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Ecological estimation of natural swards from the Central Northern region in Bulgaria

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Abstract. The efficiency and full utilization of natural resources, including natural grass associations, is essential for the development of plant and animal production. In the present study, an assessment was made of the productivity, stability and botanical composition of 8 natural swards in the region of Central Northern Bulgaria with a view to their effective use for the needs of animal husbandry. The variance analysis of the data shows a very high level of probability of the influence of the factor of grassland and the interaction of grassland × environment on the formation of yield. The most productive is sward 6, located in the area of Kateritsa - an average of 1004.21 kg ha^{-1}, and the excess compared to the average value for other grasslands is 54.8%. In terms of botanical composition, plant populations show significant variation - from 57 to 78% participation for cereal components and from 1 to 17% for legume components. The assessment of ecological stability carried out by the methods of regression, dispersion and non-parametric analysis determines different stability for grasslands, as these methods are based on different concepts of stability. GGE-biplot analysis, which allows for a comprehensive assessment of the studied grass associations in terms of their stability and productivity, identifies grassland 5 with location Lukovit as the closest to the ideal type, combining stability with relatively high productivity.

Key words: productivity; stability; natural swards; estimation.

Introduction

The efficiency and full utilization of natural resources and their conservation are essential for the development of plant and animal production (Slavkova & Shindarska, 2017). According to Pavlov (2007), the utilization rate of natural resources (soil, water, forests and natural grass associations) in the country is low and constant. According to statistical data of the Ministry of Agriculture (Agrostatistics, 2018), natural grass associations occupy about 1535812 ha, which represents 29.4% of the total area for agricultural purposes. The most valuable ecosystems in the country include natural meadows and pastures. The importance of meadows and pastures is multifaceted. Their main purpose is to be a source of fodder. The inclusion of hay and grazing in the rations reduces the amount of concentrated feed, which leads to cheaper animal products. At the same time, they are a natural reservoir of biodiversity from flora and fauna and are part of the landscape around us (Slavkova & Shindarska, 2017). Their role as a regulator of soil water regime and as an anti-erosion agent is important (Porqueddu & Roggero, 1994). The main advantage of meadows and pastures is the great variety of species and the fact that the products obtained from them are ecologically clean (Pavlov, 2007; Stoeva et al., 2010). In the future, as the number of organic livestock farms increases, the use and maintenance of natural meadows and pastures will be important to ensure high-quality grass fodder.

Meadows and pastures in Bulgaria are characterized by great plant diversity. In relatively uniform terrain and similar soil and climatic conditions, the number of species in a meadow often exceeds 50-60. Meadow and pasture grasses are divided into three groups - grasses, legumes and grasses from other botanical families, which are referred to as "mixed grasses". The most widespread in the pastures cover are grasses (Iliev, 2014). The assessment of the condition of meadows and pastures in Bulgaria (Slavkova & Shindarska, 2017) shows that their potential is not fully used for a number of reasons: low average productivity (≈ 200 kg da^{-1}) (Terziev, 2008); not particularly favorable species composition; global climate change and anthropogenic pressure, which often lead to negative changes (Stoeva & Vateva, 2013). A significant reduction of the areas is also established, as for the last 10 years it amounts to 19.3%. According to Eriksson et al. (2002), in Europe, the last 100 years have also seen a trend of drastic decline in natural grasslands, with researchers focusing on assessing, maintaining and improving their condition.

The aim of the present study is ecological assessment of natural swards in the region of Central Northern Bulgaria with a view to their effective use for the needs of animal husbandry.

Materials and Methods

The experimental activity was carried out in the period 2018-2020. The three-year period was characterized by a daily average air temperature of 13.4 °C and precipitation sum of 547 mm.

The objects of study were eight natural swards located in the region of Central Northern Bulgaria. They have been selected to cover the most typical and used natural pastures in the plains and semi-mountains of the region.

The selected locations are as follows Kirchevo (sward 1, GPS: 42.99590°N, 24.36498°E, altitude of 550 m), Slavshtitsa (sward 2, GPS: 43.05339°N, 24.34101°E, altitude of 456 m), Lesidren (sward 3, GPS: 42.97909°N, 24.40178°E, altitude of 441 m), Hlevene (sward 4, GPS: 43.08857°N, 24.70744°E, altitude of 283 m), Lukovit (sward 5, GPS: 43.20783°N, 24.16299°E, altitude of 171 m), Kateritsa (sward 6, GPS: 43.30998°N, 24.92057°E, altitude of 149 m), Odarne (sward 7, GPS: 43.34101°N, 24.93521°E, altitude of 126 m), Pleven (sward 8, GPS: 43.4132°N, 24.6169°E, altitude of 116 m). The first three are located in the foothills, and the rest - in the plains.

According to the phytocenological classification of Georgiev and Hristov (1974) the studied grass stands can be referred to the following main types: *Chrysopogon gryllus* - Swards 2, 5, 6 and 7; *Agrostis capilaris* - *Festuca fallax* – Sward 3; *Festuca pratensis* - Swards 1, 4 and 8. In each of the experimental years, the dry mass productivity (kg ha^{-1}) and the species composition of the grasslands were reported after 5-time sampling (in four replications) during the active vegetation period. The data were averaged per year and then presented on average for the 3-year period. The influence of the main factors (grassland, environment) and their interaction were determined by two-factor analysis of the variance. The assessment of ecological stability was performed by applying the following methods and parameters: regression analysis - according to Eberhart & Russell (1966), in which regression coefficient (bi) and variance of regression deviations (S^2di) were calculated; analysis of variance - mean dispersion compo-nent (θi) and variant component (θi) according to Plaisted & Peterson (1959); variance of stability (σi^2) according to Shukla (1972) and ecovalence (Wi^2) according to Wricke (1962); nonparametric analysis using the parameters $S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$ of Huhn (1990) and Nassar & Huhn (1987); $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$ by Thennarasu (1995) and KR (Kang's rank-sum) by Kang (1988). The variance coefficient (CVi) for determining stability according to Francis & Kannenberg (1978) was also calculated. A GGE biplot model was built that uses the unit value decomposition of the first two main components (Yan, 2002). All experimental data were statistically processed using the computer software GENES 2009.7.0 for Windows XP (Cruz, 2009).

Results and Discussion

Swards from the foothills show a different response to the growing environment, but all of them are characterized by significantly lower productivity (average 45.7%) than those from the plains (Fig. 1). For the conditions of the experiment, the highest yield of dry matter was realized by grassland 6, located in the area of Kateritsa - on average 1004.21 kg ha^{-1}. The excess compared to the average value for other swards is by 54.8%. Next in productivity are swards 5 and 7 (Lukovit and Odarne, respectively), whose yields have an average value of 860.00 kg ha^{-1}. Grasses representatives in these 3 plant associations have a high relative share (average 70.1%), while legumes are poorly represented - only 4.8% (Fig. 2). The lowest yields and without statistical significance are two of the pastures located in the region of Slavshtitsa and Lesidren (swards 2 and 3). They form biomass in the range 395.24 - 404.80 kg ha^{-1}, which is on average 42.3% lower than the average for the group. Intermediate position is occupied by grasslands 4 and 8 (Hlevene and Pleven), which have unproven differences, and sward 1 (Kirchevo), with an average productivity of 673.19 kg ha^{-1}. Despite their lower productivity, the last three pastures are characterized by a significantly more favorable grass-legume ratio (62:13). For the conditions of the study it was found that the dry mass yield correlated negatevely, albeit with a low value ($r = -0.341$), with % -participation of legumes in grassland, and positively ($r = 0.361$) – with % -participation of grasses.

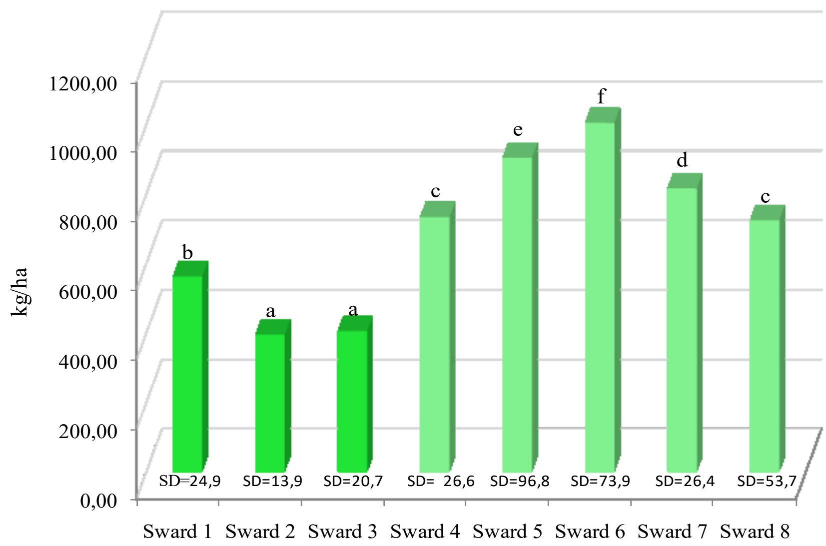

Fig. 1. Productivity of natural grasslands in foothill (1-3) and plain (4-8) regions of Central Northern Bulgaria, 2018-2020.

Sward 1 (Kirchevo), Sward 2 (Slavshtitsa), Sward 3 (Lesidren), Sward 4 (Hlevene), Sward 5 (Lukovit), Sward 6 (Kateritsa), Sward 7 (Odarne), Sward 8 (Pleven)

SD - standard deviation

The specific climatographic conditions in the individual locations have an indisputable influence on the productivity of the studied grass associations, which is interesting to establish mathematically in the long run, as well as their species composition. On average for the 3-year period the share of legumes is 9% and of grasses - 65%, in the absence of significant differences in the average values for swards of both types (foothill and plain). According to Lynch (2014), in the grassland of "good" meadows and pastures, grasses occupy 50-80% (as in the current experiment - between 57 and 78%), due to their good longevity and adaptability to adverse climatic and soil conditions, as well as their better competitiveness, compared to species from other botanical families. According to the author, legumes are species with higher nutritional value, but their share in natural swards is usually 5-10% (rarely up to 20-30%), and in the specific conditions of the study - 1-17%. The percentage of weeds varies from 18 to 31%. With the most favorable ratio of grasses/legumes is the swards in Lesidren (57 and 17%, respectively).

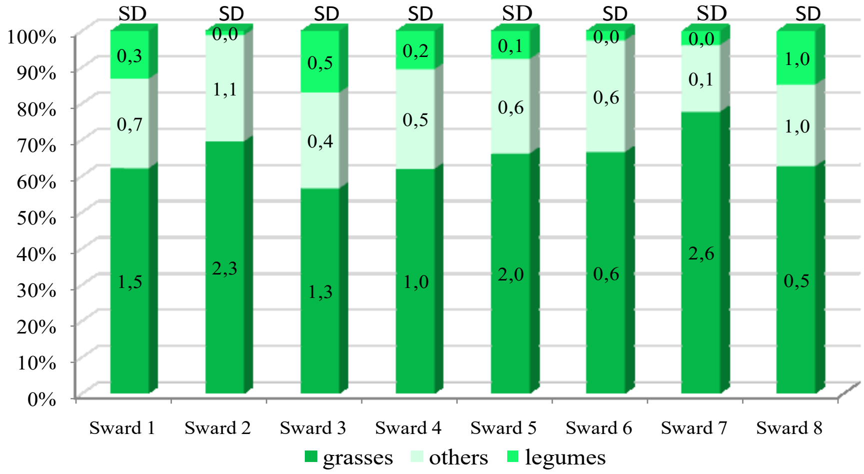

Fig. 2. Botanical composition of natural grasslands in foothill (Swards 1-3) and plain (Swards 4-8) regions of Central Northern Bulgaria, 2018-2020.
SD - standard deviation

In the conditions of organic forage production, it is necessary for the plant populations to combine high productivity with stability and adaptability to the environmental conditions. Grass associations with minimal deviations in yield under different environmental conditions are considered stable. This is seen as a biological or static concept of stability. Under dynamic stability, grass association changes predictably in a wide range of environmental conditions (Becker, 1981). Methods based on dispersion, regression and non-parametric analysis were used in this study to quantify the ecological stability. Ecological stability is measured by the deviation of empirical data from the average response of populations under each environmental condition.

Dispersion analysis

The results of the variance analysis of productivity (Table 1) show a proven influence of the three studied factors - environment, grassland and the interaction between them. The largest share of relative influence is the factor of sward (80.28%), due to which plant populations show significant variation in yield (Fig. 3). The influence of environmental factors (1.63%) and the interaction of environmental factors × grass (18.09%) is significantly less pronounced, but also statistically significant.

Table 1. Dispersion analysis of dry mass productivity in the studied grasslands

Source of variation	Df	Sum Squares	Mean Squares	F value	Pr(>F)	Significance
Environment	2	80415	40208	3.6502	0.069057	.
Replication	9	99138	11015	1.1109	0.368145	
Sward	7	3962165	566024	8.8772	0.00031	***
Sward × Environment	14	892665	63762	6.4306	7.85E-08	***
PC1	8	813595	101699	10.26	2.20E-16	***
PC2	6	80149	13358	1.35	0.2485	
Residuals	64	634581	9915			

Significance in P <0.001 (***); P <0.01 (**); P <0.05 (*); P <0.1

Regression analysis

The ideal variant, according to the model of Eberhart & Russel (1966), is a plant population with values of the linear regression coefficient and a regression variant of one and zero, respectively. In the conditions of the conducted experiment, Sward 4 (location Hlevene), which has a well-defined productivity (above the average for the group), is closest to the indicated values (bi = 0.78), which means that compared to the others plant popula-tions respond better to environmental conditions and show stability when changing these conditions (Tables 2 and 3).

During the study period, almost all plant populations did not show a pronounced responsiveness in the presence of favorable conditions for growth and development. Only grassland Sward 6 (bi = 2.33) is characterized by instability, location Katerica, whose parameter has a value above 1. The advantage of this grassland is that it responds to environmental improvement and is suitable for intensive production (fertilization, sowing). In general, it is defined as environmentally unstable, but it is the most productive, and the application of intensive technology can significantly increase its yield.

The stability parameters (bi) of the remaining grasslands have regression coefficient values below one, which determines their yield as stable under adverse environmental conditions. Of interest in this group are Swards 5, 7 and 8 (respectively Lukovit, Odarne and Pleven) due to their ability to form a significant yield in poor soil and climatic conditions.

The parameter σi^2 of Shukla (1972) confirms the estimate of Eberhart & Russel (1966) for dry mass yield stability for swards 1, 2, 3 and 8. Ecovalence Wi^2 of Wricke (1962) and the coefficient CVi of Francis & Kannenberg (1978) in plant populations 2, 3 and 8. A suitable choice in this case is grassland 8 (location Pleven) due to its relatively high yield.

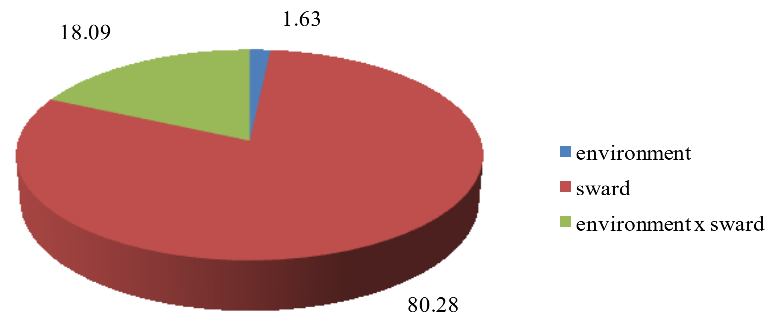

Fig. 3. Influence of studied factors on productivity.

Table 2. Parameters of productivity stability in the studied grasslands.

Variants	$S^{(1)}$	$S^{(2)}$	$S^{(3)}$	$S^{(6)}$	$NP^{(1)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	Wi^2	σi^2	S^2di	bi	Cvi%	θi	KR
Sward 1	16.14	-0.26	12640.69	18953.27	39902.25	16.14	3.33	7.00	0.11	0.21	1.67	0.28*	34	0.53	-4.00
Sward 2	20.33	1.90	1935.78	6385.70	6388.72	20.33	2.00	2.33	0.36	0.36	1.00	0.12	17	0.27	-2.00
Sward 3	19.08	2.10	970.56	6359.90	6319.93	19.08	2.67	4.33	0.09	0.18	1.33	0.19	23	0.36	-1.00
Sward4	27.55	-1.84	69641.01	91714.88	233933.21	27.55	4.67	16.33	1.40	1.00	2.33	0.78***	99	1.40	-3.00
Sward 5	11.50	2.98	-1979.82	10001.06	16029.68	11.50	2.00	3.00	1.00	1.00	1.00	0.50	71	1.00	10.00+
Sward6	20.23	2.78	60639.79	70842.45	178273.39	20.23	4.67	16.33	0.50	1.00	2.33	2.33***	247	3.50	3.00+
Sward7	11.18	0.62	12245.06	15074.14	29557.91	11.18	3.33	6.33	0.62	0.62	1.67	0.33*	47	0.77	6.00+
Sward 8	1.67	-0.28	-2355.33	4104.52	305.58	1.67	2.00	2.33	0.001	0.001	1.00	0.25	31	0.50	6.00+

$S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$-Huhn (1990) and Nassar & Huhn (1987); $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$- Thennarasu (1995); (bi), (S^2di) –Eberhart & Russell (1966); (θi),- Plaisted & Peterson (1959); (σi^2) - Shukla (1972); (Wi^2) -Wricke (1962); CVi - Francis and Kannenberg (1978); (KR) – Kang (1988)

Table 3. Ranks of stability parameters in the studied swards.

Variants	$S^{(1)}$	$S^{(2)}$	$S^{(3)}$	$S^{(6)}$	$NP^{(1)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	Wi^2	$σi^2$	S^2di	bi	CVi	θi	KR
Sward 1	4.00	4.00	6.00	6.00	6.00	8.00	5.50	6.00	3.00	3.00	5.50	4.00	4.00	4.00	7.00
Sward 2	7.00	2.00	4.00	3.00	3.00	6.00	2.00	1.50	4.00	4.00	2.00	1.00	1.00	1.00	5.00
Sward 3	5.00	3.00	3.00	2.00	2.00	5.00	4.00	4.00	2.00	2.00	4.00	2.00	2.00	2.00	4.00
Sward 4	8.00	8.00	8.00	8.00	8.00	7.00	7.50	7.50	8.00	7.00	7.50	7.00	7.00	7.00	6.00
Sward 5	3.00	7.00	2.00	4.00	4.00	1.00	2.00	3.00	7.00	7.00	2.00	6.00	6.00	6.00	1.00
Sward 6	6.00	6.00	7.00	7.00	7.00	4.00	7.50	7.50	5.00	7.00	7.50	8.00	8.00	8.00	3.00
Sward 7	2.00	1.00	5.00	5.00	5.00	2.50	5.50	5.00	6.00	5.00	5.50	5.00	5.00	5.00	2.00
Sward 8	1.00	5.00	1.00	1.00	1.00	2.50	2.00	1.50	1.00	1.00	2.00	3.00	3.00	3.00	2.00

$S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$-Huhn (1990) и Nassar & Huhn (1987); $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$- Thennarasu (1995); (bi), (S^2di) –Eberhart & Russell (1966); (θi),- Plaisted & Peterson (1959); ($σi^2$) - Shukla (1972); (Wi^2) -Wricke (1962); CVi - Francis and Kannenberg (1978); (KR) – Kang (1988)

Nonparametric analysis

According to the evaluation method proposed by Francis & Kannenberg (1978), Swards 2 and 3 (Slavshtitsa and Lesidren) are stable but low-yielding. Swards 7 and 8 are characterized by variability (high values with respect to CVi), but in comparison with 2 and 3 they have a dry matter yield above the average for the studied plant associations. The highest yielding Sward 6 (Katerica location) can be characterized as the most unstable, followed by Swards 4 and 5 (respectively Hlevene and Lukovit).

The known discrepancy in the assessment of stability between the nonparametric methods of analysis according to Thennarasu (1995), Huhn (1990) and Nassar & Huhn (1987) and the assessment by Eberhart & Russel (1966) for most of the stands is noteworthy. Therefore, according to these parameters, it is difficult to determine a standout favorite in terms of stability. The observed differences in the assessment of stability in the individual parameters are due to the fact that different methods are based on different concepts of stability.

Very important information about the populations is given by the KR parameter of Kang (1988) for simultaneous assessment of yield and stability. It is based on the reliability of the differences in dry matter yield and the variant of interaction with the environment. The value of this criterion is that, using non-parametric methods and statistical proof of differences, it gives a generalized estimate, ranking the populations in descending order according to their economic value. The non-parametric method of Kang (1988) defines Sward 5 (location Lukovit) as the most balanced in terms of stability and productivity, followed by Swards 7, 8 and 6. According to a number of researchers (Ives et al., 2000; Tilman et al., 2006; Isbell et al., 2009), the determining factor for the stability of an ecological community is the number of species that make it up. Species richness increases stability at the community level, as different species in a community are tolerant of different environmental fluctuations (Polley et al., 2013). In addition, Loreau & Mazancourt (2013) identify three main mechanisms that act to determine the stabilizing effect of biodiversity on the ecosystem: (1) the asynchrony of species' internal responses to environmental fluctuations, (2) differences in the rate at which species respond to disturbances, (3) the strength of competition. Although it is now unequivocally established that biodiversity increases the resilience of ecosystem processes over time (Griffin et al., 2009, Jiang & Pu 2009; Hector et al. 2010; Campbell et al., 2011), there is still a lack of research long to fully reveal the role of these three mechanisms (Loreau & Mazancourt, 2013).

Correlation dependencies

Of the indicators, used to assess stability, only KR ($r = 0.66$) of Kang (1988) and Cvi ($r = 0.36$) of Francis & Kannenberg (1978) correlated positively with the average dry matter yield of grasslands. All other stability parameters interact negatively with yield, although they are unreliable and their correlation coefficients range from weak to medium. Only between the $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$ indicators of Thennarasu (1995) and the dry mass yield is the correlation coefficient statistically significant (r = -0.81).

A very strong and significant positive correlation of the parameter S^2di with Wi^2, σi^2 (r = 0.93), $S^{(1)}$ (r = 0.91), $S^{(2)}$ (r = 0.89) and $NP^{(1)}$ (r = 0.91) was found, as well as of Wi^2 with σi^2 (r = 0.99), $S^{(1)}$ (r = 0.86), $S^{(2)}$ (r = 0.90), $NP^{(1)}$ (r = 0.86), $NP^{(2)}$ (r = 0.79), $NP^{(3)}$ (r = 0.79) and $NP^{(4)}$ (r = 0.79). The nonparametric parameters of Thennarasu (1995) $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$ interact strongly positively with $Si^{(2)}$ and $Si^{(6)}$ of Huhn (1990), with σi^2 of Nassar & Huhn (1987) and Wi^2 of Shukla (1972).

The GGE-biplot analysis presented in Figure 4 allows for a comprehensive assessment of the studied grass associations in terms of their stability and productivity. Higher PC1 values on the right side of the coordinate system indicate a higher dry weight. The position of grasses 6 and 5 in the far right part of the biplot characterizes them as the most productive. To the left of them, but also in the right part of the coordinate system, are Swards 7, 8 and 4. The location of Swards 2 and 3 in the far left part of the coordinate system determines them as the least productive. Sward 1 is also in the group of low yield populations. On the other hand, the values of PC2 weeds allow identifying the more stable of them. The greater length of the vectors at Swards 4, 6, and 2 defines them as unstable. In this study, Sward 5 (Lukovit location) can be indicated as the closest to the ideal type. It ranks first in stability and second in productivity. The significantly longer sward vector 6 (Katerica location) suggests a pronounced yield instability. Sward 8 (location Pleven) is also very well stable, but compared to Sward 5 (location Lukovit) it is less productive.

Figure 5, by analyzing the main components, presents a visualization of the correlations between the stands with the stability parameters. Grasslands located in the coordinate system near the relevant stability parameter are considered "stable" based on this parameter. The most stable dry mass yields have two of the plant populations: grassland 3 (Lesidren) - based on the stability parameters bi, Si $^{(3)}$, Si $^{(6)}$ and NPi $^{(2)}$ and grassland 8 (Pleven) - determined by the parameters S^2di, Si $^{(2)}$ and some of the parameters of Nassar & Huhn (1987) and Thennarasu (1995).

Table 4. Spearman correlations among stability ranks and yields.

	Yi	**CVi**	**bi**	**S^2di**	**Wi^2**	**σi^2**	**KR**	**$Si^{(1)}$**	**$Si^{(2)}$**	**$Si^{(3)}$**	**$Si^{(6)}$**	**$NPi^{(1)}$**	**$NPi^{(2)}$**	**$NPi^{(3)}$**
CVi	0.36													
bi	-0.43	0.26												
S^2di	-0.07	0.67	0.21											
Wi^2	-0.33	0.52	0.43	0.93**										
σi^2	-0.33	0.52	0.43	0.93**	0.99**									
KR	0.66	0.66	-0.02	0.62	0.41	0.41								
$Si^{(1)}$	-0.28	0.44	0.26	0.91**	0.86**	0.86**	0.43							
$Si^{(2)}$	-0.34	0.43	0.37	0.89**	0.90**	0.90**	0.41	0.98**						
$Si^{(3)}$	-0.40	0.38	0.43	0.52	0.71*	0.71*	-0.08	0.42	0.48					
$Si^{(6)}$	-0.56	0.44	0.51	0.56	0.76*	0.76*	-0.12	0.48	0.56	0.93**				
$NPi^{(1)}$	-0.28	0.44	0.26	0.91**	0.86**	0.86**	0.43	0.99**	0.98**	0.42	0.48			
$NPi^{(2)}$	-0.81*	0.14	0.67	0.57	0.79*	0.79*	-0.17	0.69	0.76*	0.69	0.81*	0.69		
$NPi^{(3)}$	-0.81*	0.14	0.67	0.57	0.79*	0.79*	-0.17	0.69	0.76*	0.69	0.81*	0.69	0.99**	
$NPi^{(4)}$	-0.81*	0.14	0.67	0.57	0.79*	0.79*	-0.17	0.69	0.76*	0.69	0.81*	0.69	0.99**	0.99**

Yi – yield; $S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$-Huhn (1990) and Nassar & Huhn (1987); $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$- Thennarasu (1995); (bi), (S^2di) –Eberhart & Russell (1966); (θi),- Plaisted & Peterson (1959); (σi^2) - Shukla (1972); (Wi^2) -Wricke (1962); CVi - Francis and Kannenberg (1978); (KR) – Kang (1988)

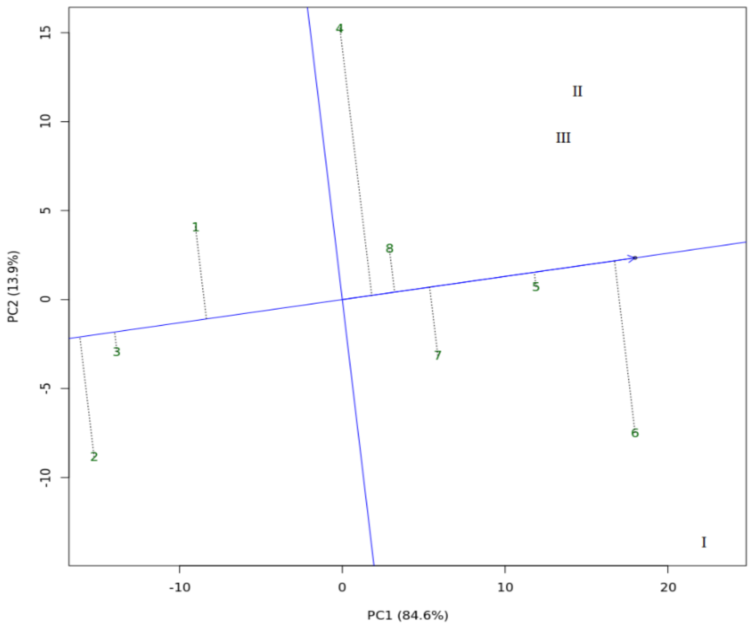

Fig. 4. GGE-biplot analysis (mean vs. stability) of the studied swards.
1-Sward 1; 2- Sward 2; 3- Sward 3; 4- Sward 4; 5 - Sward 5; 6 - Sward 6;7 - Sward 7; 8 - Sward 8;
I – 2018; II – 2019; III – 2020.

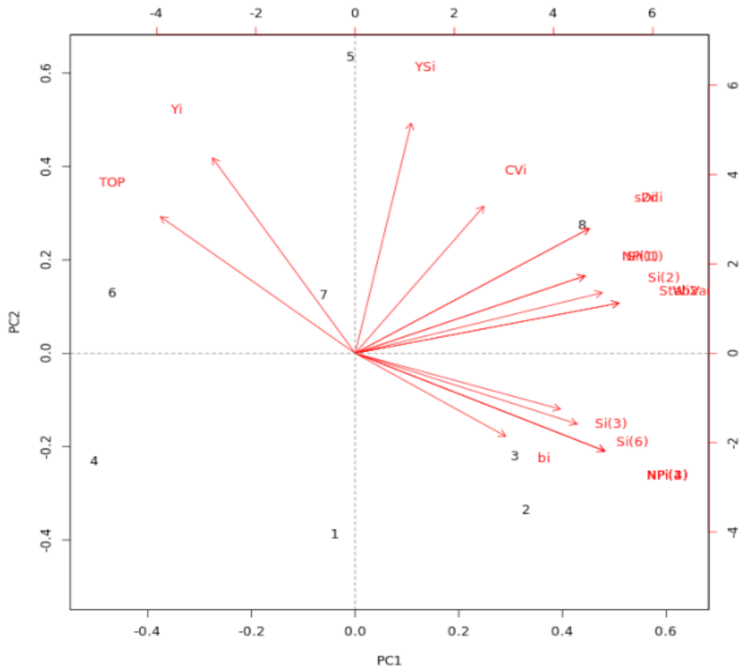

Fig. 5. PCA biplot of the studied swards with stability parameters.
Yi – yield; $S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$-Huhn (1990) and Nassar & Huhn (1987); $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$- Thennarasu (1995); (bi), (S^2di) –Eberhart & Russell (1966); (θi),- Plaisted & Peterson (1959); (σi^2) - Shukla (1972); (Wi^2) -Wricke (1962); CVi - Francis and Kannenberg (1978); (KR) – Kang (1988)
1-Sward 1; 2- Sward 2; 3- Sward 3; 4- Sward 4; 5 - Sward 5; 6 - Sward 6; 7 - Sward 7; 8 - Sward 8

Conclusions

In conclusion, the comparative assessment of the 8 plant populations in the ecological conditions of Central Northern Bulgaria determines as the most highly productive grassland 6, located in the area of Kateritsa - an average of 1004.21 kg ha^{-1}. The excess compared to the average value for other grasslands is by 54.8%.

Dispersion analysis of the data proves with a very high level of probability the influence of the factor of grassland and the interaction of grassland × environment on the formation of yield. The greatest share of influence is the factor of grass - 80.28% of the total variation.

In terms of botanical composition, plant populations show significant variation - from 57 to 78% participation for grass components and from 1 to 17% for legume components. According to the classification of Lynch (2014), their composition is relatively favorable, except for the swards with the locations Slavshtitsa, Kateritsa and Odarne.

The assessment of ecological stability carried out by the methods of regression, dispersion and non-parametric analysis determines different stability for grasslands, as these methods are based on different concepts of stability. The Kang KR parameter (1988), based on the reliability of the differences in dry matter yield and the variant of interaction with the environment, ranks the populations in the following descending order according to their economic value: Lukovit, Odarne, Pleven, Kateritsa, Lesidren, Slavshtitsa, Hlevene, Kirchevo.

GGE-biplot analysis, which allows a comprehensive assessment of the studied grass associations in terms of their stability and productivity, also identifies the sward with Lukovit location as the closest to the ideal type, combining stability with relatively high productivity.

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