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The influence of the vegetation cycle and the mixture (grasses and legumes) on the height of the plants on sown grasslands

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ABSTRACT

The speed of growth, as well as the height of plants on sown lawns, are important from the point of view of the possibility of obtaining a larger number of swaths if the growth is faster, and obtaining a higher yield, if the plants are of a higher age, at the same crop density. Sown lawns, usually called grass-leguminous mixtures in practice, comprise different types of grasses and legumes. Depending on the variety, growing conditions, vegetation cycle and the like, in principle, the plants of the first vegetation cycle (first cutting) reach the highest height. Considering the mentioned facts, the proposed research aimed to analyse the influence of the vegetation cycle and the mixture on the height of grasses and legume plants in the plant community under different defoliation regimes. The three-year research results showed that the height of the plants at mowing depended on the species (mixture), year (age of plants and weather conditions) and vegetation cycle. In general, the plants of all species are the lowest in the year of sowing. In the second and third years, the plants of the first cut are the tallest, with almost all mowing regimes. However, the tallest plants in the first swath are in the flowering phase of the plants, where among the tested species, the tallest plants are orchard grass in all mixtures (average 91.99 cm), followed by Italian ryegrass (average 82.77 cm). The lowest plants are bird's foot trefoil (average 48.97 cm).

Keywords: grasslands, stage of plant development, vegetation cycle, plant height

INTRODUCTION

The growth rate and height of plants are biological properties, in both grasses and legumes, that are typical of certain species and dependent on numerous soil characteristics and environmental conditions. The height of plants in a grassland provides information in relation to the combined use of grasses and legumes and assesses their compatibility, which in turn affects the stability and productivity of the mixed crop (Bozhanska and Churkova, 2019). Sown grasslands are usually composed of different types of grasses and legumes. Success in growing sown grasslands depends on various factors which, depending on their interactions, can cause the reduction of compatibility of certain species and significantly increase the competitiveness of others, potentially reflecting in plant height, coverage, productivity, etc. In practice, sown grasslands in Bosnia and Herzegovina most commonly consist of red clover (*Trifolium pratense* L.), bird's-foot trefoil (*Lotus corniculatus* L.), Italian ryegrass (*Lolium italicum* L.), orchard grass (*Dactylis glomerata* L.) and timothy grass (*Phleum pratense* L.). These species differ significantly not only in morphology but also in germination rate, development rate, development type, earliness of growth, etc. In terms of biology, certain species differ significantly in plant height, but also the height of

individual species can vary to a large extent depending on the type of plant development, vegetation cycle, and weather conditions. The effect of environmental factors (precipitation, temperature) and soil fertility during the growing season on the height of plants is considerable (Radović et al., 2007; Nugmanov et al., 2022). The time of sowing and the height of plants on sown grasslands is one of the important characteristics that directly impact the yield (Kelman and Ayres, 2002; Simić et al., 2011). Chapko et al. (1991) and Aydın et al. (2010) also pointed out the positive influence of plant height on forage yield. The undertaken research aimed to analyze the influence of the vegetation cycle and weather conditions on the height of grass and legume plants in a plant community (mixture), at different defoliation regimes.

MATERIALS AND METHODS

Three-year research was conducted at the Butmir experimental field near Sarajevo. The field experiment was set up according to the randomized block design in four repetitions, with the size of the elementary plot of 5 m^2 (2,5 m x 2 m). Sowing was done manually in the spring of 2011, in rows with an inter-row distance of 12.50 cm. The amounts of seed used were as follows: 15 kg/ha for red clover, 12 kg/ha for bird's-foot trefoil, 25 kg/ha for Italian ryegrass, 12 kg/ha for timothy grass, and 30 kg/ha for or-chard grass. NPK fertilizer (15:15:15) was applied in the pre-sowing preparation of soil, in the amount of 250 kg/ha. A chemical analysis of the soil done before sowing showed that the content of potassium amounted to 20.8 mg/100 g of soil, while the content of phosphorus was 9.8 mg/100 g of soil. During the research, the experiment focused on monitoring the height of plants, two types of legumes and three types of grass, in four variants of the composition of sown grasslands: 1. Red clover (*Trifolium pratense* L.) 40%, Italian ryegrass (*Lolium italicum* L.) 20%, timothy grass (*Phleum pratense* L.) 20%, and orchard grass (*Dactylis glomerata* L.) 20% (mixture S1). 2. Bird's-foot trefoil (*Lotus corniculatus* L.) 40%, Italian ryegrass (*Lolium italicum* L.) 20%, timothy grass (*Phleum pratense* L.) 20%, orchard grass (*Dactylis glomerata* L.) 20% (mixture S2). 3. Red clover (*Trifolium pratense* L.) 20%, bird's-foot trefoil (*Lotus corniculatus* L.) 20%, Italian ryegrass (*Lolium italicum* L.) 20%, timothy grass (*Phleum pratense* L.) 20% and orchard grass (*Dactylis glomerata* L.) 20% (mixture S3). 4. Italian ryegrass (*Lolium italicum* L.) 33.3%, timothy grass (*Phleum pratense* L.) 33.3% and orchard grass (*Dactylis glomerata* L.) 33.3% (mixture S4). The height of the plants was determined by measuring immediately before cutting as follows: at a plant height of 20 cm (imitation grazing), at the budding phase of the legume component, and the flowering phase of the legume component. The test results were processed using mathematical and statistical methods in SPSS and Excel programs. During the research period, the average monthly temperature and amount of precipitation were monitored (2011-2013). Data from the meteorological station in Sarajevo were used for the analysis of weather conditions. The weather conditions during the research period are characterized by a significantly lower amount of precipitation and higher mean monthly air temperatures during the growing season in comparison with the multi-year average for the Butmir area, where the research was carried out (Table 1).

RESULTS AND DISCUSSION

In the research conducted in 2011, generally, the highest average height of plants was achieved in the first cutting, except in the phase of imitation grazing (Table 2). The height of plants of all types was generally low, especially in timothy grass (12.0 to 20.7 cm) and orchard grass (12.2 to 17.6 cm). The bird's-foot trefoil plants were slightly taller, whose height ranged from 18.6 to 26.0 cm, depending on the type of mixture and the stage of development at cutting. The red clover plants were slightly taller compared to the plants of bird's-foot trefoil, with a height ranging from 19.3 to 32.7 cm. All in all, the Italian ryegrass plant grew tallest with a height ranging from 50.2 to 80.5 cm. In most cases, the differences were statistically significant, as shown in the research results. The reasons for such results in timothy grass and cocksfoot can be explained not only by the semi-winter or winter type of development because in the year of sowing, the above-ground mass consists mostly of leaves,

Table 1. Average monthly temperature and amount of rainfall

Year	Month												Avrage
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
	Avrage monthly temperature (°C)												
1961-1990	-0.9	1.5	5.1	9.4	14.1	16.9	18.9	18.5	15.1	10.4	5.3	0.3	9.5
2011	-1.4	-0.3	4,8	10.8	13.6	18.7	20,1	20,9	18.2	8.4	2.4	1.1	9.8
2012	-2.2	-5.3	6.2	9.9	13.3	21.6	23.0	22.7	17.7	11.4	8.3	-0.7	10.5
2013	1.7	2.3	5.2	12.0	14.9	18.3	20.2	21.2	15.1	11.6	6.9	-0.4	10.8
	Amount of rainfall (l/m^2)												Amount
1961-1990	71.4	67.1	70.3	73.8	81.7	91.0	79.3	70.8	70.2	77.2	94.2	84.6	931.7
2011	12.9	22.6	27.8	31.4	70.4	23.4	93.4	4.4	45.0	47.8	11.0	80.6	470.7
2012	60.5	109.3	5.5	94.9	127.0	4.4	65.0	14.6	54.0	85.8	35.0	101.1	757.1
2013	97.9	119.0	74.2	55.2	119.4	55.6	62.3	21.8	37.4	51.0	95.7	9.4	798.0

but also by the fact that the year 2011 was an extremely dry year with a total amount of precipitation amounting to only 470.7 l/m^2, which is almost by 50% lower than the multi-year average. August (4.4 l/m^2) and June (23.4 l/m^2) had particularly low precipitation, which was reflected in the subsequent growth and development rates of plants. Observed by mixtures in the year of sowing, the biggest average height was achieved by the S4 mixture, in which Italian ryegrass, timothy grass and cocksfoot were represented with 33,3% each (in all cuts and at all phases of cutting), which is not entirely realistic because two species had very low height. The reason for this lies in the fact that there are only three species in the mixture, of which the Italian ryegrass is extremely tall thus contributing to the mentioned result.

In the following year, 2012, the plants of the first cutting were again the tallest on average (Table 3), which is the result, among other things, of a good supply of water during the formation of plant species of this cutting, with the biggest height achieved by the plants of S1 mixture, in all cutting regimes (except for the second cutting at the budding phase of legumes). Of all studied species, the tallest one was the cocksfoot in all cutting regimes, whose height reached 98.5 cm (in the flowering phase). The second tallest one was the Italian ryegrass, followed by timothy grass and red clover. The lowest plants were those of the bird's-foot trefoil. Differences in the height of plants within the studied mixtures, and cutting variants are also statistically significant. The significantly lower height of the bird's-foot trefoil, apart from the biological particularity, can also be explained by the lack of light due to overshading by taller species. The same is true for red clover, although its sensitivity to lack of light is lower, and the height reached is higher compared to that of the bird's-foot trefoil. The height of the plants in other cuttings was considerably lower, not only because this is a common occurrence, but also because of a significant lack of moisture in the formation of other cuttings, as moisture is necessary for the absorption of nutrients from the soil, growth and development.

Namely, in this research year, the amount of precipitation was lower compared to the multi-year average, and its distribution was very uneven. The months of May (127.0 l/m^2) and February (109.3 l/m^2) had the most precipitation, while June had the least with just 4.4 l/m^2, followed by March with 5.5 l/m^2, and August with 14.6 l/m^2.

Table 2. Plant height in different cutting regimes in 2011 (cm)

Mixture variants	Cutting regime				
	Imitation grazing		Legume budding		Flowering
	1. cutting	2. cutting	1. cutting	2. cutting	1. cutting
Red clover 40%	19.5^{b}	24.2^{b}	22.0^{b}	24.0^{b}	32.7^{b}
Italian ryegrass 20%	55.5^{a}	55.7^{a}	76.2^{a}	53.7^{a}	80.5^{a}
Timothy grass 20% (S1)	12.2^{c}	18.0^{c}	15.0^{c}	15.0^{c}	19.2^{c}
Orchard grass 20%	12.5^{c}	16.2^{c}	15.0^{c}	13.0^{c}	17.2^{c}
Average	24.93	28.52	32.0	26.42	37.40
Bird's-foot trefoil 40%	18.8^{b}	21.5^{b}	21.2^{b}	24.2^{b}	25.0^{b}
Italian ryegrass 20%	53.7^{a}	59.7^{a}	76.5^{a}	59.0^{a}	79.5^{a}
Timothy grass 20% (S2)	12.5^{c}	18.7^{bc}	15.0^{c}	15.0^{c}	18.5^{c}
Orchard grass 20%	12.2^{c}	16.5^{c}	15.0^{c}	13.5^{c}	17.2^{c}
Average	24.3	29.10	31.92	27.92	35.05
Red clover 20%	19.3^{b}	24.2^{b}	22.5^{b}	24.0^{b}	31.0^{b}
Bird's-foot trefoil 20%	18.6^{b}	20.0^{c}	21.5^{b}	23.7^{b}	26.0^{c}
Italian ryegrass 20% (S3)	54.2^{a}	62.2^{a}	77.0^{a}	57.0^{a}	79.7^{a}
Timothy grass 20%	13.0^{c}	18.5^{cd}	15.0^{c}	13.7^{c}	17.5^{d}
Orchard grass 20%	12.8^{c}	17.2^{d}	14.7^{c}	12.2^{c}	16.7^{d}
Average	23.58	28.42	30.14	26.12	34.18
Italian ryegrass 33,3%	50.2^{a}	58.7^{a}	74.7^{a}	57.7^{a}	79.5^{a}
Timothy grass 33% (S4)	12.0^{b}	18.0^{b}	15.5^{b}	14.2^{b}	20.7^{b}
Orchard grass 33,3%	13.5^{b}	16.5^{b}	15.3^{b}	13.2^{b}	17.6^{c}
Average	25.3	31.0	35.16	28.36	39.26

^{abcd} Values marked with different letters are significantly different ($P < 0,05$); ^{ns} No significance.

Table 3. Plant height in different cutting regimes in 2012 (cm)

Mixture variants	Cutting regime								
	Imitation grazing			Budding			Flowering		
	1-cutting	2-cutting	3-cutting	1-cutting	2-cutting	3-cutting	1-cutting	2-cutting	3-cutting
Red clover 40%	29.2	31.2^{c}	27.5^{a}	46.5	33.2^{bc}	25.0^{a}	71.7^{d}	31.0^{a}	31.2^{a}
Italian ryegrass 20%	27.0	36.7^{b}	19.7^{b}	51.5	36.0^{ac}	0.00	91.5^{b}	25.2^{b}	0.00
Timothy grass 20% (S1)	31.0	43.5^{a}	20.2^{b}	53.7	31.5^{b}	14.7^{c}	80.2^{c}	20.0^{c}	17.2^{c}
Orchard grass 20%	31.0	44.7^{a}	22.0^{b}	56.2	39.7^{a}	20.0^{b}	98.5^{a}	24.2^{b}	22.2^{b}
Average	29.55 ^{ns}	39.0	22.35	51.97 ^{ns}	35.1	19.9	85.47	25.1	23,53
Bird's-foot trefoil 40%	20.7^{c}	25.0^{c}	19.5^{b}	31.2^{b}	31.5^{ba}	20.2^{a}	44.7^{d}	29.7^{a}	23.2^{a}
Italian ryegrass 20%	22.7^{ac}	34.7^{b}	19.0^{b}b	43.7^{a}	33.0^{ba}	0.00	76.0^{b}	23.0^{c}	0.00
Timothy grass 20% (S2)	25.2^{ab}	39.7^{b}	19.2^{b}	45.7^{a}	29.5b	15.0^{b}	69.0^{c}	19.5^{bc}	16.7^{b}
Orchard grass 20%	26.0^{a}	42.0^{a}	22.0^{a}	45.7^{a}	35.0^{a}	19.2^{a}	95.0^{a}	26.7^{ab}	22.7^{a}
Average	23.65	35.35	19.92	41.57	32.25	18.13	71.17	24.72	20.86
Red clover 20%	28.0^{a}	32.7^{c}	27.2^{a}	47.0^{c}	32.0^{b}	26.7^{a}	67.5^{d}	31.5^{a}	28.7^{a}
Bird's-foot trefoil 20%	19.5^{b}	24.2^{d}	19.0^{c}	26.5^{b}	25.0^{c}	18.7^{b}	46.2^{e}	21.7^{c}	18.5^{c}
Italian ryegrass 20% (S3)	27.7^{a}	39.7^{b}	20.2^{c}	50.5^{ac}	34.7^{ba}	0.00	85.7^{b}	26.2^{b}	0.00
Timothy grass 20%	30.0^{a}	45.2^{a}	21.0^{bc}	54.0^{a}	31.0^{b}	16.5^{b}	78.7^{c}	20.7^{c}	18.2^{c}
Orchard grass 20%	29.0^{a}	42.7^{a}	24.5^{ab}	53.0^{a}	37.2^{a}	19.5^{b}	91.2^{a}	24.5^{b}	23.2^{b}
Average	26.84	36.9	22.38	46.2	31.98	20.35	73.86	24.92	22.15
Italian ryegrass 33,3%	23.5	34.5	17.2^{b}	35.5	36.5	0.00	72.5^{b}	22.7^{ab}	0.00
Timothy grass 33% (S4)	24.5	38.0	19.0^{b}	39.0	38.2	13.7^{b}	61.0^{c}	19.2^{b}	17.5^{b}
Orchard grass 33,3%	25.2	37.0	22.7^{a}	40.0	36.0	17.2^{a}	84.7^{a}	24.2^{a}	22.5^{a}
Average	24.4	36.5 ^{ns}	19.63	38.16^{ns}	36.9 ^{ns}	15.45	72.73	22.03	20.0

^{abcd} Values marked with different letters are significantly different ($P < 0,05$); ^{ns} No significance

The height of plants in the last research year, 2013, does not follow the same trend as in the previous one. Thus, the S1 mixture lawn was shorter in this regard compared to the previous years, and in most cases, it was taller regardless of the cutting regime (Table 4). Contrary to this, the height of plants of certain species followed the same trend as in the previous year, because the tallest plants were again those of cocksfoot, followed by Italian ryegrass, timothy grass, red clover and bird's-foot trefoil, though their height was lower compared to the previous year. Statistically significant differences were found in the height of plants within individual mixtures, as well as in different cutting regimes. It should be particularly noted that the height of grass species was lower in the grass mixture S4, compared to the height of the same species when combined with legumes. This supports the contribution of leguminous species to the nutrition of grasses with nitrogen, the advantage of growing grass-legume mixtures in comparison to growing pure crops (Pirhofer-Walzl et al., 2012). The results of the research in this year were contributed by weather conditions that were slightly more favourable during the vegetation period, as although the annual sum of precipitation was lower compared to the multi-year average, there were no extreme droughts, while the temperatures were slightly above the multi-year average. Taking into account the fact that intensive summer growth requires about 3 l/m^2 of precipitation per day, it is safe to state that most of the summer months suffered from a lack of moisture, particularly June, August and September, which affected the growth rate and the height of plants at cutting.

Dry mass and protein yield under different cutting regimes

The results of a three-year yield study indicate a significant influence of mowing regimes on the productivity of mixtures (Figure 1). The highest dry matter yield was achieved during the flowering phase of legumes, with an average total yield of all tested mixtures amounting to 22.67 t/ha. This was followed by the budding phase of legumes, where the dry matter yield reached 18.81 t/ha.

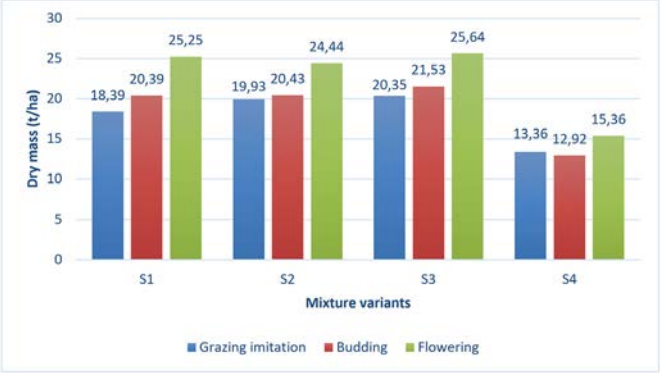

Figure 1. Comparative value of the three-year dry mass yield under different cutting regimes

The lowest dry matter yield was recorded during the imitation of the pasture phase, with only 18.00 t/ha. In this regard, the results presented by (Leto et al., 2013) also suggest that a significant increase in dry matter yield is achieved by delaying mowing until the onset of flowering. On the other hand, the botanical composition (components of mixtures) had a pronounced impact on yield. The mixture S3 proved to be the most productive overall, regardless of the mowing regime, with legumes and grasses representing 20% of the mixture. The total three-year yield of dry matter for this mixture was 20.35 t/ha (imitation of pasture phase), 21.53 t/ha (budding phase of legumes), and 25.64 t/ha (flowering phase of legumes). The lowest productivity over the three years of research was achieved by the S4 mixture, composed of Italian ryegrass, timothy grass and cocksfoot, which cannot compete with grass and legume mixtures, especially without higher doses of applied nitrogen fertilizers (Nyfeler et al., 2008).

The results of a two-year study on protein yield have shown that the mowing regime had a significant impact on the achieved protein yield, with significant positive differences observed with each subsequent mowing regime, regardless of the botanical composition of the mixtures (Figure 2). Mowing during the flowering phase of legumes resulted in a statistically significantly higher protein yield compared to yields obtained with other mowing regimes. Similarly, mowing during the budding phase of legumes resulted in a significantly higher protein yield compared to mowing during the imitation of the pasture phase.

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Table 4. Plant height in different cutting regimes in 2013 (cm)

Mixture variants	Cutting regime											
	Imitation grazing				Budding				Flowering			
	1-cutting	2-cutting	3-cutting	4-cutting	1-cutting	2-cutting	3-cutting	4-cutting	1-cutting	2-cutting	3-cutting	4-cutting
Red clover 40%	26.5^{b}	24.75^{d}	29.0^{a}	23.75^{a}	36.5^{c}	40.0^{b}	29.25^{a}	20.5^{a}	26.5^{c}	36.5^{a}	28.0^{a}	16.75^{b}
Italian ryegrass 20%	29.5^{ab}	40.75^{b}	29.25^{a}	0.00	44.0^{ab}	43.5^{b}	26.0^{a}	0.00	83.5^{ab}	39.75^{a}	25.75^{a}	0.00
Timothy grass 20% (S1)	30.25^{ab}	35.0^{c}	21.5^{c}	15.5^{b}	43.5^{b}	51.5^{ab}	20.75^{b}	12.0^{c}	79.5^{b}	26.75^{b}	17.25^{b}	14.25^{c}
Orchard grass 20%	32.5^{a}	46.25^{a}	26.0^{b}	22.0^{a}	50.5^{a}	58.0^{a}	28.25^{a}	16.75^{b}	95.0^{a}	39.25^{a}	26.25^{a}	21.0^{a}
Average	29.68	36.68	26.43	20.41	43.62	48.25	26.06	16.41	71.12	35.56	24.31	17.33
Bird's-foot trefoil 40%	29.25^{b}	23.50^{c}	23.25^{c}	19.25^{b}	37.5^{b}	38.5^{c}	23.5^{b}	16.25^{a}	53.0^{c}	36.75^{b}	28.0^{a}	15.5^{b}
Italian ryegrass 20%	31.5^{ab}	39.25^{a}	31.75^{a}	0.00	43.0^{ab}	49.0^{b}	24.75^{b}	0.00	85.0^{ab}	43.5^{a}	25.0^{b}	0.00
Timothy grass 20% (S2)	33.5^{a}	36.5b	23.25^{c}	15.25^{c}	45.5^{ab}	50.0^{b}	17.5^{c}	12.25^{b}	78.25^{b}	31.0^{c}	16.75^{c}	14.75^{b}
Orchard grass 20%	34.75^{a}	41.75^{a}	28.75^{b}	21.75^{a}	50.25^{a}	55.0^{ab}	29.5^{a}	17.75^{a}	93.75^{a}	41.5^{a}	24.5^{b}	19.0^{a}
Average	32.25	35.25	26.75	18.75	44.06	48.12	23.81	15.41	77.5	38.18	23.56	16.41
Red clover 20%	27.25^{c}	24.75^{d}	30.75^{a}	24.25^{a}	37.0^{c}	41.75^{b}	27.75^{a}	20.5^{a}	56.25^{c}	33.75^{bc}	26.25^{a}	18.75^{a}
Bird's-foot trefoil 20%	27.0^{c}	22.75^{d}	24.5^{bc}	20.5^{b}	34.0^{d}	38.5^{b}	23.25^{b}	16.75^{b}	52.0^{c}	32.0^{bc}	24.0^{b}	16.0^{bc}
Italian ryegrass 20% (S3)	28.75^{cb}	41.25^{b}	31.25^{a}	0.00	38.0^{c}	54.25^{a}	24.5^{b}	0.00	93.25^{a}	40.75^{a}	25.25^{ab}	0.00
Timothy grass 20%	30.0^{ab}	37.25^{c}	23.0^{b}	15.25^{c}	45.75^{b}	53.5^{a}	18.0^{c}	12.0^{c}	79.75^{b}	31.0^{b}	16.25^{c}	14.75^{b}
Orchard grass 20%	32.25^{a}	47.00^{a}	28.25^{ac}	23.0^{a}	51.25^{a}	57.0^{a}	28.0^{a}	18.25^{ab}	94.5^{a}	37.75^{ac}	25.25^{ab}	18.0^{ac}
Average	29.05	34.60	27.55	20.75	41.2	49.0	24.3	16.87	75.15	35.05	23.4	16.87
Italian ryegrass 33,3%	28.75	39.75^{b}	27.75	0.00	39.0^{b}	52.75	24.25^{b}	0.00	74.75^{b}	34.25^{a}	24.5^{a}	0.00
Timothy grass 33% (S4)	29.5	36.50^{b}	22.25	14.25^{b}	40.5^{b}	52.0	17.5^{c}	12.25^{b}	72.0^{b}	25.75^{b}	15.5^{b}	14.0^{b}
Orchard grass 33,3%	31.0	44.75^{a}	25.75	19.75^{a}	46.5^{a}	57.5	26.5^{a}	16.5^{a}	83.25^{a}	32.0^{a}	21.5^{a}	16.75^{a}
Average	29.77^{ns}	40.33	25.25^{ns}	17.0	42.0	54.08^{ns}	22.75	14.37	76.66	30.6	20.5	15.37

^{abcd} Values marked with different letters are significantly different ($P < 0,05$); ^{ns} No significance

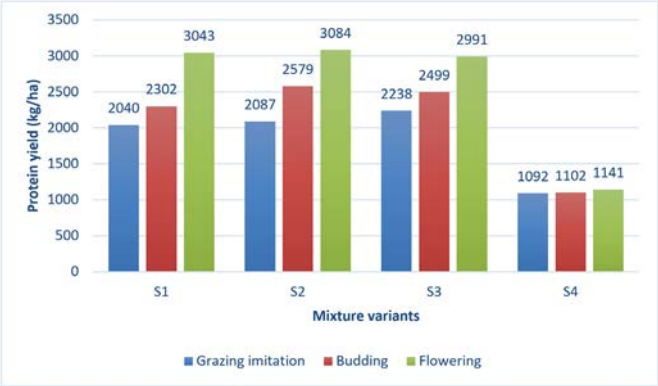

Figure 2. Comparative value of the two-year protein yield at different cutting regimes

On the other hand, the influence of the botanical composition, i.e., the mixture composition, is clearly pronounced.

The highest two-year protein yield under the mowing regime during the flowering and budding phases of legumes was achieved by variant S2 (3084 kg/ha and 2579 kg/ha), where bird's foot trefoil was represented with a high percentage (40% at the sowing). In the imitation of the pasture phase, the highest protein yield was obtained by mixture S3 (2238 kg/ha), where red clover and bird's foot trefoil were combined (each at 20% at the sowing). Mixture S4 achieved a significantly lower protein yield compared to the yield of other tested mixtures. This indicates that leguminous plants (red clover and bird's foot trefoil), regardless of their representation in the mixtures, had a positive impact on protein yield because their yield was significantly higher compared to the protein yield of grass mixtures. This is in line with the results of the research by Jose and Walter (2001), and Bezdrob and Alibegović-Grbić (2013).

CONCLUSION

Based on the obtained results of the research on the influence of the vegetation cycle and the mixture (grasses and legumes) on the height of the plants on sown grasslands, the following conclusions can be made:

The height of plants at cutting depended on the species, year (age of the plants and weather conditions), and vegetation cycle. In the year of sowing, the height of plants is mostly uncharacteristic, and generally lower, especially in species that develop more slowly and in species with a winter type of development in grasses.

In the second and third years, the tallest were the plants in the first cutting, in all cutting regimes, in general. However, the tallest plants in the first cutting were those in the flowering phase, where the tallest plants among the investigated species were those of cocksfoot and Italian ryegrass, and the lowest were the plants of bird's-foot trefoil.

The three-year results of the yield study indicate a significant impact of the mowing regime on the productivity of mixtures. The highest dry matter yield was achieved during the flowering phase of legumes, with an average total yield of all tested mixtures amounting to 22.67 t/ha. On the other hand, the influence of the composition (botanical composition) of mixtures on the expressed productivity is clearly pronounced. The highest three-year total dry matter yield, regardless of the mowing regime, was achieved by mixture S3, where red clover, bird-s foot trefoil, timothy grass, Italian ryegrass and cocksfoot were represented with 20% each in the mixture. Mowing in the later stages of plant development had a positive impact on protein yield, regardless of the botanical composition of the mixtures. However, significantly higher protein yields were achieved by mixtures S1, S2, and S3 when mowed during the flowering phase of legumes compared to earlier mowing regimes, which is not the case for mixture S4.

The research results have shown that the prevalence of certain species is highly dependent on the rate of development of individual species, regardless of the vegetation cycle or mowing regime. Italian ryegrass and red clover had a high prevalence already in the first year of the study, while the prevalence of timothy grass and cocksfoot increased only from the second year, especially in mixtures composed only of grasses. The smallest variations during the study were observed in bird's foot trefoil, which had a relatively high prevalence both at the beginning and at the end of the research period, unlike Italian ryegrass, whose prevalence decreased drastically.

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