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Henryk CZYŻ, Heidi JÄNICKE[1], Teodor KITCZAK, Marek BURY[2]

FEASIBILITY OF USING *Festuca arundinacea* FOR REGENERATION OF GRASSLANDS BY MEANS OF FULL CULTIVATION METHOD ON ORGANIC SOIL

MOŻLIWOŚCI WYKORZYSTANIA *Festuca arundinacea* DO REGENERACJI UŻYTKÓW ZIELONYCH METODĄ PEŁNEJ UPRAWY NA GLEBIE ORGANICZNEJ

Department of Soil Science, Grassland Science and Environmental Chemistry, West Pomeranian University of Technology, Szczecin, Poland
[1]Landesforschungsanstalt fűr Landwirtschaft und Fischerei MV in Dummerstorf, Germany
[2]Department of Agronomy, West Pomeranian University of Technology, Szczecin, Poland

Streszczenie. Badania przeprowadzono w dolinie rzeki Randow, na użytkach zielonych należących do gospodarstwa rolnego Raminer Agrar GmbH&Co (Niemcy). Odnowę użytków zielonych, zlokalizowanych na glebie organicznej, przeprowadzono metodą pełnej uprawy. Badaniami objęto mieszanki z dominującym udziałem *Festuca arundinacea.* Ocena obejmowała charakterystykę składu florystycznego, zadarnienie i ogólny wygląd runi łąkowej, poziom plonowania i równomierność produkcji biomasy w sezonie wegetacyjnym. Średnie wyniki z lat badań (2012, 2013 i 2015) wykazały, że zastosowane mieszanki odznaczały się zbliżonym poziomem plonowania, chociaż należy wyróżnić mieszankę *Festuca arundinacea* z *Dactylis glomerata* – po 50%; na uwagę zasługuje także mieszanka *Festuca arundinacea* z *Lolium perenne.* Jeżeli chodzi o ocenę odmian *Festuca arundinacea* ('Lipalma', 'Koral', 'Hykor', 'Fawm'), to największym potencjałem produkcyjnym odznaczała się odmiana 'Hykor'. Do wielokośnego użytkowania runi łąkowej nawet pięciokrotnie mniej przydatne są *Festuca pratensis* i *Phleum pratense*. Uzyskane wyniki wskazują, że *Festuca arundinacea* nadaje się do regeneracji użytków zielonych na glebach organicznych, przy stosowaniu w mieszankach z *Dacylis glomerata*, *Lolium perenne* i *Festulolium.*

Key words: organic soil, grass mixtures, yields, regeneration by full cultivation method, floristic composition, grassland.
Słowa kluczowe: gleba organiczna, mieszanki trawiaste, plony, regeneracja metodą pełnej uprawy, skład florystyczny, użytek zielony.

INTRODUCTION

The structure of meadow communities determines the production potential and quality of feed (Grzegorczyk 1993; Trąba 1994). Floristic composition on hydrogenic soils, e.g. peat-muck, is characterized by dynamic succession (Baryła 1997; Kamiński 2000).

Corresponding author – Adres do korespondencji: Henryk Czyż, Department of Soil Science, Grassland Science and Environmental Chemistry, West Pomeranian University of Technology, Szczecin, Juliusza Słowackiego 17, 71-434 Szczecin, Poland, e-mail: Henryk.Czyz@zut.edu.pl

Based on the studies conducted by Baryła and Kulik (2012), besides *Dactylis glomerata*, *Lolium perenne*, *Festulolium braunii* and *Phleum pratense*, also *Festuca pratensis* and *Festuca arundinacea* are suitable for regeneration mixtures in appropriate meadow habitats. Petersen (1981); Schmaler and Barthelmes (2015), as well as Troxler and Mitztal (1983) argue that different varieties of *Festuca arundinacea* are characterized by good winter-hardness and high resistance to unfavorable habitat conditions. This is confirmed by studies of Suter et al. (2009), who reported usefulness of *Festuca arundinacea* under variable climatic conditions of Switzerland and concluded that it can be an important ingredient in grass mixtures on intensively utilized pasture. Nussbaum (2015) and Niemeläinen et al. (2001) found that *Festuca arundinacea* is a species of high yielding, but not demanding. In opinion of Nussbaum (2015), due to well developed root system, it tolerates periods of drought and low temperatures and is suitable for habitats with varying humidity balance. Schubiger et al. (1997) highlight the low interest in this species in practice due to the high content of silica and hardness of its leaves.

The purpose of the study was to determine the suitability of *Festuca arundinacea* for regeneration mixtures on grassland located on organic soils.

MATERIAL AND METHODS

The meadow study carried out on grasslands located on the organic soils in the Randow river valley covered the years 2012, 2013 and 2015. In 2011, the grassland in question, which belonged to the farm Raminer Agrar GmbH & Co (Germany), was regenerated by the full cultivation method. The meadow experiment was established by split-block method in four replicates. The area of a single plot was 10 m^2. Following grass species were used to regenerate the grasslands: tall fescue (*Festuca arundinacea*), *Festulolium braunii*, perennial rye-grass (*Lolium perenne*), Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), timothy-grass (*Phleum pretense*), and meadow fescue (*Festuca pratensis*). Composition of the grass mixtures used for sowing in the individual experiments is shown in Table 1. Pratotechnical treatments performed within this method frameworks included: spraying with Roundup herbicide, plowing at a depth of 25 cm, rolling, surface treatment, grass seed sowing – first decade of September 2011, post-seeding rolling. No fertilization was used before sowing. In the years of full performance, the following treatments were carried out: dragging, rolling, fertilizing, and mowing. The collected biomass was allocated to hay-silage. In the first year of use (2012), three cuts were harvested, in the second year (2013) – four cuts, and in the fourth year (2015) – five cuts.

Meadow sward was harvested in the shooting / earing beginning phase at triple harvest, and from the end of the tillering to the end of shooting – at five harvests. At the time of spring treatments – dragging and rolling, the multi-constituent fertilizer was applied – NPK (MgS) – (5–16–24 – (4–7)), that introduced to the soil: 15 kg N, 21 kg P, 60 kg K, 7 kg Mg, and 21 kg S per 1 ha. In addition, 72 kg · ha^{-1} N was used in the form of ammonium nitrate and urea (AHL). For the second cut, nitrogen rate was 65 kg · ha^{-1}, while for the third one – 36 kg · ha^{-1} N, also in form of AHL; in the case of four cuts, 36 kg · ha^{-1} N was used for the third cut and 36 kg · ha^{-1} N for the fourth one. In the last year of study (2015) 65 kg of nitrogen was

applied in spring in the form of AHL, along with 140 kg · ha^{-1} of DAP fertilizer (18% N, 46% P_2O_5) and 300 kg · ha^{-1} KornKali (40% K_2O, 6% MgO, 3% Na, 4% S). After harvest of the first cut, KornKali was applied at the rate of 250 kg · ha^{-1} in combination with AHL – 180 dm^3 · ha^{-1}. After second cut, fertilization referred only to nitrogen, the rate of which was 54 kg · ha^{-1} N, in the form of AHL. The floristic composition of each plot (4 replicates) was assessed by botanical-weight method (Filipek 1970). Floristic composition of the first cut was presented as the results in the other cuts were similar. Dry matter content in meadow sward was determined by sampling 1 m^2 in each replicate during the harvest of the individual cuts. The product of green matter yield and dry matter content was the yield of dry matter. The dry weight yields were statistically analyzed using a classical variance analysis and the significance of the variance was determined using the Tukey test at the significance level $p \leq 0.05$.

Characterizing the water conditions of meadow habitats in the area of conducted research, it should be stated that rain water and groundwater was only available for plants. In the vegetation periods (IV–X) of the studied years, the highest rainfall (370.4 mm) was recorded in 2012, then 311.3 mm in 2013, while the lowest (305.5 mm) – in 2015. Referring to the multi-year average (378.9 mm), similar value was found in 2012. Regarding the distribution of precipitation in the growing seasons, year 2012 was comparable to the multi-year period, and 2015 was the most different one. When estimating the level of groundwater, it should be noted that the greatest amplitude (0–76 cm) was recorded in 2012, and the smallest (45–88 cm) – in 2015.

RESULTS AND DISCUSSION

The pattern of results showing the meadow grass species structure indicates that it depended on the composition of mixtures used for sowing the individual objects. It is important to note the very small proportion of species spontaneously entering the meadow sward, and sporadically occurring species were *Poa trivialis*, *Poa pratensis*, *Festuca rubra*, *Agrostis stolonifera*, *Agropyron repens*, and *Taraxacum officinale*. The individual objects exhibited high floral stability during the study period (2012–2015), although the most labile species was *Lolium perenne*. In object 7, which was sown with only two species in equal proportions – *Festuca arundinacea* and *Lolium perenne* – 50% each, a decrease in *Lolium perenne* share for the surplus *Festuca arundinacea* was observed. The share of *Lolium perenne* decreased from 50% in 2012 to 28% in 2015. In object 6, where *Festuca arundinacea* made up 30% and *Lolium perenne* 70% in the regenerative mixture, these relations were at the assumed level of 67% *Festuca arundinacea* and 31% *Lolium perenne* in the fourth year of full performance. A similarity was found for the object 12 sown with the mixture 70% *Festuca arundinacea* and 30% *Lolium perenne*; in the last year of the study (2015), the proportion of these species in the sward was 71% and 27%, respectively. If the share of *Lolium perenne* was small (5–10%), it was not subject to change in the individual years of the study. The data presented show that the succession was aimed at shaping a certain ratio between *Festuca arundinacea* and *Lolium perenne*. The results confirming great durability of *Festuca arundinacea* in post-bog habitats were reported by Grzegorczyk et al. (1995). The

results pattern (Table 1) indicates that *Lolium perenne* occurring in the community along with *Dactylis glomerata* and *Festuca arundinacea* is highly competitive and is a "filler" in the thickening of the sward.

Table 1. Floristic composition of meadow sward in the years 2012, 2013, 2015
Tabela 1. Skład florystyczny runi łąkowej w latach 2012, 2013, 2015

Objects Obiekty	Species Gatunki	Share in the mixture Udział w mieszance [%]	Share in the sward Udział w runi [%]		
			2012	2013	2015
1	*Festuca arundinacea* ('Lipalma')	100	99	100	97
	Other species – Inne gatunki		1	0	3
2	*Festuca arundinacea* ('Kora')	100	100	100	99
	Other species – Inne gatunki		0	0	1
3	*Festuca arundinacea* ('Hykor')	100	100	100	99
	Other species – Inne gatunki		0	0	1
4	*Festuca arundinacea* ('Fawn')	100	100	100	99
	Other species – Inne gatunki		0	0	1
5	*Festuca arundinacea*	20	22	28	33
	Festuca pratensis	40	39	37	36
	Phleum pratense	20	18	16	14
	Lolium perenne	20	21	19	17
6	*Festuca arundinacea*	30	43	77	67
	Lolium perenne	70	56	22	31
	Other species – Inne gatunki		1	1	2
7	*Festuca arundinacea*	50	48	68	69
	Lolium perenne	50	52	32	28
	Other species – Inne gatunki		0	0	3
8	*Festuca arundinacea*	50	46	39	43
	Festulolium braunii	50	54	61	51
	Other species – Inne gatunki		0	0	6
9	*Festuca arundinacea*	50	63	44	45
	Dactylis glomerata	50	36	54	52
	Other species – Inne gatunki		1	2	3
10	*Festuca arundinacea*	50	66	42	45
	Dactylis glomerata	45	26	52	43
	Lolium perenne	5	6	6	10
	Other species – Inne gatunki		0	0	2
11	*Festuca arundinacea*	70	67	76	67
	Phleum pratense	20	25	16	18
	Poa pratensis	10	8	8	13
	Other species – Inne gatunki		0	0	2
12	*Festuca arundinacea*	70	85	74	71
	Lolium perenne	30	15	26	27
	Other species – Inne gatunki		0	0	2
13	*Festuca arundinacea*	80	71	82	76
	Lolium perenne	20	29	18	21
	Other species – Inne gatunki				3
14	*Festuca arundinacea*	90	88	89	84
	Lolium perenne	10	12	11	13
	Other species – Inne gatunki		0	0	3
15	*Festuca pratensis*	50	36	48	41
	Phleum pratense	30	38	29	32
	Lolium perenne	20	26	23	26
	Other species – Inne gatunki		0	0	1

The high competitiveness of *Lolium perenne* in relation to the aggressive *Dactylis glomerata* is indicated by Grzegorczyk and Trąba (2003). The obtained results do not support the opinion that *Lolium perenne* is a species that is not suitable for meadow mixtures on peat-muck soils (Kowalczyk et al. 1991). Baryła (2004) studies show that *Lolium perenne* plays an important role in maintaining the stability of the community with *Festuca*

arundinacea, *Dactylis glomerata* and *Phleum pratense*. Evaluating the relation between *Festuca arundinacea* and *Festulolium* (object 8), it should be noted that the proportion of these species in the sward was appropriate for the composition of the regeneration mixture and remained at a similar level in all years of the study. Such a system of results testifies to the greater competitiveness of *Festulolium* as compared to *Lolium perenne*. A similar pattern was found in previous studies (Czyż et al. 2015).

The harvested meadow sward from individual objects was characterized by similar content of dry matter, thus the study was limited to dry matter content only (Table 3). In the first year of the full performance (2012), in which three cuts were harvested, their share in the annual yield was as follows: I – 29.7%, II – 26.3%, III – 44.1%, in the second year of the full use, with the four-time mowing of the meadow sward, the individual cuts made up: I – 38.1%, II – 20.1%, III – 29.7%, IV – 12.6% of annual yield, and in the case of five-time mowing, which took place in 2015, the share of cuts was as follows: I – 27.4%, II – 17.3%, III – 22.2%, IV – 13.5%, V – 19.5% of the annual yield. Mean values from the objects indicate that annual yields of dry matter increased along with the number of cuts harvested (Table 2). In the case of three cuts (first year of the full performance – 2012), average yield was 14.19 t · ha^{-1}. In the second year of use (2013), when four cuts were harvested, yields of 15.82 t · ha^{-1} were achieved, and in the fourth full year of use (2015) with 5 times of meadow mowing, the average annual yield of dry matter was 18.11 t · ha^{-1}. Schmaler and Barthelmes (2012), when comparing the yielding of *Festuca arundinacea* and *Dactylis glomerata* in two mowing performance systems, recorded higher yield of dry matter with lower number of cuts than at higher mowing frequencies. In later studies, Schmaler and Barthelmes (2015) compared the yielding of *Festuca arundinacea* on a three times mowed meadow at a delayed harvest of the first crop, with a four-mowing meadow, and they found higher yield in the first cut, as well as annual yield of dry matter. In the case of three harvests, the share of cuts in the annual yield was: I – 62%, II – 16%, III – 22%, and at fourfold: I – 31%, II – 31%, III – 11%, IV – 27%.

The authors report that on a three times mowed meadow, the obtained annual yield amounted to – 8.5 t · ha^{-1} DM and on a four times mowed meadow – 7.5 t · ha^{-1}. In our own research, *Festuca arundinacea* was also characterized by great production potential. When harvesting three cuts, the second species, besides *Festuca arundinacea*, was *Dactylis glomerata*. In the year, in which four cuts were harvested (2013), objects with a high proportion of *Festuca arundinacea* and *Lolium perenne* were distinguished. In the case of five-mowing (2015), objects sown both with *Festuca arundinacea* with *Lolium perenne* and *Festuca arundinacea* with *Dactylis glomerata* should be distinguished. Such a pattern of results allows for positive assessment of *Festuca arundinacea* with *Lolium perenne* and *Festuca arundinacea* with *Dactylis glomerata* mixtures. Detailed analysis of the relationship between floristic composition of the meadow sward and the level of yielding, it should be stated that on objects sown with *Festuca arundinacea* only in all years of research, object sown with Hykor cv. was characterized by the highest yield-forming potential. In objects sown with grass mixtures in the first year of the study, objects with a high proportion of *Festuca arundinacea* and *Dactylis glomerata* were exceptional – object 9 (*Festuca arundinacea* 63% + *Dactylis glomerata* 36%) and object 10 (*Festuca arundinacea* 66%, *Dactylis glomerata* 26% and *Lolium perenne* 6%). In 2013, objects 12 and 14 gave the highest yields – 17.31 t · ha^{-1} and 17.05 t · ha^{-1}, respectively (Table 2).

Table 2. Dry matter yields
Tabela 2. Plony suchej masy [t · ha^{-1}]

Years Lata	Cuts Pokosy	Number of mixtures Numery mieszanek															Mean Średnia	$LSD_{0.05}$ $NIR_{0,05}$
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
2012	1	4.31	4.63	4.33	4.61	4.06	3.59	3.79	4.23	3.99	3.88	5.32	4.12	3.94	4.37	4.13	4.21	r.n.
	2	3.29	3.59	3.57	3.02	3.45	3.91	4.07	4.10	3.78	4.25	3.66	3.70	3.69	3.56	4.26	3.73	r.n.
	3	6.18	5.61	6.64	5.35	5.60	6.60	6.88	6.31	7.78	7.78	5.88	5.74	6.19	6.19	5.06	6.25	2.42
	Total Razem	13.78	13.78	14.54	12.97	13.11	14.09	14.73	14.64	15.55	15.92	14.86	13.56	13.72	14.12	13.45	14.19	r.n.
2013	1	5.93	5.86	6.37	5.58	5.61	5.50	5.68	5.96	6.57	6.42	7.00	6.35	6.79	6.61	4.27	6.03	2.22
	2	3.29	3.53	3.06	3.36	2.75	3.33	3.32	3.26	3.16	3.12	3.10	3.36	3.25	3.05	2.72	3.18	r.n.
	3	4.39	4.41	5.02	3.51	4.42	5.52	4.38	4.67	4.42	4.41	4.69	5.58	4.56	5.21	4.17	4.62	0.21
	4	2,29	2.10	2.07	1.95	1.89	2.04	1.93	1.72	1.97	1.77	1.98	2.02	2.19	2.18	1.72	1.99	0.53
	Total Razem	15.90	15.90	16.52	14.40	14.67	16.39	15.31	15.61	16.12	15.72	16.77	17.31	16.79	17.05	12.88	15.82	3.17
2015	1	4.76	4.72	4.87	4.93	4.98	4.55	4.96	5.06	5.72	5.09	4.87	5.33	5.26	5.35	4.15	4.97	r.n.
	2	2.76	3.14	2.62	2.29	2.80	3.33	3.12	3.15	3.13	3.39	3.41	3.26	3.45	3.25	3.94	3.14	1.30
	3	3.90	4.01	4.02	3.75	3.87	4.08	4.30	4.17	4.12	3.94	4.20	3.91	4.64	3.94	3.35	4.01	r.n.
	4	2.41	2.69	2.68	2.32	2.34	2.68	2.39	2.36	2.45	2.38	2.45	2.36	2.47	2.39	2.34	2.45	r.n.
	5	3.89	3.57	3.97	4.14	3.10	3.74	3.06	2.97	4.04	3.75	2.99	2.84	3.79	3.67	3.61	3.54	0.23
	Total Razem	17.72	18.13	18.16	17.43	17.09	18.38	17.83	17.71	19.46	18.55	17.92	17.70	19.61	18.60	17.39	18.11	2.61
Mean Średnia		15.80	15.94	16.41	14.93	14.96	16.29	15.96	15.99	17.04	16.73	16.52	16.19	16.71	16.59	14.57	16.04	2.17

r.n. – not significant difference – różnica nieistotna.

These objects were sown with *Festuca arundinacea* and *Lolium perenne* (Table 1). The lowest yield (12.88 t · ha^{-1}) was obtained in object 15, where three species were present in the sward: *Festuca pratensis* 48%, *Phleum pratense* 29% and *Lolium perenne* 23%. The lowest yields on that object were obtained in the first, second and fourth cut (Table 2). In the fourth year of the full use (2015), objects 9 and 13 were distinguished, with *Festuca arundinacea* 45% and *Dactylis glomerata* 52% (object 9) as well as *Festuca arundinacea* 76% and *Lolium perenne* 21% (object 13). In these objects, dry matter yields were: 19.46 t · ha^{-1} and 19.61 t · ha^{-1}. In general, that year, the yield variation between various objects ranged from 17.39 t · ha^{-1} in object 15 sown with the mixture: *Festuca pratensis* 50% + *Phleum pratense* 30% + *Lolium perenne* 20%, up to 19.61 t · ha^{-1} in object 13 sown with *Festuca arundinacea* 80% + *Lolium perenne* 20%.

The average results from three years of the study covering the first, second and fourth year of the full performance indicate that on the organic soil, the highest yield potential was found for grassy mixtures with *Festuca arundinacea*, of which the regenerate mixture – *Festuca arundinacea* with *Dactylis glomerata* – 50% each, was distinguished. In this object, the average yield of dry matter (from three years of study) was 17.04 t · ha^{-1}. Also in objects sown with *Festuca arundinacea*, satisfactory yields were obtained, and Hykor cv. deserves a distinction, for which the average yield of dry matter was 16.41 t · ha^{-1}. The lowest yields, especially in the years with four and five-time mowing of the sward, were obtained on the object 15 sown with a mixture of *Festuca pratensis* with *Phleum pratense* and *Lolium perenne* (Table 1). Gregis and Reidy (2015), when studying the suitability of *Festuca arundinacea* of Belfine cv. for intensive pasture use during the five years of experiment (2008–2012) in the Swiss production farms, found that it is a stable species and suitable for sowing, especially in sites with less rainfall. Although its share in the sward was reduced after 5 years of use to about 50–57% depending on the pasture, it was much larger than that of *Lolium perenne*, the share of which in the sward dropped to 33% under the same production conditions. Mosimann et al. (2010) investigating the growth and development of *Lolium perenne* containing grass mixtures, as compared to *Festuca arundinacea* mixtures, reported similar increases in animal weight, indicating the good suitability of *Festuca arundinacea* for pasture performance. Similar results were obtained by Elsäßer et al. (2015), who compared the grassland mixtures with *Dactylis glomerata* and *Festuca arundinacea*. The feed uptake by cattle from plots with *Festuca* was very similar to *Dactylis* plots, and even soft-leaf varieties of *Festuca arundinacea* were more readily grazed. Schrabauer et al. (2014), when examining the yields of 10 species of grasses resistant to periodic drought (including *Festuca arundinacea*) with other fodder grass species sown in pure sowing in two habitats in the lowlands of the Danube river and the Alps grasslands, found that the highest yield among tested species at many-harvest performance was produced by *Festuca arundinacea* (average for both habitats of 12.5 t · ha^{-1} DM) with very low secondary succession of other species (only 0.1%).

CONCLUSIONS

1. By characterizing the objects sown with single varieties (‘Lipalma’, ‘Kora’, ‘Hykor’, ‘Fawm’) of *Festuca arundinacea*, based on the stability of the floristic composition and uniformity of biomass production during the growing season, it can be stated that *Festuca arundinacea* is useful for establishing the multi-cut grasslands on organic soils.

2. Shaping the yielding level in the studied years (2012, 2013 and 2015) allows to asses that *Festuca arundinacea* with *Dactylis glomerata*, or *Lolium perenne* and *Festulolium* are more effective than *Festuca pratensis* with *Phleum pratense* and *Lolium perenne*.
3. Average results from years of the study indicate that under existing habitat conditions, the greatest production potential was shown by the mixture of *Festuca arundinacea* (50%) + + *Dactylis glomerata* (50%) and in objects with *Festuca arundinacea* only, the highest yield was obtained due to Hykor cv.

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Abstract. The study was carried out in the Randow river valley, on grassland belonging to the farm – Raminer Agrar GmbH & Co (Germany). Restoration of grassland located on organic soil, was carried out using the full cultivation method. The study included mixtures with the predominant participation of *Festuca arundinacea*. The assessment included the characteristics of floristic composition, sodding, and general appearance of meadow sward, level of yielding, and uniformity of biomass production during the growing season. The average results from the years of research (2012, 2013 and 2015) showed that the applied mixtures were similar in terms of yield, although the mixture of *Festuca arundinacea* with *Dactylis glomerata* – 50% each, and the mixture of *Festuca arundinacea* and *Lolium perenne* – should be distinguished. Of the studied varieties, *Festuca arundinacea* ('Lipalma', 'Kora', 'Hykor', 'Fawm'), the greatest production potential characterized the Hykor cv. *Festuca pratensis* and *Phleum pratense* appeared to be less useful for multi-cutting management. Overall results show considerable usefulness of *Festuca arundinacea* in mixtures with *Dactylis glomerata*, *Lolium perenne* and *Festulolium* for the regeneration of grassland on organic soils.