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The dynamics of botanical composition of pure and mixed grass swards on peaty soil

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Abstract. Major part of forage grass varieties used for (re-)seeding Estonian grasslands is imported. Little is known about their performance is severe microclimatic conditions on peat soils as official testing takes place on mineral soils. A field trial comprising 7 pure-sown grass species (8 domestic, 11 foreign varieties) and 9 mixtures composed of local varieties was sown to drained peaty soil. The aim was to determine the sward components, which preserve there. Changes in grass sward composition were observed in 2005–2007. Among pure stands, Estonian *Alopecurus pratensis* variety 'Haljas', *Phleum pratense* 'Tia' and 'Tika', *Bromus inermis* 'Lehis' maintained the highest percentages (86.0–92.8) of cultivated species by the third harvest year. Only *B. inermis* survived a harsh winter with negligible winterkill. The frost devastated the stands of *Festulolium*, *Festuca pratense* and *F. arundinacea*. 'Lehis' turned out to be the most winter and drought resistant also in mixed grass swards. If added at a rate of 30 kg ha^{-1} to the mixtures with *P. pratense*, *B. inermis* effectively outcompeted the herbs (range 1.4–8.2%) by the third harvest year and became dominant (72.3–87.1%). *P. pratense* 'Tia' persisted for three years but gradually withdrew when was competing with *B. inermis*, and also with *A. pratensis*. *Phalaris arundinacea* was intolerant to three harvests per year at a cutting height of 7 cm and steadily declined from the swards. *Dactylis glomerata* and *F. pratense* were vulnerable to winterkill, but could partly recover at the end of a rainy season.

Keywords: botanical composition, sward dynamics, forage grasses, peaty soil

INTRODUCTION

Fen soils occupy 592,483 ha or 13.85% of the soilcover in Estonia. From the cultivated grassland area, fen soils make up 29,650 ha or 9.9% (Kõlli et al., 2007). According to Tomberg (1970) the mean annual decrease of the superficial peat layers through mineralization under the arable crops is 2.4 cm and under the grassland 1.4 cm. The strategy of protection and sustainable agricultural use of drained peat soils requires the establishment of perennial grasslands instead of annual crop cultivation (Kõlli et al., 2009). At appropriate cutting frequency and fertilisation regime highly productive grass swards (dry matter yield 6–9 t ha^{-1}) have been maintained on fen soils for more than 7 years (Smoljakova, 1987).

Imported forage crop seed is widely used for the establishment and renovation of Estonian grasslands. Necessity to research the agronomic performance of foreign grass varieties bred in milder climates was raised by farmers and agricultural entrepreneurs. Lack of information about the persistency and yield stability of imported varieties is

especially perceptible when the varieties are exposed to extreme microclimatic circumstances occurring on peaty soils.

Aavola & Karelson (2009) monitored the herbage productivity and the changes in botanic composition of pure and multi-species grass swards at regular cutting through three harvest years (2005–2007). The objective was to relate the response of grass stands, expressed as crop damage and levels of weed suppression to existing weather conditions. The information about the varieties, species and their mixtures that enable to minimize the risk of crop failure on peaty soils at a larger scale will be communicated to forage producers.

MATERIALS AND METHODS

A field experiment was established to a peaty soil in Kärde, Jõgeva County. 19 varieties representing 7 grass species and 9 mixtures composed of domestic varieties were seeded on 21-07-2004 with a seed-drill 'Hege 80' in four replicates to the plots 5.88 m^2 in size. The trial was located on a slightly to moderately decomposed thin (75 cm) drained peaty soil. The agrochemical properties prior to the establishment were as follows: pH_{KCl} 6.2, organic matter 69.8%, N 2.71%, P 0.011%, K 0.028%, Ca 1.17% and Mg 0.046%. We applied the following amounts of nutriets under the final tillage in 2004: N60 as ammonium nitrate, P16, K83 as fertilizer Skalsa 0-9-25 and 30 kg ha^{-1} of $CuSO_4$ in the form of water solution.

We used the following seeding rates recommended by the Jõgeva Institute for pure swards: timothy (*Phleum pratense)* 10, meadow foxtail (*Alopecurus pratensis)* 14, reed-canarygrass (*Phalaris arundinacea)* 15, *Festulolium braunii*, meadow fescue *(Festuca pratense)* and tall fescue (*F. arundinacea)* all 33, smooth brome (*Bromus inermis)* 38 kg ha^{-1} seed of 100% sowing value. Seed mixtures with various dominant species were composed of the components presented in Table 1. Figures 1–3 present the pure-sown varieties of the 7-aforenamed species and the countries of their origin.

In 2005–2007 the plots were yearly cut thrice at a height of 7 cm with a plot harvester Hege 212. The first crop of all the plots was harvested between 15–20 June at growth stages 53–57 (heading to inflorescence emergence) of timothy, second harvest by 41–47 days later and the third at the end of growing season (61–74 days onwards). At the beginning of growth in springs 2005 and 2006 the following quantities of nutrients were applied with the same fertilisers as in 2004: N80, P35 and K119 kg ha^{-1}. In summer, 3 days after the first and second harvests we applied ammonium nitrate equivalent to N50 and 40 kg ha^{-1}. Fertiliser Skalsa dissolved insufficiently when applied as top-dressing. Therefore the initially used fertilisers were replaced by more soluble compound fertlizer Kemira Power 18 in 2007. Spring application rate was N80, P18, K33, in June: N50, P11, K21 and in August: N40, P9, K17 kg ha^{-1}.

Botanical composition of pure or mixed swards was determined by weight analysis of mean samples (1 kg) composed by bulking the subsamples representing four replicates. The dicotyledonous plants together with non-seeded grasses were separated from amongst the cultivated species and unified into a single group.

Air temperatures and sum of precipitation accumulated during three periods – from the outset of vegetation period until the first defoliation, between the first and

second, second and third harvest dates were recorded from the nearest weather station. The amount of precipitation was related to the dynamics of sward composition.

Table 1. The composition of grass mixtures seeded to peaty soil.

Mixture no.	Seeding rates (kg ha^{-1}) of varieties
1	*P. arundinacea* 'Pedja' (12), *P. pratense* 'Tia' (6), *A. pratensis* 'Haljas' (3)
2	'Pedja' (12), 'Haljas' (3), *Poa pratensis* 'Esto' (3)
3	'Pedja' (12), 'Tia' (3), 'Esto' (3)
4	'Tia' (8), 'Pedja' (10), *Festuca pratense* 'Arni' (6)
5	'Tia' (7), *Bromus inermis* 'Lehis' (15), 'Arni' (6)
6	'Lehis' (30), 'Tia' (3), 'Esto' (3)
7	'Lehis' (30), 'Tia' (6)
8	'Haljas' (10), 'Tia' (3), 'Esto' (3)
9	'Haljas' (8), *Dactylis glomerata* 'Jõgeva 220' (8), 'Arni' (6)

RESULTS AND DISCUSSION

By mid-June 2005 the smooth brome 'Lehis' had formed the most vigorous and unmixed (96.8%) sward (Fig. 1).

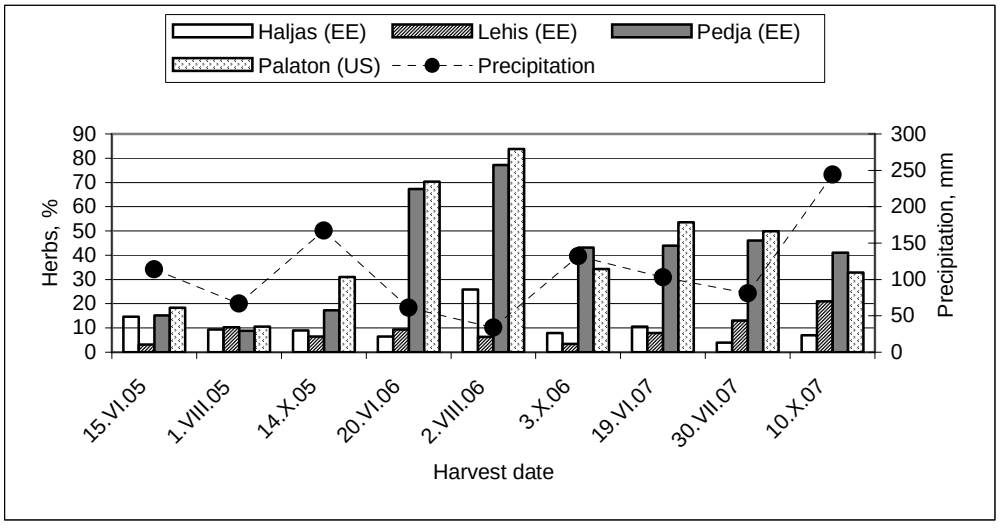

Figure 1. The content of herbs and non-seeded grasses (%) in pure stands of *Alopecurus pratensis* 'Haljas', *Bromus inermis* 'Lehis', *Phalaris arundinacea* **'**Pedja' and 'Palaton'. Amount of precipitation for each harvest date.

Timothies with their specific fast establishment after sowing contained 4.9–14.4% herbs (Fig. 2). The tall fescue 'Seine' formed a tenuous sward on fen soil in the first spring but competed later in the season more successfully with unsown species.

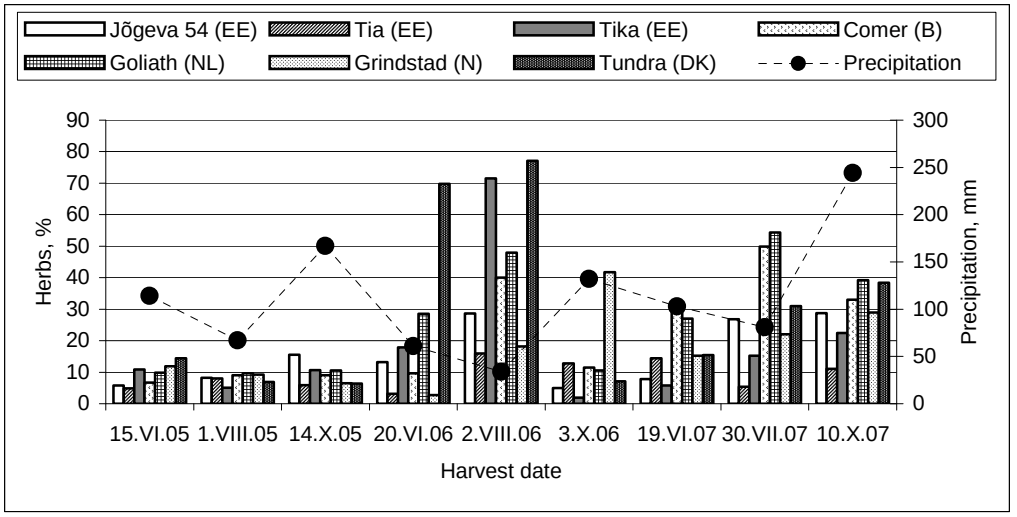

Figure 2. The content of herbs and non-seeded grasses (%) in pure stands of *Phleum pratense.*

Aftermath harvested in August had grown in the conditions of declining soil water reserves in late June and in July. During this period tall fescue and *Festuloliums* with their peculiar intensive growth suppressed most the herbs relative to spring growth (Fig. 3). These grasses do not require a rest period after defoliation and their growth continues without interruption (Tamm, 2007). Rainy August and warm autumn favoured, besides aforenamed species, also the regrowth of meadow fescue – its portion still increased (on the average by 5.2%) by the third harvest in 2005.

'Darimo' covered the ground quickly being thus the most competitive meadow fescue variety in the first harvest year. Timothy enters into dormancy earlier and its portion had no remarkable change in the herbage between August and October (Fig. 2). Reed-canarygrass withdrew in front of herbs at the end of first season (Fig. 1). As an average of 2005 the composition of harvested herbage diverged the most from the pursued in tall fescue 'Seine' and *Festulolium* 'Hykor'. The swards of timothies contained 6.3–10.0% herbs, smooth brome 'Lehis' 6.7%.

A thin cover of snow provided insufficient protection from the severe frost (–30.7°C) in January 2006. Fescues and *Festuloliums* were completely devastated therefore their samples were not collected in 2006. Reed-canarygrass suffered from extensive winterkill. Meadow foxtail, smooth brome and most of the timothy varieties survived winter with negligible damage. Delayed arrival of spring increased the infection with snow-mould (*Fusarium nivale*). The greatest share of herbs (*Anthriscus sylvestris, Ranunculus repens, Urtica dioica, Taraxacum officinale, Veronica chamaedrys, Lamium album, Barbarea arcuata, Achillea millefolium*) occurred in

those plots most devastated during winter of 2006. It is noteworthy that the variety 'Tundra' of timothy – a winterhardy species (Isolahti & Nissinen, 2004), was damaged to the same extent (Fig. 2) as reed-canarygrass weakened by inappropriately low (7 cm) defoliation height. If harvested twice per season, reed-canarygrass and smooth brome can preserve well till seventh harvest year (Smoljakova, 1987). Botanic composition of grass swards cut in August 2006, grown during extraordinarily droughty weather with daily air temperatures exceeding repeatedly 30°C describes either the drought tolerance or species' moisture preference. Considerable changes in the ratio of sown species and herbs took place during 1.5 month after the first cut primarily in the stands of meadow foxtail and timothy (Fig. 1, 2), i.e. species preferring more damp soils. As a mean of the second harvest year 2006 the greatest share of dead plants was observed in reed-canarygrass. Drought-resistant smooth brome gained higher prevalence along with advancing season.

As a result of improved growing conditions in warm and rainy October, the fescues and *Festuloliums* could partly recover. Active growing season terminated on 28-10-2006, i.e. 32 days later than ordinary. Therefore the samples of those 8 varieties were collected again in 2007. Yet, as an average of the third harvest year 'Seine', 'Jõgeva 47' and 'Laura' accounted for 52–55%; 'Arni', 'Darimo' and 'Lifara' 67–69% of the herbage (Fig. 3). On peaty soils the vanished dominant species are largely replaced by *Poa pratensis* (Smoljakova, 1987), which was also the case here.

The reason behind the large portion of weeds among fescues was that besides winterkill, the crop plants were permanently stressed due to water deficiency in preceding summer 2006. Meadow fescue can almost completely fall out from the swards on fen soils (Smoljakova, 1987). By the third harvest year 2007 even the swards of western European timothies 'Comer' and 'Goliath' deteriorated (Fig. 2).

In the mixtures no. 1 and 3, seeded with prevalence of reed-canarygrass, its share increased by mid-October 2005 to 49.1–49.8% (Fig. 4). If mixed with meadow foxtail (no. 2), 'Pedja' competed better (65.0%) with the companion species than together with quickly establishing and more agressive timothy. Timothy was absent from the mixtures no. 2 and 9 (Table 1, Fig. 4, 7) for what reason the herbs accounted for 17.3 and 24.2% of the herbage, respectively on the average of three harvests in 2005.

The mean percentages of reed-canarygrass 'Pedja' varied between 38.7–41.2% in the mixed swards no. 1–3 in the first harvest year (Fig. 4). Declining percentage of reed-canarygrass appeared since the second year 2006. Remarkable portion of alien species remained in those swards throughout summer, just the rainy autumn enabled the cultivated species to spread.

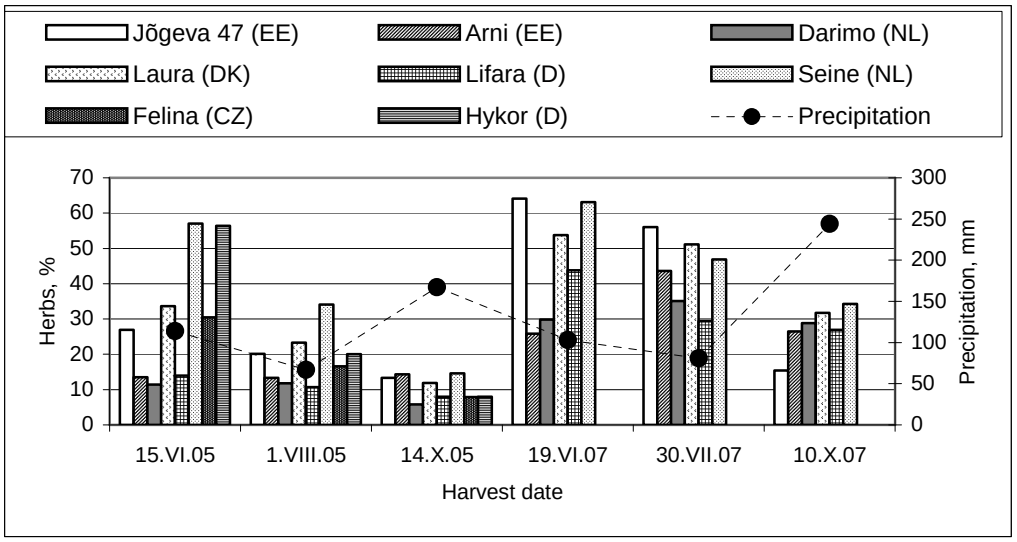

Figure 3. The content of herbs and non-seeded grasses (%) in pure stands of *Festuca pratense* (5 varieties), *F. arundinacea* 'Seine' *and Festulolium braunii* 'Felina' and 'Hykor'.

However, the utmost thinning of reed-canarygrass in the mixture no. 1 allowed no infestation with weeds as by third harvest year timothy and meadow foxtail had occupied the growth space. In the mixture no. 1, where the timothy was seeded at the rate of 6 kg ha^{-1} (Table 1), 'Tia' had nopossibilities to dominant during three years as in the mixture no. 3, where 3 kg ha^{-1} of timothy seed was added. The third component is what differed – meadow foxtail in the mixture no. 1 exerted stronger counter-effect to timothy than had Kentucky bluegrass in the mixtures no. 2 and 3. Bluegrass starts to spread since the third harvest year after withdrawal of upper grasses (Geherman et al., 2006). In our trial reed-canarygrass persisted until the third harvest year at maximum (on the average 25.4%), when had grown together with less aggressive meadow foxtail. The share of 'Pedja' was reduced to 15.0–19.7% in the swards if mixed with vigorous timothy and nearly withdrew (4.6%) if had to compete with both meadow foxtail and timothy.

In the mixture no. 4 seeded with the prevalence of timothy, the accompanying cultivated species were weakened during the winter 2005/2006 ('Arni') or by intensive defoliation ('Pedja'). As a result, timothy gained the mean share of 65.8% in the second harvest year (Fig. 5). Few plants of meadow fescue that survived the harsh winter could not fully recover in droughty and hot summer 2006. This resulted in nearly complete absence of 'Arni' in this mixture in 2007. Annuk (2006) has also found that the cut swards of meadow fescue are characterised by rather poor competitive ability and limited persistency on peaty soils. Reed-canarygrass persisted quite evenly (13.0–32.8%) in this sward no. 4 across three years. The inclusion of vegetatively spreading smooth brome as a companion species into the mixture no. 5, seeded with the prevalence of timothy, led to its gradual withdrawal by 2007. The contents of timothy and smooth brome in the mixed swards seem to be related with the amount of precipitation in the growing season and resulting soil humidity.

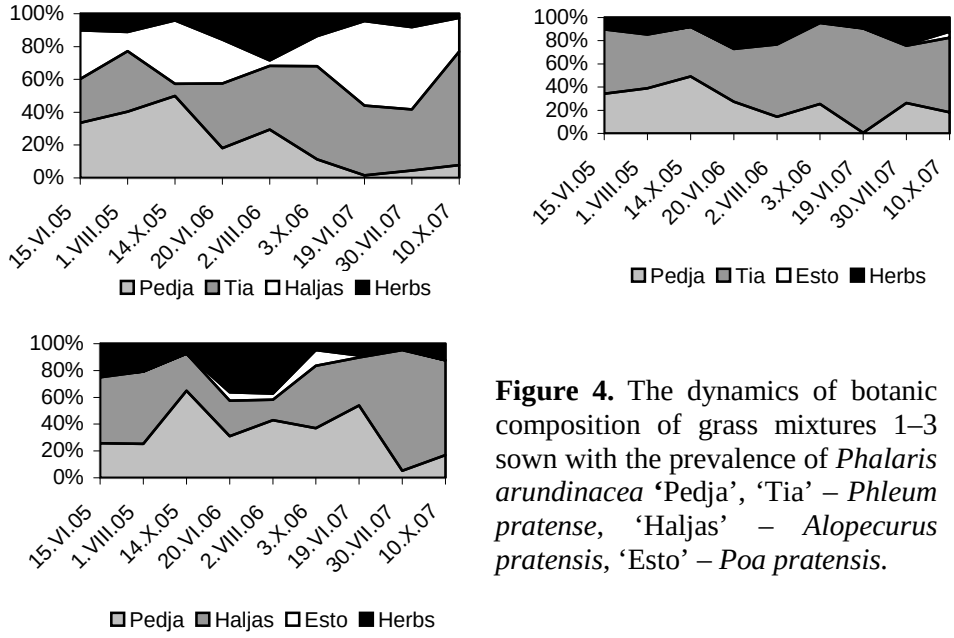

Figure 4. The dynamics of botanic composition of grass mixtures 1–3 sown with the prevalence of *Phalaris arundinacea* **'**Pedja', 'Tia' – *Phleum pratense*, 'Haljas' – *Alopecurus pratensis*, 'Esto' – *Poa pratensis*.

As soon as the sward became fully developed, smooth brome had maximum contribution to the forage yield already in the second harvest year 2006. Then the continuous soil moisture deficiency held back timothy and meadow fescue, which both thrive on the soils with moderate to damp water regime.

Seeding rates of the varieties 'Lehis' and 'Tia' differed twice in the mixtures no. 5 and 6 (Table 1). The competitive ability expressed by mean percentage of herbs was improved by 2.9% when timothy was sown at a higher rate. If the seeding rate of 'Lehis' was 30 kg ha^{-1} in the mixture no. 6, smooth brome became the most prevalent sward component in the whole trial (Fig. 6). Its content never dropped below 80% since June 2006. Timothy dominated (48.8–64.4%) within the mixtures no. 6 and 7, rich in smooth brome, only in August and October in the first harvest year but was further incapable to compete with its vigorous competitor. In the mixture no. 7, in which the sowing rate of 'Tia' was 6 kg ha^{-1}, the mean content of timothy was greater than in the mixture no. 6 (rate 3 kg ha^{-1}) in all the years.

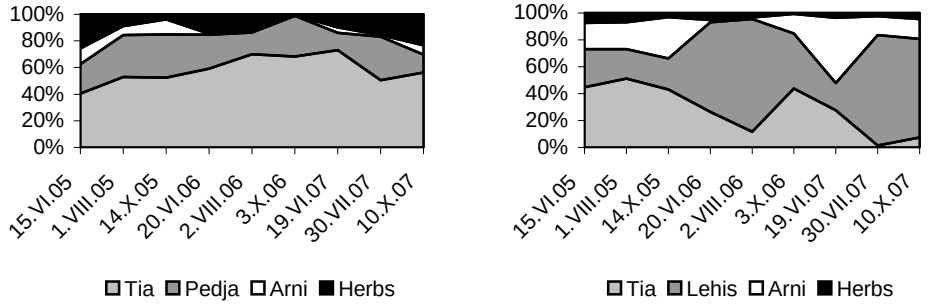

Figure 5. The dynamics of botanical composition of grass mixtures 4–5 sown with the prevalence of *Phleum pratense* 'Tia'. **'**Pedja' – *Phalaris arundinacea*, 'Arni' – *Festuca pratense*, 'Lehis' – *Bromus inermis*

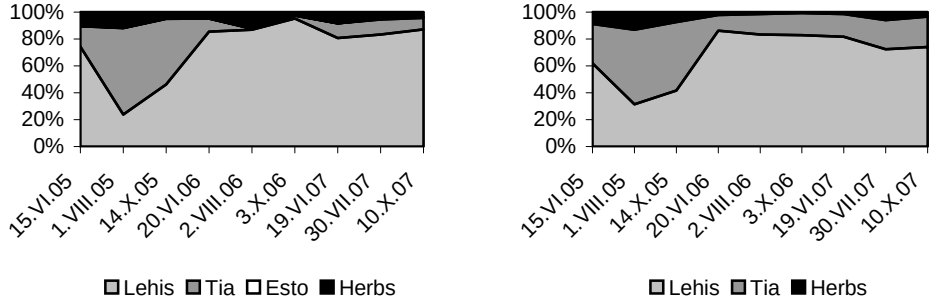

Figure 6. The dynamics of botanical composition of grass mixtures 6–7 sown with the prevalence of *Bromus inermis* 'Lehis'. 'Tia' – *Phleum pratense*, 'Esto' – *Poa pratensis*

Figure 7. The dynamics of botanical composition of grass mixtures 8–9 sown with the prevalence of *Alopecurus pratensis* 'Haljas'. 'Tia' – *Phleum pratense*, 'Esto' – *Poa pratensis*, 'Jõgeva 220' – *Dacylis glomerata*, 'Arni' – *Festuca pratense*

The earliest cultivated grass in Estonia – meadow foxtail attained in the mixtures no. 8 and 9 bigger share at the first harvests since 2006, yet the content of dominant species declined towards the end of seasons (Fig. 7). In the mixture no. 8 the mean content of timothy declined ca 50%every next year. Meadow foxtail filled up the vacant space. When mixed with vigorously regrowing meadow fescue and cocksfoot in the mixture no. 9, meadow foxtail was more suppressed in late summer and autumn than in the mixture no. 8 where timothy entered earlier into dormancy. Yet, 'Haljas' gained a higher initial level in every following spring. The share of meadow foxtail in the mixtures composed of five species has attained 78% still on the 7th harvest year, being the highest at three-cut system (Smoljakova, 1987).

The content of Kentucky bluegrass turf variety 'Esto' remained stable during the experiment – mostly around 1%. The variety appeared most (4.6–11.8%) in a droughty 2006 in the mixture no. 2 (Fig. 4), when the tillering and growth of slowly developing tall companion grasses preferring damp habitats was severly impaired. In the next year of 2007, 'Esto' almost disappared, it was suppressed by vigorously spreading meadow foxtail.

Since the second harvest year 2006 the least herbs were present (0.6–12.2% at six defoliation times) in the mixed swards no. 5–9 containing winterhardy species that persist on peaty soils – timothy, smooth brome and meadow foxtail. The two latter can make up major part of the produced forage even in the 12th year of the stand (Annuk, 2006). Rabotnov (1988) explains their superior competitive ability by the ecological individualism of these species. Smooth brome becomes dominant in both mono- and multi-species swards, if cut twice per season (Smoljakova, 1987). The share of timothy declined since the third harvest year.

CONCLUSION

Smooth brome as a prevailing component in grass mixtures seeded to fen soil forms a sward with the botanical composition being most similar to the desired. The Estonian variety 'Lehis' survived well the winters both in pure and mixed stands, was drought resistant and became dominant since the second harvest year. The qualities of mixtures composed with the prevalence of meadow foxtail were rather similar, but as the earliest maturing cultivated grass it dominated in the sward foremost till mid-summer. Meadow foxtail retreated in autumn in front of vigorously growing cocksfoot and meadow fescue. The timothy variety 'Tia' persisted for three years and was capable of competing with reed-canarygrass but withdrawed in front of rhizomatous meadow foxtail or smooth brome. Reed-canarygrass did not withstand intensive cutting at the height of 7 cm thrice per season. The content of 'Pedja' steadily declined in the mixtures during three years and the pure stands deteriorated with herbs. The fitness of dominant species to a particular habitat and management conditions is an essential element in securing the preferred composition of a grass mixture for a prolonged time. Except the mixtures no. 2, 3 and 4, the remaining multi-species swards were dense and therefore more protected from invasive weedy species than pure sowings.

The following pure-sown grass swards maintain the highest species' purity by third harvest year: meadow foxtail 'Haljas' (mean of three cuts 92.8%), timothies 'Tia' (89.7%), 'Tika' (85.5%) and smooth brome 'Lehis' (86.0%).

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