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Dry matter yield of pure and mixed stands of perennial rye (Secale cereale x S. montanum) and alfalfa or bird's-foot trefoil

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ABSTRACT

The objective of this research was to study the possibility of increasing the vegetative production of perennial rye by association with alfalfa (*Medicago sativa L.*) or bird's-foot trefoil (*Lotus corniculatus L.*) on the acid sandy soil of Nyírség in Hungary. Mixed stands were sown with different perennial rye density in autumn and spring, and the mowing technology was adapted to leguminous species. This study has revealed that it was suitable for perennial rye to be grown with perennial legumes and to increase its DM production in mixed stands, but the success of this association depended on several different conditions such as the sowing date, the rate of the components and the number of annual harvests. The cumulated forage yields of all mixed treatments were higher compared to the control pure perennial rye stands. From the aspect of perennial rye dry matter productivity and persistence, the most favourable treatment was the association of bird's-foot trefoil and perennial rye at the highest rate at autumn sowing, where the cumulative DM production of perennial rye in the two years was above the standard. This type of association of perennial cereal and legumes proved to be the most suitable one for the exploitation of the arable soil with adverse conditions.

Keywords: perennial rye, alfalfa, bird's-foot trefoil, forage yield

INTRODUCTION

The key issue of a profitable feed production on marginal arable lands is the cultivation of plant species which have excellent ecological flexibility and good vegetative production. Growing mixed stands of grasses and forage legumes have more advantages compared to pure stands. One of the principal advantages under adverse growing conditions is the wide ecological adaptability of the association of the two forage crops which results in increasing the safety of feed production. It is possible to increase the forage quality and quantity with mixed stands of grass and legume from the same area.

Perennial forage crops which can be grown on loose sandy soil with little organic matter usually yield low vegetative and grain production. Perennial rye is a new forage crop with high vegetative yield for low input farming on marginal arable lands. This plant is an interspecific hybrid of annual cultivated rye (*Secale cereale L.*) and perennial mountain rye (*S. montanum Guss.*), which is a native wild species in southern Europe, Morocco, Iran and Iraq (*De Bustos and Jouve* 2002). There have been several former attempts to create a cultivated perennial rye from these parent species, but the low perenniality and the problems with the fertility of the hybrids were obstacles to their spreading (*Stutz* 1957, *Reimann-Philipp and Gordon-Werner* 1984, *Cox et al.* 2002). *Kotvics et al.* (2001) were successful in creating a perennial rye population of adequate fertility and good perenniality, and after a selection process two new perennial rye varieties of interspecific hybrid origin were registered in Hungary (*Füle et al.* 2005).

Perennial rye promotes the effective use of spring moisture due to early growth in the spring; it is highly competitive with weeds and produces significant regrowth that can be used for silage or pasture. Its extensive fibrous root system can be used to improve soil tilth, increase soil organic matter levels and protect soil from erosion and deflation (*Acharya et al.* 2004). Besides these advantages *Oram* (1996) cautioned about the possible contamination of perennial rye by the cultured annual rye varieties, because both species are commonly grown under the same poor soil conditions which are insufficient for other cereals. Perennial rye can cross-pollinate cereal rye to such an extent that improved rye cultivars lose their identity quickly.

Some more ways of utilization of perennial rye were investigated: it can be used for food (*Reimann-Philipp* 1995, *Füle et al.* 2005), green forage (*Acharya et al.* 2004, *Füle et al.* 2004), and energy plantation (*Scholz et al.* 2004) in pure stand or associated with other species.

Perennial rye in pure and mixed stands was examined as a possibility of preserving marginal arable lands in Germany and described the competition on dry matter production in two-component-mixture stands of perennial grain crops (*Weik et al.* 2001). According to Reimann-Philipp, mixed culture with forage legumes may be profitable with emphasis on silage, particularly in dry areas where grasses are inferior (*Reimann-Philipp* 1995).

Füle analysed the quality and quantity of green and dry mass production of perennial rye and determined the optimum cutting period in Hungary (*Füle et al.* 2004). Previously we determined the potential forage production of perennial rye in pure stands with a different number of seeds sown on the two soil types. In this project the following questions were to be studied in pure and different mixed stands:

- Is it possible to increase the vegetative production of perennial rye by association with alfalfa (*Medicago sativa L.*) or bird's-foot trefoil (*Lotus corniculatus L.*)?
- How does the dry matter yield of perennial rye and legume species change in the course of years in spring and autumn sown experiments?
- What number of perennial rye germs need to be sown with legumes to create suitable mixed stands?
- Is the cropping technology of legume species suitable for cultivating mixed stands?

MATERIALS AND METHODS

The field experiment was conducted from 2008 to 2009 at the University of Debrecen, Research Institute of Nyíregyháza, Breeding Station in Kisvárda (48°14.14' N, 22°06.79' E; 106 m). While the average temperature is 10.63 °C, winter lows of -12 to -15 °C are not uncommon and summer highs of 38.3 °C have been recorded. The average annual precipitation is 604 mm. Soil at the site was an acid sandy soil with pH of 6.37

(H_2O) and 0.61% organic matter. Rainfall and temperature records in the vicinity were obtained from Micro Metos automatic weather station (Pessl Instruments) during the study (*Figure 1*).

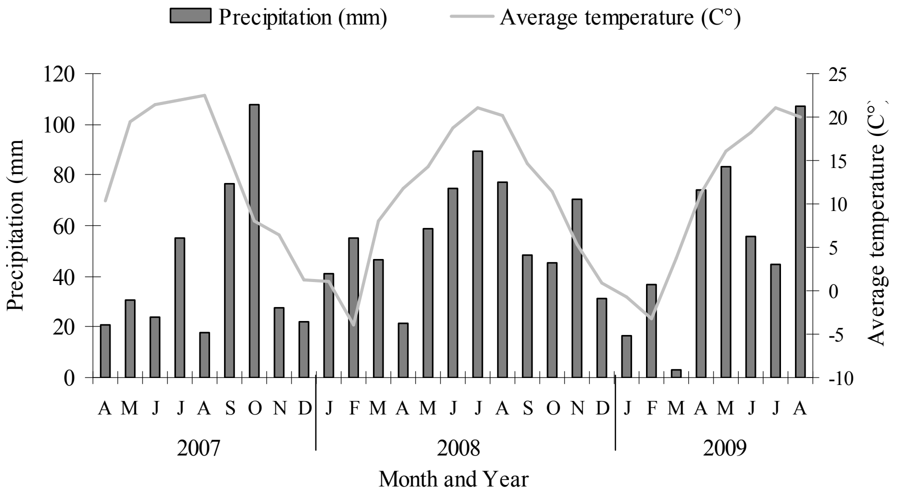

Figure 1. Summary of monthly precipitation and the mean monthly temperature during the experimental period (Apr 2007 - Aug 2009) in Kisvárda.

Experimental plots were 1.6 m × 9.2 m and were surrounded by 1 m borders. Two perennial leguminous forage species were individually sown mixed with perennial rye and compared with a perennial rye control. Treatments arranged in a randomised complete block design with 4 replicates. All treatments were repeated in the same plots in 2007 spring and autumn. The perennial leguminous were alfalfa (*Medicago sativa L.*) *cv. Hunor-40* and bird's-foot trefoil (*Lotus corniculatus L.*) *cv. Szabolcsi-1*. Perennial rye *cv. Kriszta* was sown at 0.4-2.7 million germ/ha, alfalfa at 3.2 million germ/ha and bird's-foot trefoil at 3.6 million germ/ha (*Table 1*).

The seeds of perennial rye and leguminous were mixed and sown by Wintersteiger plot seeders on 02 April and 22 August 2007.

Some fertiliser (68 kg/ha N, 40 kg/ha P_2O_5 and 90 kg/ha K_2O) and chalk powder were broadcast onto the plots before preparing seedbed, and an additional 51 kg/ha N in early April 2008 and 2009. Broadleaf weeds growing in the plots were controlled by hand weeding.

Table 1. Composition of treatments in the experiments

Number of treatment	Perennial rye	Alfalfa	Bird's-foot trefoil
	million germ/ha		
1	2.7	-	-
2	1.4	3.2	-
3	0.7	3.2	-
4	0.4	3.2	-
5	1.4	-	3.6
6	0.7	-	3.6
7	0.4	-	3.6

The first spring harvest was before perennial rye started to develop seed stalks, because after this process perennial rye can regenerate with some difficulties. Other harvests were timed to the beginning of flowering of leguminous. Four cuts were made in 2008, and three in 2009 because of the lower precipitation in June and July of the second year.

The samples for botanical composition were taken in a 1 m^2 quadrate per plot by hand-clipping and they were hand-separated into components of perennial rye and individual leguminous species. The separated components were oven-dried at 100 ^oC for weight stability to estimate the perennial rye and leguminous species proportions on a dry matter basis.

The experiment was mowed by hand and the yield was measured on the whole parcel. The fresh material was weighed and fresh forage samples (0.3 kg) were collected, dried at 100 ^oC for the weight stability and weighed to determine dry matter yields.

Cumulative dry matter (DM) yields were calculated for sequential harvests during the whole year. The analysis of the variance for DM yield was performed using the statistical package „SPSS 11.5."

RESULTS

Spring sown experiment

The spring sown perennial rye was not induced to flower because of a period of cold but stayed in the vegetative growth stage. Its yield was good only for grazing so we did not quantify it in the first year (2007). In 2008 perennial rye yielded 7.61 t dry matter (DM)/ha for three harvests and in the following year (2009) 6.22 t DM/ha for two harvests on the control parcels (*Figure 2*). 53.2-53.6% of its annual DM production was given by the first harvest.

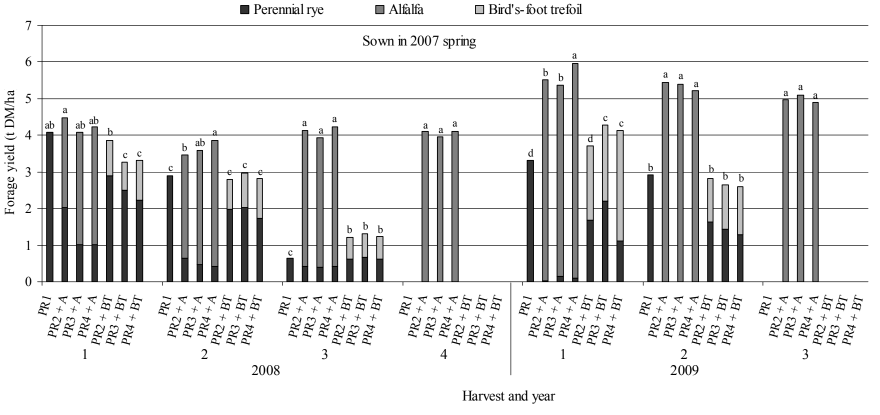

Figure 2. Dry matter (DM) yields from harvests in both years from the perennial rye control plots and perennial rye plots mixed with alfalfa or bird's-foot trefoil in the spring sown experiment. The bars with different letters were significantly different (P<0.05) regarding the forage yield.

For the mixtures with alfalfa, the DM yield of leguminous was dominant every harvest, in 2008 80.9-88.6% and in 2009 99.0-99.8% of the available forage was from alfalfa. In the first year perennial rye yielded 1.87-3.09 t DM/ha in these compositions and 0.03-0.15 t DM/ha in the second year. By the end of 2009, all of the mixed plots were virtually of alfalfa pure stand. The forage yield of perennial rye in the treatment sowing 1.4 million germ/ha (No. 2) (*Table 1*) was twofold that of the other treatments with a lower number of sowing germs (No. 3 and 4) during the first harvest in 2008, but later the differences between the perennial rye production in all mixed treatments containing alfalfa were not so noticeable (P>0.05). The differences between the cumulated DM yields of compositions with alfalfa were generally minimal and not significant (*Figure 3*).

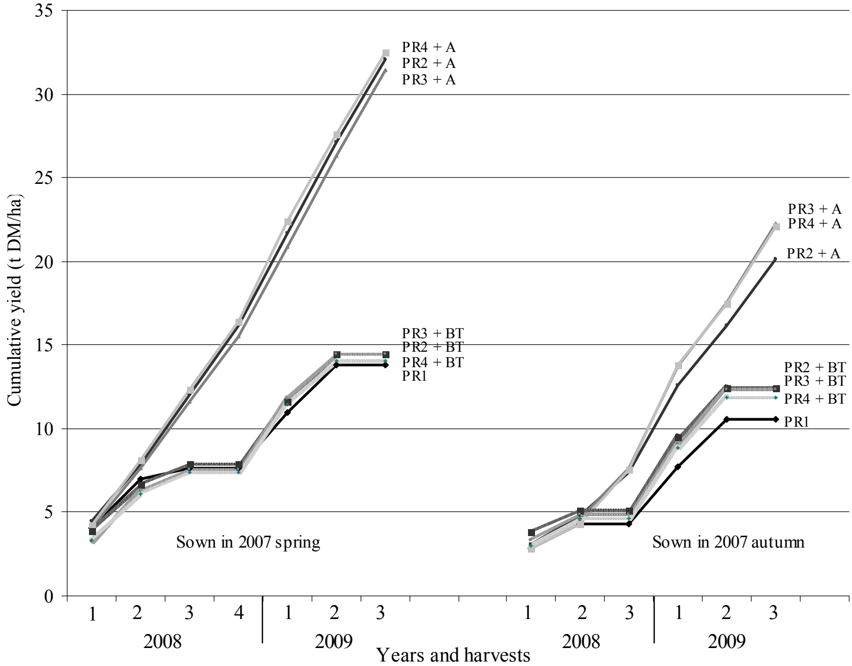

Figure 3. Cumulative forage dry matter (DM) yields over 6 or 7 harvests for perennial rye plots (control) and mixed plots with alfalfa and bird's-foot trefoil.

Perennial rye yielded 4.56-5.49 t DM/ha in 2008 and 2.41-3.64 t DM/ha in 2009 in compositions mixed with bird's-foot trefoil (No. 5, 6, 7). The rate of the forage yield of perennial rye and leguminous was 66.9:33.1 in the first and 46.4:53.6 in the following year. During the first harvests of both years there were intrinsic differences (P<0.05) among the treatments with a various number of sowing germs of perennial rye. The differences between the cumulated DM yields of compositions containing bird's-foot trefoil were not considerable.

Compared to the total forage yields of all treatments, over-yield of compositions with alfalfa were 127.5-134.9% and the compositions with bird'-foot trefoil were 1.5-4.3% according to the control parcels, but latter differences were not significant (*Figure 3*).

Autumn sown experiment

Perennial rye control parcels yielded 4.29 t DM/ha in 2008 and 6.28 t DM/ha in 2009 from two harvests in both years (*Figure 4*). 54.5-65.7% of its annual DM production was given by the first harvest.

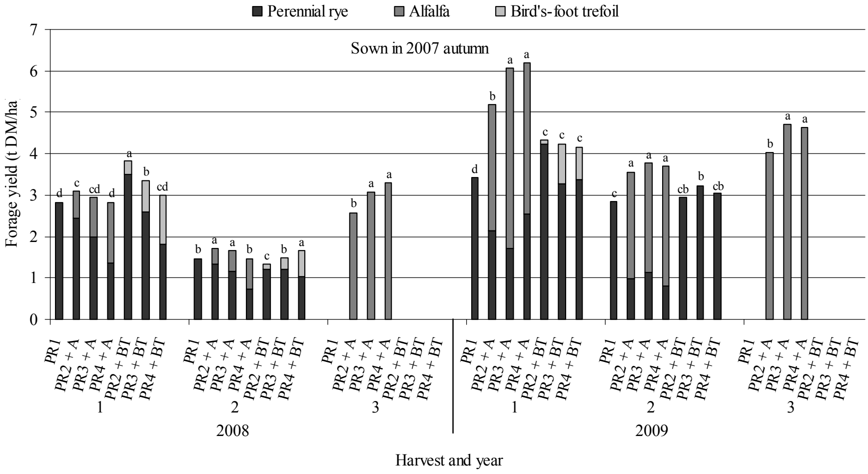

Figure 4. Dry matter (DM) yields from harvests in each of the 2 years from the perennial rye control plots and perennial rye plots mixed with alfalfa or bird's-foot trefoil in the autumn sown experiment. Bars with different letters were significantly different (P<0.05) regarding the forage yield.

Mixed plots with alfalfa yielded a mixture of leguminous and perennial rye at the first and second harvests and only alfalfa at the third harvest each year. In the first year, perennial rye yielded 2.11-3.76 t DM/ha in these compositions and 2.86-3.36 t DM/ha in the second year. In all harvests in the first year and the first harvest in the second year we found significant differences between the DM yields of perennial rye from parcels with different sowing germs (treatments No 2, 3, 4). The rate of the forage yield of alfalfa in these treatments was 49.03-72.19% in 2008 and 75.50-80.35% in 2009. The cumulated DM yield of the treatment with the least sown perennial rye (0.4 million germ/ha) was lower than the produce of other treatments containing alfalfa (P<0.05) (*Figure 3*).

Perennial rye yielded 2.84-4.73 t DM/ha in 2008 and 6.41-7.19 t DM/ha in 2009 mixed with bird's-foot trefoil (No. 5, 6, 7). During the first harvests in both years there were remarkable differences between perennial rye productions of these treatments; the parcels with higher sowing-density yielded more DM than the lower sowing-density. However, the differences between the total yields of treatments containing bird's-foot trefoil were small, because the production of leguminous compensated for the decreasing yield of perennial rye, except the first mowing in the experiment. Comparing all the mixtures, the cumulative total DM yields were consistently higher in the mixed plots with alfalfa (190.9-210.4%) than in the perennial rye control treatments (100%) and in the mixed plots with bird's-foot trefoil (114.0-117.7%) (*Figure 3*).

DISCUSSION

On the basis of *Weik*'s results, using grain crop mixtures of grasses and legumes seem to be the most promising for the cultivation on marginal lands (*Weik* 2002). Our study has revealed that it was suitable for perennial rye to be grown with perennial leguminous and to increase its DM production in mixed stands, but the success of this association depended on several different conditions such as the sowing season, the rate of the components and the number of annual harvests.

Perennial rye sown in the spring could not be mown during the first year because a period of low winter temperature is needed to extend its stems and then to begin reproductive phase. Alfalfa and bird's-foot trefoil are usually planted successfully in the spring under local climatic conditions, and so the sowing time in April was more favourable for them. Spring sown legumes strengthened and filled the increased habitat and yielded more than the plants sown in the autumn. Perennial rye was played down mainly by alfalfa and its forage yield decreased significantly in mixed treatments compared to pure stands in the control parcels. The sowing time in late August was more prosperous for perennial rye. Due to its drought tolerance it came up quickly and tillered in the autumn. In addition, leguminous came up more slowly from the dry seed-bed and then grew up haltingly under cold weather conditions, so the volume of perennial rye in the total DM production was higher than the one sown in the spring.

These results specify the previous estimates that perennial rye was in most cases a stronger competitor than the companion species such as lupine and linseed (*Weik* 2002).

Perennial rye yielded more in treatments in which cereal was at a higher sowing rate, but the production of leguminous equalized these differences so that there were no significant differences between the total DM yields of treatments containing the same species, except the treatment in the autumn with the highest rate of perennial rye and alfalfa (No 2), whose production remained behind ($P<0.05$) the other mixtures with alfalfa.

According to *Füle* et al. (2004) sometimes dry weather did not make the second cropping of perennial rye possible. In our experiment two harvests of perennial rye were possible by mowing in all years after both sowing seasons, and it produced little re-growth for grazing after the second harvest. The persistence of perennial rye was determined mainly by the number of yearly mowing. After four harvests in 2008, perennial rye nearly disappeared off the parcels by the next year (No 2, 3, 4 treatments in spring sown experiment), because after mowing cereal was squeezed out progressively by alfalfa with a quick re-growth. However, in the autumn, the sowed experiment mixed parcels with alfalfa were harvested three times in 2008 because of the weak yield of leguminous, and then in the second year perennial rye yielded nearly the same quantity of DM as in the previous year.

From the aspect of the DM productivity and persistence of the perennial rye, the most favourable treatment was the association of bird’s-foot trefoil and perennial rye at the highest rate in the case of autumn sowing, where the cumulative DM production of perennial rye in the two years was above the standard. In addition, the forage quality of both bird’s-foot trefoil and perennial rye together was better than the pure cereal. Another experiment in Germany on the persistence of perennial rye was also influenced positively by nitrogen fixed by the legumes (*Weik et al*. 2002).

The cumulated forage yields of all of the mixed treatments were higher compared to the control pure perennial rye stand. This type of association of perennial cereal and leguminous proved to be the most suitable one for the exploitation of arable soil with adverse conditions. Moreover, it is possible with the help of this species to make the texture of the topsoil better and to increase its biological activity and to protect the top layer of the soil against degradation for many years.

Az évelő rozs (Secale cereale x S. montanum) szárazanyag-hozama tiszta vetésben és lucernával, szarvaskereppel való társításban

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ÖSSZEFOGLALÁS

Munkánk célja az évelő rozs takarmányhozamának növelése céljából évelő pillangós fajokkal, lucernával (*Medicago sativa L.*) és szarvaskereppel (*Lotus corniculatus L.*) történő társíthatóságának vizsgálata volt a Nyírség savanyú homoktalaján. A fajkeverékek vetése különböző évelő rozs tőszámmal, őszi és tavaszi időpontban történt, a betakarítás technológiáját a pillangós fajokhoz igazítottuk. Publikációnkban bemutatjuk, hogy az évelő rozs keverék vetése lucernával, illetve szarvaskereppel alkalmas a szárazanyag-termés növelésére, a társítás sikere azonban több tényezőtől is függ, elsősorban az évelő rozs tőszámától, a keverék komponenseinek arányától, illetve a kaszálások számától egy évben. A két vizsgálati év összesített takarmányhozama valamennyi keverék esetében magasabb volt, mint a tiszta vetésű évelő rozs állományoknak. Az évelő rozs termésmennyisége és perzisztenciája szempontjából a legkedvezőbb kezelés a szarvaskereppel történt keverékvetés volt a legmagasabb tőszámmal, őszi vetésben, ahol a kalászos összesített szárazanyag hozama szignifikánsan meghaladta a tiszta vetésű állományét. Megállapítottuk, hogy a vizsgált takarmánynövény társítások alkalmasak lehetnek a gyenge termőhelyi adottságú területek hasznosítására.

Kulcsszavak: évelő rozs, lucerna, szarvaskerep, takarmányhozam

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