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# Yielding of *Festulolium braunii/Trifolium pratense* mixture, depending on the proportion of mixture components

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**Abstract.** Potential of legume-grass mixtures production exceeds total yield of each component. The yield depends on species/cultivars composition as well as on their participation in sowing mixture. The aim of this study was to assess the effect of red clover cultivar and its proportion of the seeding mixture on the yield of mixtures with *Festulolium*.

A field experiment was conducted in two three-year series in 2005–2007 and 2006–2008 at the Institute of Soil Science and Plant Cultivation – Agricultural Experimental Station Grabów (51°21' N; 21°40' E), in a split-plot design. Two factors were tested: percentage of red clover seeds in mixture (40, 60, 80% compared to pure sowing), and clover variety: Nike (2n), Parada (2n), Bona (4n), Jubilatka (4n). Sulino cultivar of *Festulolium* was used in all mixtures.

The botanical composition of sward was identified during the study. Dry matter yields and crude protein yield from 1 ha were determined. The results were statistically analysed in conformance with the design of experiment. The significance of differences was examined using Tukey's test at $\alpha = 0.05$.

Festulolium is a species suitable for the mixtures with red clover. The yields of dry matter and crude protein of mixtures depended significantly on the share of components. The mixture with the share of 80% of clover seeds and 20% of festulolium proved to be the best in terms of the yield. The least advisible was the mixture containing 40% of red clover and 60% of festulolium. Tetraploid varieties of red clover are more useful for mixtures with festulolium, especially under favourable weather conditions.

**key words:** legume-grass mixtures, mixture composition, *Festulolium*, diploid cultivars, tetraploid cultivars

## INTRODUCTION

The introduction of grasses and legumes for crop rotation aims to improve the forage base for the animals, and simultaneously reduces costs of feed production (Grzegorczyk, 1999; Goliński, 1998). It also takes into account the need for maintaining the biological balance of ecosystems, which is the fundamental principle of sustainable development of agriculture (Duer, 1999; Nowak, Sowiński, 2007; Søegaard et al., 2007). Production potential of legume-grass mixtures is greater than that of a monospecific crop of each component. The formulation of appropriate recommendations concerning the composition of mixtures, tillage treatment and usage systems is difficult, due to the high variability of the effects, induced by the interaction between habitat and plants in the sward (Jelinowska, Staniak, 2007; Zannone et al., 1986). Maintaining of appropriate proportion of grasses and legumes can be obtained, among others, by proper selection of species and varieties, and their participation in the sowing mixture. The optimal performance and quality of green forage is provided by clover-grass mixtures, which, according to different authors, should contain from 30–50% of clover and 50–70% of grass (Ciepiela et al., 1998; Kessler, Lehman, 1998; Kryszak, 2003). In the field conditions red clover gives good yield in the mixture with festulolium (Kryszak, 2003; Søegaard, Weisbjerg, 2007), but due to high competitive ability of that hybrid, its part in sowing mixture should be significantly reduced (Borowiecki, 1997; Ostrowski, 2000; Staniak, 2008). Another important factor is the proper choice of forms and varieties of red clover. Some of the tetraploid varieties exhibit higher yield and better durability, and therefore should be suitable for cultivation in the mixtures (Gaweł, Bawolski, 1995; Borowiecki, Ścibior, 1997).

The aim of this study was to assess the yielding potential of festulolium mixtures with selected di- and tetraploid red clover varieties and pointing the most beneficial seed proportion of the seeded mixture in terms of the yield.

## METHODS

A field experiment was conducted in two three-year series in 2005–2007 and 2006–2008 at the experiment sta-

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tion RZD IUNG-PIB Grabów (51°21'N; 21°40'E). Festulolium (Sulino cv.) mixtures with red clover were sown on the lessive soil, very good rye complex. pH of soil was neutral before setting the experiment; phosphorus, potassium and magnesium per 1000 g of soil was: P – 170 mg (high content), K – 122 mg (low content), Mg – 36 mg (low content), C – 0.7%, humus – 1.2%. The experiment, conducted according to the split-plot scheme was arranged in four replications, on plots of 22 $m^2$ size till the harvest. Two factors were included in the experiment: the contribution of clover seeds in the mixture (40, 60, 80%), compared to the mass of seeds sown in pure sowing: festulolium – 40 kg $ha^{-1}$ (750 plants $m^{-2}$), diploid varieties of red clover 12 kg $ha^{-1}$ (320 plants $m^{-2}$), tetraploid varieties of red clover 15 kg $ha^{-1}$ (390 plants $m^{-2}$) and the variety of clover: Nike (2n), Parada (2n), Bona (4n), Jubilatka (4n). Mixtures were sown on the 14th April 2005 and the 9th May 2006, in rows every 12 cm, without a protection plant. The following doses of mineral fertilization (kg $ha^{-1}$) were used in the year of sowing: N – 60 (30 +30), P – 26 and K – 66, in the year of full usage: N – 90 (30 +30 +30), P – 22, K – 66 (33 +33). At the first series, in the sowing year, two swaths of green matter were collected, whereas in the first year of utilization – three cuts, and in the second year – four cuts. In the second series, in the sowing year, only one cut was harvested, whereas in the first and second year – four cuts. The botanical composition of sward was identified at the research. The dry matter yields and crude protein yield from 1 ha were determined, on the basis of the dry matter content (by weight at 105°C) and total protein (by Kjeldahl method). The results were statistically elaborated for the randomized split-plot layout. The significance of differences was examined using Tukey's test at significance level $\alpha = 0.05$.

The weather conditions during the experiment varied significantly; they were characterized particularly by high variability of precipitation (Table 1). In 2005, heavy rainfall occurred in May and July, while the significant deficiencies of water were noted in April, June and August. The year 2006 was even less favorable for the growth and development of grasses. Two summer months: June and July were particularly dry which was also accompanied by high air temperature (in July it exceeded the multi-year mean average by 4.1°C). Heavy rainfalls occurred only in August, and were almost three times higher than the average of the region. Between 2007 and 2008, rainfall during the growing period was respectively 30 and 12% higher than long-term average, and its distribution was more balanced. The plant growth proceeded in the first series of experiment (2005–2007) in the less favourable weather conditions. The moisture conditions were better in the second series of studies (2006–2008).

## RESULTS AND DISCUSSION

### Botanical composition of sward

The emergence of plants was quite good and balanced, but the participation of clover seedling in the plant emergence was significantly lower compared to the quantity of seeds sown (Table 2). In 2005, the participation of red clover in the emergence was from 26 to 56%, while in 2006, from 39 to 61%, which was largely influenced by high competitive ability of festulolium in relation to legumes (Borowiecki, 1997; Ostrowski, 2000; Ścibior and Gaweł, 2004).

The participation of clover in the dry matter yield, in 2005, was similar to the share of clover after emergence, while in 2006, due to adverse moisture conditions, was much smaller. This was also reflected in a smaller share of clover in dry matter yield at the first year of utilization (2007). The major impact of weather conditions on the contribution of individual components in the yield of subsequent regrowths was also reported by Harkot and Trąba (1998) and Sowiński et al. (1997, 1999). The clover in the year of sowing was significantly more sensitive to soil moisture deficits than festulolium, due to the poorly formed root system. The festulolium hybrid was more sensitive to adverse conditions in the first year of utilization. It confirms the results of Borowiecki (2002) and Wilman et al. (1998) for festulolium susceptibility to drought, as well as earlier studies of the author (Staniak, 2004).

Table 1. Meteorological conditions during vegetation periods of mixtures.

| Years of research | Rainfall [mm]# | | | | | | Temperature [°C]## | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | month | | | | | | | | | | | |
| | IV | V | VI | VII | VIII | IX | IV | V | VI | VII | VIII | IX |
| 2005 | -28.8 | 27.0 | -24.7 | 48.8 | -38.2 | -6.4 | 0.9 | 0.1 | -0.6 | 1.7 | 0.2 | 1.6 |
| 2006 | -8.9 | -3.6 | -32.8 | -74.0 | 144.0 | -36.2 | 1.3 | 0.2 | 0.7 | 4.1 | 0.6 | 2.3 |
| 2007 | -25.7 | 17.6 | 28.9 | 8.5 | 76.7 | 27.4 | 1.0 | 1.8 | 2.0 | 0.9 | 1.8 | -0.4 |
| 2008 | 32.9 | 30.6 | -19.3 | 1.4 | -20.5 | 20.9 | 1.3 | -0.3 | 0.9 | 0.6 | 1.6 | -0.7 |
| Mean from the years 1871–2000 | 39.0 | 57.0 | 71.0 | 84.0 | 75.0 | 50.0 | 7.7 | 13.4 | 16.7 | 18.3 | 17.3 | 13.2 |

# the difference between the total precipitation and long term average in the given month.
## the difference between the average daily air temperature and average long term temperature of each month, during the given month.

Table 2. Emergence [%] and mean share of red clover in the dry matter yield of mixtures [%].

| Share of red clover (%) | Red clover cultivar | Emergence | | Share of red clover in dry matter yield | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | sowing year | | 1st year of utilization | | 2nd year of utilization | |
| | | series | | | | | | | |
| | | I (2005) | II (2006) | I (2005) | II (2006) | I (2006) | II (2007) | I (2007) | II (2008) |
| 40 | Parada | 11.7 | 11.2 | 13.9 | 3.9 | 46.0 | 24.5 | 54.6 | 71.9 |
| | Nike | 7.6 | 15.2 | 7.5 | 5.2 | 33.8 | 25.7 | 50.2 | 67.5 |
| | Bona | 8.3 | 18.0 | 7.6 | 7.9 | 44.8 | 34.4 | 54.5 | 74.1 |
| | Jubilatka | 13.7 | 18.3 | 9.6 | 8.0 | 48.3 | 32.6 | 54.0 | 75.8 |
| | mean | 10.3 | 15.7 | 9.6 | 6.2 | 43.2 | 29.3 | 53.4 | 72.3 |
| 60 | Parada | 17.8 | 23.5 | 19.2 | 3.9 | 61.5 | 27.2 | 65.8 | 72.0 |
| | Nike | 28.9 | 27.0 | 19.0 | 5.3 | 53.1 | 36.2 | 63.1 | 70.6 |
| | Bona | 18.7 | 30.7 | 16.8 | 13.2 | 45.9 | 47.3 | 58.9 | 82.8 |
| | Jubilatka | 19.8 | 22.6 | 20.0 | 14.2 | 61.2 | 39.3 | 61.5 | 82.4 |
| | mean | 21.3 | 26.0 | 18.8 | 9.2 | 55.5 | 37.5 | 62.3 | 77.0 |
| 80 | Parada | 35.1 | 53.1 | 24.9 | 21.2 | 64.6 | 44.6 | 68.5 | 79.4 |
| | Nike | 46.1 | 52.7 | 21.3 | 18.2 | 65.1 | 42.1 | 67.0 | 75.2 |
| | Bona | 44.9 | 49.8 | 28.6 | 36.5 | 61.7 | 54.4 | 68.4 | 83.6 |
| | Jubilatka | 53.2 | 39.9 | 31.3 | 28.7 | 67.6 | 43.5 | 69.6 | 82.2 |
| | mean | 44.8 | 48.9 | 26.5 | 26.2 | 64.8 | 46.1 | 68.4 | 80.1 |

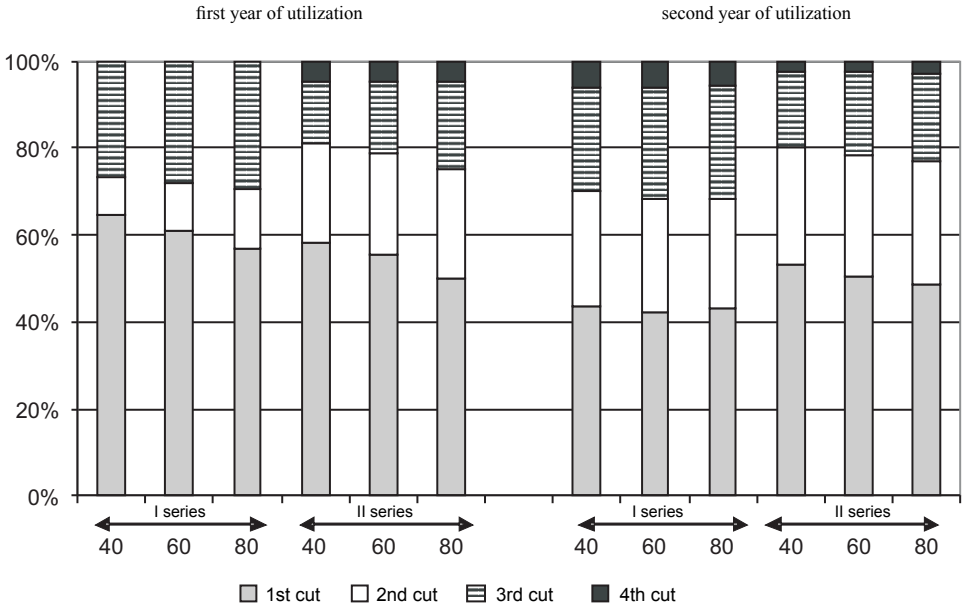


Fig. 1. The percentage participation of cuts in the whole annual dry matter yield of the mixtures.

## Yield distribution

The contribution of individual cuts to the annual yield is important in multi-harvested perennials production. The reduction of the share of the first cut in favour of the second and the third one is evaluated positively in the production of feed (Wilczek, 2008).

The proportion of individual cuts in the annual dry matter yields depends on the participation of individual components (Fig. 1). The weather conditions during the study also had strong influence on this trait. A favourable share of the first cut was recorded in the mixtures with the largest participation of clover (80%), although the differences were more pronounced in the better weather conditions (series II), where the first cut was on average 50% of total yield. With 40% share of clover in the mixture, in these weather conditions, the first crop accounted for around 56%. A small amount of rainfall during the second vegetation regrowth in 2006 (series I) significantly reduced its share in the yield, while high rainfall in August increased

Table 3. Dry matter yields of festulolium-red clover mixtures [t·ha$^{-1}$]

| Share of red clover [%] | Cultivar of red clover | Sowing year | | 1st year of utilization | | 2nd year of utilization | | Total yields | |
|---|---|---|---|---|---|---|---|---|---|
| | | series | | | | | | | |
| | | I (2005) | II (2006) | I 2006) | II (2007) | I (2007) | II (2008) | I | II |
| 40 | Parada | 3.23 | 2.69 | 9.3 | 12.2 | 14.5 | 12.1 | 27.0 | 29.7 |
| | Nike | 2.76 | 3.04 | 8.1 | 13.6 | 12.9 | 11.6 | 23.7 | 31.0 |
| | Bona | 2.99 | 2.75 | 9.3 | 15.1 | 14.0 | 14.1 | 26.3 | 35.1 |
| | Jubilatka | 2.99 | 2.67 | 9.3 | 16.8 | 14.6 | 15.1 | 27.0 | 38.0 |
| 60 | Parada | 3.41 | 2.32 | 10.3 | 14.5 | 16.2 | 13.7 | 30.0 | 33.6 |
| | Nike | 3.73 | 2.16 | 9.9 | 16.0 | 16.6 | 14.0 | 30.2 | 35.4 |
| | Bona | 3.10 | 2.59 | 9.9 | 18.3 | 14.9 | 16.3 | 27.9 | 40.9 |
| | Jubilatka | 3.87 | 2.84 | 11.2 | 17.2 | 16.4 | 15.9 | 31.4 | 39.5 |
| 80 | Parada | 4.57 | 2.42 | 11.1 | 17.6 | 17.9 | 14.8 | 33.6 | 38.3 |
| | Nike | 3.85 | 3.16 | 11.0 | 18.5 | 16.7 | 16.7 | 31.5 | 42.2 |
| | Bona | 4.17 | 3.28 | 12.0 | 19.9 | 16.8 | 19.1 | 32.9 | 46.5 |
| | Jubilatka | 4.26 | 2.93 | 11.7 | 18.5 | 17.6 | 15.8 | 33.5 | 41.0 |
| Mean for share of red clover | | | | | | | | | |
| 40 | | 2.99 | 2.79 | 9.0 a | 14.4 a | 14.0 a | 13.2 a | 26.0 a | 33.5 a |
| 60 | | 3.53 | 2.48 | 10.3 ab | 16.5 b | 16.0 ab | 15.0 b | 29.9 ab | 37.3 b |
| 80 | | 4.21 | 2.95 | 11.5 b | 18.6 c | 17.2 b | 16.6 b | 32.9 b | 42.0 c |
| Mean for cultivar of red clover | | | | | | | | | |
| | Parada | 3.74 | 2.42 | 10.2 ab | 14.8 a | 16.2 | 13.5 a | 30.1 ab | 33.8 a |
| | Nike | 3.45 | 2.79 | 9.7 a | 16.0 a | 15.3 | 14.1 ac | 28.4 a | 36.2 a |
| | Bona | 3.42 | 2.87 | 10.4 ab | 17.7 b | 15.2 | 16.5 b | 29.0 ab | 40.8 b |
| | Jubilatka | 3.71 | 2.81 | 10.7 b | 17.5 b | 16.2 | 15.6 bc | 30.6 b | 39.5 b |
| Mean for cultivar form | | | | | | | | | |
| Diploid varieties | | 3.59 | 2.63 | 9.9 a | 16.3 a | 15.8 | 13.8 | 29.3 | 31.8 a |
| Tetraploid varieties | | 3.55 | 2.84 | 10.6 b | 18.7 b | 15.7 | 16.0 | 29.8 | 36.5 b |

Numbers in columns followed by the same letters do not differ significantly

the share of the 3rd regrowth. Greatest production capacity of the plant mass of the third cut comparing to the previous one is a rare phenomenon in the literature (Ćwintal, Kościelecka, 2005). The major impact of weather conditions on this trait was also reported by other authors (Wilczek, 2008; Ćwintal, 2008; Kryszak, 2001; Sowiński et al., 1997). The selection of varieties did not affect significantly the contribution of individual cuts in the annual yield, as confirmed by the results of Ćwintal and Wilczek (2004).

## The dry matter yield

The weather conditions during the study were the most differentiating factor of the yields. The summer drought in 2006 had an especially great impact, which caused almost total loss of crops in the second cut (series I). Under these conditions, total dry matter yields of mixtures in the first year of utilization were on average 37% lower than the yields of mixtures in the first year of utilization under favourable weather conditions (series II).

There was a significant interaction during the years, which was the result of the varied response of the varieties to the weather conditions, and therefore the treatment average is given for each year separately. The seed proportions of individual components were shown to have a significant effect on mixture yields (Table 3). The most efficient were mixtures containing 80% of red clover at sowing, whereas the least efficient one was that with 40% share of the red clover.

The significant differences were found in all years of utilization, as well as in the total yields, although this trend was also maintained in the sowing year. The rise of the total dry matter yields averaged 26%, compared to a mixture with 40% share of legumes. This is confirmed by Gaweł (2009), who showed that a mixture of red clover, meadow fescue and festulolium, with 60% share of legumes was more efficient than a mixture with 40% of clover. The better yields of the mixtures with higher clover share were also reported by other authors (Sowiński et al., 1997, 1999). In terms of the cultivar factor, the mixtures of festulolium with tetraploid varieties of red clover showed higher productivity. The increase of the total dry matter yields averaged 15%. Under less favourable weather conditions (series I) the mixture that involved cv. Jubilatka gave the

best yield whereas yields of mixtures with varieties: Bona, and Parada did not differ significantly. The mixture involving the diploid cultivar Nike was the poorest one. Under the better moisture conditions (series II), a mixture with Bona and Jubilatka gave significantly higher yield. These results were confirmed in the research by Borowiecki (1997), in which the mixture of festulolium with tetraploid red clover cultivar Ulka gave higher yield than the mixture with diploid Nike cultivar. Investigations by Gaweł and Bawolski (1995) gave similar result: the mixtures of fescue with tetraploid red clover (regardless of cultivar) gave generally higher yields than the diploid clover mix. In COBORU (Broniarz, 2006) studies the cultivar Bona gave higher yield than Parada. Wilczek (2008) showed that the weather conditions with periodic shortages of water lead to the greater efficiency of green mass of Bona cultivar (in the monocultivar sowing). The same conditions lead to the greater efficiency of the dry mass of Parada cultivar, which may indicate lower demand for water of that cultivar.

### The yields of crude protein

The total protein production from 1 ha was significantly differentiated by the share of clover at sowing mixtures. The greatest yield of protein was obtained from the mixtures with the largest share of legumes (80%) and in both series was 44% greater than that from a mixture with 40% share of legumes (Table 4). A similar relationship was demonstrated by Sowiński et al. (1999), who obtained by an average of 371 kg ha$^{-1}$ more protein from the mixture with 70% share of clover seeds in a mixture with different species of grasses (ryegrass: annual, hybrid, perennial, meadow fescue) than from the sowing mixture in inverse proportion. Staniak (2008) also confirmed in other investigations the beneficial effect of increased participation of red clover in canopy mixtures on the yield of protein. The cultivar of clover was also the factor influencing the obtained yield of protein.

The mixture of tetraploid varieties showed the greater efficiency of protein, although the significant differences were recorded only in the second year of utilization and in the total yields of the 2$^{nd}$ series of the experiments. The total crop yield increase averaged 16%. Under the favourable weather conditions (series II) the most efficient cultivar was Bona while under the shortage of moisture, Jubilatka was the best. The lowest yield of protein was obtained from the mixtures with Nike cultivar. The greater efficiency of true protein of tetraploid cultivar of red clover Karo as compared with diploid cultivar Dajana was reported by Ćwintal and Wilczek (2004). No significant differences in

Table 4. Total protein yields of mixtures [kg ha$^{-1}$].

| Share of red clover [%] | Red clover cultivar | Sowing year | | 1st year of utilization | | 2nd year of utilization | | Total yields | |
|---|---|---|---|---|---|---|---|---|---|
| | | series | | | | | | | |
| | | I | II | I | II | I | II | I | II |
| 40 | Parada | 443 | 397 | 1123 | 1156 | 1945 | 1682 | 3511 | 3236 |
| | Nike | 430 | 409 | 1101 | 1259 | 1972 | 1349 | 3503 | 3017 |
| | Bona | 468 | 347 | 1112 | 1788 | 1896 | 1895 | 3475 | 4030 |
| | Jubilatka | 459 | 407 | 1289 | 1781 | 2091 | 2121 | 3839 | 4309 |
| 60 | Parada | 593 | 352 | 1460 | 1670 | 3021 | 2181 | 5074 | 4203 |
| | Nike | 592 | 350 | 1276 | 1536 | 2585 | 2002 | 4453 | 3888 |
| | Bona | 449 | 408 | 1080 | 2194 | 2482 | 2286 | 4011 | 4889 |
| | Jubilatka | 621 | 462 | 1796 | 1858 | 2553 | 2443 | 4970 | 4762 |
| 80 | Parada | 740 | 333 | 1608 | 2128 | 2871 | 2471 | 5219 | 4932 |
| | Nike | 634 | 427 | 1476 | 2282 | 2650 | 2439 | 4760 | 5148 |
| | Bona | 696 | 449 | 1734 | 2424 | 2850 | 3092 | 5280 | 5965 |
| | Jubilatka | 769 | 378 | 1736 | 2194 | 2996 | 2426 | 5501 | 4998 |
| Mean for share of red clover | | | | | | | | | |
| 40 | | 450 a | 390 | 1156 a | 1496 a | 1976 a | 1762 a | 3582 a | 3648 a |
| 60 | | 564 a | 392 | 1403 ab | 1815 a | 2660 b | 2228 ab | 4627 b | 4435 b |
| 80 | | 710 b | 397 | 1638 b | 2257 b | 2842 b | 2607 b | 5190 b | 5261 c |
| Mean for cultivar of red clover | | | | | | | | | |
| | Parada | 592 | 361 | 1397 | 1652 a | 2612 | 2112 | 4601 | 4124 ab |
| | Nike | 552 | 395 | 1284 | 1692 ab | 2402 | 1930 | 4238 | 4017 a |
| | Bona | 538 | 401 | 1308 | 2135 b | 2409 | 2424 | 4255 | 4961 b |
| | Jubilatka | 616 | 416 | 1607 | 1944 ab | 2547 | 2330 | 4770 | 4690 ab |
| Mean for cultivar form | | | | | | | | | |
| Diploid varieties | | 572 | 378 | 1341 | 1672 | 2507 | 2021 a | 4420 | 4071 a |
| Tetraploid varieties | | 577 | 409 | 1458 | 2040 | 2478 | 2377 b | 4513 | 4825 b |

Numbers in columns followed by the same letters do not differ significantly

the efficiency of the protein between two varieties: Bona (4n) and Parada (2n) were noted by Wilczek (2008).

## CONCLUSIONS

1. The differentiation of seed participation in the mixture of festulolium with red clover significantly affected the amount of dry matter and protein yields. The most efficient were the mixtures of 80% share of clover in the sowing, while the least-yielding were the mixtures with 40% share of that species. The rise of the total yield of a dry matter averaged 26%, whereas proteins 44%.

2. The weather conditions, particularly humidity and the selection of red clover varieties for the mixtures with festulolium significantly effected on their yield. The most useful proved to be tetraploid varieties of red clover. In conditions of shortage of moisture the highest yields of dry matter and total protein were obtained from the mixture with the cultivar Jubilatka, while the poorest yields were gained from the mixture with diploid cultivar Nike. The mixtures of varieties Bona and Jubilatka were characterized by greater efficiency of dry matter and total protein under the favourable weather conditions.

3. Festulolium is a species suitable for the mixtures with red clover. The mixture with the share of 80% of clover seed and 20% of festulolium proved to be the best in terms of the yield. More useful for mixtures with festulolium are tetraploid varieties of red clover.

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