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Productivity of *Festulolium*, of the *Lolium* and *Festuca* types, grown in mixtures and in pure stand in central-eastern Poland

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ABSTRACT

The aim of the research was to determine the suitability of *Festulolium* of the *Lolium* and *Festuca* types for cultivation in pure stand and in mixtures in central-eastern Poland. The following parameters were determined: dry matter yield of crops on an annual basis and in individual harvests; dry matter digestibility – determined by near-infrared spectroscopy (NIRS); The content of total protein, crude fiber, crude ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and soluble carbohydrates in the dry matter of plants – determined by NIRS. Harvested three times a year, grass mixtures, legume-grass mixtures, and *Festulolium* (the *Lolium* type cv. Hostyn and the *Festuca* type cv. Mahulena) in pure stand, grown on poor mineral soils Class 4a with water shortages during the growing season, produced satisfactory yields at an average level of 10.5 Mg/ha DM. The highest yields were produced by legume-grass mixtures with a large (over 20%) share of *Festulolium*of the *Lolium* type cv. Hostyn. With its lower share in a mixture, i.e. 7%, a 16% decrease in yield compared to the average was noted. The differences between three harvest yields during the growing seasons were typical in the conditions of summer and fall droughts. Of three annual harvest, the highest share of biomass (46% on average) was produced by plants during the first growth period. A large proportion of alfalfa in the mixture reduced digestibility, but improved the content of total protein and mineral compounds, at the same time reducing the amount of the neutral fiber fraction, which improved forage quality in terms of its energy content.

Keywords: digestibility, fiber fraction, grass, legume, mineral compounds, total protein, yield.

INTRODUCTION

The production potential and nutritional value of plant mixtures depend on their composition and the share of individual elements. In a mixture, grass should have their growth and development cycle and habitat requirements similar to those of leguminous crops. According to Staniak (2009), *Festulolium braunii*, an intergeneric hybrid, is such a plant, producing good quality forage with high yield potential (Thomas and Humphreys, 1991). However, *Festulolium* high competitiveness in relation to leguminous plants may limit its use in mixtures. According to Borowiecki (1997, 2000), with great competitive capabilities in relation to legumes, especially to red clover (*Trifolium pretense*), a *Festulolium* seed share should be reduced to 20% in a mixture with clover.

The research of Harkot and Trąba (1998), Sowiński et al. (1997, 1999), and Ścibior (1999) has found that the share of harvested plants in *Festulolium* mixtures is largely modified by weather conditions. A prolonged drought may reduce the proportion of *Festulolium* in the second cut by about 80% compared to the first one, which indicates its intolerance to a lack of moisture. Additionally, Wilman et al. (1998), Borowiecki (2002), and Staniak (2004) confirm its sensitivity to drought. However, different results were obtained by Jokś et al. (1998) and Thomas and Humphreys (1991), who observed that *Festulolium* drought resistance was similar to that of meadow fescue (*Festuca pratensis*).

While preparing a mixture, it is also important to choose the right variety.

According to the literature (Szyszkowska et al., 1997; Grzegorczyk 1999; Kryszak, 2001; Staniak, 2009), the nutritional value of mixture forage was dependent on the botanical composition of the sward. The highest protein value was recorded for a mixture planted with the highest proportion of legume seeds, while the experimental factors did not affect biomass energy value (Staniak 2009). The effect of *Festulolium* on the forage nutritional value is assessed by determining animal performance. Mikołajczak and Warda (1997) indicated a clear dependence of cow productivity on the share of grasses and legumes in the sward. As the amount of clover in a mixture increased, the milk yield of cows grew, and it was possible to significantly reduce the dose of concentrated feed without decreasing the production.

The aim of the present research was to determine the suitability of *Festulolium* of the *Lolium* and *Festuca* types for cultivation in pure stand and in mixtures in central-eastern Poland. In particular, the effect of mixture compositions on the yield, dry matter digestibility and chemical composition in the weather conditions of central-eastern Poland was determined.

METHODOLOGY

Experiment location and soil conditions

The experiment was conducted at the Prof. Feliks Ceglarek Agricultural Experimental Station of the University of Siedlce in Zawady (Mazowieckie Voivodeship; 52°10′03”N; 22°17′24”E) between 2023 and 2024. The plants were grown on brown podzolic soil made of sandy clay loam with sand as subsoil (Table 1). In terms of agricultural usefulness, it was classified as class IVa (arable soil of medium quality).

The average content of available forms of nitrogen and minerals in the soil was as follows (mg/kg): 30.3 N-NO_3; 49.0 N-NH4; 81.6 P; 182.4 K; 417.2 Ca; 66.1 Mg. Soil content of organic matter was 2.08%, with pH_{KCl} of 5.8 (Table 2).

Fertilizer treatment and crops tested in the experiment

In the 2022 growing season, after harvesting winter rapeseed, soil was loosened with a disc harrow and then with a spike-tooth harrow. Plots of 3×10 m were marked and separated by 3m wide paths, which were left fallow. Before sowing, 30 kg N per ha was applied in the form of a compound fertilizer. The content of nutrients in the fertilizer was as follows: total nitrogen – 12% (including: 5% N-NO_3 and 7% N-NH_4); phosphorus (P_2O_5) – 11%; potassium (K_2O) – 18%; magnesium (MgO) – 2.7%; sulfur (SO_3)– 20%; boron – 0.015%; iron – 0.20%; manganese – 0.02%; zinc 0.02%. The species composition and seeding rates were provided by the producer (DLF Seeds Ltd.) and are presented in Table 3.

The full cultivation cycle began in spring 2023. During each growing season, three cuts were taken. The compound fertilizer with nitrogen was applied before each growth cycle as follows: 180 kg N/ha to grass in pure stand and to BPS POWER and Łąka 6 DRY mixtures; 100 kg N/ha to mixtures with an increased proportion of legumes; 80 kg N/ha to the CutmaxALFAprotein high-protein mixture. The division of the annual amount of nitrogen was as follows: spring period

Table 2. Soil pH value in 1 mol/L KCl

Soil layer	Depth (cm)	pH_{KCL}	Acidity
Ap	0-40	5.8	Slightly acidic
Bv	40-60	5.2	Acidic
Cl	60-100	5.1	Acidic
C2	100-140	4.2	Acidic

Table 1. Soil texture

Soil layer	Depth (cm)	Particle size(mm)			Granulometric group PTG 2008*	Category of soil texture (light, medium, heavy) PTG 2008
		Sand 2.00-0.05	Dust 0.05-0.002	Silt <0.002		
Ap	0–40	65	32	3	sandy clay	Medium
Bv	40–60	76	22	2	clayey sand	
Cl	60–100	97	2	11	loose sand	
C2	100–140	97	2	–	loose sand	

Table 3. Species composition and seeding rates of legume-grass mixtures, grass mixtures and of grass in pure stand

Cultivation	Composition	Seeding rates* (kg/ha)
Legume-grass mixtures		
Cutmax 3 MILK	*Lolium perenne* L. 4n 10% *Festulolium* (*Lolium* type) 10% *Festulolium* (*Festuca* type) 18% *Festuca arundinacea* Schreb. 15% *Phleum pratense* L. 5% *Poa pratensis* L. 6% *Trifolium pratense* L. 30% *Trifolium repens* L. 6%	35
Cutmax 4 PROTEIN	*Loliumperenne* L. 12,5% *Festulolium* (*Lolium* type) 20% *Festulolium* (*Festuca* type) 25% *Trifolium repens* L. 2,5% *Medicago* × varia Martyn 40%	35
Cutmax ALFAprotein	*Festulolium* (*Lolium* type) 7% *Festulolium* (*Festuca* type) 10,5% *Trifolium repens* L. 2,5% *Medicago* × varia Martyn 80%	20
BPS POWER	Westerwold ryegrass 16% *Festulolium* (*Lolium* type) 30% *Festulolium* (*Festuca*type) 30% *Festuca arundinacea* Schreb. 20% *Trifolium repens* L. 4%	35
Grazemax 1 UNIVERSAL	*Lolium perenne* L. 4n 15% *Lolium perenne* L. 2n 10% *Festulolium* (*Lolium* type) 50% *Festulolium* (*Festuca* type) 10% *Lotus corniculatus* L. 2% *Trifolium pratense* L. 10% *Trifolium repens* L. 3%	36
Łąka 6 DRY	*Lolium perenne* L. 4n 10% *Festulolium* (*Festuca* type) 25% *Festuca arundinacea* Schreb. 20% *Trifolium pratense* L. 5% *Dactylis glomerata* L. 20% *Phleum pratense* L. 5% *Poa pratensis* L. 10% *Lotus corniculatus* L. 2% *Trifolium repens* L. 3%	35
Grass mixtures		
Cutmax 2 TURBO	*Lolium westerwoldicum* 26% *Festulolium* (*Lolium* type) 32% *Festulolium* (*Festuca* type) 42%	30
Medowmax 5 ORGANIC	*Loliumperenne* L. 25% *Festulolium* (*Lolium* type) 15% *Festulolium* (*Festuca* type) 20% *Festuca arundinacea* Schreb. 15% *Phleum pratense* L. 15% *Poa pratensis* L. 5% *Alopecurus pratensis* L. 5%	35
Grass in pure stand		
Festulolium (*Lolium* type)	*Festulolium* cv. Hostyn 100%	35
Festulolium (*Festuca* type)	*Festulolium* cv. Mahulena 100%	35

40%, summer period 30%, and fall period 30%. After the last harvest in 2023, the soil was limed with 1.5 Mg CaO/ha, using the WAP MAG fertilizer containing 28% of calcium (CaO) in a sulfate and carbonate form, 16% of magnesium (MgO) in a sulfate and carbonate form, with a maximum of 10% of sulfur (SO_3). The following parameters were determined:

- dry matter yield (Mg/ha) of crops on an annual basis and in individual harvests;
- dry matter digestibility (%) – determined by near-infrared spectroscopy (NIRS);
- the content (g/kg) of total protein, crude fiber, crude ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and soluble carbohydrates in the dry matter of plants – determined by NIRS.

Meteorological conditions

The University of Siedlce Meteorological Station based at the Zawady Experimental Farm provided data confirming climate change and shifts in temperature and weather patterns in this part of Europe. That change made agricultural production more difficult and more expensive. In order to determine the temporal variability of meteorological conditions and their impact on plant growth and development, Sielianinov's hydrothermal coefficient (*K*) was used. It was calculated on the basis of the monthly sum of precipitation (P) and the monthly sum of daily mean temperatures (t), using the formula: $K=P/0.1\sum t$. The coefficient values below 0.7 and above 2.5 were treated as very or extremely unfavorable.

Throughout the experiment, no optimal conditions, with *K* ranging from 1.3 to 1.6, for the growth and development of plants were noted, and relatively good weather was only in May and October 2023 (with *K* of 1.12 and 1.02). The remaining months of the growing season in 2023 were characterized by high temperatures and water deficits, creating extremely dry conditions in August and September. In 2024, the most difficult period for plant growth and development was in May, in which an extreme drought, compared to the multiannual data, was recorded, with the mean temperature more than three degrees higher and a more than tenfold decrease in the monthly total rainfall. It is worth noting that in each of the months, the average daily temperatures were a few degrees higher than the multiannual data. This also affected the frequency of droughts in summer and autumn.

RESULTS AND DISCUSSION

According to Figure 1, the annual yields of grass grown together with leguminous plants ranged from 9.60 to 13.1 Mg/ha, averaging at 11.8 Mg/ha DM. The highest values were noted for the Cutmax 4 PROTEIN mixture intended for poor soil, with 40% of alfalfa and over 45% of *Festulolium,* and for Grazemax 1 UNIVERSAL, a universal grazing and mowing mixture with 60% of *Festulolium* and 15% of legumes. There are many reports in the literature on the positive impact of legumes in mixtures with grasses on the yield (Hakl et al. 2018, Glowacki et al. 2023,

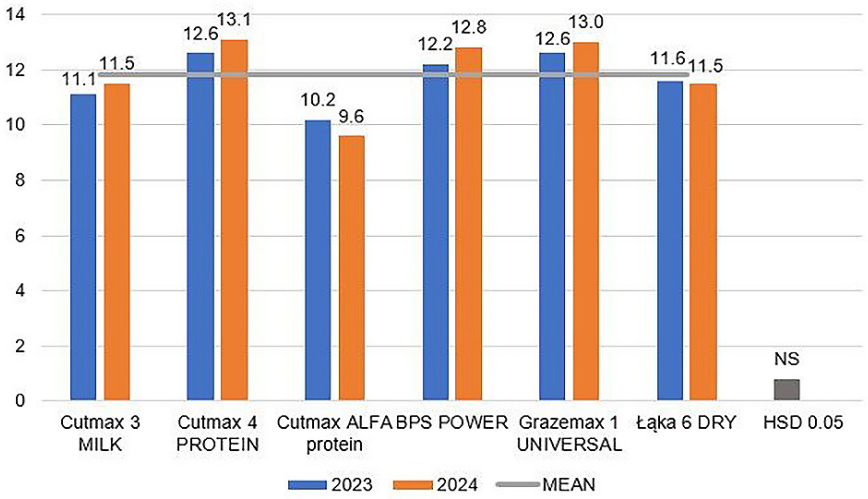

Figure 1. Annual dry matter yield (Mg/ha) of legume-grass mixtures; NS – not significant

Surault et al. 2024). Both of the above mixtures yielded better in the second year, while their average yield for two years was 7.8% higher than the experimental average. With intensive biomass growth and with a possibility of using it for overseeding, the BPS POWER mixture, to be grown on poor soil, was also yielding above the average. On the other hand, yields below the average were produced byCutmax 3 MILK, CutmaxALFAprotein and Łąka 6 DRY mixtures. The short-lived Cutmax 2 TURBO mixture, with a 74% content of *Festulolium*, in both years exceeded the yield level (Fig. 2) of Medowmax 5 ORGANIC, intended for organic soils and with 35% content of *Festulolium*. According to Lemežienė et al. (2004) Compared to other grass species, *Festulolium* has high yields. Consequently, it also increases the yields of mixtures. Moreover, *Festulolium* is considered to be a grass with high resistance to summer drought and low temperatures (Priya and Sahi 2009), which also supports high yields. In single-species crops, a 15.4% higher yield was obtained from the plots with *Festulolium* of the *Lolium* type cv. Hostyn than from the *Festuca* type cv. Mahulena (Fig. 3). It is worth noting that a higher amount of rainfall in 2024,between June and September (Table 4), had a positive effect on the yield of seven out of ten crops, but the increases were not statistically significant.

Due to the natural tendency of forage plants and the meteorological conditions in both growing seasons, the largest amount of biomass (Table 5) was from the spring harvest (the first growth period). The average dry matter yield of legume-grass mixtures per harvest was 5.45 Mg/ha DM,

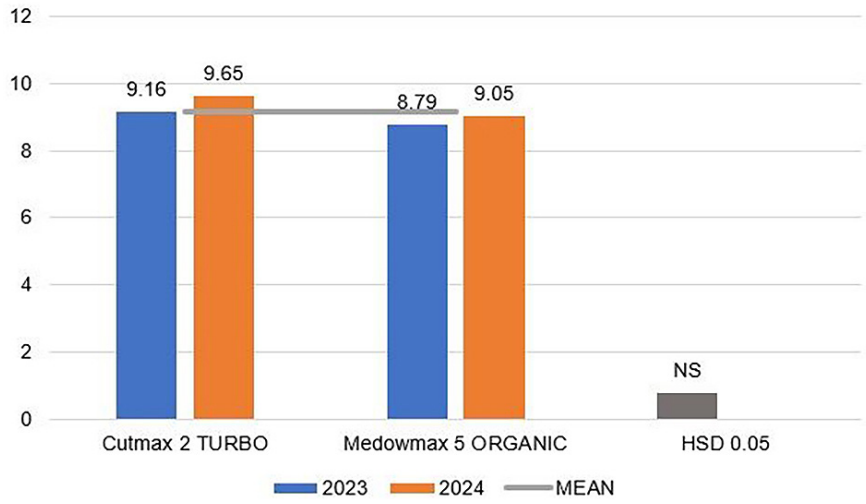

Figure 2. Annual dry matter yield (Mg/ha) of grass mixtures; NS – not significant

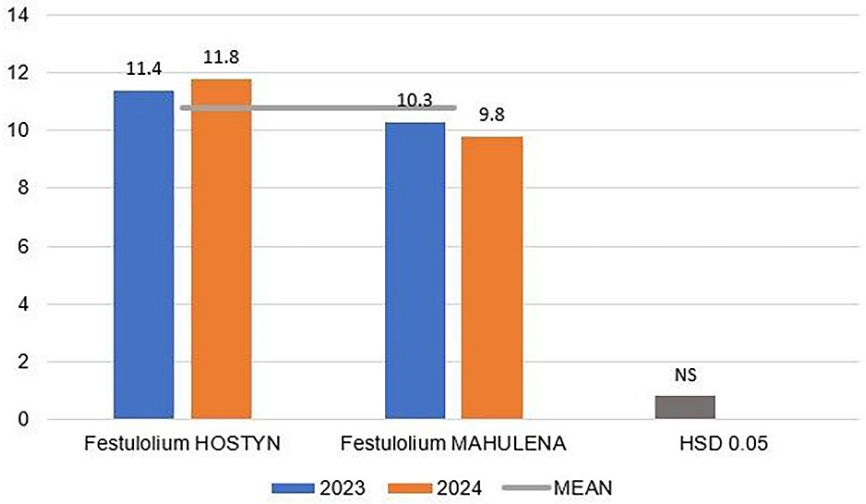

Figure 3. Annual dry matter yield (Mg/ha) of grass in pure stand; NS – not significant

Table 4. Weather conditions and Sielianinov's coefficient across months and growing seasons

Year	Month						
	Apr	May	June	July	Aug	Sept	Oct
Average monthly air temperatures (°C)							
2023	8.7	13.4	18.0	20.3	21.3	18.0	10.4
2024	10.8	16.6	19.0	21.6	20.7	18.1	9.2
1996–2010	*8.0*	*13.5*	*17.0*	*19.7*	*18.5*	*13.5*	*7.9*
Monthly precipitation (mm)							
2023	12.4	46.5	53.6	31.4	25.0	16.6	32.8
2024	23.2	5.2	65.4	59.7	55.5	25.5	25.0
1996–2010	*33.6*	*58.3*	*59.6*	*57.5*	*59.9*	*42.3*	*24.2*
Sielianov's coefficient (*K*)							
2023	0.48 (bs)	1.12 (ds)	0.99 (s)	0.50 (bs)	0.38 (ss)	0.31 (ss)	1.02 (ds)
2024	0.72 (s)	0.10 (ss)	1.15 (ds)	0.89 (s)	0.86 (s)	0.47 (bs)	0.88 (s)
K-value – period: ≤ 0.40 – extremely dry (ss), 0.41-0.70 – very dry (bs), 0.71-1.00 – dry (s), 1.01-1.30 – fairly dry (ds), 1.31-1.60 – optimal (o), 1.61-2.00 – fairly humid (dw), 2.01-2.50 – humid (w), 2.51-3.0 – very humid (bw), > 3.00 – extremely humid (sw); (according toSkower and Puła 2004).							

Table 5. Average dry matter yield (Mg/ha) per harvest and per growing period (of 2023 and 2024)

Crop	Harvest			Sum total
	1	2	3	
Legume-grass mixtures				
Cutmax 3 MILK	5.59^{ab}	3.40^{b}	2.31^{a}	11.3^{ab}
Cutmax 4 PROTEIN	6.08^{a}	4.38^{a}	2.44^{a}	12.9^{a}
CutmaxALFAprotein	3.99^{b}	3.63^{b}	2.28^{a}	9.90^{b}
BPS POWER	5.63^{ab}	4.01^{a}	2.86^{a}	12.5^{a}
Grazemax 1 UNIVERSAL	6.00^{a}	4.15$_{a}$	2.35^{a}	12.8^{a}
Łąka 6 DRY	5.45^{ab}	3.53^{b}	2.62^{a}	11.6^{ab}
Grass mixtures				
Cutmax 2 TURBO	4.13^{a}	3.18^{a}	2.10^{a}	9.41^{a}
Medowmax 5 ORGANIC	3.74^{a}	3.14^{a}	2.04^{a}	8.92^{a}
Grass in pure stand				
Festulolium cv. Hostyn	6.12^{a}	3.31^{a}	2.17^{a}	11.6^{a}
Festulolium cv. Mahulena	4.29^{b}	3.70^{a}	2.11^{a}	10.1^{b}
The means in the columns marked with the same letters do not differ significantly				

grass mixtures 3.94 Mg/ha DM, and *Festulolium* on its own 5.21 Mg/ha DM. In those soil and weather conditions the Hostyn cultivar yielded better than Mahulena. However, Mahulena produced more biomass in extremely dry conditions, i.e. in the summer growth period of 2023, and its summer yield, average of both years, was 11.8% greater than that of Hostyn. In addition, for the summer growth cycle, higher yields were obtained from the mixture with a 40% share of *Medicago* × *varia* T. Martyn and 45% of *Festulolium*. The yield of the last growth cycle was more uniform among the crops and ranged from 2.04 to 2.86 Mg/ha DM. The lowest yields were obtained from grass mixtures grown without legumes.

According to Sosnowski et al. (2022, 2023) and Abas et al. (2005), the production of high-quality roughage meeting cattle nutritional requirements is a necessary condition for their effective feeding. The basic measure of forage quality is the amount of energy in 1 kg of dry matter. Covering the energy demand of high-production cows depends, above all, on dry matter intake and energy concentration in the ration (Gaweł, 2012). Those parameters are significantly dependent on the content of structural

carbohydrates, i.e. neutral (NDF) and acid detergent fiber(ADF) in the dry matter of forage plants. For ruminants, neutral fiber is particularly important, filling the rumen, being a source of energy for its microorganisms, and giving the forage the desired structure. However, when NDF content in dry matter is too high, it negatively affects the amount of forage consumed by animals. On the other hand, the amount of acid detergent fiber determines digestibility (Gaweł, 2012; Truba et al., 2017), with both of them being negatively correlated. Low-quality forage fed to cows (with high content of NDF and ADF) results in a significant reduction in dry matter and energy intake. Among others, a lack of energy in forage prevents animals from absorbing protein. That in turn leads to a decrease in milk yield and protein concentration. The content of structural carbohydrates in plants depends on their species, morphological structure, development stage, harvest date, and on soil and weather conditions (Homolka et al. 2012). Leguminous plants contain less NDF and more ADF than grasses, therefore, to produce high-quality forage both crops are grown in mixtures. In an assessment of forage nutritional value, one of the most important parameters is digestibility. It determines the amount of energy available to ruminants, used for their living and production needs. Digestibility decreases as plant mature, and its daily decrease ranges from 0.3 to 0.5%. The differences between the digestibility of species and varieties can be significant. In the present research, the average dry matter digestibility of legume-grass mixtures was 56.9%, with 59.6% for grass mixtures, without legumes (Table 6). The highest digestibility of 60.6% was found in the biomass of *Festulolium* grown in pure stand. Therefore, it is worth noting that the share of legumes in mixtures, especially of alfalfa, reduced digestibility, which for CutmaxALFAprotein, with the lowest proportion of alfalfa, was 53.5%.

The average content of neutral detergent fiber (NDF) in dry matter ranged from 498 g/kg for the Cutmax 3 MILK mixture to 542 g/kg for CutmaxALFAprotein. It is assumed that its optimal content in roughage for dairy cattle should be 40–45%, so the above values were higher than those recommended (Andrzejewska et al., 2013). According to literature data (Østremi, 2013; Malinowska and Wiśniewska-Kadżajan, 2022; Sosnowski and Truba, 2023), *Festulolium* belongs to grasses with high content of structural carbohydrates. In the yield structure, especially of the first harvest, its generative shoots predominate, and only a small share is made up of leaf blades (Olszewska, 2008; Staniak, 2020,). The dominance of generative shoots in biomass explains the high content of the NDF fraction in *Festulolium* dry matter, with 560 g/kg for Hostyn and 576 g/kg for

Table 6. Chemical composition and dry matter digestibility of legume-grass mixtures, grass mixtures, and grass in pure stand (average across 2023 and 2024)

Mixture	Dry matter digestibility (%)	Content (g/kg)						
		Total protein	Crude fiber	Ash	NDF	ADF	ADL	Sugars
Legume-grass mixtures								
Cutmax 3 MILK	57.5^{a}	121^{b}	268^{a}	87.7^{b}	499^{b}	320^{b}	35.1^{b}	132^{a}
Cutmax 4 PROTEIN	55.2^{a}	143^{a}	246^{b}	92.0^{a}	528^{a}	352^{a}	39.8^{ab}	84.3^{b}
CutmaxALFAprotein	53.5^{a}	154^{a}	268^{a}	90.4^{b}	542^{a}	375^{a}	39.6^{ab}	85.2^{b}
BPS POWER	58.5^{a}	111^{b}	216^{c}	86.0^{b}	502^{ab}	347^{ab}	39.8^{ab}	112^{ab}
Grazemax 1UNIVERSAL	57.5^{a}	87.2^{c}	240^{b}	87.8^{b}	513^{ab}	331^{b}	44.3^{a}	141^{a}
Łąka 6 DRY	58.1^{a}	101^{c}	259^{b}	98.5^{ba}	498^{b}	333^{b}	39.6^{ab}	121^{ab}
Grass mixtures								
Cutmax 2 TURBO	60.9^{a}	80.5^{a}	249^{a}	66.6^{b}	562^{a}	318^{a}	47.4^{a}	115^{a}
Medowmax 5 ORGANIC	58.2^{a}	84.7^{a}	231^{a}	70.0^{a}	574^{a}	327^{a}	42.2^{a}	108^{a}
Grass in pure stand								
Festulolium cv. Hostyn	61.3^{a}	105^{a}	214^{a}	74.9^{a}	560^{a}	323^{a}	42.9^{a}	108^{a}
Festulolium cv. Mahulena	60.9^{a}	90.8^{a}	235^{a}	81.1^{a}	576^{a}	327^{a}	43.9^{a}	97.0^{a}
The means in columns marked with the same letters do not differ significantly								

Mahulena (i.e. 56 and 57.6%). Significantly lower values were recorded in the biomass of mixtures containing clover, trefoil (*Lotus corniculatus* L.), and alfalfa. According to the literature (Kochanowska-Bukowska, 2003; Gaweł and Madej, 2008; Godlewska and Ciepiela, 2018), compared to grasses, alfalfa contains on average 17 to 20% less NDF in dry matter. This is due to the fact that its share of stems in the yield increases much slower than in grasses. In addition, the share of alfalfa in the mixtures had a positive effect on the NDF formation in the harvested plant material. The low content of ADF (acid detergent fiber) in the forage ensures better digestibility and higher energy concentration (Jankowski et al. 2018). In the present experiment, its average dry matter content ranged from 318 g/kg for the Cutmax 2 TURBO mixture to 375 g/kg CutmaxALFAprotein – a mixture with 80% of alfalfa. According to the literature, of the legume species the most of the ADF fraction is contained in alfalfa biomass. The increased proportions of grass in the mixture with alfalfa can reduce ADF content by up to 6 to 11%, which proves that when grown together, they provide forage with a higher energy value, and at the same time with higher content of alfalfa protein.

Total protein content in plants ranged from 80.5 g/kg for the Cutmax 2 TURBO mixture to 154 g/kg for the CutmaxALFAprotein mixture. Those values were typical for such crops. The CutmaxALFAprotein mixture contains over 80% legumes, which, as confirmed by Hakl et al. (2015), significantly increases the protein content in the feed. What was worth noting was the high, over 141 g/kg^{-1} share of soluble sugars in the dry matter of the Grazemax 1 UNIVERSAL mixture, with 60% content of *Festulolium*. Research by Downing and Gamroth (2007) and Kitczak et al., (2021) shows that *Festulolium* is a sugar-rich species compared to other grasses. Its composition makes it possible to be grown for grazing or mowing in various habitat conditions. A clearly higher share of mineral compounds (ash) in the dry matter of plants was recorded in the biomass of grass-legume mixtures than in the biomass of grass grown without legumes.

CONCLUSIONS

Harvested three times a year, grass mixtures, legume-grass mixtures, and *Festulolium* (the *Lolium* type cv. Hostyn and the *Festuca* type cv. Mahulena) in pure stand, grown on poor mineral soils Class 4a with water shortages during the growing season, produced satisfactory yields at an average level of 10.5 Mg/ha DM. The highest yields were produced by legume-grass mixtures with a large (over 20%) share of *Festulolium*of the *Lolium* type cv. Hostyn. With its lower share in a mixture, i.e. 7%, a 16% decrease in yield compared to the average was noted. The differences between three harvest yields during the growing seasons were typical in the conditions of summer and fall droughts. Of three annual harvest, the highest share of biomass (46% on average) was produced by plants during the first growth period. A large proportion of alfalfa in the mixture reduced digestibility, but improved the content of total protein and mineral compounds, at the same time reducing the amount of the neutral fiber fraction, which improved forage quality in terms of its energy content.

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REFERENCES

1. Abas, I., Ozpinar, H., Can Kutay, H., & Kahraman, R. (2005). Determination of the Metabolizable Energy (ME) and Net Energy Lactation (NEL) Content of Some Feeds in the Marmara Region by In vitro Gas Technique. *Turkish Journal of Veterinary & Animal Sciences, 29*, 751–757.
2. Andrzejewska, J., Albrecht, K.A., & Jendrzejczak, E. (2013). Plant height and value of alfalfa in different development stages and cuts. *Fragmenta Agronomica, 30*, 14–22. (in Polish)
3. Borowiecki, J. (1997). *Festulolium* suitability for cultivation in mixtures with red clover. *Pamiętnik Puławski, 111*, 21–33. (in Polish)
4. Borowiecki, J. (2000). Legume – grass mixtures in the field forage production. *Zeszyty Problemowe Postępów Nauk Rolniczych, 1*, 83–94. (in Polish)
5. Borowiecki, J. (2002). Yielding of *Festulolium* variety Felopa in single-species sowing and in mixtures with orchard grass. *Pamiętnik Puławski, 131*, 49–58. (in Polish)
6. Downing, T.T.W., & Gamroth, M.J. (2007). Nonstructural carbohydrates in cool-season grasses. *Oregon State University Extension Service Special Report*, 11, 1–6.

7. Gaweł, E., & Madej, A. (2008). Yield and economic assessment of the legume-grass mixtures depending on the system and frequency of their utilization and botanical composition. *Acta Scientiarum Polonorum - Agricultura, 7*, 53–63. (in Polish)
8. Gaweł, E. (2012). Nutritive value of legume-grass mixtures cultivated in organic farms. *Journal of Research and Applications in Agricultural Engineering, 57*, 91–97. (in Polish)
9. Glowacki, S.C., Komainda, M., Leisen, E., & Isselstein J. (2023). Yield of Lucerne-grass mixtures did not differ from Lucerne pure stands in multisite field experiment. *European Journal of Agronomy*, *150*, 126927. https://doi.org/10.1016/j.eja.2023.126927
10. Godlewska, A., & Ciepiela, G.A. (2018). Assessment of the effect of various biostimulants on *Medicago* x varia T. Martyn yielding and content of selected organic components. *Applied Ecology and Environmental Research, 16*, 5571-5581, https://doi.org/10.15666/aeer/1605_55715581
11. Grzegorczyk, S. (1999). The influence of legumes on the nutritional value of meadow grass. Seminar materials: Modern methods of feed production on grasslands and assessment of their nutritional value. IMUZ Falenty Decemer 13–14, 1999, 133–143. (in Polish)
12. Hakl, J., Pisarčik, M., Fuksa, P., & Šantrůček, J. (2018). Development of Lucerne root morphology traits in lucerne-grass mixture in relation to forage yield and root disease score. *Field Crops Research*, 226, 66–73. https://doi.org/10.1016/j.fcr.2018.07.009
13. Hakl, J., Fuksa, P., Konečná, J., & Šantrůček J. (2015). Differences in the crude protein fractions of Lucerne leaves and stems under different stand structures. *Grass and Forage Science*, *71*, 413-423. https://doi.org/10.1111/gfs.12192
14. Harkot, W., Trąba, C. (1998). The influence of meadow clover share in the sward of multi-species mixtures with orchard grass, timothy grass and perennial ryegrass on the macronutrient content of the feed. *Biuletyn Naukowy, 1*, 131–139. (in Polish)
15. Homolka, P., Koukolová, V., Podsedníček, M., & Hlaváčková, A. (2012). Nutritive value of red clover and lucerne forages for ruminants estimated by in vitro and in vivo digestibility methods. *Czech Journal of Animal Science*, *57*, 454-568.
16. Jankowski, K., Truba, M., Wiśniewska-Kadżajan, B., Sosnowski, J., & Malinowska, E. (2018). The effect of soil conditioners on yield of dry matter, protein, and sugar in grass. *Acta Agrophysica, 25*, 45–58. https://doi.org/10.31545/aagr0004
17. Jokś, W., Nowak, T., Jokś, E., & Zwierzykowski, Z. (1998). Botanical and agricultural characteristics of Polish *Festulolium* varieties. Materials from the National Conference: *Festulolium*–achievements and perspectives. Poznań, November 26, 1998, 6–11. (in Polish)
18. Kitczak, T., Jänicke, H., Bury, M., Malinowski, R. (2021). The usefulness of mixtures with *Festulolium braunii* for the regeneration of grassland under progressive climate change. *Agriculture*, *11*, 537. https://doi.org/10.3390/agriculture11060537
19. Kochanowska-Bukowska, Z. (2003). The introduction to evaluate usefulness of some kinds of grasses for mixtures with *Medicago sativa* L. legend for alternating cuttings *Biuletyn IHAR, 225,* 221–228. (in Polish)
20. Kryszak, J. (2001). Yielding and quality of *Festulolium braunii* (K. Richter) A Camus mixture with red clover and lucerne on arable lands. *Zeszyty Problemowe Postępów Nauk Rolniczych, 479*, 173–178. (in Polish)
21. Lemežienė, N., Kanapeckas, J., Tarakanovas, P., & Nekrošas, S. (2004). Analysis of dry matter yiels structure od forage grasses. *Plant, Soil and Environment*, *50*, 277-282.
22. Malinowska, E., Wiśniewska-Kadżajan, B. (2022). Effects of Tytanit and Nitrogen on Cellulose and Hemicellulose Content of *Festulolium braunii* and on Its Digestibility. *Agronomy, 12*, 1547. https://doi.org/10.3390/agronomy12071547
23. Mikołajczak, Z., Warda, M. (1997). Production of pastures in conditions of limited mineral fertilization. *Zeszyty Problemowe Postępów Nauk Rolniczych, 453,* 25–38. (in Polish)
24. Olszewska, M. (2008). Gas exchange parameters in *Festulolium braunii* (K. Richt.) A. Camus grown in mixtures with legumes depending on multiple nitrogen rates. *Polish Journal of Natural Sciences, 23*, 48–72, https://doi.org/10.2478/v10020-008-0004-4
25. Østrem, L., Volden, B., & Larsen, A. (2013). Morphology, dry matter yield and phenological characters at different maturity stages of *Festulolium* compared with other grass species. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 63*, 531–542, https://doi.org/10.1080/09064710.2013.819440
26. Polish Society of Soil Science 2009. Classification of soil granulation and mineral formations - PTG 2008. *Roczniki Gleboznawcze, 41*, 3/4, 5–16. (in Polish)
27. Priya, P., & Sahi, S.V. (2009). Influence of phosphorus nutrition on growth and metabolism of duo grass (*Duo festulolium*). *Plant Physiology and Biochemistry*, *47*, 31–36. https://doi.org/10.1016/j.plaphy.2008.09.002
28. Sosnowski, J., & Truba, M. (2023). Effect of tytanit on selected physiological characteristics, chemical composition and production of *Festulolium braunii* (K. Richt.) A. Camus. *Agriculture 13,* 2155. https://doi.org/10.3390/agriculture13112155

29. Sosnowski, J., Truba, M., Jarecka, K. (2022). Effect of humus, compost, and vermicompost extracts on the net energy concentration, net energy of lactation, and energy yield of *Dactylis glomerata* and *Lolium perenne*. *Agriculture 12*, 1092. https://doi.org/10.3390/agriculture12081092
30. Sowiński, J., Gospodarczyk, F., Nowak, W., Szyszkowska, A., & Krzywicki, S. (1997). Yielding mixtures of tetraploid varieties of meadow clover (*Trifolium Pratense* L.) with grasses. *Biuletyn Oceny Odmian 29,* 155–160. (in Polish)
31. Sowiński, J., Jasiczek, G., & Kaszyca, S. (1999). Submission of tetraploid meadow clover with grasses depending on nitrogen fertilization and composition of the mixture. *Biuletyn IHAR, 210*, 131–144. (in Polish)
32. Staniak, M. (2004). Yields and fodder value of *Festulolium braunii* variety Felopa depending on the first time harvest. I. Yields and selected yield components. *Pamiętnik Puławski, 137*, 117–131. (in Polish)
33. Staniak, M. (2009). Yielding and fodder value of mixtures of *Festulolium braunii* (Richt.) A. Camus with di- and tetraploid varieties of red clover, *Fragmenta Agronomica, 26*(2), 105–115. (in Polish)
34. Staniak, M., Bojarszczuk, J., Kraska, P., Kwiatkowski, C., & Harasim, E. (2020). Prolonged drought stress induced changes in yield and physiological processes of *Trifolium repens* and *Festulolium braunii*. *Biologia Plantarum, 64*, 701–709. https://doi.org/10.32615/bp.2020.114
35. Surault, F., Huyghe, C., Sampoux, J.-P., Larbre, D., Barre, P., Louarn, G., & Julier, B. (2024). Weed control, protein and forage yield of seven grass species in Lucerne-grass associations. *Field Crops Research*, 309, 109308. https://doi.org/10.1016/j.fcr.2024.109308
36. Szyszkowska, A., Krzywiecki, S., Gospodarczyk, F., Nowak, W., & Sowiński, J. (1997). Changes in the nutritional value of mixtures of tetraploid grass and clover varieties (*Trifolium Pratense* L.) in the growing season. *Biuletyn Oceny Odmian, 29*, 179–183. (in Polish)
37. Ścibior, H. (1999). Submission of two- and three-time red clover mixtures with grasses in conditions of limited nitrogen fertilization. *Pamiętnik Puławski, 117*, 83–98. (in Polish)
38. Thomas, H., Humphreys, M. (1991). Progress and potential of interspecific hybrids of *Lolium* and *Festuca*. *Journal of Agricultural Science. 117*, 1–8. https://doi.org/10.1017/S0021859600078916
39. Truba, M., Wiśniewska-Kadżajan, B., Sosnowski, J., Malinowska, E., Jankowski, K., & Makarewicz, A. (2017). The effect of soil conditioners on cellulose, hemicellulose, and the ADL fibre fraction concentration in *Dactylis glomerata* and *Lolium perenne*. *Journal of Ecological Engineering, 18,* 107–112. https://doi.org/10.12911/22998993/66249
40. Wilman, D., Gao, Y., Leitch, M.H. (1998). Some differences between eight grasses within the *Lolium-Festuca* complex when grown in conditions of severe water shortage. *Grass and Forage Science, 53*, 57–65. https://doi.org/10.1046/j.1365-2494.1998.00104.