RESEARCH ARTICLE

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Ecological estimation of swards grown in the region of Middle Balkan Mountains

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ABSTRACT
One of the main problems in contemporary agrarian production is the irrational utilization and management of natural resources as well as non-compliance with the biological characteristics of particular species in accordance with their adaptability and yield stability. With a purpose of ecological estimation on basic indexes and parameters of swards of meadow species that are typical for semi-mountainous regions of Middle Balkan Mountains, was conducted a field experiment during the period 2007-2012. The objects of the study were white clover, birdsfoot trefoil, red clover, lucerne, perennial ryegrass, red fescue, white bentgrass. They were situated at an altitude of 400m with an eastern exposure of mountain slopes. A strong variability has been found during the experimental period which is reflected in swards productivity. High productivity was demonstrated by lucerne (14.85 t ha^{-1} average for the period), red fescue (11.77 t ha^{-1}) and red clover (11.19 t ha^{-1}). Factors such as environment, swards and the effect of their interaction were statistically significant for all populations. By the value of the regression coefficient, swards can be allocated in three groups: slightly responsive to changing conditions ($bi < 1$) – white clover, birdsfoot trefoils and perennial ryegrass; plastic ($bi \approx 1$) – red clover and white bentgrass; and highly responsive to changing conditions ($bi > 1$) – lucerne and red fescue. High values (above 10) of the general adaptive ability were established in lucerne, red clover and red fescue. The comprehensive assessment regarding dry mass production and the parameters of plasticity and adaptability determined the swards of the red clover, followed by lucerne and red fescue as the most suitable for cultivation under the conditions of Middle Balkan Mountains.

Key words: swards, productivity, adaptability, plasticity

Introduction

One of the causes of the crisis in contemporary agrarian production is the irrational utilization and management of natural resources as well as non-compliance with the biological characteristics of particular species in accordance with their adaptability. The progress in this field is related to the use of assessment methods for adaptability and stability of the species and scientifically justified organization of the contemporary agrarian production (Korzun & Brujlo, 2011; Rybas, 2016). According to Christov et al. (2002) and Dimova et al. (2006) the problem with the adaptability and the creation of plant associations with high yield stability in regional ecological circumstances holds a central position in contemporary agriculture. At the basis of the adaptive potential of the species is the modification variability characterized by the terms plasticity and stability (Dragavtcev, 2000). A possibility of tolerance evaluation of a sward or population in the terms of environment is the forage productivity which they form (Dimova et al., 2006).

In addition, an important condition for securing sustainable and organic fodder production is the use of crops which are suitable for the relevant climatic conditions with increased yield stability and expressed competition in respect of weeds (Uhr & Ivanov, 2015; Shamsutdinov et al., 2016). Sapega (2016) notes that one of the most important problems in population testing is the obtained spatial and temporally non-representative assessment. One of the reasons for this spatial non-representativeness is the underrated role of the variety of macro and microclimatic conditions in determining the range of the populations' spread.

According to Chourkova (2007), creating artificial swards in semi-mountainous and mountainous regions out of species which does not comply with the local habitable conditions, leads to their rapid degradation. Meadow plants of local origin have an advantage of forming high-productive, stable and durable swards under the particular habitat condition (Naydenova & Mitev, 2010; Mitev et al., 2013).

The aim of the study was an ecological estimation on main indicators and parameters of swards of major meadow species in semi-mountainous regions of Middle Balkan Mountains.

Materials and Methods

The experimental activity was conducted in the Research Institute of Mountain Stockbreeding and Agriculture (Troyan, Bulgaria) during the period 2007-2012. The following swards were subjects of the study: S1-white clover, (*Trifolium repens* L. f. giganteum), S2-birdsfoot trefoil (*Lotus corniculatus* L.), S3-red clover (*Trifolium pratense* L.), S4-lucerne (*Medicago sativa* L.), S5-perennial ryegrass (*Lolium perenne* L.), S6-red fescue (*Festuca rubra L.*), S7-white bentgrass (*Agrostis alba* L.). They were situated at an altitude of 400 m, on the slopes of Middle Balkan Mountains, with an east exposure. The soil was light gray forest soil, with pH $_{/KCl/}$ 4.7. The soil cultivation included autumn plowing (18-20 cm) and spring cultivations, which brought the soil to the garden state. Sowing was done manually, with a rate of 800 seeds per m^2. The experiment was carried out by the block method, with 5 replicates, in accordance with the legislative requirements in the country for organic farming. Swards were cut at the heading stage for grasses and flowering stage for legumes. Dry matter yield (t/ha) and weed participation (%) in the swards were determined in the period 2007-2012. The precipitation amount during the study period was 759 mm per year compared to 734 mm per year during the previous 30-year period.

The obtained data were processed by two-factor analysis of variance for determining the impact of sward (S), environment (E) (the year), and their interaction (S × E). The estimation of the ecological stability of the studied swards was done through the application of the next methods: regression analysis – according to Eberhart & Russell (1966) in which the regression coefficient (bi) and the variance of deviation from regression (Si^2) were calculated; analysis of variance – in which ecovalence (W^2) according to Wricke (1965) was determined; and nonparametric analysis (by rank) by the Huehn method (1990). The total adaptability (A) of populations by the Valchinkov method (1990) was calculated.

GGE biplot analysis was performed with the software product of Yan (2001) based on the linear model:

$$\hat{Y} = \mu + \alpha i + \beta j + \Phi ij$$

where $\hat{Y}$ is the yield from sward i in year j, μ is the mean yield from the whole trial, αi is the main effect of sward i, βj is the main effect of the environment, and Φij – interaction sward i × year j. All experimental data were processed statistically with using the computer software GENES 2009.7.0 for Windows XP (Cruz, 2009).

Results and Discussion

Productivity of swards

During the 6-year period of study (2007-2012), for the experimental conditions, the lucerne showed the highest yield of dry matter (Figure 1). The excess, compared to the average productivity of the rest swards, was by 45.4%. Subsequent swards by productiveness were those of the red fescue (11.77 t ha^{-1}) and red clover (11.19 t ha^{-1}) but with non-significant

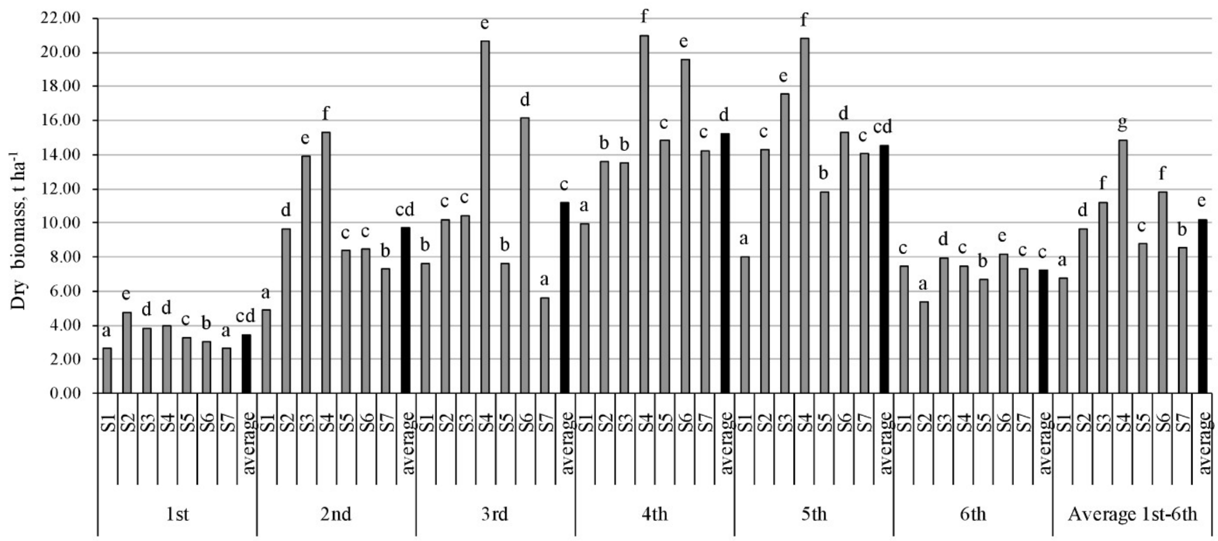


Figure 1. *Dry biomass productivity in different swards during 6-year growing period.*

S – swards: S1 – white clover, S2 – birdsfoot trefoil, S3 – red clover, S4 – lucerne, S5 – perennial ryegrass, S6 – red fescue, S7 – white bentgrass 1st, 2nd…6th – year of growing.

differences between them. The most low-productive among the species was the white clover population, whose dry matter yield was, on average 33.9% below the mean yield formed in the conditions of the experiment. In this regard, the prolonged spring-summer drought immediately after the sowing of the seeds had an adverse effect on all species, but to the greatest extent on the white clover productivity. The above-mentioned trend in forage productivity established on average for the period was as a whole identical and with few exceptions was observed over the individual years of research.

The high productivity of lucerne compared to a number of other perennial leguminous crops as well as increased feed quality have been stated by a number of researchers (Stelly et al., 1972; Sauvant et al., 2002; Coruh & Tan, 2008; Stanisavljević et al., 2008; Veronesi et al., 2010), because of which it was determined by Lacefield et al. (1987) as the "queen of forages". An average yield of dry matter ranging from 3.71 to 11.83 t ha^{-1} (Tsatsarelis & Koundouras, 1994; Gender et al., 1997; Stavarache et al., 2015; Avci et al., 2017) per year for a 3-4 year period of growth in the Mediterranean countries was reported. The larger quantities of biomass that the lucerne formed in our conditions are largely determined by the high sowing rate in swards establishment, as well as the favorable temperature and rainfall regime. Regarding red clover, Anonymous (2018) pointed that its productive potential was near that of lucerne, especially during the first 1-2 years of cultivation, and in the white clover was less than two-thirds of that of the red clover – trends, similar to which were established in the present study. According to the author, the yield of birdsfoot trefoil was considerably lower than that of lucerne, but it can be equal to that of red clover in a high soil fertility. Despite the lower productivity of birdsfoot trefoil and white clover, they are desirable components in natural and artificial grasslands because of their long life span and because they do not cause bloat in grazing livestock.

In a comparative assessment of pure swards of perennial ryegrass, cocksfoot grass, red and white clover for a 3-year period in two locations (the foot of the Balkan Mountains, at 362 m altitude and the Pleven region, at 168 m altitude), Vasilev et al. (2005, 2006) defined the red clover as the most productive and dominating species. The productivity of grass species under the present experimental conditions was generally lower than that of legumes (on average by 8.8%), but as it is known, despite their lower productivity, they have a number of valuable features (Lelièvrea et al., 2011), that can be used to solve the problem of producing more forages for livestock farming (Kostov & Pavlov, 1999). They are distinguished by ecological plasticity, adaptability and energy value of the forage. Stress-tolerant forage resources are increasingly needed for the ecological and economic sustainability of extensive livestock systems (Annicchiarico et al., 2011) as well as in conditions of global warming (Katova, 2008).

Considering the fact that most of the crops (subjects of the present study) were long lasting according to Kostov & Pavlov (2001), and with a development cycle of 6-7 years (except red clover and alfalfa with a 3-4 year cycle), maximum yields were achieved during the 4th year. An exception was observed in birdsfoot trefoil and red clover, which reached the highest yield in the 5th year, that to a certain extent can be explained by their high level of weed infestation (Figure 2). Due to their great competitive ability in species such as alfalfa, weeds had a considerably lower share in the botanical composition of the sward (mean value

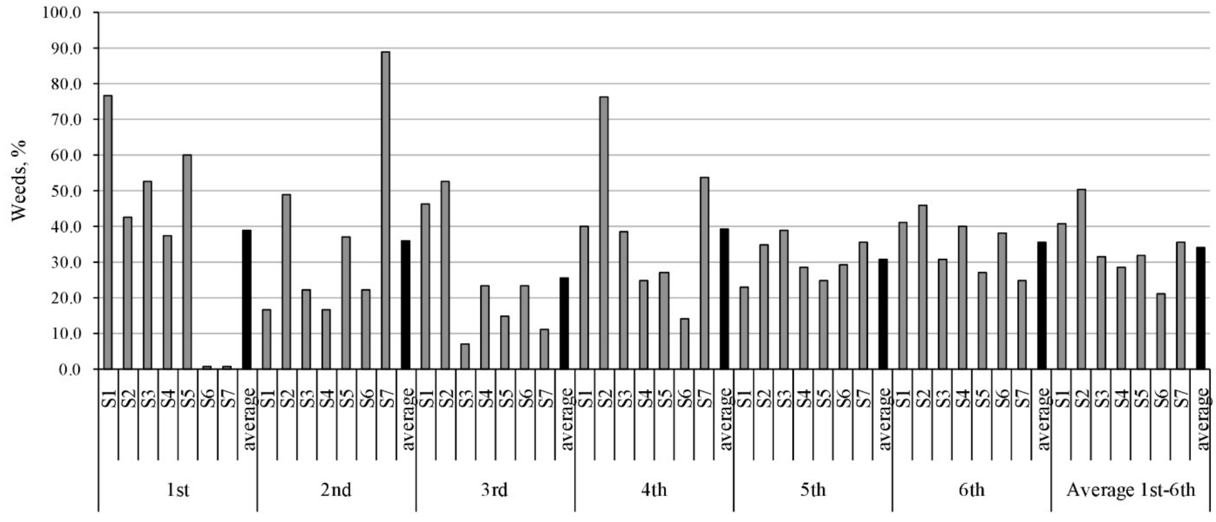


Figure 2. *Percentage participation of weeds in different swards during 6-year growing period.*
S – swards: S1 – white clover, S2 – birdsfoot trefoil, S3 – red clover, S4 – lucerne, S5 – perennial ryegrass, S6 – red fescue, S7 – white bentgrass 1st, 2nd…6th – year of growing.

for the survey period of 28.6%), while in low-competitive species such as white clover and birdsfoot trefoil, the weed participation reached 40.8 and 50.4%, respectively. An intermediate position occupied red clover, perennial ryegrass and white bentgrass, which were characterized by moderate competitivity and where the presence of weeds in the botanical composition varied from 31.7 to 33.8%. An exception to this dependence was found in the red fescue, which, although referring to the group of species with weak cenotic power, exhibited the lowest percentage of weed infestation (21.3%). An exception to this dependence was found in the red fescue, which, although referring to the group of species with weak cenotic power, exhibited the lowest percentage of weed infestation (21.3%). This can be explained by the high allelopathic potential of the weed species found by a number of authors (Ferguson et al., 2003; Willis, 2010; Vazquez-de-Aldana et al., 2011) and due to an increased content of alkaloids and flavonoids.

Overall, it was established a tendency to deepening the productivity differences among the species (relative to the average productivity for the respective experimental year) up to the 3rd year (VC = 47.8), then a decrease and achieving a minimum value (VC = 13.1) during the past year.

Analysis of variance

According to Lepekhov (2016), to determine the potential productivity of species /cultivars /populations, a moderate impact of limiting environmental factors is required, not a strong influence or extremely unfavorable growing conditions. He points out that testing in years with relatively unfavorable conditions gives a less reliable characteristic than a test in years with favorable conditions. The years of study were characterized by contrasting meteorological conditions, resulting in statistically significant values of all factors of the total variation of yield. The results of the dispersion analysis (Table 1) showed that the greatest influence had the factor of the environment, therefore the studied swards exhibited considerable variations in dry matter yield by years. With a lesser share of influence was characterized the factor "sward", but it was also statistically significant. The third factor, the interaction of year and sward, was also significant that was an objective prerequisite for determining the stability parameters.

Stability and plasticity of yield

The term plasticity was formulated by Bradshaw (1965) and expresses the quantitative change in the expression of a given parameter under a change in environmental conditions. This quality was best represented by the regression coefficient (bi). The coefficient of the linear regression of the yield of populations showed their reaction to the change in environmental conditions. On the basis of the results of the assessment, the swards of lucerne (S4) and red fescue (S6) received coefficient bi > 1, which implied their greater responsiveness and requirement for a high level of agrotechnology (intensive type) (Figure 3). However, they were less adaptable to unfavorable conditions and their adaptation was specific. The rest populations had a value of bi < 1, indicating a weak reaction to changes in environmental conditions, and they could be better utilized in extensive cultivation, providing high yields at low costs.

According to the values of Si2, all studied swords differed on the variability of the yield under the particular growing conditions. Of particular interest in this regard was the birdsfoot trefoil which had a plasticity index (bi = 0.86) approaching the unit, the smallest stability index (Si2), and can be characterized as high plastic and moderately stable sward. The square deviation (Si2) in perennial ryegrass (S5) and white clover (S1) also had a low value. Judging by the value of the linear regression coefficient, they can be referred to the group of the most stable populations.

Table 1. *Analysis of variance in regard to productivity of the studied swards.*

Sources of variation SV	**Degrees of freedom DF**	**Sum of squares SS**	**Mean square MS**	**Significance**
Environment	5	21003258.46	4200651.69	**
Sward	6	7600637.76	1266772.96	**
Interaction Sward×Environment	30	5822554.11	194085.14	**
Environment/Sward	35	26825812.5	766451.79	**
Env/Sward 1	5	1010160.28	202032.06	**
Env/Sward 2	5	2381078.97	476215.79	**
Env/Sward 3	5	3538747.73	707749.55	**
Env/Sward 4	5	8387627.36	1677525.47	**
Env/Sward 5	5	2445882.58	489176.52	**
Env/Sward 6	5	5788382.19	1157676.44	**
Env/Sward 7	5	3273933.47	654786.69	**
Residuo	**41**			

Legend: S1-white clover, S2-birdsfoot trefoil, S3-red clover, S4-lucerne, S5-perennial ryegrass, S6-red fescue, S7-white

In responsiveness to the changes in growing conditions, the white clover (S1) reacted the most slightly (bi = 0.49). It was less adaptive, a sward from an extensive type, and better adapted to moderate and less favorable environments. Therefore, it is recommended for a low agro-background where it can provide maximum returns at minimal costs.

Red clover and white bentgrass exhibited plasticity (the regression coefficient was very close to unit). Changes in their yield values were fully in line with changes in environmental conditions. An average level of agro-technology is appropriate for them when are grown in the particular soil and climatic conditions. Similar results were obtained through the parameter "Wi" of Wricke (1965).

Rank analysis

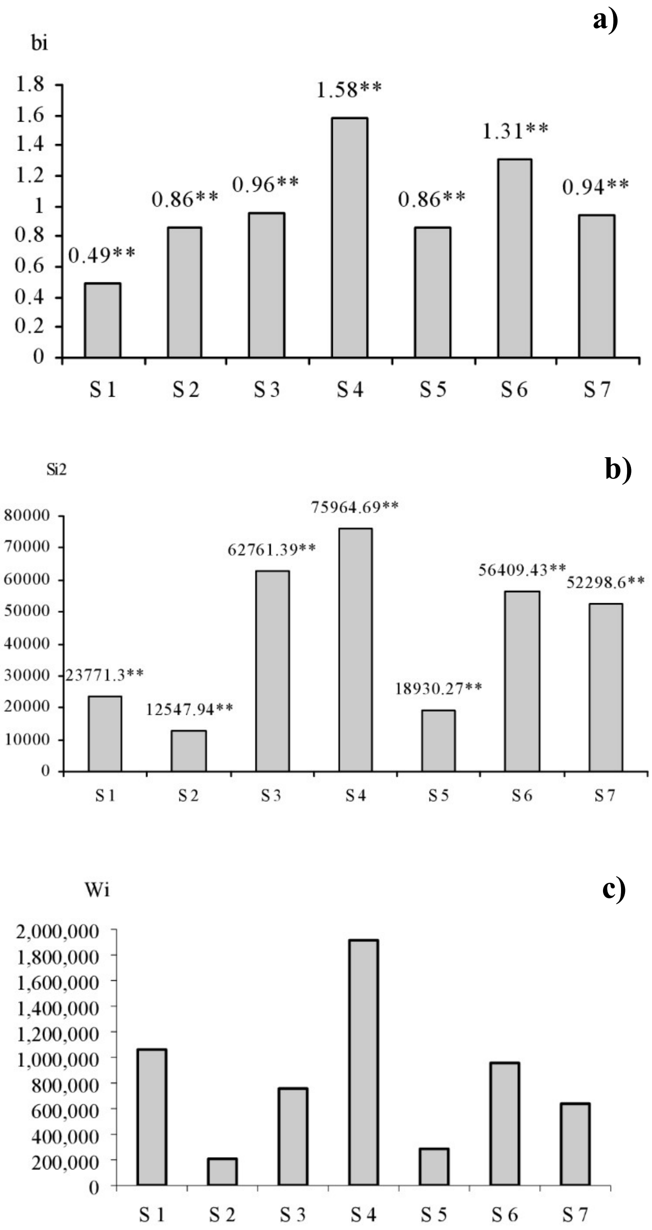
By applying the rank analysis of Huehn (1990), a substantial difference between the ranks of swards in terms of their yields was established both for the study period and within each year, indicating a strong interaction of the sward with the environment (Table 2). For example, the sward S2 (birdsfoot trefoil) in the tested years varied by rank from 1st (2007) to 7th (2012), and S3 (red clover) – from 3rd (2007 and 2009) to 6th (2010).

Lucerne sward (S4) formed the highest average yield, especially during the 2008-2011period, when the weather conditions were relatively more favorable for plant growth and development. Consequently, it was highly responsive to favorable environmental conditions.

The white bentgrass population (S7) showed the lowest average productivity (rank 6), followed by white clover (S1) and perennial ryegrass (S5) with rank 5. It is noteworthy that the white clover and perennial ryegrass demonstrated a higher rank under the unfavorable and severely dry conditions of the first and last experimental years, as opposed to their lower ranks during the favorable period 2008-2011.

Adaptive ability

The ability of a species to form high yields under different environmental conditions is determined by its adaptive capability. In order to obtain an objective estimation of the adaptability of the studied swards, the coefficient of



S1-white clover, S2-birdsfoot trefoil, S3-red clover, S4-lucerne, S5-perennial ryegrass, S6-red fescue, S7-white bentgrass

Figure 3. *Stability parameters of dry mass yield according to a) Eberhart & Russell (1966) and b) Wricke (1965).*

Table 2. *Rank analysis according the method of Huehn (1990).*

Sward/year	2007	2008	2009	2010	2011	2012	Average rank
S1	5	7	6	7	7	4	5
S2	1	3	4	5	4	7	4
S3	3	2	3	6	2	2	3
S4	2	1	1	1	1	3	2
S5	4	5	6	6	6	3	5
S6	5	4	2	2	3	1	3
S7	7	6	7	4	5	5	6

Legend: S1-white clover, S2-birdsfoot trefoil, S3-red clover, S4-lucerne, S5-perennial ryegrass, S6-red fescue, S7-white bentgrass; (1): Better performance ...(7): Worst performance general adaptability (A), according to the values of which their productiveness capacity can be estimated, was calculated (Figure 4). During the 6-year experimental period, two (red clover and lucerne) of the seven swards had a coefficient of general adaptability more than 10. With the lowest values were the white clover (6.26) and white bentgrass (7.14). According to their adaptive ability, the populations can be ranked in the following order: lucerne > red clover > red fescue > birdsfoot trefoil > perennial ryegrass > white bentgrass > white clover. Populations with high adaptability are valuable only in case of low variability of their yield under different conditions. This is only observed in red clover, whose high average productivity is combined with relatively low variability and high adaptability.

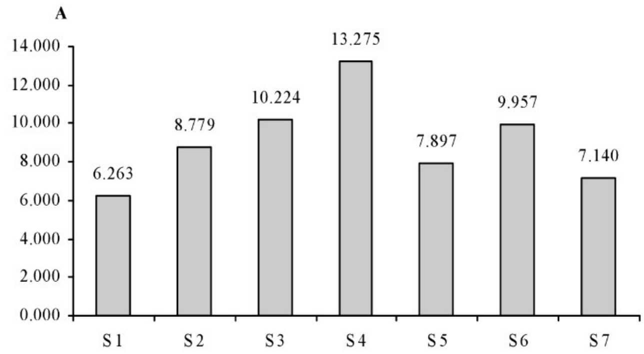
GGE biplot analysis

The GGE biplot graphical analysis enables to identify swards combining high yields and stability. The center of the concentric circles (Figure 5) represents the position of the "ideal" sward, which is determined by the projection of the axis of the peripheral medium equal to the longest vector of the sward with yield above the average and a zero projection to the perpendicular line (zero variation in all environments). A desirable and valuable sward is that whose is closest to the "ideal" one. The GGE biplot analysis shows that the first two principal components (PC1 and PC2) explain 93.6% of the overall productivity variability, due to its interaction with the environment. The birdsfoot trefoil and perennial ryegrass populations were the maximum close to the center of the concentric circles. They can be defined as "ideal" in terms of yield variability compared to the rest of the swards for the specific conditions of the experiment in Middle Balkan Mountains. On the vertices of the polygon are situated swards giving the best results (dry mass yields) in the environments where they are located respectively. Lucerne (S4) is the best sward in Env 3, Env 4 and Env 5 (forming the "mega environment"), and red clover (S3) - in the limiting (stress) environment Env 2. The birdsfoot trefoil and perennial ryegrass (S2 and S5) are performed relatively better than other populations in Env 1.

Based on the 6-year experiment conducted and the analyses carried out, the following more important conclusions can be drawn:

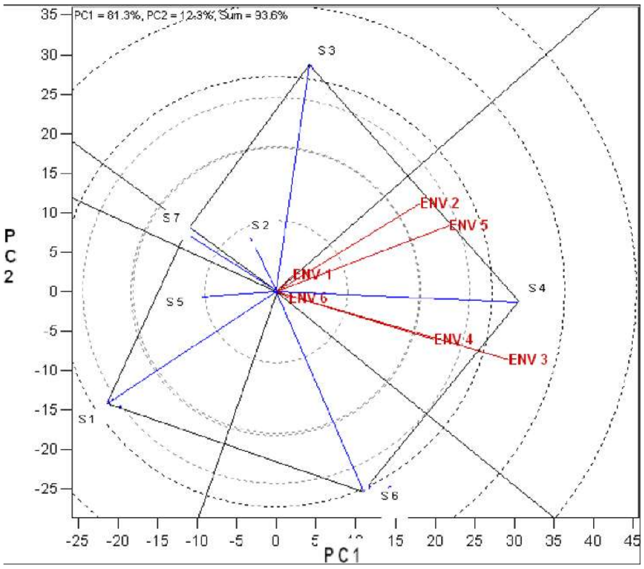
- It was established a strong variability during the experimental period which is reflected in swards productivity. High productivity was demonstrated by lucerne (14.85 t ha^{-1} average for the period), red fescue (11.77 t ha^{-1}) and red clover (11.19 t ha^{-1}).

- Factors such as environment, swards and the effect of their interaction were statistically significant for all populations.



S1-white clover, S2-birdsfoot trefoil, S3-red clover, S4-lucerne, S5-perennial ryegrass, S6-red fescue, S7-white bentgrass

Figure 4. *Total adaptive ability (A) (Valchinkov, 1990) of the studied swards.*



S1-white clover, S2-birdsfoot trefoil, S3-red clover, S4-lucerne, S5-perennial ryegrass, S6-red fescue, S7-white bentgrass

Figure 5. *GGE biplot analysis.*

- By the value of the regression coefficient, swards can be allocated in three groups: slightly responsive to changing conditions (bi < 1) – white clover, birdsfoot trefoils and perennial ryegrass; plastic (bi ≈ 1) – red clover and white bentgrass; and highly responsive to changing conditions (bi > 1) – lucerne and red fescue.

- High values (above 10) of the general adaptive ability were established in lucerne, red clover and red fescue.

- The comprehensive assessment regarding dry mass production and the parameters of plasticity and adaptability determined the swards of the red clover, followed by lucerne and red fescue as the most suitable for cultivation under the conditions of Middle Balkan Mountains.

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