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Adaptive and productive characteristics of perennial meadow grasses in the conditions of the Central Balkan Mountain

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Abstract

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During the period of 2016-2019 in the experimental field at Research Institute of Mountain Stockbreeding and Agriculture – Troyan was conducted a field experiment. It was traced the adaptability and productivity on perennial forage grasses (*Lolium perenne* L. – cv. K-11; *Lolium multiflorum* L. – cv. K-13; *Lolium multiflorum* L. – cv. K-29t; *Festuca arundinaceae* Scherb. – cv. K-20; *Festuca pratensis* Huds. – cv. K-21; *Dactylis glomerata* L. – cv. K-24 and *Bromus inermis* Leyss – cv. BV-1 exp.) in the conditions of the Central Balkan Mountain, Bulgaria. The highest average fresh mass productivity in the first (1740.7 kg/da) and second (629.6 kg/da) regrowth, and the highest average dry mass yield in the second regrowth (226.7 kg/da) were found in tall fescue (cv. K-20). Smooth brome (cv. BV-1exp.) achieves maximum yield of dry mass in the first regrowth (487.8 kg/da). Compared to the other types of forage grasses included in the experiment, the Italian ryegrass (cv. K-29t) gave ($P < 0.05$ – $P < 0.001$) the highest grass cover in spring (84.1 cm) and summer (59.8 cm) regrowths.

Keywords: perennial meadow grasses; yield; grass stand height

Introduction

Sustainable agriculture requires organic production of fodder species with high potential, durability and optimal suitability to the ecological conditions of a given area (Reheul et al., 2007; Reheul et al., 2015; Katova, 2016). Promising in this regard are the species *Dactylis glomerata* and *Festuca arundinacea*, which show high resistance to drought and offer opportunities to reduce environmental impact (Pontes et al., 2007; Reheul et al., 2015). From a biological point of view, the species and cultivars of perennial meadow grasses should be a balanced product (Rotili et al., 1996), regarding the quantitative and qualitative composition of the available metabolites at different stages of individual plant development. Their combined use is subject to biological features in the species growth and development during vegetation, as well as to changes in the chemical composition of the formed biomass (Kusvuran et al., 2014). Perennial ryegrass (*Lolium perenne* L.) has high digestibility and tolerance of grazing (Katova, 2011; Katova, 2017 a, b), and Italian ryegrass (*Lolium multiflorum* Lam.) is characterized by high productivity and nutritional value (Pavinato et al., 2014). Perennial meadow grasses have a slow rate of development and low yield in the year of sowing (Vasileva et al., 2017). The formed biomass is a cheap source of ecologically clean fodder, with good quality and favourable chemical composition.

The testing of the individual species and cultivars of perennial meadow grasses will lead to establishment of their ecological plasticity, adaptability and productivity under the soil and climatic conditions of the Central Balkan Mountain.

Material and Methods

In the period 2016-2019, in the experimental field of the Research Institute of Mountain Stockbreeding and Agriculture – Troyan (Bulgaria), the growth and productivity of Ser-

bian perennial grasses were observed in the Central Balkan Mountain in Bulgaria.

The field experiment is based on light gray, pseudo-podzolic soils with a content of basic nutrients in the soil layer of 0-20 cm and 20-40 cm as follows: total N – 20.2 mg/1000 g, $P_2 0_5$ – 2.4 mg/100 g, K_2O – 9.9 mg/100 g, humus – 1.44% and N – 8.6 mg/1000 g, $P_2 0_5$ – 1.2 mg/100 g, K_2O – 5.9 mg/100 g, humus – 0.96%.

Variants of the experiment include seven cultivars of fodder grasses: perennial ryegrass – cv. K-11 (*Lolium perenne* L.); Italian ryegrass – cv. K-13 (*Lolium multiflorum* L.); Italian ryegrass – cv. K-29t (*Lolium multiflorum* L.); tall fescue – cv. K-20 (*Festuca arundinaceae* Scherb.); meadow fescue – cv. K-21 (*Festuca pratensis* Huds.); cock's-foot – cv. K-24 (*Dactylis glomerata* L.) and smooth brome – cv. BV-1 exp. (*Bromus inermis* Leyss), laid by the block method in four replications with a plot size of 5 m^2. Sowing was manual, scattered, with a sowing rate in accordance with that for the species in pure condition at 100% seed germination. A single fertilization with nitrogen at a dose of 6 kg da^{-1} active substance was applied.

The grass stands were mowed in the flag leaf sheath opening/earing phase for grasses For the experimental period, nine cuttings were made, of which: three in the year of sowing (2016) – in the form of sanitary mowing and six – distributed in the second (2017), third (2018) and fourth (2019) vegetation.

Perennial meadow grass species are characterized by a long vegetation, and the water and temperature regime in the experimental area play a crucial role in their development, productivity and nutritional value (Staniak, 2016). The sum of the monthly vegetation precipitations on average for the experimental period (705.5 mm) was inferior to that after the year of sowing (762.4 mm) (Figure 1).

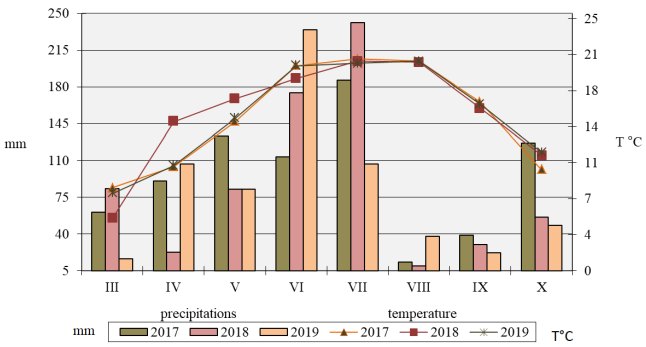

Fig. 1. Average monthly temperatures (°C) and monthly precipitation amounts (mm) for the vegetation period (March-October) 2017-2019

The relative difference expressed in percentages is 8.1%. The vegetation amount of precipitation in 2018 and 2019 was inferior in quantity to the average for the period by 0.9 and 7.8%, respectively. In total for the experimental period, the average air temperature for March-October varied from 15.0 to 15.3°C.

In 2017 and 2018, July had maximum average air temperatures (20.6 and 20.4°C, respectively) and maximum monthly precipitation amounts (186.6 and 241.1 mm, respectively). During the vegetation period of 2019, the maximum amount of precipitation (234.6 mm) was in April, and the absolute maximum air temperature (20.4°C) was measured in August.

For the purpose of the study, the following indicators were reported and analyzed: meteorological observations (temperature and precipitation amount during vegetation), yield of green and dry mass (kg/da), and grass height (cm).

Statistical data was processed by dispersion analysis (ANOVA), multiple comparison of means over the smallest statistically proven differences (LSD).

Results and Discussion

Yield of fresh and dry mass of perennial grasses

In the period of the experiment, tall fescue (cv. K-20) showed the highest ecological plasticity and adaptability to the soil and climatic conditions of the Central Balkan Mountain. That species had the highest fresh mass productivity in the first (1740.7 kg/da) and second (629.6 kg/da) regrowth and the highest dry mass yield in the second regrowth (226.7 kg/da) compared to the other grasses included in the present study (Tables 1 and 2).

Fresh mass – first regrowth

In the year after sowing (2017), perennial ryegrass (2544.4 kg/da) had the highest values of the indicator, followed by Italian ryegrass (2477.8 kg/da – cv. K-29t) and cock's-foot (2377.8 kg/da) (Table 1). The registered annual yields exceeded the average for the period by 54.7%, 62.8% and 42.7% respectively. The crops of Italian ryegrass (cv. K-13) and tall fescue had a minimal difference in the values of the indicator. In the first harvest year, the amount of formed biomass was higher by 54.5% and 30.9%, respectively, compared to the average for the study period. In 2017, Smooth brome and meadow fescue had the lowest productivity of fresh mass in the first regrowth compared to other perennial grasses, despite the fact that the indicator in both crops exceeded the average for the period by 40.3% and 33.5% respectively.

Table 1. Fresh mass yield (kg/da) of perennial meadow grasses, by regrowth, years and average for the period 2017-2019

Cultivar / Year	K-11	K-13	K-29t	K-20	K-21	K-24	BV-1exp.	*Average* (annual)
I regrowth								
2017	2544.4	2288.9	2477.8	2277.8	2066.6	2377.8	2177.8	*2315.8*
2018	1222.2	1344.4	1233.3	1311.1	1366.7	1388.9	1266.7	*1304.7*
2019	1166.7	811.1	855.5	1633.3	1211.1	1233.3	1211.1	*1160.3*
Average	*1644.4*	*1481.5*	*1522.2*	*1740.7*	*1548.1*	*1666.7*	*1551.8*	
$LSD_{0.05}$ = 280.0								
$LDS_{0.01}$ = 373.3								
$LSD_{0.001}$ = 490.0								
II regrowth								
2017	322.2	255.6	300.0	500.0	277.8	388.9	388.9	*347.6*
2018	344.4	411.1	233.3	766.7	366.7	544.4	522.2	*455.6*
2019	300.0	388.9	211.1	622.2	355.6	488.9	422.2	*398.4*
Average	*322.2*	*351.8*	*248.1*	*629.6*	*333.3*	*474.1*	*444.4*	
$LSD_{0.05}$ = 153.3								
$LDS_{0.01}$ = 206.7								
$LSD_{0.001}$ = 270.0								

With increasing the age of the grass stand the amount of fresh mass in the first regrowth followed a downward trend. In the second harvest year (third vegetation), the yield varied from 1222.2 kg/da (cv. K-11) to 1388.9 kg/da (cv. K-24), and in the third (fourth vegetation) – from 811.1 kg/da (cv. K-13) to 1633.3 kg/da (cv. K-20). Tall fescue is an exception, where in 2019, the yield of fresh biomass from the first regrowth prevailed by 24.6% compared to 2018.

On average for the period, no significant difference was found in the yield of fresh mass in the first regrowth. Cock's-foot and perennial ryegrass registered the smallest percentage (4.4-5.9%) difference in the values of the indicator compared to the maximum productivity of tall fescue. For other perennial forage grasses, the yield of fresh mass in the first regrowth was lower by from 17.5% (Italian ryegrass – cv. K-13) to 12.2% (smooth brome) compared to that of *Festuca arundinaceae* Scherb.

Fresh mass – second regrowth

On average for the period, the highest yield of fresh mass in the second regrowth was reported for tall fescue (cv. K-20). The crops of cock's-foot (474.1 kg/da) and smooth brome (444.4 kg/da) had lower average productivity at $P < 0.05$, as well as the cultivars: perennial ryegrass (322.2 kg/da), Italian ryegrass (248.1 and 351.8 kg/da) and meadow fescue (333.3 kg/da) at $P < 0.001$.

The studied species of meadow grasses registered maximum values (344.4-766.7 kg/da) in the second harvest year. Compared with the spring, in the summer regrowth there was no decrease in the productivity of the studied species with increasing the age of the grassland. In the fourth vegetation (third harvest year), some of the species (representatives of genus *Festuca*, cock's-foot, smooth brome and Italian ryegrass – cv. K-13) showed good growth energy and maintained relatively high productivity in the regrowth compared to the first harvest year. The Italian ryegrass was an exception (cv. K-29t). The fresh mass yield of *Lolium multiflorum* L. decreased from 28.6% (2018) to 42.1% (2019). In the fourth harvest year, perennial ryegrass also formed less amount of fresh vegetative mass by 7.4% in the second regrowth compared to 2017. According to data from Kostov and Pavlov (1999), Italian and perennial ryegrass reached maximum productivity in the second year of its development. The perennial ryegrass cultivars imported in Bulgaria are poorly adaptable and have specific eco-adaptability to the climatic conditions of the country (Katova, 2005; Katova, 2018). In the present study, the amount of biomass formed during summer growth decreased in the crops of the first (perennial ryegrass) and third (Italian ryegrass – cv. K-29t) variant with increasing sequence of the vegetation period.

Dry mass – first regrowth

The studied grasses do not differ in the amount of dry fodder mass obtained in the first regrowth (Table 2). The difference in the average values of the species expressed as a percentage and compared to the maximum dry mass yield (487.8 kg/da) obtained from the grass stands of smooth brome (cv. BV-1exp) is statistically unproven and varies from 6.6% to 17.1%.

In 2017, the dry mass yield in all studied variants exceeded the average for the period by 6.8% (cv. K-20) to 45.6% (cv. K-29t). The variants with Italian ryegrass and smooth brome had the highest annual productivity, followed by cock's-foot, perennial ryegrass, meadow and tall fescue. In the second harvest year, the values exceeded the average for the period by 5.1-6.8% in the crops of meadow fescue and Italian ryegrass (cv. K-13). In the fourth vegetation (third harvest year) only tall fescue marked a minimal predominance (by 0.7%) in the dry mass yield in the first regrowth compared to the average for the study period (457.8 kg/da).

Festuca arundinaceae Scherb. and *Festuca pratensis* Huds. are the perennial forage crops with the smallest difference in the amount of dry mass obtained in the first regrowth for the years of study.

Dry mass – second regrowth

In total for the period, there were significant differences regarding the amount of dry mass in the summer regrowths. Compared with the maximum productivity (226.7 kg/da) of *Festuca arundinaceae* Scherb., meadow fescue realized – lower yield of dry mass in the second regrowth – 94.8 kg/da ($P < 0.01$). The species of Italian ryegrass also had lower productivity – (cv. K-29t) – 105.2 kg/da ($P < 0.01$) and (cv. K-13) – 133.7 kg/da ($P < 0.05$), perennial ryegrass – 123.7 kg/da ($P < 0.05$) and cock's-foot – 137.4 kg/da ($P < 0.05$). The pure crop of smooth brome had the smallest difference in the values compared to the most productive species, which suggests that this genotype has good potential (after tall fescue) for adaptation and productivity to higher temperatures in the summer months in the mountain conditions of the Central Balkan Mountain.

Yield is a variable influenced by the genotype and agro-ecological conditions of the area (Babić et al., 2010). For *Lolium multiflorum* L. was observed a genotypic difference in terms of dry mass yield in the first and second regrowth. The productivity of the diploid cv. K-13 in the spring and summer regrowths exceeded that of the tetraploid (cv. K-29t) by 6.6% and 27.1%, respectively.

Height of cultivars perennial grasses

The height of grass stand is a major structural element of the yield and a genetic trait of the species. Its values provide information related to the use, sustainability and productivity of forage crops in the predominantly unfavorable

Table 2. Fresh mass yield (kg/da) of perennial meadow grasses, by regrowth, years and average for the period 2017-2019

Cultivar / Year	K-11	K-13	K-29t	K-20	K-21	K-24	BV-1exp.	*Average* (annual)
I regrowth								
2017	545.6	627.8	606.7	488.9	498.9	564.4	674.4	*572.4*
2018	418.9	474.4	401.1	423.3	466.7	378.9	414.4	*425.4*
2019	300.0	230.0	242.2	461.1	366.7	342.2	374.4	*330.9*
Average	*421.5*	*444.1*	*416.7*	*457.8*	*444.1*	*428.5*	*487.8*	
$LSD_{0.05} = 73.3$								
$LDS_{0.01} = 100.0$								
$LSD_{0.001} = 130.0$								
II regrowth								
2017	153.3	113.3	153.3	184.4	107.8	113.3	156.7	*140.3*
2018	117.8	154.4	84.4	262.2	110.0	165.6	181.1	*153.6*
2019	100.0	133.3	77.8	233.3	66.7	133.3	144.4	*127.0*
Average	*123.7*	*133.7*	*105.2*	*226.7*	*94.8*	*137.4*	*160.7*	
$LSD_{0.05} = 80.0$								
$LDS_{0.01} = 106.7$								
$LSD_{0.001} = 136.7$								

soil and climatic conditions in mountainous areas (Churkova, 2013; Bozhanska & Churkova, 2019). Italian ryegrass cultivars showed a very fast growth rate and high growth energy. In spring and summer regrowths, cv. K-29 t gave higher biomass compared to cv. K-13. The difference in the mean values of the trait was 9.2 cm ($P < 0.001$) and 2.8 cm ($P < 0.01$), respectively, with a coefficient of variation of 13.6% and 18.8% in the first and second regrowth (Table 3 and Figure 2).

Italian ryegrass is demanding to moisture and heat. In this case in summer regrowth, the representatives of this species registered higher grass stands (from 17.0 cm to 24.8 cm at $P < 0.001$) compared to forage grass crops (cock's-foot, tall fescue and smooth brome) characterized by good drought resistance and ecological plasticity. Cultivar K-13 registered a maximum value (85.1 cm) of the indicator in the second vegetation, in the conditions of higher humidity and lower temperatures during April and May, and cv. K-29t in the third vegetation (90.0 cm).

Perennial ryegrass had the smallest (8.6 cm) and meadow fescue had the largest (38.9 cm) difference in the average values in spring and summer regrowths. In the year after sowing, the representatives of cv. K-11 reached a maximum height (79.9 cm) in the first regrowth. In the third and fourth vegetation, as well as in the second regrowth, the difference in the height of the grass stands was 3-4 cm.

In mountainous areas, meadow fescue grows in early spring and has a fast growth rate. Environmental conditions favour the rapid growth of the species and the receipt of the optimal amount of vegetative mass (Mitev et al., 2013; Bozhanska & Churkova, 2019). During the experiment, the height of the grass stands varied from 49.8 to 82.2 cm (for the first regrowth) and from 29.0 to 32.0 cm (for the second regrowth). In the spring and summer biomass, the deviation in the values compared to the standard is 17.2 cm with a coefficient of variation of 20.4% and 1.5 cm with a coefficient of variation of 14.5%, respectively.

The combination of soil and climatic factors with the biological characteristics of the species has a strong impact on the growth and development of plants (Naydenova & Mitev, 2017). Cock's-foot and smooth brome are perennial grasses with high energy to grow after mowing. The spring and summer grass stands formed in the year after sowing had the highest values regarding the height of the plants.

In 2017, in the first regrowth, cock's-foot exceeded the average for the period (75.8 cm) by 16.0 cm and smooth

Table 3. Average height (cm) of perennial grasses for the period 2017-2019

Cultivar / Year	K-11	K-13	K-29t	K-20	K-21	K-24	BV-1exp.	*Average* (annual)
I regrowth								
2017	79.9	85.1	87.5	80.1	76.0	91.8	75.0	*82.2*
2018	58.5	72.9	90.0	85.9	82.2	59.8	47.9	*71.0*
2019	54.9	66.8	74.9	60.1	49.8	75.9	86.8	*67.0*
Average	*64.4*	*74.9*	*84.1*	*75.4*	*69.3*	*75.8*	*69.9*	
SD	*13.5*	*9.3*	*8.1*	*13.5*	*17.2*	*16.0*	*20.0*	
$LSD_{0.05} = 3.5$								
$LDS_{0.01} = 4.6$								
$LSD_{0.001} = 5.9$								
II regrowth								
2017	55.1	54.5	61.7	42.9	30.3	45.9	40.9	*47.3*
2018	57.3	60.0	60.5	40.2	32.0	42.6	33.5	*46.6*
2019	55.1	56.6	57.1	37.3	29.0	40.0	30.7	*43.7*
Average	*55.8*	*57.0*	*59.8*	*40.1*	*30.4*	*42.8*	*35.0*	
SD	*1.3*	*2.8*	*2.4*	*2.8*	*1.5*	*3.0*	*5,2*	
$LSD_{0.05} = 1.8$								
$LDS_{0.01} = 2.3$								
$LSD_{0.001} = 3.0$								

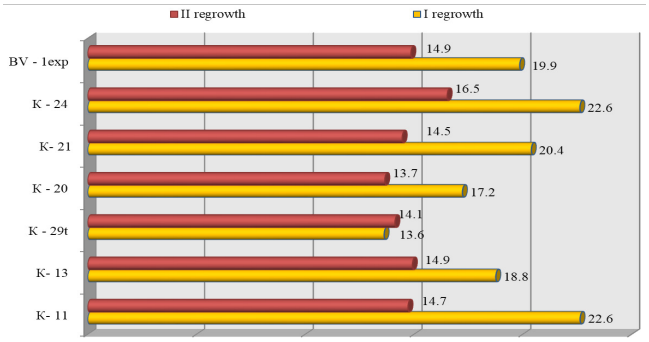

Fig. 2. Coefficient of variation (CV, %) in the average values of the plant height indicator, by regrowths

brome (69.9 cm) by 5.1 cm. In the second regrowth was observed a decrease in the values of the indicator from the second to the fourth vegetation, in both crops. The ability of *Dactylis glomerata* L. to grow evenly throughout the year determines the high and well-distributed productivity during the summer season (Pavlov, 1996; Katova, 2007; Naydenova & Katova, 2013). The established grass stands are well balanced, but with significantly lower average values of the indicator between the first and second regrowth for cv. K-24 and cv. BV-1exp.

The cultivar with the highest productivity (cv. K-20) realized spring grass stands with an average plant height of 75.4 cm at high values of standard deviation – 13.5 cm and coefficient of variation – 17.2%. The height of plant biomass in summer regrowths varied from 37.3 to 42.9 cm at SD = 2.8 cm and CV = 13.7%.

Significance of the factorial influence on the productivity and height of perennial meadow grasses

For the experimental period, the factors such as type of grass, year of use / age of grass stand have significant influence ($P < 0.05$ – $P < 0.001$) on the yield and height of pure crop grass stands of forage grasses (Table 4).

The year and age of the grass stand significantly affected ($P < 0.001$) the studied indicators in the studied varieties, mainly in the first regrowth (η^2 is in the range of 0.1% to 75.0%). The type of grass stand has a significant effect on the yield of green (η^2 – 38.9%) and dry mass (η^2 – 24.2%) in summer crops, as well as on the growth and height of plant species in the first (η^2 – 9.3%) and second (η^2 – 69.5%) regrowth.

The interaction between the studied factors causes a significant part of the factorial dispersion on the characteristics: dry mass yield in the first regrowth (η^2 – 17.2%) and plant height by regrowths (η^2 = 2.0% and η^2 = 27.3% respectively).

Conclusions

On average for the experimental period, in the mountainous conditions of the Central Balkan Mountain, tall fescue (cv. K-20) showed the highest productivity of fresh mass in the first (1740.7 kg/da) and second (629.6 kg/da) regrowths, and provided the highest dry mass yield in the second regrowth (226.7 kg/da). Italian ryegrass (cv. K-29t) gave the highest biomass in spring (84.1 cm) and summer (59.8 cm) regrowths compared to other perennial forage grasses included in the experiment.

The factorial influence of the year and the age of the grass stand is significant ($P < 0.001$) regarding the yield and the height of the vegetative biomass in the first regrowth (η^2 = 0.1% – 75.0%). The type of grass stand has a significant impact on the yield of green (η^2 – 38.9%) and dry mass (η^2 – 24.2%) in summer crops, as well as on the yield of dry mass in spring grass stands (η^2 – 17.2%), and plant height in the first (η^2 – 9.3%) and second (η^2 – 69.5%) regrowths.

Table 4. Degree and significance of the factorial influences on the yield and height of perennial meadow grasses by regrowth

Sources of variation / Indications	Year and age of grass stand η^2		Type of grass stand P		Interaction of η^2 and P	
	η^2 (%)	P	η^2 (%)	P	η^2 (%)	P
FMY I regrowth	75.0	P <0.001	2.1	ns	6.6	ns
FMY II regrowth	5.5	ns	38.9	P <0.001	38.9	ns
DMY I regrowth	56.4	P <0.001	2.9	ns	17.2	P <0.05
DMY II regrowth	1.7	ns	24.2	P <0.05	6.8	ns
Height I regrowth	11.4	P <0.001	9.3	P <0.001	27.3	P <0.001
Height II regrowth	0.1	ns	69.5	P <0.001	2.0	P <0.001

Significance of differences at P <0.05, P <0.01 and P <0.001; ns – not significant

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