Károly Penksza, Judit Házi, Szilárd Szentes & Barnabás Wichmann

Long-term changes of natural pannonic grasslands in the Balaton Uplands National Park (Hungary)

Abstract

Phytosociological samples were collected in the Balaton Uplands National Park (Hungary) dominated by grassland habitats. Samples in the Tihany Peninsula were taken in a pasture of Hungarian Grey Cattle in the years of 1994, 2002, 2006, 2007 and 2008. Until 2000, the area was under intensive agricultural usage as meadow, after which it was converted to grey cattle pasture. The drinking area was considered separately to the rest of the grazing area. In addition, a facing slope with similar location was included in the study, which is under continous mowing management by the National Park. On each sample area, ten 2x2 m coenological relevés were surveyed (values of estimated plant coverage in percentages). Regarding species composition and cover values, the drinking area appeared to be different from all the other areas examined, since coverage value was small and number and coverage of species was dominated by weeds. Vegetation, species composition and coverage values of the areas used as hay meadows in 1994 and of those that are still mown by Balaton National Park Directorate (hereinafter BfNPI) showed similar values according our measurements were highly similar. The changes in grassland vegetation have been recorded since 1994. Results showed that the stock kept for conservation purposes – a bull, 5 cows and five calves – is sufficient to maintain this grassland. Instead of broad-leaved grass species such as the tall fescue (*Festuca arundinacea*), narrow-leaved *Festuca* species with xeromorphic characters were dominant, since these are better adapted to drier conditions. Changes in vegetation of the grassland are associated with climate changes – especially the occurred rainfall changes.

Langzeit-Veränderungen natürlicher pannonischer Grasländer im Nationalpark Balaton-Oberland (Ungarn)

Zusammenfassung

Pflanzensoziologische Aufnahmen wurden im Nationalpark Balaton-Oberland (Ungarn), einem hauptsächlich von Grasländern dominierten Gebiet, gemacht. Die Aufnahmeflächen auf der Tihany Halbinsel befanden sich auf einer von Ungarischem Grauvieh beweideten Weide und wurden in den Jahren 1994, 2002, 2007 und 2008 aufgenommen. Bis zum Jahr 2000 wurde das Gebiet intensiv als Wiese genutzt, danach wurde es in eine Grauvieh-Weide umgewandelt. Der Tränkenbereich innerhalb der Weide wurde separat aufgenommen. Ein gegenüberliegender Hang im gleichen Gebiet, der vom Nationalpark durch regelmäßige Mahd bewirtschaftet wird, wurde zusätzlich in die Studie aufgenommen. Auf jeder Fläche wurden zehn 2 x 2 m große Vegetationsaufnahmen durchgeführt (geschätzter Deckungsgrad in Prozent). Bezüglich Artenzusammensetzung und Deckung wurden Unterschiede zwischen dem Tränkenbereich und den anderen Aufnahmeflächen festgestellt. Die Deckungsgrade waren hier sehr niedrig, und die Anzahl und die Deckung der Arten wurden von Unkrautarten dominiert. Vegetation, Artenzusammensetzung und Deckung der Gebiete, die bis 1994 als Heuwiesen genutzt wurden und die bis heute von der Nationalparkleitung (BfNPI) gemäht werden, zeigten ähnliche Werte. Die Änderungen in der Graslandvegetation sind seit 1994 erfasst worden. Die Ergebnisse zeigen, dass die Tiere, die für Pflegemaßnahmen gehalten wurden (ein Bulle, fünf Kühe und fünf Kälber), ausreichend sind, um die Fläche zu erhalten. Anstelle von breitblättrigen Grasarten wie dem Rohr-Schwingel (*Festuca arundinacea*), dominierten schmalblättrige *Festuca*-Arten mit xeromorphem Charakter, da diese an Trockenheit besser angepasst sind. Veränderungen in der Graslandvegetation sind mit Klimaveränderungen – insbesondere mit Niederschlagsänderungen – assoziiert.

1 Introduction

In the Pannonian region, there are several naturally treeless vegetation types, which have persisted for centuries. For instance, the rocky, open sandy and saline grasslands belong to this group (Isépy & Csontos 1996, Borhidi 2003). In this region today, however, anthropogenic and maintained grasslands are more frequent than in other regions. The main purpose of the present study is to reveal the coenological conditions of grasslands and to examine how altered farming techniques affect the species composition and coverage conditions of the grasslands. Herbivores can affect the diversity of grasslands (Peco et al. 2006): in some cases to increase it, in others to decrease it (Olff & Ritchie 1998). In the case of Spanish dehesas, grazing has been shown to influence the vegetation structure

and composition, as well as the physical and hydrological properties of the soil. According to an experiment, 60% of grassland species disappeared after the cessation of grazing (Peco et al. 2006). Pykälä et al. (2004) demonstrated that the total number of species correlated with the number of grass species and number of scarce grass species in the meadows examined in Finland. In addition, solar radiation positively affects, and time since cessation negatively affects the richness of species (Sala et al. 1996). Results from another experiment support the hypothesis that if the water uptake is not restricted, the richness of species depends on solar radiation only (Pausas & Austin 2001). Several studies showed that a productive grazing environment positively influences the richness of plant species (Huston 1994, Proulx & Mazumder 1998, Pykälä et al. 2004). According to Losvik (1999), richness of plant species is reduced by abandonment of mowing and grazing, which was also confirmed by Smith & Rushton (1994). In their study, the plant species richness is significantly lower than those of grazed areas. Lower management pressure can also increase diversity (Bakker 1989, Nösberger et al. 1998, Tscharntke 2005, Kampmann et al. 2007). Planned and carefully controlled grazing can be a suitable option in case of abandoned agricultural areas (Barbaro et al. 2001, Fisher & Wipf 2002, Pykälä 2003, Kampmann et al. 2007). It is proved that grazing as a management type in order to maintain grassland species diversity and landscape scale processes is essential (Luoto et al. 2003). Thus, grazing may be the best option to protect nature and restore ecology (Wieren 1991, Wallis De Vries 1995, Bakker & Londo 1998; Cosyns & Hoffmann 2005, Kramberger & Kaligaric 2008).

In the study areas, grey cattle were used as large herbivores. Grazing by large herbivores affects grassland communities through changes in vegetation structure (Sala 1988, Enyedi et al. 2007), composition of species (Kahmen et al. 2002, Moog et al. 2002) and the diversity of species (Virágh & Bartha 1996, Pykälä et al. 2005). Two management types, grazing animals and mowing, were used in the study area. During the experiment we had the opportunity to compare the influences of the two regimes on the vegetation. The area was converted from hay meadow to pasture in 2000. Since 2000, a certain number of grey cattle provide a constant trampling pressure on the area (0.9 cattle/ha). Meteorological data were also taken into account in order to examine how rainfall and temperature affect the changes of vegetation.

Our preliminary hypothesis was that even if the total species richness did not decrease during the intervening period as shown by previous experiments, the continuous presence of grazing livestock presumably will cause degradation in the vegetation, i.e. significantly modifying the species composition of the area. We further assume that it will increase the number of weed type species which were observed in several previous studies (Orr 1980, Dwayne & Mertens 1995, Pettit et al. 1995, Renzhong & Ripley 1997, Tóth et al. 2003). Data from some Hungarian grasslands reported by Penksza et al. (2007) and Szentes et al. (2007) could serve as a basis for later trends or basis for comparison as well. Our prior expectation was also that the mowed areas become more enriched in species than the grasslands. Member States of the EU apply different agri-environmental programs in order to stop or if possible to reverse the loss of biodiversity (Kleijn & Sutherland 2003). The national agri-environmental program (NAKP) helps to achieve these goals (Government Decision 2253/1999 (X.7.). As a result of this government decision, grey cattle have been recognised as a tool of grassland maintanence. By 1960, this variety almost disappeared from the Hungarian plain, and since 1989 it has become an increasingly important element in grassland maintanence. The advantage of this variety is that the animals can be kept for longer on the grassland, thereby extending the grazing period (which was traditionally from 24th April until 29th September).

2 Methods and materials

The sample areas were as follows:

10 hectares of grassland lying along the southern shore of the Inner Lake (Tihany peninsula) (1). Until 2000, this area was used as a hay meadow and vegetation was surveyed in 1994. (Nomination: 1994H/hayfield/). Resurveys were carried out in 2002, 2006, 2007 and 2008 when the area was already converted to grassland (Penksza et al. 2003). These results are found under the titles: 2002G, 2006G, 2007G, 2008G. The drinking area was considered separately from the 10 hectares due to the fact that animals spend more time here and trampling is a dominant influence. In addition, another area was surveyed which is located west of the examined area on a slope and elevation mowed by BfNPI. This 0.9 hectare open plot was declared as hay meadow (2007H/hayfield/).

For coenological recordings, ten 2 x 2 m quadrats were surveyed on every sample area between 10th and 20th of June based on the methods of Braun-Blanquet (1964). Coverage is expressed in percentages. De facto measured total coverage refers to the absolute coverage, while the relative coverage refers to the values calculated give a total of 100%. For data analysis we chose cover (D) and species number (n). This grassland is grazed by 5 cows, 1 bull and their 5 calves.

During the evaluation of the vegetation, species were grouped according to type of farming as well, because traditional farming and conservation-centered farming have different effects on species (Briemle et al. 2002, Kahmen & Poschlod 2008, Malchair et al. 2010). Regarding environmental indicator values and conservation status of species, the works of Borhidi (1995) and Simon (2000) were used. Nomenclature follows Simon (2000).

To investigate the effects of rainfall and temperature on species composition, the data used are as follows: precipitation and temperature data from 1994 and from the period 2000-2008 were evaluated at monthly intervals. Vegetation surveys were carried out in July, therefore data from the first 6 months of the year were used in the present study as possible influential factors. Precipitation data were recorded at measuring station 26403, Tihany: longitude 17°53'30'', latitude 46°55', altitude 7.0 m. Temperature data were recorded at measuring station 36100, Siófok: longitude 18°02'27'', latitude 46°54'39'', altitude 108.2 m.
In statistical analyses, ANOVA was used to compare means of reproductive variables among the three study sites (InStat 1998). Raw data showed normal distribution in all cases, however, standard deviations proved to be different (in Bartlett test) in the case of some variables. In these latter cases, the Kruskal-Wallis test was used for evaluation. As post hoc tests, the Tukey-Kramer test was applied following ANOVA and the Dunn test in the other cases. Significant differences were accepted at $p<0.05$.

3 Results and discussion

Among the examined areas, 1994H had a total of 40 species, and the average number of species per quadrat was 25.8. The highest values were encountered in 2002, when the total number of species was 70 and the average value was 44.2. On grassland the total and average number of species decreased, but it exceeded the earlier hay meadow (Table 1). In the drinking area, the total number of species reached 21, but the average number of species was the lowest, only 8. Examining the species composition of the drinking area, an increase in the number of weeds was seen, which is a good indication of trampling and large quantity of nitrogen. Species found only here were: *Arctium lappa, Chenopodium album, Ballota nigra, Plantogo major, Hordeum murinum.*
Vegetation coverage values of hay meadow and pasture were almost identical in 2007. The lowest average coverage was measured for 1994H and for the drinking area (Table 1). Average coverage values of the pasture were constant in the years of interest. In 2002 and 2008 there was a reduction (87.1%; 86.6%) in the total coverage but the tendency showed that coverage values of the examined areas increased year by year.

Table 1:
Characteristic data of the grassland in the Tihany Peninsula.

Functional group (%)	**1994H**	**2007H**	**2002G**	**2006G**	**2007G**	**2008G**	**2007DA**
Poaceae species	7	7	9	8	7	7	2
Fabaceae species	6	13	12	9	11	7	2
other *Poaceae, Carex* species	0	3	1	3	1	2	2
Dicotyledonous species	19	27	35	30	21	22	9
Poisonous species	2	6	6	8	4	4	4
Thorny species	6	4	7	8	4	3	2
Total number of species	40	60	70	66	48	46	21
Average number of species	25.8	32	44.2	34.6	31.8	29.4	8
Average coverage (%)	74.6	72	87.1	94.9	97.1	86.6	58

Annual changes in the coverage of grazing plots showed close correlation with the change of rainfall values. The lowest value of annual rainfall was in 2002 (169.6 mm), while the highest value was in 2008 (202.7 mm) which is also reflected in the lower coverage. Additional rainfall amounts were as follows: 244.3 mm in 1994, 335 mm in 2006 and 310 mm in 2007. The average temperature did not show any trend similar to the rainfall average. The average temperature values were higher in 1994 (10.25 ˚C), 2002 (10.7 ˚C) and 2008 (10.6 ˚C) than in 2006 (8.35 ˚C). 2007 had the highest mean temperature (12.2 ˚C), but this was not significantly correlated with values of vegetation coverage.
The number of species increased (from 40 to 48-70) during the examined 15 years in the case of the converted area. A protected species also appeared (*Lotus borbasii*). According to the data on hay

meadow in 2007, the number of species is lower (36) than in case of grassland. The lowest number of species (9) was found in the drinking area. Table 2 shows the distribution of groups of species in percentages based on economic criteria. Average coverage values of grass species were over 40% in case of the two hay meadow areas. In contrast, values of grasslands varied between 30.5-37.4%. Due to the change of cultivation method, a significant increase was detected (from 17-20.4% to 27.3-30.2%) in the coverage of dicotyledonous species known to be indifferent to grazing. A completely different species composition developed in the drinking area, since only weeds and disturbance-tolerant species were found (Simon 2000, Borhidi 1995).

Among the lawn formings, the dicotyledonous species had the second largest coverage area and *Polygonum aviculare* showed the largest coverage (15-30% of total coverage). Coverage of *Fabaceae* species was 3.4-3.8% in the hay meadow while in the pasture it was significantly higher (5.2-11.6%). As a result of grazing, the vegetation was more species rich, as has been shown by various other publications from different climate areas (Luoto et al. 2003, Mitchley & Xofis 2005, Peco et al. 2006, Pejman et al. 2008).

The quantity of poisonous species also increased in the pasture since the cattle avoided them. The percentage of poisonous species was still not notable (3.1-6%). Number of thorny species similar to the typical Pannonian grasslands were intermediate (8.7-13.9%) in the case of the pasture and significantly lower in the hayfields (1.4-6.8%) (Table 2).

Table 2:
Composition of the grassland in the Tihany Peninsula based on % distribution of important species groups of grassland management.

Functional group (%)	**1994H**	**2002G**	**2006G**	**2007G**	**2008G**	**2007H**	**2007DA**
Poaceae species	46.2	30.5	37.4	34	28	44.8	14.2
Fabaceae species	3.8	10.3	11	5.2	11.6	3.4	0.8
other *Poaceae, Carex* species	0	3.8	3.2	8	5.4	2.2	3.6
Dicotyledonous species	17	28.7	29.2	30.2	27.3	20.4	32.2
Poisonous species	0.8	6	3.2	5.8	3.1	0	4.2
Thorny species	6.8	7.8	11.2	13.9	11.2	1.4	2.6
∑	74.6	87.1	95.2	97.1	86.6	72.2	57.6

For further investigation, t-tests were applied in order to visualize coverage and area distributions. Significant differences were found between examined areas. The drinking area was the most different from the other areas because of large number and coverage values of weeds. Both pasture and hay meadow are isolated separately. There was a difference between wetter (2006, 2007) and drier years (2002, 2008) in the case of pastures.

For further investigation, *Poaceae* species were chosen to detect differences between sample areas. There is a significant change between drinking area and hay meadows, and between drinking area and pastures (Fig. 1). There is no significant difference between pastures and hay meadows if all sample areas are considered.

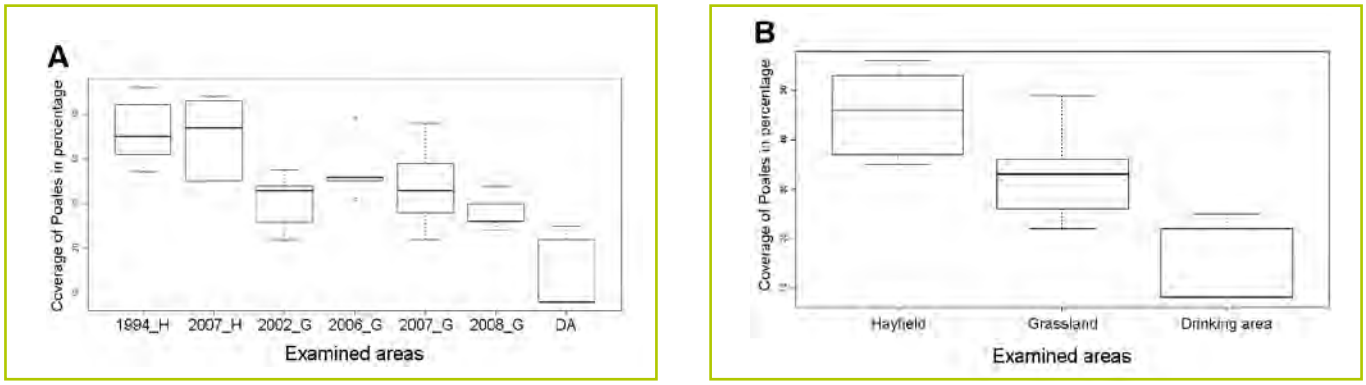

Fig. 1:
Left: (A) shows TukeyHSD results: hay meadow (H), pasture (G) and drinking area (DA) significantly differ ($p<0.05$) in the coverage of *Poaceae* species. Right: (B) If the 3 sample areas are homogenized in the calculation, all the sample area types differ from each other. Hay meadow, pasture and drinking area significantly differ ($p<0.01$) in coverage of *Poaceae* species.

Species were divided into groups based on their adaption to environmental conditions (Borhidi 1995, Simon 2000). Based on the criteria mentioned the following categories were created:

1: Fibrous leaved, xerothermic species: *Festuca rupicola, F. valesiaca, F. pseudovina, Poa angustifolia,*
2: Broad-leaved, mesophilic environment indicator species: *Festuca arundinacea, Dactylis glomerata, Elymus repens*
3: Weed species: *Lolium perenne, Hordeum murinum*
4: Disturbance, trampling indicator species: *Cynodon dactylon*

On the basis of *Poaceae* groups, broad-leaved species had 1-2% (Fig. 2, B) coverage in the drinking area while fibrous leaved species were not found (Fig. 2, A). Broad-leaved species covered an exceptionally high proportion of hay meadows and mowed sloping steppe maintained by BfNPI. For mesophilic grassland species, the ratio remained stable around 5%, however larger values were represented in 2006 and 2007. The distribution of xerophylous *Poaceae* species showed no significant difference. These species showed significant coverage values in the hay meadows, however, they were more dominant in pastures. The largest proportions were found in 2002 and 2008 when rainfall was lower in the region.

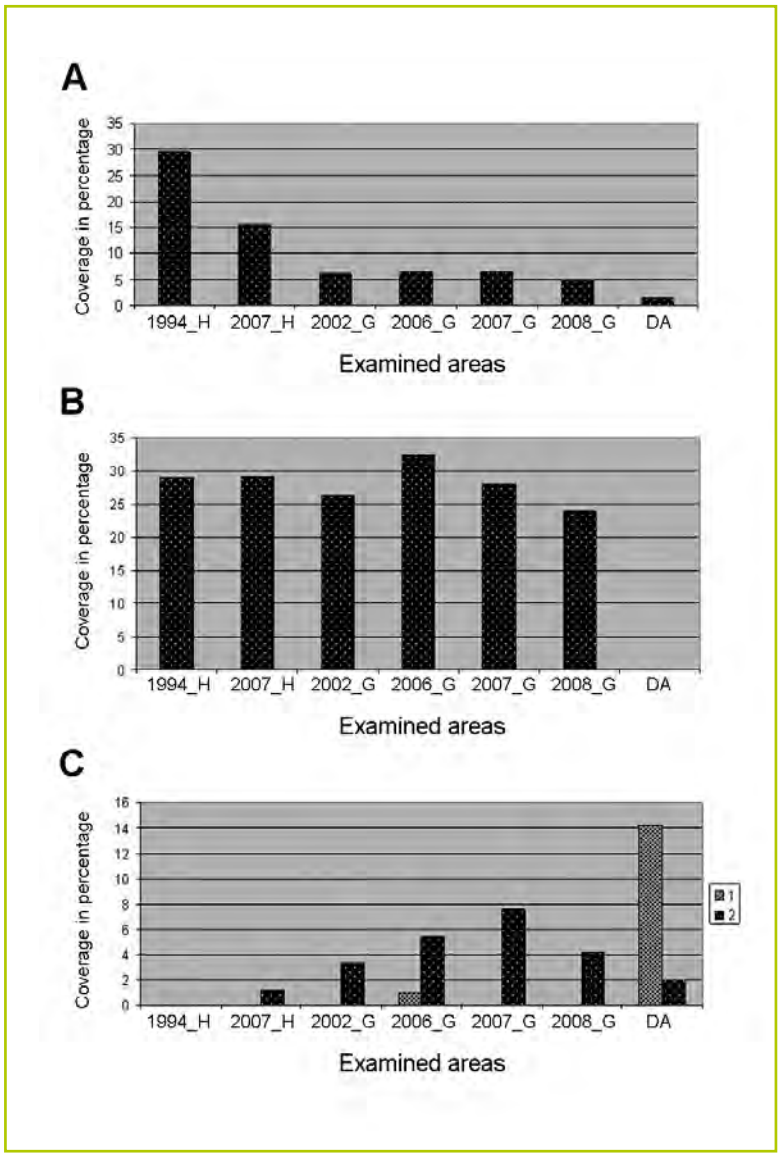

Fig. 2:
Average coverage values of fibrous-leaved (A), broad-leaved (B) and trampling-adapted (C) species in the surveyed areas.

The amount of *Cynodon dactylon* indicates trampling, which appears as an effect of over-grazing. Its coverage increased in 2007 which probably occurred because of the warmer period. Trampling-adapted species (*Lolium perenne, Hordeum murinum*) had the largest coverage values around drinking area.

Festuca species were analyzed separately, which is crucial in point of view of coeno-taxonomy and nature conservation as well. *Festuca* species differ between the hay meadow surveys of 1994 and 2007. *Festuca rupicola* was found to be dominant in 2007 while *Festuca arundinacea* had extremely high coverage values in 1994. According to the pasture surveys, the species of drier areas (*Festuca valesiaca* and *Festuca pseudovina*) as well as mesophilic *Festuca rupicola* increased in less humid years (2002, 2008).

4 Conclusions

A pasture (transformed from hay meadow) at the Tihany peninsula was examined over a 15 year period, during which both the number of species and coverage values increased. *Poa* and *Festuca* species dominant in the sward remained significant. The change within the *Festuca* genus appeared as a change in dominance and quantity of species. These alterations showed close relationship with climatic changes especially with the amount of rainfall.

In contrast to our expectations, the continuous presence of grazing animals did not cause any degradation in the volume of sward and did not change the composition of species during the examined years, except at the beginning when transformation from hay meadow to pasture occurred. The amount of weed species was extremely high in the drinking area, presumably because of the intense trampling.

The regular mowing caused an increase in the coverage of *Poaceae*, while the quantity of fibrous-leaved species remained the same, and, changes were not observed since 2002. In the two years when the weather was warmer and drier (2002, 2008), coverage and frequency of the more aridity-tolerant species *Festuca pseudovina* and *Festuca valesiaca* increased on the pasture. This composition is advantageous for well-chosen livestock, in our case grey cattle. The breed evolved on the Hungarian steppe with similar species composition. In contrast to some previous studies published reporting that the effects of grazing reduced the number of species (Orr 1980, Pettit et al. 1995, Dwayne & Mertens 1996, Renzhong & Ripley 1997, Tóth et al. 2003), in this study we did not find any decrease in the number of species. Our results support other publications where no observation was made on reduction of number of species (Huston 1994, Smith & Rushton 1994, Proulx & Mazumder 1998, Pykälä et al. 2004, Losvik 1999). The reason is that besides a well-chosen grazing livestock, the appropriate grazing pressure is essential as well. Based on the observations of grey cattle, an area which has slope steppe vegetation, grazing pressure of 0.7–1 livestock units/ha is appropriate for nature conservation. On a 10 ha area, 7–9 cattle can maintain the balance of grasses (Nagy 1993).

Acknowledgements

This work was supported by the OTKA 2341563, further thanks to Balaton Uplands National Park Directorate, Bolyai fellowship and OMSZ for providing meteorological data.

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Addresses of authors

Dr. Károly Penksza, Dr. Judit Házi, Barnabás Wichmann
Szent István University, Faculty of Agricultural and Environmental Sciences,
Institute of Environmental and Landscape Management,
Department of Nature Conservation and Landscape Ecology
Páter Károly str. 1
2103 Gödöllő
HUNGARY

E-Mail: penksza@gmail.com
hazijudit246@gmail.com
wwbarna@yahoo.com

Szilárd Szentes
Szent István University, Faculty of Agricultural and Environmental Sciences,
Institute of Plant Production, Department of Grassland Management
Páter Károly str. 1
2103 Gödöllő
HUNGARY