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Productive capacities and adaptability of meadow legume crops under mountain conditions

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Abstract

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During the period 2020-2022, the following types of meadow legume crops were tested on light gray pseudopodzolic soil on the territory of the experimental field of Research Institute of Mountain Stockbreeding and Agriculture-Troyan: *Lotus corniculatus* L., *Trifolium hibridum* L., *Medicago sativa* L., *Trifolium pretense* L., *Trifolium repens* L. The matter yield, the biodiversity of the species in the grass stand and the impact of the factors, such as conditions of the year and the type of grass stands were studied to determine the acclimatization of meadow legume crops under mountain conditions. It was established that the tested legume forage species realized a high yield of dry matter under mountain conditions, which varied from 836.68 to 971.13 kg/da, which determined their good adaptability for cultivation under the conditions of light gray pseudopodzolic soils. The low values of their variation coefficients by year and average yield of 909.35 kg/da of all species show that they are suitable for inclusion in the structure of farms in mountain conditions. Alfalfa proved to be the most rational for cultivation, followed by red clover.

The botanical composition of the grass stands depends on the rate of growth and development of the herbaceous species. The high productivity of alfalfa corresponds to its high presence in the grass stand, which also indicates its high productivity.

Natural factors determine the productivity of the grass stands of the various legume species, and subsequently the economic efficiency in the production of fodder.

Keywords: legume grasses; productivity; botanical composition; two-factor analysis of variance

Introduction

Legume fodder crops meet the requirements for sustainable agriculture in repeated environmental studies (Kirilov, 2016). The area with legumes has increased in Bulgaria since the European Union's decision to further subsidize farmers for the cultivation of legumes during the 2014-2020 programming period (Kirilov, 2016). In this regard, the production of ecologically pure fodder production represents a multifaceted, balanced approach in agricultural production, combining agronomic, economic, ecological and social scientific solutions (Gliessman, 2007; Tomich et al., 2011). The capacity of legumes to fix nitrogen from the air (Peeters et al., 2006; Luscher et al., 2014) and to increase the nutritional value of fodder (Halling et al., 2002) thanks to the high protein content, good adaptability, the possibility of favourable coexistence with grasses when creating highly productive artificial grass stands, determine their role and significance in sustainable agriculture.

Agriculture in the 21st century is faced with the challenge of overcoming the effects of climate change and at the same time preserving the environment. Achieving this balance is aimed at the sustainable management of natural resources and in this sense, the effective management of agricultural practices is a crucial factor.

For the conditions of sustainable agriculture (Wezel & Jauneau, 2011), legume crops are becoming increasingly popular. With their unique ability to establish symbiotic relationships with rhizobial bacteria and fix atmospheric nitrogen (Vasileva et al., 2017), they are an important component for ecological forage systems and allow obtaining high yields using less /or no/ mineral nitrogen fertilizers (Graham & Vance, 2003; Pypers et al., 2005).

In order for agricultural systems to remain productive and sustainable in the long term, it is necessary to replenish the supply of nutrients obtained from atmospheric nitrogen through biological fixation. Therefore, current farming systems need sustainable intensification by incorporating legume crops (Kakraliya et al., 2018). Productivity, quality and sustainability of mixed grass stands depend to a large extent on the choice of the type and variety of the legume grass. The meadow legume crops introduced into the crop rotation must have adaptive potential to unfavourable soil and climatic conditions or have a specific adaptation to the regional agroecological conditions. Their inclusion in mixed grass stands is determined by the competition or compatibility of components in the grass association at both species and genotypic levels (Annicchiarico & Proietti, 2010). This in turn affects the productivity and sustainability of the mixture (Arturi et al., 2012).

In the Strategic Plan for the Development of Agriculture and Rural Areas of the Republic of Bulgaria for the period 2023–2027 the possibility of better using the potential of protein crops in animal husbandry is indicated, with the aim of reducing production costs and dependence on variable fodder prices, which leads to improving the sustainability of farms and contributes to addressing the crisis in the animal husbandry sector. Both in the current program period and in the framework of the new program period, Bulgaria will support the production of protein crops with the maximum possible amount equal to 2% of the limit for direct payments for the specific year. Eligible crops under the coupled income support intervention for protein crops are: beans (grain); vigna; grain peas (winter and spring); chickpeas; fava bean; lentils; lupine; vetch; sainfoin; bird's-foot-trefoil; soy; bitter fee; peanuts; alfalfa; clover and/or mixtures thereof.

At the present stage, there is much to be desired in terms of a thorough study of the role of legume crops in the production of organic fodder production related to their productivity and ecological effect.

The purpose of the present research is to determine the productive capabilities and adaptability of meadow legume crops under mountain conditions.

Material and Methods

The experiment was carried out in the period 2020-2022 on light gray pseudopodzolic soil. According to the block method, the following types of meadow legume crops were tested in four replications with a harvest plot size of 5 m^2: *Lotus corniculatus* L., *Trifolium hibridum* L., *Medicago sativa* L., *Trifolium pretense* L., *Trifolium repens* L. A generally accepted technology for growing meadow legume crops for fodder was applied. The sowing rate for herbaceous species is as follows: for bird's-foot-trefoil and white hybrid clover, 1.2 kg/da, and for alfalfa and red clover, 2.5 kg/da. The sowing of the grass stand was done manually, scattered with a different sowing rate according to the type of crop. No fertilizing was applied during the research experiment.

In the first year, one regrowth was harvested, and in the remaining two years, two regrowths were harvested in the bud-formation period-beginning of blossoming phase of the legume crops.

The following indicators were studied:

Dry matter yield (kg/da), which was determined by mowing the area of each harvest plot in replications with subsequent drying in laboratory conditions at 105^{o}C of plant samples of 1 kg and recalculation for 1 da based on the obtained dry matter by years and mowing.

Botanical composition of the grass stand was analyzed by weight as green matter samples were taken at each mowing of each variant during the years of the experimental period. The samples were weighed in an air-dry state, as the percentage share of the sown herbaceous species and motley grasses was weighed (total).

Statistical data processing includes:

Two-factor analysis of variance is the mathematical processing of the results performed according to ANOVA. The reliability of the assessment and the strength of the impact of the factors were calculated according to the Plohinsky method. The between-group variation in the total variation is defined as a proportion. The calculations were conducted according to the formula, where: ss – dispersion characterizes the degree of dispersion of the data; df – number of degrees of freedom; Ms – variance; P value – level of significance; F – Fisher's criterion; F crit. – critical value; (η) – Power of impact.

Average values (X), minimum (min) and maximum (max) limits of dry matter yield were calculated (Lidanski, 1988). The degree of variation of the parameters was determined by the coefficient of variation (VC) according to the Mamaev scheme: up to 7% – very low; 7.1 to 12.0% – low; 12.1 to 20.0% – moderate; 20.1 – 40.0% – high; above 40.0% – very high. The coefficient of variation measures variability relative to the mean and is found by dividing the standard deviation by the mean. It is a statistical metric that shows the dispersion of data points that are around the mean.

Results and Discussion

According to the temperature values, 2022 was the warmest for the experimental period with an average monthly temperature of 12.7°C, as the second year of the experimental period was the coolest (11.0°C).

The average values of temperatures during the vegetation period (March-October) were with an air temperature of 15.1°C in the first year, and 15.6°C in the third year and exceeded the average value for the study period.

The March-October precipitation in the study years was as follows: 550.2 mm (2020), 405.5 mm (2021) and 376.7 mm (2022) with a period average of 475.3 mm.

Productivity of the grass stand

In the first experimental year (Table 1), the productivity of the examined herbaceous species was relatively low. The lowest yield was registered by bird's-foot-trefoil (376.15 kg/da). According to the values of the variation coefficient VC=12.34%, legume species have a low degree of variability, standard deviation SD=57.49 with an average value of dry matter yield X=57.49. The white clover stood out as the most productive during the first experimental year with a yield of 513.12 kg/da. Alfalfa (509.01 kg/da) is close to this productivity.

In 2021, the yield of all species increased approximately four times compared to the first year. *Trifolium pretense* L. was the most productive species, whereas the bird's-foot-trefoil reported the lowest yield value (1150.49 kg/da). The variation coefficient was low (VC = 12.42%) and was similar to that in the first year. The mean value of dry matter yield was X = 1311.68, and the standard deviation SD = 162.95. *Trifolium hibridum* L. reported a close yield value (1162.98 kg/da) to that of bird's-foot-trefoil. The high yield productivity is due to the high rate of growth and development of all types of legumes and to their high percentage share in the grass stand, which is evident from the botanical composition of the grass stand mentioned below. The rainfall amount of 405.5 mm (2021) also favored plant development and contributed to the harvest of two regrowths during the year.

In the third year of the experimental period, all species had a higher dry matter yield than that in the first year and lower than the yield in the second year. The productivity of the grass stands of the different legume species varied from 1044.42 to 1096.97 kg/da and to a large extent the realization was determined by the impact of the soil and climate conditions of the area (Vasileva, 2017). The very low degree of yield variation is indicative, which according to the variation coefficient (VC) is 1.98% with a standard deviation SD = 21.19. The low variation coefficient is due to the extremely low difference in yield obtained by grass stands from the tested meadow legume crops.

All tested grass stands consisting of meadow legume crops realized productivity on average during the study period ranging from 836.68 to 971.13 kg/da, which showed good adaptability to the conditions of light gray pseudopodzolic soils, with a low degree of yield variability according to the values of the variation coefficient (VC = 6.65%), standard deviation (SD = 60.44) and average yield of all species 909.35 kg/da. Alfalfa stood out as the most productive with a recorded dry matter yield of 971.13 kg/da, followed by red clover (956.69 kg/da). The obtained results for alfalfa approach those reported by Kertikova & Kertikov (2007; 2021), where the crop was grown on a soil subtype of slightly leached chernozem. The different climatic conditions during the years of the experimental period provide the degree of production risk in the scientific experiment and prove that the more favorable the year, the greater the stability of

Table 1. Dry matter yield by year and average for the period (kg/da)

Meadow legume crops	2020	2021	2022	Average for the period
	kg/da	kg/da	kg/da	Yield, kg/da
Lotus corniculatus L.	376.15	1150.49	1065.50	836.68
Trifolium hibridum L.	488.74	1162.98	1044.42	855.02
Medicago sativa L.	509.01	1442.94	1096.97	971.13
Trifolium pretense L.	442.32	1512.64	1082.94	956.69
Trifolium repens L.	513.12	1289.37	1054.78	927.24
X	465.87	1311.68	1068.92	909.35
SD	57.49	162.95	21.19	60.44
VC	12.34	12.42	1.98	6.65
Min	376.15	1150.49	1044.42	836.68
Max	513.12	1512.64	1096.97	971.13

dry matter yield. The analyzed results prove that the realized yields during the years of the experimental period correspond to the biological features of legume crops and their adaptability, which is indicative of their appropriate cultivation in mountain conditions.

The meadow legume crops tested were perennial and their yield varied over the study years depending on climatic factors and crop biology. When applying a constant cultivation technology, applied variations from the mean value to calculate standard deviations allow for comparison of individual species. The analysis of the data according to the values of the variation coefficient shows that all tested legumes are suitable for inclusion in the structure of a farm under mountain conditions.

Botanical composition of the grass stand

Figure 1 presents the botanical composition of the grass stand, which determines the biodiversity of herbaceous plants in monoculture crops sown with meadow legume crops, distributed in the botanical groups. In the year of sowing, with the exception of the red clover grass stand, in all other variants, the degree of weeds significantly exceeded the quantitative share of the sown species. The motley grasses group of alfalfa has the most species and participation of 76.9%, followed by that of white clover (61.8%). The grass stand of red clover recorded the lowest share of motley grasses both in terms of species composition and quantity (21.2%). The grass stand of bird's-foot-trefoil has a similar participation of the cultural species and motley grasses at a ratio of 50:50. Biodiversity is represented by species, such as birdweed (*Poligonum aviculare* L.), shepherd's purse (*Capsela bursa pastoris* L.), creeping thistle (*Cirsium arvense*), bristle-grass (*Setaria verticillata*).

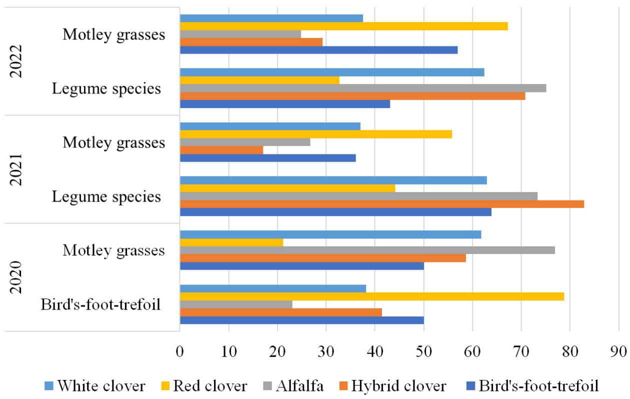

Fig. 1. Botanical composition of the grass stand (%) for the period 2020–2022

In the second experimental year, for all herbaceous species, the sown species were in a significantly greater quantity than the motley grasses. A significant presence was observed in the grass st ands of hybrid clover (82.9%) and alfalfa (73.3%), which is attributed to their increased rate of growth and development in the second year of their development. The share of white clover and bird's-foot-trefoil is almost similar and also high, 63.0 and 63.9%, respectively. A minor presence of various grasses was recorded by the following species: bristle-grass (*Setaria verticillata*), plantain (*Plantago major*), chicory (*Cichorium intybus*), whitetop (*Cardaria drava*). The rate of growth and development of the leguminous species also follows the course of their share in the grass stands. The quantitative share of the tested legume species in the grass stand proves their adjustability and good adaptability to the mountain conditions. This determines their ability to grow in an acidic soil reaction.

In the third experimental year, a high presence of sown species was recorded in the alfalfa (75.1%) and hybrid clover (70.8%) stands. White clover also retained a high relative share, respectively 62.4%. The percentage share of bird's-foot-trefoil is slightly higher compared to the previous two years (43.1%). Biodiversity is represented in motley grasses by species, such as birdweed (*Poligonum aviculare* L.), shepherd's purse (*Capsela bursa pastoris* L.), creeping thistle (*Cirsium arvense*), bristle-grass (*Setaria verticillata*), plantain (*Plantago major*), chicory (*Cichorium intybus*), whitetop (*Cardaria drava*). A tendency to increase the species diversity in the grass stands was observed with the advancing age of the plant. This proves that the competitive ability of weed species increases and they take the place of cultivated (sown) species.

The presented botanical composition of the grass stands sown with meadow legume crops, which determines the biodiversity of the species of the botanical groups is related and determines the bioproductive and qualitative indicators of the obtained fodder production.

Relative level of average dry matter yield expressed by two-factor analysis of variance depending on the conditions of the year, the type of grass stand and the interaction between them

According to the results of the two-factor analysis of variance (Table 2), the studied factor – conditions of the year, reliably influenced the variance in dry matter yield at a significance level of $P < 0.1$. The established values of the F criterion show that there are reliable differences between the studied conditions during the years of the study, and no such were found for the type of grass stand and the interaction of the factors type of grass stand x conditions of the year,

Table 2. Two-factor analysis of variance to determine the influence of the conditions of the years and the type of grass stand on dry matter yield

Source of variation	SS	df	MS	F	P-value	F crit	η
Conditions of the year	22.76268	2	11.38134	62.89115	1.858E-11	3.31583	76.78
Type of grass stand	0.661124	4	0.165281	0.913312	0.4689153	2.689628	2.23
Interaction of factors Conditions of the year x Grass stand type	0.794316	8	0.099289	0.548655	0.8103332	2.266163	2.68
Within	5.429067	30	0.180969				
Total	29.64719	44					

which means that the gradation of the tested species changes depending on climatic changes over the years.

The largest share of the total variation falls on the conditions of the year. The manifested specific genotypic responses of the species in the grass stand compared to the conditions of the year are expressed to a lesser extent in terms of productivity. The degree of influence of the interaction of the species characteristics and those of the year is weakly manifested. The differences in the conditions of the year are greater than those of the species differences in terms of productivity and the trait should be used in determining species with adaptation to growing in mountain conditions.

The applied two-factor analysis of variance for the different types of meadow legume crops gives reason to conclude that the natural factors are a very strong and unpredictable factor that directly affects the productivity of the grass stands of the different herbaceous species, and this also implies the economic efficiency of the obtained fodder.

Conclusions

Legume fodder species, such as bird's-foot-trefoil, hybrid, white, red clover and alfalfa realized a high dry matter yield under mountain conditions, which varies from 836.68 to 971.13 kg/da. This proves a good adaptability for their cultivation under the conditions of light gray pseudopodzolic soils. The low degree of yield variability according to the values of variation coefficient (VC=6.65%), standard deviation (SD=60.44) and average yield of all species (909.35 kg/da) indicates that they are suitable for inclusion in the structure of the holdings are alfalfa and red clover (956.69 kg/da) under mountain conditions.

The botanical composition of grass stands sown with meadow legume crops, determining the biodiversity of the species of the botanical groups is related to the growth and development of the herbaceous plants. The high productivity of alfalfa corresponds to the high and presence in the grass stand, which also indicates the high and productivity.

Two-factor analysis of variance proves that natural factors are a determining factor influencing the productivity of the grass stand of the different legume crops, and subsequently also the economic efficiency in fodder production.

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