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THE USE OF SPECIES RICH ASSOCIATIONS FOR ESTABLISHMENT OF GRASSLANDS ON ARABLE LAND

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ABSTRACT

Over the last decades, the land-use changes require new mitigating strategies and a sustainable way to prevent environmental degradation and erosion of genetic resources. Semi-natural grasslands are a valuable source of seeds and plant material which can help to restore and maintain biodiversity. The use of species rich associations for restoration of arable land using the green hay method has been realized in the buffer zone of the Low Tatras National Park from 2009 to 2015. The donor sites were *Arrhenatherion* and *Mesobromion* communities. This method proved to be efficient in our pedoclimatic conditions, allowing a good percentage of the target species present in the donor site to be transferred to the receptor site. The highest total transfer rate (81 %) was observed with both communities one year after restoration in 2010. The success of the establishment and settlement of species in the receptor site might be attributed to soil conditions, especially to soil pH, where the average cover of target species was higher at the *Arrhenatherion* receptor site comparing to the *Mesobromion* one. The limited diffusion of knowledge concerning the planting techniques of the semi-natural grasslands is still one of the most obstacles to the use of native propagation material in Slovakia. The main purpose of the interventions carried out with this project was to improve the experiences and skills of farmers and stakeholders.

Keywords: grassland, ecological restoration, arable lands, green hay transfer, soil

INTRODUCTION

Traditional agricultural practices have created a wide diversity of habitats suitable for hosting grassland communities with high animal and plant biodiversity. The changes occured over the last decades with the development of intensive agriculture and the abandonment of marginal agricultural areas have led to the loss of those habitats everywhere in Slovakia. In the plain these surfaces are now less frequent and even rare those with highly natural vegetation. The reconstitution of high biodiversity grasslands occurs through the use of seeds of spontaneous species of local origin. The use of native propagation material satisfies the needs of sustainable use of natural resources and favors the conservation of floristic and faunistic biodiversity. The common approach is based on the use of biological and non-biological material (plants, animals, soil, etc.) coming from areas adjacent to the site where the intervention will have to be carried out or coming from ecologically similar and geographically close areas. As regards the restoration of the semi-natural grasslands, it is used to the identification of grasslands called "donors", phytocoenoses of a certain type of vegetation that are capable of providing suitable seeds for an area to be restored, known as the "receptor" site. The use of locally sourced species serves to counteract genetic pollution, which is produced by introducing exotic species. In addition to the choice of the floristic composition must be taken into account the consistency between the sites i.e. the characteristics of the soil and other stational factors that can influence vegetation and management (*Ibáñez et al*., 2014; *Scotton, et al*., 2012).

In general, former arable land is characterized by high concentration of plant available nutrients, which can limit the success of new plant establishment (*Törok et al.,* 2011). Another fundamental aspect of successful grassland restoration is the form of utilization and the fertilization used for the restored site which should be similar to those of the donor site. In fact, the floristic composition of the semi-natural grasslands is strongly influenced by the management and the seed collected by them can allow the creation of new stable phytocoenoses only if their future management is compatible with the species transferred (*Baasch et al.,* 2012, *Kiehl et al.,* 2010). During the past period, various methods for harvesting and transfer of seeds from species-rich grasslands have been developed and tested. The green hay method among the available techniques, is in our pedoclimatic situation the one that can most easily lead to good results, allowing a good percentage of the target species present in the donor site to be transferred to the receptor site (*Baasch et al*., 2012, *Rasran et al.*, 2006).

The green grass has a seed content on the total material and is cut when the grassland is in the seed maturity stage (*Kiehl et al.*, 2010). The amount of seed harvested depends on the type of vegetation and the age of the cut. The weather conditions at the time of the cut have little influence as the grass is immediately brought to the receptor site. By avoiding haymaking, seed losses are reduced to a minimum and harvest efficiency is the highest of the harvestable production. Moreover, given the immediate use, the method does not have limitations for the cutting time. Other advantages are the ease of finding the equipment, common in most Slovak farms and in economic use, the low impact on the donor site and the double use of the material, both as a propagation material and as a mulching material.

According to guidelines of the Society of Ecological Restoration International the assessment of restoration success should monitor nine ecosystem attributes (SER, 2004). However, most studies monitor three ecosystem attributes: diversity (species richness and abundance), vegetation structure (cover of plant functional groups) and ecological processes (nutrient cycling and biological interactions) (*Ruiz-Jaen and Aide*, 2005). In addition to the estimation of total number of plant species in restored grassland, also the presence of target species which represent the target habitats is often defined (*Scotton et al.*, 2012).

The aim of our study was to evaluate the restoration success of conversion of arable land into grassland by transfer of green hay from two grassland communities.

MATERIAL AND METHODS

The trial was established in the buffer zone of the Low Tatras National Park (altitude 647m a.s.l.; 48°44'57.05´´N, 19°02'44.35´´E; geological substratum: carbonate rock and dolomitic limestone). The receptor site was former arable land used for silage maize production. In spring 2009 the receptor site was prepared by ploughing and harrowing. The experiment was arranged in two blocks, each containing two plots (5 m x 10 m). The donor sites were *Arrhenatherion* and *Mesobromion* communities. The distance between the donor and the receptor sites was about 2 km. The soil samples were taken at the donor and receptor sites. The soil characteristics are shown in the *Table 1*.

Table 1: Soil characteristics of donor and receptor sites in 2009

Parameter	Donor site		Receptor site
	Arrhenatherion	*Mesobromion*	
$pH_{(KCl)}$	5.82	4.75	7.16
C_{ox}(g.kg^{-1})	72.91	52.79	15.45
Humus (g.kg^{-1})	125.42	90.8	26.59
N_t (g.kg^{-1})	5.2	3.99	2.03
P (mg.kg^{-1})	4.52	29.61	72.23
K (mg.kg^{-1})	154.73	122.69	114.18
Mg (mg.kg^{-1})	1224.8	153.4	690.3

The donor sites were cut in early July 2009. The plant material - green hay from the donor sites was applied manually to the receptor site immediately after harvesting. The material was turned over several times to avoid rot and damage to born seedlings. During the period 2010 – 2015, the experimental plots were cut twice per year (June and September) except of 2012 when only one cut was made in July.

The cover of plant functional groups and plant species was visually estimated in percentages at the donor sites in June 2009 and at new re-established grasslands in June 2010, 2011, 2013, 2014 and 2015. Out of total 51 (*Arrhenatherion* community) and 56 plant species (*Mesobromion* community), 22 and 23 target species were selected.

The success of restoration was expressed by total transfer rate and transfer rate of target species. The total transfer rate and the transfer rate of target species were calculated as the percentage of transfer of total/target species in relation to the total number of species of the donor site *Scotton et al.* (2012).

RESULTS AND DISCUSSION

In the first year after restoration18 of 22 and 19 of 23 introduced target species were recorded in the *Arrhenatherion* and *Mesobromion* receptor sites (*Table 2*), proving a relative high transfer rate of 81% and 82 %, respectively. During the next years of the experiment, the establishment success differed between both communities. Over the whole experimental period the presence of the target species was higher than 80 % at the *Arrhenatherion* receptor site, while the highest value (95 %) was recorded in 2015. An increase in number of target species during the experimental period was also found by *Baasch et al.* (2018) in the establishment of a grassland in the Natura 2000 habitat 6510 (Lowland hay meadow). At the *Mesobromion* receptor site the number of target species decreased from 19 to 13, resulting in 56 % transfer rate. Contrary to establishment of target species, the number of total species was only about two thirds and halves the numbers of the donor *Arrhenatherion* and *Mesobromion* sites, respectively (Table 2). Similar results have been showed by *Prach et al.* (2014) who found that 10 years after establishment of grassland on ex-arable land the numbers of total and target species were about 50% - 60 % of the long existing reference grassland. Despite the reduction of established total and target species within both communities, similarly to other restoration experiments in Europe (*Kiehl et al.*, 2010, *Kirmer et al.*, 2012), transfer rate was in the mid-range of successful establishment of species-rich grassland.

Table 2: Number of all species and target species in the *Arrhenatherion* and *Mesobromion* community

Community	Functional group	Donor site 2009	Receptor site 2010	2011	2013	2014	2015
Arrhenatherion	Grasses	13	13 ± 0	10 ± 2.1	8 ± 3.5	10 ± 2.1	12 ± 0.7
	Legumes	6	3 ± 2.1	4 ± 1.4	3 ± 2.1	4 ± 1.4	4 ± 1.4
	Forbs	32	16 ± 11.3	13 ± 13.4	17 ± 10.6	20 ± 8.4	19 ± 9.1
	Total	51	32 ± 13.4	27 ± 16.9	28 ± 16.2	34 ± 12.0	35 ± 11.3
	Target species						
	Grasses	8	8 ± 0	8 ± 0	7 ± 0.7	7 ± 0.7	8 ± 0
	Legumes	3	3 ± 0	3 ± 0	3 ± 3.0	3 ± 0	3 ± 0
	Forbs	11	7 ± 3.5	8 ± 2.8	7 ± 3.5	7 ± 3.5	10 ± 1.4
	Total	22	18 ± 3.5	19 ± 2.8	18 ± 3.5	18 ± 3.5	21 ± 1.4
Mesobromion	Grasses	13	14 ± 0.7	9 ± 2.8	9 ± 2.8	12 ± 0.7	12 ± 0.7
	Legumes	6	4 ± 1.4	7 ± 0.7	6 ± 0	5 ± 0.7	5 ± 0.7
	Forbs	37	28 ± 6.3	23 ± 9.8	20 ± 12.0	16 ± 14.8	20 ± 12.0
	Total	56	46 ± 7.0	39 ± 12.0	35 ± 14.8	33 ± 16.2	37 ± 13.4
	Target species						
	Grasses	8	8 ± 0	5 ± 2.1	6 ± 1.4	6 ± 1.4	6 ± 1.4
	Legumes	4	3 ± 0.7	4 ± 0	4 ± 0	4 ± 0	3 ± 0
	Forbs	11	8 ± 2.1	7 ± 2.8	7 ± 2.8	3 ± 5.6	5 ± 4.2
	Total	23	19 ± 2.8	16 ± 4.9	17 ± 4.2	13 ± 7.0	14 ± 6.3

Within both communities, different pattern of cover of plant functional groups was observed. One year after establishment of the *Arrhenatherion* community, the cover of grasses was similar to the donor site whereas at the *Mesobromion* community the cover of grasses was 20 % lower than at the donor site (Table 3). From the 2nd year after restoration the cover of grasses decreased and fluctuated from 21 % to 44 % at the *Arrhenatherion* receptor site and from 26 % to 39 % at the *Mesobromion* receptor site, respectively (*Table 3*).

Table 3: Cover of all species and target species in the *Arrhenatherion* and *Mesobromion* *community*

Parameter	Functional group	Donor site	Receptor site				
		2009	2010	2011	2013	2014	2015
Arrhenatherion	Grasses	59.5	58.5 ± 0.7	21.5 ± 26.8	33.0 ± 18.7	29.0 ± 21.5	44.0 ± 10.9
	Legumes	11.7	17.5 ± 4.1	66.5 ± 38.7	32.0 ± 14.3	27.0 ± 10.8	25.0 ± 9.4
	Forbs	28.8	19.0 ± 6.9	9.0 ± 14.0	33.0 ± 2.9	42.0 ± 9.3	27.0 ± 1.2
	Total	100	95.3 ± 3.3	97.0 ± 2.1	98.0 ± 1.4	98.0 ± 1.4	96.0 ± 2.8
	Target species						
	Grasses	53.9	46.0±5.5	19.5±24.3	29.0±17.6	23.0±21.8	37.5 ± 11.5
	Legumes	9.5	17.5 ± 5.6	66.0 ± 39.9	32.0 ± 16.9	25.0 ± 10.9	24.5 ± 10.6
	Forbs	14.8	11.5 ± 2.3	6.5 ± 5.8	16.0 ± 0.8	20.5 ± 4.0	17.0 ± 1.5
	Total	78.2	75.0 ± 2.2	92.0 ± 9.7	77.0 ± 0.8	68.5 ± 6.8	79.0 ± 0.5
Mesobromion	Grasses	75.3	59.0 ± 11.5	31.0 ± 31.3	26.0 ± 34.8	39.0 ± 25.6	33.0 ± 29.9
	Legumes	7.5	12.0 ± 3.1	44.0 ± 25.8	47.0 ± 27.9	31.0 ± 16.6	35.0 ± 19.4
	Forbs	12.2	28.0 ± 11.1	20.5 ± 5.8	24.0 ± 8.3	27.0 ± 10.4	25.0 ± 9.0
	Total	95.0	99.0 ± 2.8	95.5 ± 6.35	97.0 ± 1.4	97.0 ± 1.4	93.0 ± 1.4
	Target species						
	Grasses	67.2	42.5 ± 17.4	18.0 ± 34.7	20.0 ± 33.3	21.0 ± 32.6	16.0 ± 36.2
	Legumes	5.0	10.5 ± 3.8	42.5 ± 26.5	46.0 ± 28.9	30.0 ± 17.6	30.5 ± 18.0
	Forbs	7.0	11.5 ± 3.1	6.5 ± 0.3	7.0 ± 0	4.0 ± 2.1	5.5 ± 1.0
	Total	79.5	64.5 ± 10.6	66.5 ± 9.1	53.0 ± 18.7	55.0 ± 17.3	52.0 ± 19.4

The cover of legumes markedly increased and the highest coverage was observed in the 2nd or 3rd year after restoration. It must be mentioned that *Trifolium pratense* covered 57 % and 27 % at the *Arrhenatherion* and *Mesobromion* receptor site, respectively. The dominance of *Trifolium pratense* in the *Arrhenatherion* receptor site could be attributed to soil conditions (*Table 1*), especially to soil pH and content of plant-available phosphorus of the receptor site (ex-arable land) were more suitable for development of legumes in comparison to donor site; and/or *Arrhenatherion* donor site was anthropized during the 1970s and 1980s. Likewise to our study, *Lawson et al*. (2004) reported successful establishment of *Trifolium pratense* at two experimental sites on former arable land where soil conditions favour the establishment of species that develop naturally on fertile soils. However, in the second half of experimental period, the cover of legumes decreased by 62 % and 20 % at the *Arrhenatherion* and *Mesobromion* receptor sites, respectively. Our results are in contrast with *Albert et al.* (2019) who reported gradual increase in legume coverage on ex-arable land during the monitoring period of 5 years.

In the same way of what was registered for the number of all species, the average cover of target species was higher at the *Arrhenatherion* receptor site comparing to the *Mesobromion* one.

In the first and the last year of observation, the cover of target species was rather high and was similar to donor site with the *Arrhenatherion* community. Only slight changes in the cover values of target species in the lowland grassland restoration during the experimental period of 7 years, was also recorded by *Baasch et al*. (2014). *Mesobromion* receptor site exhibited decrease in the cover of target species with the lowest values in the last year of experiment.

The limited diffusion of knowledge concerning the planting techniques of the semi-natural grasslands is one of the most obstacles to the use of native propagation material. The overcoming of this obstacle is the main purpose of the interventions carried out with this project.

CONCLUSIONS

With reference to the two semi-natural grasslands rich in species of agricultural origin here described, this work has chosen to start a proposal of conservation and characterization of the surfaces that still exist in the Slovak plains and could form the basis for their future maintenance. The project showed that is possible to protect the still existing semi-natural grasslands trying to stimulate an adequate environmental policy (EEA, 2004) and to create new grasslands on arable lands that for various reasons may be reconverted to grasslands. The reconstitution of high biodiversity grasslands through the use of seeds of spontaneous species of local origin is possible for farmers with the very simple and economic techniques described in this paper. The green hay method used in our pedoclimatic situation proved to be efficient allowing a good percentage of the target species present in the donor site to be transferred to the receptor site. The success of the establishment and settlement of species in the receptor site may be attributed to soil conditions, especially to soil pH as in our environmental conditions, where the average cover of target species was higher at the *Arrhenatherion* receptor site comparing to the *Mesobromion* one. The limited diffusion of knowledge concerning the planting techniques of the semi-natural grasslands is one of the most obstacles to the use of native propagation material. The overcoming of this obstacle is the main purpose of the interventions carried out with this project.

FAJOKBAN GAZDAG TÁRSULÁSOK FELHASZNÁLÁSA SZÁNTÓFÖLDI GYEPEK LÉTESÍTÉSÉRE

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ÖSSZEFOGLALÁS

Az elmúlt évtizedekben a földhasználat változásai, új mérséklő stratégiákat és fenntartható módot igényelnek a környezet degradációjának és a genetikai erőforrások eróziójának megelőzésére. A féltermészetes gyepek értékes vetőmag- és növényi anyagok forrásai, amelyek segíthetik a biológiai sokféleség helyreállítását és fenntartását. Az Alacsony-Tátra Nemzeti Park pufferzónájában 2009-től 2015-ig valósult meg a fajgazdag társulások használata a szántóföld helyreállítására zöldszénás módszerrel. A donor helyszínek az *Arrhenatherion* és a *Mesobromion* közösségek voltak. Ez a módszer a mi talaj-klimatikus körülményeink között hatékonynak bizonyult, lehetővé téve, hogy a donor helyen jelen lévő célfajok jó százaléka átkerüljön a receptor helyre. A 2010-es helyreállítás után egy évvel mindkét közösségnél a legmagasabbnak bizonyult a teljes átviteli arány (81%). A fajok megtelepedésének sikere a befogadóhelyen a talajviszonyoknak, különösen a talaj pH-értékének tudható be. A célfajok esetében magasabb volt az *Arrhenatherion* receptor helyén, mint a *Mesobromion* receptornál. A féltermészetes gyepek telepítési technikáira vonatkozó ismeretek korlátozott terjesztése, továbbra is az egyik legnagyobb akadálya az őshonos szaporítóanyag használatának

Szlovákiában. A projekt keretében végrehajtott beavatkozások fő célja a gazdálkodók és az érdekelt felek tapasztalatainak és készségeinek fejlesztése volt.

Kulcsszavak: gyep, ökológiai helyreállítás, szántóterületek, zöld széna átvitel, talaj

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