Invasion of broad-leaved weeds into alfalfa stand during time of utilisation of alfalfa stands in low-input farming system

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Abstract. The objective of the investigation was to determine the percentage and yield of weeds in lucerne stands during the productive period. Different cutting regimes (first and final cut date and cutting frequency) were applied as treatments for estimating the extent of the invasion of weeds. Experiment 1 was conducted in 1980–1995 with the locally-bred alfalfa cv. Jõgeva 118 to study the connection between the invasion of broad-leaved weeds in the stand and weather conditions. Experiment 2 was carried out in 1991–2003 to investigate the impact of the first cut date and cutting frequency on the total DM yield of the alfalfa stand (cv. Karlu), partial DM yield of weeds, and the percentage of weeds in the stand. Experiments 3 and 4, *Medicago sativa* type WL 252 HQ variety (US), were sown in Tartu and Koonu to study weed spreading and alfalfa production at different locations. The results showed that management system had a strong impact on the productivity and competition ability of alfalfa and the invasion of weeds into the stand. Decreasing cutting frequency to 2–3 harvest times per season and performing the final cut in the second half of September or in early October allowed us to successfully depress the weeds in the alfalfa stands under Estonian pedoclimatic conditions. It is especially important to avoid more intensive management when extremely rainy and cool, or opposite droughty, weather conditions (total precipitation from May to September below the equivalent of 200 mm) dominate during vegetation period.

Key words: alfalfa, weeds, DM yield, harvesting schedule, weather conditions, low-input farming system

INTRODUCTION

Competition for mineral nutrients, water, light and space makes weeds a serious problem in cultivation of field crops, especially in organic production systems (Penfold et al., 1995). In grasslands the harm is not as relevant as multi-species plant communities are more resistant to weed invasion than field crop monocultures (Levine & D'Antonio, 1999; Tracy & Sanderson, 2003). In addition, many non-seeded plant species, as *Taraxacum officinale* and *Achillea millefolium*, have high palatability and quality for herbivorous animals in pastures. The increasingly accepted multifunctional services of agricultural production (OECD, 2001) and ecological concern for agricultural production raise the importance of maintaining and restoring the botanical diversity of grasslands. Investigations conducted during the last decade have shown that weeds play an important role within agroecosystems in supporting biodiversity, not only in flora but also in other taxa (Stoate et al., 2002; Marshall et al., 2003). However, weeds have an allelopathic potential or exhibit high seed production, rapid seedling growth, long-term seed dormancy and strong rizomatous growth that may be a serious threat to the biodiversity of grasslands, especially in sensitive vegetation communities.

In Estonia a dramatic decline in demand for agricultural products and a rise in prices of energy carriers on the market in the early 1990s have impelled the farmers to cut expenses for production. Instead of grasses they started to grow forage legumes, able to fix symbiotically large amounts of nitrogen from atmosphere, and desisted from using chemicals, incl. herbicides in grasslands. At the same time, many fields were abandoned (about 25% of the total cultivated areas) and become sources of weed spreading to fields still cultivated, complicating weed control problems. According to investigations in such abandoned fields, weed seed density in the upper 30-cm soil layer amounted 157,000–666,000 seeds per m^2 (Lauringson & Talgre, 2003). The increased environmental concern and economical difficulties have changed paradigms, and many Estonian dairy farmers have chosen the extensive low-input way of grassland management including non-chemical weed control. These attempts have often been unsuccessful as only limited information is available on cultural and mechanical weed management in grasslands.

Perennial lucerne is known as an energy-efficient forage crop of excellent quality, well adapted to grow in different pedoclimatic conditions (Barnes et al., 1988; Michaud et al., 1988). Results of many investigations reflected that the persistence of alfalfa is strongly connected with cutting regimes as well as with weather conditions. These groups of external factors affect the accumulation/consumption cycle of storage carbohydrates and winter-hardening processes, and through that, also the winter survival, following year's productivity and competition ability of alfalfa. However, these changes are not always connected with an invasion of weeds.

This paper discusses the results of an investigation performed with perennial lucerne at the Estonian Agricultural University during 1980–2003. The objective of the research was to study the percentage and yield of broad-leaved weeds in lucerne stands during the productive period. Different cutting regimes (first and final cut date and cutting frequency) in two pedoclimatic conditions (Tartu and Koonu) were applied as treatments for estimating the extent of the invasion of weeds. The long-term investigation period enabled us to study the correlation between the total precipitation and average air temperature during the vegetation period and the percentage of weeds in the alfalfa stand in the following year.

MATERIALS AND METHODS

Design of the experiments and soil properties

Data for the investigation were obtained from 4 randomised complete block field trials established in the spring of 1979, 1990 (in Tartu), and 2000 (in Tartu and Koonu). A loamy podzoluvisol soil of moderate natural fertility (content of organic matter 1.9–2.6% by Tjurin method, available potassium and phosphorus in 0–20-cm soil layer 33–115 and 42–85 mg kg^{-1}, respectively, by Egner-Riehm method) and light acid content (pH_{KCl} = 5.0–6.4) was typical of Tartu experiments (Table 1). In Koonu the experiments were situated in a haplic luvisol soil close to neutral and rich in macro-elements.

Table 1. Agrochemical characteristics of soils.

Location	In 0–20 cm soil layer					
	pH_{KCl}	P, mg kg^{-1}	K, mg kg^{-1}	Ca, mg kg^{-1}	Mg, mg kg^{-1}	Organic matter, %
Tartu	5.0–6.4	42–85	33–115	1,100	45–80	1.9–2.6
Koonu	6.6–6.8	135–147	160–170	2,800	120–140	2.7–2.8

Experiment 1 was conducted in 1980–1995 with the locally-bred alfalfa cv. Jõgeva 118 to study the correlation between the invasion of weeds in the stand and weather conditions from May to September. The total precipitation and mean air temperature were determined to characterise growing conditions during the vegetation periods. A three-cut harvesting system, with cutting performed at the bud stage of alfalfa, was used.

Experiment 2 was carried out in 1991–2003 to investigate the impact of the first cut date and cutting frequency on the total DM yield of the alfalfa stand (cv. Karlu), partial DM yield of weeds, and the percentage of weeds in the stand. Eight different times of the 1^{st} cut were used in the trial: from 15^{th} of May to 3^{rd} of July (at 7-day intervals). According to the date of the 1^{st} harvest, the annual number of cuts varied between 5 and 2.

Experiments 3 and 4, *Medicago sativa* type WL 252 HQ variety (US), were sown in Tartu (South-Estonia; 58º21´ N and 26º40´ E) and Koonu (North-Estonia; 59º10´ N and 26º15´ E) in May 2000. Starting from the second year, the three-cut harvesting schedule at the bud stage of alfalfa was applied in both experiments. At the same time, plots were divided into 6 treatments (date of the final cuts form the end of August to early October). At both locations, all treatments and measurements were carried out nearly at the same time (maximum difference was one day).

Forage yield was determined by cutting plants to a stubble height of 8–10 cm. Species composition was determined manually in sub-samples prior to each cut, separating plants by species or plant-groups (alfalfa, grasses, and board-leaved weeds). All components were dried and weighed. According to the DM yield and botanical composition of the stand, partial DM yield for separate herbs was calculated. All measurements and determinations were replicated 4–5 times.

Weather conditions

For characterisation of weather conditions, air temperature, the amount of rainfall and depth of snow cover were determined (Table 2).

Table 2. Weather conditions during the experimental period.

Rating	Years	Average		
		Air temperature, °C	Precipitation, mm	Depth of snow cover, cm
VEGETATION PERIOD (May–Sept.)				
Cool and rainy	85, 87, 90, 93	12.4–13.5	437–508	X
Warm and rainy	81, 86, 88, 01	14.1–16.0	322–448	X
Cool and droughty	80, 96	13.6–13.7	245–258	X
Warm and droughty	83, 92, 99, 02	14.9–16.2	157–230	
Near normal	other	13.3–16.0	300–396	X
WINTER PERIOD (Dec.–March)				
Critical	87/88, 98/99	-3.2…-3.7	X	6.8–10.2
Frosty with a lot of snow	79/80, 81/82, 84/85, 85/86, 86/87, 95/96	-5.2…-8.8	X	13.9–22.6
Mild with little snow	other	-0.2…-4.7	X	1.6–13.1

According to these data, vegetation periods could be divided into 5 groups: 1) cool and rainy, where the growth and productivity of alfalfa was suppressed by the lack of warmth; 2) warm and rainy near ideal for alfalfa growth and development, when high air temperature was accompanied by adequate rainfalls; 3) cool and droughty, problematic for alfalfa during some years (1980 and 1996); 4) warm and droughty, when the main limitation factor was water deficiency, and 5) near normal (like 1997).

Winter periods were mild with little snow or frosty with a lot of snow, suitable for successful wintering of alfalfa, as a rule. Only the winters of 1987/88 and 1998/99 were close to the so-called 'test winter' where cold and snowy weather changing with prolonged thawing periods in the second half of winter exposed plants to the next frost. The differences in climatic conditions between Tartu and Koonu were insignificant.

Statistical analysis

Analyses of variance were performed to test the treatment effect by using standard ANOVA test (SAS, 1996), completed by Statistica 5.0. For finding correlation between cutting intensity and stand DM yield, correlation coefficients between the percentage of weeds or partial DM yield of weeds and total precipitation during the vegetation period, or mean air temperature, and the following year's weed percentage in the alfalfa stand were calculated.

RESULTS AND DISCUSSION

Among non-seeded herbs, simple and creeping perennial weeds dominated during the time of utilisation of the alfalfa stand. From these *Taraxacum officinale* F.H.Wigg. (coll.), *Leontodon autumnalis* L., *Achillea millefolium* L., and *Veronica chamaedrys* L. were the most common species in the alfalfa stands of Eerika and Koonu.

First cut date and cutting frequency

Mowing is an effective non-chemical method for controlling weeds, especially during alfalfa establishment (Medlin & Siegelin, 2003). However, in northern latitudes and in established stands there are only limited chances for success as by reducing food reserves in weeds we also reduce the growing vigour of alfalfa. Moreover, perennial weeds are well adapted to periodic defoliation (Strauss & Agrawal, 1999). For that reason, non-chemical weed control in mature stands is aimed at increasing the competitive ability and productivity of seeded species, that of alfalfa in our case.

Our investigation showed a clear trend (R = 0.95***) for increasing the total DM yield of the alfalfa stand, by decreasing cutting frequency and making the first cut at later stages of alfalfa development (Table 3). At the same time, the percentage of weeds in the stand decreased significantly (R = 0.89**) and the partial DM yield of weeds also exhibited a tendency to decrease. The last correlation was comparatively weak (R = 0.54). As in the case of a very intensive harvesting schedule (4–5 cuts per season), alfalfa was greatly replaced with white clover and forage grasses (like *Poa pratensis*) able to form a dense stand and reduce weeds growing ability. It is also a reason why the percentage of weeds in the stand and partial DM yield of weeds are not always in a very strong correlation (in our case R = 0.80**).

Table 3. The first cut date and cutting frequency of alfalfa stand impact to invasion of the weeds in 1991–2003.

First cut date	Number of cuts	Total DM yield of the stand, t ha^{-1}	Percentage of weeds, %	Partial DM yield of weeds, t ha^{-1}
15.05	5	5.35	13.7	0.73
22.05	4	6.76	10.5	0.71
29.05	4	7.07	14.2	1.00
05.06	3	8.80	11.7	1.03
12.06	3	8.63	9.6	0.83
19.06	3	9.96	5.8	0.58
26.06	3	9.67	6.4	0.62
03.07	2	10.11	4.9	0.50
X	X	$P<0.001$	X	$P<0.001$
X	X	$LSD_{05}=0.94$	X	$LSD_{05}=0.11$

Final cut date

After applying the treatment, significant difference between varieties was observed in the following productive year (Table 4). The yielding ability of the alfalfa stand decreased significantly (40 and 20%, respectively) if the final harvest was done from late August to early September (35–45 days after the previous cut in Koonu) or from late August to the beginning of the third ten-day period in September (in Tartu). This phenomenon is usually explained by the destruction of the accumulation-consumption cycle of natural storage carbohydrates if the final cut is made too close to the previous harvest in the period when comparatively warm weather enables intensive regrowth of tillers (Mays & Evans, 1973; McKenzie & McLean, 1980; Sheaffer & Marten, 1990; Shimada, 1994). According to our expectations, deterioration in alfalfa productivity resulted in an increased invasion of weeds into the stand. The percentage of herbs increased in Koonu by up to 9%, and partial yield of weeds increased by 29.7%. In Tartu the difference in weed invasion between varieties was not so clear, obviously connected to less favourable soil conditions and the spreading of non-seeded forage grasses (like *Phleum pratense, Festuca pratensis, Agropyrum repens*) increased stand density. According to previous investigations, most perennial weeds may come into established alfalfa stands if they become thin (Peters & Linscott, 1988). However, even in such conditions a decrease in stand productivity is accompanied by a tendency of increased weed invasion.

Table 4. Impact of the final cut date on the formation of partial DM yield of the weeds in two different pedoclimatic conditions in 2001–2003.

Data	Final cut date						*P*
	28.08	05.09	12.09	19.09	26.09	03.10	
KOONU							
Total DM yield of the stand, t ha^{-1}	5.26	5.87	5.93	9.22	9.31	11.23	<0.001***
Percentage of weeds in the stand, %	14.1	16.0	14.8	7.5	5.9	5.0	x
Partial DM yield of weeds, t ha^{-1}	0.74	0.94	0.88	0.69	0.55	0.56	<0.001***
TARTU							
Total DM yield of the stand, t ha^{-1}	3.93	3.98	4.29	4.74	5.44	5.35	0.013*
Percentage of weeds in the stand, %	9.2	8.3	9.3	9.1	5.1	7.5	x
Partial DM yield of weeds, t ha^{-1}	0.36	0.33	0.40	0.43	0.28	0.40	0.003**

Weather conditions

Weather is an important factor, having an impact on the productivity and competition ability of all organisms. Because of the complexity, it is usually very difficult to find correlation between climatic conditions and stand situation in field conditions, especially when short-term stands are used. Alfalfa is a forage species usually persisting in Estonian grasslands as a dominant species during 4–5 years. Seeding alfalfa with grasses makes it possible to keep a stand productive and control successfully weeds during much longer periods.

In our experiment, the percentage of weeds fluctuated annually on a large scale (between 10–50%; Fig. 1). Nevertheless, the phenomena were not clearly connected with meteorological characteristics of any studied vegetation periods (correlation coefficients between the percentage of weeds in the stand and the total precipitation or mean air temperature were 0.52* and 0.02, respectively). Usually, rainy weather was accompanied by a lack of radiation (in 1987, 1990, and 1993), increased alfalfa sensitiveness to winter-stresses, and increased weed problems in the following year. However, in 1981 rainy and comparatively warm weather initiated the same processes. Due to several morphological advantages (like deep rooting system) alfalfa is excellently adapted to growing under warm and droughty weather conditions (Carter & Sheaffer, 1983). We found that the advantage works only in case if the total precipitation from May to September exceeded the equivalent of 200 mm. When the total precipitation dropped below the level (in 1992), stand deterioration processes accelerated, and an increased invasion of weeds was observed in the subsequent year.

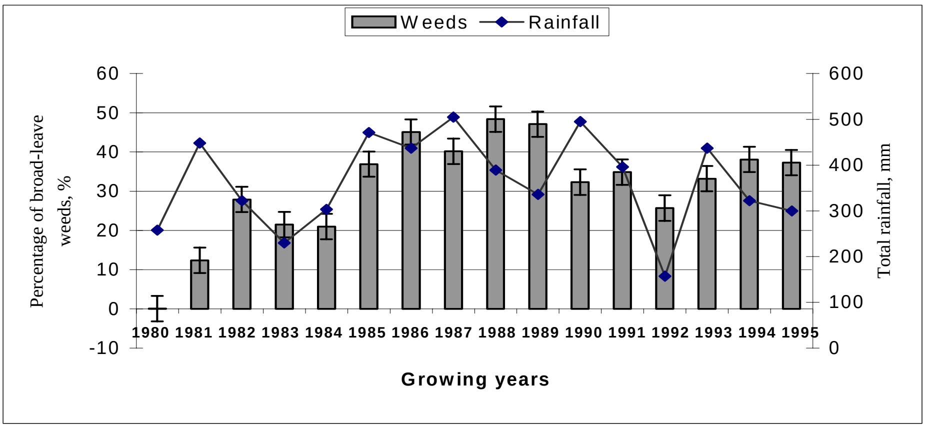

Fig. 1. Change in the percentage of broad-leaved weeds and precipitation during 1980–1995.

CONCLUSIONS

Our results show that management system has a strong impact on the productivity and competition ability of alfalfa and the invasion of broad-leaved weeds into the stand. Decreasing cutting frequency to 2–3 harvest times per season and performing the final cut in the second half of September or early October can successfully depress weeds in Estonian pedoclimatic conditions. It is especially important to avoid more intensive management when extremely rainy and cool, or opposite droughty, weather conditions (total precipitation from May to September below the equivalent of 200 mm) dominate during the vegetation period. Otherwise, losing stand vigour may be a reason for increased weed problems in the following year.

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