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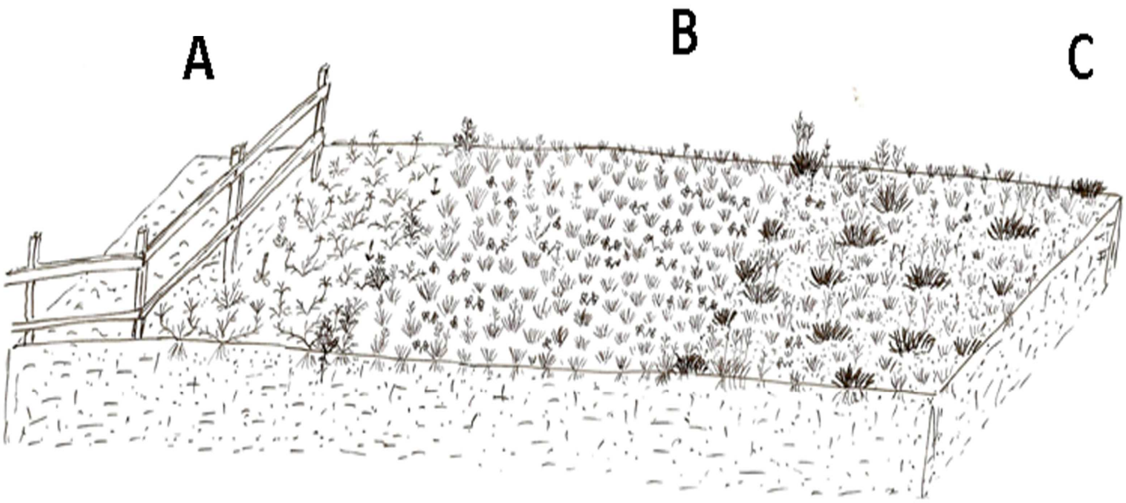

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CHANGE OF COMPOSITION AND DIVERSITY OF SPECIES AND GRASSLAND MANAGEMENT BETWEEN DIFFERENT GRAZING INTENSITY IN PANNONIAN DRY AND WET GRASSLANDS

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Abstract. Investigations were carried out in wet and dry pasture. Coenological recordings were taken in three zones. The first zone (“A”) located 0-50 m near the stable, second zone (“B”) located 50-150 m from the stable, while the third zone (“C”) located farther than 150 m. We have carried out analyses of ecological and environmental factors and life form types. Based on our results for both dry and wet grasslands, quadrates of “A” zone were well isolated from the rest of the zones. Overgrazing, which involves considerable trampling, vanishes differences among vegetations, thereby promotes weed and disturbance tolerant rich vegetation. The lowest species number and diversity could be found here. Due to the nitrogen enrichment due to the constant presence of livestock, drier and less heat demanding habitat developed in the “A” zones, according to the environmental indicators. Because of the change in management, conservation and diversity values of “C” zone increased, however, according to nature protection values it underperformed compared to “B” zone. According to the sample area, wet grasslands from the sandy areas of Kiskunság, preserve nature protection values and grass composition better moving away from stables, due to less grazing pressure. Drier backgrounds tolerate stronger grazing pressure.
Keywords: *indicator value, ecological values, grassland maintain, nature conservation Kiskunság*

Introduction

Characteristic vegetation types have evolved in Pannon biogeographic region situated in the Great Hungarian Plain’s area. Human activity is responsible for the preservation of many of these habitats and associations. At the diverse sandy region in Danube - Tisza region large extent mosaic like grasslands can be found parallel with the appearance of saline soil and these are adjusted to geomorphology. More than 9% of the territory of Hungary (approximately 1.0042 million hectares) belongs to grassland cultivation (Kárpáti and Takács, 2008) which comprises 6.5% of the country's agricultural land. The size of grassland area follows a steady downward trend, which can be explained by the decrease of the number of livestock. In addition, different types of grass represent the largest part of nature sanctuaries, so grasslands not only have major role in grassland management but also are important in preserving the natural vegetation. In the Pannonian region one third of the protected plant and animal species are grassland related, besides a number of vulnerable associations are also presented there. The appropriate conservationist handling is essential, since both their economic utilization and diversity preservation are common tasks.

The significant proportion of dry and wet grasslands can only be preserved with the adequate maintenance. The appropriate handling options are the extensive husbanding forms – mainly grazing and mowing – in addition, a reasonable and well thought-out load application is very important (Catorci et al., 2006, 2007a, 2007b, 2009, 2011; Stampfli and Zeiter, 1999; Ilmarinen, 2009; Willems, 1983; Török et al., 2009, 2010; Tóth et al., 2003; Bakker et al., 1996; Noble and Gitay, 1996; Roberts, 1996; Campbell et al., 1999; Kleyer, 1999; Pausas, 1999).

As part of grassland management, in connection to grazing, examining over-grazing has an essential importance. A number of articles deal with over-grazing, however, their approach to the subject is quite diverse.

Regulation in the UK takes the vegetation into consideration that over-grazing can be observed in case of areas where livestock is presented in such numbers that it effects vegetation growth, quality or species composition significantly and negatively (Statutory Instrument, 1996). According Wilson and MacLoad (1991), considering the livestock factor, areas are over-grazed if because of herbivores grazing the vegetation changes and the amount of animal products reduces. Overgrazing has different meanings in the aspects of farmers and botanists. Over-grazing, as a concept – in terms of grassland management – indicates the grazing animal carrying capacity, the maximum number of tenable species/varieties per area unit, and the number of livestock kept for a period in order to produce needed product. An optimum stocking rate is the value, which regulate the number of grazing animals at the most economical rate (Cowlishaw, 1969). Over-grazing can be interpreted as an indicator of the actual number of livestock, but its time/interval defining dimension/role is more important (Pratt, 2002). According to Brizuela and Cid (1993) the first signs of over-grazing on the composition of vegetation are the decrease in the proportion of legumes/pulses as well as the increase in the proportion of other dicot species and baring spots.

Lack of grazing also has negative effect on evolved pasture at continental climate, which for instance induces spatial spread of weed and shrub species (Jávor et al., 1999). In an experiment, carried out by Longhi et al. (1999), the number of species was higher in case of fence enclosed isolated area than areas sheltered by hills. Moreover, the number of species correlated with plant height, which is used as an indicator of grazing intensity. Nevertheless, results indicate that both fenced and grazed areas had the same number of species, but their species composition differed (Paulsamy et al., 1987). As a result, the intensive- and especially over-grazing environment leads a relatively low number of delicious species to decline, while favours the proven less tasty non-proliferation plant species to thrive. According to Fuls (1992), the long-term spot over-grazing leads to significant degradation, which can result in even 90% decrease in coverage.

In the highly degraded plots, plant coverage fell below 1% and the low-level succession and pioneer plant composition were dominant. Anderson and Radford (1994) monitored grazing efficiency for eight years. If the grazing pressure reduced from 0.4 to 5.6-2.3 ha pasture (in both cases one sheep were grazed), the average plant vegetation

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coverage increased from 49% to 91.7% in parallel. Communities sensitively respond to the specific grazing pressure similarly to vintage effects (Aiken, 1990). Herbivores are able to positively influence the diversity of grasslands (B. Peco et al., 2006), although some studies prove the existence of opposite processes (Ritchie and Olff, 1998). Reportedly, grazing of large herbivores has its impact on primary production (Noy-Meir et al., 1989) and spatial heterogeneity (Adler and Lauenroth, 2000; Peco et al., 2006) of associations; influences vegetation structure (Sala, 1988), species composition (Kahmen et al., 2002; Moog et al., 2002) and species diversity (Virágh and Bartha, 1996; Pykälä, 2003; Pykälä et al., 2005). Grazing manners are indicated in vegetation and types of grazing appear in production (Naveh and Whittaker, 1979; Milchunas et al., 1988).

The grazing-induced changes depend on the type of vegetation, such as upon disturbance different species may react differently (Lavoro et al., 1998). Abandonment of grazing – on fields, which well adapted to grazing – has its significant effect on vegetation, in many cases, abandonment could be interpreted as disturbance (Sala et al., 1996). The review of studies on the effect of grazing clearly discloses that grazing as a form of field management has its great importance in maintaining diversity of grassland species and processes of landscape (Luoto et al., 2003).

Our pre-grazing hypothesis during the investigation was that grazing livestock are the most determination state of field. Their presence due to continuous grazing led to degradation of the vegetation thereby significantly transformed species composition this area, which increased the amount of weed species.

Investigations were directed primarily on the changes in vegetation. It was further questioned if changes can be observed, in which direction change the original vegetation, composition of association, dominance relations and dominant species.

Overall, we were looking for answers:

- To what extent can detect the changes in the grazing areas of vegetation in context of space and time?
- Are the species composition of dry and fresh vegetation and dominance relations react similarly to grazing? Is grazing homogenize the grazing areas or mask the differences? The different intensity of grazing how contributes to the preservation of diversity?
- Are there any (if so, where and with what load) parts of the areas where the management, conservation grazing meet the needs?

Materials and methods

Sampling fields

The sampling areas were located in the Pannonian biogeographical region between Danube and Tisza rivers (Marosi and Somogyi, 1990). From Kiskunság National Park area two sample areas were selected, one dry and one wet grassland. Dry grassland, which formed on sand located west of Bugac, while the more humid grassland located west of Tatárszentgyörgy (*Fig. 1*).

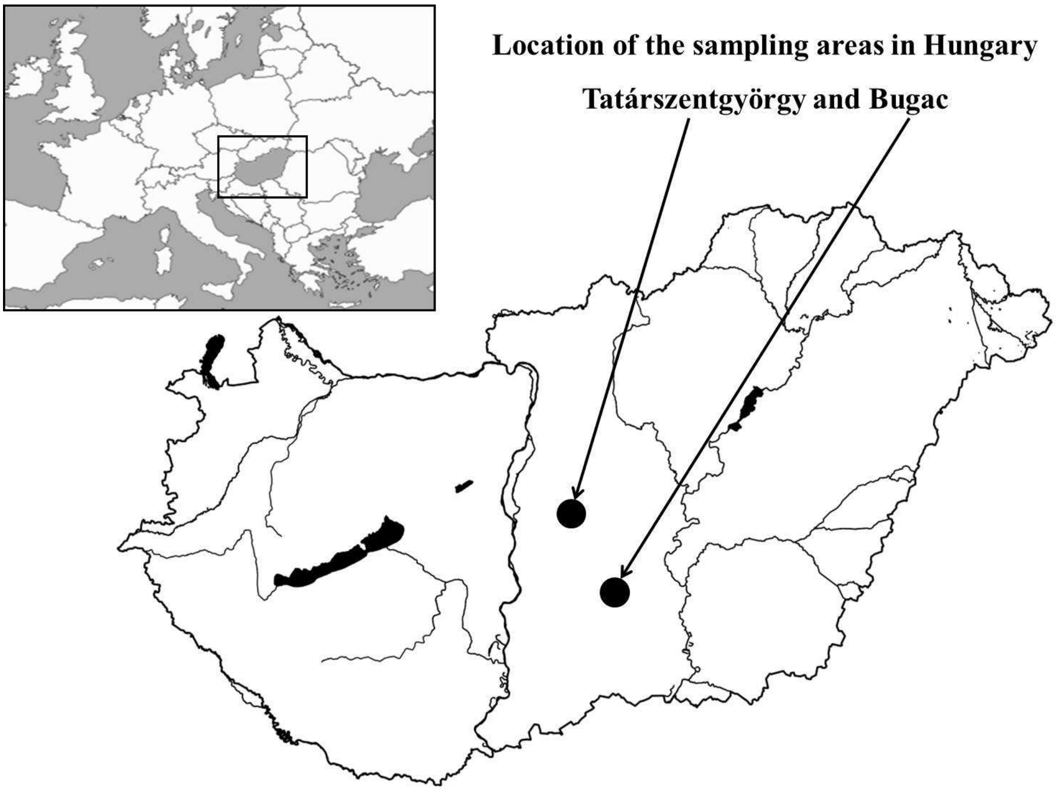

Figure 1. *Location of examined areas*

The Bugac dry sandy grassland pasture (*Potentillo arenariae-Festucetum pseudovinae* Soó 1938, 1940), located at a higher altitude, is engaged in grazing since 1990. Free grazing was applied until 2000 section making has been applied. Cattles and sheep graze the area and the grassland load is 0.4 ha/livestock.

Sample plot Tatárszentgyörgy is situated lower and can be classified into the *Deschampsenion caespitosae* association class (Borhidi, 2003) with marshes associations (*Agrostio-Deschampsenion caespitosae* Ujvárosi, 1947). Salinity can be observed in some places as well as wet meadow vegetation fragments (*Molinio-Salicetum rosmarinifoliae* Magyar ex Soó, 1933). The area is only grazed by cattle, while the grassland load is similar to the previous one: 0.4 ha/livestock.

Data collection

The plant cover records were prepared in June of 2007, 2008, 2009 and 2010 in case of Tatárszentgyörgy, while in June of 1997, 2005 and 2010 in case of Bugac. For recording the Braun-Blanquet (1964) method was followed, in which 2x2 m quadrates were used; whereby the percentage of coverage was rendered to each species. However, coverage values of each level were recorded separately, thus in some cases more than 100% total coverage occurred in some places. Names of species follow the nomenclature of Simon (2000). To monitor changes in grazing pressure, three plant sections were established based on distance from the cattle-pen (*Fig. 2*):

- Zone A: 0-50 m (the greatest degree of disturbance and trampling can be observed here)
- Zone B: 50-150 m (moderate disturbance prevails)
- Zone C: farther than 150 m (interference is negligible)

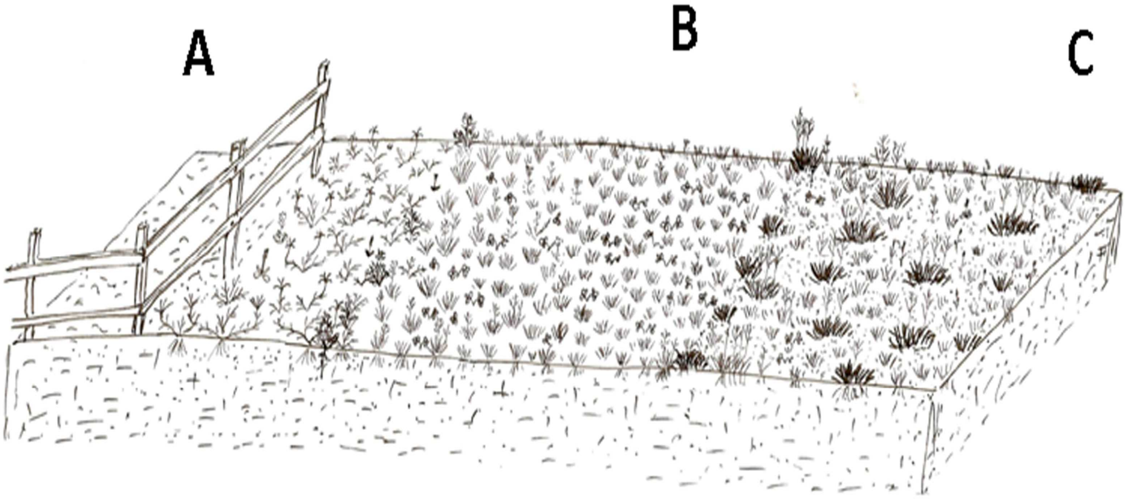

Figure 2. *Location of sampling area zones*
A: 0-50 m, B: 50-150 m, C: 150 m-

The following abbreviations were used in case of tables and graphs: if only some of the “A”, “B” or “C” zones were compared of the areas, then numbers of years were not used. In case if five average year’s records were examined, both town, zone and year were indicated (e.g.: BA97, where “B” represents the settlement (Bugac), “A” represents the distance (0-50m from the stable) while “97” represents the year 1997). If the plant covers for each recording are indicated, then numbers from 1 to 5 is indicated after the year.

In all three zones 5-5 quadrates were recorded.

Data processing

The entire table was used to calculate diversity and species richness determination during processing of coenological data. Species that were rare with coverage value less than 1% were omitted from classification and ordination analyses, since then only the diagnostic species were studied. For compilations in the first table only diagnostic species were used. Clustering was based on Borhidi (1995) social types and Simon (2000) nature conservation categories.

From bioindicator values relative water demand (WB), relative nitrogen requirement (NB) and relative temperature requirement (TB) were evaluated based on the data (Borhidi, 1995). Social behavior assessment was carried out according to Borhidi (1995), while distribution of categories of conservation was based on Simon (2000). Life forms based on Simon (2000) were implemented by Pignatti (2005) categories.

During statistical analyses normally distributed models were set up, in which the number of species and individuals were included (cover value in case of plants) as dependent variables. As explanatory variables SHDI values and transect position values were applied indicating marginal or internal position of transects. Farmer and field effects were taken into account as random factors.

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Statistical methods

Two way clustering is a graphical way of displaying measured values by using colours that represent numerical values. Lower values tend towards green, while higher values tend towards red tones. Re-arranged rows and columns of the table grouped together represent similarity of dendrograms on the two axes. For the clusters Euclidian distance measure were applied as ordinary distance between two points.

For each area, total coverage, species richness and the Shannon-diversity (Pielou, 1975) was calculated. The effects of different grazing intensities were tested using repeated – measure analyses of variance (ANOVA). For post-hoc test the Tukey Honestly Significant Difference (HSD) with corrections (adjusted p-values for the multiple tests) was used. Data were analyzed by the R-statistical program (R Development Core Team, 2009).

After calculating the Shannon-diversities for each recording, the average of areas were taken and compared in both areas beside the increasing disturbance. Beyond calculating average diversity values additional information can be obtained from drawing diversity profiles to each type. This was carried out by Rényi-diversity (Tóthmérész, 1995).

Results

Species composition, diversity and vegetation analysis

Distribution of species by area and type of treatment is shown in *Table 1*. Three weed species were reported only in “A” record. Among species general in all areas – both in “A”, “B” and “C” zones – only one characteristic vegetation species were presented: *Achillea asplenifolia* (Simon, 2000). This species is considered a disturbance tolerant species according Borhidi (1995). From species occurring in lands regardless of land category, 10 species were weeds. In addition, only disturbance tolerant species were presented with high rate: 47%.

Among species that only occur either in Bugac or in Tatárszentgyörgy, the affiliation rate was reversed. The amount of weeds reduced or completely disappeared, like in case of Tatárszentgyörgy. In case of Bugac, only one weed species occurred, *Carduus nutans*. Among disturbance tolerant species we recorded only two species in Bugac, while no such was recorded in Tatárszentgyörgy. In Bugac, pioneer species also occurred in recordings (e.g., *Bromus squarrosus, Anthemis ruthenica*).

Species that occurred in both areas were presented in a significant proportion (20-25%) (*Table 1*), however, their incidence was lower than that of typical species in some areas. Latter includes natural grassland species and taxons from disturbed areas. From the common species, natural grasslands elements (K, E, C, G) showed higher coverage values in case of Tatárszentgyörgy.

Table 1. *Distribution of coenological recording species in Bugac and in Tatárszentgyörgy (GY: weeds, RC: ruderal competitors, K: competitors, DT: disturbance tolerants, C: competitors, G: generalists, TP = NP: natural pioneers)*

Species of A zones	BA	± SD	BB	± SD	BC	± SD	TA	± SD	TB	± SD	TC	± SD
GY (RC)												
Amaranthus retroflexus	**1**	±1.00	0,1	±0.25	0	±0.00	**0.4**	±0.67	0	±0.00	0	±0.00
Poa humilis	**0.3**	±0.68	0	±0.00	0	±0.00	**4.5**	±2.32	0	±0.00	0	±0.00
Polygonum aviculare	**0.9**	±1.33	0	±0.00	0	±0.00	**3.9**	±2.17	0	±0.00	0	±0.00
Veronica arvensis	**0.3**	±0.70	0	±0.00	0	±0.00	**0.1**	±0.22	0	±0.00	0	±0.00
Species of A, B and C zones	**BA**	**± SD**	**BB**	**± SD**	**BC**	**± SD**	**TA**	**± SD**	**TB**	**± SD**	**TC**	**± SD**
K (DT)												
Achillea asplenifolia	0.07	±0.25	2.3	±2.56	1.33	±1.67	0	±0.00	2.1	±1.02	1.5	±1.46
GY (RC)												
Agropyron repens	2.2	±2.70	2.9	±2.01	6.4	±1.67	0	±0.00	0.35	±0.67	0.9	±1.66
Ambrosia artemisiifolia	0.8	±1.14	0.1	±0.25	0	±0.00	0.45	±0.88	0	±0.00	0	±0.00
Capsella bursa-pastoris	0.87	±0.74	0	±0.00	0.13	±0.51	0.4	±0.88	0	±0.00	0	±0.00
Conyza canadensis	1.13	±0.99	0	±0.00	0.07	±0.25	0.35	±0.67	0	±0.00	0	±0.00
Eryngium campestre	0.93	±1.53	1.7	±3.34	0.2	±0.77	4.35	±2.88	0	±0.00	0	±0.00
Euphorbia cyparissias	0	±0.00	0.1	±0.51	0.8	±2.14	0.4	±0.99	0	±0.00	0	±0.00
Medicago lupulina	1.27	±1.43	2.6	±1.59	1.87	±2.06	0	±0.00	0.65	±0.75	0	±0.00
Siline alba subsp. longolia	0.67	±1.67	0	±0.05	0.33	±1.67	0.65	±0.88	0	±0.00	0	±0.00
Ononis spinosa	0.13	±0.35	4.5	±3.70	4.33	±3.59	1.2	±1.23	2	±1.29	2.1	±1.80
Taraxacum officinale	0.93	±1.09	0.8	±0.86	0.27	±0.59	0.2	±0.89	0.25	±0.63	0	±0.00
TZ (DT)												
Achillea collina	2.8	±3.72	5.7	±3.11	2.93	±1.94	2.05	±2.01	2.3	±0.92	0.6	±0.10
Bromus mollis	2.87	±3.13	0.9	±1.22	0.2	±0.41	3.2	±2.56	0	±0.00	0	±0.00
Bromus tectorum	0.87	±1.18	0	±0.00	1.07	±1.83	0.1	±0.44	0	±0.00	0	±0.00
Centaurea pannonica	0.13	±0.35	0.3	±0.49	0.13	±0.52	0.4	±0.82	**4.7**	±3.13	2.6	±2.28
Cynodon dactylon	**27**	±10.91	6.5	±5.43	5.2	±2.85	**45**	±18.06	4.95	±3.39	2.8	±1.40
Festuca pseudovina	1.13	±1.06	**13**	±6.81	**4.5**	±3.48	0	±0.00	0.3	±0.73	1.9	±1.65
Lolium perenne	**9.2**	±10.15	**5.7**	±12.56	1.13	±0.74	**6.7**	±6.11	0	±0.00	0	±0.00
Plantago lanceolata	2.2	±1.56	3.9	±2.81	2.07	±1.09	0.9	±1.02	0.45	±0.82	0.9	±0.71
Poa angustifolia	0.93	±1.27	2.9	±1.03	8.27	±4.74	6	±5.11	0.65	±1.18	3.7	±2.36
Trifolium repens	1.2	±2.62	4.4	±2.35	1.27	±1.03	1.85	±2.34	0.15	±0.67	0	±0.00
TZ, GY (DT)												
Potentilla reptans	**0.1**	±0.35	**0.3**	±0.70	**1.7**	±1.58	0	±0.00	**0.9**	±0.58	**2**	±0.51
Trifolium pratense	**0.3**	±0.70	**1.5**	±1.50	**1.3**	±1.62	**0.3**	±0.78	**0.2**	±0.48	**0**	±0.44

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Table 1. *cont.*

Species only in Bugac	BA	± SD	BB	± SD	BC	± SD	TA	± SD	TB	± SD	TC	± SD
K, E (C, G)												
Astragalus cicer	**0.1**	±0.51	**1.7**	±1.75	**0.1**	±0.35						
Astragalus onobrychis	0	±0.00	0	±0.00	**0.5**	±0.83						
Carex stenophylla	**1.5**	±3.87	**1.6**	±1.68	**0.7**	±0.96						
Coronilla varia	0	±0.00	0.3	±1.29	0.73	±1.33						
Potentilla arenaria	0	±0.00	**1.7**	±0.00	0.8	±0.00						
Salvia pratensis	0	±0.00	**0.3**	±1.29	**1.2**	±2.83						
Thymus pannonicus	0	±0.00	**1.5**	±3.99	0	±0.00						
TP, NP												
Bromus squarrosus	0	±0.00	0	±0.00	**1.1**	±3.13						
Trifolium campestre	0.67	1.11	**2.6**	±2.13	0.67	±0.97						
TZ (DT)												
Medicago falcata	**0.3**	±0.59	**1.3**	±1.43	0	±0.00						
Veronica prostrata	0	±0.00	**0.4**	±0.50	**0.5**	±0.51						
K, TP (NP, G)												
Anthemis ruthenica	**0.2**	±0.41	**0.6**	±0.63	**0.3**	±0.59						
Medicago minima	**0.5**	±0.83	**1.3**	±1.22	**0.6**	±0.50						
Poa bulbosa	0	±0.00	**0.9**	±1.53	**0.7**	±0.70						
Potentilla argentea	0	±0.00	**0.2**	±0.77	**0.7**	±0.97						
Veronica chamaedrys	0	±0.00	**0.7**	±0.97	**0.9**	±0.63						
TP, NP												
Arenaria serpyllifolia	**1.4**	±1.68	**1.1**	±1.50	**0.3**	±0.70						
GY (RC)												
Carduus nutans	**0.2**	±0.77	**0.5**	±1.35	**1.1**	±1.22						
Species only in Tatárszentgyörgy	**BA**	**± SD**	**BB**	**± SD**	**BC**	**± SD**	**TA**	**± SD**	**TB**	**± SD**	**TC**	**± SD**
K, E (C, G)												
Carex distans							0	±0.00	**2**	±1.93	**2**	±2.02
Carex flacca							0	±0.00	**1.9**	±1.59	**4**	±3.62
Carex panicea							0	±0.00	**0.4**	±0.87	0	±0.00
Centaurium erythraea							0	±0.00	**0.7**	±0.67	**0**	±0.67
Crataegus monogyna							0	±0.00	**0.2**	±0.69	**1**	±0.68
Genista tinctoria							0	±0.00	**0.1**	±0.44	**1**	±0.82
Linum austriacum							0	±0.00	0	±0.00	**0**	±0.52
Lotus tenuis							0	±0.00	**1.5**	±0.68	**1**	±0.44
Mentha aquatica							0	±0.00	**0.6**	±0.88	**0**	±0.87
Molinia coerulea							0	±0.00	**0.4**	±0.88	**1**	±2.44
Odontites rubra							0	±0.00	**1**	±0.56	0.8	±0.61
Plantago maritima							0	±0.00	**1.5**	±1.35	2	±1.29
K (S)												
Polygala amarella							0	±0.00	**0.8**	±0.71	**1**	±0.71

Table 1. *cont*

Common species in Bugac and in Tatárszentgyörgy of B and C zones	BA	± SD	BB	± SD	BC	± SD	TA	± SD	TB	± SD	TC	± SD
K, E (C, G)												
Agrostis stolonifera	0	±0.00	**0.5**	±1.55	0	±0.00	0	±0.00	**8.2**	±4.79	**7**	±5.59
Botriochloa ischaemum	0	±0.00	**0.3**	±1.29	0	±0.00	0	±0.00	0	±0.00	**1**	±1.14
Chrysopogon gryllus	0	±0.00	**0.9**	±1.84	0	±0.00	0	±0.00	0	±0.00	**2**	±2.94
Deschampsia cespitosa	0	±0.00	**0.4**	±1.54	**1.3**	±2.02	0	±0.00	**7.3**	±4.72	**10**	±11.60
Galium verum	0	±0.00	**2.6**	±2.52	**7.3**	±4.70	0	±0.00	**2.5**	±0.94	**2**	±1.06
Serratula tinctoria	0	±0.00	**0.4**	±1.54	**2.9**	±2.79	0	±0.00	**6.8**	±3.17	**4**	±1.98
Tetragonolobus maritimus	0	±0.00	**0.4**	±0.73	**0.4**	±0.82	0	±0.00	**1.8**	±1.15	**2**	±1.68
GY (TC)												
Inula britannica	0	±0.00	**0.1**	±0.35	0	±0.00	0	±0.00	**0.6**	±0.82	**0**	±0.73
Ranunculus acris	0	±0.00	**0.1**	±0.25	0	±0.00	0	±0.00	**1.1**	±0.97	**0**	±0.30
Senecio erucifolius	0	±0.00	0	±0.00	**0.3**	0.72	0	±0.00	**1.2**	±0.95	**1**	±0.59
Trifolium fragiferum	**0.3**	0.07	0	±0.00	0	±0.00	0	±0.00	**1.6**	±1.57	0	±0.00
TP (NP)												
Cerastium semidecandrum	0		0		**1.5**	±1.88	0	±0.00	0	±0.00	**0**	±1.46
TZ, GY (DT)												
Bolboschoenus maritimus	0	±0.00	**0.5**	±1.18	0	±0.00	0	±0.00	**0.6**	±1.27	**1**	±1.46
Dactylis glomerata	0	±0.00	**2.4**	±2.47	**3.3**	±2.46	**0.3**	±0.80	**1.5**	±1.19	**4**	±3.34
Festuca arundinacea	0	±0.00	2.3	±3.08	2.9	±2.26	0	±0.00	12	±6.86	8	±6.66
Leontodon hispidus	0	±0.00	0	±0.00	**0.1**	±0.35	0	±0.00	**0.8**	±0.76	**0**	±0.67

Recordings of both sample areas is shown with application of diagnostic species on *Fig. 3*. Near to the stable, the “A” coenological recordings were well distinguished. Records from Tatárszentgyörgy are unitary. From those, “C” areas in 2007 stand apart and and as a single group lodge into “A” zone. In case of Bugac, recordings from “B” (in 1997) wedge into the values of “A”, the closest quadrates to the stables.

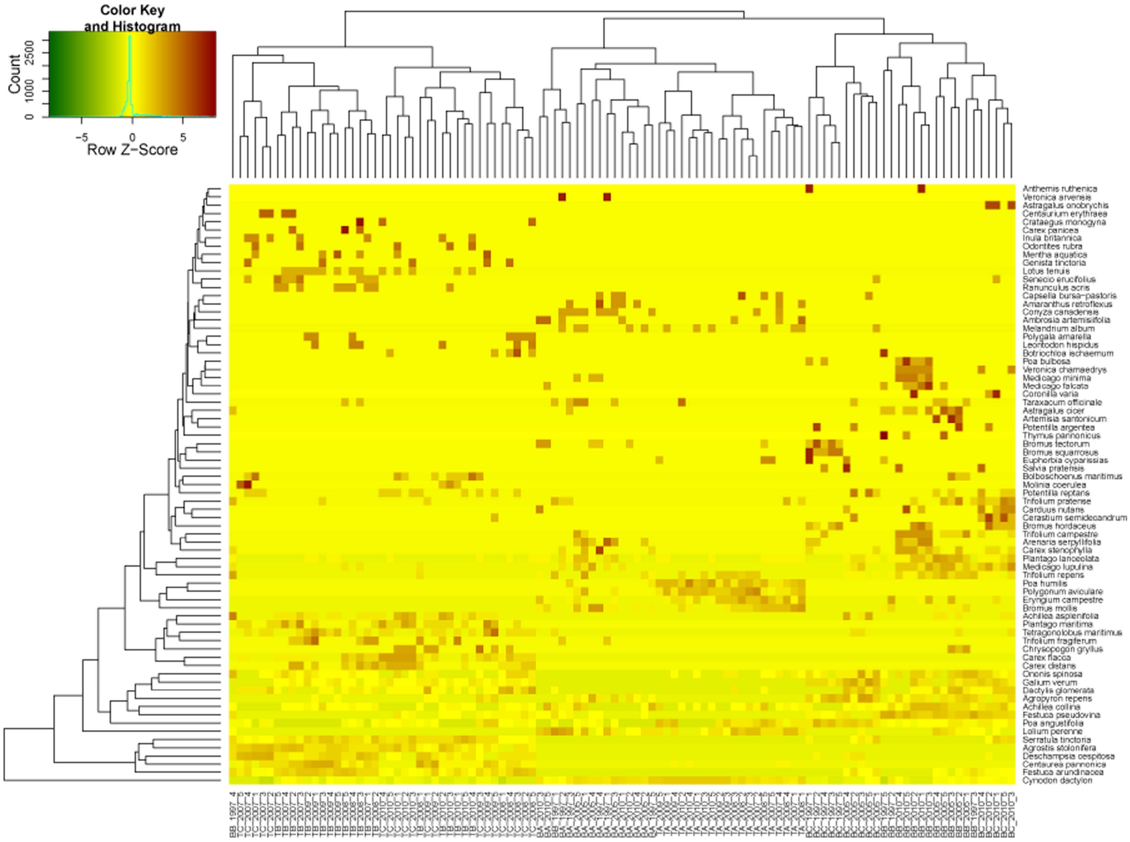

Figure 3. *Two-way clustering results of coenological records of Tatárszentgyörgy and Bugac according to diagnostic species*

From the two-way ANOVA analysis of coenological records from Bugac (*Fig. 4*), values from “A” plots were not separated from each other. These recordings are mixed with recordings from “B” from 1997. Sample plots of “B” and “C” overlap as well.

In case of Tatárszentgyörgy, the two-way clustering (*Fig. 5*) firmly separated plots of “A” zone. In addition, recordings from “B” zone also appeared in a block. Coenological recordings of “C” zone became divided, while recordings from 2007 formed an intact group enclosed between “A” and “B” zones.

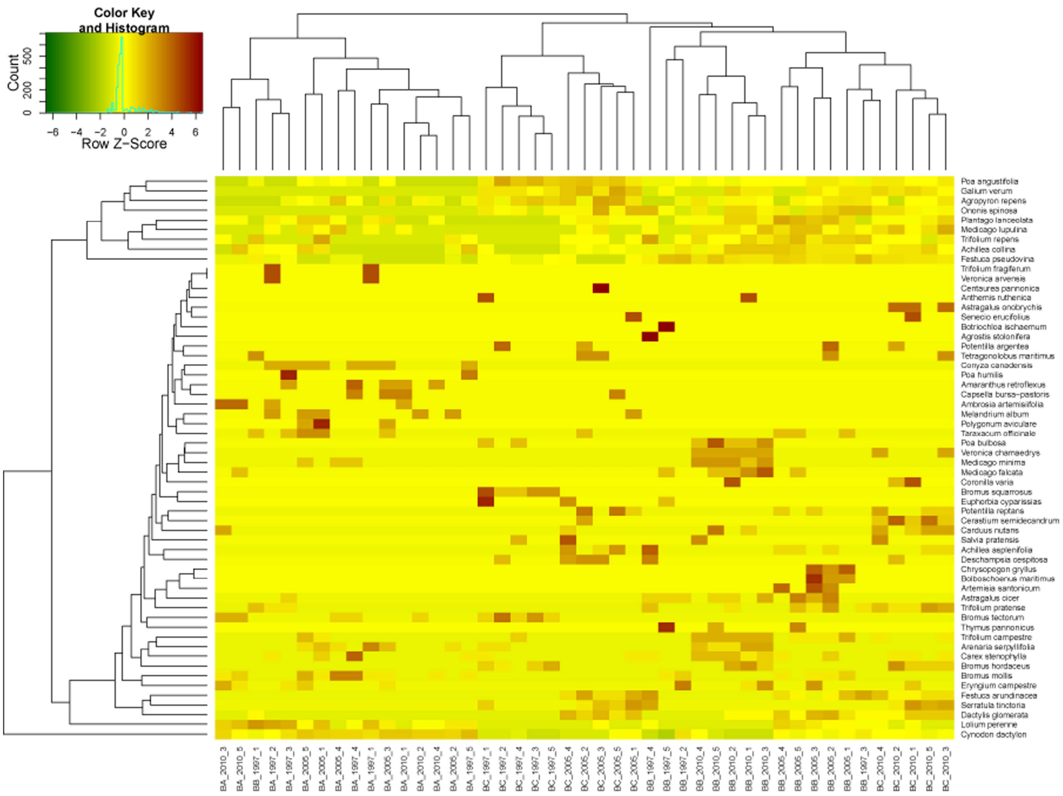

Figure 4. *Two-way clustering results of coenological recording according diagnostic species in case of Bugac*

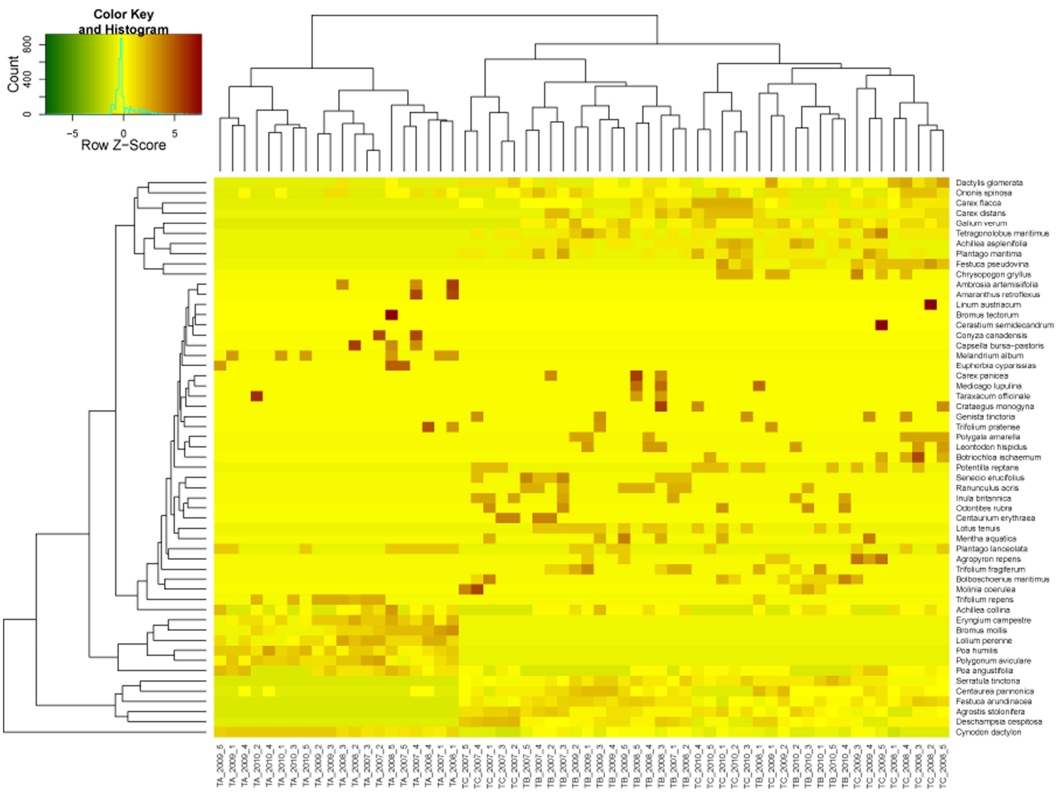

Figure 5. *Two-way clustering results of coenological recording according diagnostic species in case of Tatárszentgyörgy*

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Classification assessment of coenological recordings from Tatárszentgyörgy and Bugac are shown in *Fig. 6*. According to the results from the classification, most recordings from the "A" zone separated even at 0.8 differential level, while other recordings from "A" zone also separated, at high levels. Around 0.42 differential level, two major groups could be distinguished. From those, the small set contained primarly "B" recordings from Bugac, while the larger group contained "B" and "C" quadrates from Bugac and Tatárszentgyörgy.

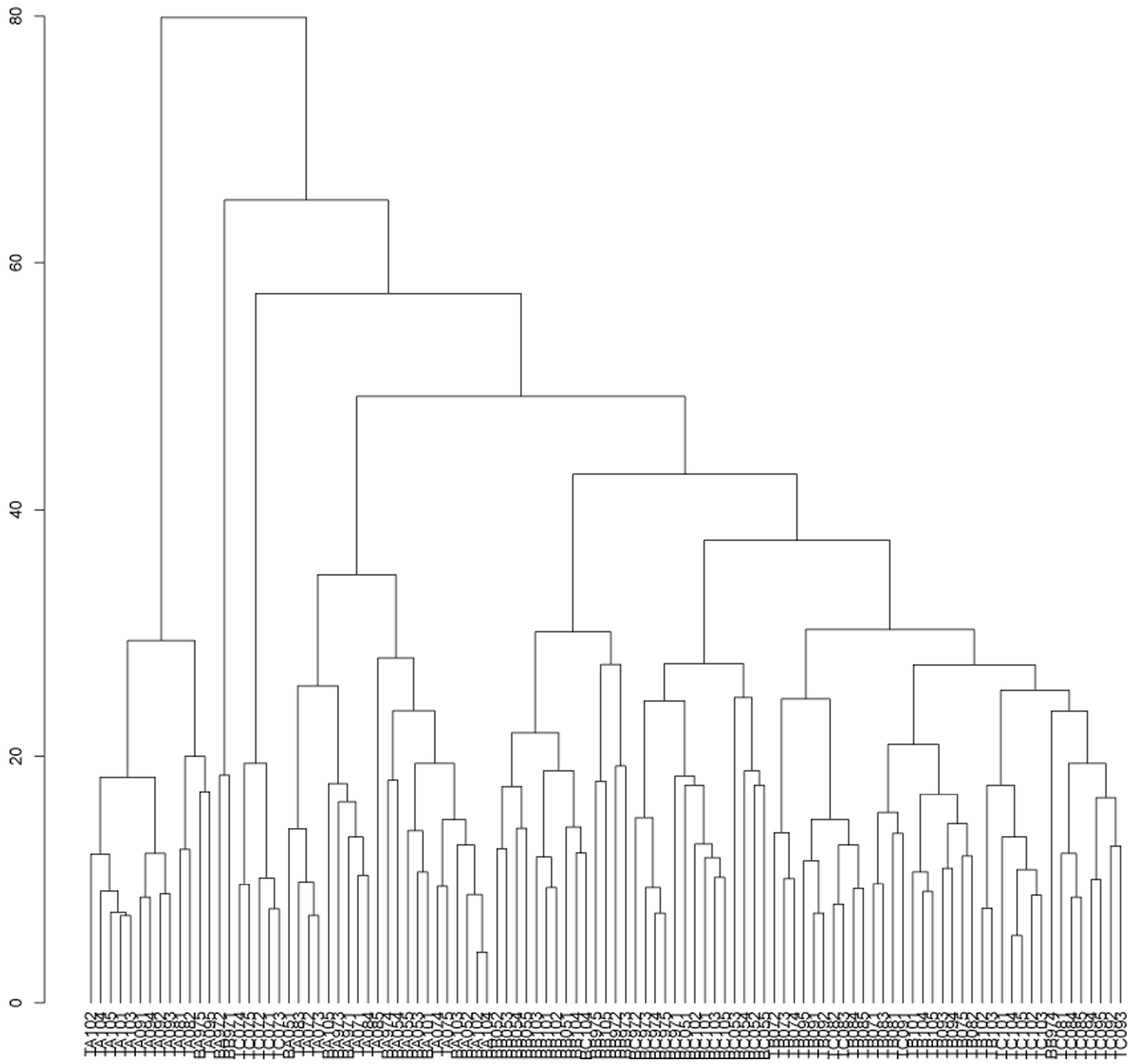

Figure 6. *Classification outcome of coenological results of Bugac and Tatárszentgyörgy areas*

Fig. 7. shows classification evaluation of coenological recordings from Bugac. Recordings in case of field "A" separated at 0.6 differential level. "B" recordings from 1997 were enclosed into "A", just like in the previous section. At 0.3 different level, recording of "B" from 2005 and 2010 are sorted into a common group. Quadrates of "C" zones are concentrated into one group.

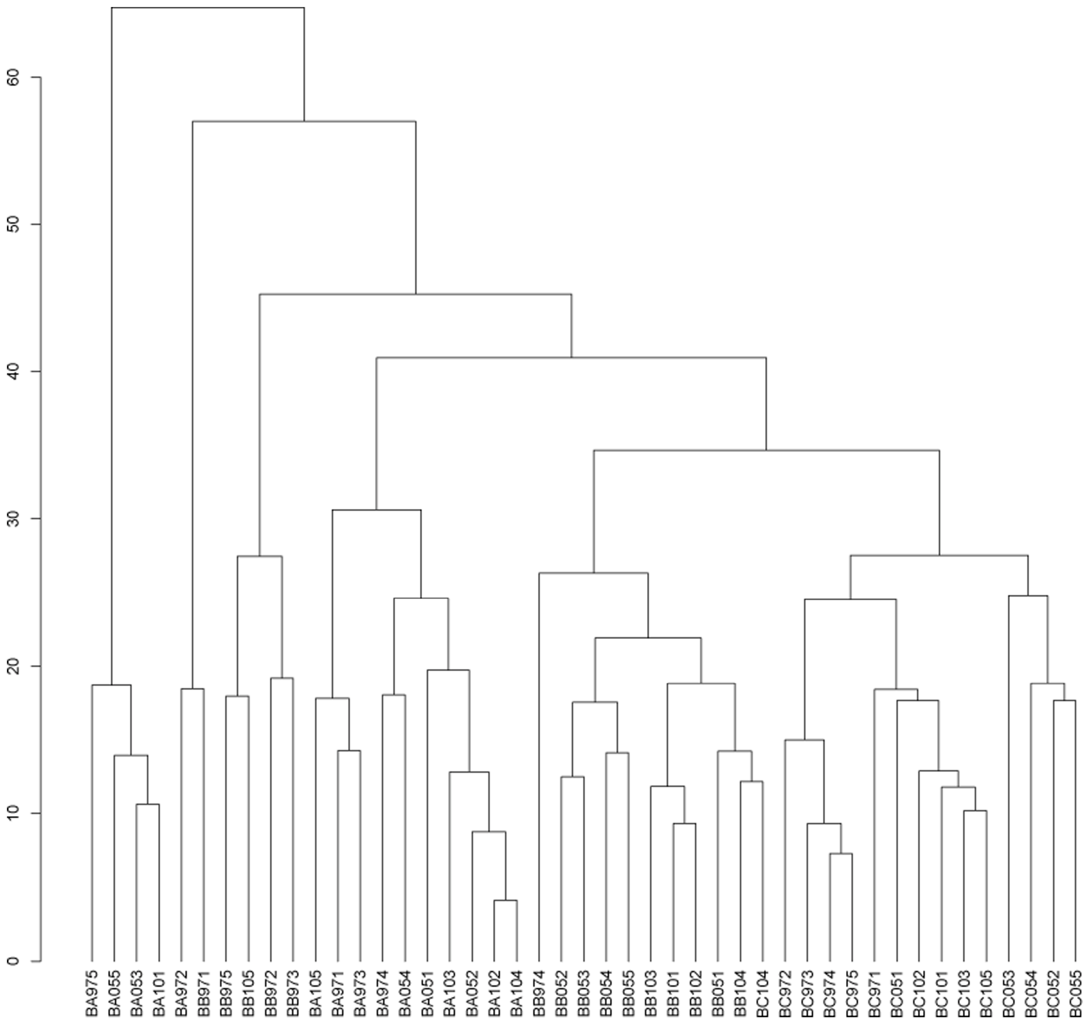

Figure 7. *Classification of coenological results from Bugac*

Fig. 8. shows classification evaluation of coenological recordings from Tatárszentgyörgy. Dendogram at 0.8 differential level separated two distinct groups. Group "A" zone formed an integrated block, recordings from group "B" zone were found in the middle block. "C" zone formed two large groups. Recordings from 2007 separate into a single block.

PCA analysis of recordings from Tatárszentgyörgy can be seen in *Fig. 9*. Results confirm the classification results. Recordings of "A" field formed a long-shot data set, distinct from quadrates of "B" and "C". In case of Bugac, squares from "B" zone were the closest to "A" areas. This included three "C" recordings, one quadrate from 2009 and two from 2008. The remaining "C" zone was organized sharply into two groups. Recordings from 2007 were uniformly and completely separated. Recordings of "B" and "C" zones from Tatárszentgyörgy and Bugac separated.

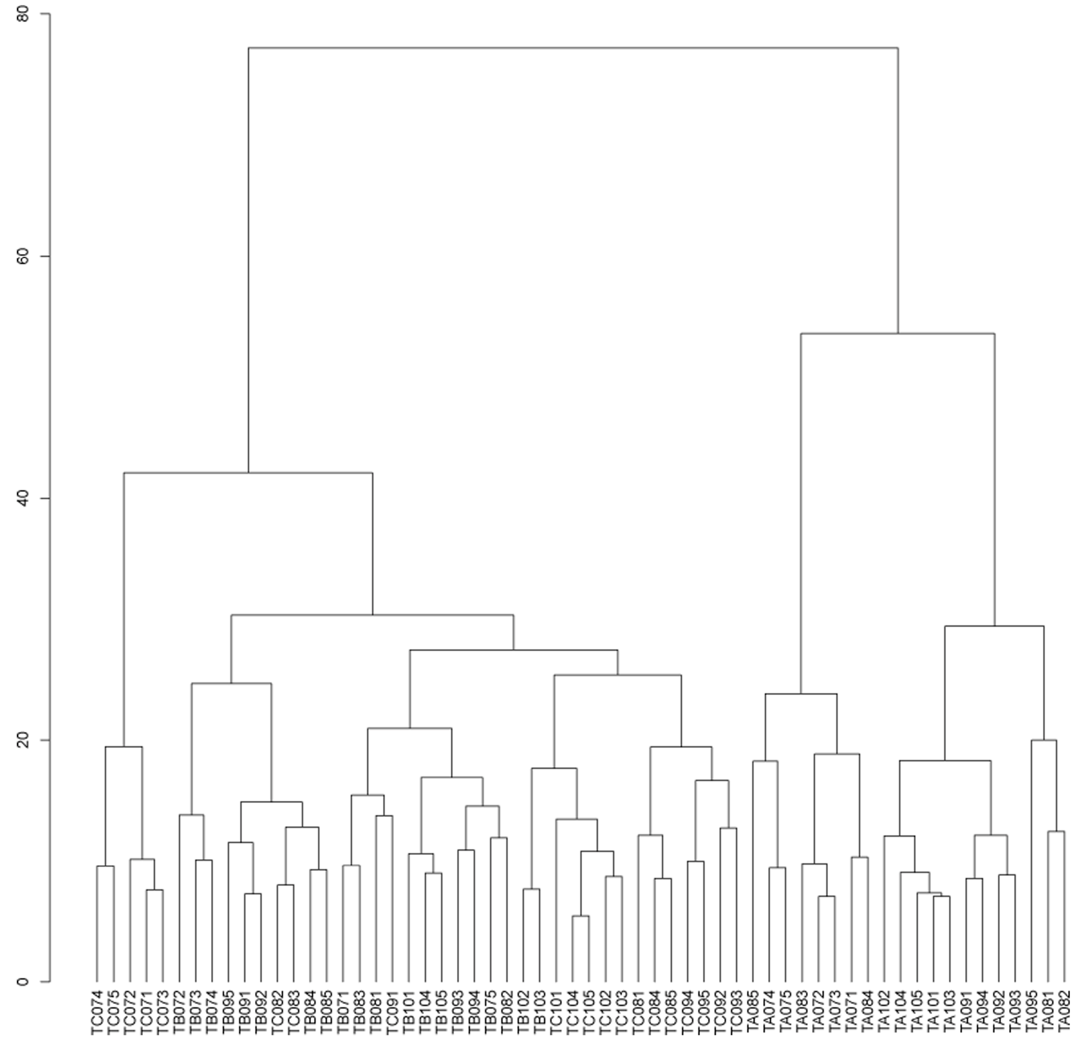

Figure 8. *Classification of coenological results from Tatárszentgyörgy*

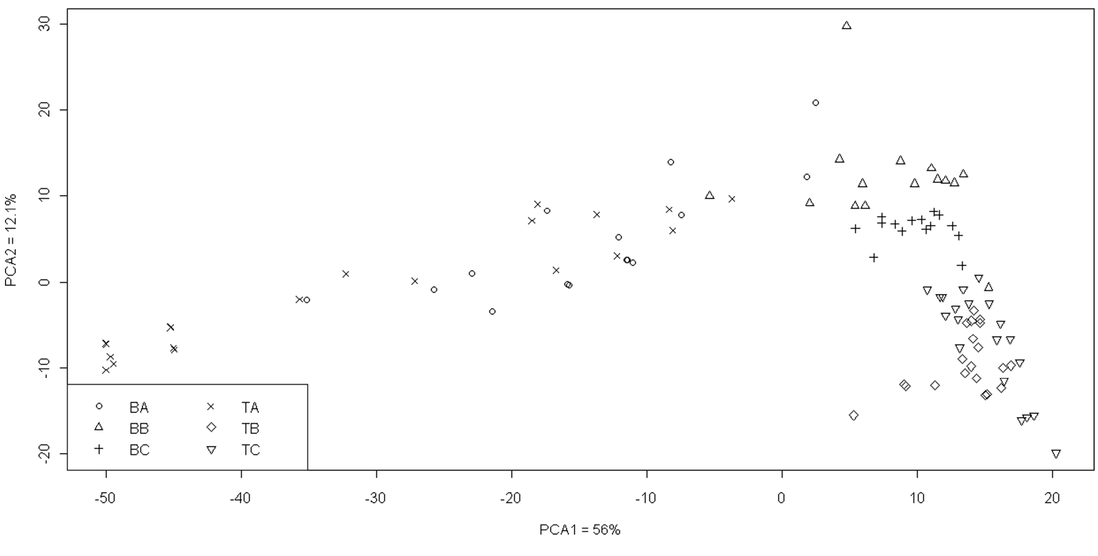

Figure 9. *PCA-ordination of coenological data from Bugac and Tatárszentgyörgy according to the average coverage of quadrates*

Evolution of number of species can be seen in *Table 2-3.* and *Fig. 10-11*. The maximum total number of species occurred in case of Bugac “B”, while Bugac “C” zone also had a greater number of species then Tatárszentgyörgy “C”. Annual breakdown of the total number of species showed a continuous decline in case of Bugac, while increment could be observed in case of “C” zone. The evolution of average number of species in case of quadrates indicated another trend. Number of species in case of “C” zone was balanced, while in case of “B” zone lower values were typical due to the average number of species, despite the highest number of species can be found here. Values increased during examination.

Table 2. *Whole species set of coenological recordings from Bugac in the examined years and number of species from “B” and “C” zones by year.*

	1997-2010	1997	2005	2010
Bugac A	35			
Bugac B	50	38	36	31
Bugac C	47	37	41	38

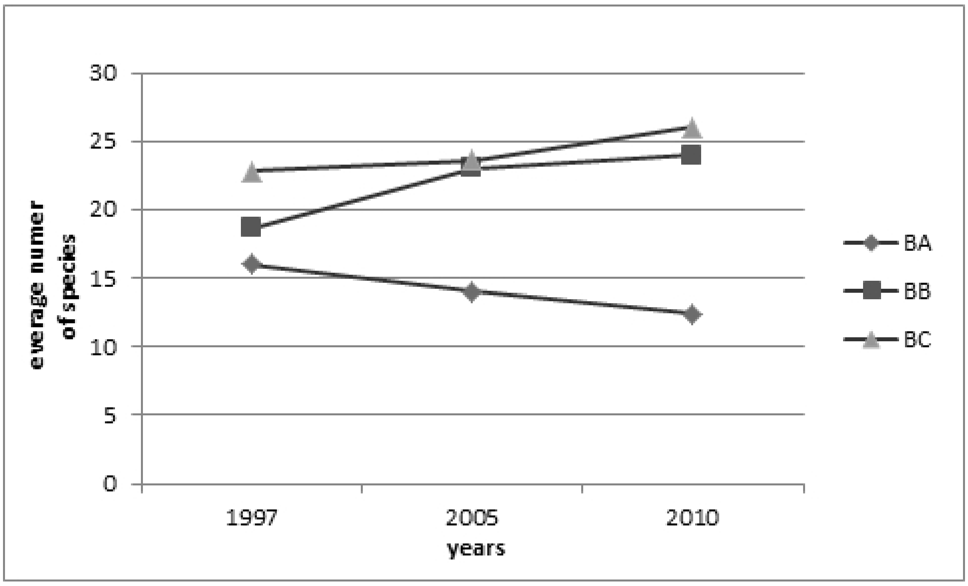

Figure 10. *Coenological results of average number of species in the examined period in case of Bugac*

Table 3. *Whole species set of coenological recordings from Tatárszentgyörgy in the examined years and number of species from "B" and "C"zones by year.*

	2007-2010	2007	2008	2009	2010
Tatárszentgyörgy A	23				
Tatárszentgyörgy B	39	28	32	30	30
Tatárszentgyörgy C	38	28	27	32	38

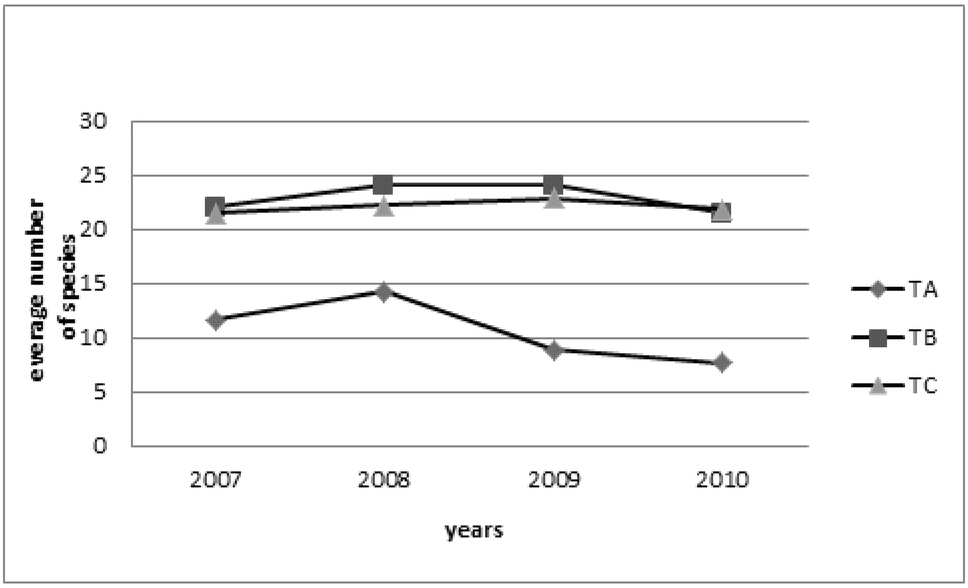

Figure 11. *Coenological results of average number of species in the examined period in case of Tatárszentgyörgy*

According to the Shannon diversity the following was determined:

- Every examined year, in zone “A” zone nearest the stable, the diversity was smaller then in fields farther from stable (total year average: 2.291). This value was higher in case of “B” and “C” zone (2.881 and 3.025 respectively). It could be noticed that in all three regions (“A”, “B” and “C” zones) the lowest diversity was in 1997, while diversity in 2005 and 2010 was higher (*Fig. 12*).
- In Bugac, the diversity did not change significantly in case of “A” zone, it was 2.15, 2.41 and 2.30, respectively. Value of diversity increased moving away from the stable, both in case of “B” zone – it was 2.48, 2.97 and 3.18, and in case of “C” zone – it was 2.89, 2.92 and 3.25.
- Similar conclusions were reached by examining the evolution of the number of species. The smallest number of species was measured in case of “A” field, where high degree of disturbance was exposed. In case of “B” and “C” area, the number of species was higher and increased with time.
- Diversity values of recordings from Tatárszentgyörgy clearly indicate the “A” zone had the lowest (1.62), while areas located farther from the stable (“B” and ”C” zones) had higher diversity values (2.93 and 2.80) during the examined years (*Fig. 13*).
- Interestingly in case of “A” zone, a relatively high diversity (2.03 and 2.10) was observed in the first two years (2007 and 2008), which values sharply decreased by 2009 and 2010 (1.32 and 1.03). In the “B” zone, diversity was almost constant during the examined 4 years, while in case of “C” zone it was initially moderate, then in the following 3 years it was high.

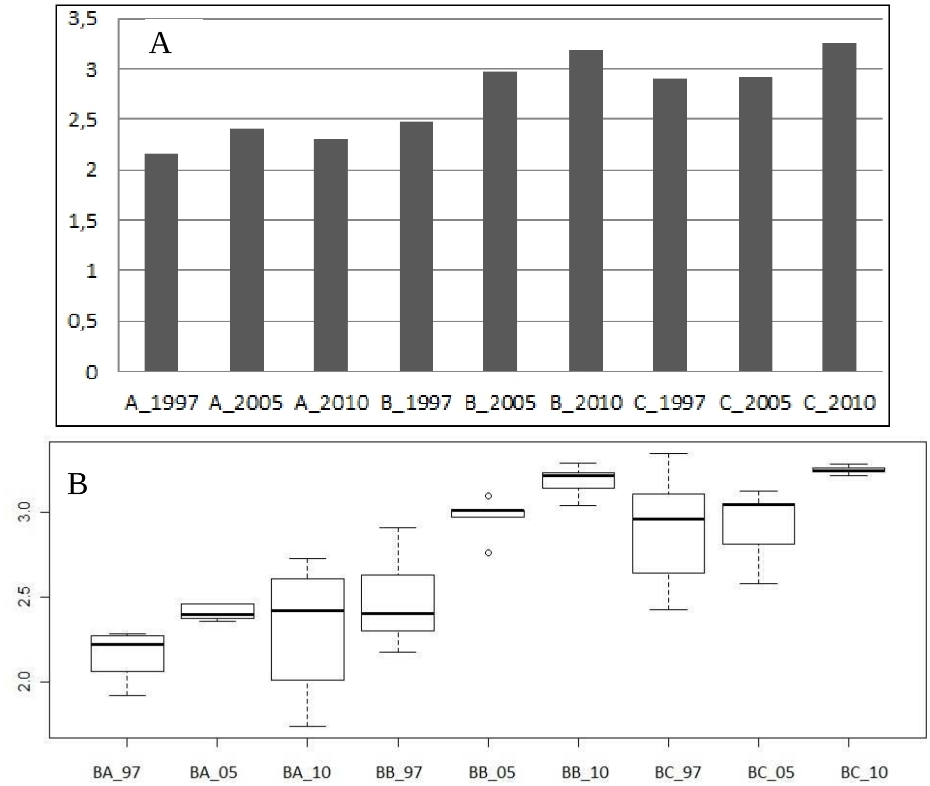

Figure 12. *Diversity values of sample areas ("A","B" and "C" zones) of Bugac*
A: Shannon-diversity average values, B: results of one-way ANOVA

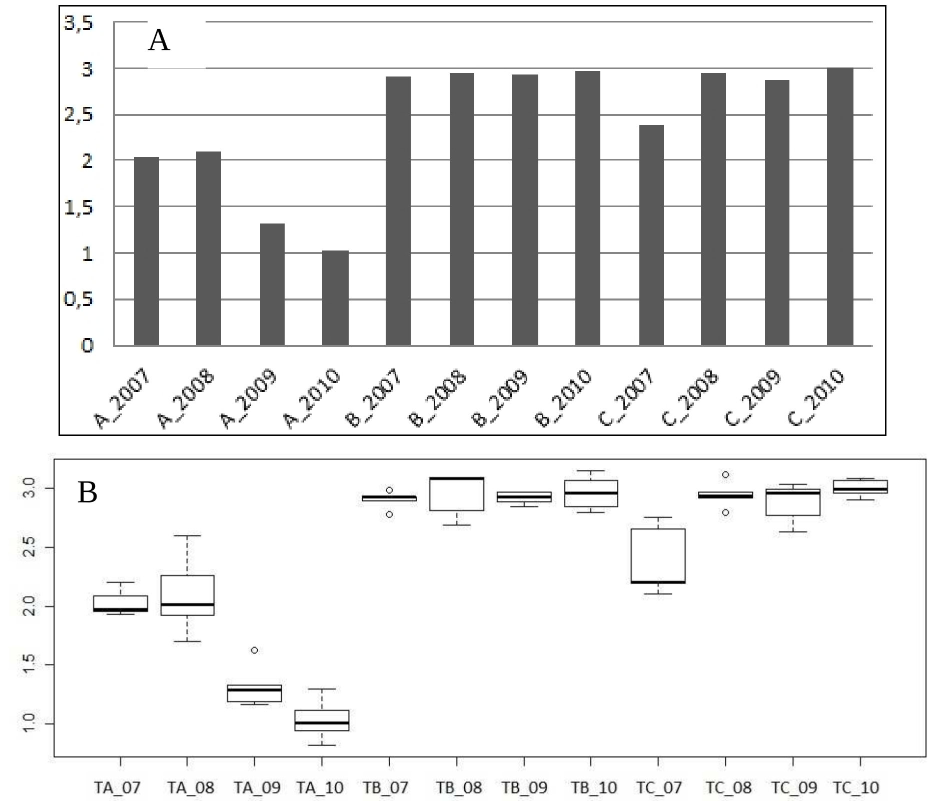

Figure 13. *Diversity values of sample areas ("A","B" and "C" zones) of Tatárszentgyörgy*
A: Shannon-diversity average values, B: results of one-way ANOVA

Using Rényi-diversity profile, three distinct types of disturbance clearly separated in case of Bugac. The most disturbed area is "A" zone that also has the lowest diversity values. The curve of fields "B" and "C" zones initially changed together with the same diversity, then later divided at alpha values and diversity of "C" zone – previously less disturbed area – became the highest. In this study, measurements from each year were combined and only the differences between sites and fields were evaluated (*Fig. 14-15*).

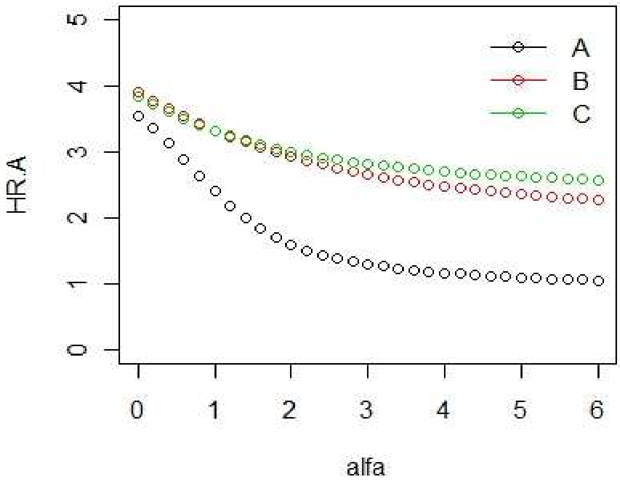

Figure 14. *Rényi-diversity profile of Bugac. A - mostly disturbed, B - moderately disturbed, C - the farthest plot from stable, near natural part*

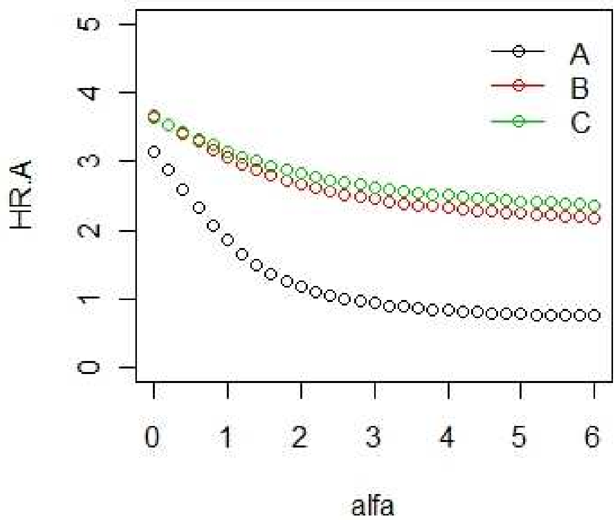

Figure 15. *Rényi-diversity profile of Tatárszentgyörgy. A - mostly disturbed, B - moderately disturbed, C - the farthest plot from stable, near natural part*

In case of Bugac dry grassland, among important and dominant grasses *Cynodon dactylon, Festuca pseudovina* and *Poa angustifolia* occurred, as indicated in *Fig. 16*. *Cynodon dactylon* was found all along, however it reached its maximum in the over-grazed field "A". Among recordings from field "B" zone in 1997, it was also prevalent in recordings 2 and 3, where its coverage was nearly 20%. *Festuca pseudovina* occurred in “B” zone with large coverage values, however, it was common everywhere. The most significant occurrence of *Poa angustifolia* was in quadrates of field “C” zone in 1997, however, it dropped to 10% by 2005.

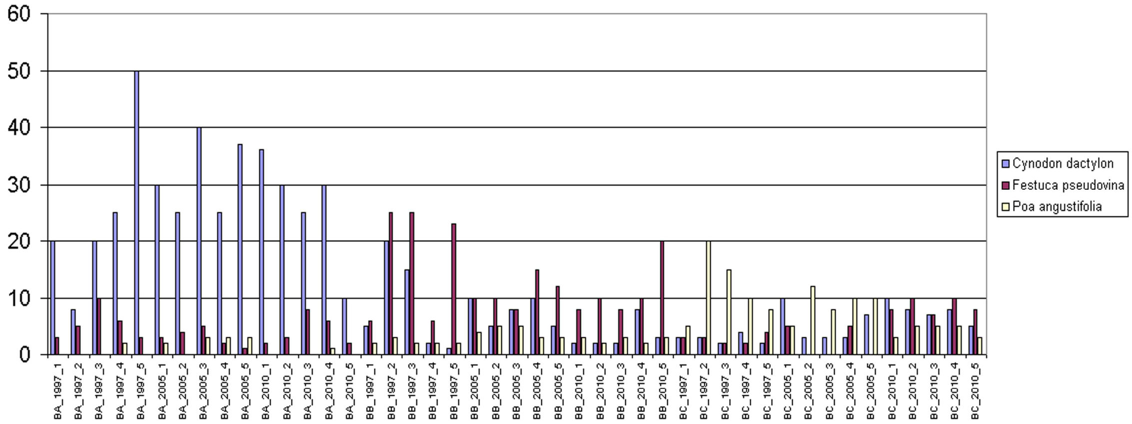

Figure 16. *Occurrence of dominant grass species in percentages at the examined fields in Bugac (“A”,”B” and “C” zones)*

In recordings from Tatárszentgyörgy *Cynodon dactylon* was also the dominant grass in case of “A” zone. *Lolium perenne* was also presented at a large proportion (*Fig. 17*) in case of “A” zone. In Bugac, it also had higher coverage values in “B” zone from 1997.

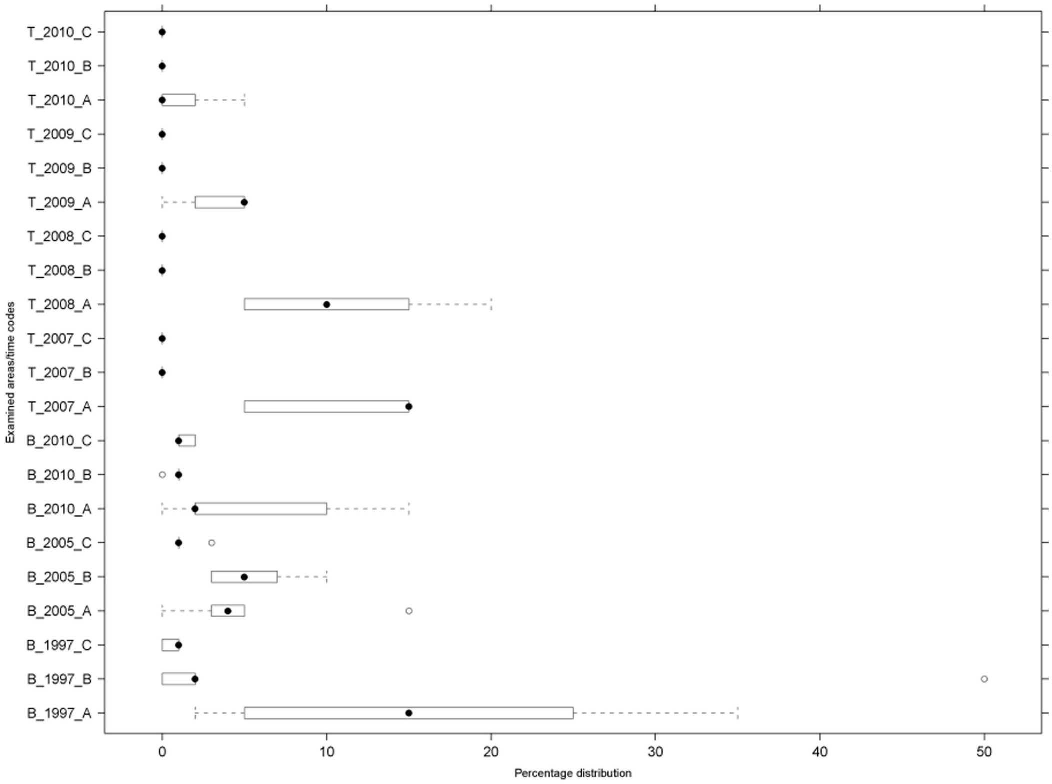

Figure 17. *Occurrence of Lolium perenne in percentages at the examined fields*

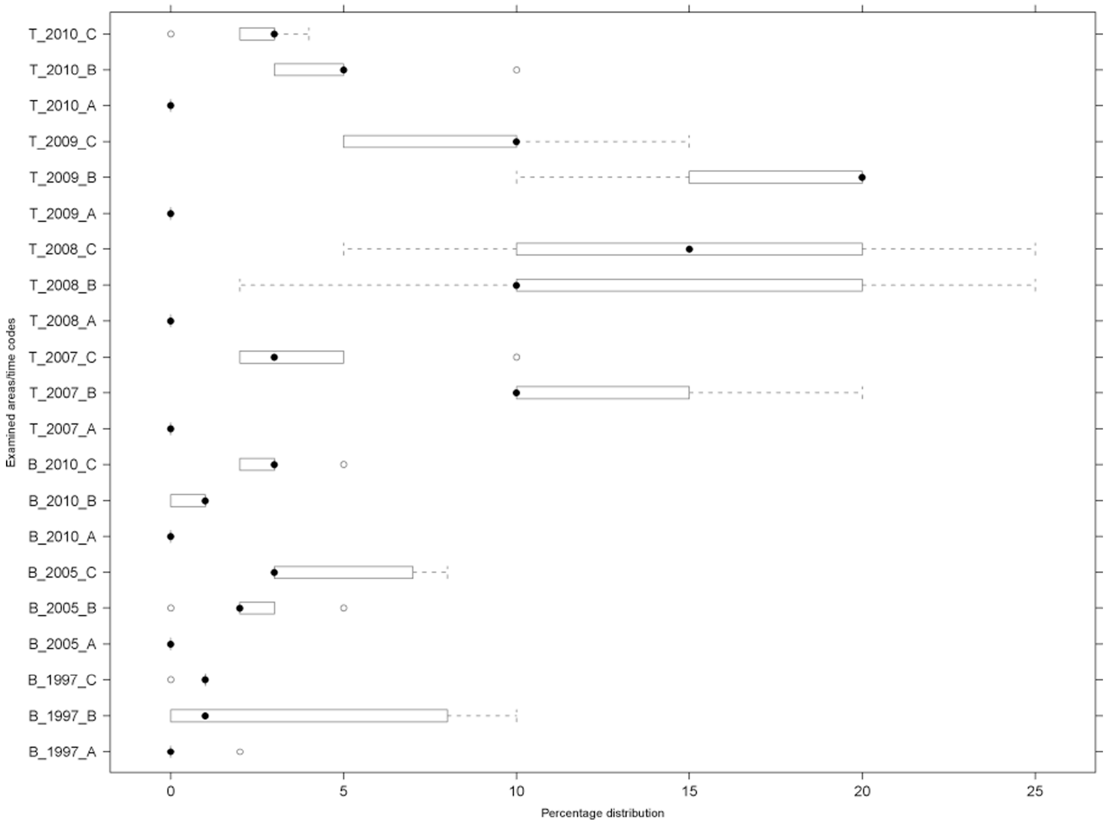

Figure 18. *Occurrence of Festuca arundinacea in percentage at the examined fields*

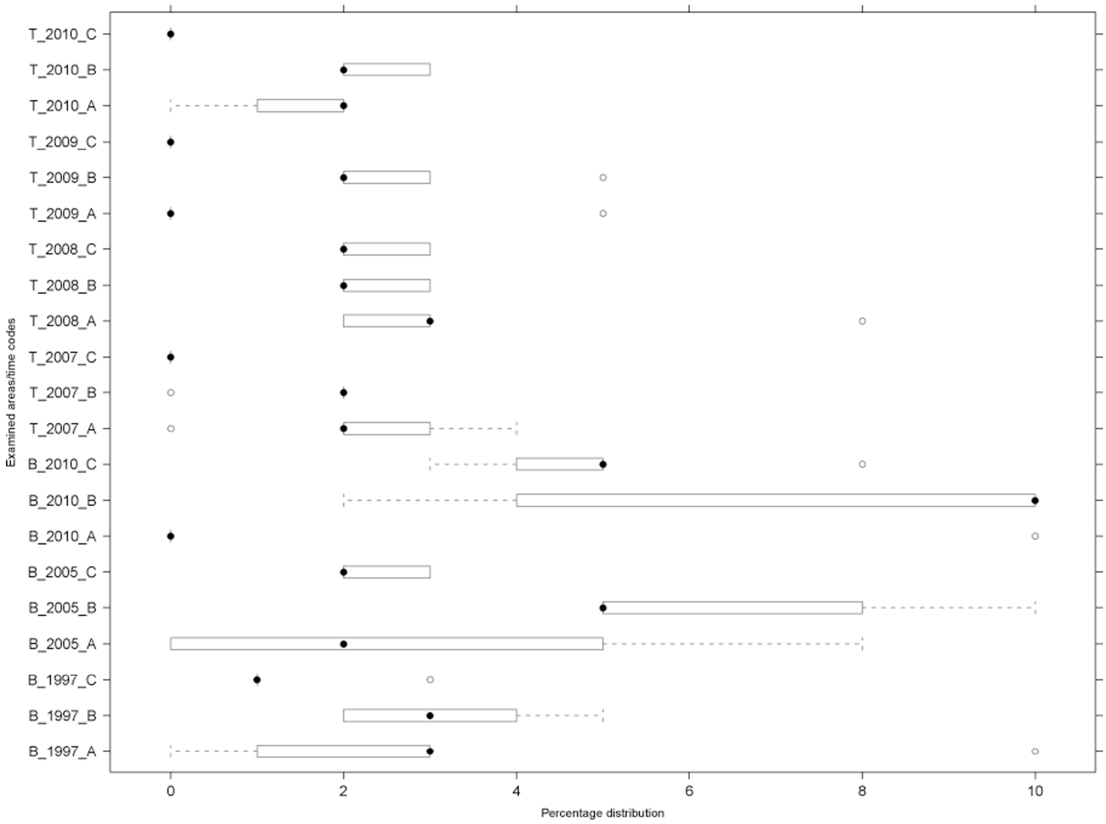

Figure 19. *Occurrence of Achillea collina in percentages at the examined fields*

The highest coverage values for *Festuca arundinacea* were measured in case of Tatárszentgyörgy "B" zone. In Bugac, it was only presented in the "B" quadrates in 1997 (*Fig. 18*). Coverage values for the typical dry grassland species *Achillea collina* clearly showed high prevalence in Bugac (*Fig. 19)*.

Analysis of ecological and environmental factors

Based on relative values of Borhidi the followings were concluded:

Averages of nitrogen demand (NB) of species reduced moving away from the stable in case of the drier area of Bugac, while nitrogen-loving species multiplied better when located closer to the stable, fertilized and trampled area (*Fig. 20*). Based on 5-quadrates' species list, the average nitrogen need showed a decreasing trend moving away from the stable (4.66, 4.00 and 3.91).

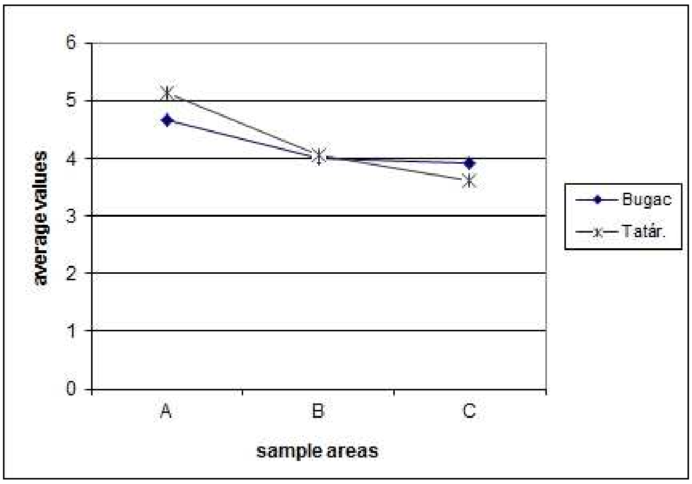

Figure 20. *Average of relative nitrogen demand in fields of Bugac and Tatárszentgyörgy*

Based on the averages of relative water demand (WB) of species, the wettest fields were in the "B" region quadrates in both cases. It is well defined, that areas around the stable had the same values but moving away from it clearly showed that dry habitat species in case of Bugac, while wet habitat species in case of Tatárszentgyörgy became dominant (*Fig. 21*).

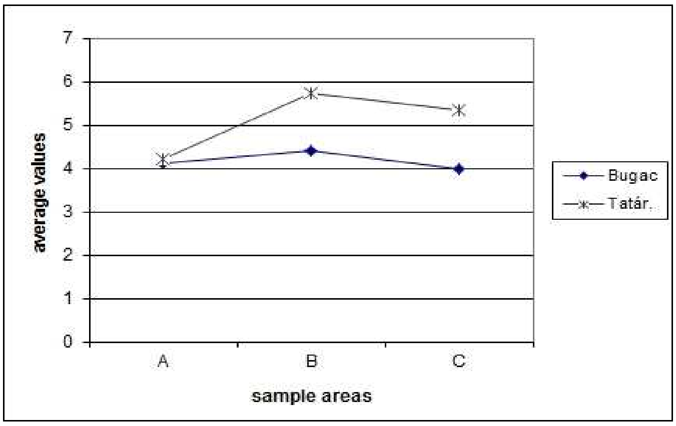

Figure 21. *Average of relative water demand in fields of Bugac and Tatárszentgyörgy*

Average values of heat demand (TB) clearly indicated that Bugac area was warmer and drier *(Fig. 22).*

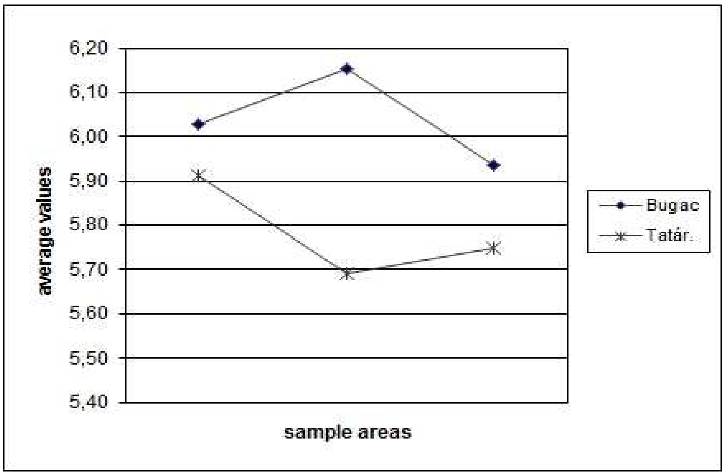

Figure 22. *Average of relative heat demand in fields of Bugac and Tatárszentgyörgy*

Significant changes can be observed in the distribution of life forms (*Fig. 23*) for each quadrates of area category. In the "A" sample areas, both in proportion and in the number of species the one-year stems emerging species (T scap) were significant; their amount was the largest in both areas (9 and 8 species). In addition, repent perennial species (H rept) had a large proportion as well. The amount of perennial grass species (H caesp) increased moving away from the stable and together with the amount of perennial emerging-driven (H space wrap) species, they possessed the largest species number. At the "B" zone in Tatárszentgyörgy, the volume of perennial creeping species (H rept) was also significant (13 species).

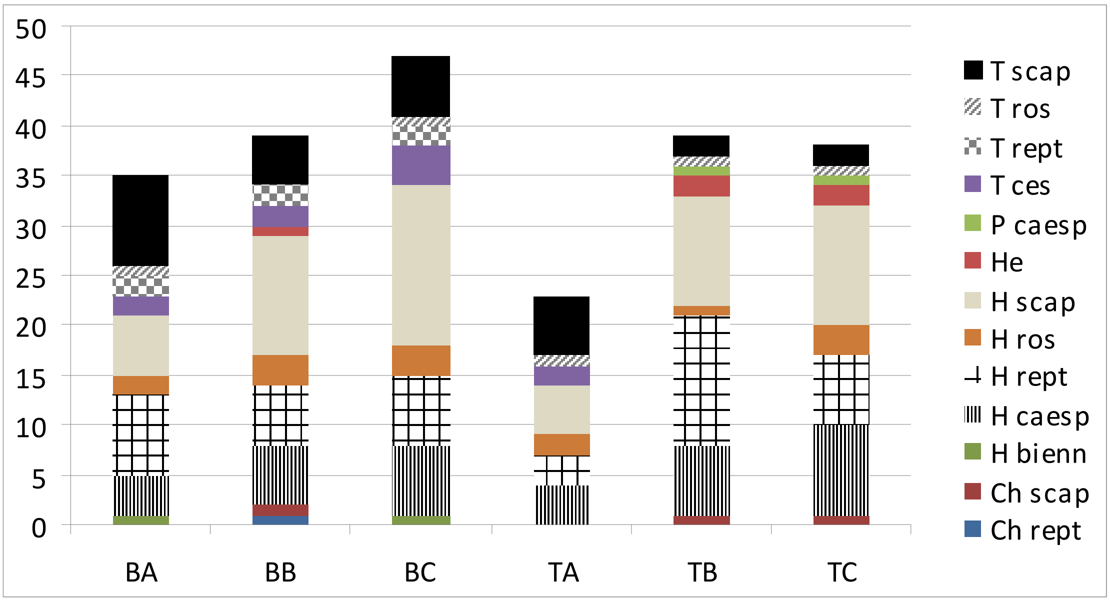

Figure 23. *Distribution of life forms in Bugac and Tatárszentgyörgy fields*

Analysis based on conservation value categories

Assessment based on social behavior types of Borhidi the natural disturbance tolerants (DT) and ruderal competitor (RC) species had the largest proportion near the animal husbandry sites ("A" zone) (*Fig. 24-26*). In the same fields, natural pioneers (NP), agressive competitors (AC), competitors (C) and weeds (W) proportion had not changed significantly, however, presence of generalists (G) decreased in the examined three years.

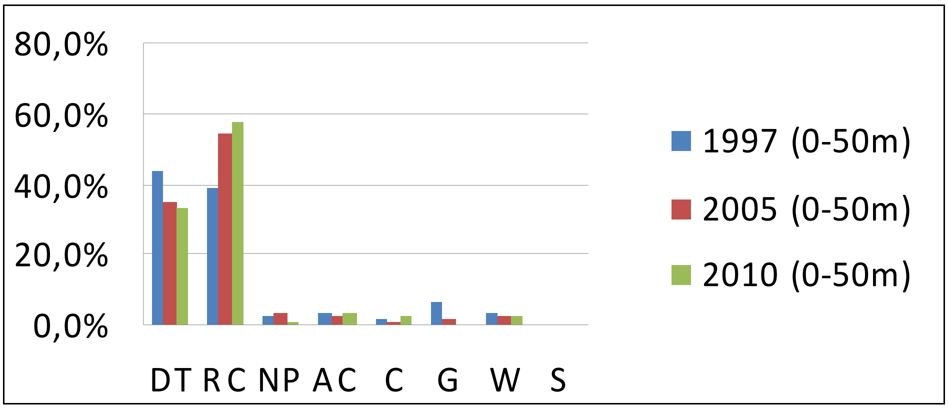

Figure 24. *The social behaviour type values between 1997 and 2010 in Bugac (0-50 m)*

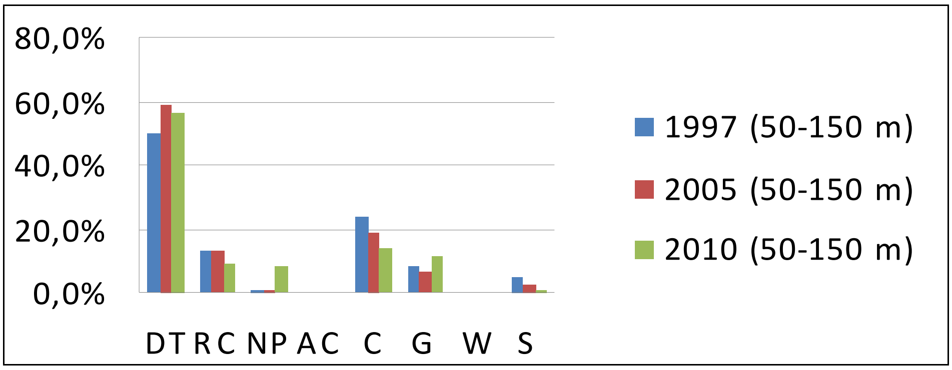

Figure 25. *The social behaviour type values between 1997 and 2010 in Bugac (50-150 m)*

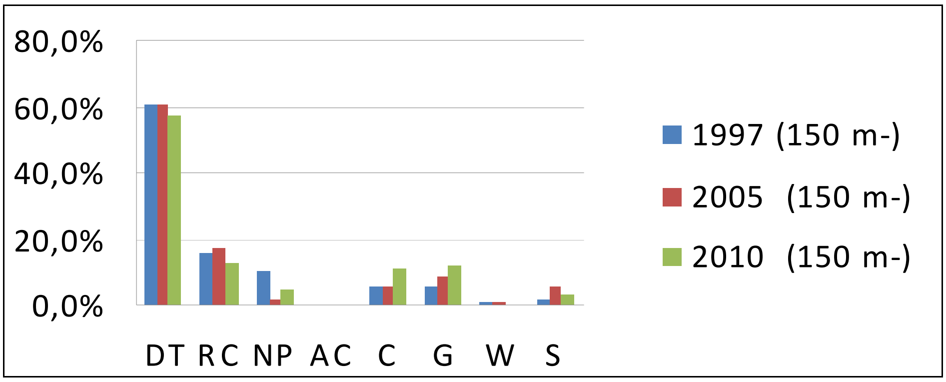

Figure 26. *The social behaviour type values between 1997 and 2010 in Bugac (150 m -)*

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The presence of ruderal competitors (RC) was lower in the following region categories (“B” zone), however, DT had an unchanged proportion. Competitors (C), generalists (G) and specialists (S) were presented in greater species numbers. Distribution of the third field category ("C" zone) was nearly identical, except that weeds (W) appeared again, which were not presented in 50-150 m distance from the stable (“B” zone).

Assessment based on natural protection categories of Simon, disturbance tolerant species (TZ) were presented in 50% in the 0-50 m distance category, however their presence increased to 70% in 2010 (*Fig. 27-29*).

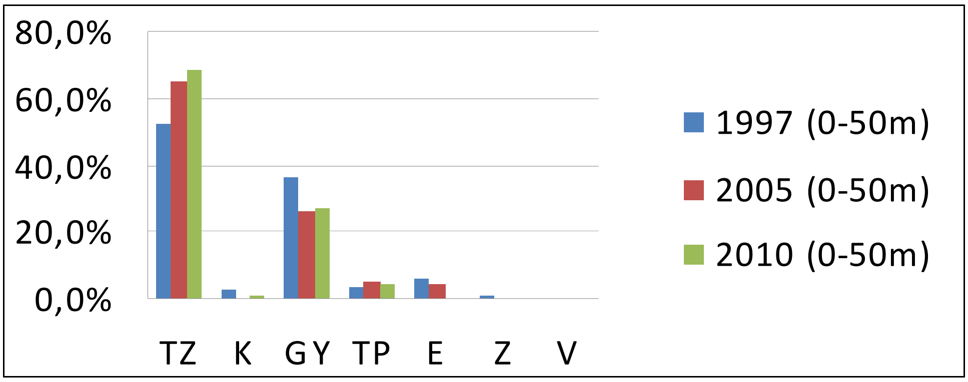

Figure 27. *The nature protection value categories between 1997, 2005 and 2010 in Bugac (0-50 m)*

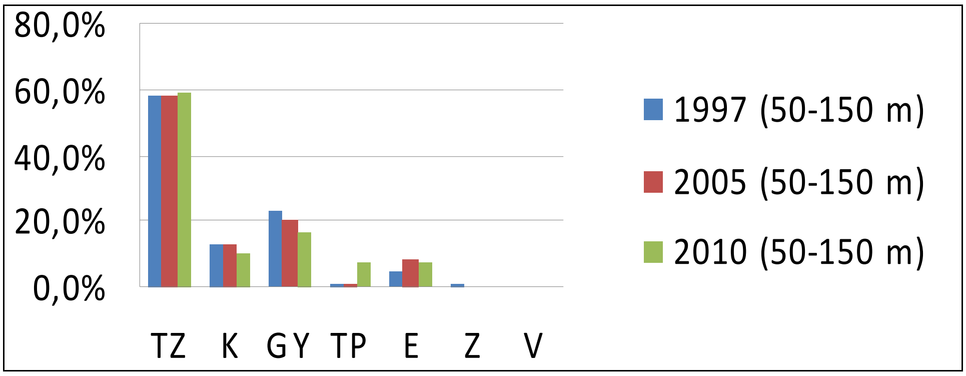

Figure 28. *The nature protection value categories between 1997 and 2010 in Bugac (50-150 m)*

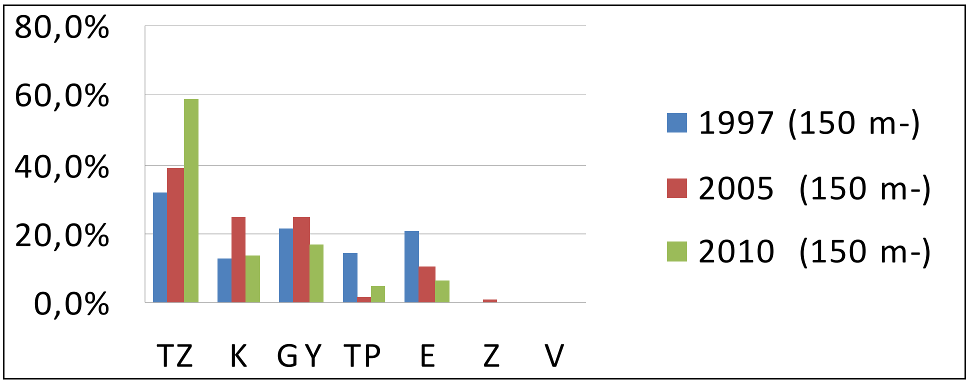

Figure 29. *The nature protection value categories between 1997 and 2010 in Bugac (150 m -)*

Proportion of weeds was initially around 40%, then their presence decreased. Species that suggested natural conditions were presented in minimal quantities near the stable in all three examined years. TZ species attended in middle field category ("B" zone) in the largest quanity.

Proportion of W species evolved around 20%, together with dominant species (E), accompanying species (K) and natural pioneers (TP). In the farthest category ("C" zone), the proportion of species referring to natural conditions was the largest, however, protected species (V) were not presented in Bugac either year.

According to Borhidi values, in the category "A" zone of Tatárszentgyörgy, DT and RC species were presented in the largest proportion (*Fig. 30-32*). While proportion of the former decreased, the latter increased during the examined years. Presence of weeds was low in the same place.

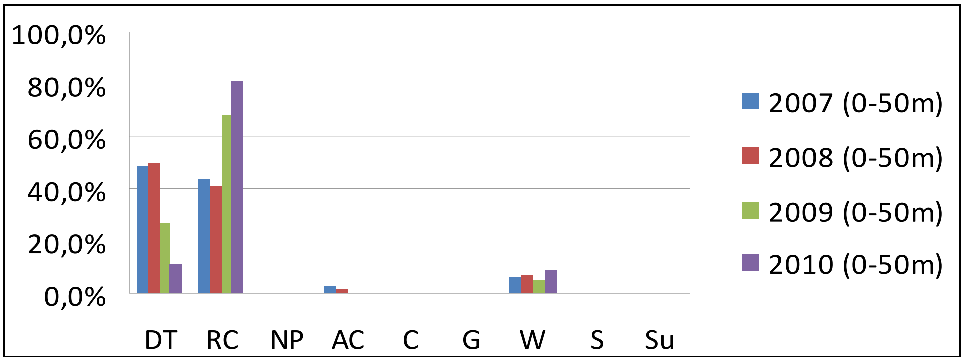

Figure 30. *Social behaviour type values between 2007 and 2010 in Tatárszentgyörgy (0-50 m)*

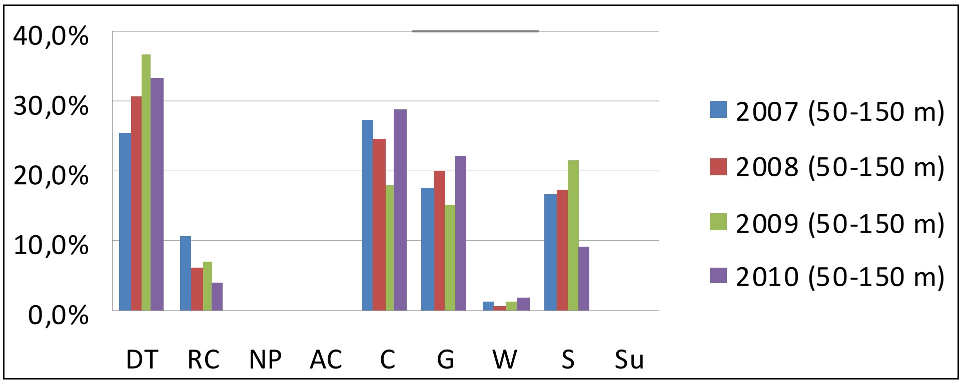

Figure 31. *Social behaviour type values between 2007 and 2010 in Tatárszentgyörgy (50 -150 m)*

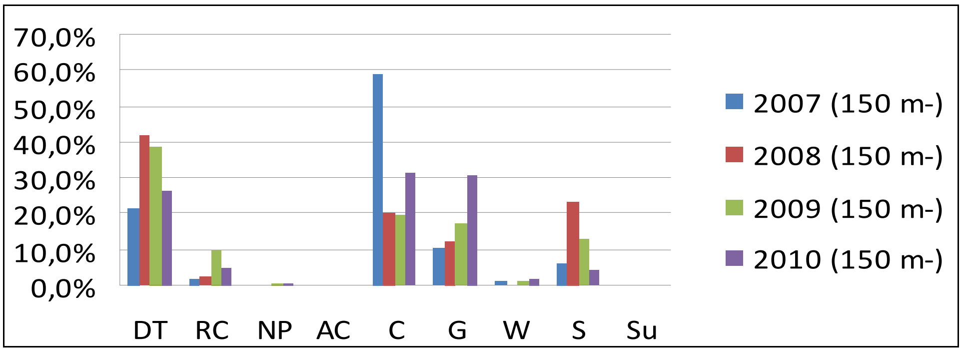

Figure 32. *Social behaviour type values between 2007 and 2010 in Tatárszentgyörgy (150 m -)*

In case of “B” zone, DT species were presented in a large proportion, however, instead of stress tolerant RC, the presence of G, S and C species was common. Both the proportion of C and G decreased until 2009, then increased in 2010.

Recordings from “C” zone indicate that quantities based on social behaviour types developed similarly to the “B” zone. The proportion of C exceed the volume of DT in 2007, however, this condition was not characteristic for measurements of other years (*Figure 25-27*). Determinative species were C, G and S species.

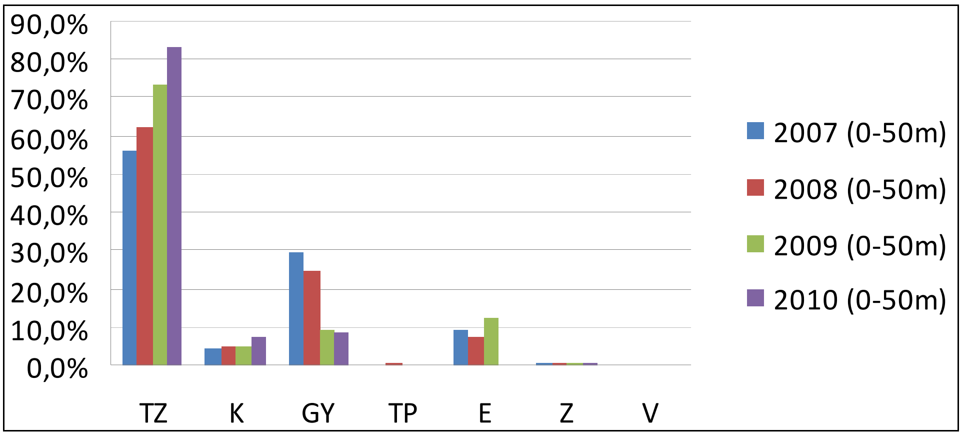

Figure 33. *The nature protection value categories in Tatárszentgyörgy (0-50 m)*

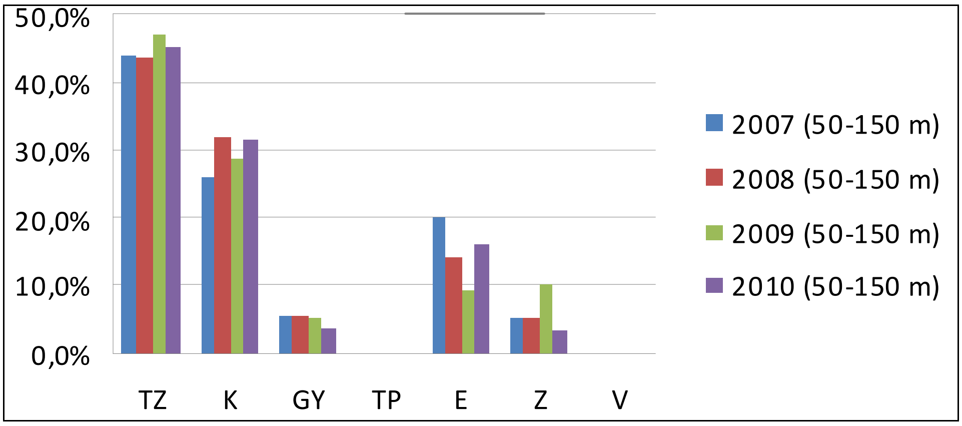

Figure 34. *The nature protection value categories in Tatárszentgyörgy (50-150 m)*

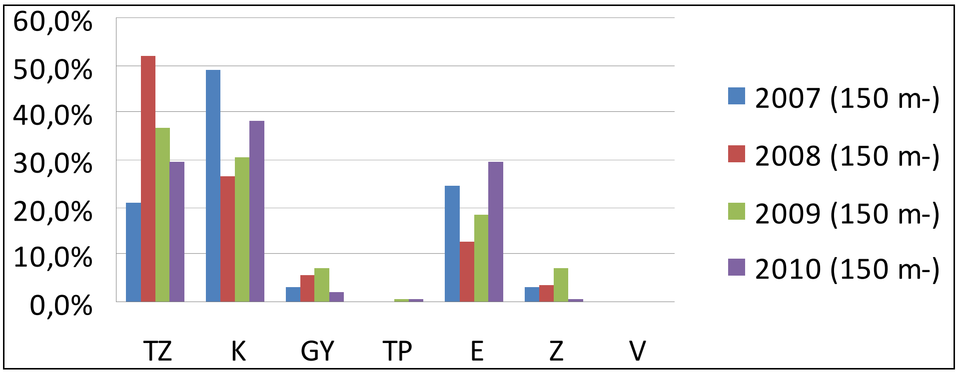

Figure 35. *The nature protection value categories in Tatárszentgyörgy (150 m -)*

Classification of natural protection categories developed similarly to social behavior characterization (*Fig. 33-35*). In the “A” zone, TZ species occurred in the largest quantities. Proportion of weeds was nerly 30%, however, their ratio decreased below 9% by 2010. Associate (K) and dominant (E) species appeared in the examined period, which refers to the natural state.

The volume of those was more significant in case of “B” region. The proportion of TZ species were 30%, smaller then the proportion in the “A” zone, while weeds showed lower shares. TZ species were presented in the largest proportion in 2008, while K species in 2007. Weeds and disturbance tolerant species appeared in smaller ratio. Dominant species reached 30% by 2010.

Discussion

Based on species composition and vegetation composition

Stable close “A” zones were rich in weed species, which occurred because of strong over-grazing and significant trampling (Wilson and MacLoad, 1991). From graminea species, only *Poa humilis* appeared on this kind of areas. This race – and similarly on other Pannonian over-grazed areas (Szentes et al., 2007, 2009a, 2009b; Penksza et al., 2009) – is an indicator of over-grazing, however, a characteristic species of ruderal fields as well (Penksza and Böcker, 1999/2000). General occurring species in the coenological recordings – one fourth of diagnostic species – were weeds or disturbance tolerant species, which clearly implies interference of the fields (Simon, 1988). However, specific and natural species of the arid grassland of Bugac, sandy grassland and wet ground of Tatárszentgyörgy are presented, and their presence is dominant in number of species and coverage. Besides commonly occurring species, ratio of both weeds and disturbance tolerant species were small. Grazing did not modify race composition significantly – against the preliminary hipothesis – as composition of vegetation did not change dominantly and irreversibly. Several publications confirmed that grazing has its positive effects on both species composition and the number of species (Noy-Meir et al., 1989; Fernández-Alès et al., 1993; Hadar et al., 1999; Tóth et al., 2003; Fischer and Wipf, 2002; Catorci et al., 2009, 2011).

Recordings from Bugac sample area are seemingly contradictory, since a number of species continuously decreased during the examined time in case of ”B” zone. The reason could be that there was a change in grazing type (from free to switch grazing) in 2001. Previously, higher species number could occur, because of higher ratio of weeds. Free grazing was applied until 2000, and until that time the natural vegetation declined and the volume of weeds increased due to greater trampling and over-grazing. This was confirmed by several authors (Szentes et al., 2007, 2009a, 2009b; Penksza et al., 2009). The total number of species was high, however, the average number of species and species number of quadrates were low. This resulted from that each quadrates were greatly different; the stability of vegetation was weak, and the ratio of smaller constancy species was high in the examined area (Whittaker, 1965, 1975; Adler and Lauenroth, 2000; Peco et al., 2006). Higher species number occurred because of the arid character of the area in case of Bugac, since these values were usually smaller in wetter regions of Great Hungarian Plain (Borhidi, 2003; Herczeg et al., 2006; Kiss et al., 2006; Penksza et al., 2009). In case of Bugac, the species number was low in “C” zone – practically it was an abandoned area in 1997. This confirmed the results of several other publications, in which a decrease of species number was reported in case of abandoned fields (Smith and Rushton, 1994). According to several publications, appropriate grazing favors species enrichment (Huston, 1994; Proulx and Mazumder, 1998; Pykälä et al., 2005). According to Losvik (1999), species enrichment is attenuated by the discontinuation of grazing and mowing. This was confirmed by Smith and Rushton (1994) too, since according to them, plant species richness and species diversity is lower in ungrazed areas than in grazed areas. Our study confirms this as well.

The volume of grasses increased during grazing (McNaughton and Chapin, 1985). This was easily tracked down in different zones, however, a remarkable variance was measured in case of dominant species. Coverage of disturbance tolerant *Cynodon dactylon* was notable in the “A” zone, while the also disturbance tolerant *Festuca pseudovina* was notable in case of "B" zone in both of the areas. Other disturbance tolerant species, *Festuca arundinacea* and *Molinia coerulea*, specific to wet areas, showed high coverage values in Tatárszentgyörgy. These appeared in higher rate in the “B” zone of Tatárszentgyörgy, as an effect of grazing pressure. It is also demonstrating that grazing increases quantity of grasses (McNaughton and Chapin, 1985; Catorci et al., 2011).

Based on diversity values

Diversity values increased away from the stable and this was specific in both cases (“B” and “C” zones). This indicated that with moderation of disturbance might natural regeneration processes come into view and succession complexity of association increase (Tóthmérész, 1995; Virágh and Bartha, 1996; Barbaro et al., 2001; Pykälä et al., 2005). Similar conclusion could be reached by examining the developement of species numbers. In case of major disturbance (“A” zone), stochastic processes come into view, sortedness becomes smaller and the evolution of species number becomes less predictable, however, measured data scattered heavily (Tóthmérész, 1995; Luoto et al., 2003; Házi et al., 2011). Change in species number shows positive correlation with time in the other two farther zones so it is increasing monotonically in time, similarly to our expectations. Although the number is not a completely reliable criterion of the association, comparing the observed diversities of the two metrics shows a complementary and reliabile increase (Virágh and Bartha, 1996; Luoto et al., 2003; Pykälä et al., 2005; Házi et al., 2011).

Diversity profiles of Rényi showed similar tendencies in both cases thus confirmed that grazing exhibits similar effects in both wet and dry Pannonian grasslands. These values were higher in case of drier areas, which confirmed that due to intensive grazing, drier areas preserve species richness, thereby more appropriate for grazing. In the “A” zone, the low management pressure led to an increase in diversity and this is consistent with literature data (Bakker, 1989; Tóthmérész, 1995; Nösberger et al., 1998; Kampmann et al., 2007).

Based on ecology and environmental factors

According to the relative ecology values, species occurring in the “A” zone were high nitrogen demanding species, which is caused by trampling and manuring by livestock (Penksza et al., 2009a, 2009b). In both “B” and “C” zones, grazing intensities were smaller – smaller level of trampling and manuring – thus it resulted in the appearance of smaller nitrogen demanding species (Penksza et al., 2009a, 2009b). According to the relative water need (WB), “B” zone was the wettest in both of the sample areas. In the “B” zone of Tatárszentgyörgy, species from wet areas dominated, represented by the high water demand *Carex* species (Borhidi, 1995; Simon, 2000). According to relative heat demand of species (TB), Bugac area had dry grassland vegetation features, since each zones consisted of species that are typical in warmer climate areas. The largest difference was in the case of “B” zone that contained species from wetter (Tatárszentgyörgy) areas, which were species of cooler areas (*Carex* ssp., *Mentha aquatica, Molinia coerulea*).

According to life form distributions, there are significant differences between quadrates of area categories. Besides annuals (T scap), creeping perennials (H rept) were significant both in number of species and percentage. These proliferated because of intensive grazing (Gatti et al., 2007; Catorci et al., 2011). In “A” zone, the annual and rosulate form species there was no significantly higher coverage value compared to the other two zones. This is conflicting previous studies (Kahmen and Poschlod, 2008; Catorci et al., 2011). The amount of annual grassland species (H caesp) showed similarity with previous studies (Gatti et al., 2007; Sebastià et al., 2008), since their amount increased moving away from the yard in grazing exposed zones. Perennial reptan (H rept) species amount was significant in “A” zone of Tatárszentgyörgy as well, which showed the effects of intensive grazing (Gatti et al., 2007; Sebastià et al., 2008).

Evaluation based on nature protection value categories

In the conservation evaluation, “A” zones showed richness in weed and disturbance tolerant species, similarly to stable close areas of Pannonian grasslands (Penksza et al., 2009a, 2009b). In drier grasslands (Bugac), from the aspect of natural protection criteria, stronger grazing led to a more valuable vegetation in the “B” zone. Nature protection and diversity values increased in “C” zones as well, however, these values were below the values of “B” zones. Its reason could be the change in management, since free grazing was converted to switch grazing, thereby the grazing pressure became uneven in both “B” and “C” zones. According to the data, preservative grass composition developement can occur father from yard with smaller grazing pressure.

Conclusions

In the examined dry (Bugac) and wet (Tatárszentgyörgy) vegetations, species composition totally changed in “A” zones due to intensive trampling and grazing and degraded into a characterless areas. The other two zones of vegetation were not homogenised due to grazing. Specific species of arid and wet areas remained and preserved their significant coverage. Diagnostic species showed that vegetation of the two different areas reacted to grazing in a different way. While the Bugac area was capable of tolerating higher pressure independently from the distance, until in “B” zone of Tatárszentgyörgy a significant change could be observed in the volume of disturbance indicator species because of grazing.

Environmental background well expressed by relative ecological. Based on this, the ratio of degradation indicator species was high as far as 50 m from the stable in both examined places. However, in case of farther areas – more than 50 m from the stable –, the ratio of species referring to natural conditions was great. In recordings close to the yard (0-50 m), only weeds (W) and disturbance tolerant (DT) species were presented. 50-150 m distance from the yard, natural vegetation forming generalist and competitors remained, and according to this, this particular distance is suitable enough to sustaine grass composition for long-term.

With the decrease of grazing intensity, the examined fields would fit to natural protection claims. Compliance for natural protection claims can be realised in “B” zone in case of dry grassland – and “C” zone – in case of wet grassland. Grazing, as environmental protection treatment, has an important role in preservation of biodiversity, however, can-not be applied generally and universally for wet and dry grasslands or for fields close together. In conclusion, a rather careful planning and accuracy is necessary. According to the result of this study, grazing – besides mowing – can become an indispensable method of environmental protection and restoration ecology (van Wieren, 1991, Wallis De Vries, 1995, Bakker and Londo, 1998; Cosyns and Hoffmann, 2004; Kramberger and Kaligarič, 2008).

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ALGAL VEGETATIVE ACTIVITY IN THE UPPER JORDAN RIVER (NORTHERN ISRAEL): AN *IN VITRO* GLASS SLIDE EXPERIMENT

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Abstract. Algal vegetative activity and intensity of self purification processes were determined via a two stage in vitro artificial substrates (glass slides) occupation experiment, conducted during winter 2006-2007 and summer 2007 in the streams of the Upper Jordan River Basin. Daily measurement of temperature, conductivity, mineralization and pH were performed. Once a week algal species where identified, snd their Abundance (cells/cm^2), Cell volumes (μm^3/cm^2) and richness of species (taxa encountered/600 algal cells) tabulated for each taxon. Algal communities where richer in the summer in all stations and contained mainly Diatoms or Diatoms/green algae mix. Only the Banias station winter community was dominated by the green algae. Highest self-purification activity was observed during the summer in the upper part of the basin (Banias station). Species richness grew with anthropogenic influence and self-purification intensity. Self-purification proceeded faster in conditions of high temperature and solar radiation. The Shannon index positively correlated with species richness in both winter and summer experiments. The artificial colonization of substrates by algae took 2-3 weeks; formation of small celled green algae encouraged by high temperatures and solar radiation conditions increased colonization speed in the summer. Statistically significant factors influencing algal activity were found to be pH and Total Dissolved Solids concentration.
Keywords: *Upper Jordan River, artificial substrate, in vitro experiment, season, Israel*

Introduction

The Upper Jordan River is the major source of fresh water feeding Lake Kinneret. Therefore its water must be of sufficient quality.

The surface water quality is determined by loads penetrating the water basin, as well as the intensity in which self-purification processes occur. Algae serve as the first element in the nutrients utilization process and in small rivers they develop on substrates.

The intensity of the self-purification process is directly linked to the amount of nutrients and the speed of their utilization. Within the water monitoring framework in countries of the European Union, periphyton in the rivers is monitored (European Parliament, 2000). For this purpose, the species content, presence of indicator species, abundance, species biomass in the community as well as chlorophyll concentrations were determined (Cardoso et al., 2005).

Observations of substrate occupation are recommended during the vegetation period (Ács et al., 2005). In the Upper Jordan River basin algae developed more actively during the rainy season (December-March). In order to make any conclusion regarding to the intensity of these processes, it was essential to determine the attributes of four general classes: (1) taxonomic composition, (2) species richness and diversity, (3) tolerance/intolerance, and (4) trophic structure (King and Richardson, 2003). Referring to the first three classes we previously assessed the algal diversity in the Upper Jordan River basin on the basis of our data base (Barinova et al., 2006).

A two stage experiment for the determination of algal vegetative activity in the streams of the Upper Jordan River Basin was conducted during December-January 2006-2007 and September-October 2007. Via this study we determined the speed at which colonization of substrates occurs and the activity levels of self purification processes at different stations of the Upper Jordan River Basin.

Materials and methods

Each stage of the experiment was conducted *in vitro* on artificial substrates. Water samples (each of 30 l volume) as well as substrates and algae samples where collected from the habitats at the sampling stations in the Upper Jordan River area (*Fig. 1*). For each sampling station the collected water, substrates and algae where mixed together in a plastic container of 50 l volume. The pool shaped containers where placed on the roof of one of the buildings in Haifa University.

Daily measurement of temperature, conductivity, mineralization and pH were performed using the HANNA HI 9813 apparatus and a thermometer. Nitrates concentration in each pool was determined via the HANNA HI 93728 apparatus at stage 1 and by a specialized water laboratory (The Neve Yaar field laboratory) at stage 2. Glass slides served as the artificial substrates. They where placed horizontally in parallel to the water surface on buoys at 5 cm depth (Ács et al., 2005).

Each 7 days slides where collected from all the pools to determine the present algal species, their abundance/number and algal biomass on each slide.

The identification of algal species on the sufrace of the glass slides was performed using a dissecting Swift microscope under magnifications of 800. Cell counting for each species was performed via the direct counting method.

To simplify calculating periphyton algae we made sure the encrustation grew on a flat surface of a known area (PhycoTech, 2007).

Abundance (cells/cm^2), Cell volumes (μm^3/cm^2) and Species richness (taxa encountered/600 algal cells) where tabulated for each taxon (Charles et al., 2002). For each sampling slide cell counting was performed in numerous view fields until at least 600 cells were enumerated. The counting of each field (330x330 µm) was repeated for 10-100 times for each species and the average was registered. Average cell volume was estimated by measuring the dimensions of at least 30 representative cells and calculating cell volume in accordance with the nearest geometric shape (Charles et al., 2002; Hillebrand et al., 1999). The obtained cell volumes where multiplied by the previously obtained cell numbers. Taxa without distinct cell walls and certain colonial algae (e.g. Cyanobacteria) were counted as colony operational units.

Since in our experiment we have counted the number of individuals of each species in the present community we were able to calculate the Shannon index *H’* which reflects the degree of abundance equality among the species in the community and is correlated to the entropy of the ecosystem (Good, 1953). The non-parametric Shannon index is calculated as follows:

$$H' = -\sum_{i=1}^{S} \frac{n_i}{N} \ln \frac{n_i}{N}$$

where:
n_i – Number of individuals in each species;
S – The number of species: species richness;
N – Total number of all individuals;

$\frac{n_i}{N}$ – Relative abundance of each species.

Results and discussion

During the experimental periods water temperatures ranged between: 24.6-29.3°C (at times reaching 32°C) in the summer and between 13-19°C (at times reaching 11°C) in the winter (*Table 1*).

Table 1. *Summary of parameters for all sampling stations during the four weeks of both summer and winter experiments.*

Banias									
Day of	**TDS (mg/l)**		**pH**		**Temperature °C**		**NO_3 (mg/l)**		
Experiment	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
7	295	234	7	7.6	15	28.8	0	1.2
14	333	211	8.1	7.35	19	29.1	0	0.9
21	224	214	8.2	8.1	13	24.7	0	0.7
28	123	246	6.4	7.9	13	26.1	0	0
Yosef								
Day of	**TDS (mg/l)**		**pH**		**Temperature °C**		**NO_3 (mg/l)**	
Experiment	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
7	213	158	7.45	7.7	15	28.6	0.2	1.6
14	246	178	7.8	7.5	19	28.9	0	0.9
21	197	193	8.1	7.85	13	24.7	0	0
28	132	200	6.6	7.8	13	26.4	0	0
Jordan								
Day of	**TDS (mg/l)**		**pH**		**Temperature °C**		**NO_3 (mg/l)**	
Experiment	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
7	213	193	7.45	7.8	15	26.5	0.2	0.2
14	246	166	7.8	7.65	19	28.8	0	0
21	197	217	8.1	7.8	13	24.6	0	0
28	132	186	6.6	7.8	13	26.2	0	0
Meshushim								
Day of	**TDS (mg/l)**		**pH**		**Temperature °C**		**NO_3 (mg/l)**	
Experiment	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
7	276	241	8	8.8	15	28.7	0	1.9
14	295	252	8.8	8.2	19	29.3	0	1.1
21	201	261	7.5	7.7	15	25.1	0	0.4
28	139	217	7	7.7	13	26.6	0	0

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As it can be seen in the *Table 1*, in both experiments at the beginning the highest water acidity was observed in the Banias stream, while the most alkali water was observed in the Meshushim stream. Acidity of the Yosef bridge waters closely resembled those of the Jordan River but, tended to be more neutral.

At the end of the winter experiment the pH in all pools was ≤7.0. The summer final pH values on the other hand where much more alkali and came close to ~8.0.

There was no rain fall during the entire summer experiment period. Whereas during the winter experiment there was rain fall each 5-7 days as common in the north of Israel.

During the winter experiment in each of the experimental pools we have observed a tendency of TDS lowering towards the 4th week, with final values being about half those we have started with (*Table 1*). This points to a demineralization process that could be related to the activity of the algal communities. During the summer experiment we have observed a peak in the TDS values on the third week in the Jordan and Meshushim stations and on the forth week in the Banias and Yosef stations. The dynamics of Mineralization values is related to the self-purification processes. The overall TDS values during the entire experiment remained low which indicates the general purity of water in our experimental stations.

Nitrates can serve as indicators of both water quality and the activity level of the algal community. In *Table 1*, we see that in the winter experiment very low amounts of nitrates where present at the Yosef and Jordan stations.

However during the summer experiment nitrates were present in all stations (with maximal initial concentration observed at the Meshushim station) but lowered with time. This shows that in the winter water is cleaner and the algal communities are more active.

Comparing winter and summer results in the Banias station (*Fig. 2*) the general range of both abundance and biomass were similar during both experimental periods. Yet in the winter experiment the average cell volume (biomass) was almost twice that of the one found in the summer experiment. This points to the difference in stress factors during the two periods being much higher during the summer time. Cells were smaller in the summer as a result of environmental stress influences. The trend lines are in agreement with these conclusions.

Comparison of algal abundance and biomass in the Yosef station (*Fig. 3*) shows that while the abundance remains about the same in both periods, cell biomass was four times higher during the summer period. Average cell volume during the first three weeks of both experiments where somewhat similar; however, on the fourth week of the summer experiment the average cell volume increased tremendously suggesting the stress factor influence subsided. All trend lines show opposite tendencies in each of the factors during winter as opposed to summer.

At the Jordan station during both experiments (*Fig. 4*) both abundance and biomass where somewhat higher during summer. Since average cell volume fluctuated in the winter experiment while, remaining constantly small during the summer period, we can say that a higher level of stress factors influenced the system during the summer period. The trend lines confirm similar tendencies for all factors except abundance for which they are opposite in the winter and the summer.

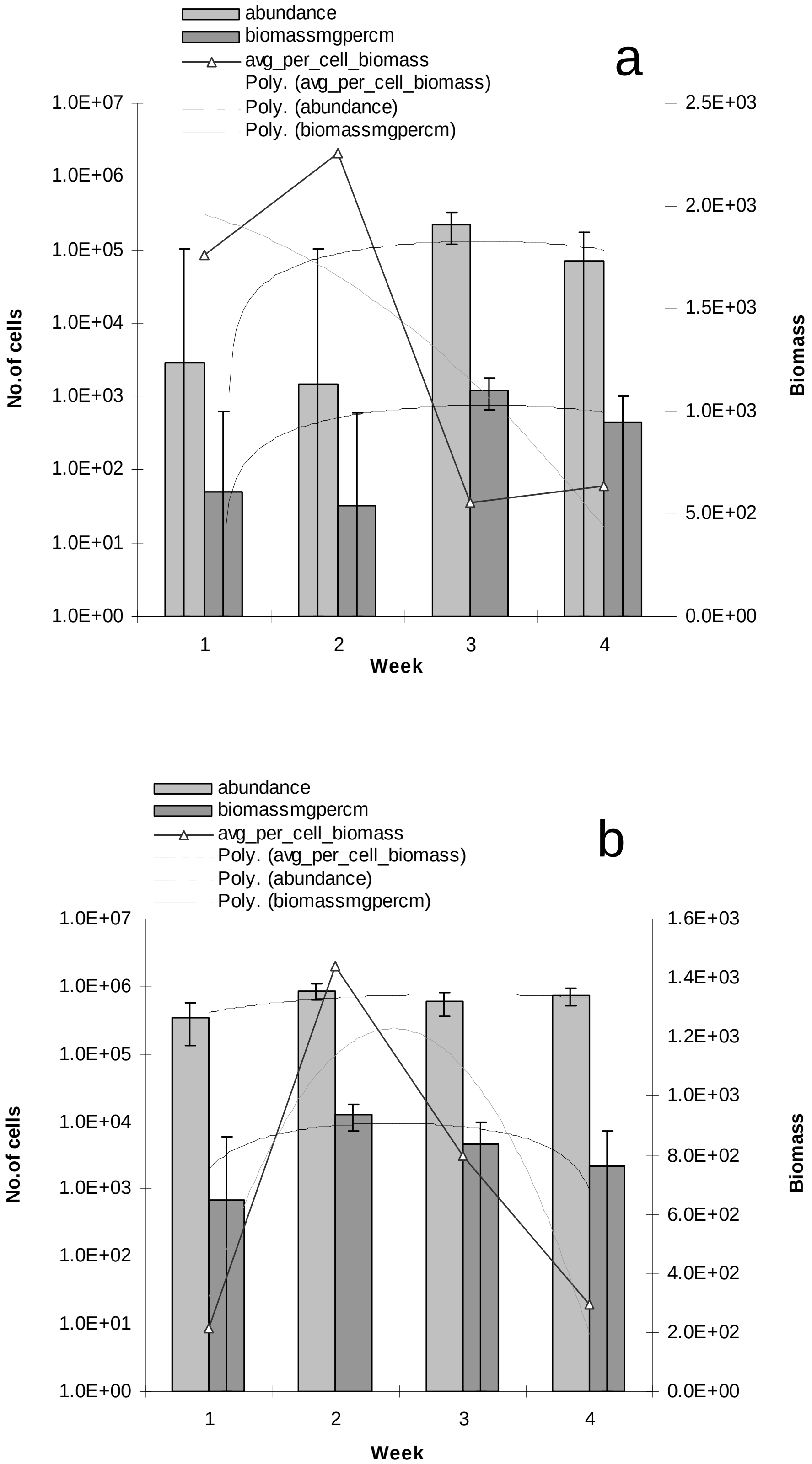

Figure 2. *Changes in abundance biomass per cm^2 average cell biomass during the summer and winter experimental periods in the Banias station – a: winter; b: summer*

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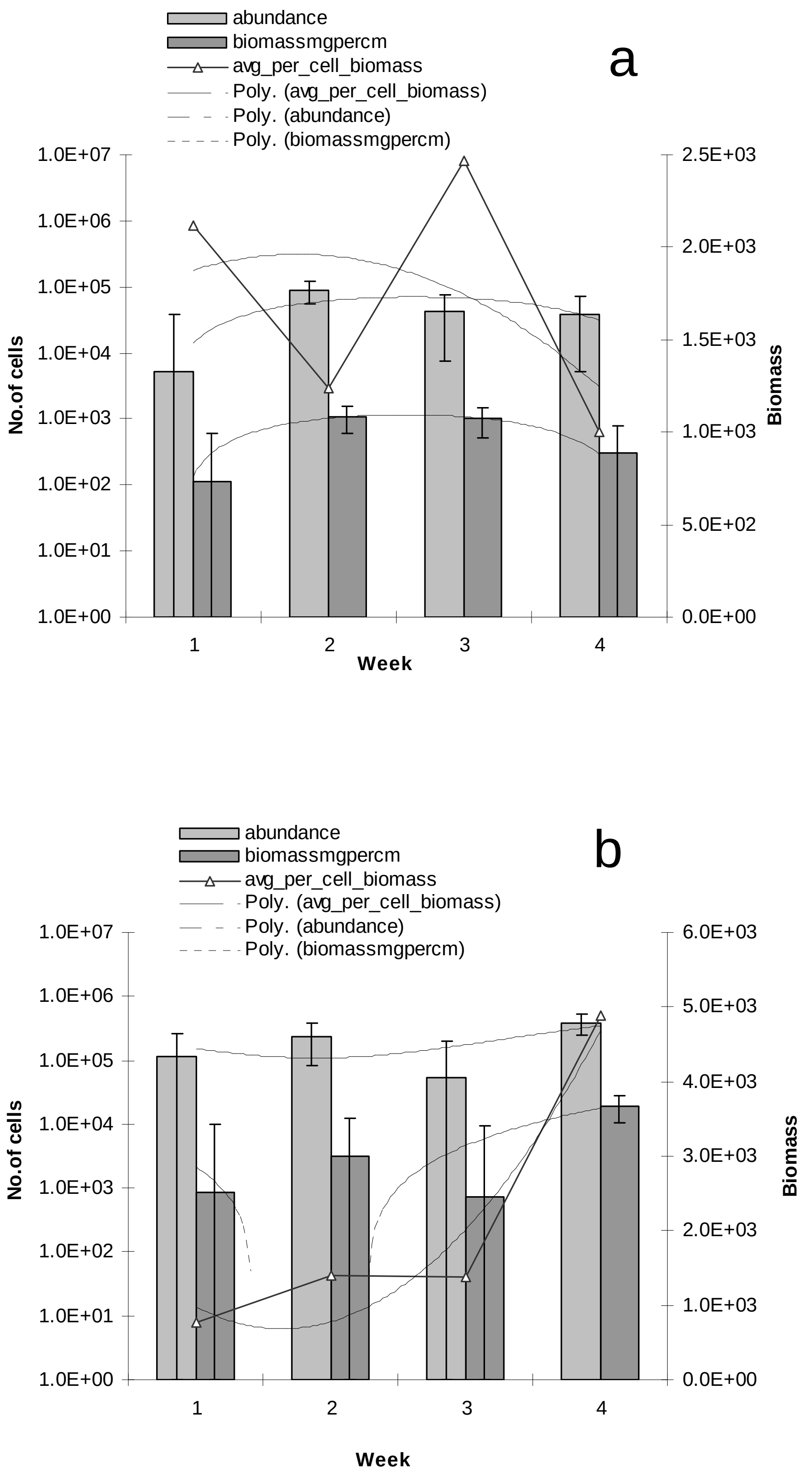
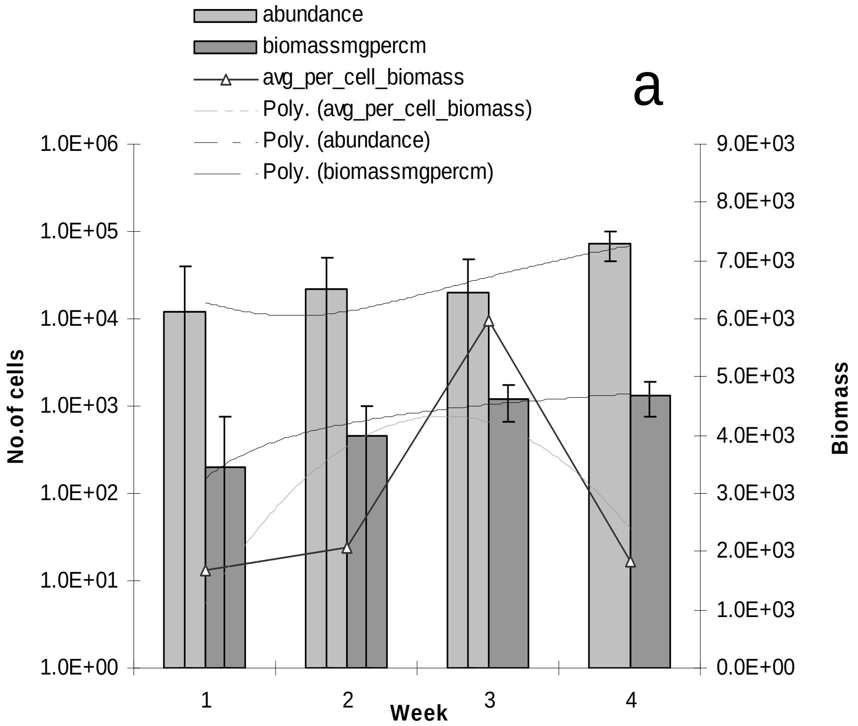


Figure 3*. Changes in abundance biomass per cm^2 average cell biomass during the summer and winter experimental periods at the Yosef station – a: winter; b: summer*



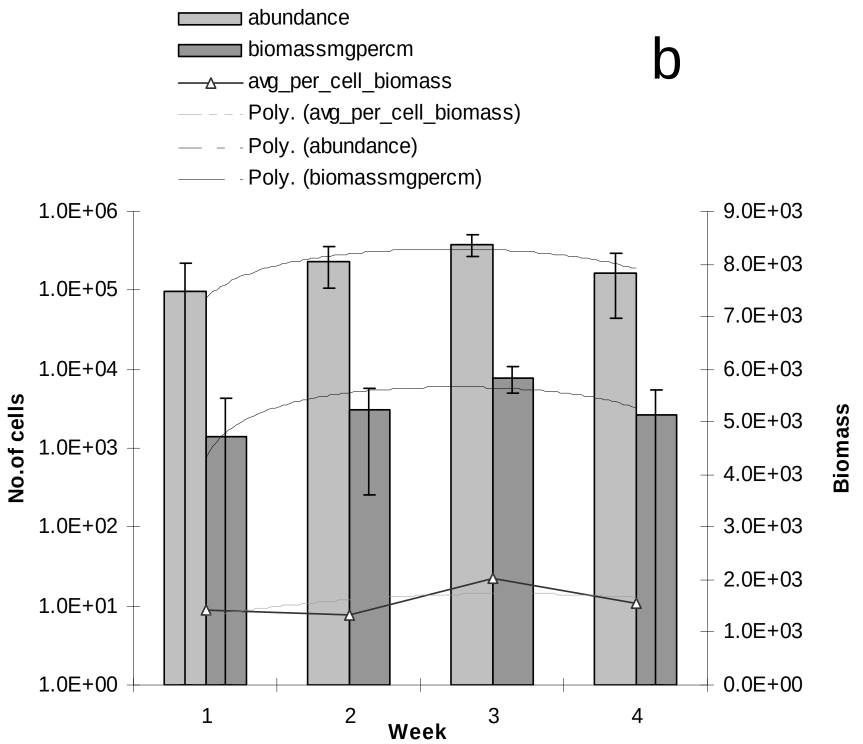


Figure 4. *Changes in abundance biomass per cm^2 average cell biomass during the summer and winter experimental periods at the Jordan station – a: winter; b: summer*

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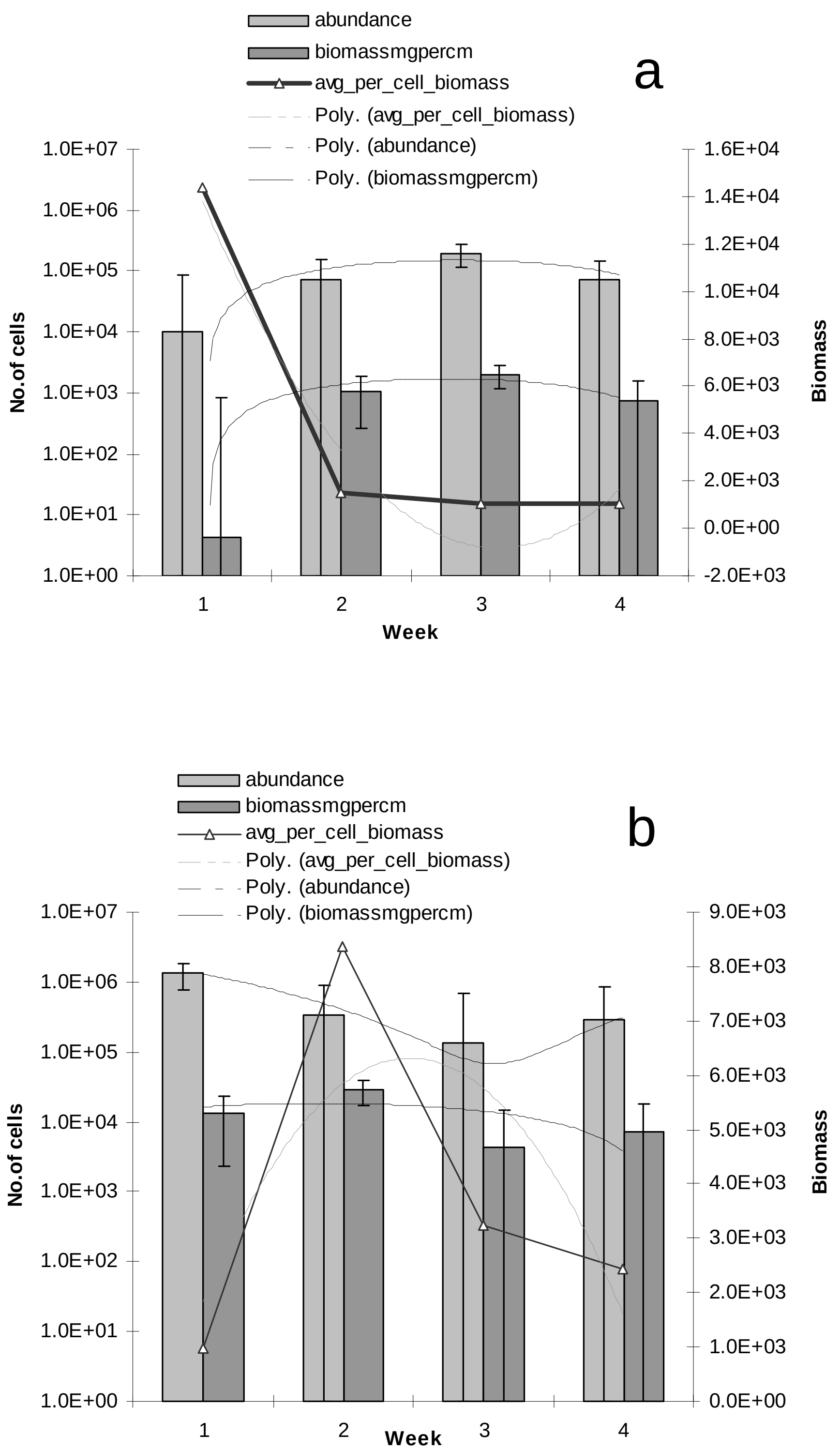

Figure 5. *Changes in abundance biomass per cm*^{2} *average cell biomass during the summer and winter experimental periods at the Meshushim station – a: winter; b: summer*

At the Meshushim station (*Fig. 5*) abundance during the summer period was ten times higher; however, the biomass remained in the same range during both experiments. The average cell volume in the summer was ten times lower than in the winter.

These results suggest that there are stress impacts in the system during the summer. The trend lines confirm similar changes during the experiment for all factors except for the average cell volume for which they are opposite.

At the Banias station the total number of species during both experimental periods was about the same, under 20 species in total (*Fig. 6*). However, the diversity of the community in the Banias station was the richest among all stations. The Banias station diversity peak was achieved on the third week of the winter experiment and was mostly due to green algae species. At the same time the maximal diversity during the summer experiment was obtained already on the second week and was mostly composed of diatoms as well as green algae.

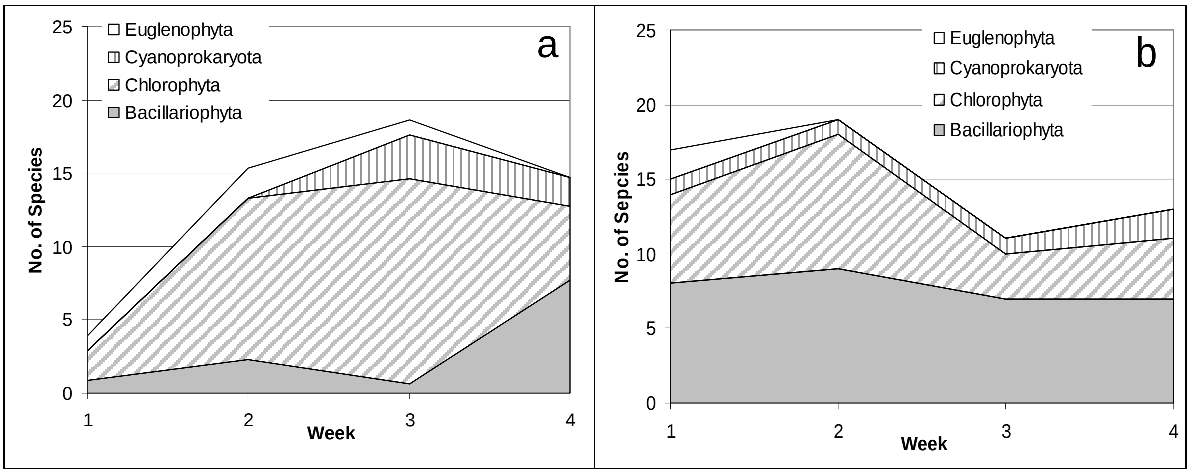

Figure 6. *Divisional and numeric changes in the community of species during the summer and winter experimental periods at the Banias station – a: winter; b: summer*

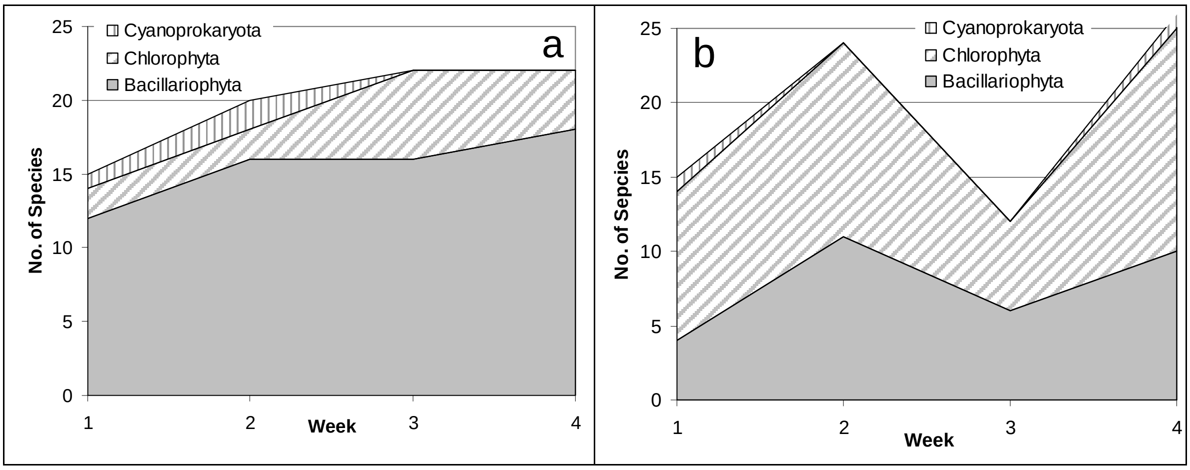

Figure 7. *Divisional and numeric changes in the community of species during the summer and winter experimental periods at the Yosef station – a: winter; b: summer*

Maximal species richness at the Yosef station was in the range of 20-25 species (*Fig. 7*). The winter community reached its peak on the third week mostly due to diatom species, while in the summer community the diversity fluctuated and had contained equal amounts of both diatoms and green algae.

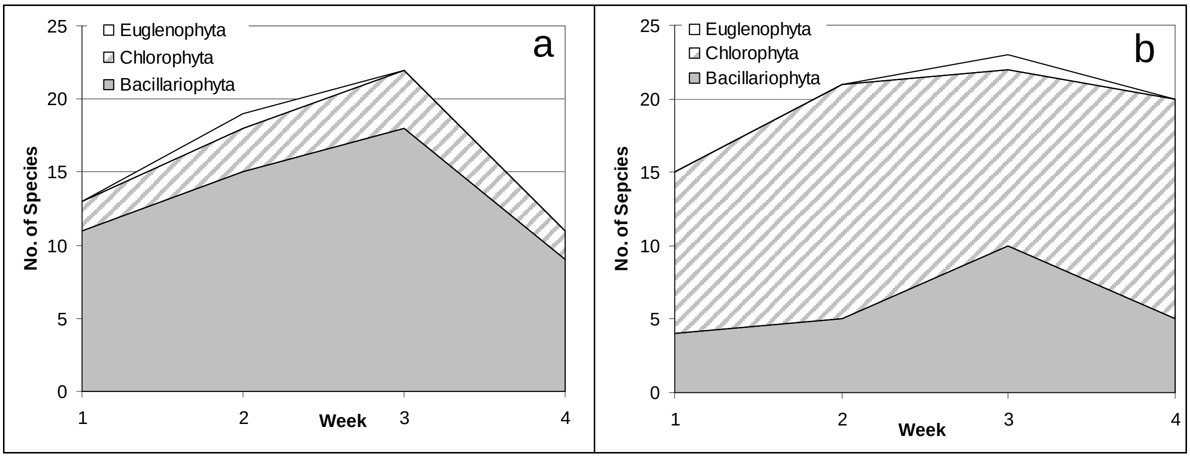

Figure 8. *Divisional and numeric changes in the community of species during the summer and winter experimental periods at the Jordan station – a: winter; b: summer*

Maximal number of species at the Jordan station was reached on the third week of both experiments and ranged from 20-25 species (*Fig. 8*). Yet, the winter community was comprised mostly of diatoms while the summer community was dominated by green algae.

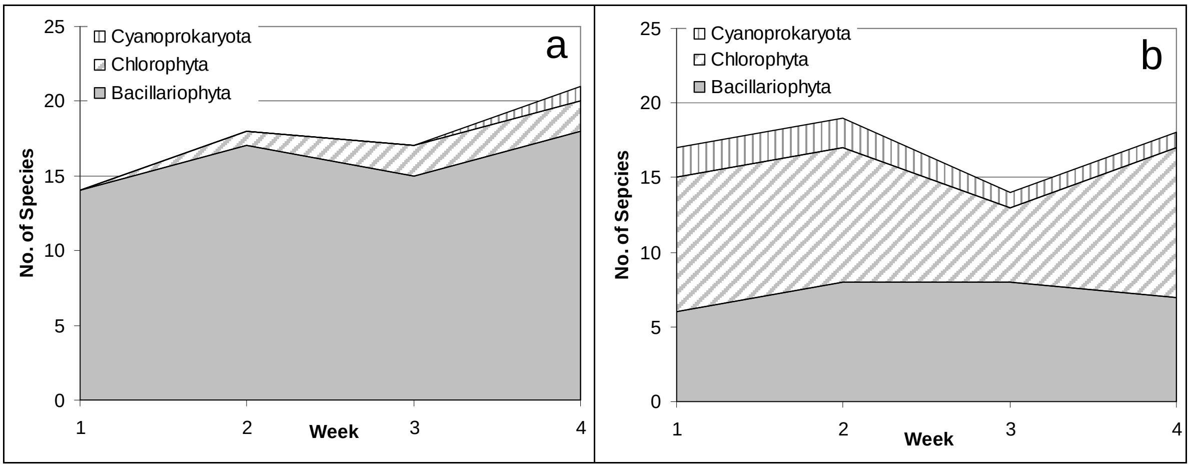

Figure 9. *Divisional and numeric changes in community of species during the summer and winter experimental periods at the Meshushim station – a: winter; b: summer*

The low diversity community of the Meshushim station reached its peak (21 species) in the winter period only on the fourth week mostly due to diatom species (*Fig. 9*). The summer community was about equally comprised of diatoms and green algae and during the entire period was enriched with cyanobacteria. The total low diversity as well as the presence of cyanobacteria during the summer period indicate a reaction of the Meshushim ecosystem to stress impacts.

Table 2 shows that the factors positively influencing species richness in general and diatoms richness in particular, are pH and TDS. These factors have positive influence on the biomass as well.

Table 2. *Multivariate regression stepwise statistical analysis results for the winter experiment in the entire Jordan Basin*

Winter basin	Step 1	Step 2	Step 3	Step 4	Step 5
No. of Species	-	pH TDS 0.57**	-	-	-
Abundance	-	-	-	-	-
Biomass	-	-	TDS pH 0.35*	-	-
Avg_per_cell_biomass	-	-	-	-	-
Bacillariophyta	-	-	TDS pH 0.34*	-	-
Chlorophyta	-	-	-	-	-

Multivariate regression analysis of the summer communities in the entire upper Jordan basin in *Table 3* shows that factors possessing very slight positive influence on the Chlorophyta species richness are TDS, temperature and Nitrate concentrations.

Table 3. *Multivariate regression stepwise statistical analysis results for the summer experiment in the entire Jordan Basin*

Summer basin	Step 1	Step 2	Step 3	Step 4	Step 5
No. of Species	-	-	-	-	-
Abundance	-	-	-	-	-
Biomass	-	-	-	-	-
Avg_per_cell_biomass	-	-	-	-	-
Bacillariophyta	-	-	-	-	-
Chlorophyta	-	-	-	TDS Temp NO_3 0.504*	-

Since the Meshushim station was found to be a point suffering from environmental stress impacts we have performed a Multivariate regression analysis on the data collected for this station in both the winter and summer experiments.

Table 4. *Multivariate regression Stepwise statistical analysis combined results for the summer and winter experiment at the Meshushim station*

Meshuhsim Summer-Winter	Step 1	Step 2	Step 3	Step 4	Step 5
No. of Species	-	-	-	-	-
Abundance	NO_3 0.77**	-	-	-	-
Biomass	Temp 0.52*	-	-	-	-
Avg_per_cell_biomass	-	-	-	-	-
Bacillariophyta	Temp 0.82**	Temp 0.83**	Temp 0.79*	-	-
Chlorophyta	-	Temp TDS 0.95***	Temp TDS 0.94**	Temp 0.93*	-

Table 4 shows that only the number of species in the community and the average cell biomass where not influenced by the fluctuating environmental factors.

However two very strong factors having positive influence on species development were: temperature – influencing the total community biomass and the number of diatom specie, and the concentration of nitrates which causes an increase in the total number of cells. Another mildly influencing factor is the TDS which increases the diversity of green algae. The total influences of all the above mentioned factors are caused by either climate (temperature) or anthropogenic activity (TDS, NO_3).

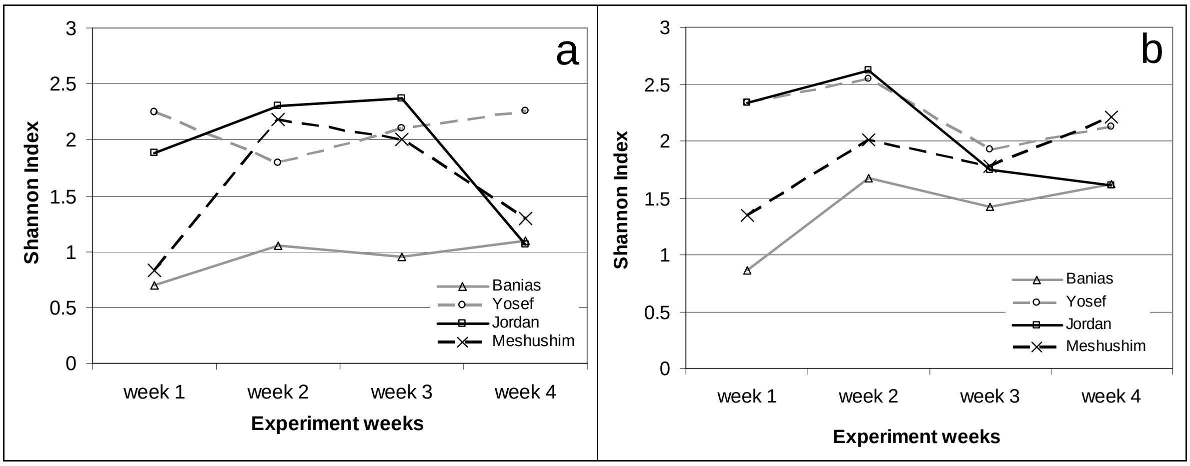

Figure 10. *Changes of the Shannon index for all experimental stations during the summer and winter experimental periods – a: winter; b: summer*

During the summer experimental period the Shannon index for each station was registered. In *Fig. 10* it can be seen that the initial values of the index are different and are highest in the Jordan and Yosef stations. When comparing the obtained index values with the number of developing species for each of the stations, we find strong positive correlations – high index values correlate with high species numbers. During the experiment, index values in the stations with relatively low species numbers – Banias and Meshushim – had a rising tendency. However, at the species richer Yosef and Jordan stations, we registered an index lowering tendency. Since the Shannon index reflects the structural complexity of the present community we can conclude that: the break in the development of communities represented by the highest structural complexity was achieved on the second week for all stations. The overall rising tendency from the second week till the end of the experiment for all stations, points to rising complexity in the communities structures. This correlates to the processes of stabilization and self-purification.

Similarly during the winter experimental period the Shannon index for each station was registered. In *Fig. 10* initial Shannon index levels in the Banias where and remained the lowest with only slight changes during the entire experiment. In the Jordan and Yosef stations we observed similar and high initial index levels However, communities' development was quiet the opposite for these two. Community structure at the Yosef station became more complex towards the end of the experiment while at the Jordan station the index dropped till it reached the value of 1 suggesting the community became poor with overall low number of species (*Fig. 8a*). At the Meshushim station the community significantly developed right until the second week reaching highly

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complex community structure *Fig. 10*. Afterwards and till the end of the experiment the Shannon index declined.

When comparing the changes of the Shannon index with changes in cell/biomass values we find that the community's high structural complexity is achieved due to the development of small cell species (as for instance in the Jordan station *Fig. 4a and Fig. 10a*). This type of change indicates that the community is influenced by some stress impacts.

Conclusion

As can be seen from the above listed data and calculations, water temperature during the experimental period was typical for the winter (11-19°C) and summer (24-32°C) seasons. During the summer period the pH was alkaline while in the winter it declined below 7.0.

Nitrates concentration was higher during the summer especially at the Meshushim station; however it declined during the experiment as a result of the algal activity.

TDS values stabilized on the 2^{nd}-3^{rd} weeks of both experiments. The demineralization process reflects the water quality and is related to the activity of the algal communities. We can see that during the summer experiment a peak in the TDS values was reached on the third week at the Jordan and Meshushim stations and on the fourth week in the Banias and Yosef stations. The lowering of TDS values reflects the self-purification processes. Stabilization of the parameters in the ecosystem at each of the stations confirms that the self-purification process came to an end. The peak points to the self purification proccess which was more noticeable in the winter.

Algal diversity found on glass slide accretions in each of the experimental pools contained about 15-25 species for each of the pools. Algal communities where richer in the summer in all stations and contained mainly Diatoms during the winter and equal proportions of diatoms and green algae during the summer. Only the Banias station winter community was dominated by the green algae.

During the winter experiment at the Banias and Jordan stations maximal diversity was reached by the 3^{rd} week and in the Yosef and Meshushim stations by the 4^{th} week.

During the summer experiment maximal diversity was reached at the Banias and Meshushim stations by the 2^{nd} week, in the Jordan station by the 3^{rd} week and at the Yosef station there were two peaks on the 2^{nd} and the 4^{th} weeks. This implies that in the upper part of the basin (Banias station) during the summer the self-purification activity is higher. The Yosef and Meshushim stations were under anthropogenic influence so their diversity had a constant growing tendency till the end of the experiment. Alternatively at the Jordan station diversity stability was reached on the 3^{rd} week. These observations lead us to the conclusion that species richness grows in proportion to the anthropogenic influence on one hand and the intensity of the self-purification process on the other. Moreover the self-purification process proceeds faster in conditions of high temperature and high solar radiation – during the summer.

Algal abundance and biomass in all stations were ten times higher during the summer experiment in comparison to the winter experiment, due to the increased activity.

At the same time cell sizes were smaller in the summer communities. When comparing with species diversity (*Fig. 6b, 7b, 8b, 9b*) we see that the high cell numbers found in the summer communities are comprised mostly of new small celled green algal

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species. Therefore we can conclude that: the speed with which algal encrustation is formed is influenced by temperature and solar radiation.

According to our calculations of the non parametric structural index of Shannon we can conclude that high Shannon index values correlate with species rich communities in both winter and summer experiments.

Overall, the experimental study showed that artificial colonization of substrates by algae takes about 2-3 weeks. Colonization is more active during the summer as a result of the formation of small celled green algae which growth is promoted by high temperatures and high solar radiation conditions. As found via the Multivariate statistical analysis- the important factors influencing algal activity are pH and Total Dissolved Solids concentration (major factors in water quality assessment). A detailed observation of the self-purification process can be conducted by monitoring diversity dynamics, cell counts, and biomass.

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TO BAN OR NOT TO BAN FEBRUARY FERTILIZATION IN HUNGARY?

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Abstract. At present, it is allowed to apply fertilizers starting from 1st of February in Hungary. According to a proposal of the EU this date would be moved to 1st of March. Regarding this issue the following question could be formulated: Does the earlier starter fertilization increase the risk of nitrate leaching significantly? Experimentally, this question could not be answered within the available timeframe. The only scientific tool that is able to handle this problem is a crop simulation model. The 4M crop simulation model was used for answering the above question. The required weather, soil, plant and agrotechnical data were provided for the model using the available Hungarian databases. Three scenarios differing only in the date of the first spring fertilization were compared. According to the results the amount of nitrate leaching does not increase as the date of the first spring fertilization moves from the end of February to the beginning of the month, thus there is no need for extending the fertilization prohibition period. Leaving the prohibition period as it is today will not increase the risk of contaminating the subsurface water reservoirs due to nitrate leaching.
Keywords: *fertilization prohibition period, nitrate leaching, crop model, decision support*

Introduction

Experts of the European Union revise the practical realization of the Nitrate Directive (*91/676/EEC)* in every five years. Based on the collected experiences the EU proposes amendments to the Directive for every member state in order to minimize the nitrate leaching risk of agricultural origin. One of the most recent proposed amendments is the idea of extending the spring fertilization prohibition period. At present, it is allowed to apply fertilizers starting from 1st of February. According to the proposal this date would be moved to 1st of March. Hungarian experts expressed their concerns about the extension of the prohibition period. If the starter fertilization delays one month because of the modified directive it could cause yield loss for the crops sown in the autumn (e.g. barley, wheat, rape) due to the increased nutrient shortage in the early vegetative phase. On the other hand the earlier the fertilizer gets on the soil surface in the spring the higher the possibility might be that a considerable fraction of it leaches out of the root zone due to the usually moist spring weather. It has to be noted that the spring starter fertilizer is applied directly to the soil surface and is not incorporated into the soil. By the time it is applied the root zone is already 10-15 cm deep. Though one can state that is highly unlikely that a portion of the fertilizer applied on the soil surface can go through the continuously deepening root zone without taken up by the plants, someone else can be more aware of the environment protection aspects. The Hungarian experts usually emphasize the yield safety in this matter while EU experts tend to focus on the increasing risk of subsurface water contamination. Regarding this issue the following questions could be formulated: Does the earlier starter fertilization increase the risk of nitrate leaching significantly? Could the initiative to lengthen the fertilization prohibition period be substantiated scientifically?

Experimentally, these questions could be answered only by time-consuming and expensive long-term field trials. Since we do not have years to find the answers by measurements the only remaining scientific tool that is able to handle this problem is a crop simulation model (CSM).

The primary purpose of crop models is to describe the processes of the very complex atmosphere–soil–plant system using mathematical tools (functions, differential equations, etc.) and to simulate them with the help of computers. In the 1970's developments in information technology enabled scientists to create the first crop model software using the accumulated scientific knowledge. Today, there are many well-developed, user friendly crop model software already available such us WOFOST (Boogaard et al., 1998), STICS (Brisson et al., 1998), DSSAT (Jones et al., 2003), CropSyst (Stöckle et al., 2003). During the past two decades crop models have been used in numerous educational and scientific projects (Kovács et al., 1995; Jamieson et al., 1998; Ladányi et al., 2003; Máthéné et al., 2005, Harnos et al., 2006; Fodor, 2006; Kaur, 2008). According to the acquired modelling results CSMs are effective tools in scientific research, education, practical problem exploration and problem solution. They integrate the processes of the crop production, its ecological and technological system of conditions into a functioning simulation model using the achieved scientific results for supporting decision making on every possible level. The presented model application is a nice example how a CSM can support the work of policy makers.

The main objective of the present study is to give a scientifically sound answer for the above formulated question: Does the earlier spring starter fertilization increase the risk of nitrate leaching significantly?

Materials and methods

The 4M crop simulation model (Fodor et al., 2002; Máthéné et al., 2005; Fodor, 2006) has been used in the study. 4M is a daily-step, deterministic (not stochastic) model whose functioning (computation) is determined by the numerical characteristics (parameters) of the atmosphere–soil–plants system. Besides the data that describe the physical, chemical and biological profile of the system, it is also necessary to set its initial, boundary and constraint conditions in the input file of the model. The parameters regulate the functions and equations of the model: the development and growth of plants or the heat, water and nutrient balance of the soil. The initial conditions are the measured system variables at the beginning of the simulation run such as the water or nutrient content of the soil. The boundary conditions are primarily the daily meteorological data such as the global radiation, temperature and precipitation. The constraint conditions cover the numerical expressions of the human activities such as data about planting, harvest, fertilization or irrigation. A short description about the functioning of 4M is provided in Fodor and Pásztor (2010). The following input data were used during the simulations.

Weather data

Artificial but realistic weather data series for the 1951-2100 period was created for the 4M model using the ARPEGE global circulation model (Déqué et al., 1998) combined with the ALADIN-Climate regional climate model (Bubnova et al., 1995; Wang et al., 2011). Regarding the most relevant climatic characteristics (annual precipitation amount, average temperature, etc) for the 1961-1990 reference period, there are no significant differences between the synthetic data and the data observed in Hungary. Based on the available generated temperature and precipitation data the daily global solar radiation values were estimated using the S-shape method (Fodor and Mika, 2011). *Fig. 1* summarizes the most important climatic characteristics of the weather data used in the study. According to the used climate change scenario the atmospheric CO_2 concentration raised from 315 to 720 ppm with a moderate exponential character in the 1951-2100 period. The monthly precipitation amounts will prospectively change considerably only in July, August and September compared to the present situation: there will be 30-40 % less rain in these months around 2100 due to climate change. The monthly average temperatures are expected to rise with 1.5 – 4 °C by the end of the investigated period. The months of the summer half year will be prospectively 3 °C warmer at the end of the century than at present.

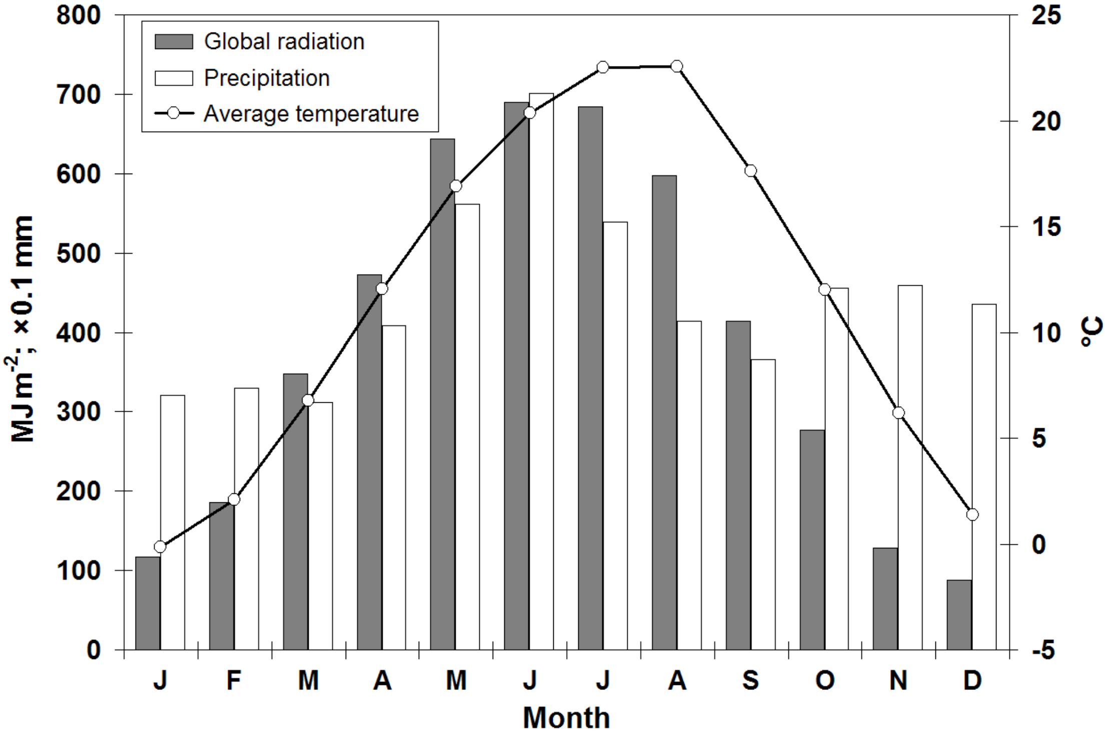

Figure 1. *Average monthly values of the weather data used in the study based on the 150 year long (1951-2100) data series.*

Soil data

Simulations were carried out for the five characteristic soil groups of Hungary. Soil data required by the model were retrieved from the database of RISSAC (Pásztor et al., 2010). The average physical and chemical parameters (bulk density-BD, humus content-

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HC, field capacity-FC, wilting point-WP, saturated hydraulic conductivity-Ks and drain constant-DC) of the five soil groups were used during the model runs (*Table 1*).

Table 1. *Soil parameters of the characteristic Hungarian soils used as model inputs in the study*

Soil texture	BD (gcm^{-3})	HC (%)	FC (cm^3cm^{-3})	WP (cm^3cm^{-3})	Ks (cmd^{-1})	DC
Sand	1.55	1.00	0.160	0.030	100	0.5
Sandy loam	1.45	1.65	0.290	0.130	50	0.4
Loam	1.40	2.30	0.340	0.160	10	0.3
Clay loam	1.45	2.60	0.360	0.180	5	0.2
Clay	1.45	3.00	0.400	0.200	1	0.1

Plant data

The approximate values of the plant specific parameters (phenological characteristics, stages, maximum root depth, light use efficiency, specific N content, etc.) were determined based on the pertaining scientific literature. Then, the parameters were fine-tuned in four steps by inverse modelling (Soetaert and Petzoldt, 2010) so that the averages and the variances of the simulated yields were similar to those observed in the 1961-1990 reference period. First the phenological parameters (base temperature and length of phenological stages) were set so that the simulated occurrence of the main phenological stages would be in conformity with the real dates well-known from the literature. In the second step the model should have calculate the potential yields of the crops. This was achieved by adjusting the light use efficiency and the mass – leaf area conversion parameters. Then, in the third step, the effect of the water stress was 'switched on' in the model, and thus the parameters of the relationship defining the effect of the waters stress were set so that the model results would be realistic among rain-fed conditions. Finally, the parameters defining the effect of the nitrogen stress were determined.

The development and growth of the plants in *Table 2* were simulated. Although, it is obvious that some of the plant specific parameters did change and will change in the investigated period, all these parameters were considered to be constant during the simulations.

Agrotechnical data

The model input data regarding plant production (planting date, plant density, harvest date, fertilization doses, etc.) were provided according to the common agro-technology of each plant (*Table 2*). It is well-known that the plant production went through an enormous change during the past 60 years. Despite this fact the agrotechnics was postulated to be invariant during the investigated period.

Every crop rotation was simulated on every soil texture in three scenarios that differed only in the date of the first spring fertilization (with grey background in *Table 2*) of the crop sown in the previous autumn. The most relevant outputs (yield, nitrate leaching, etc.) of the model runs were recorded during the simulations. Calculated yields of the simulations where the first spring fertilizer was applied on the 1^{st} of February were compared to those of the other two scenarios (fertilization date: 15/02 and 01/03) with paired t-tests. The annual nitrate leaching amounts as well as the distribution of the nitrate leaching rates over the months of the year were investigated depending on the date of the first spring fertilization.

Table 2. *The relevant agrotechnical data used as model input data in the study. Three scenarios were defined for each rotation with first spring fertilization on 01/02, 15/02 and 01/03.*

Crop rotation	Crop	N fertilization		
		Date, dd/MM	Amount (kgha^{-1})	Depth (cm)
maize – winter wheat	maize	01/04	170	0-25
	winter wheat	05/10	40	0-25
		01/02; 15/02; 01/03	100	soil surface
		25/04	30	soil surface
winter wheat – rape	winter wheat	01/02; 15/02; 01/03	130	soil surface
		25/04	40	soil surface
	rape	10/08	30	0-25
		01/02; 15/02; 01/03	70	soil surface
		20/04	70	soil surface
winter barley – rape	winter barley	10/09	70	0-25
		01/02; 15/02; 01/03	70	soil surface
	rape	10/08	30	0-25
		01/02; 15/02; 01/03	70	soil surface
		20/04	70	soil surface
silage maize – winter barley	silage maize	01/04	150	0-25
	winter barley	10/09	70	0-25
		01/02; 15/02; 01/03	70	soil surface

Results and conclusions

The calculated yield results of the four investigated crop rotations are presented in *Table 3.*

Table 3. *Ca1culated yields averaged over the three investigated scenarios (75 seasons per crop, 1951-2100)*

Crop rotation	Crop	Yield, kg/ha				
		Sand	Sandy loam	Loam	Clay loam	Clay
maize – winter wheat	maize	6863	8605	9157	9138	8568
	winter wheat	6400	7313	7601	7624	7397
winter wheat – rape	winter wheat	6584	7836	8345	8380	8209
	rape	2462	3012	3109	3198	3154
winter barley – rape	winter barley	5890	7449	7967	8012	7835
	rape	2407	2883	2982	3064	3049
s. maize – winter barley	silage maize	22759	27853	29510	29535	28018
	winter barley	5938	7117	7464	7504	7315

Though it was not the focus of this study, it has to be noted that the 30 year moving averages of the calculated yields practically did not change in the 1951-2100 period. It seems that the factors causing yield increase and/or decrease (just to name the two main

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antagonistic factors: increase of CO_2 concentration and decrease of precipitation) may compensate each other in the future. This result is in full conformity with the previous finding of van de Geijn and Goudriaan (1996). On the other hand, approaching 2100, the variations compared to the average yields (SD) increased for all of the investigated plants (from 27% to 35%) indicating the prospected increase of extremes as well as the decrease of yield safety as a consequence of climate change.

The calculated yields of the scenarios with different first spring fertilization dates confirmed the concerns about the yield loss of winter crops due to the increased nutrient shortage in the early vegetative phase. If the prohibition period would have been lengthened with one month the yields of the winter crops would significantly decrease independently of the soil type (*Table 4*).

Table 4. *Calculated winter crop yield losses of two fertilization scenarios compared to those of the 01/02 first spring fertilization scenario for the five investigates soil groups. Asterisks denote the significant differences (α=0.05)*

Soil group	Date of fertilization, dd/MM	
	15/02	01/03
Sand	-29*	-101*
Sandy loam	-15	-57*
Loam	-7	-31*
Clay loam	-8	-33*
Clay	-11	-44*

According to the results presented in *Fig. 2* the amount of nitrate leaching does not increase as the date of the first spring fertilization moves from the end of February to the beginning of the month.

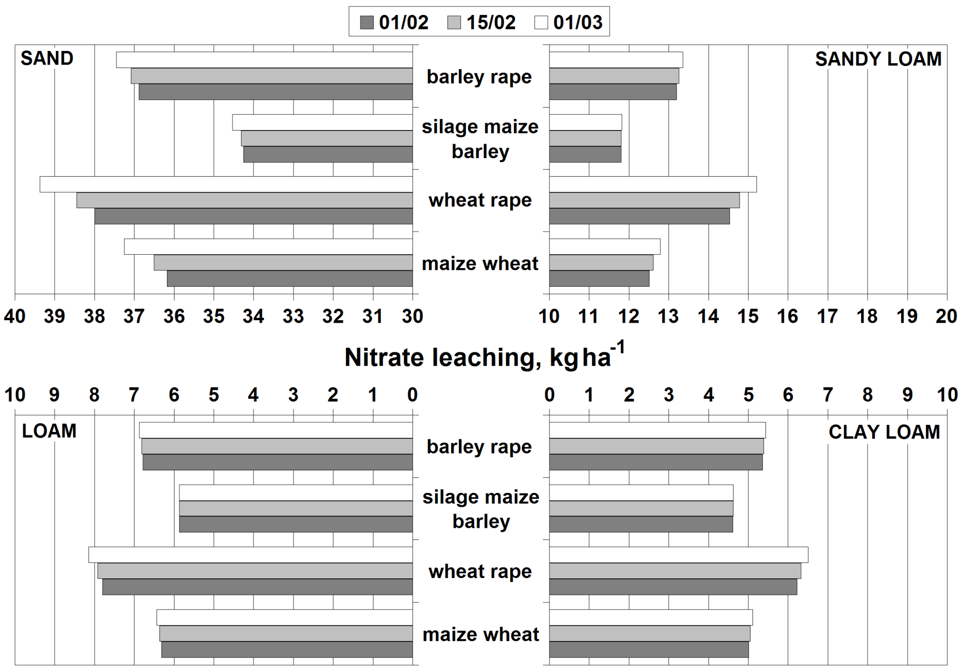

Figure 2. *Annual nitrate leaching rates as a function of the 1st spring fertilization date (dd/MM) of winter crops based on 150 year long simulations (1951-2100)*

The earlier spring fertilization does not cause increased nitrate leaching rates during the spring (*Fig. 3*). On the contrary, the earlier fertilization resulted in lower nitrate leaching rates in every month. During the moistest spring (290 mm precipitation between February and May compared to the average of 160 mm) of the 1951-2100 period, zero $kgha^{-1}$ nitrate left the root zone till the end of June according to the simulations.

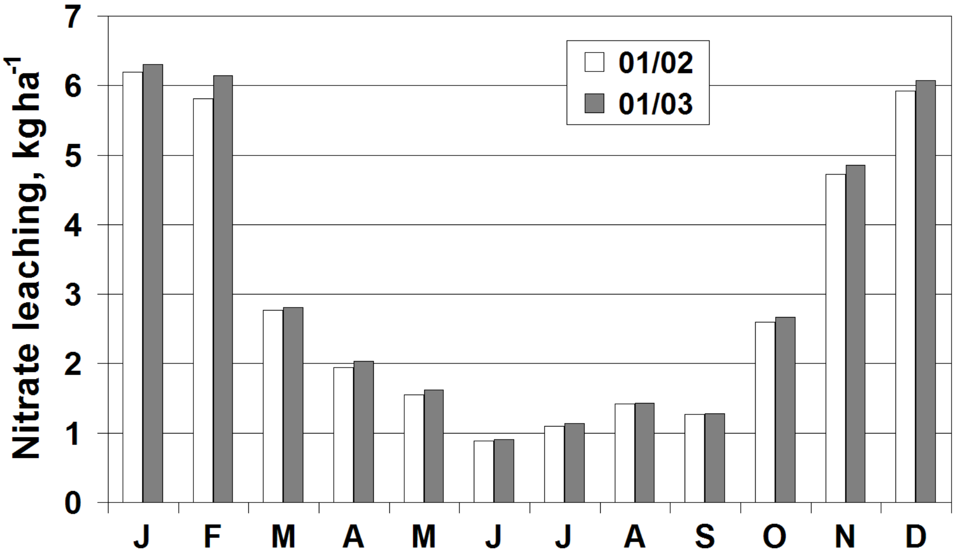

Figure 3. *Monthly nitrate leaching rates as a function of the 1st spring fertilization date (dd/MM) of winter crops based on 150 year long simulations (1951-2100).*

Based on the findings there is no need for extending the fertilization prohibition period by moving its end to 1st of March, in fact it may cause yield loss. Leaving the prohibition period as it is today will not increase the risk of contaminating the subsurface water reservoirs due to nitrate leaching.

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LANTANA CAMARA L. INVASION AND IMPACT ON HERB LAYER DIVERSITY AND SOIL PROPERTIES IN A DRY DECIDUOUS FOREST OF INDIA

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Abstract. Invasion of lantana (*Lantana camara* L.) in dry deciduous forest is capable of causing changes in micro sites (soil properties and species composition) in which they invade. As lantana is most conspicuous invader in the Vindhyan dry deciduous forests of India. We analyzed the effect of this invasive species on the composition of herbaceous layer and on soil properties. Habitats with different level of canopy cover were analyzed. And the canopy cover was significantly related to the lantana cover. Results indicate that different levels of lantana cover affect soil properties and herbaceous species composition. We found as the lantana cover increases some of the species get locally extinct and some are favored by lantana invasion. Principal Component Analysis (PCA) ordination indicated that the quadrates with nil and differently covered lantana were unique with herb species composition, especially the sites with no lantana cover had native species which were not present in site with differently covered lantana. The distinctness of herb species composition is indicative of marked spatial dynamics with regard to nil and differently covered lantana. Concentration of organic carbon (OC) and total nitrogen (TN) were significantly higher in habitats having large lantana cover. Thus we may conclude that lantana modifies the spatial pattern of herbaceous plant species and the nutrient levels of soil.
Keywords: *Lantana camara, local extinction, soil properties, species composition*

Introduction

Exotic species invasion is amongst the most important global scale problems experienced by natural ecosystems and is also considered as the second largest threat to global biodiversity (Drake et al., 1989). In India, dry tropical accounts for 38.2% of the total forest cover (MoEF, 1999). These forests are under immense anthropogenic pressure in form of rapid industrialization and related land-use change in the past few decades. With increase in human population forests are also exposed to illegal sporadic tree felling, widespread lopping of trees for timber resources and shrubs for fuel wood or leaf fodder (Singh and Singh 1989; Jha and Singh, 1990). All these have lead to forest fragmentation, which is prone to subsequent invasion by exotic species (Tripathi, 2003). Invasion of species may lead to local declines (Islam, 2001) and even extinction of native species (Pimm, 1986) thus altering species richness in the forest fragment (Carey et al., 1996). We studied Lantana (*Lantana camara* L.) as it has spread in almost all the fragmented areas in the Vindhyan dry deciduous forest, and has been ranked as the highest impacting invasive species (Batianoff and Butler, 2003), and is among the 100 worlds worst invasive alien species (GISP, 2003), because it posses great potential to escape cultivation and have deleterious effect on species richness (Islam, 2001). In India it was introduced in early nineteenth century as an ornamental plant (Sharma, 1988), but now it is growing densely throughout India (Sharma et al., 2005a,b).

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However, small-scale environmental changes caused by lantana invasion have not been addressed in dry tropical forest areas. The objective of the present study was to analyze the effect of lantana invasion on the composition of the herbaceous layer and on the soil properties of the dry deciduous forest.

Materials and methods

Study area

The study area (*Fig 1*) lies on the Vindhyan plateau in the Sonebhadra district of Uttar Pradesh (24º 6' to 24º21' N; 82º59' to 83º14'). The elevation above the mean sea level ranges between 315 and 485 m (Singh and Singh, 1992).

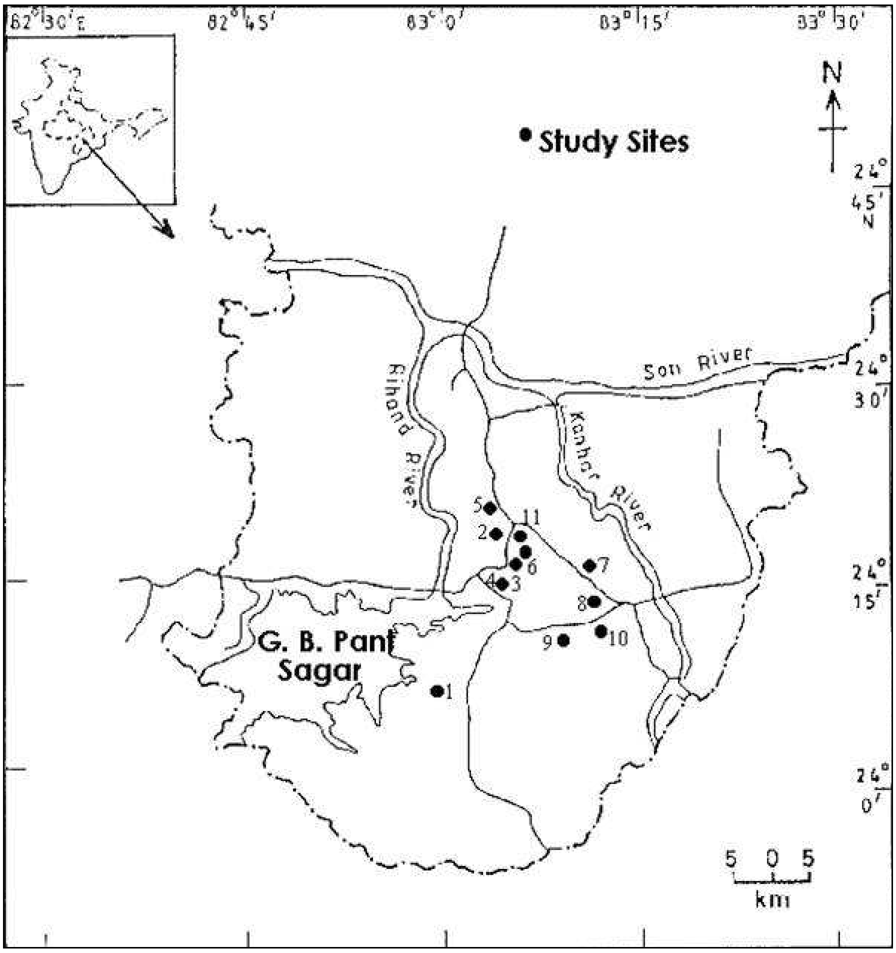

Figure 1. *Location of study sites within Vindhyan highlands, India.
1- Khatabaran; 2- Hathwani I; 3- Hathwani II; 4- Kadhpathar; 5- Majhauli;
6-Hathinala I;7- Bhaheradol; 8- Rajkhar; 9- Manbasa; 10- Runtola; 11- Hathinala II*

The climate is tropical with three seasons in a year, i.e. summer (from March to mid June), rainy (mid June to September) and winter (October to February). October and March constitute the transition months between the rainy and winter seasons, and between winter and summer seasons, respectively. The average rainfall varies between 850 and 1300 mm. About 85% of the annual rainfall occurs during the rainy season from the southwest monsoon. The maximum monthly temperature varies between 20ºC

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in January to 46ºC in June, and the mean minimum monthly temperature between 12ºC in January to 31ºC in May.

Red coloured and fine textured sandstone (Dhandraul orthoquartzite) is the most important rock of the area. Sandstone is generally underlain by shale and limestone. The soils derived from these rocks are residual ultisoils and are sandy-loam in texture (Raghubanshi, 1992). These soils are part of the hyperthermic formation of typical plinthustults with ustorthents according to VII approximation of the USDA soil nomenclature (Singh et al., 2002).

The potential natural vegetation of the region is tropical dry deciduous forest, which is locally dominated by species such as *Acacia catechu, Anogeissus latifolia, Boswellia serrata, Buchanania lanzan, Diospyros melanoxylon, Hardwickia binata, Lagerstroemia parviflora, Madhuca longifolia* and *Terminalia tomentosa*. Height of the locally dominant canopy tree species varies from 6 m to 14 m (Troup, 1921) across the sites and the height of the herb layer varies from 2 cm to 75 cm.

Lantana is a perennial woody shrub and in its naturalized range, lantana forms dense mono-specific thickets 1-4 m high and ≈ 1-4 m in diameter (Sharma et al., 2005b), although some of the clumps smother near by trees and reach up-to the height of 8-15 m (Sharma et al., 2005b). Eleven sites were selected at random in the region, within a radius of approximately 10 km. These sites had visually different levels of invasion of lantana, with one as control site i.e. having no lantana. In Vindhyans micro-distribution pattern of lantana occurs in patches as homogenous clumps.

Data collection

A total of 11 sites were sampled and at each site, three large quadrats (10m x10m) were sampled randomly for vegetation and soil features in the year 2003, i.e. a total of 33 quadrats were sampled in the entire study area. Tree canopy cover in each quadrat was measured by estimating the area, shaded directly by the overhead tree canopy. The values were then transformed into percentage area. All the measurements were taken during mid-day when the sun was approximately perpendicular to the surface.

Lantana cover was estimated using the Domin Krajina scale and was transformed into percentage cover for final analysis (Mueller-Dumbois and Ellenberg, 1974).

The light intensity was measured by LCA-2 battery portable infrared carbon dioxide analyser having PAR (Photosynthetic Active Radiation) sensors (filtered selenium photocell) (ADC Scinokem International, U.K.); the 70-100% sunlight (measured as PAR at 11.00 am on a cloud-free day) corresponded to 1,600-1,720 μmol m^{-2} s^{-1}. Light intensity was measured above and below the lantana bushes of the total light received (values reported are in percent). Percentage light attenuation below lantana was calculated using formula:

$$\%\text{ light attenuation} = \frac{\text{Light above lantana - Light beneath lantana}}{\text{Light above lantana}} \times 100$$

Within each large quadrate, four (0.5 X 0.5 m) mini plots were randomly sampled and density, frequency and cover of herbaceous species were estimated. For density individual plants were counted while frequency of species in each large quadrate was calculated using the ratio of total number of mini plots in which the species occurred to the total number of mini plots studied (i.e. 4) in each quadrate and cover was estimated using the ground percentage cover of Domin Krajina scale and transformed into percentage cover in the final analysis (Mueller-Dumbois and Ellenberg, 1974).

Importance values were calculated as the sum of the mean values of relative cover, relative density and relative frequency (Phillips, 1959). Soil samples from the upper10 cm soil layer were collected randomly from three places in each quadrat. Each sample was mixed thoroughly, air dried and sieved through a 2mm mesh screen. Fine roots were hand picked. Soil pH (1:2.5; Soil:Water) was determined by digital pH meter (model 7025M Titrino, Metrohm ion analysis, Metrohm Ltd. Switzerland), organic carbon was measured by Walkey and Black rapid titration method (Jackson, 1958) and total nitrogen by Gerhardt Kjeldal analyzer (Gerhardt Gmbh, Germany). Soil moisture was measured in the field condition using the Theta probe (Delta-T devices Ltd., England). Sampling was carried out during October, when luxuriant mature herbaceous vegetation is present in the area.

Data analysis

Diversity was measured by Shannon-Weiner index (H'):

$$H' = -\sum pi * \ln pi$$

where pi is the importance value contributed by the i^{th} species.

Relationship between tree canopy cover, lantana cover and soil parameters was analyzed by using SPSS Version 10.0 (SPSS, 1997) software and Shannon-Weiner diversity and Principle Component Analysis was calculated using Biodiversity Pro Version 2.0 (McAleece, 1997). Quadrats were segregated into nil, low, medium and high lantana cover, on the basis of PCA ordination.

Results

Lantana cover varied between sites and with tree canopy cover (*Table 1*). For example, when tree canopy cover was >30% (Hathwani I, Hathwani II, Hathinala, Baheradol, Rajkhar, Runtola sites), then the lantana cover varied from 27 to 60% and when the tree canopy cover was <30% (Khatabaran, Kadhpather, Majhauli, Manbasa sites) then there was a considerable increase in lantana cover and it varied from 62 to 84%. Lantana cover was negatively related to tree canopy cover (*Table 2*). At Hathinala II site where the canopy cover was 63% no lantana was reported.

Mean vales of light intensity above the lantana bushes was 20 ± 1.73, 25.4 ± 1.94, 39 ± 2.17 and 63 ± 3.08 for nil, low, medium and high lantana cover respectively, on the other, light intensity recorded beneath the lantana bush was 15.4 ± 1.50, 18.3 ± 2.69 and 8.0 ± 2.73 for low, medium and high lantana cover respectively, of the total light received. The percentage attenuation of light beneath the lantana increased with increasing lantana cover i.e. 40, 53 and 87 % for low, medium and high lantana cover respectively.

Although the lantana cover varied with changes in soil moisture and pH (*Table 1*), it was not significantly related to these soil parameters. There was a strong positive linear relation of lantana cover with soil carbon (*Table 2*). At the maximum (Manbasa site) and minimum (Hathinala II site) lantana cover, organic carbon varied from 3.38 to 1.46% (*Table 1*). The lantana cover also had a strong positive linear relation with soil nitrogen (*Table 2*) which varied from 0.29 to 0.11% among the sites (*Table 1*).

Table 1. *Vegetation and soil characteristics at different sites (Values in parenthesis are ± SE). Sites are arranged in order of increasing tree canopy cover.*

Sites	Tree canopy cover (%)	Lantana cover (%)	Total herb cover (%)	Shannon diversity (H')	Soil moisture (%)	pH	C (%)	N (%)	Light Intensity (μmol m^{-2} s^{-1})
Khatabaran	15.00 (5.00)	75.00 (10.41)	33.33 (10.26)	0.24 (0.04)	12.50 (1.59)	7.32 (0.07)	2.18 (0.26)	0.14 (0.02)	1706.6 (8.8)
Manbasa	20.67 (9.68)	83.33 (14.24)	32.33 (8.76)	0.55 (0.19)	14.50 (2.01)	7.48 (0.07)	3.38 (0.40)	0.29 (0.04)	1688.3 (6.0)
Majhauli	26.67 (7.26)	68.33 (21.86)	17.66 (9.27)	0.52 (0.18)	20.33 (0.43)	7.42 (0.08)	2.42 (0.49)	0.18 (0.04)	1656.6 (14.5)
Kadhpathar	28.33 (10.93)	61.67 (18.56)	51.66 (17.81)	0.65 (0.13)	19.43 (1.22)	7.44 (0.08)	3.26 (0.44)	0.26 (0.05)	1616.7 (4.4)
Bhaheradol	33.33 (18.33)	60 (21.79)	31.66 (11.09)	0.98 (0.48)	17.23 (1.37)	7.24 (0.08)	2.48 (0.64)	0.20 (0.06)	1536.6 (32.4)
Hathwani I	36.67 (11.67)	48.33 (19.22)	70.66 (16.80)	0.73 (0.07)	15.47 (1.39)	7.26 (0.07)	1.78 (0.23)	0.13 (0.01)	1375.0 (22.5)
Runtola	36.67 (16.91)	58.33 (21.67)	47.00 (23.50)	0.45 (0.25)	13.43 (0.88)	7.46 (0.05)	2.26 (0.35)	0.15 (0.02)	1295.0 (35.1)
Rajkhar	45.00 (16.07)	56.67 (20.28)	36.66 (11.66)	0.66 (0.04)	18.30 (2.89)	7.13 (0.02)	2.36 (0.47)	0.17 (0.03)	956.7 (15.8)
Hathwani II	51.67 (12.02)	56.67 (17.40)	21.33 (5.04)	0.55 (0.09)	17.60 (0.85)	7.29 (0.07)	2.64 (0.30)	0.19 (0.03)	859.3 (11.0)
Hathinala I	56.67 (8.33)	26.67 (10.14)	73.66 (21.34)	0.86 (0.02)	18.53 (1.06)	7.33 (0.06)	1.66 (0.30)	0.13 (0.01)	784.3 (4.7)
Hathinala II	63.33 (1.66)	0.00 (0.00)	94.66 (0.88)	1.16 (0.01)	18.70 (1.22)	7.35 (0.11)	1.46 (0.20)	0.11 (0.008)	707.6 (17.1)

Table 2*. Correlation matrix of vegetation and soil parameters in a lantana invaded forest.*

	Canopy cover (%)	Herb layer diversity	Herb cover (%)	Lantana cover (%)	Carbon (%)	Nitrogen (%)	pH	Moisture (%)
Canopy cover (%)	1							
Herb layer diversity	0.662**	1						
Herb cover (%)	0.503**	0.612**	1					
Lantana cover (%)	-0.853**	-0.749**	-0.544**	1				
Carbon (%)	-0.688**	-0.514**	-0.256	0.824**	1			
Nitrogen (%)	-0.627**	-0.409*	-0.202	0.743**	0.966**	1		
pH	-0.199	-0.143	0.129	0.100	0.192	0.245	1	
Moisture (%)	0.202	0.276	0.136	-0.159	0.060	0.052	-0.094	1

** significant at level 0.01, * significant at level 0.05 (Values are Pearson's correlation coefficients)

The analysis of variance (ANOVA) revealed that the sites differed significantly in terms of canopy, lantana cover, carbon, nitrogen, diversity and herb cover (*Table 3*).

Maximum herb layer diversity occurred at the Hathinala II site which had no lantana cover followed by Hathinala I site which had 27% lantana cover, and the minimum occurred at the Khatabaran site where lantana cover was 75% (*Table 1*). Lantana cover showed a strong linear negative relationship with Shannon-Weiner diversity index of herbaceous layer (*Table 2*) and herbaceous cover (*Table 2*).

Table 3. *Summary of ANOVA of different sites for vegetation and soil parameters*

Vegetation		**df**	**Mean Square**	**F**	**P**
Canopy cover (%)	Between groups	3	3649.7	22.50	0.000
	Within groups	29	162.2		
	Total	32			
Herb layer Diversity	Between groups	3	0.536	14.54	0.000
	Within groups	29	0.036		
	Total	32			
Herb cover (%)	Between groups	3	4000.5	6.29	0.002
	Within groups	29	636.0		
	Total	32			
Lantana Cover (%)	Between groups	3	11195.23	214.2	0.000
	Within groups	29	52.27		
	Total	32			
Light intensity	Between groups	3	1526668.6	321.9	0.000
	Within groups	29	4742.4		
	Total	32			
Soil parameters					
Carbon (%)	Between groups	3	4.288	17.88	0.000
	Within groups	29	0.240		
	Total	32			
Nitrogen (%)	Between groups	3	0.027	11.92	0.000
	Within groups	29	0.002		
	Total	32			

The Principal Component Analysis (PCA) ordination of 33 quadrates on the basis of IVI of herb species is present in *Fig 2*. The PCA 1 and PCA 2 axis accounted for 14 and 12 % variation respectively. PCA 1 represented the lantana cover (r^2 = 0.36, p = 0.05) cover and the PCA 2 axis was related to tree canopy (r^2 = -0.45, p = 0.009). *Fig 2* indicated that the quadrates segregated on the basis of different lantana cover. Revealing that the nil, low, medium and high lantana cover quadrates are behaving differently in terms of herb species composition.

The dominance spectrum of the herbaceous species changed with the increasing level of lantana cover. *Alysicarpus vaginalis* dominated the herbaceous vegetation at lantana nil sites on the other, *Evolvulus alsinoides* L. dominated the herbaceous vegetation at low, *Oplismenus compositus* Beaub. at medium and *Corchorus trilocularis* L. at high lantana cover (*Table 4*). Species that occurred at high lantana cover with proportionally greater IVI could be considered lantana tolerant species (*Cassia tora* L., *Corchorus trilocularis* L, *Echinochloa colona* Link., *Ichnocarpus frutescens* (L.) R. Br., *Ludwigia perennis* L.) and species that were more predominant at low lantana cover may be considered lantana intolerant (*Dichanthium annulatum* Stapf., *Evolvulus alsinoides* L.,

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Leucas aspera Spr., *Sida acuta* Burm. F., *S. cordifolia* L., *S. rhombifolia* L., *Tephrosia purpurea* Pers.).

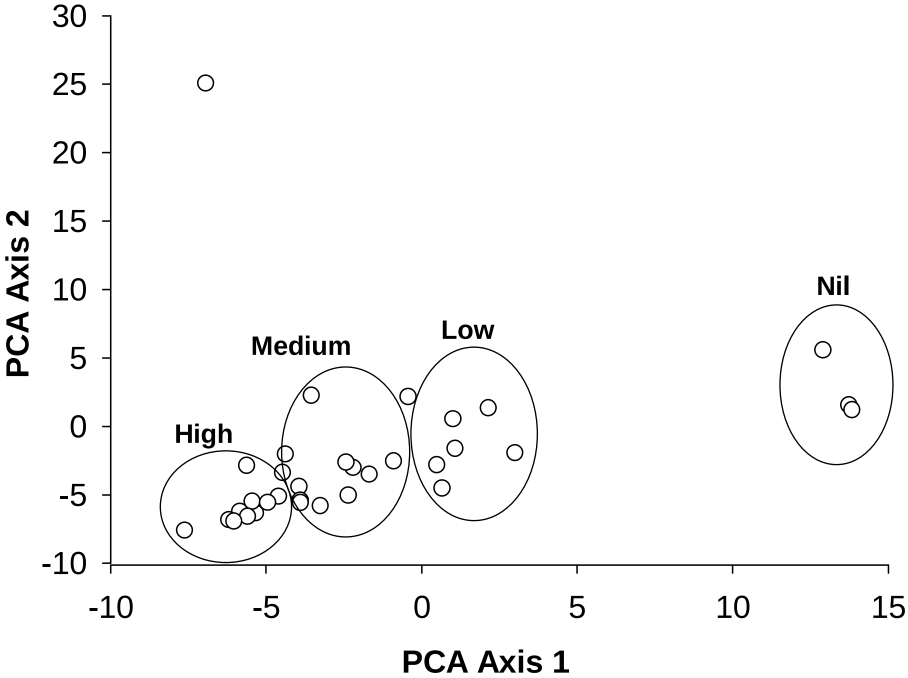

Figure 2. *PCA ordination of herbaceous species showing segregation of quadrats at different level of lantana cover (nil, low, medium and high).*
The PCA 1 and PCA 2 axis accounted for 14 and 12 % variation respectively.

Species which are unique to the no lantana site may be considered as highly sensitive species to lantana and proportionality of these unique species increased on the nil lantana cover site with respect to differently covered lantana sites. Species that occurred ubiquitously, irrespective of lantana cover may be considered as species insensitive to lantana cover (*Table 4*).

Table 4. *Importance value indices of herbaceous species under nil, low, medium and high lantana cover and species information*

Species	Family	Life form	A/P	N/NN	Lantana cover (%)			
					Nil (0%)	LOW (0-30%)	MEDIUM (31-60%)	HIGH (61-100%)
Alysicarpus vaginalis (L.) DC	Fabaceae	Th	A	N	8.76	0.00	0.00	0.00
Andrographis echioides Nees.	Acanthaceae	Th	A	N	5.29	0.00	0.00	0.00
Anagallis arvensis L.	Primulaceae	Th	A	NN	0.00	0.00	1.17	0.00
Barleria cristata L.	Acanthaceae	H	P	N	0.00	0.00	0.65	0.00
Begonia picta Sm**.**	Begnoniaceae	H	A	N	3.96	0.00	0.00	0.00
Cassia tora L.	Caesalpiniacae	Th	A	NN	3.02	1.01	2.79	3.75
Ceropegia bulbosa L.	Asclepediaceae	G	P	N	2.83	0.00	0.00	0.00
Chloris dolichostachya Lag.	Poaceae	H	P	N	0.00	0.53	0.00	0.74

***Table 4.** cont.*

Species	Family	Life form	A/P	N/NN	Lantana cover (%)			
					Nil (0%)	LOW (0-30%)	MEDIUM (31-60%)	HIGH (61-100%)
Chryanthellum americanum (L.) Vatke	Poaceae	Th	A	NN	0.00	0.00	2.30	1.84
Commelina benghalensis L.	Commelinaceae	H	P	N	0.00	0.00	1.56	0.58
Corchorus trilocularis L.	Tiliaceae	Th	A	N	4.71	10.15	14.60	15.96
Coronopus didymus (Linn.) Smith	Brassicaceae	Th	A	NN	0.00	0.00	0.00	0.00
Cyanotis axillaris Schult.	Poaceae	Th	A	N	5.87	0.00	0.00	0.00
Cynodon dactylon Pers.	Poaceae	H	P	N	1.68	2.83	0.00	2.38
Cyperus cyperoides Kuntze.	Cyperaceae	H	P	NN	2.77	1.90	6.02	0.00
Desmodium triflorum DC.	Fabaceae	H	A	NN	4.10	11.10	5.32	11.48
Dichanthium annulatum Stapf	Poaceae	H	P	NN	1.70	1.33	0.00	0.00
Digitaria ciliaris Koel.	Poaceae	Th	A	-	5.66	7.52	11.03	3.59
Echinochloa colona Link.	Poaceae	The	A	NN	0.00	0.00	0.00	0.72
Euphorbia hirta L.	Euphorbiaceae	Th	A	N	0.00	0.00	0.79	0.00
Evolvulus alsinoides L.	Convolvulaceae	H	P	NN	5.94	12.72	3.45	5.54
Evolvulus nummularius L.	Convolvulaceae	H	P	NN	3.14	8.63	6.13	8.32
Fimbristylis ferruginea Vahl	Cyperaceae	Th	A	NN	1.37	0.91	0.00	2.96
Hyptis suaveolens (L.) Poit.	Lamiaceae	Th	A	NN	2.02	0.67	2.62	0.00
Ichnocarpus frutescens (L.) R. Br.	Asclepediaceae	Ch	P	NN	0.00	0.00	0.00	1.70
Justicia simplex Don.	Acanthaceae	Th	A	N	3.17	0.00	0.00	0.00
Leucas aspera Spr	Lamiaceae	Th	A	N	1.67	0.61	0.00	0.00
Lindernia ciliata Pennell.	Scrophulariaceae	Th	A	N	6.59	0.00	0.00	0.00
Ludwigia perennis L.	Onagraceae	Th	A	NN	0.00	1.47	1.95	5.02
Malvastrum tricuspidatum Gray.	Malvaceae	Th	A	NN	2.27	0.76	2.32	0.92
Mukia maderaspatana Roem.	Cucurbitaceae	Th	A	N	0.00	1.77	0.00	2.27
Oplismenus compositus Beaub.	Poaceae	H	P	NN	2.80	7.04	20.82	6.84
Phyllanthus niruri L.	Euphorbiaceae	Th	A	NN	3.34	2.82	0.00	7.81
Phyllanthus urinaria L.	Euphorbiaceae	Th	A	NN	2.81	1.32	0.00	1.19
Physalis minima L.	Solanaceae	Th	A	NN	0.00	0.00	1.56	0.00
Rungia pectinata Nees.	Acanthaceae	Th	A	N	1.30	0.77	0.00	0.58
Setaria pumila R. & S.	Poaceae	Th	A	NN	0.00	0.00	1.37	0.00
Sida acuta Burm. F.	Malvaceae	Th	P	NN	4.20	10.01	6.82	4.88
Sida cordifolia L.	Malvaceae	H	P	NN	5.79	5.00	4.39	1.16
Sida rhombifolia L.	Malvaceae	H	P	NN	3.25	2.54	0.00	0.58
Sporobolus diander Beauv.	Poaceae	H	P	NN	0.00	0.00	1.56	0.00
Tephrosia purpurea Pers.	Fabaceae	Th	P	NN	0.00	1.03	0.00	0.00
Urena lobata L.	Malvaceae	Th	P	NN	0.00	5.58	0.76	9.18

A= Annual, P= Perennial; N= Native, NN= Non-native (Jackson, 1895) and personal communication with Dr. U Dhar.
Th = Therophyte, H = Hemicryptophyte, G = Geophytic, Ch = Chamaephytic

Discussion

The presence of disturbance in the form of canopy openings increases resource availability and also modifies the microclimate, which is consistent with the disturbance patch invasion model (Gentle and Duggin, 1997). The model state that the removal of competitive biomass and disruption of inter specific competitive interactions creates patches of increased resources. In the present study area canopy openings, which resulted from local disturbance, create patches of greater light availability. Increase in light availability follows gradient of disturbance intensities. Light has long been recognized as an important plant resource (Maximov, 1929; Blankenship, 2002) that may interact with other plant resources to affect plant performance (Cole, 2003). The increase in light availability increases the overall performance of lantana particularly the growth rate (Duggin and Gentle, 1998). Moreover, Chandrashekar and Swamy (2002) also reported that light availability in relatively less canopy enhance the growth of individual lantana.

With increased growth rate, lantana proliferates luxuriantly, which, as demonstrated in this study results in changes in species composition and soil properties. The growth architecture of lantana is such that it prevents light infiltration to the ground. Resulting in marked heterogeneity in terms of irradiance beneath the lantana bush and affects species diversity beneath its canopy. Light availability on the forest floor has been recognized as a key factor that influences intrinsic traits of inhabiting species (Jones et al., 1994; Walters and Reich, 1996). The dense cover created by vertical stratification of lantana may reduce the intensity or duration of light under its canopy and thus decrease the herbaceous cover. This could be due to the creation of a photosynthetically inactive light regime at ground level (Fetcher et al., 1983; Turton and Duff, 1992). Below certain thresholds, however, light limitation alone can prevent herbaceous species survival regardless of other resource levels (Tilman, 1982). It is likely that herbs are influenced by the amount of light that reaches the forest floor, and this may be probably one of the mechanisms responsible for the decline of herbaceous vegetation. Sharma and Raghubanshi (2006, 2007) advocated that the growth architecture pattern of lantana is such that it prevents the light penetration to the forest floor, leading to the decline of tree seedlings and possibly the herb flora.

Species like *Anagallis arvensis* L, *Barleria cristata* L., *Dichanthium annulatum* Stapf, *Physalis minima* L., *Setaria pumila* R. & S., *Sporobolus diander* Beauv. with limited distribution as the lantana cover increases can be more susceptible to loss from physical damage or altered habitat conditions (Meier et al., 1995). Species like *Dichanthium annulatum* Stapf, *Evolvulus alsinoides* L., *Leucas aspera* Spr, *Malvastrum tricuspidatum* Gray., *Rungia pectinata* Nees., *Sida acuta* Burm. F., *Sida cordifolia* L., *Sida rhombifolia* L., *Tephrosia purpurea* Pers. which decrease and ultimately get locally extinct with increasing level of lantana cover may not recover quickly because of the altered physical environmental conditions (Roberts and Gilliam, 1995). Species which are unique (*Alysicarpus vaginalis* (L.) DC, *Andrographis echioides* Nees., *Begonia picta* Sm**.,** *Ceropegia bulbosa* L., *Cyanotis axillaris* Schult., *Justicia simplex* Don. and *Lindernia ciliata* Pennell.) to no lantana cover sites are native species and are highly sensitive to environmental perturbations, are of great concern.

Lantana also possesses the capability to trap wind blown litter. This trapping of litter is also dependent on lantana cover, as denser the lantana cover, greater the trapping potential. So, more organic matter accumulates/builds up with increasing lantana cover.

Deposition of litter due to wind also affects the herbaceous vegetation (Everham and Brokaw, 1996).

Accumulation of litter beneath the lantana canopies builds up soil organic matter. Accumulation of soil N closely follows that of soil organic matter because, on average 99% of the N in terrestrial ecosystem is organically bound (Rosswall, 1976). Raghubanshi (1992) reported strong positive relation between total N content and organic C content of soil in the dry deciduous forest ecosystem. According to Rawat et al., (1994) superiority in N extraction from the soil along with an efficient retranslocation of N from the senescing leaves enables lantana to perform better as an invasive species. Several studies have shown that soil nutrient levels play an important role in determining community invasibility (Shea and Chesson, 2002; Reinhart and Callaway, 2006). This self perpetuating changed microhabitat could probably provide lantana with increased resource leading to its successful proliferation.

In conclusion the presence of *L. camara* in the dry deciduous forest of India alters the spatial pattern of herbaceous layer vegetation and also changes the microhabitat conditions which could probably help towards its successful proliferation.

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EVALUATION OF THE EXPECTED CLIMATIC CONDITIONS REGARDING CHERRY PRODUCTION IN CENTRAL HUNGARY

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Abstract. Production possibilities and risks of a given plant are basically determined by climatic factors. Expected future climate is modelled by several climate scenarios. In this study results of the RegCM3 model downscaled to the Carpathian Basin were used. This paper focuses on the climatic conditions of cherry production in Central Hungary in three time periods: 1961-1990 as a base, 2021-2050 as the near future and 2071-2100 for the long-term analysis. Results show that in the near future fruit cracking risk could be higher, but in overall the expected changes are mostly favourable for cherry production. By the end of the century irrigation may be required for the secure and quality cherry production. It is also advised to re-evaluate the varieties according to the indicated changes, as a new orchard planted nowadays will have many productive years in the second period.
Keywords: *climate change, cherry production, adaptation, fruit cracking, year types*

Introduction

Security of agricultural production is very sensitive to weather and changing climate. However, it is very difficult to express the agriculture related effects of the climate change in numbers and figures, since the soil–plant–atmosphere system is very complex. The crop simulation models were created to give an approximate description of this complex system, and were applied also in Hungary in case of field crops (Fodor and Pásztor, 2010; Erdélyi, 2009).

Another method is the application of climatic indicators defined for certain phenological phases of a given plant (Diós et al., 2009; Ladányi et al., 2010a,b). This kind of examination can be done separately by seasonal effects, but an overall evaluation should be done, too. Also the climatic indicators can easily be related to risk values.

The other components of the climate change studies are the climate scenarios. Results from coarse resolution global climate models (GCM) can only be considered as a first-guess of regional climate change consequences of global warming (Bartholy et al, 2009). Regional studies for agricultural purposes have been possible since the global models were downscaled by statistical methods to high resolution (10-20 km) data. One technique that can be used to obtain climate change information at finer scales is the use of nested regional climate models (RCMs) (Torma et al, 2011). Expected regional climate change focused to the Carpathian Basin is modelled by four different RCMs, run by the Department of Meteorology, Eötvös Lóránd University (Bartholy et al, 2006; Torma et al., 2008) and by the Hungarian Meteorological Service (Szépszó and Horányi, 2008).

Studies on climate change impacts in agriculture are needed very much in order to find adaptation strategies. It is especially important in case of fruit production, where the change of varieties is slow and the orchards are planted for long time. This paper focuses on the expected climatic conditions and opportunities of cherry production in Central Hungary in the near future (2021-2050) and at the end of the century (2071-2100), compared to the base period of 1961-1990.

Materials and methods

Climate data

Climate data were provided by the Department of Meteorology of the Eötvös Lóránd University. The horizontal grid spacing is 10 km – the highest one reached by RegCM3 model – and the database contains daily data of precipitation and temperature for the baseline period (1961-1990) and for the future (2021-2050 and 2071-2100) using the A1B scenario.

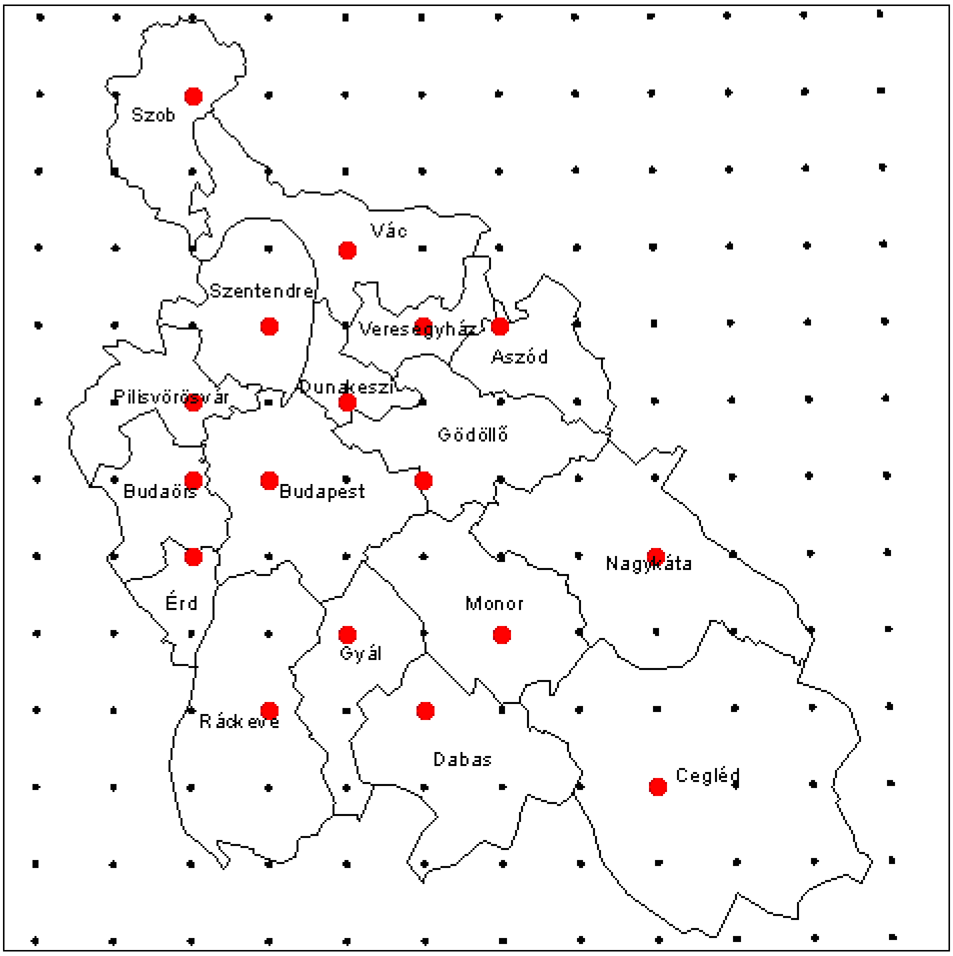

Figure 1. *Local administrative units in Central Hungary and the grid of the meteorological data – data of red ones were analysed*

Data were converted into an Access database and software was developed to make the further calculations. The program can be parameterised according to the user's requirements. The necessary calculations for any year or time period such as decade, century, etc. can be calculated with this software.

Although the 10 km resolution grid covers the whole area of the Central Hungary region (*Fig. 1*), due to the huge amount of data, analyses were carried out characterising each of the 17 local administrative units (LAU 1) – subregions – by one grid point's data.

Definition of climatic year types

The evaluation of the important climatic factors of a certain plant in a specified phenophase can be done separately and estimated utility or risk values can be defined for them. Summarizing these values an overall utility or risk value can be calculated for each year. Having an adequate database, results can be extended both in time and space. However, these calculations do not take into account the interactions of the meteorological factors, so they can lead to false results.

Instead, in our work climatic year types were defined based on several factors. This method allows to concentrate the effects of climatic factors and to define some interactions among them. Utility values based on expert estimates were also added to the year types. In case of cherry production – like in case of growing possibilities of sour cherry (Szenteleki et al., 2011) – 12 climatic year types were defined, while the years not belonging in one of the categories, were defined as common or "normal" with a utility value of 0.88. In the followings (*Table 1-4*) climatic year types are grouped according to the precipitation.

Table 1. *Extreme dry climatic year types in case of cherry production*

Meteorological factors	**Extreme dry and extreme cold**	**Extreme dry and cold**	**Extreme dry and warm**
Precipitation in April	0-15 mm	0-15 mm	0-15 mm
Precipitation in May	0-25 mm	0-25 mm	0-25 mm
Precipitation in June	0-20 mm	0-20 mm	0-20 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C
Utility value (H)	0.2	0.35	0.6

Table 2. *Dry climatic year types in case of cherry production*

Meteorological factors	**Dry and extreme cold**	**Dry and cold**	**Dry and warm**
Precipitation in April	15-25 mm	15-25 mm	15-25 mm
Precipitation in May	25-50 mm	25-50 mm	25-50 mm
Precipitation in June	20-40 mm	20-40 mm	20-40 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C
Utility value (H)	0.2	0.75	0.86

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Table 3. *Wet climatic year types in case of cherry production*

Meteorological factors	Wet and extreme cold	Wet and cold	Wet and warm
Precipitation in April	40-100 mm	40-100 mm	40-100 mm
Precipitation in May	70-180 mm	70-180 mm	70-180 mm
Precipitation in June	80-150 mm	80-150 mm	80-150 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C
Utility value (H)	0.2	0.8	1

Table 4. *Extreme wet climatic year types in case of cherry production*

Meteorological factors	Extreme wet and extreme cold	Extreme wet and cold	Extreme wet and warm
Precipitation in April	above 100 mm	above 100 mm	above 100 mm
Precipitation in May	above 400 mm	above 400 mm	above 400 mm
Precipitation in June	above 200 mm	above 200 mm	above 200 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C
Utility value (H)	0.2	0.55	0.6

Risk of fruit cracking

Cherry and sour cherry production has a specific risk factor. This is the fruit cracking due to the excessive precipitation in the harvest period, resulting decrease of quality and significant yield loss. In some extreme years the cracking damage can cause up to 80-100% loss in sweet cherry and about 40-50% loss in sour cherry orchards (Christiensen, 1996, Csiszár, 2004).

According to an earlier study (Szenteleki et al., 2010) harvest period of sweet cherry is considered between 20th May and 10th July and four risk factors are calculated for every harvest day using the following algorithm:

- K2 risk factor: 10-6. days before harvest at least 15 mm rain occur once → K2=0.15; twice→0.4; three times→0.7
- K3 risk factor: 5-1. days before harvest at least 10 mm rain occur once→ K3=0.2; twice→0.5; three times→0.8
- K4 risk factor: during harvest at least 5 mm rain occur once→ K4=0.8; twice→1

The overall risk factor is like follows:

- K2+K3+K4=K5; if K5>1, than K5=1.

To obtain the overall utility value of a given year, its utility value based on the climatic year types must be corrected with this risk value.

Results

Overall evaluation of the Central Hungary region

Central Hungary region is partitioned into 17 local administrative units (subregions), which have slightly different climatic and topographic characters. Despite that – for

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practical computing reasons – each of them was represented by one grid point's meteorological data. A joint evaluation of these data (17 places x 30 year for each period) allows giving a general estimation of the future climatic potential of cherry production.

Analysing the distribution of climatic year types regarding temperature (*Fig. 2*) the significant decrease of the extreme cold years can be observed. The number of cold years is increasing but there is no contradiction with the expected; it means that the formerly extreme cold years become only cold. Decrease of the number of normal years can be the reason of the continuous and significant increase of the warm years. Overall, a tendentious warming can be observed, which is favourable for quality cherry production. The utility value of the extreme cold years is very low because of the high risk of winter and spring frost damages. The significant decrease of the extreme cold years indicates the decrease of the frost damages, especially in long-term.

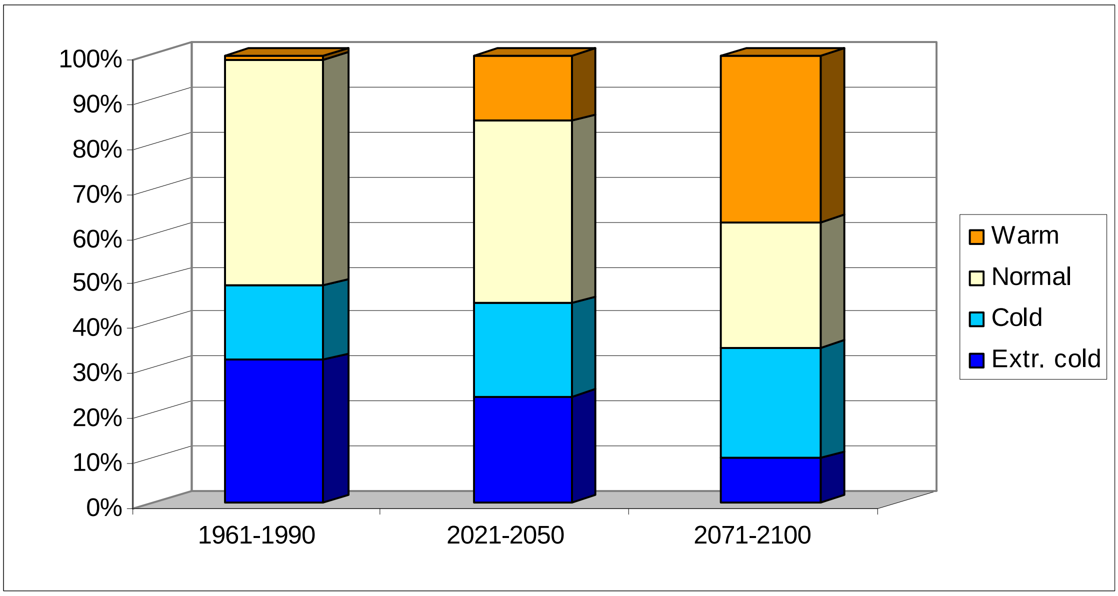

Figure 2. *Distribution of climatic year types regarding temperature*

However, results call the attention to a very important but rarely mentioned question: the re-evaluation of the varieties. The considerably extent of climate change would have a great impact on the time and length of ripening, dormancy and blooming period of cherry varieties (Ladányi et al., 2009). Milder winters can lead to the shortening of the deep dormancy period, resulting earlier blooming. As a consequence despite of the milder climate the risk of the spring frost can increase in case of some varieties, too. Changes in the well-known and so far successfully applied blooming time groups and pollination partners are also expected. Re-evaluation of the varieties according to the indicated changes is important in case of planning a new orchard. Counting with a 20-25 year lifetime, orchards planted nowadays will have most of the productive years in the second period examined (2021-2050), already under changed climatic conditions.

In case of precipitation (*Fig. 3*) there are unfavourable tendencies, too. The number of extreme dry years is insignificant in the baseline period and also in the near future, but there is a significant increase by the end of the century (in every 5-6 years one extra dry year is expected). There is a continuous increase in the number of dry years and decrease in case of the normal years. Not completely though in a great part, these opposite tendencies correspond to each other. In case of the wet years a temporary increase, while in long-term their decrease can be observed. The number of extreme wet years is insignificant in all the three periods moreover this year type disappears.

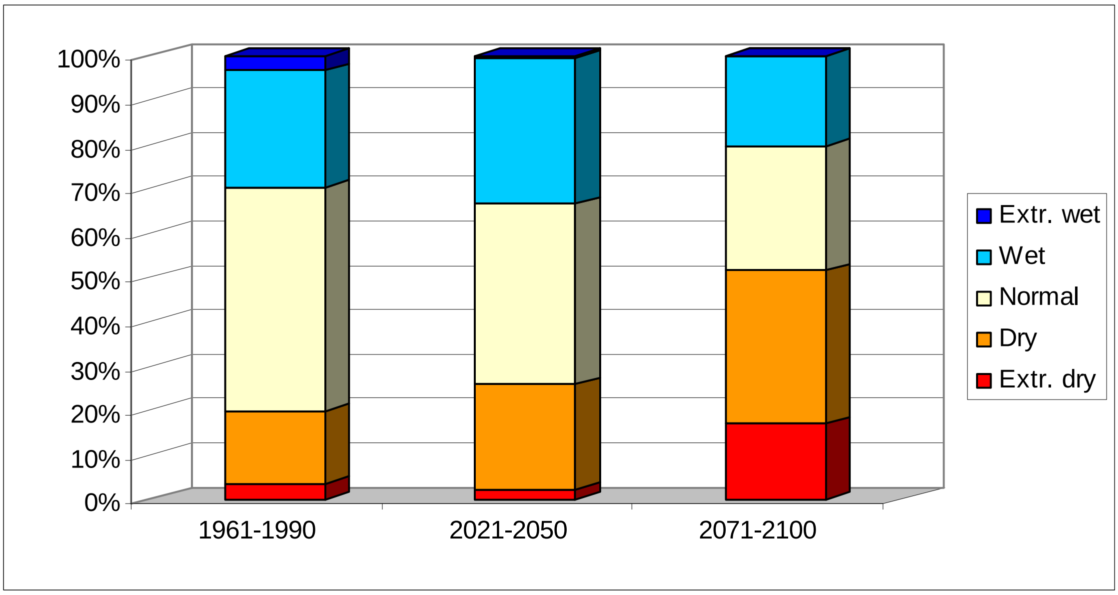

Figure 3. *Distribution of climatic year types regarding precipitation*

All together an aridification tendency can be observed, but the dry and warm (H=0.86) as well as the normal (H=0.88) year types are still favourable for cherry production. However, the significant number of extra dry years at the end of the century is a warning sign. In very dry years the fruit development is not appropriate and it affects the fruit size as well as the yield adversely. It calls the attention to the importance of irrigation. Changes are not so drastic that it would require immediate investments in existing orchards, but may be considered in the future.

Based on the climatic year types the continuous increase of the utility values can be observed (*Table 5*). However, in short-term the fruit cracking risk is higher, so the overall utility remains almost the same as it was in the baseline period. Two reasons can explain the increase of the fruit cracking risk in the near future. One of them is the increase of the number of wet years. At the same time, the number of dry years is also higher. If the cherries grow on drier conditions and precipitation is before harvest, cracking damage is higher than under balanced water conditions. Importance of irrigation possibility is great in this point of view and may be justified even in existing young plantations, while other protection methods are also available. In long-term, due to the more arid climate, the fruit cracking risk is decreasing again, and compared to the base period, 9% increase can be expected in the overall utility.

Table 5. *Cherry production utility in Central Hungary*

Period	Climatic utility	Fruit cracking risk	Overall utility
1961-1990	65 %	5 %	61 %
2021-2050	70 %	11 %	62 %
2071-2100	73 %	5 %	70 %

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Spatial variability

The overall evaluation of the Central Hungary region gives a general aspect but has the disadvantage of masking spatial variability. In the followings the spatial and temporal variability of the utility/risk values will be discussed.

As it can be seen in *Table 6*, in the near future the ranges of the utility values – calculated from the 17 subregions – are similar to the ones of the base period, but at the end of the century the ranges are expected about the half these. This tendency can be observed in both climatic utility and risk of fruit cracking as well as in overall utility. Ranges of the overall utility values of the subregions are over 20% in the first two periods and about 10% in the future (standard deviations are approximately 6% and 3%). It means that more favourable climatic conditions will appear in most of the subregions and the potential for cherry production will be more similar across the whole region.

Table 6. *Ranges of the cherry production utility values in Central Hungary (17 subregions)*

Period	Climatic utility	Fruit cracking risk	Overall utility
1961-1990	20% (51-70%)	10% (3-12%)	24% (44-68%)
2021-2050	17% (60-77%)	11% (6-17%)	22% (49-71%)
2071-2100	10% (68-78%)	6% (3-8%)	11% (63-74%)

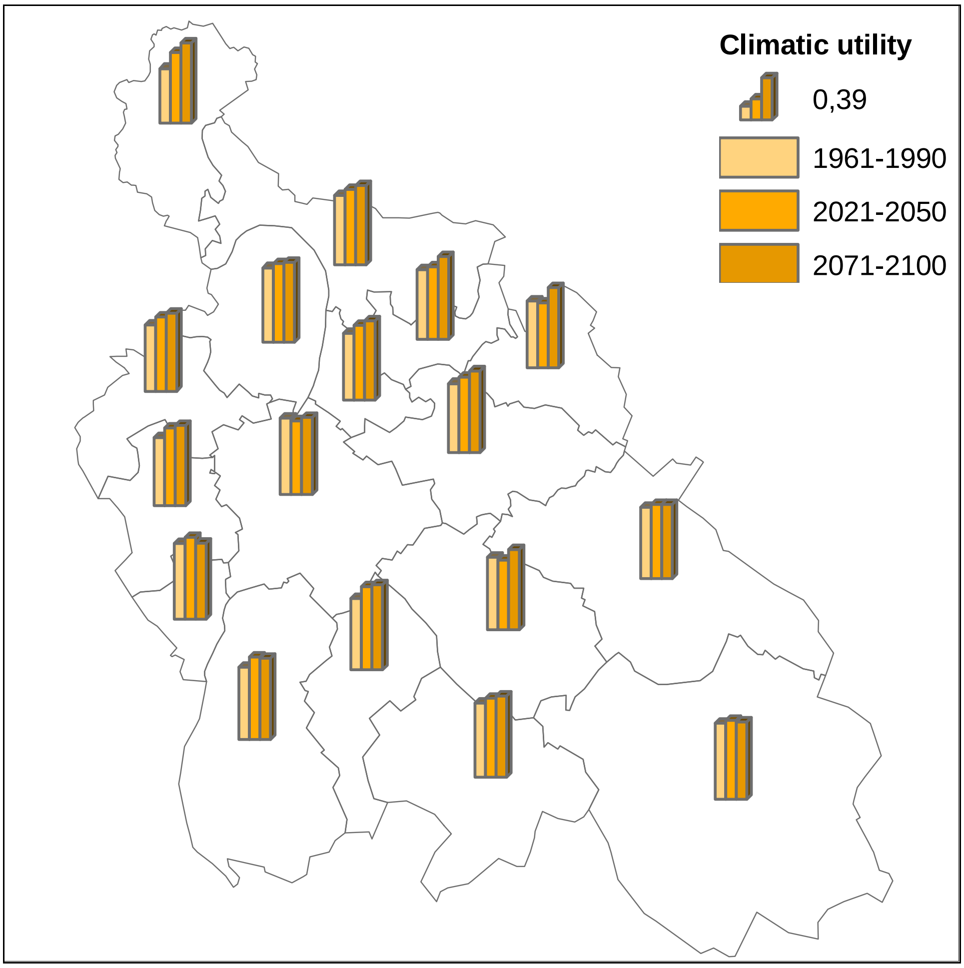

Figure 4. *Climatic utility of the subregions regarding cherry production in Central Hungary (the value refers to the highest column in the chart symbol)*

As it was presented previously, the warming climate is favourable for cherry production. In the majority of the subregions a continuous increasing tendency of the climatic utility values can be observed (*Fig. 4*). This is especially characteristic in the northern part (Szob), where the utility value was the lowest in the base period. In some subregions (Budapest, Aszód, Monor) in the near future (2021-2050) the climatic utility value can slightly be lower (2-3%) than in the base period. For the third period examined (2071-2100) the climatic utility values are always greater than in the base period.

According to the general results, the fruit cracking risk is always the highest in the period 2021-2050, except the surroundings of Ráckeve (*Fig. 5*). The increment is between 1-10% compared to the base period, the greatest change is in Pilisvörösvár. However, the worst situation (highest risk) is expected in the subregions of Aszód, followed by Szob and Veresegyház.

As it was presented during the overall evaluation, at the end of the century the average of the cracking risk values is similar to the one of the base period. But the situation is more complex. There are some significant changes in the risk values – in Aszód it drops to the one-third, in Monor and in Szob to the half of the base value – while in Cegléd, Dunakeszi and Szentendre the risk values are almost doubled.

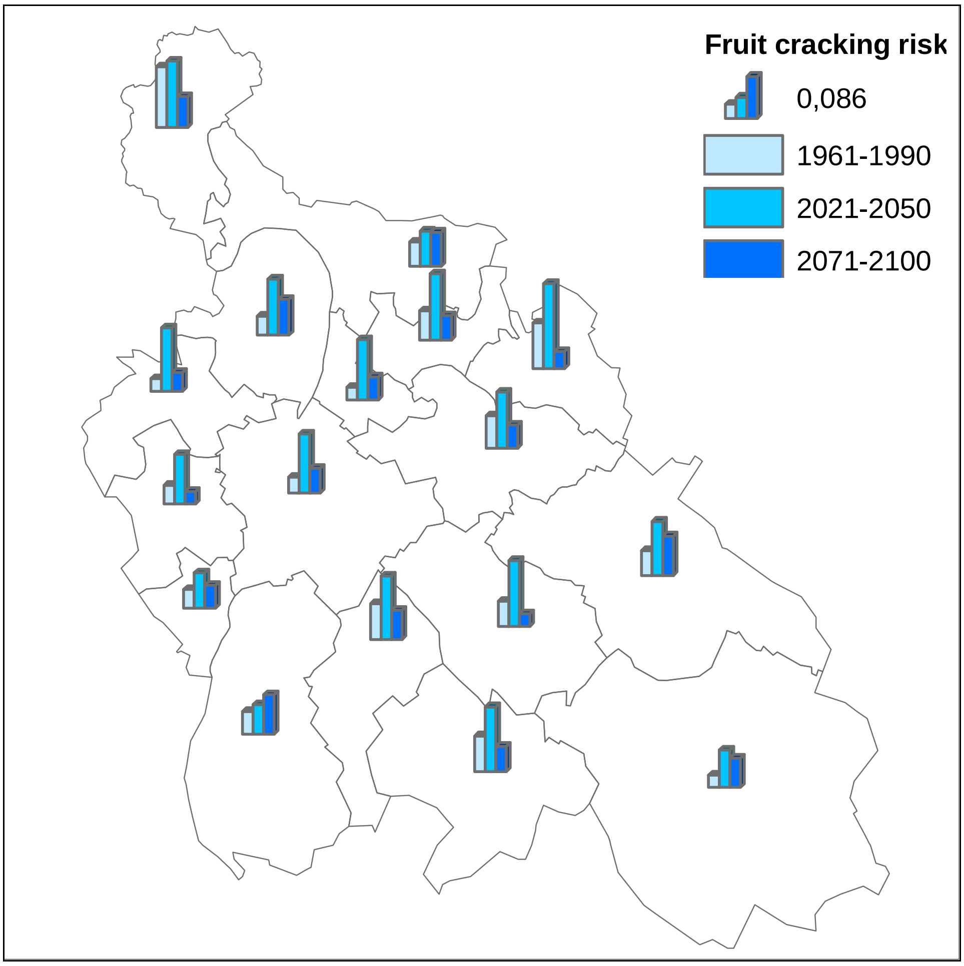

Figure 5. *Fruit cracking risk of cherries in the subregions in Central Hungary (the value refers to the highest column in the chart symbol)*

In the near future (2021-2050) the fruit cracking risk is higher, so despite of the increasing climatic utility values, the overall utility remains almost the same as it was in the base period. There is an interesting pattern (*Fig. 6*), because on the western side of Central Hungary region mostly some increase, while on the eastern side some decrease can be observed. The most important changes are in Szob and Ráckeve (12% and 8% increase), where the increase of the cracking risk was quite small. By the end of the century the overall utility values are generally higher than they were in the base period. The exceptions are Budapest and Cegléd by 1% decrease and Érd with no change. By that time the overall utility value in Szob increases by 25%, which is much more than in the other subregions. The subregion of Aszód shows also an outstanding result (16% increase), as the cracking risk is very low in the third period.

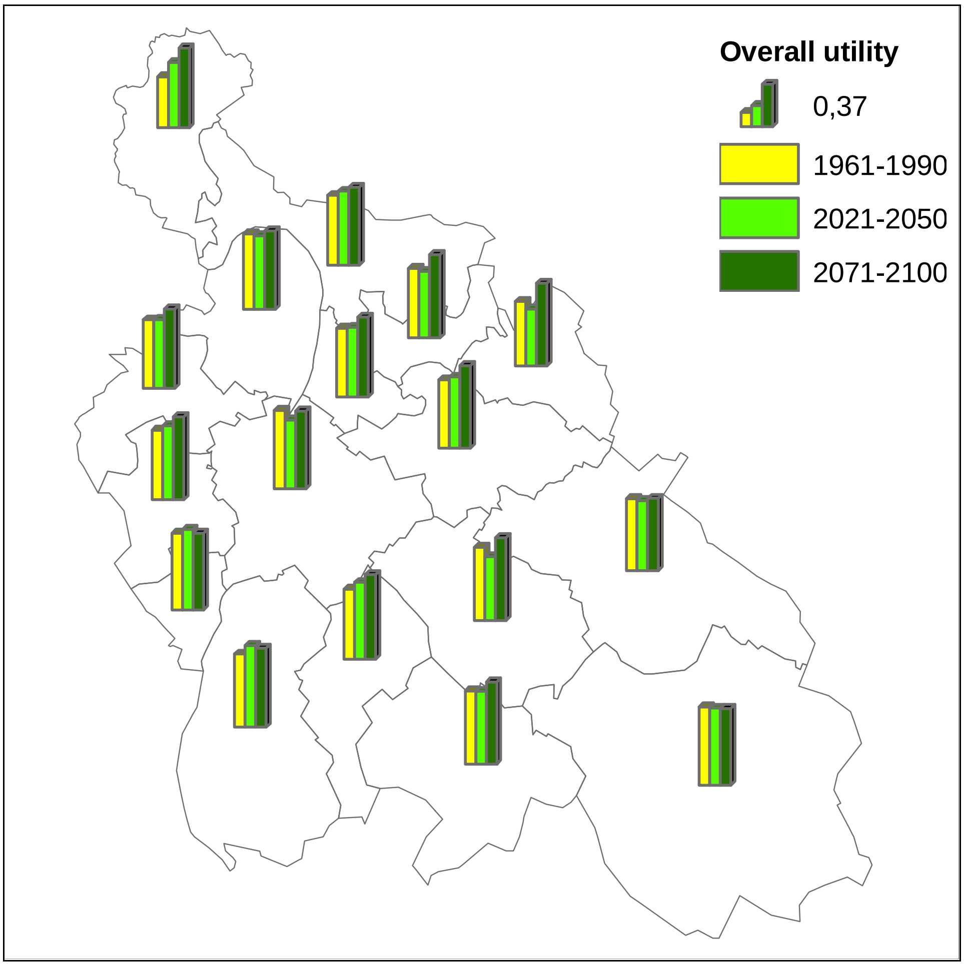

Figure 6. *Overall utility of the subregions regarding cherry production in Central Hungary (the value refers to the highest column in the chart symbol)*

Statistical data of cherry growing areas are usually structured by regions (NUTS 2 level) or counties (NUTS 3). Data by local area units (subregions) are available unfortunately only from the year 2001 (*Table 7*), when the most important areas were Cegléd, Ráckeve, Veresegyház, Budaörs and Érd.

Table 7. *Net cherry growing areas in the subregions (source: KSH, 2001)*

Local area (subregion)	Net cherry area (ha)
Aszód	0.16
Budaörs	28.89
Budapest	0.15
Cegléd	119.42
Dabas	0.15
Dunakeszi	0.00
Érd	25.17
Gödöllő	7.97
Gyál	0.00
Monor	4.50
Nagykáta	2.00
Pilisvörösvár	2.41
Ráckeve	65.11
Szentendre	9.64
Szob	0.00
Vác	4.71
Veresegyház	49.11

Despite of the differences in time periods it is worth to compare these data with the overall utility values of the base period. It can be observed that most of the production was under appropriate climatic conditions, as Cegléd had the highest utility value (0.68) in the base period. The same utility value has Budapest, but of course the growing area there is very low due to the high urbanisation. The overall utility value of Érd is also high (0.67) but the area of this subregion is small, and production of sour cherry is more important there. The other three areas have lower but still acceptable utility values: Ráckeve 0.64, Veresegyház 0.61 and Budaörs 0.6. (Some warming up between the base period and the survey date of the growing areas can also be considered.)

In the near future (2021-2050) both the climatic utility and the cracking risk are expected to increase in all of the subregions highlighted but with different extent. As a result, the overall utility value of Cegléd remains almost the same (0.67), the ones of Érd and Budaörs increase by 3-4% and the value of Veresegyház decreases by 3%. The most important change can be observed in Ráckeve by 7% increase.

Regarding the long-term tendencies the following overall utility values are expected: Cegléd and Érd 0.67 (the same as before), Ráckeve 0.69 (between the base and the near future), Budaörs and Veresegyház 0.72 (more than 10% increase compared to the base period). The most significant changes can be observed in the areas (Szob, Aszód and Gyál), which were unsuitable for cherry production in the base period.

Discussion

Based on the presented results the following conclusions can be drawn concerning the future climatic conditions of cherry production:

- Decrease of the extreme cold and cold year types have a yield enhancing effect, first of all due to the decrease of the frost damages.
- Increase of the warm year types indicate the improvement in climatic conditions for quality cherry production.

- The precipitation amount in the vegetative period shows a temporary slight increase in short-term, but in long-term its decrease can be observed. It calls the attention that appropriate infrastructure for irrigation may be required in the future.
- The uneven distribution of precipitation during the harvesting season in short-term indicates increase of yield loss risk caused by fruit cracking, but in long-term this risk is moderate. Risk of fruit cracking might significantly reduced by adequate irrigation, so the above mentioned need for irrigation systems is important also from this point of view.
- The serious decrease of the extreme cold years and the increase of warm year types – despite the tendentious aridification – indicate an overall increase of utility values in cherry production and decrease of their variation.

The re-evaluation of the varieties according to the indicated changes is advised, as a new orchard planted nowadays will have most of the productive years in the second period examined (2021-2050). In this work international cooperation can help. With the method of spatial climatic analogy (Horváth et al., 2009) such regions can be found where the present climate is similar to the expected one of the studied area in the future. Thus, the future behaviour of the varieties can be evaluated and tested in the present days.

More solar radiation means warmer air temperature and higher temperature also in the upper layers of the soil. Therefore, not only in case of cultivars but in case of rootstocks it is advised choosing such kinds that tolerate summer heat having their roots in deeper soil layers. Irrigation is able to reduce soil temperature significantly and to avoid drought. When water supply of the soil is lower than the plant needs, it is ground draught. Drip irrigation, for example, is a good method to prevent ground draught. When the air temperature is above 30°C, air humidity is usually very low, therefore fruit trees close stomas in the leaves and transpiration stops. Despite there is good water supply from the soil the plant shows draught symptoms. In this case drip irrigation is not effective at all, sprinkler irrigation is needed to cool down the surface of the leaves and raise air humidity in the orchard. This problem is not so important for sweet cherry but, for example, in case of apple production sprinkler irrigation during summer nights is a corner stone to reach the necessary coloration.

The rise of temperature can affect not only the growing but also the post-harvest technology. Even a small rise of temperature increases the risks during post-harvest handling. The transportability and shelf life of cherry fruits depend first of all on the time elapsed between picking and cooling as well as on the continuous temperature control of the supply chain. In addition, experiences show that fruits harvested on warmer days can be stored for shorter time as fruits harvested with the same technology but on cooler days.

To prevent fruit cracking in the second period (2021-2050) many protection methods can be applied (Simon, 2006). The most effective but very expensive protection technique is the plastic rain cover over the trees. Spraying with minerals (calcium) or metallic salts and fruit drying techniques need less investment. Risk of fruit cracking might significantly reduced by adequate irrigation, by means of maintaining balanced water conditions during vegetation period.

Up to now each of the 17 local administrative units – subregions – were represented by one grid point's data. As the 10 km resolution grid covers the whole area of Central Hungary region, analyses can be carried out for all grid points to obtain a more precise

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view. The only limitation factor of it is the computer capacity, as due to the large amount of data and the number of climatic parameters considered, at present the calculations take a rather long time.

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PHYTOPLANKTON COMPOSITION IN RELATION TO HYDROCHEMICAL PROPERTIES OF TROPICAL COMMUNITY WETLAND, KANEWAL, GUJARAT, INDIA

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Abstract. A limnological investigation was carried out in Tropical Community Wetland, Kanewal, Gujarat, India from June 2007 to May 2008. Water quality parameters like temperature, pH, dissolved oxygen, secchi depth, total solids and total dissolved and suspended solids, free carbon dioxide, phenolphthalein alkalinity, total alkalinity, carbonates, bicarbonates, total hardness, calcium and magnesium hardness, chloride, phosphate, sulphate and nitrate and phytoplankton composition were investigated during the study period. Correlation coefficients were calculated among the various physico-chemical variables and phytoplankton groups. Sulphate and nitrate both showed a positive correlation with phosphate. However, dissolved oxygen showed a negative correlation with phosphate, sulphate and nitrate at both the sites. Pearson Product Analysis for phytoplankton at the two sites was performed and it showed a high significance of Bacillariophyceae members between both the sites than other two groups. A total of 45 species were identified belonging to Cyanophyceae, Chlorophyceae and Bacillariophyceae but members of Euglenophyceae were found to be absent indicating a lesser degree of organic pollution. Moreover, species of Bacillariophyceae were recorded to be the most occurred group compared to others throughout the study which shows relatively unpolluted nature of wetland.
Keywords: *Bacillariophyceae, Chlorophyceae, Cyanophyceae, wetland*

Introduction

Wetland ecosystems are among the most productive ecosystems in the biosphere. Wetlands receive surface water inputs from streams (surface run off), precipitation, and overland flow and subsurface water inputs from surface infiltration, stream hyporheic zones, and ground water. These different inputs are important to wetland productivity because they contain markedly different quantities of transported nutrients (Stanley and Ward, 1997) and organic matter (Mann and Wetzel, 1995). Wetlands are recognized as ecosystems that harbor high biological diversity, provide sustenance for millions of people and face ongoing threats as results of human activities throughout the world (Gopal and Chauhan, 2001). As ecosystems, wetlands are highly volatile being particularly vulnerable to environmental fluctuations. Although wetland biodiversity constitutes a significant portion (e.g., 15-20%), of the total biodiversity of the Indian Subcontinent (Gopal and Chauhan, 2001) studies of wetland ecosystems are limited (Tsai and Ali, 1997; Gopal and Zutshi, 1998; Gopal and Chauhan, 2001; de Graaf and Marttin, 2003). In recent years, increasing anthropogenic interventions influence in and around aquatic systems and their catchment areas have contributed to a larger extent towards deterioration of water quality leading to accelerated eutrophication. The hydrogeochemical characteristics and phytoplankton biomass of water bodies are not

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constant and fluctuate with seasonal variation as well degree of pollution (Prasad, 2006).

Phytoplanktons are integral components of freshwater wetlands, which significantly contribute towards succession and dynamics of zooplankton and fish (Payne, 1997). Community structure, dominance and seasonality of phytoplankton in tropical wetlands are highly variable and are functions of nutrient status, water level, morphometry of the underlying substrate and other regional factors (Gopal and Zutshi, 1998; Zohary et al. 1998; Agostinho et al. 2001). Phytoplanktons form the main producers of an aquatic ecosystem which control the biological productivity. They not only provide an estimation of standing crop but also represent more comprehensive biological index of the environmental conditions (Misra et al., 2001). Phytoplankton, which include blue-green algae, green algae, diatoms, desmids and euglenoids etc are important among aquatic micro-flora. They form the basic link in the food chain of all aquatic animals (Misra et al., 2001). Many herbivores, mostly zooplankton, graze upon the phytoplankton thus, passing the stored energy to its subsequent trophic levels. The phytoplanktons float passively and spread uniformly and extend down to various depths, where hydrochemical properties influence the plankton population and its occurrence. Therefore, an attempt has been made to study ”Phytoplankton Composition in Relation to Hydrochemical Properties of Tropical Community Wetland, Kanewal, Gujarat, India”.

Review of literature

In recent past, studies on phytoplankton in relation to environmental conditions have been made by Demir and Kirkagac (2005)**.** Muzaffar and Ahmed (2007) studied the effect of the flood cycle on the diversity and composition of phytoplankton community of a seasonally flooded Ramsar wetland in Bangladesh. Moreno-Ostos et al (2008) investigated spatial distribution of phytoplankton in a Mediterranean reservoir. Cardoso and Marques (2009) determined the short-term patterns derived from the interactions of wind-driven hydrodynamics and the plankton community in a large, shallow lake.

In India, studies on phytoplankton of lentic systems in relation to their environmental conditions have been made by Ganapathi (1941), Pandey et al. (2000). Mohan (1980) compared the values of organic carbon and planktonic biomass with that of dominant algal associations in two lakes of Hyderabad. Padhi (1995) in his studies on water chemistry and algal communities on the three freshwater ponds in and around Berhampur suggested revival methods using the algal communities as biological indicators. He recorded wide variations in pH, dissolved oxygen, BOD, COD, phosphate and nitrates. Pandey et al. (2000) investigated the nutrient status and cyanobacterial diversity of tropical freshwater wetlands of Udaisagar and clearly indicated elimination of sensitive cyanobacterial species from the substations receiving urban industrial effluents. Pulle and Khan (2003) analyzed the qualitative and quantitative concepts of phytoplankton and recorded 43 species, of which 18 were Chlorophyceae, 10 Bacillariophyceae, 10 Cyanophyceae and 5 Euglenophyceae. Angadi et al. (2005) studied physico-chemical and biological status of aquatic bodies and recorded 39 species of algae from four classes.

In Gujarat state, Nandan (1983) studied the algal flora of polluted waters. Shaji (1989) and Jose (1990) evaluated the algae as pollution indicators in running waters. Rana and Nirmal Kumar (1992) and Nirmal Kumar et al. (2005, 2008) also studied physico-chemical characteristics of water and sediments, diversity of macrophytes and planktons of certain wetlands of Central Gujarat. Nirmal Kumar (1992) also prepared indices based on chemical properties in relation to planktons. However, there is no report on phytoplankton composition in relation to hydrochemical properties of tropical community wetland, Kanewal, Gujarat, India**,** so far. Looking into significance in mind, it is very much essential to carry out this interaction of plankton composition and nutrient status in this wetland, which is first of its kind in the state and as the wetland is also very much utilized by villagers of eight surrounding villages for their daily purposes.

Materials and methods

Study area

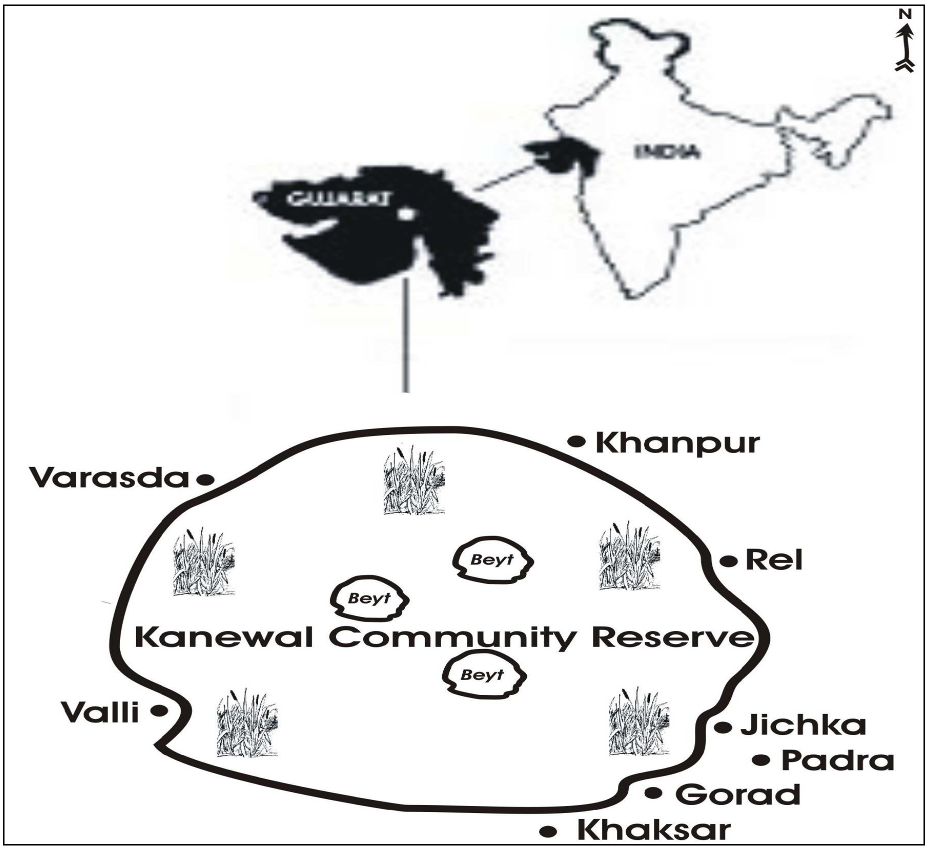

Figure 1. *Location of Kanewal wetland, showing the eight villages around it*

In the present study, a significant freshwater inland wetland habitat of the state, Kanewal Wetland of Anand District has been selected, which is an important water-storage wetland and regularly harbours more than 20,000 water fowls during peak winter season (GSFD,2004); makes it eligible for RAMSAR convention. The population estimation of waterfowls of this wetland clearly signifies it as internationally important wetland (Koning and Koning-Raat, 1975; Scott, 1989) and the ‘Wetlands of National Importance’ (MoEF, 2005). Besides, it has already been recognized as Community Reserves by the Gujarat State Forest Department (GSFD, 2005). The water regime of Kanewal Community Reserve (KCR) supports around 130 species of

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waterfowls with an average of 20,000 waterfowls during peak winter months (Van Der Ven, 1987). Moreover, it is also one of the main water sources for Charotar, Bhal and Saurashtra regions of Gujarat, which supply water on the regular basis for irrigation and drinking and/or domestic purposes to the inhabitants of aforesaid regions through Saurashtra Pipeline Project (SPP). It is also cited in Asian Wetland Bureau, Kuala Lumpur, Malaysia (AWB and WWF-India, 1993) for Asian Waterfowls Census (AWFC).

Kanewal wetland is located between 22º 35' N latitude and 72º 36' East longitude at an altitude between 14 to 15m above the mean sea level, covering an area of 1500ha. It is situated nearly 60kms from Anand, the Milk City of India and falls under 4- B Gujarat Rajwara region of Central Gujarat. It lies in a natural depression; surrounded by embankment with a circumference of about 15km and comprises of three islands. This wetland is surrounded by eight villages (*Fig. 1*), which has a total population of 5000 and the villagers are completely dependent on this wetland for food, fodder and economy for their livelihood. Climatically, it experiences dry tropical monsoon, with an average annual rainfall of about 850mm concentrated in the months of July, August and September. The other seasons include summer (March to June) followed by winter (November to December). However, pre-monsoon in the month of June 2007 has been recorded. The wetland harbours an abundant growth of aquatic vegetation e.g. *Ipomoea aquatica, Marselia quadrifolia, Hydrilla verticillata*, *Vallisneria spiralis, Nymphea stellata, Nelumbo nucifera* and plenteous beds of *Typha angustata.* Besides, it also harbours some resident avian species e.g. Moorhens, Egrets, Ibises, Lapwings, etc. and also attracts various migratory species of birds from remote countries like Europe, Russia, Siberia, China etc., which comprises waterfowls such as Coots, Plovers, Spoonbills, migratory ducks, etc during peak winter period. This wetland also supports a small fishery.

Site 1

This site is approached by main road, close to irrigation department and agriculture fields westwards. There is a permanent open well located adjacent to this site. The bank of this site is endowed with abundant beds of *Typha angustata*. It has a more open water surface, spanning more stretch of water and shallow basin. Due to shallow basin, the water level reaches hardly 9 to 10 ft. round the year. Although it attracts a good number of aquatic birds, the site is frequently seen being disturbed by the local inhabitants of the islands, situated opposite to the site. The site supports good vegetation such as *Echinochloa colonum, Ipomoea aquatica, Nelumbo nucifera* and *Typha angustata*. Due to presence of bank vegetation, birds like Egrets, Ibises, Herons and Moorhens prefer this site for foraging and roosting.

Site 2

This site is situated about 1km from Valli village, adjacent by small 'kachcha' road and agriculture expansion towards west. Though the site is absolutely devoid of human settlements, it is frequently visited by 'Beyt' population (inhabitants) for boating and fishing. The mode of transport to this site is by bicycles and light vehicles. The bank of the site supports considerable growth of aquatic weed *Typha angustata* and *Ipomoea aquatica*. The average depth of water at this site is 18 to 20 ft through out the year. There is a permanent water station and over-head water tank nearby this site for canalsing, providing water to local people for drinking and irrigation. The habitat is

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mainly dominated by aquatic macrophytes such as *Echinochloa colonum, Hydrilla verticillata, Ipomoea aquatica, Nelumbo nucifera*, *Typha angustata* and *Vallisneria spiralis*. Local people use the water mainly for irrigation and domestic purposes. Washing of clothes and utensils, bathing, cattle-wading and grazing is observed upto considerable extent at this site which contributes to non-point source of pollution.

Sampling

Surface water samples were collected in two litres polythene bottles from two sites in the wetland in the 2nd week of every month from June 2007 to May 2008 and analyzed in the laboratory for important hydro-chemical properties. Physical parameters like pH, temperature, secchi-disc transparency and dissolved oxygen (DO) were performed on the field. The rest of the parameters like total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), free carbon dioxide, phenolphthalein alkalinity, total alkalinity, total hardness, calcium hardness, magnesium hardness, chloride, phosphate, sulphate and nitrate were analyzed in the laboratory. Samples were not collected in June and July due to heavy monsoon and flooding. Analysis of all the parameters was performed according to the methods described by APHA (1998) and Trivedy & Goel (1986).

Phytoplankton samples were collected using phytoplankton nylon net, with sieve size of 10 microns and preserved in 4% formalin at the field and identified according to standard monographs- Cyanophyta (Desikachary, 1959), Fresh-Water Biology (Edmundson, 1963) and Indian Freshwater Microalgae (Anand, 1998) and books. Correlation coefficients were calculated among the various physico-chemical variables and phytoplankton groups. Pearson Product Analysis (PPA) was performed for phytoplankton at the two sites.

Results

Physicochemical variables

The hydro-chemical parameters of Kanewal wetland have been shown in *Table 1, Fig. 2* for site 1 and *Fig. 3* for site 2. Water temperature varied between 19ºC and 31ºC during the study period, maximum temperature of 31^{o} C was achieved in the month of May 2008 at Site 2, while the minimum temperature was recorded in the month of January 2008 at Site 1. Values for pH remained close to neutral through out the investigated period but highest value of 7.8 was observed in the month of March 2008 at Site 1 and Site 2. Secchi depth varied between 115cms in August 2007 at Site 1 and 200cms in October 2007 at Site 2. Dissolved oxygen varied between 4.7 mgl^{-1} and 11.27mgl^{-1} at Site 2 in May and January 2008, respectively. Total hardness ranged between 74mg$CaCO_3$l^{-1} and 142mg$CaCO_3$l^{-1}, lowest being at Site 1 in August 2007 and highest at Site 2 in December 2007 and at Site1 in May 2008. The lowest and highest values of calcium hardness were measured as 31.5mg$CaCO_3$l^{-1} in December 2007 and 63.0mg$CaCO_3$l^{-1} at Site 1 in January 2008, respectively. Magnesium hardness ranged between a minimum of 25.7mg$CaCO_3$l^{-1} at Site 1 in August 2007 and a maximum of 102.1mg$CaCO_3$l^{-1} at Site 2 in December 2007. The lowest concentration of chloride was measured as 25.56mgl^{-1} in September 2007 at Site 2 and highest as 52.54mgl^{-1} in March 2008 at Site 1. The total phosphorus varied between 0.010 and 0.099mgl^{-1}, the lowest in month of February 2008 at Site 1 and the maximum measured in May 2007 at Site 2.

Table 1. *Monthly variation in hydro-chemical parameters at Kanewal wetland from June 2007 to May 2008*

	Site	Temperature	pH	Transparency	TDS	TSS	Free CO_2	PA	Total Alkalinity	Carbonates	Bicarbonates	Calcium Hardness	Magnesium Hardness
Jun	S1	-	-	-	-	-	-	-	-	-	-	-	-
	S2	-	-	-	-	-	-	-	-	-	-	-	-
Jul	S1	-	-	-	-	-	-	-	-	-	-	-	-
	S2	-	-	-	-	-	-	-	-	-	-	-	-
Aug	S1	26	7.1	115	20	20	0	12	62	24	38	48.3	25.7
	S2	27	7.2	139	40	20	0	12	98	24	74	49.3	54.7
Sep	S1	28	7.4	130	20	20	0	8	76	16	60	46.2	37.8
	S2	28	7.6	150	60	40	13.2	0	86	0	86	45.6	58.4
Oct	S1	24	7.1	126	120	60	0	10	84	20	64	48.3	43.7
	S2	26	7.6	200	100	60	17.6	0	98	0	98	58.8	51.2
Nov	S1	22	7	133	20	20	0	6	80	12	68	48.3	49.7
	S2	25	7	196	100	40	0	6	96	12	84	48.3	61.7
Dec	S1	20	7.2	120	100	20	0	12	82	24	58	31.5	76.5
	S2	22	7.2	170	140	20	26.4	0	128	0	128	39.9	102.1
Jan	S1	19	7.4	137	80	40	17.6	0	170	0	170	63	65
	S2	20	7.6	156	100	40	0	10	150	20	110	59.3	46.7
Feb	S1	20	7.3	140	120	20	0	8	96	16	80	46.2	91.8
	S2	21	7.3	161	100	40	0	4	86	8	78	42	72
Mar	S1	22	7.8	136	120	20	0	4	80	8	72	39.9	86.1
	S2	21	7.8	153	80	40	0	0	96	0	96	44.1	59.9
Apr	S1	25	7.7	125	130	20	0	8	140	16	124	45.7	93.3
	S2	24	7.8	141	110	25	0	6	108	12	96	49.5	75.5
May	S1	29	7.8	119	135	35	0	8	154	16	138	47.8	94.2
	S2	31	7.7	130	90	30	0	8	114	16	98	52.4	77.6

All values are in mgl^{-1} except temperature (°C), pH and transparency (centimeters)
*Samples not collected in June and July due to heavy monsoon and flooding

Sulphate concentration ranged between a lowest of 6.211mgl^{-1}, observed at Site 1 in September 2007 and highest of 27.029mgl^{-1} at Site 2 in May 2008. The lowest and highest values of nitrate were measured as 0.149mgl^{-1} in September 2007 at Site 1 and 0.476mgl^{-1} in May 2008 at Site 2 respectively. The values of hydrochemical properties were higher at Site 2 as compared to Site 1, probably due to vicinity to the villages, addition of village wastes, interference of cattle, bathing and washing.

Correlation coefficient showed that at Site 1, temperature and pH correlated positively (0.0429). Phosphate also correlated positively with temperature (0.1162). Sulphate and nitrate both showed a positive correlation with phosphate (0.6098 and 0.2695 respectively). However, DO showed a negative correlation with phosphate (-0.2978), sulphate (-0.660) and nitrate (-0.850). At Site 2, temperature and DO showed a positive correlation (0.033). Phosphate also correlated positively with temperature (0.613). Unlike Site 1, sulphate and nitrate correlated negatively with phosphate (-0.0134) and (-0.472), at Site 2. DO showed a negative correlation with phosphate (-0.476), sulphate (-0.766) and nitrate (-0.472).

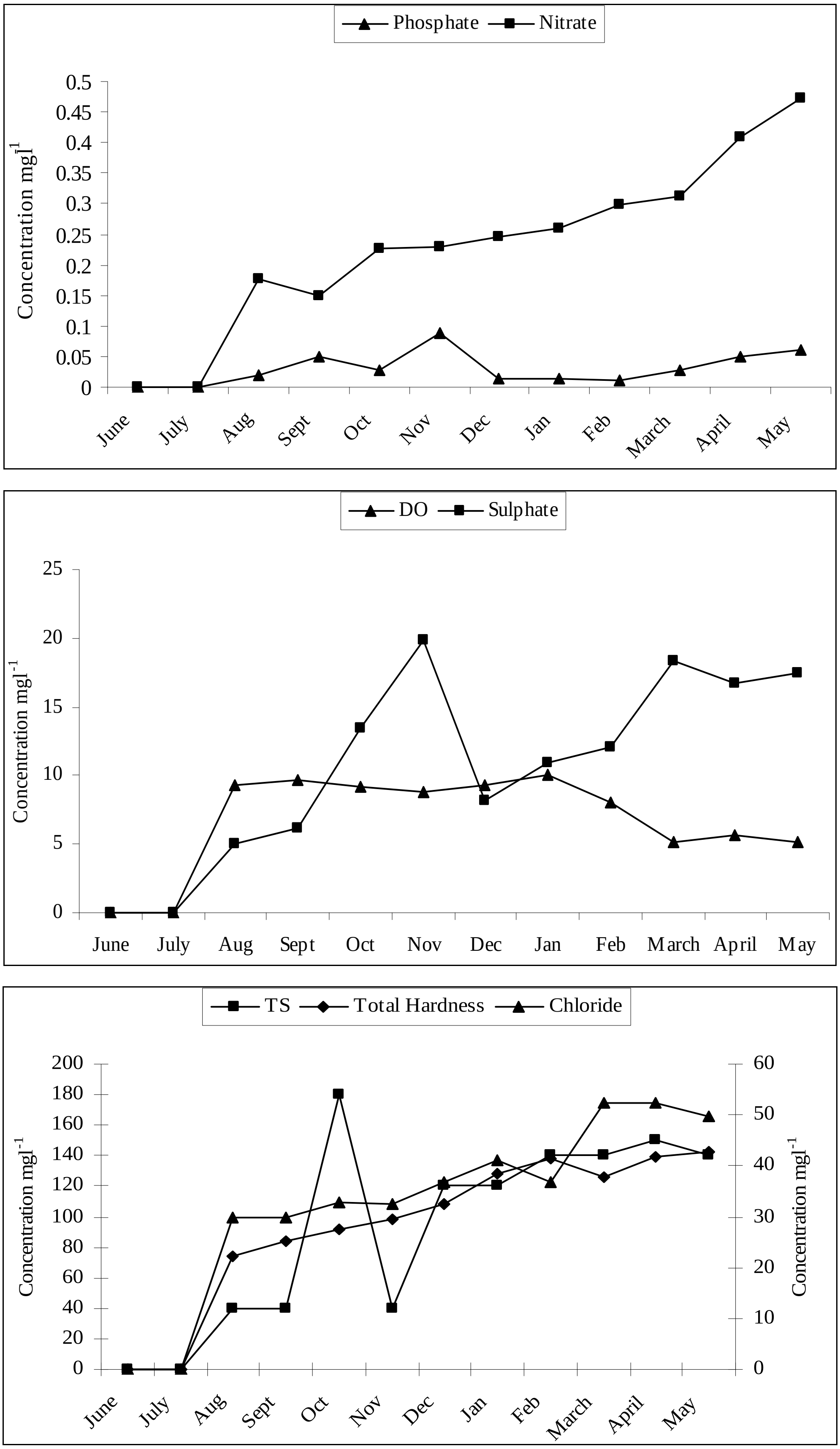


Figure 2. *Monthly variation in hydro-chemical parameters at Kanewal wetland from June 2007 to May 2008., Site 1*

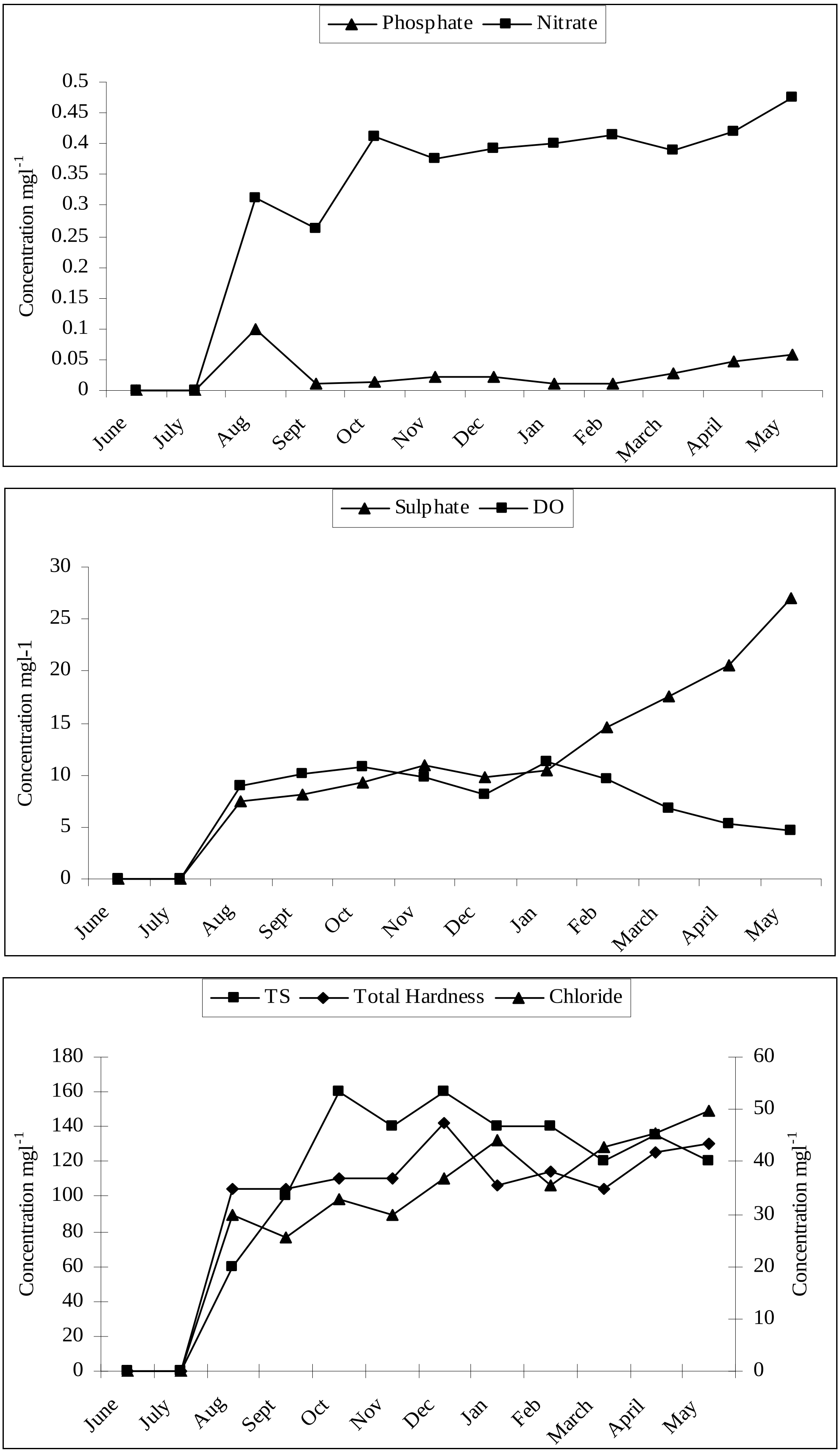


Figure 3. *Monthly variation in hydro-chemical parameters at Kanewal wetland from June 2007 to May 2008., Site 2*

Phytoplankton community

The study of the phytoplankton sampled in Kanewal wetland showed 45 species (*Table 2*). The phytoplankton assemblage was represented by three classes of algae viz. Cyanophyceae, Chlorophyceae and Bacillariophyceae: 18 taxa were Cyanophytes, 17 were Chlorophytes and 9 were diatoms. The wetland showed the post monsoon months dominated by the Chlorophytes whereas; Bacillariophytes dominated the winter months at both the sites. Some species occurred in all the months at both the sites during the sampling period viz. *Merismopoedia convulata, Oscillatoria princeps*, *Spirulina princeps, Cosmarium monomazum, Cosmarium granatum, Desmidium sp.*, *Euastrum sp*. and *Mastogloia vasta.*

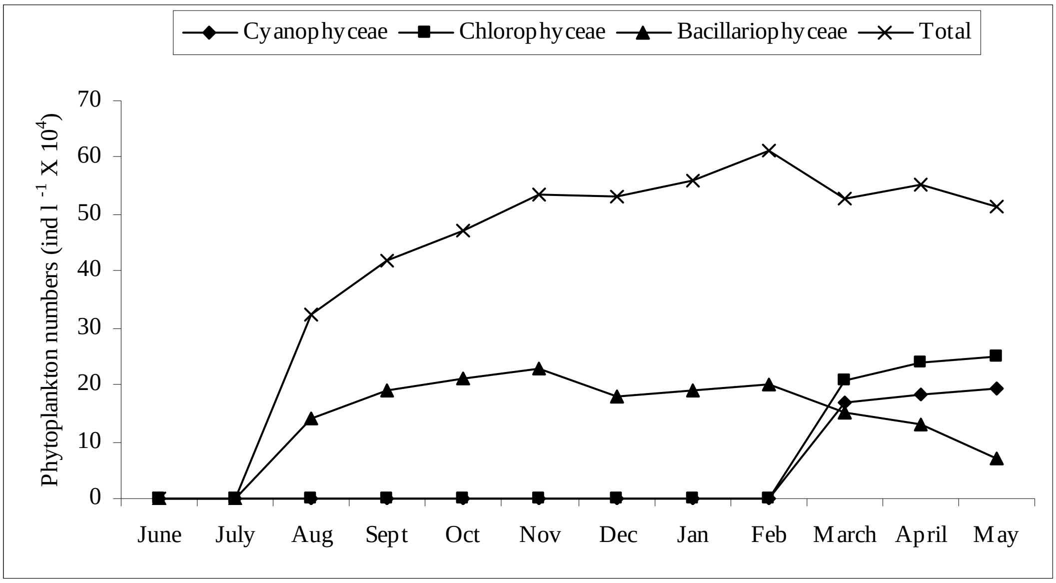
Table 2. *Occurrence of phytoplankton species at both the sites at Kanewal Wetland*

Cyanophyceae	**Chlorophyceae**	**Bacillariophyceae**
Gloeocapsa atrata	*Chlorella* sp.	*Cyclotella* sp.
Gloethece rupestris	*Pediastrum duplex*	*Cymbella* sp.
Chroococcus indicus	*Coelastrum cambricum*	*Gomphonema* sp.
Chroococcus minor	*Scendesmus quadricauda*	*Nitzschia* sp.
Microcystis aeruginosa	*Scendesmus armatus*	*Navicula* sp.
Merismopoedia minima	*Ankistrodesmus falcatus*	*Fragillaria* sp.
M. glauca	*Zygnema inisigne*	*Mastogloia vasta*
M. elegans	*Spirogyra* sp.	*M. elliptica*
M. convulata	*Closterium libleinii*	*Achnanthes* sp.
M. punctata	*Staurastrum orbiculare*	
Arthrospira platensis	*S.* sp.	
Spirulina princeps	*Euastrum spinulosum*	
S. laxissima forma major	*E. gemmatum*	
Oscillatoria limosa	*Cosmarium monomazum*	
O. princeps	*Cosmarium granatum*	
Lyngbya porphyrosiphonis	*Spondylosium moniliforme*	
Anabaena sphaerica	*Desmidium* sp.	
Nostoc muscorum	*Gloeotaenium loitlesbergianum*	

The total density of phytoplankton was found maximum during February month while it was minimal during rainy months (*Fig 4*).

The class Cyanophyceae was represented by 18 species belonging to 11 genera. The members of family Chroococcaceae were among the most abundant in the class. The family was represented by the species of genera *Merismopoedia, Chroococcus, Gleocapsa* and *Gloethece.* Cyanophycean community appeared in greater numbers when phosphate, sulphate and nitrate concentrations of waters were comparatively moderate to higher, during winter and summer months.

The class Chlorophyceae was represented by maximum genera. Among the members, the representatives of family Desmediaceae were the abundant and consisted of genera *Cosmarium, Closterium, Staurastrum, Euastrum, Desmidium and Spondylosium.* Desmediaceae was followed by Zygnemaceae consisting of genera *Zygnema* and *Spirogyra.* The other members of the class were *Scendesmus, Pediasrtrum* and *Ankistrodesmus.* The community of Chlorophyceae was rich during high DO and comparatively low chemical status, especially during winter months.



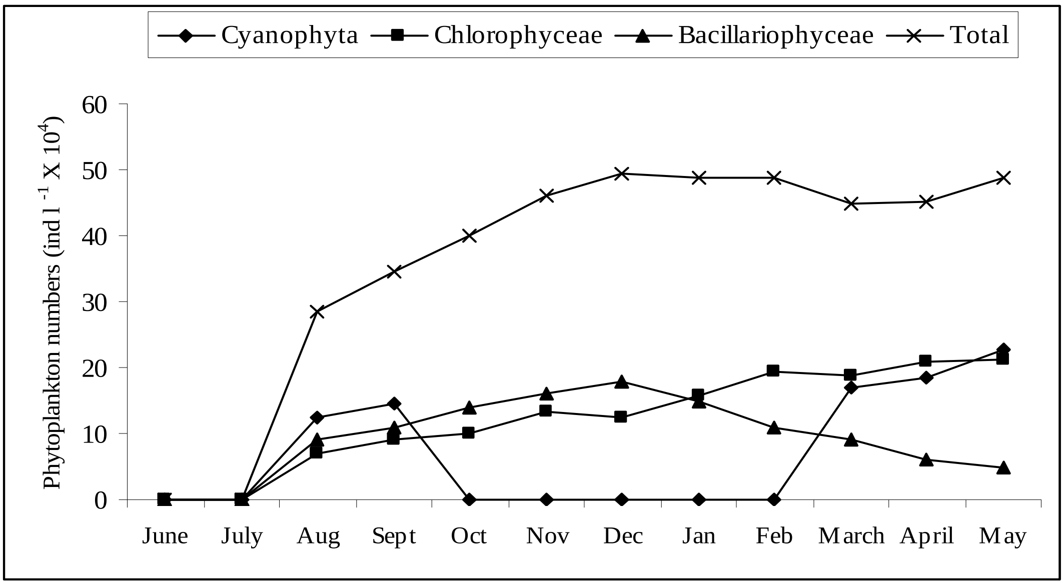


***Figure 4**. Monthly variation in phytoplankton number at Kanewal wetland from June 2007 to May 2008., Site 1 (upper) and Site 2*

The class Bacillariophyceae being the most dominant was represented by the genera, *Fragillaria, Navicula, Achnanthes, Mastogloia, Cyclotella, Cymbella, Gomphonema* and *Nitzschia*. However, except *Navicula* species, most of the members appeared round the year particularly during winter because of high DO and low nutrient condition of waters and their community became smaller as the summer progressed at both the sites. The correlation analysis of the important parameters with the phytoplankton showed a positive correlation with DO, a value of 0.377 at Site 1 and 0.187 at Site 2 (*Table 3*). Sulphate showed a positive correlation with phytoplankton at Site 2 (0.440). Phosphate and nitrate showed a negative correlation at both the sites (-0.127) at Site 1 and (-0.562 at Site 2). Sulphate showed a negative correlation at Site 1 (-0.593). Pearson Product Analysis for phytoplankton showed a high significance of Bacillariophyceae members between both the sites than other two groups.

Table 3. *Correlation Coefficient Analysis of important chemical parameters with total phytoplankton species*

Hydro-chemical Properties	Site 1	Site 2
Phosphate	-0.122	-0.562
Sulphate	-0.594	0.440
Dissolved Oxygen	0.378	0.187
Nitrate	0.703	0.756

Discussion

Diversity of plankton population is fairly dependent on quality of water and climatic factors. Phytoplankton diversity and productivity are strongly related to water quality (e.g., Moss, 1988) as well as to biotic factors (Scheffer, 1998). Singh (1965) stated that temperature, pH, alkalinity and phosphate have been emphasized to be significant factors for controlling distribution of Cyanophyceae which is also corroborated with the present study. Alkalinity range of 50 to 110 mg/L has been reported as optimum for the Cyanophyceae (Jackson 1971) which coincide with current findings where alkalinity is within the range. Tripathy & Panday (1990) Rana and Nirmal Kumar (1993), Hegde and Sujata (1997) and Nirmal Kumar et al. (2005) reported that high water temperature, phosphate, nitrate, low DO and CO_2 supported the growth of Chlorophyceae and Diatoms. Harish (2002) concluded that phosphates, nitrates and nitrites control the growth of Chlorophyceae and Diatoms in lentic waters. Perhaps this could be the reason in the present study, species of Chlorophyceae and Diatoms were found abundant, which was having phosphate, nitrate and high DO concentrations at both sites.

Patrick (1973) observed that the acidic waters do not support an abundance of Bacillariophyceae, while in alkaline waters with pH above 8.0, their density is more. In the current investigation, pH was found to be in the neutral range (7.0 – 8.0) supporting a good population of the diatoms. Zafar (1964) and Singh & Swarup (1979) reported that higher concentrations of calcium promote the growth of diatoms but Harish (2002) pointed out that there is no relationship between abundance of diatoms and calcium. In Kanewal, the Bacillariophyceae were the most dominant and occurred through out the period of study. Moreover, DO content was found to be considerably high in colder months. Reid (1961) stated that the solubility of oxygen in water increased by lowering the temperature, that is, solubility of oxygen in water was known to be affected inversely by the rise in temperature (Moss 1988). Nitrate showed lower values but an increase in its concentration was observed in winter months. This may be attributed to inflow of rain water and partly by decomposition of macrophytes. The plankton community, on which the whole aquatic population depends, is largely influenced by interaction of a number of hydro-chemical factors like low DO, moderate sulphate, nitrate, phosphate and other characters. Moss, (1988) and Rana et al (1995) showed that a number of physico-chemical and biological factors acting simultaneously must be taken into consideration in understanding the diversity of plankton population. The present study ensures that variation in the abundance of plankton can be best explained when environmental factors jointly influence. Thus, it may be concluded that the composition of phytoplankton is dependent on different abiotic factors either directly or indirectly.

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COMPARING OF MESOPHILIC AND THERMOPHILIC ANAEROBIC FERMENTED SEWAGE SLUDGE BASED ON CHEMICAL AND BIOCHEMICAL TESTS

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Abstract. In the course of anaerobic sludge treatment (digestion) biogas can be acquired from the sludge, its use for energetic purposes has a determinative significance in a wastewater treatment plant. The biogas, produced in the course of decomposition, covers – among others – a considerable portion of the heat- and electric energy consumption in a wastewater treatment plant, thus an increase of the biogas volume is an outstanding task. It is possible to increase the biogas volume if the anaerobic digestion processes are thoroughly well known. The anaerobic digestion process is determined by temperature, substrate composition, loading, and also by toxic substances that might be present. In our experimental work the thermophilic and mesophilic full scale anaerobic bioreactors of a communal sewage treatment plant were tested by applying usual control parameters and enzyme activity tests.
Keywords: *anaerobic fermentation, thermophilic, mesophilic, biogas*

Introduction

Biogas with methane may be produced during the anaerobic fermentation process of the sewage sludge. Usage of the biogas can be really importanat in the electric power supply of the wastewater treatment plant. Biogas derived from the fermentation can cover the greatest part of the power and electric needs of the plant thatswhy one of the most important tasks is to increase its volume. Biogas is a renewable and sustainable energy source. Biogas can be produced from solid and liquid wastes (for example: sewage sludge, agricultural or food industrial wastes). Biogas will act the part of renewable energy sources in the world. India has the second largest biogas and improved stove programme in the world (Raghuvanshi et al., 2008). For growing the biogas volume we have to understand more detailed the anaerobic fermentation process, which is determined by temperature, substrate composition, load, and toxic materials which might be presented (Schroeder, 1977; Malina and Pohland, 1992). In our study we compared anaerobic fermentation made on thermophilic and mesophilic temperatures on full scale anaerobic bioreactor by applying usual control parameters (pH, volatile acid content, alkalinity, gas composition) and by enzyme activity (dehydrogenase, protease, lipase) tests.

Investigation of the methane gas production depended on temperature has been existing for a long time. Methane gas production starts above 0°C (phsichrofil range: 0-25°C) then with the increasing temperature gas volume is growing. Temperature's role in the anaerobic decomposition has been investigated by many authors (Fair and Moore, 1934; Goulecke, 1958; Hills and Schroeder, 1969) who suggested the mesophilic range (35-40°C) for optimal methane producing temperature, and reported drastic decrease in gas production above 42°C (Fair and Moore, 1934; Hills and Schroeder, 1969). Nowadays it is known that there are two optimal temperature intervals (Malina and Pohland, 1992). The optimal temperature of the mesophilic range is about 55°C. Based on economical considerations the mesophilic (at about 35°C) and the thermophilic (at about 55°C) decomposition have spreaded in everyday practice. Mesophilic range is: 25-45°C while thermophilic is: 45-60°C. Malina and Pohland (1992) reported drastic gas production decreasing above 60°C and ceasing above 70°C. Kardos et al. (2009) had the same results in their investigation made in pilot plant scale. The mesophilic fermentation is still in the first place in the sludge treatment however the thermophilic fermentation proccesses higher decomposition efficiency, thatswhy bigger gas volume, and shorter hydraulic retention time. Comparison of the mesophilic and thermophilic fermentations can be seen in the *Table 1*. *Table 2* contains their advantages and the *Table 3* includes their disadvantages. The tables (*Table 1, Table 2, Table 3)* were set up from results of many experiments made in pilot and full plant scales by many authors (Ahring, 1994; Aitken et al., 1992; Garber, 1982; Iranpour et al., 2002; Moen et al., 2003; Nielsen, 1999; Nielsen et al., 2001; Rimkus et al., 1982; Zábránská et al., 2000a, 2000b, 2002).

Table 1. *Comparison of mesophilic and thermophilic fermentation based on operating and controlling parameters*

Parameter	**Mesophilic system**	**Thermophilic system**
Optimal temperature (°C)	35-40	55-60
pH	7.2-8.0	7.2-8.5
Temperature's fluctuation tolerated by the system (°C)	3-5	1-2
Hydraulic retention time (d)	15-25	3-10
Max. COD reduction (%)	65-85	85-95
Max. BOD_5 reduction (%)	60-80	80-90
Max. organic material reduction (%)	45-55	55-70
Biogas production (Nm^3/1000kg dry organic material)	920-980	950-1000
Methane gas content of the biogas (%)	60-70	70-85
Volatile acid (mg CH_3COOH/dm^3)	1500-2500	3000-4000
Alkalinity (mg $CaCO_3/dm^3$)	4000-6000	3000-5000

Explanation: COD: chemical oxygen demand; BOD_5: five days biochemical oxygen demand

To see the *Table 1* it is remarkable that the results of enzyme activity measurements are missing. Application of the results of the enzyme activity investigations can be usefull in the plant control process, because hidrolysis processes – as the first steps of the anaerobic digestion and beeing also fermenetation's speed determining – can be described by them (Thiel and Hattingh, 1967).

Table 2. *Advantages of the mesophilic and thermphilic systems*

Mesophilic system (related to the unstabilised sludge)	**Thermophilic system (related to the mesophilic system)**
during the biogas production organic material is stabilising; fermented sludge can be applied as dung	increased gas output due to the faster reaction; higher methane gas content and reduces hydrogen-sulfid content in the biogas
sludge's quantity reducing	staying-duration shorter
sludge's fertilisation ability reducing	smaller reactor volume demand
sludge's water downtake capacity getting better	more patogen's distruction
	sludge's dehydratation getting better
	reduced foam formation in the reactor

Table 3. *Disadvantages of the mesophilic and thermophilic systems*

Mesophilic system (related to the unstabilised sludge)	**Thermophilic system (related to the mesophilic system)**
due to the longer staying duration - larger reactor volume demand, higher investment's costs	higher heater energy demand
sludgewater's quality getting worse	sludgewater's quality getting worse
fermentation blocking influence of heavy metals	sensitivity to the sudden temperature fluctuation, more precise temperature regulation demand
	sensitivity to the toxic heavy metals

In spite of some disadvantages of the thermophilic system, it is more favourable than the mesophilic one, because of its larger gas output capacity and higher methane gas content. Neverthless the mesophilic systems have been usual in the fermentation process. An anaerobic digestion process consists of several sub-processes. According to Lawrance and McCarty (1969) and Malina and Pohland (1992) in an anaerobic digestion process also three steps are existing: hydrolysis, acid production, methane production. However essentially only two phases the acidic and methane phases must be dealt with, as the process of hydrolysis is also carried out by the acid producing bacteria. In the course of the hydrolysis – due to the effect of the extracellular enzymes of acid producing bacteria – the large moleculas in the solid sludge are decomposed into symple carbohydrates, amino acids and fatty acids. Thus this step and its rate has a deterministic role in the process of the methane production. The substrate's degradation can be described by the hydrolytic enzym activity, as the decomposition speed depends on that (Thiel et al., 1968).

For describing anaerobic processes the use of several methods has been tested. Chung and Neethling (1988) suggested to determine the concentration of ATP (adenosine-5-thriphospate) since its concentration and the rate of gas production are in close relationship with each other and these two parameters property describe the activity of an anaerobic system. In certain cases the measurements of hydrogen can adequately describe the equilibrium of the methane producing phase (Mosey and Fernandez, 1988). However following hydrogen usage is only one way to control methane production, thus is not really typical of the total methane production process. For controlling the operation of anaerobic fermenters, the use of hydrolytic enzyme activity tests were already proposed by Thiel and Hattingh in their article published in 1967.

Since than more authors (Goel et al., 1998; Li and Chróst, 2006) tried to follow the enzyme activity processes by measurements but for daily control this applications have not become part of the control parameters, only the usual control parameters (pH, volatile acid content, alkalinity, gas composition) are used in the practise. From the plant operation point of view it is very important to control and to intervene the anaerobic fermentation process in every cases, if it is needed.

In the following we describe our investigations made in full scale plant with the usually applied parameters (pH, volatile acid content, alkalinity, gas volume, gas composition) and biochemical parameters (dehydrogenase, protease, lipase) based on our former pilot plant investigations (Kardos et al., 2009).

Materials and methods

The investigations was carried out at a communal sewage treatments plant in Budapest (Budapest Sewage Works Ltd., South-Pest Wastewater Treatment Plant). In our work we investigated the usually applied control parameters and the relation of enzyme activity and gas output in mesophilic and thermophilic towers.

At the sewage treatment plant there are three mesophilic anaerobic fermenters (2600m^3 each) and one thermophilic anaerobic reactor of 2000m^3. From both of them, one was investigated. The most important operating parameters of 50 days investigations can be seen in the *Table 4*.

Table 4. *The average daily values of the operating parameters over the experimental period (n=50)*

Parameters	Mesophilic system	Thermophilic sytem
Temperature (°C)	35.6±0.6	54.6±0.5
Specific organic material load (kg/m^3 * d)	3.24±0.74	2.10±0.76
Hydraulic retention time (d)	16.45±1.25	5.65±0.45

In our work the control parameters were investigated, such as total volatile fatty acid, alkalinity, gas composition, pH, dry and organic material content of the sludge. These parameters were measured on the basis of the requirements given in the Standard Methods. Gas composition of the biogas was determined according to the Hungarian Standard (MSZ5313-57) based on the absorbancy of the gas components and also on burning methane. The produced gas quantity was measured by gas volume registrating system.

For the enzyme activity measurements has not existed international standard, so the determination of the measurements method is published in this work. Before their application, receipt's adaptation investigations on anaerobic sewage sludge samples were made based on former scientific literature's data.

Dehydrogenase enzyme activity

The dehydrogenase activity was measured on the basis of García et al. (1993), Skujins (1976), Griebe et al. (1997) and the Hungarian Standard No. (MSZ-08-1721/3-86). Satureted $NaHCO_3$ as a buffer, and 2,3,5-triphenyltetrazolium chloride (TTC) as a substrate were added to the digested sewage sludge sample. Then for one hour the samples were stopped by ethanol. After filtering, the solution's absorbancy-applying ethanol as blank was measured at 485nm. The obtained absorbancies were evaluated using calibrations. The calibration series contained triphenyl-phormazane (TP) in known concantration as – due to the result of the process catalyzed by the enzyme – TTC transforms its quantity could be measured by spectrophotometry. The activity is expressed in triphenyl-phormazane mass produced by a unit weight of dry organic sludge per hour.

Protease enzyme activity

The protease activity measurement was carried out on the basis of Thiel and Hattingh's method (1967). In these test series casein solution was used as a substrate. Each sample contained 1/3 part sludge sample, 1/3 part substrate and 1/3 part distilled water. After incubation at room temperature for 1 hour the reaction was stopped by trichloroacetic acid. After alkalization, which followed filtering-due to the separated iron precipitate- it was refiltered and adding diluted Folin-reagent the appearing blue clolour was measured at 660nm. As a blank, anaerobic sludge treated in the above rations without incubation was used, immediately after its treatment with trichloroacetic acid. The measured data were evaluated by L-tyrosine calibration. The activity is expressed in tyrosine quantity produced during one hour by a unit mass of dry organic sludge.

Lipase enzyme activity

Lipase enzyme activity was measured according to Vorderwülbecke et al. (1992) and Li and Chróst (2006). For carrying out these tests the emulsion of two reagent solutions (containing 4-nitrophenyl palmitate-NPP-as substrate) had to be prepared then its predetermined portion was added into the supernatant of the centrifuged sludge. The incubation time was one hour at 45°C, light absorption of the sample was then measured by spectrophotometer. The activity is expressed in 4-nitrophenol (NP) mass produced by 1 g of dry organic sludge per hour.

Results

To see the *Table 5* it can be said that in the thermophilic system – as a result of the higher utilisation of the organic materials – the specific gas production is higher which is according with former published results. Methane content of the biogas increased with 9.4% (mesophilic avarage: 54.2±3.9%, thermophilic avarage: 59.3±2.3%).

Neither of the investigated systems showed significant pH variation, its value was in reasonable interval in both of cases. Average pH value in the thermophilic system was about the minimum level (7.2±0.5) of the optimal range. It can be said that the pH itself is not an adequate parameter for following the processes. Volatile acid's content changed according to the pH and its value is higher by the thermophilic fermentation (3709±793 $mgCH_3COOH/dm^3$), at the same time bacterial utilization of volatile acid is also higher which can be confirmed by the larger gas output and methane content. In the relation of the above mentioned aspect the alkalinity value – as the buffer capacity of the system – was higher in the mesophilic system (average: 5982±951 $mgCaCO_3/dm^3$).

Table 5. *Variation of control parameters and enzyme activities data in the full scale plant in mesophilic and thermophilic process over 50 days investigation period*

Parameters	Mesophilic system		Thermophilic system	
	Average	RSD (%)	Average	RSD (%)
Specific gas quantity (Nm^3/1000kg organic material)	965	10.8	990	10.9
Methane content of the biogas (%)	54.2	7.1	59.3	4.0
pH	7.8	3.7	7.2	6.3
Alkalinity ($mgCaCO_3/dm^3$)	5982	15	4658	25
Volatile acid ($mgCH_3COOH/dm^3$)	2077	17	3709	21
Dehydrogenase (mg TP/g org.m.*h)	19.5	17.8	29.4	23.4
Protease (mg tyrosine/g org.m.*h)	119.7	25.4	154.6	19.8
Lipase (mg NP/g org.m.*h)	224.5	40.5	294.2	30.2

Nm^3 = normal m^3 (in normal state: 273,15 K, 0,1 MPa), TP = triphenyl-phormazane, NP = 4-nitrophenol, org.m. = organic material

All of the three enzyme activity's values were higher in the thermophilic fermentation than in the mesophilic one – due to the more intensive bacteria's activity – which were indicated also by the larger gas output. Dehydrogenase activities as indicator of total biomass activities in the two different anaerobic systems is shown in the *Fig. 1*; the substrate specific protease activities can be seen in the *Fig. 2* and the lipase activities is in the *Fig. 3*. The average values of the 50 days investigations are described in the *Table 5*. Based on the figures it can be said that the enzyme activity of the thermophilic system is higher than the mesophilic one in each case.

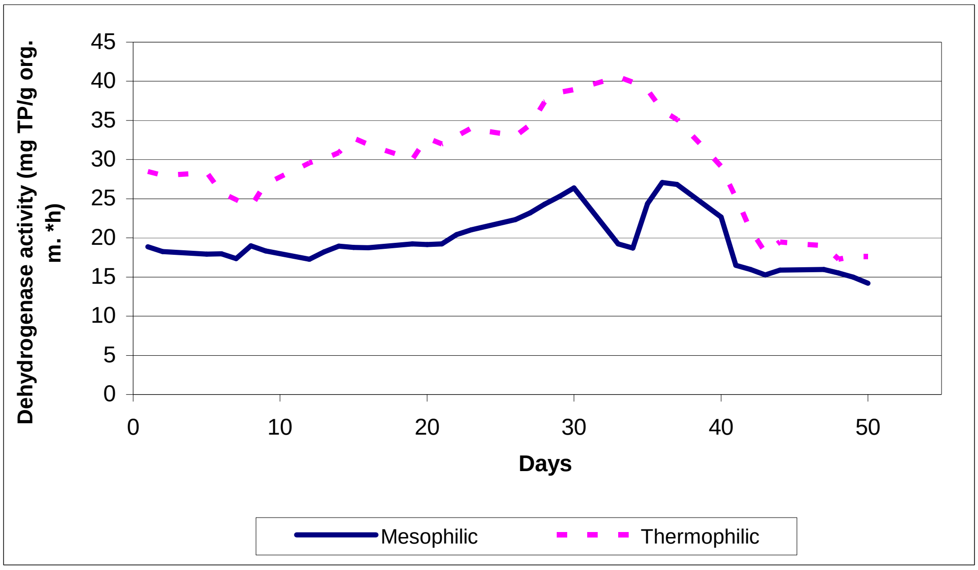

Figure 1. *Variation of dehydrogenase activities in thermophilic and mesophilic systems (TP = triphenyl-phormazane, org.m. = organic material)*

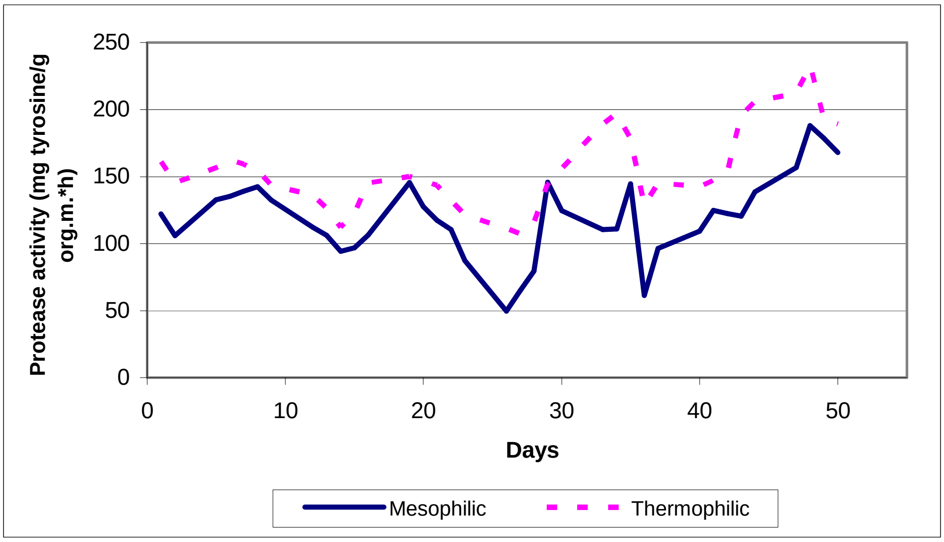

Figure 2. *Variation of protease activities in thermophilic and mesophilic systems (org.m. = organic material)*

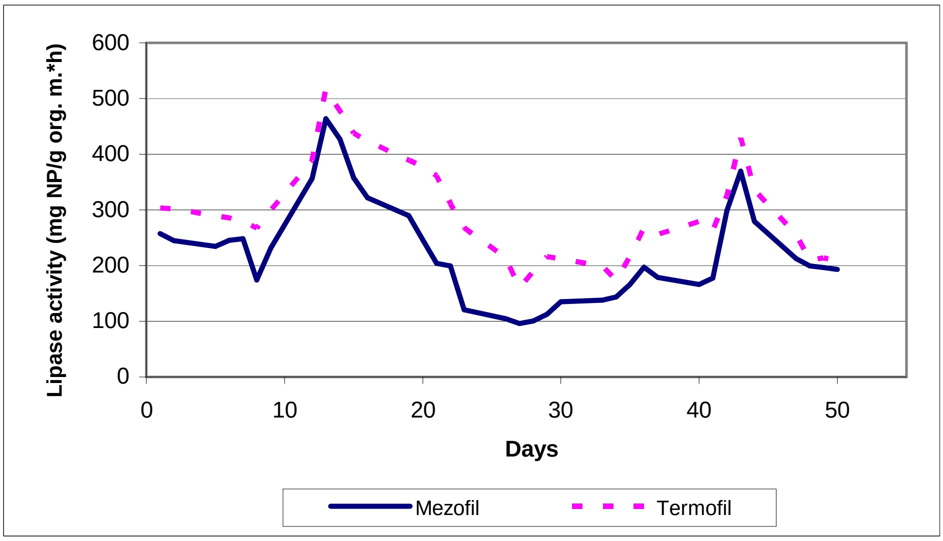

Figure 3. *Variation of lipase activities in thermophilic and mesophilic systems (NP = 4-nitrophenol, org.m. = organic material)*

Summary

Based on the 50 days investigations made in full scale plant anaerobic fermenters at mesophilic and thermophilic temperature, it can be said that the specific gas output of the thermophilic system is higher. Methane gas content – as indicator of the heater capacity – in the biogas increased from 54.2±3.9% to a value of 59.3±2.3, this means 9.4% average growing. The average quantity of daily methane production increased from 523 Nm^3/1000kg dry organic material to 587 Nm^3/1000kg dry organic material which means 12.3 % rising (64.5 Nm^3 methane). This important fact compensates that larger heat demand and smooth temperature’s regulation are needed in the thermophilic fermenters. In this system the 1-2°C sudden temperature changes can cause operating trouble. Among the usually applied control parameters, pH has not shown significant variation in the two investigated systems, its value has stayed in the optimal interval thatswhy pH, itself can not be adequate control parameter. The average values of the alkalinity in the mesophilic system was higher comparing to that at thermophilic temperature was observed, despite of it the system's buffer capacity was provided suitable by that. The system's buffer capacity is determined by the alkalinity which has crucial role in the safe plant operation. Increased volatile acid concentration and utilization were measured in the thermophilic system than those at mesophilic temperature and it is also confirmed by the larger specific gas production data. Thermophilic system proccesses higher enzyme activities than the mesophilic one. All of the three investigated biochemical parameters (dehydrogenase determining the total biomass activities, and the substrate specific protease and lipase) values were higher at thermophilic temperature. The biochemical activity parameters are proposed to apply for control the anaerobic digestion balance, as the first speed determining steps of the fermentation can be described by them. The advantage is that simplified enzyme activity tests require relatively short time and low investment costs also in low level equipped laboratories.

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LIGHT TRAPPING OF THE TURNIP MOTH (*AGROTIS SEGETUM* DEN. ET SCHIFF.) DEPENDING ON THE GEOMAGNETISM AND MOON PHASES

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Abstract: The study deals with the change of light-trap catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.), in connection with the horizontal component of geomagnetic field and the moon phases. The numbers of specimens caught by generation relative catch values were calculated. These hourly relative catch data were assigned to the hourly values of horizontal component of geomagnetic field. They were separated by the moonlit and moonless hours of the four quarter of the Moon (New Moon, First Quarter, Full Moon and Last Quarter) were classified. We correlated the hourly catch results pertaining to the hourly values of both the horizontal component and moonlit or moonless hours of four moon quarters. After that we made correlation calculations to demonstrate the assumed connection. Our calculations have shown that in the period of the New Moon when there is no measurable moonlight, the higher values of the horizontal component are accompanied by a falling relative catch. In the other moon phases, i.e. in the First Quarter, Full Moon and the Last Quarter, growing values of the horizontal component are accompanied by an increasing catch in both the moonlit and moonless hours.
Keywords: *geomagnetic field, lunar month, insects*

Introduction

It has been known for decades that the insects detect the geomagnetic field, and even can use it as a three-dimensional orientation. It is also known for decades that the spatial orientation of the insect is able to use the Moon. We investigated, therefore, that the effectiveness of light-trap catch of insects changes to the combined effect of the horizontal component of the geomagnetic field strength and the moon phases?

A number of laboratory experiments and comprehensive studies are devoted to the physiological bases of perception and the ways of orientation (Wehner and Lobhart, 1970; Kirschvink, l983; Wehner, 1984 and 1992; Jahn, 1986). Becker (1964) has found that certain species of termites (Isotermes), beetles (Coleoptera), flies (Diptera), orthopteroids (Orthoptera) and membrane-winged insects (Hymenoptera) are guided in their orientation by the natural magnetic field. Mletzko (1969) carried out his experiments with specimens of ground beetles (*Broscus cephalotes* L., *Carabus nemoralis* Mull. and *Pterostichus vulgaris* L.) on a 100 square meter asphalt coated area in the Moscow botanical garden. He placed the insects in the middle of the area and followed their movement with a compass. After some uncertainty, the insects flew in a given direction with an accuracy of ±5° at daylight and ± 60° at night. The author assumes that orientation is guided by geomagnetism. Iso-Ivari and Koponen (1976) studied the impact of geomagnetism on light trapping in the northernmost part of Finland. In their experiments they used the K index values measured in every three hours, as well as the ΣK and the δH values. A weak but significant correlation was found between the geomagnetic parameters and the number of specimens of the various orders of insects caught. Studying the few Willow Ermine (Y*ponomeuta rorella* Hbn.), Pristavko and Karasov (1970) revealed a correlation between the C and ΣK values and the number of individuals caught. In a later study (Pristavko and Karasov, 1981) they also established that at the time of magnetic storms ΣK has a greater influence on the flying activity of the above species. The influence is also significant in years when ΣK is not higher than 16-26. Equally interesting is the observation that if ΣK $\leq$ 26, flying activity intensifies the same day, if ΣK = 27-30, this happens the following day and if ΣK = 33-41, intensification follows only on the second or third day. Studying the termite species *Heterotermes indicola* Wasmann, Becker and Gerisch (1977) found a stronger correlation between this activity and the vertical component of geomagnetism (Z) than with the values of the K index. Tshernyshev and his colleagues have discussed in a series of studies the results of their laboratory and light trapping experiments with species of different orders of insects to reveal a connection between geomagnetism and certain life phenomena. Tshernyshev (1966) found that the number of light-trapped beetles and bugs rose many times over at the time of geomagnetic storms in Turkmenia. He found a high positive correlation between the horizontal component and the number of trapped insects. In laboratory conditions, Tshernyshev and Danilevsky (1966) could not reveal the influence of an alternating magnetic field on the activity of flies at low temperature (22°C), but observed a significant rise at 29°C. Tshernyshev (1968) studied the changes in the biological rhythm of the *Trogoderma glabrum* Herbst. as a function of the perturbations of the magnetic field. His assessment was based upon the K-index values over 4, i.e. over 40γ measures at 6 and 9 p.m. as well as at 3 a.m. It was proved that the biological rhythm of the species observed was influenced by factors that coincided with perturbations of the magnetic field. It was also observed by Tshernyshev (1965) that the number of light-trapped insects significantly rose at the time of magnetic perturbations. Later, however, he reported that while light-trap catches of some Coloptera and Lepidopera species increased, that of other Lepidoptera and Diptera species fell back during magnetic perturbations (Tshernyshev, 1971 and 1972). Tshernyshev and Afonina (1971) also observed that the activity of certain moths and beetles increased, but in some cases fell back under the influence of a weak and changing magnetic field induced in laboratory conditions. Based on international literature and his own results, Tshernyshev (1989) published a comprehensive study to give a summary of the latest state of knowledge on the relation between geomagnetism and the activity of insects. Tshernyshev and Dantharnarayana (1998) used an infrared actograph to study in laboratory conditions the activity of (*Helicoverpa armigera* Hbn.), Native Budworm (*Helicoverpa punctigera* Wallengren) and (*Heliothis rubescens* Walker). Examining the influence of the geomagnetic K index also in the context of the four typical lunar quarters (First Quarter, Full Moon, Last Quarter and new Moon), a significant negative correlation was found in the Last Quarter and a positive correlation in the other three. Moths are also disturbed by geomagnetic perturbations. 30 hours after perturbations the influence was still felt.

Examinations over the last decade**s** have also confirmed that some Lepidoptera species, such as *Noctua pronuba* L. (Baker and Mather, 1982) and *Agrotis exclamationis* L (Baker, 1987) are guided by both the Moon and geomagnetism in their orientation, and they are even capable of integrating these two sources of information. On cloudy nights, the imagos of *Noctua pronuba* L. orientated with the help of geomagnetism. In this case, too, their preference lay with the direction they had chosen when getting their orientation by the Moon and the stars. Using hourly data from the material of the Kecskemét frationating light-trap, we have examined the light trapping of Turnip Moth (*Agrotis segetum* Den. et Schiff.), Heart-and-Dart (*Agrotis exclamationis* L.) and Fall Webworm Moth (*Hypantria cunea* Drury) in relationship with the horizontal component of the geomagnetic field strength (Kiss et al., 1981; Nowinszky and Tóth, 1983).

According to the authors of recent publications (Srygley and Oliveira, 2001; Gillet and Gardner, 2009; Samia et al., 2010) the orientation/navigation of moths at night may becomes not by the Moon or other celestial light sources, but many other phenomena such as geomagnetism.

The average field strength of the Earth as a magnetic dipole is 33,000γ. (1γ = 10^{-5} Gauss = 10^{-9} Tesla = 1 nanotesla (nT)). Geophysical literature uses γ as a unit. Geomagnetic field strength can be divided into three components: H = horizontal, Z = vertical and D = declination components. The magnetic and geographic poles of the Earth do not coincide, therefore in addition of geographic; there are also geomagnetic co-ordinates of latitude and longitude. The latter characterize the geomagnetic conditions of a given geographical location. Geomagnetic parameters greatly differ in any given moment of time at the various points of the surface of the Earth. A distance of approximately 300 kms along the geomagnetic meridian may produce significantly different characteristics. So in Hungary, geomagnetic data registered at a single post of observation will provide sufficient information for the entire territory of the country. These measurements are made at the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences at Nagycenk, near Sopron and the Observatory of the Hungarian Loránd Eötvös Geophysical Institute at Tihany.

Material and methods

The yearbooks of the latter supplied us with the data we needed in our research, namely, those of the horizontal (H) component of the geomagnetic field strength. The yearbooks include values of the horizontal component over 21 500 nT over 41 800 nT. Since the values of the horizontal components of the geomagnetic field strength showed great differences in the years examined, we could work with values over 21 250 nT respectively, when processing our light trapping data.

For the purposes of our examination we had at our disposal three years of catch data pertaining to Turnip Moth (*Agrotis segetum* Den. et Schiff.) from the material of the Kecskemét fractionating light-trap. From the number of specimens caught we calculated relative catch values (RC) by generations. We had stated before in our earlier work (Kiss et al., 1981; Tóth and Nowinszky, 1994) that the impact of geomagnetism on light-trap catches should not be studied without consideration to the prevalent illumination conditions. Therefore we divided our relative catch data to those gained in or in the absence of moonlight and within these two classes established sub-categories according to the Moon phase angle around the four Moon quarters in the following way: In the swarming period of the various species, we calculated the value of the Moon phase angle for the 24^{th} hour (UT) of each night. Then we formed 30 groups of phase angles of the 360 phase angle values of the complete lunar month. The group containing the phase angle values found in the vicinity of a Full Moon (0°, or 360°) $\pm$ 6° is marked: 0. Proceeding from here through the First Quarter in the direction of the new Moon, the groups are marked as: -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. From the Full Moon through the final quarter in the direction of the new Moon the groups are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The group of phases containing the new Moon is

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marked: ± 15. Each group contains 12-phase angle value. The four typical Moon quarters contain the following phase angle groups: Full Moon (-2 - +2), final quarter (3 -9), new Moon (10 - -10) and First Quarter (-9 - -3).

The numbers of specimens caught by generation relative catch values were calculated. These hourly relative catch data were assigned to the hourly values of horizontal component of geomagnetic field. They were separated by the moonlit and moonless hours of the four quarter of the Moon (New Moon, First Quarter, Full Moon and Last Quarter) were classified.

We correlated the hourly catch results pertaining to the hourly values of both the horizontal component and moonlit or moonless hours of four moon quarters. After that we made correlation calculations to demonstrate the assumed connection.

Results and discussion

The relative catch values of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) connected to the values of the horizontal component in moonlit and moonless hours of four quarters of the Moon can be seen in *Fig. 1*, *Fig. 2* and *Fig. 3.*

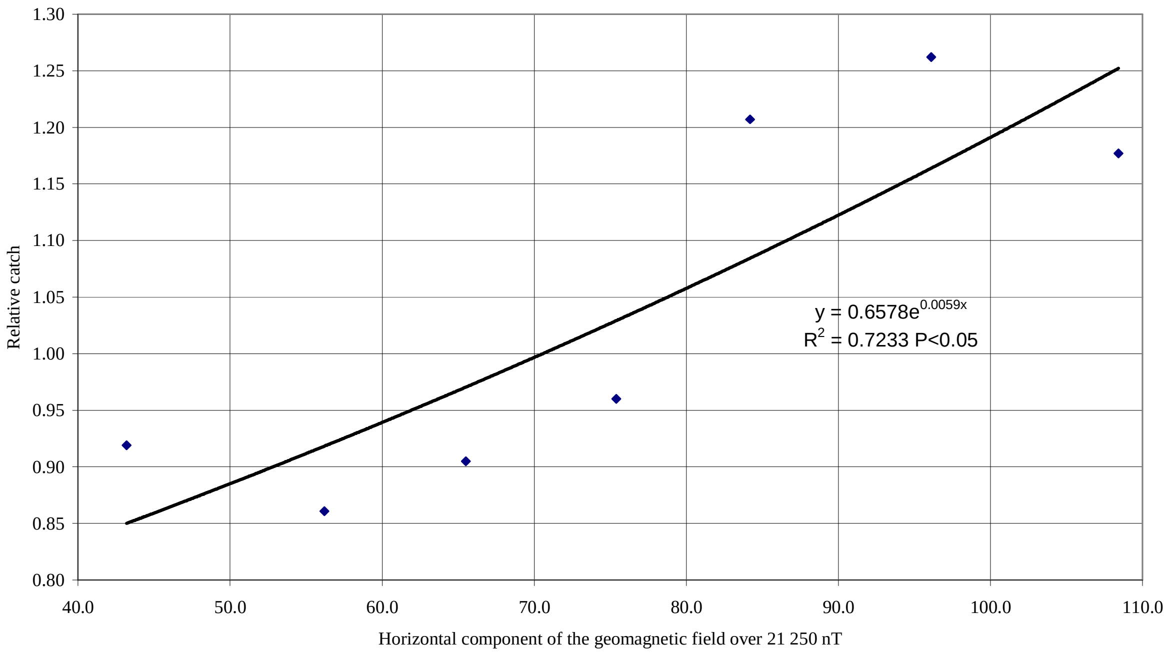

Figure 1. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) in moonlit hours of First- and Last Quarers and Full Moon in connection with the horizontal component of the geomagnetic field over 21 250 nT*

Our calculations with data of the horizontal component supplied by the material of the Kecskemét fractionating light-trap have shown that in the period of the new Moon when there is no measurable moonlight, the higher values of the horizontal component are accompanied by a falling relative catch. In the other Moon phases, i.e. in the First Quarter, Full Moon and the final quarter, growing values of the horizontal component are accompanied by an increasing catch in both the moonlit hour and those without moonlight. So it appears that in the period of lunation in which the presence of the Moon provides insects with orientation information at some time of the night, orientation is guided primarily by light stimulus even if the Moon is not over the horizon. Growth of the geomagnetic field strength may generate an intensification of the flying activity of insects, yet, with the role of the light stimulus being of prime importance in orientation, collecting is even more effective. On the other hand, in the vicinity of the new Moon when at no time of the night can insects base their orientation on the Moon, it is presumable that intensifying geomagnetic field strength that increases the security of the orientation of insects will, as against light stimuli, receive an increasingly important role in the process of orientation.

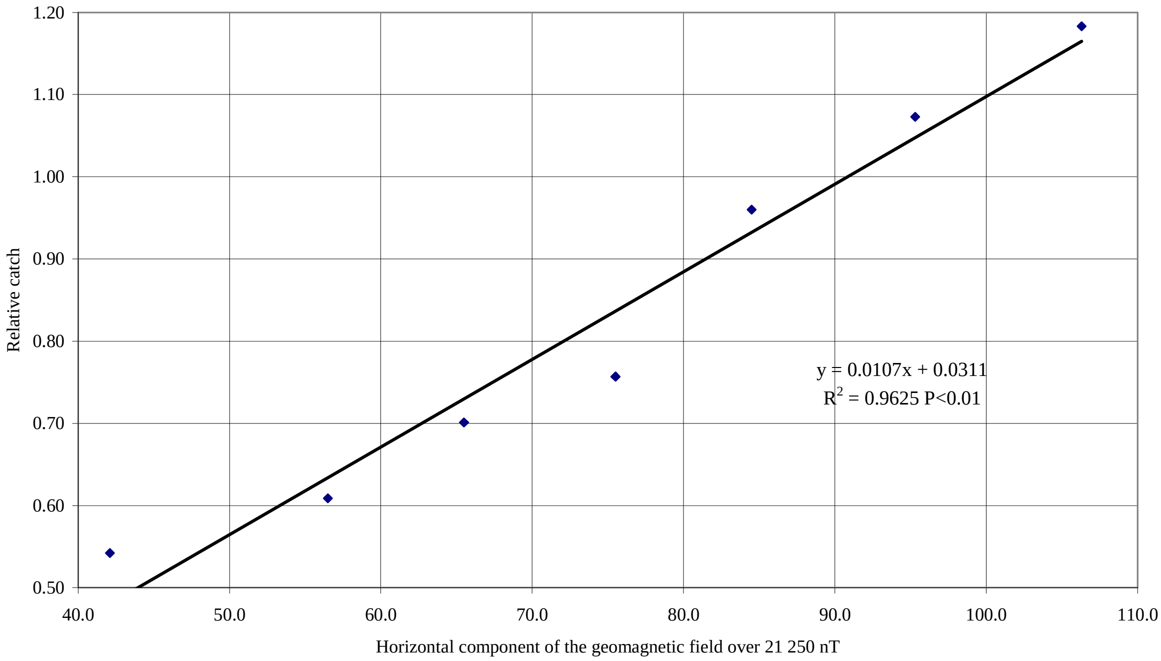

Figure 2. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) in moonless hours of First- and Last Quarers and Full Moon in connection with the horizontal component of the geomagnetic field over 21 250 nT*

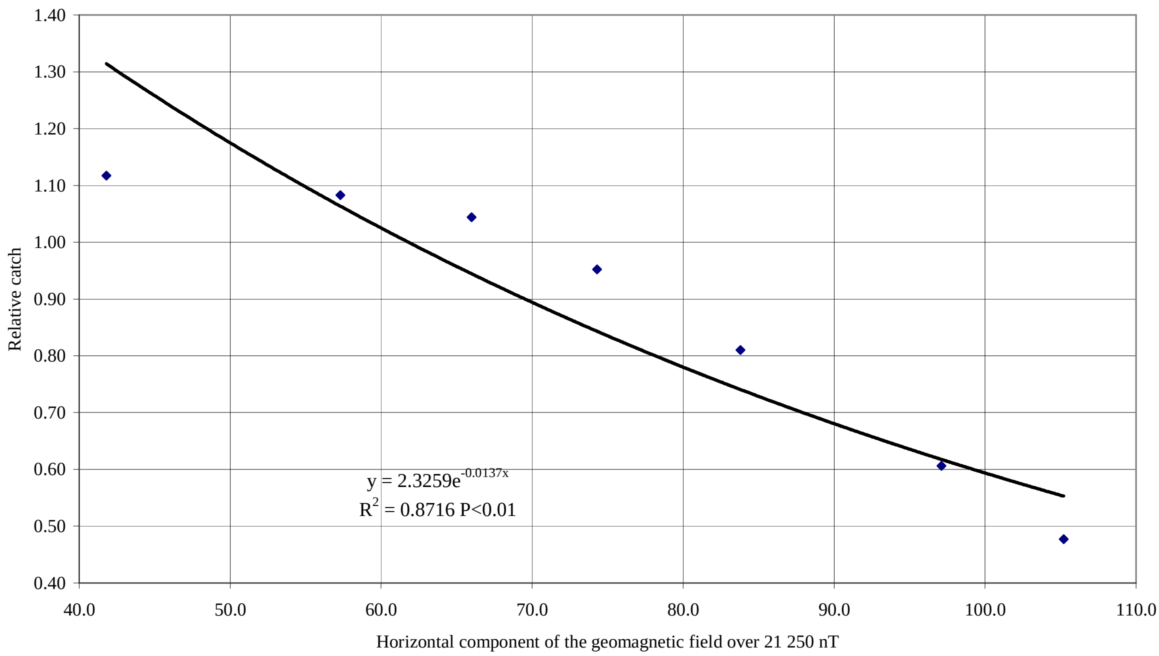

Figure 3. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) in moonless hours of the New Moon in connection with the horizontal component of the geomagnetic field over 21 250 nT*

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