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ECOLOGICAL AND SOCIO-ECONOMIC EVALUATION OF WEED VEGETATION IN STANDS OF ENERGY GRASS *MISCANTHUS × GIGANTEUS*

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Abstract

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In experimental research plots in Kolíňany (SW Slovakia), ecological and socio-economic characteristics of weed vegetation were evaluated in the energy stands of *Miscanthus ×giganteus* during three vegetation seasons (2010–2012). The spontaneous vegetation in the Miscanthus stand was dominated by annual therophytes (55.5 to 62%) and geophytes (17.2 to 22.2%). We identified two categories of herbaceous undergrowth in Miscanthus plantation: with potential positive (e.g. presence of medicinal plants and plants with melliferous potential) and potential negative impacts (e.g. invasive and toxic plants). Based on our observations, we can conclude that the species composition of spontaneous herbaceous vegetation is comparable with weed vegetation found on arable land.

Keywords: agricultural landscape, biodiversity, energy crop, *Miscanthus ×giganteus*, weed

INTRODUCTION

Biodiversity is important for maintaining essential ecological functions (decomposition, nutrient cycling, soil formation, pollination etc.) (Balvanera *et al*., 2006; Primack, 2010; Fehér *et al*., 2012). There has been a general decline in biodiversity in European agricultural landscapes over the last decades. Not only rare and threatened species are declining, but also common ones which are often ecological generalists, and are responsible for most of the regulating and supporting services in agri-ecosystems (Billeter *et al*., 2008; Dauber *et al*., 2010; Werling *et al*., 2014). Annual arable crops (e.g. wheat, barley, maize, oilseed rape) in comparison to short rotation coppice (SRC) and perennial rhizomatous grasses (PRGs) crops have more species only of ground beetles and a few other dwelling arthropods (Emmerson *et al*., 2011). Baum *et al*. (2009) found out that SRC fields of different age classes and a variety of crop species or clones would support a more diverse community of plant species at a landscape-scale. Similarly, Rowe *et al*. (2009) and Dauber *et al*. (2010) reported for Miscanthus and willow plantations some benefits for biodiversity as they are less intensively managed and as are less disturbed.

The remarkable adaptability of the genus Miscanthus to different environmental conditions makes this crop suitable for establishment and distribution under a range of European climate conditions. In Europe these grasses started to be cultivated, initially as ornamental plants. Miscanthus occurred in Europe in the beginning of 1930s. Perennial energy grasses are, from the agricultural point of view, low cost on energy (energy ratio can be less than 0.2 in this production) (McLaughlin and Walsh, 1998).

At present, there are only few scientific papers dealing with evaluation of the impact of energy grass cultivation on biodiversity. The literature available on the subject of this study has focused to date on evaluating the effect of growing switchgrass (*Panicum virgatum*) on species richness of birds in North America (Murray *et al*., 2003) and the impact

of growing Miscanthus on other animal species in Germany (Eppel-Hotz and Marzini, 1998). More comprehensive research in this area is an evaluation of the diversity of herbaceous vegetation, small mammals and birds in Miscanthus plantations in Great Britain (Semere and Slater, 2007; Clapham, 2011).

MATERIAL AND METHODS

Our research plots were established in Kolíňany. Cadastral area of Kolíňany is located in the province of West Pannonian Basin and Danubian Lowland region (approx. 10 km northeastern from Nitra, SW Slovakia). Area of Kolíňany is located on the dividing line Zobor hill and Žitava hill land.The study site was located near the regulated water stream Bocegaj that is a right tributary of river Žitava. Altitude of the experimental base is 180 m a.s.l. Climate region is warm, moderately humid with mild winter. Main soil unit is haplic luvisol. Terrain steepness is from 0° to 2°. The experiment was established on agricultural land located in the research site belonging to the Slovak University of Agriculture in Nitra (coordinates: 48° 21' 20" N, 18° 12' 23" E).

Observations were made during three growing seasons (2010–2012) in stands of sterile allopolyploid hybrid of perennial rhizomatous grass *Miscanthus ×giganteus* Greef&Deuter ex Hodkinson. Plant material was purchased from a commercial supplier (seller: Hannes Stelzhammer, Giganteus Miscanthusproduktion, Austria). Planting of the rhizomes was carried out on the 7th of May 2010. The rhizomes of 6–12 cm in length were planted by hand in the spacing of 1×1 m (1 plant per 1m^2) to a depth of about 10–20 cm. The research plot had a size of 100 m^2. The observation of spontaneous vegetation species composition was performed at fortnight intervals throughout the whole growing season of the studied years. Regular censuses in 2010 were conducted after the planting of the rhizomes. Nomenclature of the taxa was revised by the checklist of vascular plants of Slovakia (Marhold and Hindák, 1998). Alien species were classified according to Medvecká *et al*. (2012). The abundance of the taxa was evaluated by the Braun-Blanquet scale (Braun-Blanquet, 1964). Ecological and socio-economic evaluation of the plant species, according to Jurko (1990), was focused on the following characteristics: life forms, soil moisture, soil reaction, soil nitrogen, therapeutic value, toxicity, melliferousness and distribution of diasporas. Meteorological data were presented by data obtained from the Slovak Hydrometeorological Institute (SHMU, 2010–2012).

RESULTS AND DISCUSSION

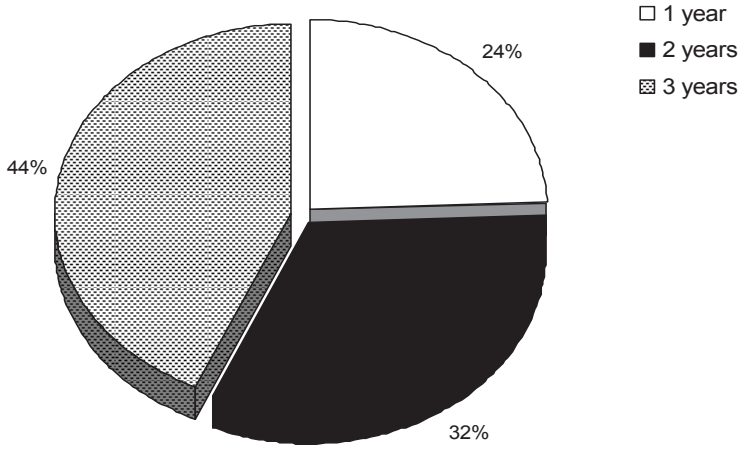
In the growing seasons of 2010–2012, we recorded from 25 to 29 weed species (2010 – 25, 2011 – 29, 2012 – 27 species) in the research site. We found that half of the local species richness occurred only once or twice within three years study period (Fig. 1).

In the spontaneous herbaceous vegetation of secondary phytocoenoses of hybrid *M. ×giganteus*, we recorded from 55.5 to 62% share of annual therophytes that survive unfavourable periods of winter in the form of seeds, and 17.2 to 22.2% share of geophytes that store renewal buds in the soil (Fig. 2).

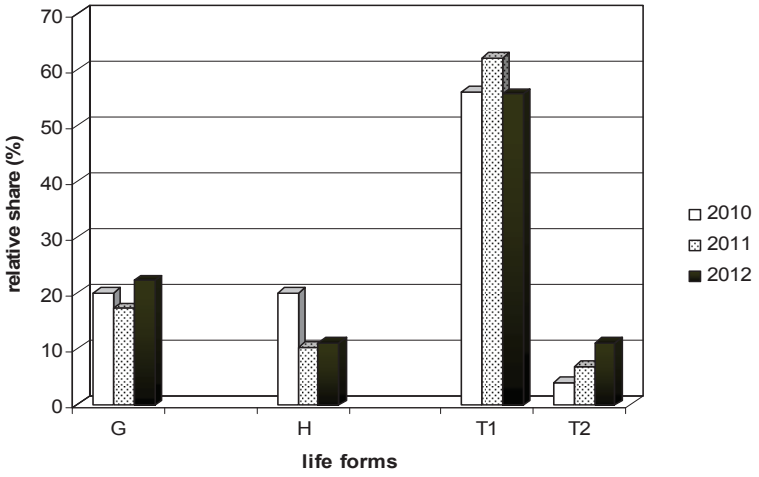
The distribution of plant diasporas on the site was very diverse with different variants of polychory and diplochory.

Clapham, Slater (2008) recorded similarly 29 weed species within Miscanthus plantation. The most frequent were *Epilobium montanum, Rumex obtusifolius,* and *Ranunculus repens*. In our case, during the growing periods 2010–2012, the dominant species were *Equisetum arvense*, *Amaranthus retroflexus* and *Convolvulus arvensis*. Semere and Slater (2007) observed in Great Britain that the dominant plant species in Miscanthus crop fields were the following ones: *Elytrigia repens, Poa annua* and *Bromus sterilis*. These species are requiring drier conditions.

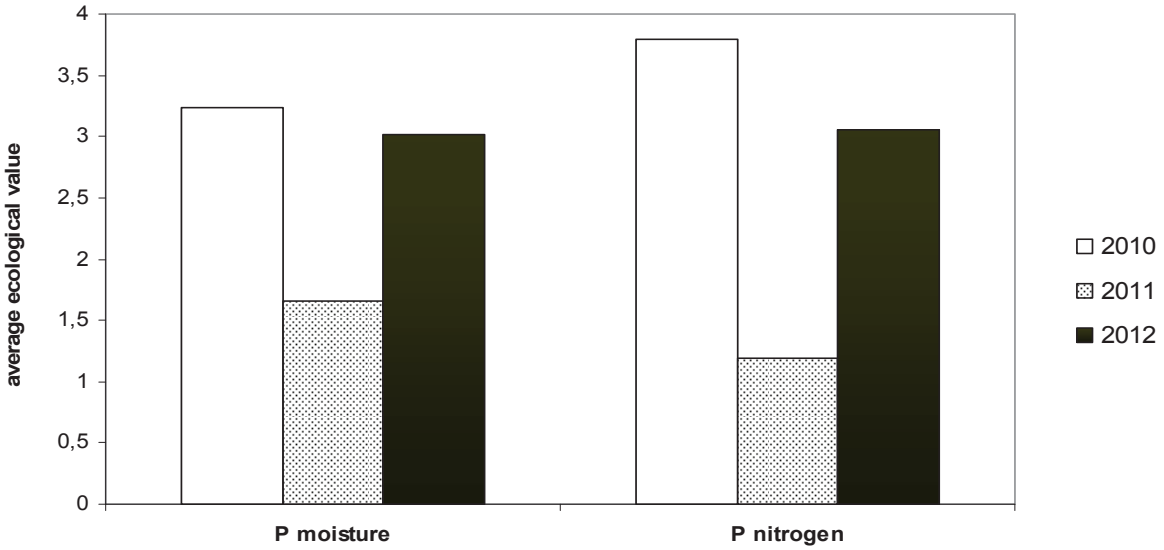
Our results showed that the species linked to disturbance were annuals, in particular *Amaranthus retroflexus* and *Chenopodium album, Galium aparine* and *Stenactis annua*, which are characteristic



1: *Constancy in temporal occurence of weed species*



2: *Percentage of various life forms of weeds within Miscanthus ×giganteus plantation in the locality Kolíňany*
G – geophytes, H – hemicryptophytes, T_1 – annual therophytes, T_2 – biennial therophytes

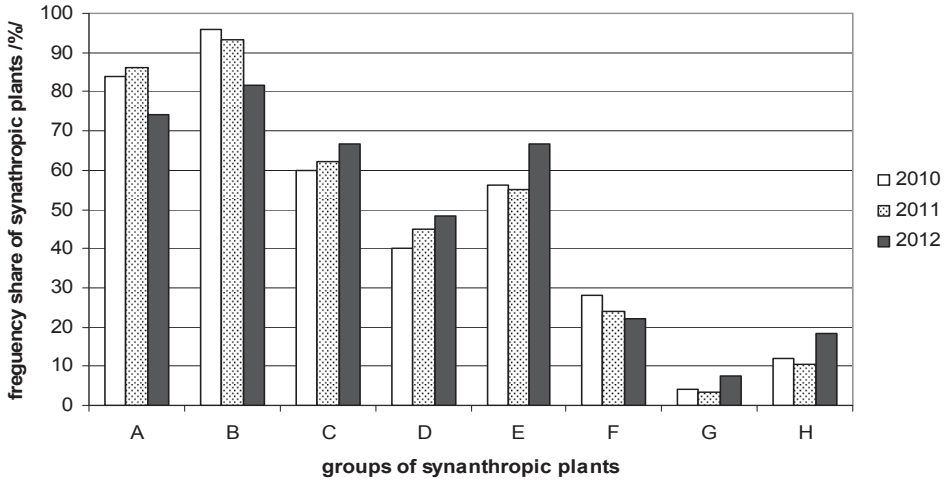


3: *Mean ecological values of bioindication characteristics of spontaneous herbaceous vegetation: soil moisture ($P_{moisture}$) and soil nitrogen ($P_{nitrogen}$) in 2010–2012*

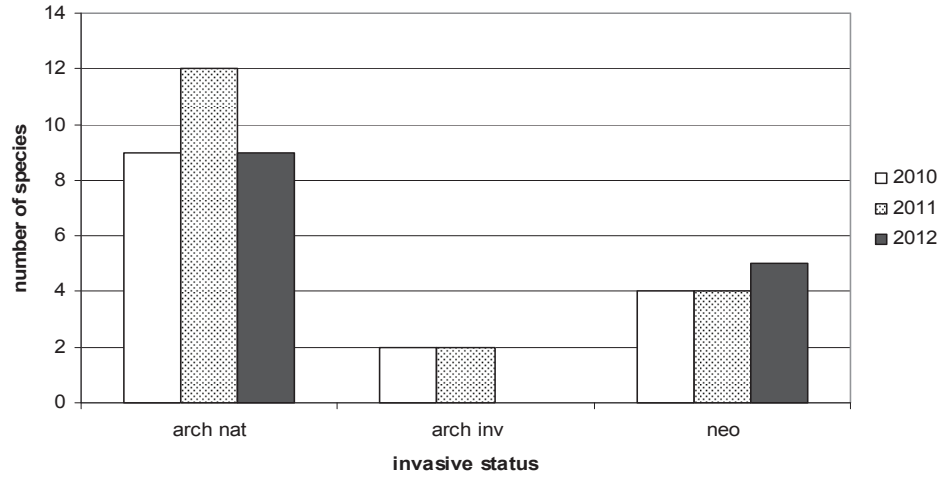
for weed communities of the more intensively managed fields in the lowland areas. The amount of perennial species (geophytes, hemicryptophytes) was higher at the Miscanthus plantation margins.

Within the bioindication properties of the vegetation, we focused on the evaluation of soil moisture ($P_{moisture}$) and soil nitrogen ($P_{nitrogen}$). The soil moisture comes mainly from atmospheric precipitation, but in some cases also from fluctuating underground water table. Based on the average ecological value $P_{moisture}$, we found that species of fresh soil types dominated in 2010 and 2012, and species of dry soil types in 2011. These facts partly correspond with the trend of the atmospheric precipitation, because in 2010, the total precipitation was 648 mm in the period from March to October and for the same period in 2011 it was 458 mm. But in 2012, the atmospheric precipitation was only 319 mm and the value of $P_{moisture}$ was comparable with 2010. A similar trend was recorded in the mean ecological value of $P_{nitrogen}$. In 2010 and 2012, the prevalent species were ones of medium-rich soils and in 2011, species of very poor soils in the stand of *M. ×giganteus*. We assume that the plant community development was affected by fertilization with mineral fertilizers (NPK) applied in 2010 one month after planting, while the release of nitrogen (NO_3^-) in the soil and its intake by plants were also affected by soil temperature and soil moisture conditions (Fig. 3).

Based on the evaluation of species synanthropicity, we found that the maximum share of species from phytosociological relevés in the years 2010 to 2012 were included into the group of species



4: *Frequency of synanthropic plant groups in Miscanthus stands in 2010–2012*
A – cereal weeds, B – root crop weeds, C – annual ruderals, D – xerophilous perennial ruderals, E – fresh/hygrophilous perennial ruderals, F – tramped perennial ruderals, G – species of river banks, dikes H – species of forest margins, shrubs and boundaries



5: *Invasion status of species in phytocoenoses of hybrid M. ×giganteus in 2010–2012*
(*arch nat* –archaeophytes naturalized, *arch inv* – archaeophytes invasive, *neo* – neophytes)

occurring in root crops and cereals. We assume an influence by both impact of the prior land use and impact of crops from the surrounding arable land. During the growing period of 2012, we recorded an increase in the frequency of other groups of synanthropic species as well as groups of species with a predominance in semi-ruderal communities (categories G and H, Fig. 4). This arises from the fact that in dense plantations of *M. ×giganteus* little land disturbance during the year creates conditions for increasing the proportion of species within the categories G, g and H, h. Although the frequency of individuals of these categories was lower, we located them in the stands regularly. Plantations of *M. ×giganteus* were invaded by invasive species as well. We recorded the occurrence of several archaeophytes e.g. *Echinochloa crus-galli* and *Cardaria draba*. A group of neophytes recorded on the site included *Amaranthus retroflexus*, *Conyza canadensis*, *Galinsoga parviflora* and *Stenactis annua* (Fig. 5).

By evaluating socio-economical characteristics of individual species, we observed that spontaneous vegetation in Miscanthus plantation had a low level of melliferous potential during the studied years. During the evaluated years, the number of species with melliferous potential as well as therapeutic plant species increased. The possible use of these plants needs more research considering the fact that the herbs in energy plantations are less contaminated than plants in the rest of the agricultural landscape but a lower intensity of light may cause a decrease in amount of secondary metabolites. Stanley (2013) found out higher abundances and species richness of solitary bees in bioenergy crops than in conventional ones, and community composition of this group differed between bioenergy crops as well. Evaluation of plant toxicity rate as potential

I: *Selected socio-economical characteristics of spontaneous vegetation in Miscanthus plantation*

Evaluated years	Melliferous potential /sum of values/	Store of therapeutic plant species /% share/	Rate of toxic plant /% share/
2010	29	44.00	68.00
2011	34	51.70	62.60
2012	38	51.85	66.60

risk for human and animal health showed relatively balanced proportion of potentially toxic plants (Tab. I). Species with low toxicity were represented by 16 taxa (of which 11 species were potentially, facultatively or partly harmful and 5 species harmful and/or slightly poisonous) and allergenic species were represented by 9 species according to classification scale of Jurko (1990).

CONCLUSION

Perennial rhizomatous grasses are an attractive source of biomass for bioenergy, but there is very little data available on potential impacts on native wildlife and local biodiversity of these crops. This study's objective was to evaluate ecological and socio-economical properties of weed vegetation in the *Miscanthus ×giganteus* plantations in SW of Slovakia during three vegetation seasons (2010–2012). The ground cover vegetation in the Miscanthus stands contained dominantly common annual species (therophytes – 55.5 to 62%) typical for disturbed arable land with high share of synanthropic species. Compared to constancy in temporal occurrence of weed species it was found that 44% of all species occurred every year of the three years period. The mean Jurko's indicator values for moisture and nitrogen were fluctuated over study time. Weed categories of both impacts on local biodiversity were identified. Positive impact was characterized by presence of melliferous potential and medical plants, negative impact on local biodiversity was confirmed by occurrence of invasive and toxic weed species. We can conclude that the species composition of spontaneous herbaceous vegetation is comparable with species found on arable land.

SUMMARY

Based on the results from the three-year study in Miscanthus plantation, we observed 55.5 to 62% share of annual therophytes and 17.2 to 22.2% share of geophytes, which were dominated by species *Equisetum arvense, Amaranthus retroflexus* and *Convolvulus arvensis*. We found that half of the local species richness occurred only once or twice within three years study period. From the bioindication properties of the vegetation, we can conclude that the dynamics of spontaneous herbaceous vegetation were influenced by both precipitation and nutrient conditions, which resulted in differences in the species composition of community between the three years. At the same time, we observed occurrence of species with therapeutic value and melliferous potential. From the synanthropic point of view, the most prevailing species during the studied period were the groups of species occurring in root crops and cereals. The occurrence of archeophytes (e.g. *Echinochloa crus-galli* and *Cardaria draba*) and neophytes (*Amaranthus retroflexus, Conyza canadensis, Galinsoga parviflora,* and *Stenactis annua)* was confirmed. Based on our observations, we can confirm that the composition of the weed species vegetation corresponded to the species found on arable land.

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