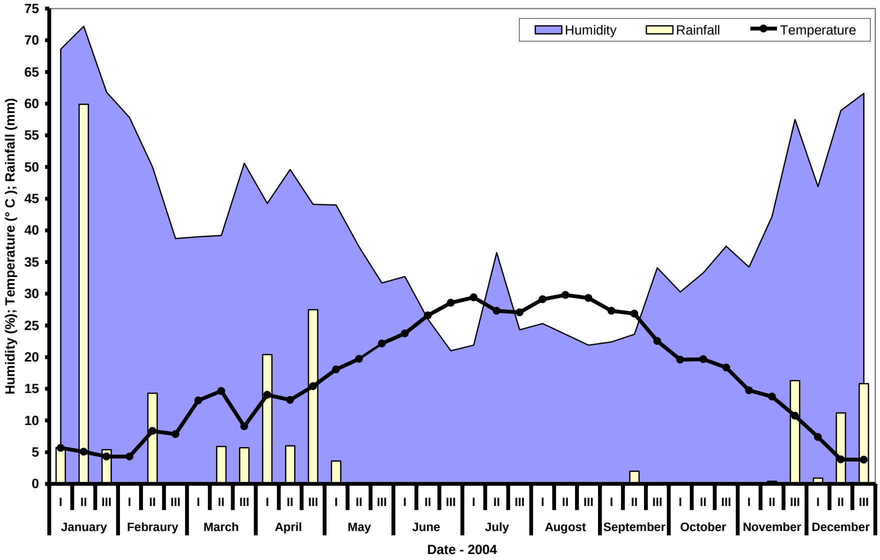

Figure 4. Weather information (mean of daily temperature, rainfall, and humidity) of Isfahan city in 2004

The temperature does not only have a direct influence on the rose aphid but it also changes the physiology of the rose plant, which results in the stagnation of the plant. So, it would not be a suitable food source for the rose aphid. Therefore, aphids have to migrate to their secondary host plants to avoid these unsuitable conditions. Results obtained by Maelzer (1977) and Jaskiewicz (1997) also confirm these cases [6, 16].

The decrease of population begins with the increase of temperature from the end of May and will continue so that there will be no rose aphid on the rose plants by the end of June. During summer, when the average temperature is more than 22 ˚C, the rose aphid aestivates on its secondary host plant, *Dipsacus fullonum* (Dipsacaceae). It should be noted that Eastop and Hodjat (1980) published their personal observations that rose aphid can be found on roses in the cold and mountainous regions of Iran from April to November [17]. Nevertheless, the current study shows that in Isfahan rose aphids migrate to their secondary host plant in summer, where they aestivate. Therefore, it will not be found on roses from late June until early October. In mid-October, as the daily average of temperature in Isfahan is less than 22 ˚C (fig-s 3 and 4), alate aphids are produced and migrate towards the rose plant and establish new colonies. These colonies will continue their growth at the appropriate temperature of autumn, and their population increases. During this time of the year, with respect to the fact that natural enemies are intensely active, their role in the control of aphid population cannot be neglected. The increase of the rose aphid population will continue during autumn and, in fact, the beginning of the severe winter cold determines the time when the population growth is stopped. During this research, we found that in the climatic conditions of Isfahan the cold of winter could not have a considerable effect on the decrease of the rose aphid population. *Macrosiphum rosae* primarily produces its dense colonies on the rose at early spring and infests twigs and buds severely. From late spring and early summer, which is a warmer period, there will be more alate morphs, causing the spread of this pest to other rose bushes or resulting in migration to secondary host plants for aestivation. The population of this aphid is very low during summer, so that nearly no rose aphid is observed on the roses. In early autumn, which is cooler, these aphids return from their secondary host plants to the rose bushes, and produce new, dense colonies. Because of the cold weather in winter, the growth of these colonies is limited and the aphid population is decreased; this trend is also reported by [6, 9, 25].

Temperature is one of the most important factors that affects the fluctuation of aphid populations [21, 26, 27]. Environmental temperature causes severe changes in the aphid population, and thus in summer, with the increase of the temperature, the number of aphid individuals is reduced very much on the host plants. Hot and dried climates, temperatures above 30 °C, severe wind and rainfall reduce the population of this aphid on roses [16]. Our results show that rainfall has a considerable effect on the population dynamics of the rose aphid, so that the aphid population decreases severely after raining. The reasons for this matter lie in aphids being washed off by drops of rain, so that they cannot return to the plants again. Rainfall may cause nearly 100% mortality of adults and older nymphs [6]. The physiological conditions of the host plant are also very effective in the growth and increase of the rose aphid population [11]. In autumn, when migrant alate morphs are produced and migrate from the secondary host plants to their primary ones, first, newly established colonies can be observed on the bushes of dog-rose. In winter, since rose bushes do not have fresh twigs and buds, the rose aphid is transferred to the lower parts of the plant, especially to the lower surface of the remained leaves. Red adult individuals in a colony are darker than red spring individuals; however, some winter morphs are dark green or have some green spots on their bodies. In IUT, the decrease of the winter population began sooner than in Ghadir Park, which is probably due to the proximity of the IUT campus to the mountain and higher altitude, so the cold of winter of IUT is more severe than in Ghadir Park, which is located in the city of Isfahan.

Mainly three factors influence the dynamics and the structure of aphid populations including: A) The potential fertility of aphids influenced by the physiological condition of host. B) The density of population and climatic condition, which result in the production of winged morphs [28–30]. C) Presence and activity of predators and parasitoids [11, 31]. But, because of the complexity of the system, there is no general or certain view about the relative importance and interactions of the active factors [11].

In addition to the rose aphid, which is the most important rose pest in Iran [9, 25] and the world [e.g. 5, 8], other aphids, such as *Amphorophora catharinae* (Nevsky, 1928) and *Rhodobium porosum* (Sanderson, 1900), are also active on roses in Isfahan with a very high population. These two species have considerable population in Isfahan and sometimes the number of observed colonies and their population is even greater than that of the rose aphid. The above mentioned species are active on the rose when it is warmer in summer. In autumn, the population of these aphids and of the rose aphid increases simultaneously. However, in autumn, in addition to these colonies, other small colonies of *Aphis fabae* Scopoli, 1763, and *Aphis craccivora* Koch, 1854 are also observed on roses. The activity of these species in autumn begins sooner than those of the rose aphid.

According to the reports [4–6, 11, 16, 32], *M. rosae*, depending on the region of activity, has three kinds of life cycles. So, if the climatic conditions of a region change severely and these fluctuations remain stable for a long time, the life cycle of the rose aphid and the way of its overwintering will probably change.

In the current study, we found that the rose aphid reproduced viviparously at the climatic conditions of Isfahan throughout the whole year, and there was no sexual form. It also migrated to its secondary host plant in summer. Accordingly, *M. rosae* is anholocyclic with host alternation in Isfahan.

Weekly observations revealed that the population of predators relatively increases at two time points of the year, in spring (May) and in autumn (October and November), while the rose aphid population decreases. It should be noted that the population of natural enemies is basically low early in the season, and after a while it increases. During this time, aphids can increase their population rapidly. However, when there is a delay for the appearance of natural enemies, especially coinciding with the increase of the aphids' population, they will not be effective, and these natural enemies will not be able to control the population of aphids. Overall, it can be said that fluctuations in the rose aphid population depend on the changes of climatic factors, the host condition, and the natural enemies during its activity.

Secondary host plants

One of the characteristics of the evolution of aphids' life cycle is host alternation [4, 5]. On the whole, the distribution of the aphids on the plant or host plants or among them is determined according to the qualitative fluctuation of plant sap [21]. In this research, *M. rosae* in summer was collected only from the *D.*

fullonum (Dipsacaceae). *Dipsacus* species are biennial plants with prickly stems and have divided branches at the top parts. This plant has been distributed in Iran especially in the northern, north-eastern, north-western, southern, and central parts of Iran [33]. This plant may be cultivated in the gardens of urban regions as an ornamental plant, which is partially scattered in Isfahan. Since the rose aphid is large and heavy, the possibility of the migration of this aphid from remote regions to the roses of the gardens in the city seems impossible. Although frequent visits demonstrated that the rose aphid was not available on other plants in summer, it is possible that this aphid spends the summer on other plants in addition to *D. fullonum*.

Various plants have been named as secondary host plants for the rose aphid. These plants are those hosts on which aestivation takes place, and most of them belong to families such as Dipsacaceae, Valerianaceae, and Onagraceae [4–6, 18, 19]. These plants belong to species such as *Dipsacus sativuspilosus*, *D. strigosa*, *D. silvestris*, *D. fullonum*, *Succisa pratensis*, and *Knautia arvensis* of the family of Dipsacaceae [4, 5, 8], *Centranthus rubber*, *Centranthus* sp., and *Valeriana* sp. of the family of Valerianaceae [5, 32], *Chamaenerion* and *Epilobium* of the family of Onagraceae [4]. Heie (1994) introduced *Chamaenerium angustifolium* (Oenotheraceae) as the most important secondary host plant instead of *Knautia arvensis* in northern Sweden and Finland [5]. This aphid is occasionally observed on the other Rosaceae such as *Fragaria*, *Geum*, *Pyrus*, *Malus*, and *Rubus* in summer [4, 5]. Furthermore, late in summer, the rose aphid may also be seen on *Ilex aquifolium* [5, 8]. In 1990–1996, Ripka et al. collected rose aphid on some plants such as *Fontanesia fortunei*, *Gleditsia triacanthus*, *Symphoricarpos albus*, *Symphoricarpos* sp., *Orbiculatus* sp., and *Vitex agnus-castus* as well as rose plant in Hungary [34].

Place and stage of aestivation and overwintering

The rose aphid overwinters as alate and apterous viviparous females on the lower surface of leaves and on lower branches of the rose plant in Isfahan. Weekly sampling in winter demonstrated that viviparous females are always observed together with different nymphal instars. It should be added that this aphid is seen reproductively in the cold of winter, so this species reproduces viviparously during the whole winter. Since in our study egg stage and sexual morphs were never observed, it can be concluded that the rose aphid is anholocyclic in Isfahan.

In this study, *D. fullonum* was identified as secondary host plant for *M. rosae*. The rose aphid spends the summer as alate and apterous viviparous morphs on this plant. The situation and ecological niche of those aphids that aestivate are different from the colonies of this aphid in other seasons of the year. In summer, because of the high temperature and changes in the physiological conditions of the rose plant, the aphids have to leave the roses and migrate to secondary host plants. *Dipsacus fullonum* has wide, large, and dense leaves, and so it will have intensive canopies and will make a cooler environment with more humidity for the rose aphids.

Aestivating colonies were observed in IUT for the first time in early June 2004. The population of the rose aphid on the secondary host plant reached its maximum in mid-July, and these aestivating aphids remained on the secondary host plants until late October. Aestivating colonies on the secondary host plant have a much smaller population than those on the rose and their colonies seemed to be scattered. The colour of aestivating aphids is different; this change of colour is probably due to the host plant [21]. Aestivating aphids were located and active on the stems and lower surface of leaves of the secondary host plant.

Natural enemies of the rose aphid

The collected natural enemies of the rose aphid belonged to various groups of arthropods such as insects (*Table 1*), mites, and spiders.

Table 1. Predators and parasitoids of the rose aphid, *Macrosiphum rosae*, collected in Isfahan, Iran.

Order	Family	Scientific name
Coleoptera	**Coccinellidae**	*Hippodamia variegata* Goeze *Coccinella septempunctata* L. *Adalia bipunctata* L. *Exochomus nigromaculatus* Goeze
Diptera	**Syrphidae**	*Syrphus vitripennis* Meigen, *Ischiodon aegyptius* (Wied.) *Scaeva albomaculata* Macquart
	Chamaemyiidae	*Leucopis glyphinivora* Tanas. *Leucopis* sp.
Hemiptera	**Miridae**	*Deraeocoris punctulatus* (Fallen) *Deraeocoris* sp.
	Anthocoridae	*Orius niger* (Wolff) *O. minuta* L. *Anthocoris limbatus* Fieber
Neuroptera	**Chrysopidae**	*Chrysoperla carnea* (Stephens)
Hymenoptera	**Braconidae**	*Aphidius rosae* Haliday *Aphidius ervi* Haliday *Praon volucre* Haliday *Ephedrus plagiator* Nees

In this study, four species of Coccinellidae were identified. Three species including *Hippodamia variegata* Goeze, *Coccinella septempunctata* Linnaeus, and *Adalia bipunctata* Linnaeus belonged to the subfamily of Coccinellinae and *Exochomus nigromaculatus* Goeze belonged to the subfamily of Chilocorinae. Furthermore, three species of Syrphidae were identified as *Syrphus vitripennis* Meigen, *Ischiodon aegyptius* (Wiedemann), and *Scaeva albomaculata* Macquart; among them, the first one was the dominant species. Two more species of Chamaemyiidae, *Leucopis glyphinivora* Tanasijtshuk and *Leucopis* sp., were also collected. Furthermore, some predator bugs of Miridae including *Deraeocoris punctulatus* (Fallen) and *Deraeocoris* sp. and of Anthocoridae, such as *Orius niger* (Wolff), *O. minuta* Linnaeus, and *Anthocoris limbatus* Fieber, were identified. One species of predator beetle of the family Cantharidae was also collected. *Chrysoperla carnea* (Stephens) of Chrysopidae, one species of parasitic mites of Prostigmata (Erythraeidae), and some species of predator spiders were also collected.

The most active and important parasitoid wasps of the rose aphid belong to the Braconidae. In this study, four species of parasitoid wasps of the family Braconidae, namely *Aphidius rosae* Haliday, *Aphidius ervi* Haliday, *Praon volucre* Haliday, and *Ephedrus plagiator* Nees, were collected. *Aphidius rosae* is one of the most important natural enemies of *M. rosae* in many parts of the world like Germany, Australia, and Poland [11, 32, 35, 36]. This parasitoid is specialized on *M. rosae* and is rarely active on other aphids [36]. *Aphidius rosae* has been reported for the first time by the authors in Iran [37]. These parasitoids are found in spring during April and May to early June. In autumn, they are active from November to early December. *Pachyneuron aphidis* (Bouche) of Pteromalidae was collected as hyperparasitoid of the rose aphid.

4. Conclusion

Bioecological studies and interaction between a pest and its environment is very important because the relationship between the pests and environmental factors should be recognized at first for a correct and effective control. Any effective control of pests requires a precise knowledge of their dynamics and factors, such as temperature, which influence them. Temperature is an important environmental variable that affects the rate of aphid development, reproduction, mortality, and survival [30]. At present, in most regions of the world, determining the suitable time for controlling pests is based on the seasonal fluctuations of the pest population and it is a subject about which we tried to describe some important points on the fluctuations of the rose aphid population in this study.

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The importance of protecting unique Romanian landscape values, illustrated by examples of problem solving in other countries

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Abstract: Nature and landscape protection has gained importance over the past 50 years from the economic, cultural, health, and recreational point of view. The process is closely linked to our civilizational endeavours (such as economic interests, pollution, urbanization, super-intensive agriculture, etc.) that threaten our natural values as well as to the ever more frequent environmental disasters resulting from the above. The continued destruction of our natural and landscape values is not reversible. The aim of this article is to determine the important and urgent professional tasks regarding exploring, documenting, safeguarding, and raising awareness of values. My work wishes to draw attention to the landscape values and deficiencies of Transylvania, working with examples from other countries; by using Romanian examples, I also wish to support my assumption according to which if we want to preserve unique landscapes on the European level we need to act quickly.

Keywords: landscape protection, exploration, unique character, landscape element

1. Introduction

The European Landscape Convention – signed on October 20, 2000 by Romania – defines landscape assessment as a task for the acceding countries. Analysing the way the Convention was put into practice, it can be stated that in Romania there is much more emphasis on conservation than on the exploration of the landscape, of its parts, and unique characteristics. The definition and practical applications of the terms related to landscape potential, landscape characteristic, landscape shaping, and others pertaining to landscape architecture and protection are still not emphatic enough. Landscape protection and development investments, landscape and regional planning, as well as landscape rehabilitation, conservation, and development are in most cases still not carried out by experts. Such phenomena are due – among other things – to the lack of training of landscape architects in Romania.

2. Materials and methods

We can conclude that while protecting nature is mainly based on ecological grounds, landscape protection is a more complex, interdisciplinary task as it involves not only the protection of the natural value of landscapes but also that of architectural treasures as well as the cultural heritage of humankind forming the landscape. Protecting the landscape character does not only mean the protection of nature (values created by the individual and society are at least just as important in this respect). "Landscape character is the totality of characteristic features of a landscape or part of a landscape that allows it to be distinguished from other landscapes or parts of landscapes, or makes comparison with other landscapes or parts of landscapes possible. [...] the most important factors in determining landscape character are: character-value natural element groups, landscape use and landscape structure developed over time (even centuries), landscape facilities (the quality of the aspect of the landscape), as well as the traditions and emotions connected with the landscape, as well as their expression in the elements constituting the landscape" [1]. Determining landscape character can be achieved through analyses based on surveys, landscape history research, and field observations of sample areas (*Fig. 1.*).

The working methods and experiences of field work need to be taught to students in addition to the theoretical background of landscape character analysis in the landscape architect training programme, during field exercises. The students are able to understand the landscape and the most important milestones of landscape development as the result of research, analysis, and field surveys of landscapes and parts of landscapes of different characteristics and scales.

The rural landscapes of small Transylvanian settlements – due to traditional and sometimes still existing landscape use – are particularly rich in elements and methods of use that define the landscape character, that are unique on a global scale, and that differentiate the given landscape from other landscapes of the country and of other landscapes of the larger region. We can pride ourselves on anthropogenic landscapes that are unique in Europe. According to Bertalan Andrásfalvi, human beings not only impoverish or damage nature and biodiversity with their lifestyles and by providing the goods needed to stay alive but they can also enrich it [2].

Figure 1. The Landscape architecture students during field practice and landscape character assessment in Torockó (Alba County) (the author’s photos).

The landscape elements of the unique landscape values of the history of culture need to be able to strengthen identity. “In today’s individualized local society, saving ‘traditional’ spiritual and natural values might seem anachronistic. The use of the landscape is extreme and is characterized by strict regulations and protection, but it is also market-oriented. [...] The past characteristics of landscape using also underline important relationships in the questions of the relationships between landscape protection and the local population, first regarding ownership, the organization of work and the use of resources” [3].

Landscape elements belonging to the history of culture are not necessarily linked to a place or determine the character of a landscape or a region solely as the elements of traditional agriculture. The details, cyclical changes of a landscape, the experience provided by it, the events taking place in it, the series of landscapes were strongly encoded into our minds during human ontogeny. This also contributes to the fact that the landscape is based on the ethos of the people living there, and this can be the result of a social class (bourgeoisie, aristocrats), of a national minority, or even that of a community living in a certain location [4].

By way of a Transylvanian example, the castle gardens along the River Someș are tied with thousands of threads to the landscape exactly due to the fact that they are perfectly fitted into the landscape as well as because of their links with the landscape, economic embeddedness, social role, etc. It is a real cultural landscape due to its characteristic buildings and peculiar landscape structure. It is a good example for the former and current significance of noble residences on landscape architecture [5].

I would like to highlight the issues and deficiencies regarding landscape in Romania with the landscape strategies of two countries I have met and studied in detail. Scotland could be the best example, a direction to follow, while Hungary's inspiring initiative can be stimulating in defining the strategies on landscape protection and preservation of landscape character in Romania, promoting and raising awareness of landscape values.

Róbert Kabai (2010) also highlights the Scottish landscape character assessment programme conducted between 1994 and 1999, which is the first in Europe to grant full coverage and include not only results based on a thorough analysis but also – and perhaps this is the most important aspect – the practical implementations of the results [6].

The Landscape Assessment Guidance constituted the basis of the valuation methodology conducted by the Countryside Commission in 1993, while the presentation of important practical applications as well as the evaluations of results follow the work of Julie Martin Associates and Swanwick from 2003, entitled Overview of Scotland's National Programme of Landscape Character Assessment.

The assessment programme was initiated by the Scottish Natural Heritage, which had a dual objective: creating a landscape database and a practical application of the results. In addition to the Scottish conservation office, external contractors, individuals, and experts of the local governments also participated in the realization of the studies. The landscape architects had an important role in carrying out the studies, and they were helped by ecologists, archaeologists, historians, and town planners with local knowledge.

Beyond the survey conducted throughout the whole territory of Scotland, the aims of the studies are: raising awareness of the importance of the landscape; exploring effects that form the landscape, facilitating building permits and other decisions regarding landscape; promoting strategic connections between the Scottish conservation office, local government authorities, town planning, and use of landscape; establishing a national policy [7]. As a result, the presentation of the factors that form the landscape, the types of landscape characters, the definition and description of landscape character areas, landscape architectural guidelines that help long-term planning and utilization can be found in this work. The most important step, however, is the practical application of the above-mentioned results: the national planning policy makes references in several cases to the topic of landscape character, including the National Planning Policy Guidance 14: Natural Heritage, which provides that the development and settling plans of the county are required to include the regulations on preserving and enriching the landscape [6].

The example in Scotland confirms the fact that a landscape character assessment implemented on national level and its practical application can help town planning, the rational utilization of the landscape and of various investments.

The second example to follow for Romania is the Hungarian Cultural Landscape Database programme (TÉKA), supported by the Norwegian Financial Mechanism. As part of the programme, 114 thousand landscapes have been explored in Hungary over two years (the number of the expected values is 150–170 thousand), with a total of 1,066 settlements and 30–50 registered landscapes on every settlement [8]. The program is an interactive online database, which can be improved by anyone with unique landscapes examined by a specific set of criteria, after which an expert will overlook the inserted data and accept them if they meet the criteria. Thus, the database is constantly growing with high efficiency.

3. Results and discussions

Intact agricultural landscapes can still be found in Romania and in some neighbouring countries, in mountainous regions. The biological diversity and the preserved landscape culture are outstanding even in international context, and it can be considered a significant landscape value. The Transylvanian and Swedish methods applied concerning livestock and harvesting appeared to be similar; therefore, our landscapes have been researched often by Scandinavians. The uniqueness of the Transylvanian countryside is outstanding on international level, and it has served as an example to follow and a reference in the preservation and reconstruction of the Swedish agricultural landscapes (this is confirmed by a study carried out in 2006, published in 2007 KUNGL. SKOGS- OCH LANTBRUKS-AKADEMIENS TIDSKRIFT a: Valuable Agricultural Landscapes – the Importance of Romania and Scandinavia for Europe, published by the Royal Swedish Academy of Agriculture and Forestry in Stockholm.

The Romanian landscapes have one of the richest biological diversity in Europe, especially due to the large pastures of Transylvania, close to nature (*Fig. 2.*). At the same time, as compared with other countries, the number of preserved landscapes is higher in Romania. The land use, the old traditional methods, and the peasantry as creator of popular culture had not been assessed until they nearly disappeared in some countries. The intensive, mechanized, and overly chemical agriculture led to marginalization, and this process had its negative effects especially on the rural landscape in the case of mown meadows.

Figure 2. The unique landscape character of Maramureș County (the author's photos).

4. Conclusion

In Romania, the legal background of landscape protection barely offers any help at all. Some of them are the European Landscape Convention, the lawn law's conservationist aspect (*Legea fondului funciar nr. 18/1991*, overridden by the Emergency Regulation 34/2013, *Ordonanţa de Urgență nr. 34/2013 privind organizarea, administrarea şi exploatarea pajiştilor existente*, which came into force on 13.05.2013), the forestry law (*Codul Silvic din 2008*, which came into force on 30.03.2008.), and, of course, the law regulating the settlements' area redevelopment: General Urbanistic Plan – PUG (*Plan Urbanistic General, Legea 350/2001*, completed by *Legea 289/2006*, which entered into force on 07.07.2006), and the Urbanistic Zonal Plan – PUZ (*Plan Urbanistic Zonal 350/200*1, which entered into force on 07.06.2001, with its subsequent amendments), which mostly regulates construction and urban development in urban areas.

As for the questions about landscape, using the term cultural landscape has become fashionable, but in many cases "cultural landscape" is followed by negative examples. The number of landscape character assessments carried out by professionals has proven to be insufficient. Promoting sensitivity regarding the category of landscape and human-scale landscape management as well as strengthening the local character and identity are considered important priorities.

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Ground-dwelling arthropod (Araneae, Coleoptera: Carabidae, Isopoda: Oniscidea) assemblages on Hungarian main road verges

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Abstract: In this study, we research ground-dwelling arthropods along four road stretches, which represent the main verge habitats (arid grassland, agricultural area, forest, and wetland) of Hungary. Besides the faunistic investigation of arthropod communities, we described and compared dominance relation and species composition. We identified 83 carabids, 81 spiders, and 4 isopod species. Seven beetle species and one spider species are included in the invertebrate Red List of Hungary. The registered species were dominant on main road verges bordering arid grassland and wetland. Main road verges proved to be a diverse habitat; hence, it is important to carry on more investigation.

Keywords: spider, beetle, woodlice, species richness, abundance, diversity

1. Introduction

The establishment of road networks is one of the most prevalent ways of land usage these days with more and more studies focusing on the effect of roads on biodiversity [1]. Road ecology is a new discipline nowadays [2]. Researchers of roadside and highway verges provide several data about beetles [3, 4, 5, 6, 7, 8, 9], spiders [3, 6, 7, 10], and isopods [11, 12, 13, 14]. Trombulak and Frissell [15] examined the short- and long-term effects of roads on environment. The studies of Holderegger and Di Giulio [16] targeted the effects of barriers on mortality and gene replacement; also, Forman et al. [2] have closely investigated the flora and fauna of roadside verges. All of this referred literature shows that the effects of roads on wildlife are multiple, which can be positive or negative. The negative effects of roads on organisms are changing habitats, changing the environment's chemistry and physics, road kills, changing behaviour of animals, chemical pollution, acting as barrier and intensifying the dispersal of invasive and also exotic species [15, 7]. However, roadside verges function as ecological corridors, serve as suitable habitat sources and conditions for organisms [17, 18, 19, 20, 21, 22, 7]. All of these potential effects are dependent on the complex interactions between species infrastructure and landscape [23, 24].

Owing to the ecological and biological features of beetles [25, 26], spiders [27], and woodlice [28, 29], they are excellent biological indicators. They can be also called hitchhiker insects as their spreading along roads has widely influenced the traffic. In addition to traffic, the quality of the habitat, the interactions between populations and the structure of the landscape also affect the spreading of arthropods and the composition of the communities [30, 31, 32, 33].

The main objective of this paper is to report on the spider, isopod, and ground beetle fauna of main road verges situated beside different habitat types that represent the main verge habitats of Hungary. Besides faunistic research, the effects of the different vegetation of main road verges on wildlife should also be investigated.

2. Material and methods

Along the Hungarian main roads, four sampling sites were selected, representing the main types of verge habitats. The first sampling area, Pilisjászfalú (Budapest–Esztergom, Pest County), was along Road No 10 and consisted of arid grassland with some small bushes shown in *Fig. 1*. The second sampling area, Mány (Budapest–Győr, Fejér County), was situated along Road No 1 between two roads in agricultural areas, in the lowlands and the hilly landscape of Hungary, shown in *Fig. 2*. The third sampling area, Herceghalom (Budapest–Győr, Pest County), was located along Road No1 between the road and the forest, shown in *Fig. 3*. The fourth sampling area, Agárd (Budapest–Székesfehérvár, Fejér County), was along Road No 7, crossing a wetland area in the western section of Lake Velence, shown in *Fig. 4*.

Figure 1. Pilisjászfalu sampling sites along Road No 10

Arthropods were sampled using 15-15 pitfall traps on each site and the distance between the traps was 5 m. The 60 pitfall traps used in the study were transparent plastic cups filled with a 65% aqueous solution of ethylene glycol as a preservative fluid [34]. The traps were in the fields for three weeks, placed four times a year in different seasons (early spring, spring, summer, and autumn).

Figure 2. Mány sampling sites along Road No1

Figure 3. Herceghalom sampling sites along Road No1

Figure 4. Agárd sampling sites along Road No 7

The characterizations of the ground-dwelling arthropod communities were based on species richness and abundance. For the analysis of the data, we used the PAST Paleontological Statistic suite. We counted Shannon-Wiener (H) diversity for an accurate characterization of the examined isopod communities. We studied the species' preference for habitat using correspondence analysis.

3. Results and discussion

The sampling resulted 7,563 ground-dwelling arthropods from 168 species along main road verges. In total, 1,139 beetles from 83 species, 2,212 spiders from 81 species, and 4,212 isopods form 4 species were collected as shown in *Table 1*. Seven beetle species (*Carabus convexus*, *Carabus coriaceus*, *Carabus germarii*, *Carabus granulatus*, *Carabus scheidleri*, and *Carabus violaceus*) and one spider species (*Nemesia pannonica*) are included in the invertebrate Red List of Hungary [35]. The total Shannon-Wiener diversity was relatively high (2.69). On each verge, the Shannon-Wiener diversity of spiders was the highest (3.58), followed by beetles (3.32) and isopods (0.36).

In this study, beetles was the richest group of species. With regard to the size of beetles, the species can be grouped into small-sized species and medium-sized species [36]. Based on food reference, the omnivoreous or phytophagous and spermophagous species (*Amara* and *Harpalus* genus) were dominant [37]. According to wing development, the macropterous and dimorphous or polimorphous species (*Amara* and *Harpalus* genus) [36] were frequent. The majority of the species are common in Hungary, except the seven protected beetle species, among which *C. cancellatus* (42 individuals) was the dominant, followed by the *C. coriaceus* (36 individuals). *Brachinus explodens* (167 individuals) was recorded with the highest abundance, followed by *Harpalus tardus* (130 individuals) and *Bembidion properans* (100 individuals). *H. tardus* in arid grassland and the other two mentioned species in wetland were predominant. The sporadic *Pterostichus elongatus* benefits from wet sodic habitats [38, 39] and flies towards light [40]. *P. incommodus* is not a common species either [41], but its lifestyle is less known, except that it lives in open forests and wooded steppe [36]. In the Netherlands,Vermeulen [4] collected several rare carabid beetles on roadside verges. This and our results indicate that roadsides have a potential conservation value. In the case of beetles, wetland verges were prominent as they were found to dispose of the highest species richness and abundance as shown in fig-s 5, 6, and 7.

Lycosidae and *Gnaphosidae* of spider families were dominant. The highest species richness was observed in arid grassland verges and the abundance of spiders in the wetland verges was the highest as shown in fig-s 5, 6, and 7. *Pardosa lugubris* (263 individuals), *Alopecosa trabalis* (216 individuals), and *Alopecosa pulverulenta* (155 individuals) of spiders were observed as having the highest abundance.

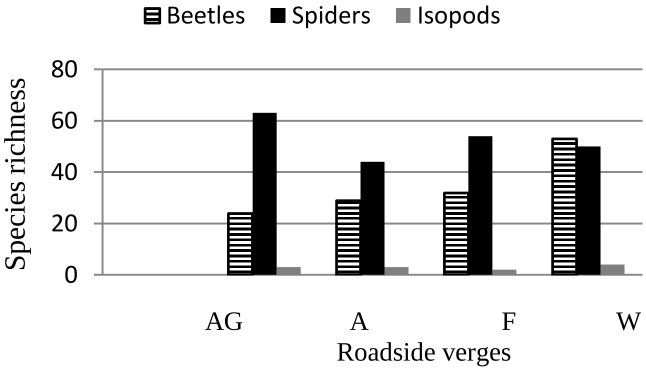

Figure 5. Species richness of ground-dwelling arthropods on the four roadside verges

In this regard, we have to mention *Pardosa bifasciata* (148 individuals), *Xysticus kochi* (147 individuals), and *Pardosa agrestis* (133 individuals). While *P. lugubris*, *P. bifasciata*, *P. agrestis*, and *X. kochi* dominated the wetland, *A. trabalis* was present in arid grassland and *A. pulverulenta* in agricultural landscapes with a high number of individuals.

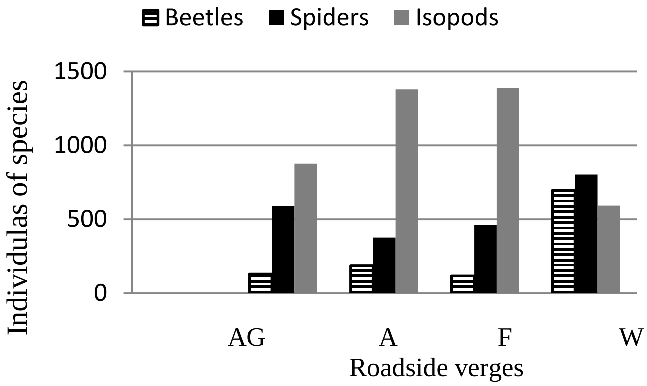

Figure 6. Individuals of species of ground-dwelling arthropods on the four roadside verges

Table 1. Distribution of species based on habitat types. Habitat types: AG: arid grassland, A: agricultural area, F: forest, W: wetland.

Species	**Verges types**			
	AG	**A**	**F**	**W**
Carabidae				
Abax parallelepipedus (Piller & Mitterpacher, 1783)			x	
Amara aenea (Degeer, 1774)	x	x	x	x
Amara anthobia (A. et G. B. Villa, 1833)	x			x
Amara apricaria (Paykull, 1790)		x		
Amara consularis (Duftschmid, 1812)			x	
Amara convexior (Stephens, 1828)	x		x	
Amara equestris (Duftschmid, 1812)		x		
Amara familiaris (Duftschmid, 1812)	x		x	x
Amara lucida (Duftschmid, 1812)				x
Amara ovata (Fabricius, 1792)			x	
Amara saphyrea (Dejean, 1828)			x	x
Amara similata (Gyllenhal, 1810)			x	x
Amara tibialis (Paykull, 1798)				x
Anchomenus dorsalis (Pontoppidan, 1763)		x	x	x
Anisodactylus binotatus (Fabricius, 1787)				x
Badister bullatus (Schrank, 1798)			x	
Bembidion properans (Stephens, 1828)				x
Bembidion quadrimaculatum (Linnaeus, 1761)				x
Brachinus crepitans (Linnaeus, 1758)			x	x
Brachinus explodens (Duftschmid, 1812)		x	x	x
Brachinus ganglbaueri (Apfelbeck, 1904)				x

Species	**Verges types**			
	AG	**A**	**F**	**W**
Bradycellus harpalinus (Audinet-Serville, 1821)				x
Calathus ambiguous (Paykull, 1790)		x		x
Calathus cinctus (Motschulsky, 1850)		x		
Calathus fuscipes (Goeze, 1777)		x	x	x
Calathus melanocephalus (Linnaeus, 1758)	x			x
Callistus lunatus (Fabricius, 1775)	x			
Carabus cancellatus (Illiger, 1798)				x
Carabus convexus (Fabricius, 1775)				x
Carabus coriaceus (Linnaeus, 1758)		x	x	x
Carabus germarii (Sturm, 1815)				x
Carabus granulatus (Linnaeus, 1758)				x
Carabus scheidleri (Panzer, 1799)	x		x	
Carabus violaceus (Linnaeus, 1758)		x		
Chlaenius festivus (Panzer, 1796)				x
Chlaenius nigricornis (Fabricius, 1787)				x
Chlaenius nitidulus (Schrank, 1781)				x
Chlaenius spp.				x
Dischyrius globosus (Herbst, 1784)			x	
Harpalus affinis (Schrank, 1781)				x
Harpalus azureus (Fabricius, 1775)		x	x	x
Harpalus calceatus (Duftschmid, 1812)		x		
Harpalus puncticeps (Stephens, 1828)	x			
Harpalus cribricollis (Dejean, 1829)		x		
Harpalus distinguendus (Duftschmid, 1812)			x	x
Harpalus flavicornis (Dejean, 1829)	x	x		x
Harpalus griseus (Panzer, 1796)	x		x	
Harpalus pumilus (Sturm, 1818)	x	x		
Harpalus caspius roubali (Schauberger, 1928)	x			
Harpalus rubripes (Duftschmid, 1812)	x			
Harpalus sabulicola (Panzer, 1796)		x		
Harpalus rufibarbis (Fabricius, 1792)				x
Harpalus rufipes (De Geer, 1774)		x	x	x
Harpalus serripes (Quensel in Schönherr, 1806)		x	x	x
Harpalus signaticornis (Duftschmid, 1812)	x			
Harpalus smaragdinus (Duftschmid, 1812)		x		
Harpalus tardus (Panzer, 1796)	x	x	x	x
Leistus ferrugineus (Linnaeus, 1758)	x	x	x	x
Microlestes maurus (Sturm, 1827)				x
Microlestes minutulus (Goeze, 1777)				x
Nebria brevicollis (Fabricius, 1792)				x
Notiophilus spp.			x	x

Species	**Verges types**			
	AG	**A**	**F**	**W**
Panagaeus bipustulatus (Fabricius, 1775)	x		x	x
Panagaeus crux-major (Linnaeus, 1758)				x
Parophonus complanatus (Dejean, 1829)		x		
Parophonus maculicornis (Duftschmid, 1812)		x	x	
Platyderus rufus (Duftschmid, 1812)			x	
Poecilus cupreus (Linnaeus, 1758)	x			x
Poecilus Lepidus (Leske, 1785)				x
Poecilus sericeus (Fischer von Waldheim, 1823)		x		
Poecilus versicolor (Sturm, 1824)				x
Pterostichus elongatus (Dufrschmid, 1812)				x
Pterostichus incommodus (Schaum, 1858)		x		
Pterostichus melanarius (Illiger, 1798)				x
Pterostichus niger (Schaller, 1783)				x
Pterostichus vernalis (Panzer, 1795)			x	
Stenolophus discophorus (Fischer von Waldheim, 1824)				x
Stenolophus mixtus (Herbst, 1784)			x	x
Stenolophus teutonus (Schrank, 1781)				x
Syntomus pallipes (Dejean, 1825)		x		
Tachys diabrachys bisbimaculatus (Chevrolat, 1860)				x
Trechus quadristriatus (Schrank, 1781)	x	x		x
Zabrus tenebrioides (Goeze, 1777)	x	x		
Araneae				
Nemesiidae				
Nemesia pannonica (Herman, 1879)	x			
Segestriidae				
Segestria senoculata (Linnaeus, 1758)				
Dysderidae				
Dysdera erythrina (Walckenaer, 1802)	x	x	x	
Dysdera spp. juvenilis	x	x	x	
Harpactea rubicunda (C. L. Koch, 1838)	x	x	x	
Mimetidae				
Ero furcata (Villers, 1789)			x	
Theridiidae				
Asagena phalerata (Panzer, 1801)	x	x	x	x
Enoplognatha thoracica (Hahn, 1833)		x	x	
Euryopis flavomaculata (C. L. Koch, 1836)	x			
Euryopis quinqueguttata (Thorell, 1875)			x	
Steatoda albomaculata (De Geer, 1778)		x		x
Linyphiidae				
Centromerus sylvaticus (Blackwall, 1841)	x		x	x
Diplostyla concolor (Wider, 1834)			x	x

Species	Verges types			
	AG	A	F	W
Erigone dentipalpis (Wider, 1834)			x	x
Megalepthyphantes nebulosus (Sundevall, 1830)			x	
Prinerigone vagans (Audouin, 1826)				x
Stemonyphantes lineatus (Linnaeus, 1758)	x			
Tetragnathidae				
Pachygnatha degeeri (Sundevall, 1830)			x	x
Araneidae				
Agelenatea redii (Scopoli, 1763)	x			
Araneus diadematus (Clerck, 1757)			x	
Argiope bruennichi (Scopoli, 1772)	x			
Cercidia prominens (Westring, 1851)			x	
Lycosidae				
Alopecosa accentuata (Latreille, 1817)	x			
Alopecosa cuneata (Clerck, 1757)	x	x		x
Alopecosa pulverulenta (Clerck, 1757)	x	x	x	x
Alopecosa sulzeri (Pavesi, 1873)	x			
Alopecosa trabalis (Clerck, 1757)	x	x	x	x
Alopecosa spp. juv	x	x	x	x
Arctosa leopardus (Sundevall, 1833)				x
Aulonia albimana (Walckenaer, 1805)	x	x	x	x
Hogna radiata (Latreille, 1819)	x	x		x
Pardosa agrestis (Westring, 1861)	x	x	x	x
Pardosa amentata (Clerck, 1757)			x	
Pardosa bifasciata (C. L. Koch, 1834)	x	x	x	x
Pardosa lugubris (Walckenaer, 1802)	x	x	x	x
Pardosa paludicola (Clerck, 1757)			x	x
Pardosa proxima (C. L. Koch, 1847)				x
Pardosa riparia (C. L. Koch, 1833)	x	x	x	x
Pardosa spp. juv	x	x	x	
Trochosa robusta (Simon, 1876)	x	x	x	
Trochosa terricola (Thorell, 1856)	x	x	x	x
Trochosa spp. juv	x	x	x	x
Xerolycosa miniata (C. L. Koch, 1834)				x
Xerolycosa nemoralis (Westring, 1861)				x
Pisauridae				
Pisaura mirabilis (Clerck, 1757)	x	x	x	x
Agelenidae				
Allagelena gracilens (C. L. Koch, 1841)	x		x	x
Coelotes terrestris (Wider, 1834)			x	
Eratigena agrestis (Walckenaer, 1802)		x	x	x
Urocoras longispinus (Kulczynski, 1897)	x	x	x	

Species	**Verges types**			
	AG	**A**	**F**	**W**
Titanoecidae				
Titanoeca quadriguttata (Hahn, 1833)		x		
Titanoeca shineri (L. Koch, 1872)		x		
Eutichuridae				
Cheiracanthium virescens (Sundevall, 1833)	x			
Miturgidae				
Zora spinimana (Sundevall, 1833)	x	x	x	
Anyphaenidae				
Anyphaena accentuata (Walckenaer, 1802)		x	x	
Liocranidae				
Agroeca cuprea (Menge, 1873)	x			x
Liocranoeca striata (Kulczynski, 1882)				x
Scotina celans (Blackwall, 1841)			x	
Phrurolithidae				
Phrurolithus festivus (C. L. Koch, 1835)	x	x		
Clubionidae				
Clubiona pseudoneglecta (Wunderlich, 1994)	x			
Clubiona terrestris (Westring, 1851)			x	
Zodariidae				
Zodarion germanicum (C. L. Koch, 1837)	x			
Zodarion rubidium (Simon, 1914)	x			x
Zodarion spp. juv	x			
Gnaphosidae				
Drassodes cupreus (Blackwall, 1834)		x		
Drassodes lapidosus (Walckenaer, 1802)		x		
Drassodes pubescens (Thorell, 1856)	x	x	x	x
Drassyllus praeficus (L. Koch, 1866)	x	x	x	x
Drassyllus pusillus (C. L. Koch, 1833)		x		x
Drassyllus villicus (Thorell, 1875)		x	x	
Drassyllus spp. juv	x	x	x	x
Gnaphosa lucifuga (Walckenaer, 1802)			x	
Haplodrassus signifer (C. L. Koch, 1839)	x	x	x	x
Haplodrassus umbratilis (L. Koch, 1866)				x
Trachyzelotes pedestris (C. L. Koch, 1837)	x	x	x	x
Zelotes apricorum (L. Koch, 1876)	x		x	x
Zelotes electus (C. L. Koch, 1839)	x	x	x	x
Zelotes latreillei (Simon, 1878)	x		x	x
Zelotes longipes (L. Koch, 1866)	x		x	
Zelotes petrensis (C. L. Koch, 1839)	x			x
Zelote spp. juv	x		x	x
Philodromidae				

Species	**Verges types**			
	AG	**A**	**F**	**W**
Thanatus arenarius (Thorell, 1872)	x	x		
Thanatus formicinus (Clerck, 1757)	x			
Thanatus spp. juvenilis	x	x	x	x
Tibellus spp. juvenilis	x			x
Thomisidae				
Ozyptila atomaria (Panzer, 1801)		x	x	
Ozyptila claveata (Walckenaer, 1837)	x	x	x	
Ozyptila praticola (C. L. Koch, 1837)		x		x
Ozyptila scabricula (Westring, 1851)	x			
Ozyptila simplex (O. P.-Cambridge, 1862)	x			x
Xysticus acerbus (Thorell, 1872)	x			
Xysticus cristatus (Clerck, 1857)	x			x
Xysticus luctator (L. Koch, 1870)				x
Xysticus kochi (Thorell, 1872)	x	x	x	x
Xysticus spp. juvenilis	x	x	x	x
Salticidae				
Euophrys spp. juv	x			
Heliophanus cupreus (Walckenaer, 1802)			x	
Pellenes tripunctatus (Walckenaer, 1802)	x			
Phlegra fasciata (Hahn, 1826)	x			
Salticus ssp. juvenilis	x			
Isopods				
Trachelipodidae				
Porcellium collicola (Verhoeff, 1907)	x	x	x	x
Trachelipus rathkii (Brandt, 1833)	x			x
Porcellionideae				
Porcelliodides pruinosus (Brandt, 1833)		x		x
Armadillidiidae				
Armadillidium vulgare (Latreille, 1804)	x	x	x	x

Only the arid grassland provides suitable habitats for the one registered protected species: *Nemesia pannonica*, which is one of the most valuable (10 000 HUF) nature conservation spider species in Hungary. The single Hungarian representative of the *Nemesiidae* family is submediterranean-distributed. Last year, a growing number of occurrences of this species were registered, such as in Pilis [42], East Mezőföld [43], and Mátra [44]. The presence of this species with special needs confirms that main road verges occasionally expand the area of nature reserves [4]. Web spiders (*Agelenidae* and *Araneidae* family) mainly selected the verges' borders with forests and meadows, which provide suitable conditions for spiders to make web. Crab spiders, generally waiting to prey on colourful flowers, were found near grasslands.

These findings demonstrate the importance of mowing for floral diversity [45, 46]. Each of the four registered ant-specialist species (*Zodarion rubidum, Zodarion germanicum*, *Asagena phalerata*, and *Thanatus arenarius*) was identified on arid grasslands as well and the *A. phalerata* stands out from among the others with its high abundance and incidence rate. Just few individuals of the rare *Drassodes cupreus*, *Coelotes terrestris*, and the previously mentioned ant specialist *Z. rubidum* were observed, and they did not show any habitat preference. The ant-specialist species show that ant as pioneer species are highly abundant on main road verges.

In this study, isopods proved to be the most poorly represented group of species. The highest abundance of species was found on the forested verges, but we also found the lowest species richness there as shown in fig-s 5 and 6.The ordination statistics demonstrates well that woodlice species prefer the wetland to other regions as shown in *Fig. 7*.

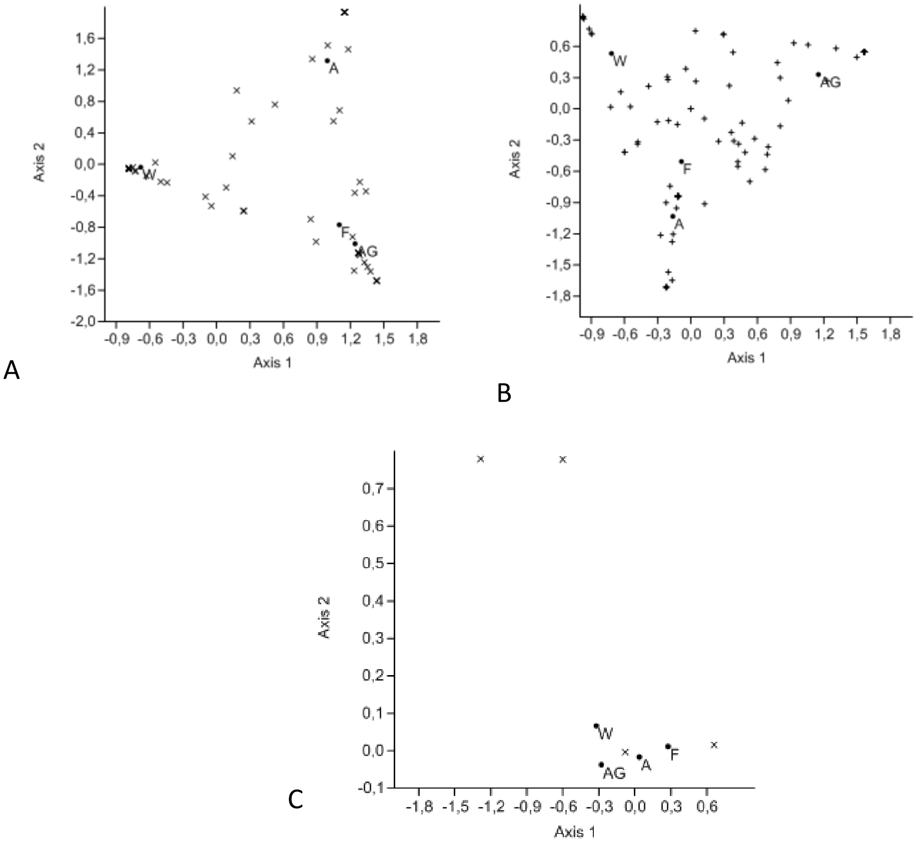

Figure 7. Correspondence analysis of carabidae (A), aranea (B), and isopod (C) species

Each of the four registered isopod species are habitat generalists – they are able to successfully adapt to most continental habitats, whether natural or not. In all of the four investigated sites, *Armadillidium vulgare* of the isopod species was the most prevalent, followed by *Porcellium collicola*. Both of these species were present with a high abundance in forested and agricultural verges. The typical indicator of anthropogenic impacts, the cosmopolitan *A. vulgare*, can be found in most habitats except for protected hardwood forests [47]. *P. collicola* is one of the most frequent species in Hungary – found especially in parks and gardens, it can also be detected in most continental landscapes, excepting densely populated urban areas and protected hardwood forests [47]. Few individuals of *Trachelipus rathkii* and *Porcelliodides pruinosus* occurred in only two types of main road verges. *T. rathkii* is a common species in Hungary [48]: it can be observed near synanthropic environments, moderately humid habitats, and river valleys [49, 50]. *P. pruinosus* is a cosmopolitan, widely spread species in Europe [51] and it can be found in synanthropic habitats indicating active human influence [52]. We expected the presence of exotic species because during our previous studies carried out along highways [13, 14] we have experienced that highway verges contribute to the creation of new habitats for several alien species. The explanation for this might be that highway networks are very different from lower-level roads [53, 54] and the number of sampling sites on main roads was different from the case of the highways.

4. Conclusions

Our study has clearly demonstrated that main road verges prove to be suitable habitats and provide necessary conditions for several carabid beetle and spider species, but isopods do not benefit from this landscape type. Roadside verges are frequently connected with natural reserves and urban habitats, allowing the spreading of species between them. These verges function as invasion pathways for arthropod species, but are also refuges for protected and endangered species in agriculture-dominated landscapes in Hungary. The different surrounding vegetation of the examined main road stretches substantially affects the diversity and the spreading of ground-dwelling arthropods. The observed high diversity of arthropods reflects that the main road verges are important in terms of species richness.

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Varietal performance and correlation of okra pod yield and yield components

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Abstract: Field irrigation experiments were conducted to assess the varietal performance and correlation of pod yield and yield attributes under irrigation at the Teaching and Research Farm, University of Maiduguri, Nigeria, during the 2015 and 2016 dry seasons. The results revealed that the most outstanding for fresh pod yield per plant were okra cultivar Kwadag Y'ar gagure Salkade, and Kwadam, in descending order, with yield ranging from 580.38 to 622.67 g, while the Composite cultivar had the lowest value of pod yield of 428.62 g over the two years. The greatest average values for the number of pods per plant and the number of primary branches per plant were observed for Salkade and Y'ar gagure, respectively. Highest fresh pod length and fresh pod diameter were also exhibited for Salkade and Kwadag. The genotypic coefficient of variation was higher than the phenotypic variation for the entire yield-contributing characters. Days to 50% flowering were positive and highly significant differences associated with plant height, number of pods per plant, and fresh weight per pod could be observed. Path coefficient analysis showed that the number of pods per plant exhibited positive and direct influence on the pod yield across the studied years. Indirect influence of other yield components through this character also contributed mainly towards pod yield. Therefore, days to 50% flowering, plant height, pod length, number of pods per plant, pod diameter, number of primary branches per plant, and fresh weight per pod could be taken into consideration for the selection and development of high pod-yielding varieties in okra.

Keywords: phenotypic, genotypic, correlation coefficient, path analysis, okra pod yield

1. Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a member of the hibiscus family Malvaceae and is a popular vegetable in the world, originating from Africa [1]. It ranks above other vegetable crops including cabbage, amaranths, and lettuce [2]. Okra is an annual, hardy, erect, and high-yielding plant, which varies in size, pod shape, pigmentation, degree of branching, period of maturity, and plant height [3]. Okra is usually grown in Nigeria during the rainy season; it is limited to irrigation in the dry season, especially in the Fadama vegetation [4]. Fresh okra fruit, leaves, buds, and flowers are consumed as vegetables. According to [6], okra fresh fruits contain nutrients including water (88%), protein (1.52 grams), dietary fibre (2 grams), carbohydrates (5.76 grams), vitamin C (13.04 mg), vitamin A (460 IU), calcium (0.4 mg), folic acid (36.5 micrograms), magnesium (46 mg), and potassium (256.6 mg) [7]. Based on [8], okra pod, containing vitamin B_6, calcium, and folic acid, could help in good vision, bone formation, growth, proper circulation of blood, and digestion. The okra pod protein assists in building muscle tissues and enzymes, which control the hormones of the organs. Its soluble fibre also helps in lowering serum cholesterol, reducing heart disease and cancer, especially colorectal cancer.

Information on the genetic variability of crop is essential for the identification and breeding of unique accessions vital for curators of gene banks for germplasm conservation [9–14]. Diversity of crops and morpho-agronomical characters are the first step highly recommended to be taken before in-depth molecular and biochemical studies [15]. Knowledge of correlation between pod yield and its related characters could also improve the efficiency of selection in okra breeding. Progress and gain from selection in any breeding programme depend upon the magnitude of useful variability present in the population and the degree to which the desired traits are heritable. Yield is a complex quantitative character and controlled by several genes that interacting with the environment. Yield is also the product of various factors known as yield components. The efficiency of selection in any breeding programme mainly depends upon the knowledge of association of the characters. The suitable knowledge of such associations between yield and its related characters could appreciably enhance the efficiency of the crop improvement through the utilization of the appropriate selection indices [16]. The correlation coefficient that indicates an association between two characters is useful as a basis for indirect selection for further crop improvement. It does not only assist in the formation of selection indices but it also permits the prediction of correlated response. Selection of parents based on yield alone could be misleading. Correlation analyses are mainly used where values of two traits are analysed based on paired bases. Such results might be positive or negative. The findings of correlation are of immense benefit in determining the most effective methods for choosing cultivars. If there is a positive relationship among the main yield traits, component breeding could be very efficient; on the other hand, when these traits are negatively related, applying simultaneous selection could be challenging in improving the genotypes.

In order to formulate selection indices for the genetic improvement of yield, the cause and effect relationship of the trait is very essential, and this can be achieved through path analysis. Path coefficient analysis provides information on the effect of each character contributing to yield indirectly and directly [17]. The analysis allows breeders to rank genetic components according to their influence. This is also essential in the indirect selection of elite cultivars from diverse genetic populations. Availability of good information of these genetic components existing in various yield-contributing traits and the relative proportion of genetic information in different quantitative attributes are pre-requisites for efficient crop breeding. As okra plays an important role among other annual crops in the economy of nations, further consideration should be given to choosing varieties of higher yield for edible and seed pods. This study was conducted to assess the varietal performance and correlation of pod yield and other related characters of okra cultivars under irrigation with a view to devising a breeding stratagem for development, selection, and conservation.

2. Materials and methods

Field irrigation experiments were carried out at the Teaching and Research Farm, University of Maiduguri (11^0 53′N, 16′E) in the Sudan savannah of Nigeria, during the 2015 and 2016 dry seasons. Of the ten okra cultivars, four (Kwalpuku, Kwadag, Mola kwadag, and Composite) were obtained from the Borno State Agricultural Programme, Maiduguri, Nigeria, and six cultivars (Yar’duwi, Salkade, Yar’gagure, Y’ar kwami, Kwadam, and Lai-lai) originated from the Gagure Gulani Local Government Area of Yobe State, Nigeria. The pictures of the okra grown on the field are presented in plates 1 and 2.

Figure 1. The Okra plant

Figure 2. Okra evaluation on the field

The field experiment was arranged in a Randomized Complete Block Design along with three replications. The plot was 216 m^2, divided into 33 plots of 2 m x 2 m with 1 m spacing between replications, and 0.5 m between treatments. Weeding was carried out manually at 3, 6, and 9 weeks after sowing (WAS). N.P.K. 15:15:15 fertilizer was spread at a proportion of 60 kg N/ha in two doses, first at three weeks after planting and then at flowering. Two millilitres of Ultracide 40EC insecticide in 15 litres was applied fortnightly to control insect pests. Light watering was applied using a watering can every morning and afternoon. This was continued for a week for the rapid and good establishment of the germinated seedlings.

Six plants were randomly chosen from each plot to evaluate the okra quantitative characters. Data were recorded on a number of primary branches per plant, days to 50% flowering, number of pods per plant, fresh pod length, fresh pod diameter (cm), plant height, fresh weight per pod (g), and fresh pod yield per plant (g). Statistical analysis of the data was computed on all measured traits using the Statistical Analysis System (SAS) software for Windows Version 9.2 [18]. Data collected regarding each character were first determined with analysis of variance (ANOVA) distinctly prior to a combined ANOVA in the two years. The variability of each agronomic character was estimated by simple measures such as ranges, means, and values of ‘F’ (variance ratio) test. The SAS GLM procedure employed for the ANOVA was mixed model. Replication was regarded as a random effect, while cultivars as fixed effects. The degree of variation was assessed utilizing % coefficient of variation at $P< 0.05$. Treatment means were separated with the help of Duncan’s Multiple Range Test (DMRT) at 0.05 percent probability suggested by [19].

Genotypic and phenotypic variances were estimated as suggested by [20]. The correlation coefficients were classified into indirect and direct effects utilizing the path coefficient analysis as suggested by [21]. Path coefficient analysis was also determined based on the approach suggested by [21].

3. Results and discussion

In the two years, the varietal mean performances of irrigation for okra crop phenology and fruit characters indicated significant differences in the cultivars for all the agronomic traits (*Table 1*). The most outstanding for fresh pod yield per plant were okra cultivar Kwadag, Y'ar gagure, Salkade, and Kwadam, in descending order, with yield ranging from 580.38 to 622.67g, while the Composite cultivar had the lowest value of pod yield of 428.62 g over the two years. [22] reported that pod yield varied significantly among okra genotypes. The number of pods the flower buds produced is a measure of fruit yield potential, but this potential could not be realized in the two dry seasons because of flower bud abscission. It is, however, interesting to note that once the flower buds have developed into flowers they have equal chances of developing into pods. Breeding for drought tolerance using the number of flower buds could produce a desirable cultivar for the dry season. Plant height at harvest varied from 1.11 to 1.49 m with a mean of 1.25 m (tables 1 and 2) with Kwadag having the highest. The range observed for days to 50% flowering was 33.00–50.33 days with the overall mean of 46.82 days. This revealed that dissimilar okra cultivars take a significantly different number of days to flowering and that cultivars were morphologically different from one another in flower-bearing habits. Several researchers have found that days to flowering varied significantly among the okra genotypes [22, 23]. The greatest average values for the number of pods per plant and the number of primary branches per plant were noted for Salkade and Y'ar gagure, while the highest fresh pod length and fresh pod diameter were exhibited by Salkade and Kwadag. [24, 25] earlier observed significant differences among the okra accessions for the number of primary branches per plant, which implied that the collected cultivars were phenotypically different. The mean fresh pod length and fresh pod diameter ranged between 11.49 and 14.88 cm and between 1.22 and 1.84 cm respectively. The highest fresh weight per pod (16.88 g) was recorded for Y'ar gagure, while Kwalpuku had the lowest (13.14 g). The error of variance of the mean was small for all the characters (*Table 2*). This might be the result of an optimum number of replications (three) and data used in estimating the components of variance for the characters in the two dry seasons. The wide variability recorded for pod yield among the genotypes shows that there is copious opportunity for selection and improvement. This variability is possibly heritable and could be used in the selection processes during improvement programmes.

Significant positive interrelationships among yield and yield-contributing traits that would increase yield are suitable in crop improvement programmes, as they do not only simplify the selection process but it also gain from the selection [17]. The progress from selection does not only depend on the knowledge of interrelationships of yield and yield-contributing characters but it is also useful in the efficient selection of characters. In this study, the phenotypic and genotypic correlation coefficients calculated in the examined okra morpho-agronomic characters are presented in *Table 2*. The phenotypic correlation coefficients of the okra traits showed a highly significant and positive correlation of the number of pods yield per plant with plant height (r = 0.61), days to 50% flowering (r = 0.72), fresh weight per pod (r = 0.44), and pod length (0.43) (*Table 2*). This indicated that increasing these attributes could invariably increase pod yield. These findings also conformed to previous studies [24] in which pod yield per plant was positively associated with the number of branches per plant, number of pods per plant, and pod length. The authors further stressed that traits that are phenotypically associated but not genotypically correlated will be relevant for selection because selection is sometimes due to the phenotypical performance of traits. The significant relationship between plant height and pod yield in flowering also revealed that yield could be improved via the direct selection of plant height during flowering, as a single trait could be practicable during crop improvement. Days to 50% flowering were positive and highly significantly associated with plant height (r = 0.99) and the number of pods per plant with r = 0.45, and fresh weight per pod (r = 0.55). The days to 50% flowering that positively correlated with plant height morphologically indicated that when the internodes' formation ceases at floral initiation the early maturing okra cultivars usually have short status. Similar findings of fruit yield, which was positively and significantly associated with plant height, number of pods per plant, number of branches per plant, and weight per pod, have been observed by many researchers [26–28]. This also conformed to the report of [29]. These studies, therefore, showed the prospect of improving early-, short-, and higher-yielding okra cultivars by employing the aforesaid associations.

It is of interest to note that genotypic correlation coefficients (*Table 3*) were comparable in magnitude with phenotypic coefficients, except the number of pods per plant with negative and non-significant correlation with fresh pod yield per plant. A high genotypic correlation implied that the selection of one character directly affected the other character. Conversely, low or non-significant correlation suggested independence of association that would be possible to select for the two characters in question for diverse directions. There were positive significant phenotypic and genotypic correlations of fresh weight per pod with days to 50% flowering, pod length, and pod diameter, similar to the findings of [24]. This has also revealed that genetic factors were responsible for these associations. The significant positive association between plant height and number of pods per plant was not surprising because pods in okra are usually borne in the leaf axil at the nodes; number of pods per plant was also found to be strongly correlated positively with the number of nodes on the main stem [30]. Delay in fruiting could be a result of prolonged vegetative growth induced by certain factors of the environment such as photoperiod.

Even though both phenotypic and genotypic correlations were comparable in magnitude, genotypic correlations were higher than phenotypic correlations for entire pairs of traits, indicating that these characters were genetically controlled and that their expression is lessened under the influence of environment. Several works [11, 31] found that phenotypic correlation is an aggregate of environmental and genotypic correlations. However, it has been noted that genotypic correlations have always been stronger than phenotypic correlation coefficients in many crops. The relationship of days to 50% flowering and fresh pod yield per plant was negative and significant at both phenotypic and genotypic levels in this study. This connoted that exceedingly early maturity might enhance decline in the pod yield of okra [16, 24, 32. 33]. Since the pod yield did not correlate phenotypically and genotypically with days to 50% flowering, deviations from anthesis to physiological maturity could influence pod yield as compared with plant emergence to anthesis period. Association between pod yield per plant and pod diameter was low at the phenotypic and genotypic levels across the two years, indicating that there is ample opportunity of receiving plum pods with the least leeway in improving fresh pod yield per plant.

The significant phenotypic and genotypic relationship between pod yield per plant and plant height and number of branches per plant might be related to appropriate light interception provided by greater height. This could also provide higher photosynthetic capacity acquired by other leaves that were on the branches [34]. It is from the leaves that the plants manufacture their food through photosynthesis. The higher the number of leaves, the higher the yield in crops. This is based on higher photosynthetic capacity and photosynthetically active radiation (PAR) via enhanced leaf area index, higher intercepted and fraction of intercepted radiation (FI) as well as its utilization efficiency. Also, in okra, more branches produced increased fruit-bearing nodes.

Table 1. Combined mean performance of ten okra genotypes for fresh pod yield per plant and other related characters under irrigation between the 2015 and 2016 dry seasons in Maiduguri (Nigeria)

Genotypes	**Days to 50% flowering**	**Plant height at harvest (m)**	**Number of primary branches per plant (no)**	**Number of pods per plant (no)**	**Fresh pod length (cm)**	**Fresh pod diameter (cm)**	**Fresh weight per pod (g)**	**Fresh pod yield per plant (g)**
Y’ar duwi	43.11	1.14	2.84	25.34	12.34	1.56	15.96	479.38
Salkade	50.33	1.44	4.23	33.75	14.88	1.22	16.23	598.65
Y’ar gagure	50.75	1.39	3.51	34.45	14.73	1.83	16.56	616.97
Composite	44.23	1.11	1.89	22.54	12.52	1.48	14.73	428.62
Kwalpuku	43.00	1.18	3.18	23.92	11.49	1.51	13.14	488.38
Kwadag	49.31	1.49	3.75	34.35	14.37	1.84	16.83	622.67
Mola kwadag	49.11	1.21	2.66	24.88	12.84	1.48	14.64	457.92
Y’ar kwami	45.34	1.18	3.33	25.18	13.37	1.52	14.34	431.63
Kwadam	45.11	1.22	1.67	28.23	13.64	1.44	15.11	580.38
Lai–lai	47.93	1.16	2.12	28.64	11.59	1.52	14.98	532.85
Mean	46.82	1.25	2.92	28.03	13.08	1.54	15.25	523.75
Range	7.33	0.38	2.56	11.91	3.39	0.62	3.68	194.05
SE±	11.849	6.111	2.759	6.654	6.149	11.234	10.171	11.73
LSD α 0.05	2.23*	1.11*	1.45*	4.62**	2.14*	1.01*	1.43*	3.57
CV%	4.36	7.82	6.39	4.92	10.52	7.45	7.18	6.83

Table 2. Ranges, means, and values of ‘F’ from estimates for fresh pod yield per plant and other related characters of okra cultivars under irrigation between the 2015 and 2016 dry seasons in Maiduguri (Nigeria)

Characters	**Range of variation**	**Means**	**S.E.**	**Standard deviation**	**Error variance**	**F value**
Days to 50% flowering	33.00–50.33	46.82	0.91	3.45	0.54	45.28
Plant height at harvest (m)	1.11–1.49	1.25	0.84	0.33	7.25	26.72
Number of primary branches per plant	1.67–4.23	2.92	1.25	0.34	3.52	35.98
Number of pods per plant	22.54–34.45	28.03	1.12	1.48	2.35	10.63
Fresh pod length (cm)	11.49–14.88	13.08	1.38	1.32	7.75	40.73
Fresh pod diameter (cm)	1.22–1.84	1.54	1.52	0.87	0.53	22.53
Fresh weight per pod (g)	13.14–16.88	15.25	1.58	0.12	3.78	33.54
Fresh pod yield per plant (g)	428.62–622.67	523.75	0.47	0.83	1.52	67.93

PHT: plant height (cm), DF: Days to 50% flowering, NBP: Number of primary branches per plant, NPP: Number of pods per plant, PL: Pod length (cm), PD: Pod diameter (cm), FPW: Fresh weight per pod (g), and FPY: Fresh pod yield per plant (g)

Table 3. Genotypic and phenotypic correlations for okra pod yield and yield attributes combined across the years under irrigation in Maiduguri, Nigeria

S/N		PHT	DF	NBP	NPP	PL	PD	FPW	FPY
PHT	rg	1.00							
	rp	1.00							
DF	rg	–0.55**	1.00						
	rp	–0.53**	1.00						
NBP	rg	0.21	0.26	1.00					
	rp	0.22	0.27	1.00					
NPP	rg	0.52**	0.47**	0.19	1.00				
	rp	0.48**	0.46**	0.20	1.00				
PL	rg	0.60*	0.14	–0.50**	0.18	1.00			
	rp	0.59*	0.11	–0.47**	0.19	1.00			
PD	rg	0.18	0.11	–0.13	–0.30	–0.22	1.00		
	rp	0.17	0.13	–0.10	–0.27	–0.19	1.00		
FWP	rg	0.29	0.52**	0.18	0.10	0.53**	0.85**	1.00	
	rp	0.25	0.48**	0.10	0.07	0.51**	0.78**	1.00	
FPY	rg	0.61**	–0.51**	0.32*	0.79**	0.72**	0.25	0.75**	1.00
	rp	0.50**	–0.43**	0.29*	0.65**	0.63**	0.20	0.61**	1.00

*,**, significant at $P< 0.05$ and $P< 0.01$ respectively.

PHT: plant height (cm), DF: days to 50% flowering, NBP: number of primary branches per plant, NPP: number of pods per plant, PL: pod length (cm), PD: pod diameter (cm), FPW: fresh weight per pod (g), and FPY: fresh pod yield per plant (g)

The pod yield of okra is governed by several agronomic traits with either indirect or direct contribution to the yield. The path coefficient analyses employed to acquire more information on the associations between morpho-agronomic characters and their influences on okra fresh pod yield per plant are described in *Table 4*. The number of pods per plant had the greatest direct influence on pod yield (p = 6.63), followed by fresh weight per pod (p = 6.13), which had positive genotypic association with pod yield. Previous literature on path coefficient analysis showed that the number of pods per plant and fruit weight had positive and high direct effects on fruit yield, indicating their importance as reliable selection criteria for the improvement of yield in okra [22, 35].

Table 4. Path coefficient of okra fresh pod yield and other related attributes combined across the years under irrigation in Maiduguri, Nigeria

Character	**Genotypic correlation**	**Indirect effects**						
		PHT	**DF**	**NBP**	**NPP**	**PL**	**PD**	**FPW**
PHT	0.58**	**–3.56**	1.67	0.47	–0.56	1.31	–0.76	0.17
DF	–0.48**	0.41	–0.87	0.18	0.12	1.29	0.64	0.41
NBP	0.27*	–0.55	0.59	–1.67	0.13	0.45	0.83	0.73
NPP	0.77**	0.80	2.83	–2.05	6.63	1.23	–1.71	0.34
PL	0.74**	0.92	1.45	–1.72	0.49	–3.57	3. 11	0.59
PD	0.21	–0.30	–5.33	2.11	–0.73	1.33	3.76	–0.42
FPW	0.62**	–0.63	–7.76	–0.79	0.81	–4.81	1.22	**6.13**

*,**, significant at P< 0.05 and P< 0.01 respectively. Direct effect and indirect values are provided in diagonal and off-diagonal, respectively.
Residual effect (h = 0.30). PHT: plant height (cm), DF: days to 50% flowering, NBP: number of primary branches per plant, NPP: number of pod per plant, PL: pod length (cm), PD: pod diameter (cm), FPW: fresh pod weight (g)

It is of the opinion that by enhancing ear weight because of the increased absorption of photoassimilates, the best segment of assimilates remobilize to grains, and consistently enhance grain weight. However, as direct and indirect influences of the number of pods per plant were prominent, these had a positive impact on pod length and pod diameter, which could have resulted the high correlation coefficient that existed between pod yield and the number of pods per plant (rg = 0.77). The direct response of this character could be attributed to the indirect positive influence of plant height, days to 50% flowering, pod length, and fresh weight per pod. Some researchers reported that plant height exhibited positive direct influence on okra pod yield per plant [7, 36]. This, therefore, suggests the vital and successful achievement in choosing these characters once high yield is the main objective. Pod length had the highest negative direct influence on pod yield despite its positive genotypic interrelation with pod yield per plant. This showed the flaw of selection based on inter-character association only. Therefore, the selection of this character may not produce the desired results. While direct influence of plant height on fruit yield resulted a negative value (p = –3.56), its correlation coefficient also had a negative value (rg = –0.58), whereas it had a high positive indirect influence on pod length and number of pods per plant.

Regardless of the importance of pod-yield-contributing traits used in path coefficient analysis computation, the residual effect (h = 0.10) is relatively low, denoting that the characters considered in this analysis have sufficiently accounted for the variability in okra yield as supported by many researchers [37–39]. It is projected that 78.93% difference in pod yield at a genotypic level is determined. This further portrayed the occurrence of some factors that contributed to okra pod yield that were not considered in this study. It could also be due to that correlation coefficients were ordinary estimates and were constantly used for rounding-off errors. Pod length, days to 50% flowering, number of pods per plant, and weight per pod are favourable characters that could be utilized in choosing high pod yield in okra due to their highly significant genotypic and phenotypic associations with fresh pod yield per plant in this study. It was also observed by [40] that a significant increase in each of these parameters tested could lead to an increase in the total okra pod yield. These evaluated traits also had the greatest indirect and direct influences via the majority of other traits. It is apparent that these prominent agronomic parameters could be given attention as essential condition in advancing okra varieties for high pod yield.

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Joint overview of the Rhédey Castle and Park in Sângeorgiu de Pădure based on maps resulting from military measurements

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Abstract: Sângeorgiu de Pădure (in Hungarian: Erdőszentgyörgy) is situated 37 km south-east of Târgu-Mureș, in the Târnava Mică valley, at an altitude of 340 m above see level. It was first mentioned in 1333 as 'Sancto Georgio's' in contemporary documents. In the middle of the 16th century, the most important holder was the Göncruszkai Kornis family [1]. Councillor John Rhédey became the owner in 1627, when the settlement's name was already the actual name 'Sangherghiu de Padure'. On January 16, 1629, it was donated by Gábor Bethlen to John Rhédey and his wife, Margit Kornis. According to tradition, a reinforced abbey, church, and monastery were placed where the actual castle and its garden were settled. In 1569, the new building named Kornis Castle was built on the ruins of the former monastery. Here was born on September 1, 1812 Klaudia Rhédey, her later name being Countess of Hohenstein, known as the founder of the well-known British Windsor house dynasty.

Keywords: Rhédey Castle, Sancto Georgio, Rhédey Klaudia, Kornis family

1. The history of the castle

Using materials from the former Castle of Kornis, the actual castle was built up by masters from Târgu-Mureş in the second half of the 19th century – more precisely its first version of today's Rhédey Castle. Constructions started on Rhédey (V.) Sigismund's (1727–1758) and his wife's, Catherine's, order. After Sigismund's death, the owners became his son Ferenc, and then (1756–1772), after his death, the castle passed to László. The building suffered further modifications during László Rhédey's and his wife's ownership, in the period of 1807–1809 [2].

Countess Claudine Rhédey de Kis-Rhéde, daughter of Count László Rhédey IX, was the wife of Duke Alexander of Württemberg, but she died tragically in Gratz, Austria, in 1841. Their child, Prince Francis of Tech was educated in England and married an English princess. Their daughter, Princess Victoria Mary, wife of King George V, erected a marble slab to the memory of her grandmother, Claudine, in the Reformed Church in Sângeorgiu de Pădure [3]. The plaque reads the following text in Hungarian and English:

"To the memory of Countess Claudia Rhédey, Countess of Hohenstein, wife of Duke Alexander of Württemberg, his Royal Highness. Erected by her granddaughter: Mary, Princess of Wales."

After World War I, the owner of the Rhédey Castle was the Schuller business house and from 1935 onwards several governmental agencies operated in the building. The castle garden can be thoroughly studied with the help of the military surveys maps. According to the I. Military Map, the castle around the park as well as the garden can be well distinguished. To the north of the castle, on a hillside, a crypt can also be seen. The survey shows approximately ninety images on the northern side of Târnava Valley (*Figure 1*).

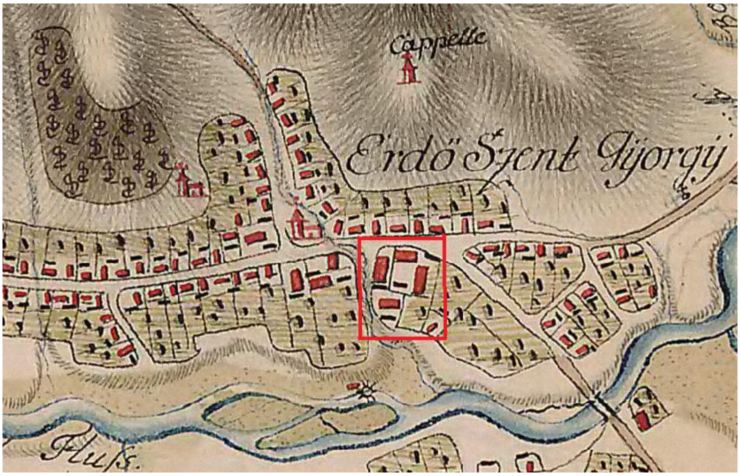

Figure 1. The Rhédey Castle on the I. Military Survey Map

The II. and III. Military Survey Maps are very similar to each other. Already listed in the appendix, the castle park is well distinguishable on the II. Military survey map. Around the castle, an amazing French garden can be seen with walkways and diagonally arranged, trimmed plant compositions. In the middle of the garden, a fountain was built and other characteristic structures of French gardens as greenhouses and small forest parks were also constructed. The best images of the historic park come from a 19th-century engraving that shows the former French garden as it once was (*Figure 2*).

Figure 2. Engraving of the Rhédey Castle in Sângeorgiu de Pădure at the beginning of the 19th century – Biró J., 1943, LVI. plate

2. The actual stage of the castle and its park

The Rhédey Castle's actual structure reveals the late Baroque style and reminds more of an urban or city castle than of a rural bunk. The historic building was finished in its actual form in the years 1807–1809, during the reconstruction works (*Figure 3*) [2].

Figure 3. The Rhédey Castle in Sângeorgiu de Pădure – original drawing of Károly Cserna – keptar.oszk.hu/060218

On the ground-floor rooms, the floors are knuckled and ornately painted. The ceiling of the large salon on the first floor is higher than any other rooms; however, a wood-beamed ceiling was created inside the salon during the communist regime. The original, ornate paintings remained intact in this way. The dominant elements on the eastern and western façades are the balconies [4]. The historic building was the place of the local elementary school between 1948 and 2010. In 2011, renovation works were carried out funded by the Ministry of Culture and National Heritage: the castle doors, windows, roof linings, and the building's pillars were rebuilt to their former and original state [5]. Today, the castle is planned to be used for the purposes of tourism and culture and to give place to exhibitions, restaurants, and wineries (*Figure 4*).

Figure 4. The Rhédey Castle in Sângeorgiu de Pădure – MTI Photo: László Beliczay

On the basis of the surveys, the original castle park was almost destroyed and used for agricultural purposes. Just a small garden place remains in front of the Castle, incorporating a monument of World War II. In spite of its historical importance, the former park and garden survive only in historic documents, maps, drawings, and photographs (*Figure 5*).

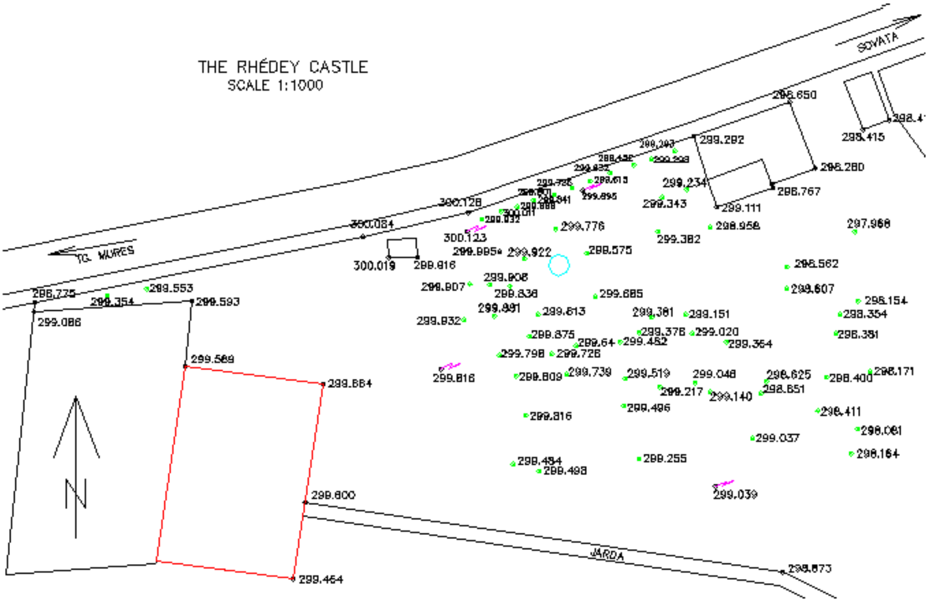

Figure 5. Geodetic survey of the Rhédey Castle

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Short evaluation of eggplant production and variety usage in Romania – short overview and perspectives

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Abstract: Eggplant (Solanum melongena L.) became wide-spread after the First World War in Romania. The most important growing areas of this plant are located in the southern, south-eastern, and south-western parts of Romania and are usually cultivated on open fields as well as in unheated greenhouses. In the past, only Romanian OP varieties were grown. Over the past ten years, requirements of eggplant varieties have increasingly shifted towards productivity, uniformity, and high tolerance to stress factors, diseases, and pests. Therefore, the cultivation of hybrids and the disappearance of Romanian OP cultivars have intensified. Due to monoculture practice, the soil was attacked by pathogens in many areas. As a result, grafting became necessary to be put into practice. Consumption of eggplants is about 4.5 kg per person per year in Romania and they are consumed in many different ways such as baked, grilled, or as a special cream. Agrosel SRL has gained a significant role in supplying the Romanian vegetable seed market over the past twenty years and has started its own hybrid programme to renew eggplant production in Romania.

Keywords: cultivation, breeding programmes, vegetable crop, seed production

Eggplant is a tropical perennial herbaceous plant often cultivated as a half-hardy annual in temperate climates. The species *S. melongena* has been cultivated and regarded as a native in South and East Asia from ancient times. In Europe, it was introduced through the Mediterranean area (first in Greece and Italy) by the Arabs in the early Middle Ages (around 1200) (Singh et al. 2004, Al-Awwam I. 1889).

In Romania, it was propagated by Greek and Bulgarian gardeners in the 18th century and it became wide-spread after the First World War. In 1992, the cultivated areas of eggplant were 4,500 ha, which has significantly increased to almost 9,500 ha with a 125,000 t yield in the recent years (Echim I. et al. 1983, FAO 2013).

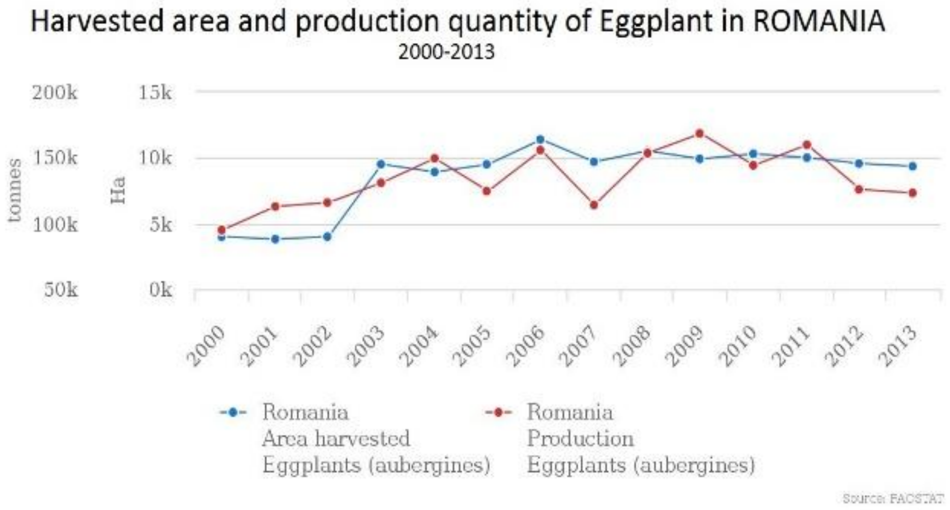
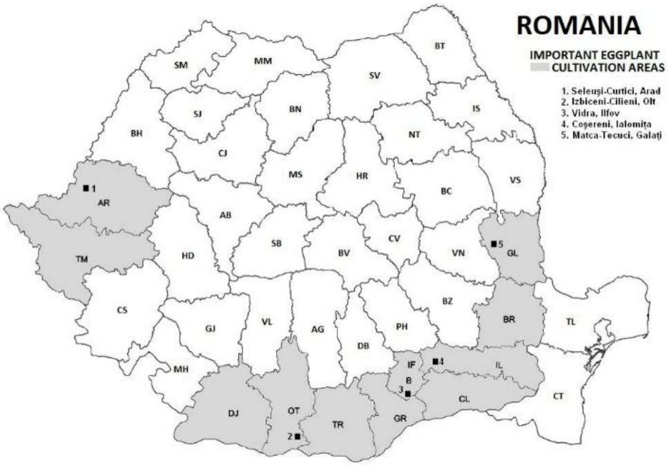


Figure 1. Harvested area and production quantity of eggplant in Romania (FAO 2016)

The most important growing areas of eggplant are located in the southern, south-eastern, and south-western parts of Romania: Matca-Tecuci, Galaţi; Coşereni, Ialomiţa; Izbiceni-Cilieni, Olt; Vidra, Giurgiu; Seleuşi-Curtici, Arad.

Eggplants are usually cultivated on open fields as well as in unheated greenhouses. For open-field cultivation, nursing time begins with sowing at the end of February and planting time starts when the temperature of the soil reaches a minimum of 14 °C in 10–15 cm depth. The harvest begins when the fruit reaches market maturity and a 30–40 t/ha yield can be obtained. To achieve market maturity earlier, plastic tunnels are being used to cover the plants.



Source: Agrosel 2016

Figure 2. Important eggplant cultivation areas (AGROSEL)

Figure 3. Open-field cultivation (AGROSEL)

For unheated greenhouse cultivation, nursing time begins about three weeks earlier; planting time begins when the air temperature remains stable at 15 °C outside the greenhouse. Eggplant production under heated greenhouses still does not exist (Ciofu R. et al. 2003).

Figure 4. Unheated greenhouse cultivation (AGROSEL)

In the past, only Romanian OP varieties were grown, namely **Danubiana** (55–65 cm plant height, light green colour, fruit weight 240–320 g, ovoid, dark violet colour);

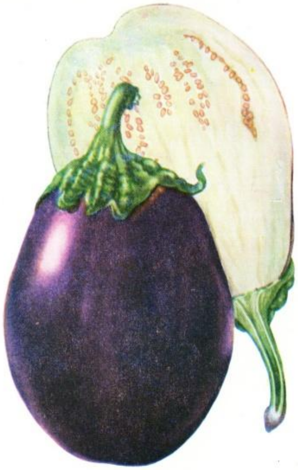


Figure 5. Danubiana variety (Andronicescu D. et al. 1970)

Bucureștene 33 (70–80 cm plant height, grey-green colour, fruit weight 250–300 g, pear-shaped, dark violet-black colour);

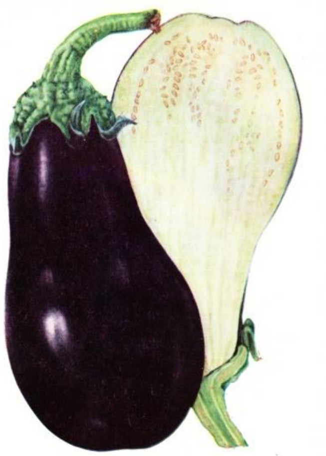


Figure 6. Bucureștene 33 variety (Andronicescu D. et al. 1970)

Pana Corbului 36 (75–85 cm plant height, green colour, fruit weight 240–300 g, pear-shaped, glossy dark violet-black colour);

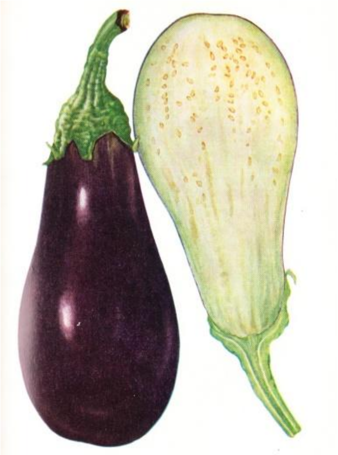


Figure 7. Pana Corbului 36 variety (Andronicescu D. et al. 1970)

Lidia (60–65 cm plant height, fruit shape obovate, glossy dark violet-black colour, tolerant to *Verticillium dahlie* and *Phytophthora parasitica*); **Narcisa**. In the 1960s, a hybrid created in Ţigăneşti, Romania, called **Delicia** (70–80 cm plant height, violet-green colour, fruit weight 300–350 g, obovate-pear shaped, glossy dark violet-black colour, tolerant to *Fusarium oxysporum* f. sp. *melongenae*) was mentioned (Gheorghe A. et al. 1997, Andronicescu D. et al. 1970).

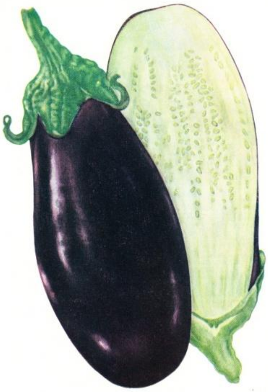


Figure 8. Delicia hybrid (Andronicescu D. et al. 1970)

Over the past ten years, requirements of eggplant varieties have increasingly shifted towards productivity, uniformity, and high tolerance to stress factors, diseases, and pests. Therefore, the cultivation of hybrids and the disappearance of Romanian OP cultivars have intensified. The most important international hybrids in Romania are: Aragon, Mirval, Classic, and Mirabelle with more or less cylindrical shaped and dark purple-black fruits. White eggplant hybrid Bibo is also becoming accepted by consumers.

Figure 9. Infested plants (AGROSEL 1970)

Due to monoculture practice, the soil was attacked by soil-borne pathogens and nematodes in many areas, which are very destructive in vegetable crops and can have an impact on the producers’ income. Soil fumigation has been an essential component of greenhouse production since the 1960s, but it is a very expensive method. As a result, grafting (known for many years) has become necessary to be put into practice. Several trials have been carried out on grafted eggplants in Romania over the past years. The experiment in The Institute of Research and Development for Industrialization and Marketing of Horticultural Products Romania has successfully proved the advantage of this method: there was a significant reduction of infested plants, the production increased up to 34%, and the quality of the harvest improved by 19% (Bogoescu M. et al. 2014). Furthermore, another research aimed to establish the technology for obtaining the eggplant grafted seedlings by manual or mechanical grafting with a semi-automatic machine. For the manual grafting of 1,000 eggplants, 1.52 men were required per day, while when a semi-automatic machine was used only 0.16 man per day was necessary. The cost price reduction of grafting with semi-automatic machine was over 16% (Bogoescu M. et al. 2013).

The consumption of eggplants is about 4.5 kg per person per year in Romania. They are consumed in many different ways such as baked, grilled, or as a special cream and they are also one of the main ingredients of the popular Balkan food, zakuszka.

Agrosel SRL has gained a significant role in supplying the Romanian vegetable seed market over the past twenty years. The company is one of the leaders in the small seed packages segment in Romania. In 2004, the firm started its own breeding programme to increase the diversity of the eggplant cultivars available in Romania.

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Evaluating the effect of plant population densities and nitrogen application on the leaf area index of maize in a reclaimed wetland in Kenya

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Abstract: Maize is the main staple food in Kenya with over 90% of Kenyans relying on it. While the annual national consumption is increasing, the production of this crop has been on the decline in the last two decades. Maize production in Kenya fell by 33.4% in 2013 with Nyeri among the counties said to be grappling with the production of this crop. Land pressure is one of the major causes of decreased availability of food as well as soil depletion and encroachment upon fragile ecosystems such as wetlands. Nitrogen is a key nutrient in the production of maize, and its deficiency is a major factor limiting its production. This study investigated the effect of N application at 120 kg N/ha and maize density on the Leaf Area Index in reclaimed wetland soils in an experimental set-up comprising a randomized complete block design with three replications. The research was carried out in Nyeri County, Kenya. Leaf Area Index (LAI) was determined using the given SunScan formula. Measurements were done continuously until crop physiological maturity. Results indicated that the leaf area index increased with nitrogen application and reduced with spacing for most treatments. There were no significant differences between the two methods (Copy Method and SunScan). Leaf Area Index (LAI) was high in treatments containing nitrogen and high plant density. It was concluded that high plant density gives high LAI. 50 cm * 12.5 cm (-N) and 50 cm * 12.5 cm (+N) are the recommended plant densities for the site.

Keywords: maize density, land use, N application, food supply, agriculture

1. Introduction

Crop yield commonly depends on the total amount of the intercepted photosynthetic active radiation (PAR), particularly when crop growth is not limited by other factors such as nutrients, water deficiency, or temperature extremes. The availability or deficiency of nitrogen also determines the leaf area index of crops, such as maize, since it is very essential for proper leaf formation, and thus very important in the determination of the photosynthetic ability of the crop, and hence productivity. Leaf Area Index (LAI) is defined as the total one-sided green leaf area per unit ground surface area [1]. LAI controls photosynthetic activity, influences CO_2 exchange in the atmosphere, and thus plays an important role in ecological studies. LAI is used in ecosystem analysis to monitor canopy structure, water and energy exchange, and to scale up ecosystem processes from land to landscape level. LAI is also important in environmental sciences in detecting anthropogenic and natural stresses of forest systems that may affect water quality and results in drought, desertification, and deforestation.

Planting densities have been found to contribute towards significant increase in grain yield [12]. Maize yield response to density depends on the variety [3], nutrition, and environmental factors [4]. Biomass yield, plant height, and ear length have been found to increase with increase in plant density and N rate [12], thus increasing the leaf area [5].

Management practices, such as fertilizer application or thinning, have a strong effect on LAI. The leaf area may be decreased by N deficiency, depending on the severity. According to [7], leaf breadth decreased under high soil nitrogen level and high plant density, while leaf area and yield increased with a higher rate of nitrogen. Thus, a combination of factors, which include the difference in assessment methods, nitrogen rate, and planting density, may therefore lead to widely varying LAI values. The objectives of this study were (i) to assess the effects of varying plant densities on the Leaf Area Index of maize, (ii) to assess the effects of nitrogen fertilizer application on the LAI of maize on reclaimed wetlands in Nyeri County, and (iii) to determine the relationship between the SunScan and Copy methods of LAI determination.

2. Materials and methods

The research was carried out for two rainy seasons (short rains 2012 and long rains 2013) in a ‘small wetland’ in the Karatina – Mathira Constituency, Nyeri County. The wetland lies on a plateau directly below the southern side of Mount

Kenya. The main economic activity of people here is subsistence farming of vegetables, maize, beans, arrowroot tea, and coffee [4]. The area is densely populated with 304 inhabitants per km^2. The experimental plots, each measuring 5 by 1.5 m, were laid out randomly and planted with maize (Hybrid 516 – Kenya Seed Company). Different spacing was applied on the plots while nitrogen was applied as split-plot (some plots were treated with nitrogen, while others remained without) and laid out in a randomized complete block design. A basal application of Muriate of Potash (MOP) was applied to provide phosphorus for maize (tables 1 and 2).

Table 1. Biophysical characteristics of the study site

Description	**Characteristics**
Longitude	37^{0}05'57"E
Latitude	00^{0}27'58"S
Altitude (m.a.s.l.)	1868
Agro-ecological zones (AEZ)	Upper Midland Zone
Annual rainfall (mm)	1450
Temperature range (^{0}C)	11–27
Population density (inhabitants/km^2)	304
Soil properties	
Sand (%): Silt (%): Clay (%)	16:26:58
Textural class	Clay
Soil type	Fluvisols/ Gleysols
Moisture Regime	Hydric

In this study, both direct (non-destructive) and indirect (destructive) methods were applied in the measurement of LAI. Leaf Area Index (LAI) was determined directly by taking a set of sample (based on previous research data) foliage from a plant canopy, measuring the leaf area per sample plot, and dividing it by the plot land surface area. Indirect methods of LAI measured the canopy geometry or light extinction using LAI equipment (Sun Scan) and related it to LAI.

The non-destructive leaf area index measurements were carried out using the SunScan canopy analysis system (Delta-T Devices, Cambridge, UK). The SunScan probe has an array of 64 PAR sensors embedded in a 1-metre-long probe and is connected via cable to a handheld PDA (*Figure 1*).

Figure 1. Delta-T Sunscan equipment for measurements of LAI

Table 2. Description of the treatments' application in the experiment

Treatment description	Plant density/ha	Nitrogen applied (Urea)
100 * 12.5 (-N)	80,000	0
100 * 12.5 (+N)	80,000	120 kg N/ha
100 * 25 (-N)	40,000	0
100 * 25 (+N)	40,000	120 kg N/ha
50 * 12.5 (-N)	160,000	0
50 * 12.5 (+N)	160,000	120 kg N/ha
50 * 25 (-N)	80,000	0
50 * 25 (+N)	80,000	120 kg N/ha

The probe is placed under the canopy, where 3 readings are taken from every point (6 points per plot), which amounts to 18 readings from every plot (*Figure 2*). When taking measurements, the rod is held in the same angle and in the same direction from the beginning to the end of sampling to minimize variations. SunScan readings are taken when the sky is clear to avoid the interference of the clouds. The Leaf Area Index model for SunScan is as follows:

Equation 1: $K(X, \theta) = \sqrt{(X^2+\tan(\theta)^2)} / X+1.702(X+1.12)^{-0.708}$ (1)

θ – Zenith angle of the direct beam
X – ELADP (Ellipsoidal Leaf Angle Distribution Parameter)

Readings are in units of PAR quantum flux (mol m^{-2} s^{-1}) and units of LAI ($m^2.m^{-2}$).

2.1. Procedure for determining Leaf Area Index using the Copy method (destructive method)

Another method known as the Copy method was also used as a comparison for the leaf area index measurement since it is affordable. The method requires stripping off the leaves from the plant in the field, storage (to avoid shrinkage), and copying of the leaves using a normal photocopy machine. The copied leaf images from the paper were cut and weighed and a plain paper of the same size as the paper leaves was also weighed to assist in calculating the leaf area. The paper leaves were then air-dried and leaf area was calculated as follows:

Equation 2: LAI = weight of leaf paper (g) / (weight of paper/area of paper) (2)

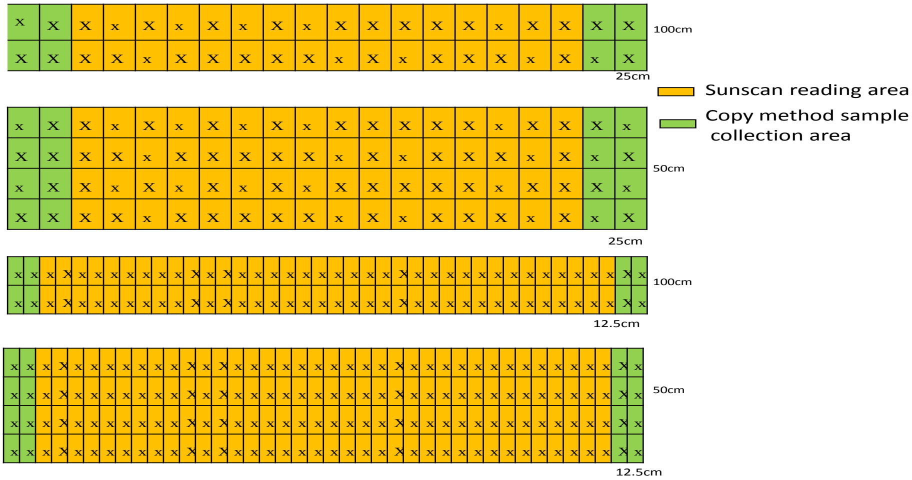

Figure 2. A schematic drawing of maize spacing in the field and the positions where the SunScan probe was positioned while taking the readings for the Leaf Area Index

Data analysis

Statistical analysis was done using the following model, as applicable to the RCBD design.

$$Y_{ij} = \mu + \alpha_i + \beta_j + \sum_{ij}, \qquad (3)$$

where: Yij = Plot Observation, μ = Mean of observations, α = Effect due to treatment application, β_j = Effect due to blocking, $\sum_{ij}$ = Experimental error.

Data was managed using Microsoft Excel and subjected to Analysis of Variance (ANOVA) with Least Square Difference (LSD) using Genstat statistical software version 12.

3. Results and discussion

N values were above 0.25% before planting the maize, and are therefore considered high according to [10] and [11]. At the start of the experiment, the % soil N ranged from 0.44 to 0.48%, while at the end of Season 1 the range was 0.34–0.36%. This was a minimal decline in soil N, and therefore the soil may not be considered to have lost a lot of nitrogen through the various mechanisms like leaching. At the end of Season 2, the values of soil N did not differ so much as compared to the values at the end of Season 1, indicating that the rate at which the crops used soil N in both seasons was constant (*Figure 3*).

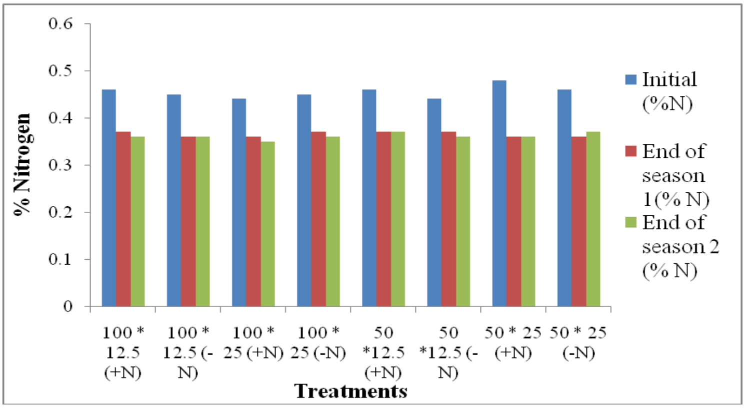

Figure 3. Shows nitrogen values of the soil at the site

Effect of nitrogen fertilizer application and plant population density on the leaf area index

LAI measurements using SunScan direct method

The LAI means for the growing period indicated as day of year (DOY) for treatments with nitrogen and without nitrogen are as shown below. The LAI values obtained during the first season indicated that the treatments with nitrogen application had higher LAI values compared to those treatments without N application. Maize spacing of 50 cm ∗12.5 cm for the treatments to which nitrogen fertilizer was added had the highest LAI ranging between 4.7 and 6. The spacing of 100 cm ∗ 12.5 cm recorded the lowest LAI values ranging between 2.2 and 3. This indicates that the high plant density limited the light penetration to the crop, and hence the lower LAI values observed. An increase in LAI index was observed from the early stages of maize growth to physiological maturity, and this is due to the transfer of products, which occurs after silking. A similar observation was reported by [10] (*Figure 4*). It also shows a trend of the leaf area index of maize between the beginning of the season or 21 days after emergence of maize up to physiological maturity. The treatment 100 ∗ 12.5 (+N) had the highest mean value for LAI, but it was not significantly different from the mean of LAI on treatment 50 ∗ 12.5 (+N) at 99% level of probability. LAI was highest ($P \leq 0.01$) on DOY 19, which was taken when the maize was at physiological maturity.

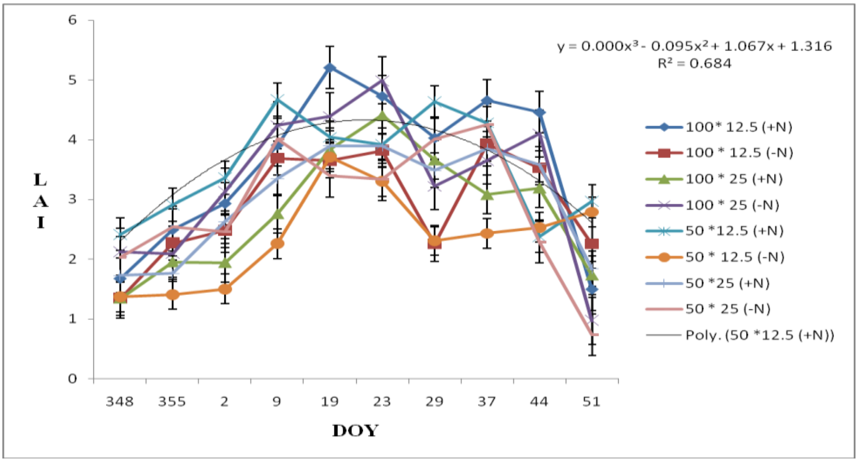

Figure 4. Changes in LAI with time (Days Of the Year) in the different treatments. (The arrows indicate hailstone attack during the growing period)

LAI measurements using the Copy method – indirect method

The spacing of 50 cm ∗ 12.5 cm (+N) had the highest LAI ranging between 2.7 and 5.8. The spacing of 100 cm ∗ 12.5 cm (-N) recorded the lowest LAI values ranging between 1.8 and 3.5. However, the trends of LAI when measured using the copy method were different from the SunScan method. This is attributed to possible errors – a common disadvantage of the manual method of LAI determination (*Figure 5*).

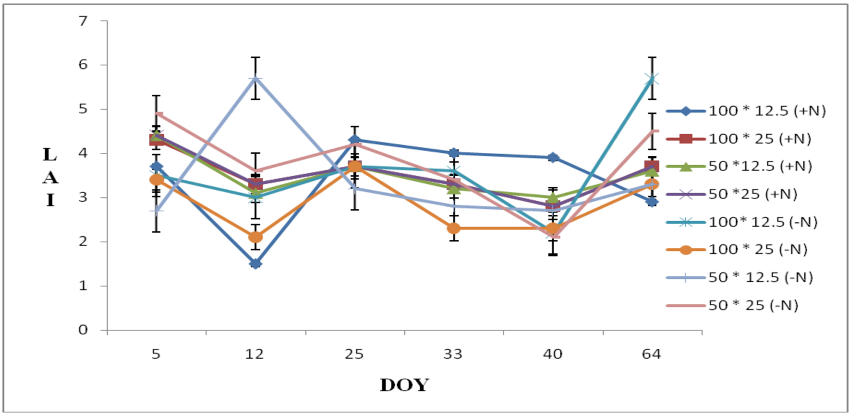

Figure 5. LAI means for the growing period (DOY) using copy method

Several studies have used indirect methods to estimate LAI in field crops and forests with reasonable successes. The values of LAI were also high in the treatments which contained additional nitrogen compared to those which had no Nitrogen added. This, therefore, shows that nitrogen is an important nutrient since it has a positive effect on the Leaf Area Index of maize. Leaf area serves as the dominant control over primary production (photosynthesis), transpiration, energy exchange, and other physiological attributes pertinent to a range of ecosystem processes. LAI constantly changes during the growing period of the crop and the vegetative stage showed higher LAI values compared to the stage after silking, which is attributed to the transfer of products as the crop enters the physiological maturity stage [7].

Comparison of the SunScan and Copy methods of LAI measurements during the growing period

There was an increase in leaf area index from emergence to physiological maturity, as observed in figures 5 and 6. The Copy method, which was an indirect method of measuring leaf area index, showed slightly lower values for the LAI compared to the SunScan method during all measuring times.

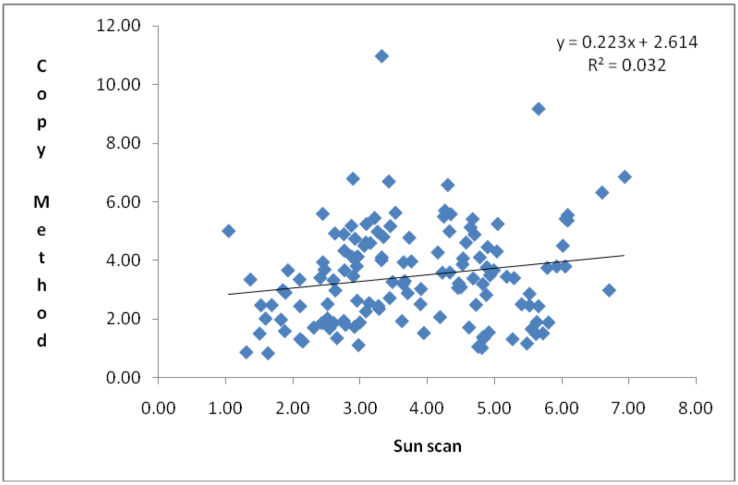

Figure 6. Correlation between the Copy method and SunScan method of measuring Leaf Area Index

However, there was a similar trend in the values with treatments with N application having higher values than those without N application.

This confirms that, depending on the availability of resources, either of the methods can be used to determine the LAI, and thus the productivity of the crop. Specifically on smallholder farms and in research institutions in Africa where capital resources are limited, the copy method may be used to obtain indicative results of the LAI. Results showed a positive linear correlation between the two methods, but a low R^2 value (*Figure 6, Table 3*).

Table 3. Effect of the spacing and N application on Leaf Area Index during the growing season

Treatments	LAI	Grain yield
25*100 –N	1.87a	1.739a
25*100 N	2.19b	1.727a
25*50 –N	2.33b	1.556a
25*50 N	2.93c	3.614b
12.5*100 –N	3.37d	3.077b
12.5*100 N	3.41d	3.2b
12.5*50 –N	4.24e	3.822b
12.5*50 N	4.54f	2.646ab
LSD	0.1607	1.3
Probability	<.001	0.009

LAI and grain yield were significantly high in treatments with high plant density and Nitrogen.

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