INFLUENCE OF NITROGEN FERTILIZATION RATES ON *FESTULOLIUM* AND *LOLIUM X BOUCHEANUM* FORAGE AND SEED YIELD AND QUALITY

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ABSTRACT. *The objective of this research was to study the influence of fertilization rate on dry matter yield structure and sward persistency of Festulolium and Lolium x boucheanum varieties under agro-ecological conditions of Latvia. Field trials were established on the sod-podzolic soil and fertilized with N 120 $_{(60+60)}$, N180 $_{(60+60+60)}$, P 78 and K 90 kg ha^{-1}. Forages were harvested three times during the growing season. Festulolium hybrids are among the most persistent and productive genotypes of the grasses used in many Europe countries, especially in adverse environments. The productivity of grasslands mostly depends on cultivated grass cultivars. The results of the experiments in the years 2003−2007 highlight the significant DM yield dependence on used variety and the N fertilizer dose increase. On the average the N fertilizer dose increase from 120 to 180 kg ha^{-1} contributed to DM yield increase by 1.6 t ha^{-1} or 17 percent. In the first year of yielding the positive effect of increased nitrogen rates was better expressed on loloid Festulolium cultivars DM yield, and was less expressed on festucoid Festulolium cultivars. On second and third year of the yielding difference in increased nitrogen rates positive effect between loloid and festucoid Festulolium cultivars were not observed. Increasing amount of nitrogen fertiliser provided significant increase in seed yields for all trial varieties. The influence of nitrogen fertiliser rates on seed yield formative elements was different in trial years.*

Keywords: *Festulolium, Lolium x boucheanum*, *nitrogen fertilization, grassland productivity.*

Introduction

Nitrogen fertilization is a management factor that greatly influences the perennial grass yield. *Lolium* species requires high nitrogen fertilisation when it is grown for high dry matter yield. The requirement to reduce N losses to the environment has changed the fertilization practice. Under more sustainable agricultural practices, the N fertilizer rate has to be reduced to an ecological optimum in the order of 150−200 kg ha^{-1} per year (Lantinga, 2002).

A higher herbage production rate from newly established grass swards is one of the expectations in temporary grasslands. Under cutting conditions the yield is often reported to decrease over successive years, with the highest yield in the first harvest year (Lemeziene, 2004). The fertilization level has an effect on the persistence and affects the yield progress during the grass development phase. Tolerance to adverse weather conditions and winter resistance may enhance markedly when plants are provided with abundant N (Aavola, 2005). On the other hand lower N rates can have positive effect on persistance (Soegaard *et al.,* 2007). Introduction of biotic and abiotic stress tolerance from *Festuca* spp. into *Lolium* spp. is offering unique opportunities for the production of versatile hybrid varieties with new combinations of useful characters suited to modern grassland farming (Humphreys et al. 2006). *Festulolium* hybrids are promising species to be used as fodder grasses. Due to its competitive productivity *Festulolium* may be equally ranked with the main forage grasses timothy and meadow fescue grown in climatic zone of Latvia (Gutmane, Adamovics, 2006).

Materials and methods

Field trials were conducted at the Research and Study Farm 'Vecauce' of the Latvia University of Agriculture (LLU) over the period from 2002 to 2007 in different parts of one trial field on a calcareous sod-gleysolic soil (*Luvic Epigleyic Phaeozem (Calcaric) – WRB 2006*), fine sandy loam (medium cultivated, medium deep to deep arable layer, medium high humus content). Soil pH_{KCl} – 7.2, plant available phosphorus (P_2O_5) – 579 mg kg^{-1}, potassium (K_2O) – 238 mg kg^{-1}, humus content 31 g kg^{-1}.

Sowing in trial plots was performed in three years: in May of 2002, 2003 and 2004 in complete block design with four replications, recorded area of a plot – 8 m^2. Grasses were row-seeded using an experimental seeder 'Hege 80', row spacing – 11 cm. For each sowing year (cycle) trial was established in two parts – swards used for herbage production and swards used for seed production, in each separate trial part seven varieties of grasses were tested in two nitrogen fertiliser backgrounds. Perennial ryegrass, hybrid ryegrass and festulolium varieties in the breeding of which parental species represent different species were used in trials.

Developed in Latvia, variety 'Saikava' in EU catalogue has been registered as hybrid ryegrass *(Lolium* × *boucheanum* Kunth*)*, however in trials it is estimated as festulolium *(× Festulolium),* because its parental species used in crossing represent two genera – fescue *(Festuca)* and ryegrass *(Lolium)*.

The sowing rate of grasses was 1,000 germinating seeds per m^2. In the year of sowing, nitrogen (N) – 108 kg ha^{-1}, phosphorus (P_2O_5) – 78 kg ha^{-1} and potassium (K_2O) – 90 kg ha^{-1} were applied as preplant fertiliser. In the production year of grass sward, 78 kg ha^{-1}

P_2O_5 and 90 kg ha^{-1} K_2O were applied as preplant fertiliser in both fertiliser backgrounds prior to the commencement of vegetation. In the first fertiliser background the nitrogen fertiliser rate was N $120_{(40+40+40)}$, in the second fertiliser background it was N $180_{(60+60+60)}$. The nitrogen fertiliser was split into three applications – for the first time prior to the commencement of vegetation, for a second time after the first cut and for the third time after the second cut.

Herbage yield in the vegetation period was recorded by direct method when the grass was harvested from a plot and weighted. In three production years herbage yield was obtained from each grass sward of each sowing year (cycle):

- Sward sown in 2002 was cut respectively in 2003, 2004 and 2005;
- Sward sown in 2003 was cut respectively in 2004, 2005 and 2006;
- Sward sown in 2004 was cut respectively in 2005, 2006 and 2007.

Winter hardiness for trial varieties was assessed visually (in accordance with the regulation No. 6 of the Ministry of Agriculture of the Latvia Republic of 20/06/2003), using a scale 1–9, where 9 is very good winter hardiness, plants have fully survived and 1, where plants are completely winterkilled. Yields of herbage mass were recorded for three cuts in vegetation season, dry matter yields were determined according to 'Value for Cultivation and Use Testing of Plant Varieties (VCU)' (regulation No. 6 of the Ministry of Agriculture of the Latvia Republic of 20/06/2003).

By the LLU Analytical Laboratory for Agronomy Research, the first cut herbage dry matter yield was analysed for the following quality indices: total N, crude protein content in herbage dry matter was calculated as total N x coefficient 6.25 (ISO 5983-2: 2005), neutral detergent fibre NDF (LVS EN ISO 16472: 2006); acid detergent fibre ADF (LVS EN ISO 13906: 2008); the dry matter digestibility *in vitro* (cellular method); net energy of lactation NEL MJ kg^{-1}:

$$NEL = (0.0245 \times TDN\ \%\ DM - 0.12) \times 4.184;$$

Total digestible nutrients DM (TDN), %:

$$TDN = 88.9 - (ADF\ \% \times 0.779)$$

Spreading of snow mould infection in grass swards was detected in spring 2005. Severity of the disease was assessed using a scale 1–9, assuming that 1 – disease symptoms are not evident, all plants are healthy; 9 – all plants are diseased.

For data processing, analysis of variance, simple and multiple linear regression analyses were employed. Data probability level was estimated using Fisher's criteria.

Meteorological information was provided by automatic meteostations 'Hardi Metpole' and Dacom Metapole' located at LLU Research and Study Farm 'Vecauce' and by the nearest weather station in Dobele. Weather conditions in 2002 were favourable for the growth and development of grasses contributing to better establishment and strengthening of stand. Meteorological situation in 2003 was satisfactory for the growth and development of grasses and very good for seed production. All the growing season of 2004 was exceedingly good for vegetative growth of grasses, but excess of moisture had a negative impact on seed yield. The year 2005 was satisfactory both for the growth and development of grasses and seed production. Due to drought, the season of 2006 was unfavourable for vegetative growth. All season long, the year 2007 was favourable for vegetative growth.

Results and Discussion

Winter hardiness. Wintering conditions differed among trial years and that is why results characterising winter hardiness were different. In the first production year all trial varieties showed good mean values of winter hardiness. 'Punia' (developed in Lithuania) was most winter hardy but perennial ryegrass 'Spīdola' and festucoid (F) type festulolium 'Hykor' were somewhat less hardy than 'Punia'. Good winter survival of 'Punia' and 'Spīdola' may be related to their origin, because in breeding new varieties under Baltic climatic conditions more emphasis has been placed on winter hardiness.

Winter survival was the lowest for loloid (L) type festulolium 'Lofa' and late hybrid ryegrass 'Tapirus', however 6.8 points is also a good result for Latvian conditions. Also in the second and third production year Lithuanian variety 'Punia' and F type festulolium 'Hykor' were superior in winter hardiness. Hybrid ryegrass 'Tapirus' and L type festulolium 'Lofa' showed the lowest winter hardiness.

In three production years of swards, consecutive reduction in parameters of winter hardiness was stated for all trial varieties. Reduction was more rapid for L type festulolium varieties than for F type festulolium varieties. The most rapid reduction in parameters of winter hardiness was stated for variety 'Lofa'. The results of three-factor analysis of variance show that variety used and specific production year of sward had significant influence on results of winter hardiness, but the influence of N fertiliser rate, in its turn, was non-significant.

Winter hardiness in 2004/2005 was lower for all trial varieties due to snow mould infection. It was caused by a cover of snow on unfrozen soil in winter. Significant ($p < 0.05$) correlation between the level of infection and winter hardiness of varieties was established.

In swards used for seed production, mean values of winter hardiness were higher for F type festulolium varieties 'Felina' and 'Hykor' (respectively 7.8 and 7.7 points). 'Punia' (developed in Lithuania) with 7.5 points and 'Saikava' (developed in Latvia) with 7.3 points were somewhat behind the above-mentiond varieties. The lowest mean value of winter hardiness (6.6 points) was detected for L type festulolium 'Lofa' and late hybrid ryegrass 'Tapirus'. Poor survival in the severe winter 2002/2003 was the cause why early hybrid ryegrass 'Ligunda' (winter hardiness 2.5 points) was excluded from trials in subseqent sowing years and

instead of it variety 'Felina' was included in seed production trials.

Dry matter yield. Cutting regime consisted of three cuts, which is the average number of cuttings appropriate for cultivated grassland swards in Latvia. Most of the dry matter yields were produced by the first cut. Average dry matter yield of the first cut in three years of production was 4.89 t ha^{-1} or 49% of the annual yield. Higher dry matter yields of the first cut grass were produced by the varieties that characterised with higher total dry matter yields. The influence of winter hardiness on dry matter yields of the first cut grass was different among different production years of sward. The influence of winter hardiness increases with the increase of sward age, and it was higher in the third production year. In the first production year, the influence of winter hardiness on dry matter yield of the first cut grass was low (coefficient of linear regression $b_{yx} = 0.54$) and non-significant ($p > 0.05$), in the second production year in turn it was higher ($b_{yx} = 0.61$) and significant ($p < 0.01$). In the third production year, the influence of winter hardiness was significant ($p < 0.01$), and it was the highest ($b_{yx} = 1.03$), as it is suggested by coefficients of linear regression.

All trial varieties produced low dry matter yields in the second cut under the influence of meteorological conditions – warm and dry weather in mid-summer during several trial years. Average dry matter yield of the second cut in three years of production was 2.09 t ha^{-1} or 21% of the annual yield.

In the first production year, significant differences in mean dry matter yields were found for festulolium, hybrid ryegrass and perennial ryegrass varieties. F type festulolium variety 'Felina' was the most high-yielding, however it should be considered that these are only one sowing year results. Analysis of variance in all production years was employed for varieties with three sowing cycle trial results (n = 24). Comparison among varieties with three sowing cycle trial results showed, that the highest mean values of herbage dry matter yields in the first production year were obtained with another F type festulolium variety 'Hykor' and L type festulolium varieties 'Punia' and 'Perun' (Table 1).

Table 1. Dry matter yield in the first, second and third years of sward use, t ha^{-1} (average for three sowing cycles)

Year of sward use	Variety							
	Spīdola	Tapirus	Perun	Punia	Lofa	Hykor	Felina[1]	Saikava[2]
	Three sowing cycles trial results[3]							
First	9.16 ^{a}	12.32 ^{b}	14.42 ^{c}	14.58 ^{c}	12.67 ^{b}	14.40 ^{c}	16.41	10.91
$S_{\bar{x}}$	0.56	0.67	0.72	0.7	0.68	0.74	0.39	0.86
Second	6.13 ^{a}	7.92 ^{b}	9.27 ^{c}	9.14 ^{c}	8.25 ^{b}	11.94 ^{d}	13.76	6.78
$S_{\bar{x}}$	0.5	0.72	0.66	0.7	0.69	0.78	0.46	0.21
Third	5.34 ^{a}	6.83 ^{b}	8.21 ^{c}	7.36 ^{d}	7.30 ^{d}	10.81 ^{e}	9.26	6.77
$S_{\bar{x}}$	0.27	0.37	0.43	0.27	0.34	0.3	0.34	0.37

[1] *one sowing cycle trial results* (n = 8);
[2] *two sowing cycles trial results* (n = 16);
[3] *for varieties with three sowing cycles trial results (n = 24), mean values in each year of sward use with different letters on superscript are significantly different at the p<0.05 level*.

In the second production year, mean values of the dry matter yields for festulolium, hybrid ryegrass and perennial ryegrass varieties were significantly lower than in the first production year. For perennial ryegrass, the dry matter yields in the second production year decreased by 3.03 t ha^{-1} or 33%. Similar yield decrease – by 36% was observed for hybrid ryegrass and L type festulolium varieties, which accounted for 4.40 and 4.78 t ha^{-1}, respectively. Considerably lower drops in productivity, by 2.46 t ha^{-1} or 17% between the first and second production year was found for F type festulolium 'Hykor', however it was also significant. For another F type festulolium variety 'Felina' (one sowing cycle trial results) this drop in productivity was also 17%.

In the third production year, the average dry matter yield of herbage was significantly lower than in the second production year, however decline in productivity was not so rapid as it was observed between the first and second production year. For perennial ryegrass, reduction in total dry matter yield between the first and third production year was 42% and accounted for 3.82 t ha^{-1}. Similar yield reduction was observed for hybrid ryegrass and L type festulolium varieties (respectively 45% and 44%), which accounted for 5.49 and 5.73 t ha^{-1} respectively. F type festulolium varieties were more stable in productivity with less reduction in yielding ability –35% .

The dry matter yield differences among varieties in sowing cycles formed similarly. Varieties that characterised with higher mean dry matter yields were also higher-yielding in all years of sowing cycles, respectively lower-yielding varieties produced lower yields of dry matter also in each of the trial year. The same relationships were also observed among three production years of sward. It allows conclusion that varieties included in this trial, regardless of their genetic differences, show similar response to ageing of sward and to influence of climatic factors.

In three production years, higher mean annual dry matter yields were produced with F type festulolium 'Hykor' (12.38 t ha^{-1}). Also other variety 'Felina', according to one sowing cycle trial results, had high mean dry matter yields (13.14 t ha^{-1}). 'Perun' (10.63 t ha^{-1}) and 'Punia' (10.36 t ha^{-1}) excelled with yielding ability among festulolium varieties of L type.

Nitrogen fertiliser rate increase from 120 to 180 kg ha^{-1} provided significant increase of mean dry matter yields for all festulolium, hybrid ryegrass and perennial ryegrass varieties in all production years.

In the first production year, the influence of rised rates of nitrogen fertiliser on the increase of dry matter yield was different for festulolium varieties of both L and F type. For L type festulolium varieties 'Perun', 'Punia', 'Lofa' and 'Saikava', increase of N fertiliser rate from 120 to 180 kg ha^{-1} resulted average dry matter yield increase of 2.46 t ha^{-1} or 21%. In turn for F type festulolium varieties 'Hykor' and 'Felina', the positive effect of the increased nitrogen fertiliser rates on crop yield increase was less expressed. For these varieties, the average increase of dry matter yield was only 1.18 t ha^{-1} or 8% (Figure 1).

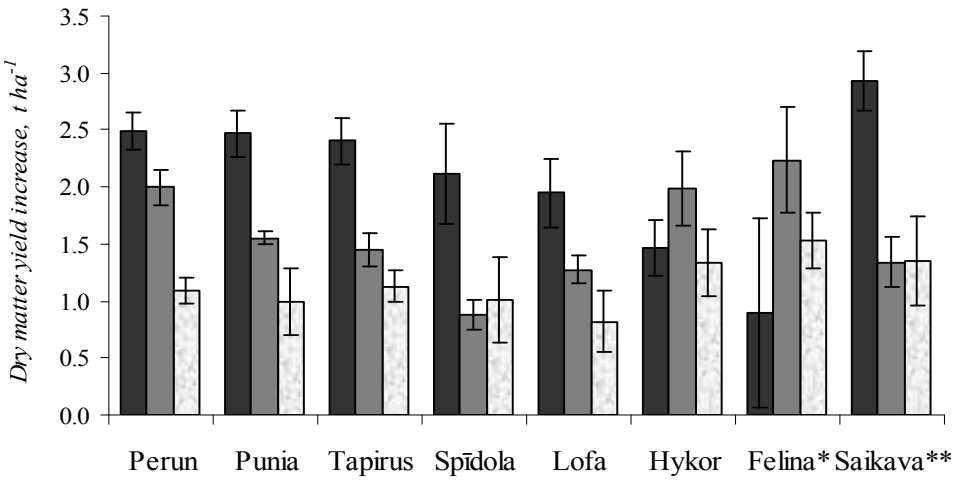

Figure 1. Dry matter yield increase from applied fertiliser rate N 120 rise to N180 kg ha^{-1}.
■ *1st year of sward use*; ■ *2nd year of sward use*; □ *3rd year of sward use*;
** one sowing cycle trial results*; *** two sowing cycles trial results.*

In the second and third production year, differences in dry matter yield increase among festulolium varieties of L type and F type are not found.

The value of the determinant factors influence on dry matter yield formation indicate, that cutting as a factor provides the greatest differences between the herbage dry matter yields in the first and third production year (Table 2). The high influence of cutting factor may be explained not only with the changes in regrowth rate, but also with differences in meteorological conditions during growing season.

Table 2. Variety, nitrogen fertilisation and cut factors influence on average dry matter yield for 3 sowing cycles trial results

Factors	Year of sward use		
	First	Second	Third
Variety (A)	11.8*	39.1*	15.5*
N fertiliser rate (B)	3.8*	7.4*	1.6*
Cut (C)	78.6*	32.3*	76.1*
Interaction (A x B)	0.1	0.5*	0.0
Interaction (A x C)	4.3*	14.9*	3.8*
Interaction (B x C)	0.1*	0.5*	0.8*
Interaction (A x B x C)	0.1	1.1*	0.4*

* *Influence of factor significant at the 95% probability level* ($F_{fakt} > F_{0.05}$).

Variety used was an important factor in the formation of yield differences in all production years of sward. The value of the influence of the variety factor was the highest in the second production year. Though the increase of nitrogen fertiliser rates provided significant increase in the mean dry matter yields, nevertheless the influence of this factor was the lowest. The low influence of the nitrogen fertiliser factor may be possibly explained with optimised nitrogen fertiliser rates applied in the trial when unfertilised control treatment was not used. Regrowth of grass after cutting is influenced not only by meteorological conditions but also by regrowth ability of specific grass species. It is indicated by the significant influence of variety and cutting factors interaction effect on the yield of dry matter in all production years of sward. Climatic and meteorological conditions in particular influence the productivity of perennial grasses to a great extent. The influence of meteorological factors was estimated comparing different trial years as a total of meteorological factors in specific trial year.

Results showed significant differences in the dry matter yields between production years of sward. In both nitrogen fertiliser treatments, production year of sward provided the greatest variation in data for the first cut yield, but meteorological conditions as a factor were also significant (Table 3).

The great influence of sward production year and meteorological conditions interaction effect on the dry matter yield should also be noted. Though the second-cut yields in several trial years were exceedingly low due to dry and warm weather, nevertheless the influence of meteorological conditions was not determinant one. The greatest variation in data of the second-cut and third-cut yield was provided just by interaction between production year and meteorological conditions. The

influence of interaction effect was higher than the influence of separate factors. It suggests that with ageing of sward herbage plants respond to adverse weather conditions more sharply.

Table 3. Variety, year of sward use and meteorological factors influence on dry matter yield formation

Faktors	*N rate*	*Cut*		
		First	*Second*	*Third*
Variety (A)	N 120	9.4*	7.5*	26.4*
	N 180	9.7*	7.3*	21.5*
Year of sward use (B)	N 120	36.1*	16.2*	8.6*
	N 180	33.0*	20.3*	17.2*
Meteorological conditions (C)	N 120	18.9*	6.4*	12.0*
	N 180	14.5*	10.5*	10.9*
Interaction (A x B)	N 120	1.9*	2.0*	3.1*
	N 180	1.2*	1.5*	3.3*
Interaction (A x C)	N 120	0.8*	0.6*	3.7*
	N 180	1.1*	0.7*	0.5
Interaction (B x C)	N 120	28.1*	59.8*	32.4*
	N 180	36.1*	54.9*	37.3*
Interaction (A x B x C)	N 120	0.9*	4.3*	9.4*
	N 180	1.3*	2.8*	3.4*

**Influence of factor significant at the 95% probability level*($F_{fakt} > F_{0.05}$).

In vegetation season the value of the influence of variety on yield differences formation in yield increases, and the influence of variety factor is higher in the third cut. In turn the influence of a specific production year decreases, and it was lower in the third cut than in the first and second cut.

Determinant factors of seed yield and its formative elements. Resistance to lodging and plant length, as agronomically important traits, may have direct or indirect impact on seed yield formation. In all trial years, the influence of variety on lodging resistance was significant ($p < 0.001$). The influence of variety (η, % = 91.8) was considerably higher than the influence of nitrogen fertiliser and factors interaction effect. Analysing the influence of the nitrogen fertiliser rate on lodging resistance, differences in results were detected in trial years. In two years (2003 and 2004), the influence of the nitrogen fertiliser was not significant ($p > 0.05$). Only in 2005 it was significant at the 95% probability level. It could be explained with high level of lodging observed in swards of all L type varieties in both fertiliser backgrounds. Severe lodging of L type festulolium and hybrid ryegrass varieties requires careful consideration whether the increased nitrogen fertiliser rates are useful at the existing agricultural background and sowing rate of seeds.

The generative tiller number per m^2 is is an important indicator in grass swards used for seed production. On the average for three trial years, the generative tiller number was greater for L type festulolium varieties 'Lofa' and 'Saikava'. These varieties also produced the highest yields of seeds. Variety and nitrogen fertiliser rate had different influence on the generative tiller number in trial years. The influence of non-studied factors was high (η, % = 45.1). Such results, possibly, are due to great differences within varieties which made it difficult to find out significance of the influence of studied factors − variety and N fertiliser rate − on generative tiller number.

1,000 seed weight (TSW) in research literature is most frequently characterised as a trait of quality and not determinant indice of seed yield, because grass seeds are very small in size. Higher mean values of TSW were found for L type festulolium 'Perun' and hybrid ryegrass 'Tapirus'. The lowest values of TSW were stated for 'Felina' and 'Hykor'. In all the three years of trials, the influence of variety on TSW was significant ($p < 0.001$). The influence of variety on TSW (η, % = 95.9) was considerably higher than the influence of nitrogen fertiliser and factors interaction effect.

As breeding effect following the cross and parental species vary considerably, festuloliums are morphologically different. Crossings between tall fescue and Italian ryegrass have resulted in varieties sharply different in morphology. Three varieties – 'Felina', 'Hykor' and 'Lofa' – out of all varieties included in trials, is a result of crossing between Italian ryegrass and tall fescue *(L. multiflorum × F. arundinacea)*, but flower head – panicle is observed only for 'Felina' and 'Hykor', while 'Lofa' is characterised with flower head – ear.

Length of a flower head**,** corresponding to type of a flower head – panicle, was shorter for 'Hykor' and 'Felina' than for other varieties that characterise with flower head – ear. In all trial years, the influence of variety on the length of a flower head was significant ($p < 0.001$). The high influence of non-studied factors (η, % = 36.7) on the length of a flower head was stated. It could be explained with a wide range of differences in the length of a flower head within variety.

Weight of a flower head among L type festulolium varieties, was higher for 'Perun' and 'Lofa'. For 'Ligunda' this parameter was the lowest after poor winter survival. The influence of variety on the weight of a flower head was significant ($p < 0.001$), and the influence of variety (η, % = 69.2) was higher than that of nitrogen fertiliser and factors interaction effect.

Number of spikelets per flower head**,** corresponding to type of a flower head – panicle, was considerably higher for 'Hykor' and 'Felina' than for other varieties. For L type festulolium varieties, it was greater for 'Lofa' and 'Saikava'. The influence of variety on spikelet number per flower head was significant ($p < 0.001$), and the influence of variety as a factor was considerably higher (η, % = 97.8) than N fertiliser and factors interaction effect.

The influence of nitrogen fertiliser rates on seed yield formative elements and seed morphological traits, such as plant length, the generative tiller number, TSW, length of a flower head, weight of a flower head and the spikelet number per flower head was different in trial years. Such fluctuations in results may be explained with considerable differences in parameters of previously mentioned seed yield formative elements within variety. The differences within variety at equal fertiliser rates were higher than the mean differences of parameters in two fertiliser backgrounds.

More extended analysis of seed yield formative elements was performed for varieties representing L type

and having ear as a flower head, such as 'Ligunda', Tapirus', 'Saikava', 'Perun', 'Punia', 'Lofa'.

Analysing relationships between seed yields and evaluated quality traits for L type varieties, significant correlation, at least in one of trial years, was established for the tiller number per m^2, ear length and the spikelet number per ear (Figure 2).

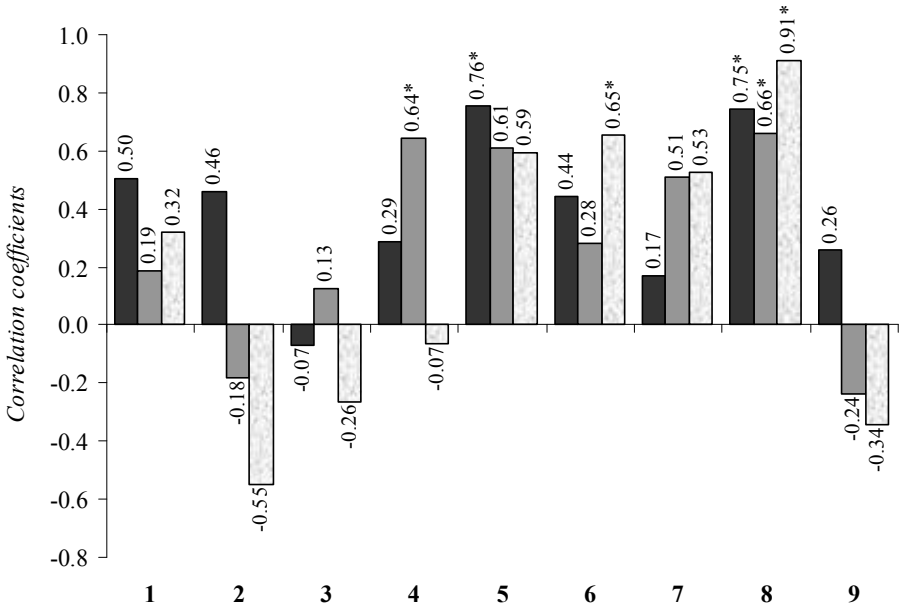

Figure 2. Correlation among seed yield and its formative indices for loloid type varieties.
Year ■ 2003 ■ 2004 □ 2005
1 – *overground biomass*; 2 – *winter hardiness*; 3 – *lodging resistance*; 4 – *plant length*; 5 – *number of generative tillers*; 6 – *ear length*; 7 – *ear weight*; 8 – *number of spikelets per ear*; 9 – *TSW*

The generative tiller number had a positive effect on seed yields of festulolium and hybrid ryegrass varieties in all the three years of trials. Significant linear relationship ($p < 0.05$) between the generative tiller number and seed yield was established in 2003, but in two remaining trial years the probability level was lower ($p < 0.1$).

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The spikelet number per ear had a positive effect on the yield of seeds produced by L type varieties. Significant linear relationships ($p < 0.05$) between the spikelet number and seed yield were established in all the three years of trials. It suggests that just the spikelet number per ear could be one of determinant factors of seed yield formation for hybrid ryegrass and L type festulolium varieties.

Significant positive correlation in all trial years is stated between the length of ear and weight of ear ($r_{2003} = 0.88 > r_{(0.05;\ 12)} = 0.58$; $r_{2004} = 0.68$ and $r_{2005} = 0.76 > r_{(0.05;\ 10)} = 0.63$). For the major trait that influences seed yield – spikelet number per ear – significant linear relationships ($p < 0.05$) are established with the length of ear in two years of trials. Relationship between the spikelet number per ear and the length of ear was not significant ($p = 0.18 > 0.05$) in 2004. With the increase of the spikelet number per ear the weight of ear increases. Significant linear relationship ($p < 0.05$) is stated in years 2004 and 2005, but in 2003 the probability level ($p = 0.54 < 0.1$) was lower.

Varieties characterised with greater productive tiller number showed the tendency of forming greater spikelet number per ear in all the three years of trials as indicated by positive coefficients of correlation. Significant linear relationship ($p < 0.05$) between the productive tiller number and the spikelet number per ear is stated in 2003, but in two subsequent trial years the probability level was lower ($p < 0.1$). Mutual correlative relationships between thousand seed weight and seed yield as well as between other traits studied were inconsistent between years.

Dry matter quality indices. Crude protein (CP) content is the main determinant of forage quality. The first cut crude protein yield was significantly influenced by variety ($p < 0.01$) in all production years of grass sward. Total crude protein yields in each production year were higher (on average from 321 to 1,177 kg ha^{-1}) with F type festulolium varieties 'Felina' and 'Hykor'. For these varieties, the highest total crude protein yields were provided not only by good yielding ability, but also by higher crude protein content in herbage dry matter as compared to other varieties. Among L type festulolium varieties, 'Punia' produced higher total yields of crude protein in each production year (on average from 241 to 616 kg ha^{-1}). Crude protein content

in herbage dry matter, as well as its yield obtained with the first-cut grass were significantly ($p < 0.01$) influenced by the increase of N rate from 120 to 180 kg ha^{-1} in all production years of sward. In the first production year, the average increase in crude protein yield was 88 kg ha^{-1} or 20%. In the second production year it was 75 kg ha^{-1} or 42%, but in the third production year 131 kg ha^{-1} or 56% (Table 4).

Table 4. First cut crude protein yield for three years of sward use, kg ha^{-1} (average for three sowing cycles)

Variety	Crude protein yield at N120, kg ha^{-1}			Increase of crude protein yield at N180, kg ha^{-1}		
	Year of sward use			Year of sward use		
	First	Second	Third	First	Second	Third
Spīdola	385	173	169	111*	52*	140*
Tapirus	394	131	208	126*	102*	122*
Perun	493	157	241	125*	97*	106*
Punia	559	192	220	113*	99*	151*
Lofa	458	164	205	66	60*	134*
Hykor	639	278	320	80	85*	98*
Felina[1]	1170	330	330	15	35	246
Saikava[2]	310	192	178	67	69	48
Mean	551	202	234	88	75	131
$S_{\bar{x}}$	96	24	21	14	9	20

[1] *one sowing cycle trial results*; [2] *two sowing cycles trial results*;
* *yield increase significant at the 95% probability level for varieties with three sowing cycles trial results*.

The highest increase in crude protein yield in three production years was stated for hybrid ryegrass 'Tapirus' and L type festulolium 'Punia' (respectively 350 kg ha^{-1} or 48% and 363 kg ha^{-1} or 37%).

Acid and neutral detergent fiber (ADF and NDF) content in herbage, on average for three production years, was the lowest for perennial ryegrass 'Spīdola' (respectively 24% and 43%). For the rest of L type varieties NDF was in the range of 46% to 50%, but ADF content ranged from 27% to 30%. Both festulolium varieties of F type 'Hykor' and 'Felina' showed higher mean values for NDF (respectively 56% and 58%) and ADF (respectively 33% and 33%).

The dry matter digestibility is one of the major determinant factors of grass forage quality. On the average for three production years, perennial ryegrass 'Spīdola' was of higher dry matter digestibility (76%). For the rest of L type varieties digestibility was in the range from 69% to 73%. On the average for three production years, F type festulolium varieties 'Felina' and 'Hykor' were of lower dry matter digestibility (respectively 61% and 65%). For the three production years, significant negative correlation is established between the dry matter digestibility and fiber characteristics NDF ($p < 0.001$) and ADF ($p < 0.001$).

Net energy of lactation (NEL), a parameter of forage quality, is closely related with ADF content in herbage dry matter. On the average for three production years, NEL was the highest for perennial ryegrass 'Spīdola' (6.7 MJ kg^{-1} DM). For the rest of L type varieties NEL ranged from 6.2 to 6.5 MJ kg^{-1} DM. For both F type festulolium varieties 'Felina' and 'Hykor' NEL was lower (6.0 MJ kg^{-1} DM), on average in three production years.

The increase in parameters of both fiber fractions, as well as decline in the dry matter digestibility and net energy parameters in the third production year of sward suggest, that the quality of grass forage is influenced by the age of sward.

In all production years of sward, NDF and ADF content in herbage dry matter, the dry matter digestibility and indices of NEL were significantly influenced by grass variety ($p < 0.01$). Significant influence of N fertiliser on NDF and ADF content in herbage dry matter, the dry matter digestibility and NEL was not stated ($p > 0.05$).

Conclusions

Trial varieties of festulolium and late maturity hybrid ryegrass are suitable for seed production and establishment of long-term grassland swards used for forage production under Latvian agro-climatic conditions. Early hybrid ryegrass variety, due to low winter hardiness, is not suitable for production under Latvian conditions.

Yields of dry matter and forage quality formation for festulolium and hybrid ryegrass were significantly influenced by several factors: variety, a seasonal pattern of meteorological factors in specific year, production year of sward, nitrogen fertiliser, regrowth period.

Dry matter yields obtained with perennial ryegrass, hybrid ryegrass and festulolium varieties were equal in production years of sward. Higher-yielding varieties characterised with higher mean dry matter yields in all trial years. All species studied, regardless of genetic differences, equally responded to ageing of sward and impact of meteorological factors.

The influence of winter hardiness on the first-cut yield of festulolium and hybrid ryegrass increases with the increase of sward age. Consecutive reduction in parameters of winter hardiness across production years of sward is stated.

Festucoid type festulolium characterised with higher crude protein content in herbage dry matter, and interaction with higher dry matter yield provided higher first cut crude protein yield.

The dry matter digestibility, neutral detergent fiber (NDF) and acid detergent fiber (ADF) in grass dry matter, as well as net energy of lactation (NEL MJ kg^{-1}) were higher for loloid type festulolium than for festucoid type festulolium.

Festulolium varieties tested are characteristic of two sharply different genotypes – loloid (L) and festucoid (F). These genotypes differ by the structure of a flower head, length of a plant and resistance to lodging.

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