Original scientific paper
Оригинални научни рад
UDC 633.16-155.9(497.6)
DOI 10.7251/AGREN1804287K

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

Morphological Characteristics of Two-rowed Barley (*Hordeum sativum* ssp. *distichum* L.) Landraces Originating from Herzegovina

Ivan Kovačević[1], Đurađ Hajder[2], Danijela Kondić[2], Dragan Mandić[1], Desimir Knežević[3]

[1]*Agricultural Institute of the Republic of Srpska, Banja Luka, BiH*
[2]*University of Banja Luka, Faculty of Agriculture, Republic of Srpska, BiH*
[3]*University of Priština, Faculty of Agriculture, Lešak, Kosovo and Metohia, Serbia*

Abstract

Barley is a small grain cereal, tolerant to high temperatures and drought. Due to this characteristic, it can be regarded as a promising crop for production in dry conditions. Research on five spring landraces of two-rowed barley lasted two experimental years (2011 and 2012) in agro-ecological conditions of Banja Luka. In the experiment, the standard cropping practices were applied, without irrigation. The experiment was set as a complete randomized design with four replications. All measurements were performed in 10 plants per replication. Morphological characteristics included plant height (cm), spike length (cm), grain number per spike and grain weight per spike (g). Obtained data were subjected to two-way analysis of variance with landrace and growing season as main factors. Significant treatment or interaction effects were further analysed by Fisher's least significant difference (LSD) test, often utilized for pairwise comparisons among arithmetic means. In all tested traits the maximum average values were obtained in barley landrace AM2, i.e. the plant height (86.89 cm), the spike length (8.90 cm), the grain number per spike (24.74) and the grain weight per spike (1.17 g). Due to these facts, two-rowed barley landrace AM2 can be marked as the most productive in this research, bearing a potential for different crop breeding practices.

Key words: barley, local population, characterization, evaluation, productivity

Introduction

Barley is the fourth most important cereal crop in the world. In most of the European continent, spring barley is being grown more than winter type (Spunar et al., 2008) because it is an important source of raw material for the malting industry. In France, which is the main producer of malt in the world, six-rowed and two-rowed winter barley are used for malting process. The main reason for using winter barley is about 20-30% higher yield in comparison to spring barley (Špunar et al., 2002).

Two-rowed barley (ssp. *distichum*) domesticated from progenitor *Hordeum vulgare* ssp. *spontaneum* about 10,000 years ago (Badr et al., 2000), while six-rowed barley appeared about 8,000 years ago (Komatsuda et al., 2007). It is generally known that the barley is one of the first domesticated plants and usually produced in areas with limited rainfall, and it is among the small grains most adapted to drought.

Barley is usually produced in semi-arid areas, characterized by varying of the annual amount of rainfall. Local populations of two-rowed barley were significantly grown in the mountainous regions of the north-western part of Montenegro (Jovović et al., 2017). Generally, on the global arable land barley landraces were replaced by modern cultivars produced by plant breeders. In the Republic of Srpska barley is produced at about 12,000 hectares, with low national average yield of 3.3 $t \cdot ha^{-1}$. Nevertheless, barley yields of up to 9 $t \cdot ha^{-1}$ are achievable (Heyland and Werner, 2002).

In the sowing area of the Republic of Srpska modern barley cultivars are usually produced, while the production data for barley landraces do not exist. In the Gene Bank of the Institute for Genetic Resources, University of Banja Luka, about 50 barley accessions are kept. Landraces represent a valuable plant material, which can be recommended for the breeding activity after morphological and molecular characterization.

Due to this fact, barley germplasm should be available to the plant breeding community. Many modern crops cultivars are often genetically similar, with a rather narrow genetic base (Dotlačil et al., 2010), while landraces are genetically heterogeneous (Camacho Villa et al., 2005). A landrace represents an equilibrium between heterogeneous and heterozygous genotypes within a population of a crop that is maintained by continuous multiplication under a given set of climatic, soil and husbandry conditions (Bothmer et al., 2003).

The aim of this research was to assess the yield characteristics of five landraces of two-rowed spring barley, with regard to their utilization as genetic resources in the future.

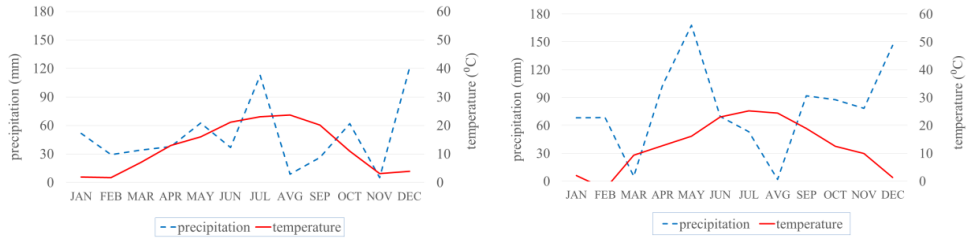
Materials and Methods

The two-year research was conducted in the region of Banja Luka (158 m altitude), the Republic of Srpska, in 2011 and 2012 growing seasons. A total of five landraces of two-rowed spring barley were used in this research, marked as AM1, AM2, AM3, AM4 and AM5. Landraces were previously collected in the region of Gacko (Herzegovina), located at an average altitude above 1000 m.

The experiment was set as a complete randomized design with four replications, and the experimental plot was 5 m^2. All measurements were performed in 10 plants per replication. In the experiment, the standard cropping practices for spring barley were applied, without irrigation.

For all landraces, sowing was completed in the last decade of March and harvesting in the last decade of July in both growing seasons. Plants were sampled just prior to harvest. Following parameters for spring barley were evaluated on taken samples: plant height (cm), spike length (cm), grain number per spike and grain weight per spike (g).

Obtained data were subjected to two-way analysis of variance with landrace and growing season as main factors. Significant treatment or interaction effects were further analysed by Fisher's least significant difference (LSD) test, often utilized for pairwise comparisons among arithmetic means. Walter-Lieth climate-diagram was done for 2011 and 2012 (Graph 1).



Graph 1. Walter-Lieth climate-diagram for 2011 (left) and 2012 (right) growing periods

Tab. 1. Chemical analysis of soil sample plots to a depth of 30 cm

year	pH reaction		Humus content in %	AL-P_2O_5 mg/100g	AL-K_2O mg/100g
	in H_2O	in KCl			
2011	7.03	6.40	3.25	15.52	35.56
2012	7.80	6.50	2.20	48.0	48.5

Chemical analysis showed that soil has a neutral pH reaction, which is suitable for the barley production. Soil organic matter content is moderate, with a very high content (mg/100g of soil) of available phosphorus and potassium (Tab. 1).

Results and Discussion

In this research five landraces of two-rowed barley were evaluated. Landraces were produced in agro-ecological conditions which differ from the area in which they were collected. Namely, the barley landraces were collected in the region of Gacko, located at an average altitude above 1000 m, while the experiment was set up in Banja Luka, located at an altitude of 158 m. According to Graph 1, climate diagram (Walter, 1955) shows that the first growing season (March-July in 2011) was characterized by a 284.2 mm precipitation and an average temperature of 16.1 ºC, while in the same period in the second growing season the precipitation was 398.8 mm with an average temperature of 17.3 ºC. Therefore, the second growing season was warmer for 1.2 ºC with 114.6 mm more rainfall.

Plant height

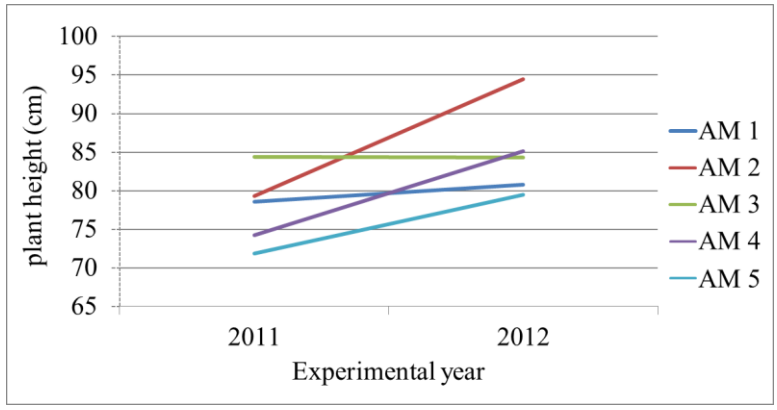
Plant height is an important morphological trait directly related to the obtained yield. Barley landraces in this research achieved a two-year average of 81.3 cm (Table 2), which is significantly lower than the modern cultivars.

Tab.2. Plant height (cm) in different two-rowed barley landraces

Barley landrace	Year		$\bar{X} \pm SD$ for landraces
	2011	2012	
AM1	78.56 ± 1.23	80.79 ± 4.54	79.68 ± 1.11
AM2	79.30 ± 1.24	94.48 ± 3.10	86.89 ± 7.59
AM3	84.39 ± 2.26	84.35 ± 1.68	84.37 ± 0.02
AM4	74.26 ± 2.28	85.15 ± 2.60	79.71 ± 5.44
AM5	71.85 ± 1.25	79.49 ± 0.97	75.67 ± 3.82
$\bar{X} \pm SD$ for years	77.67 ± 2.17	84.85 ± 5.88	–
$F_{\text{landraces}} = 6.9570^{**}$; $F_{\text{years}} = 23.1160^{**}$; $F_{\text{landraces} \times \text{years}} = 3.4667^{*}$ ^{ns} not significant (P > 0.05), * (P ≤ 0.05), ** (P ≤ 0.01)			
LSD $_{\text{landraces} \times \text{years}}$	0.05	0.01	
	6.82	9.18	

According to Madić et al. (2016), new barley cultivars are generally characterized by a very good lodging resistance and an average plant height of 90 to 100 cm. On the other hand, according to the research conducted by Akgun et al. (2012), barley landraces were characterized by relatively higher plants, so that the average plant height of Anatolian barley landraces was 129.8 cm, while Chalak et al. (2015) obtained an average plant height of 57.9 cm for Lebanon barley landraces.

According to Table 2, the average plant height ranged from 75.67 cm (AM5) to 86.89 cm (AM2) in different barley landraces. Higher values of this trait were obtained in 2012 (84.85 cm). Analysis of variance indicated that the effect of landraces and the effect of years were statistically significant at $P \leq 0.01$. The interaction effect landraces × years were also statistically significant at $P \leq 0.05$. This interaction effect was further graphically analysed (Graph 2).



Graph 2. The interaction effect analysis for plant height (cm) in five spring barley landraces in 2011 and 2012

According to Graph 2, barley landraces AM1 and AM3 showed a stagnation of the average plant height (cm) in two growing periods (2011 and 2012). Contrary to this, landraces AM2, AM4 and AM5 obtained a noticeable increase of this trait in 2012. Although landrace AM2 obtained the highest plant height in 2012 (94.48 cm), it was the second best in 2011 (79.30 cm).

Spike length

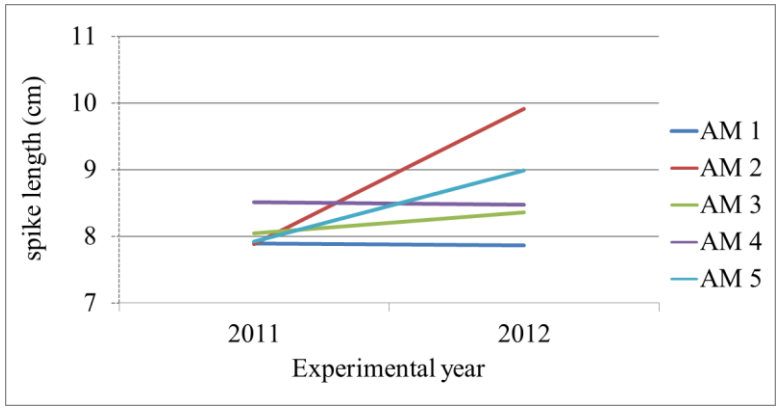
Spike length, grain number per spike and grain weight per spike are important barley yield components, and an increase in these parameters represent breeding programs goals, aiming to increase the yield potential.

The number of spikelets and the number of formed flowers and grains depends also on the spike length which ultimately determines the productivity of an inflorescence.

Tab. 3. Spike length (cm) in different two-rowed barley landraces

Barley landrace	Year		$\bar{X} \pm SD$ for landraces
	2011	2012	
AM1	7.90 ± 0.32	7.87 ± 0.24	7.88 ± 0.02
AM2	7.89 ± 0.08	9.91 ± 0.14	8.90 ± 1.01
AM3	8.05 ± 0.10	8.36 ± 0.15	8.21 ± 0.16
AM4	8.51 ± 0.23	8.48 ± 0.05	8.49 ± 0.02
AM5	7.93 ± 0.21	8.99 ± 0.14	8.46 ± 0.53
$\bar{X} \pm SD$ for years	8.06 ± 0.12	8.72 ± 0.35	–
$F_{landraces}$ = 8.3580**; F_{years} = 32.7908 **; $F_{landraces \times years}$ = 11.5026 ** ns not significant (P > 0.05), * (P ≤ 0.05), ** (P ≤ 0.01)			
LSD	0.05		0.01
landraces × years	0.53		0.72

The average spike length ranged from 7.88 cm (AM1) to 8.90 cm (AM2) for different barley landraces (Table 3.). These results obtained for the analysed trait are similar to Madić et al. (2012) and Miletić et al. (2018). Higher values of this trait were obtained in 2012 (8.72 cm). Analysis has shown that there are significant differences between the landraces and years at P ≤ 0.01. The interaction effect landraces × years was also statistically significant at P ≤ 0.01, which is graphically analysed (Graph 3).



Graph 3. The interaction effect analysis for spike length (cm) in five spring barley landraces in 2011 and 2012

According to Graph 3, barley landraces AM1 and AM4 obtained a stagnation of the average spike length (cm) in two growing periods (2011 and 2012). Contrary to this, landraces AM2, AM3 and AM5 obtained a noticeable increase of this trait in 2012. Although AM2 obtained the highest spike length in 2012 (9.91 cm), it obtained the lowest spike length in 2011 (7.89 cm).

Grain number per spike

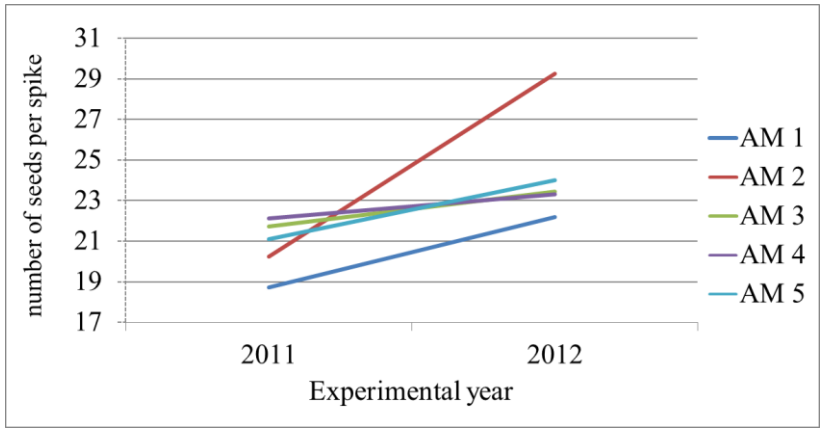
A grain number per spike is associated with the spike length and the number of internodes of inflorescence as well as the number of fertile spikelets. Six-rowed barley generally has a high number of grains per spike so that the number reaches 100 or more, while in two-rowed barley it ranges from 30 to 40 (Madić et al., 2004). According to Ceccarelli (1987), the grain number per spike depends on the water availability during the early vegetative phase and during the shooting stage, and if water deficit occurs after the flowering stage, it decreases barley grain weight and thus its yield.

Tab.4. Grain number per spike in different two-rowed barley landraces

Barley landrace	Year		$\bar{X} \pm SD$ for landraces
	2011	2012	
AM1	18.73 ± 1.04	22.20 ± 0.99	20.46 ± 1.74
AM2	20.23 ± 0.70	29.25 ± 0.38	24.74 ± 4.51
AM3	21.73 ± 0.80	23.45 ± 0.72	22.59 ± 0.86
AM4	22.13 ± 0.37	23.30 ± 0.66	22.71 ± 0.59
AM5	21.10 ± 0.66	24.00 ± 0.36	22.55 ± 1.45
$\bar{X} \pm SD$ for years	20.78 ± 0.61	24.44 ± 1.24	–
$F_{\text{landraces}} = 9.1511^{**}$; $F_{\text{years}} = 66.9668^{**}$; $F_{\text{landraces} \times \text{years}} = 9.8270^{**}$ ^{ns} not significant (P > 0.05), * (P ≤ 0.05), ** (P ≤ 0.01)			
LSD	0.05		0.01
landraces × years	2.04		2.75

The average grain number per spike ranged from 20.46 (AM1) to 24.74 (AM2) for different barley landraces, which is in accordance with Al-Nashash et al. (2005). According to Madic et al. (2009), the three-year average grain number per spike of examined barley cultivars was 19.91. The average number of seeds per spike was again higher in 2012 (24.44). Both the effect of landraces and years were statistically significant at $P \leq 0.01$.

The interaction effect landraces × years was statistically significant at P ≤ 0.01. The analysis of this interaction effect is presented in Graph 4.



Graph 4. The interaction effect analysis for number of seeds per spike in five spring barley landraces in 2011 and 2012

All barley landraces obtained an increase of the average number of seeds per spike in 2012, with a noticeable increase of this trait in 2012 in landraces AM1 and AM2. The rank of different landraces in two growing periods differs, which caused an interaction effect. Although this is two-year research this trend can indicate stability across landraces. Therefore, barley landraces AM3, AM4 and AM5 can be determined as promising when it comes to grain number per spike.

Grain weight per spike

The obtained results for grain weight per spike (g) in different barley landraces in this research are presented in Table 5.

Grain weight per spike in tested barley landraces ranged from 1.04 g (AM1) to 1.17 g (AM2), but landraces showed no statistically significant differences. Polish spring cultivars obtained the average grain weight of 0.82 g·spike^{-1} (Noworolnik, 2010), whereas the examined Serbian two-rowed winter malting barley cultivars obtained an average grain weight of 1.70 g·spike^{-1} (Madić et al., 2017). It is expected that winter forms have higher spike productivity compared to the spring forms of barley.

The effect of years was statistically significant at P ≤ 0.01. Significantly higher values of this trait were obtained in 2012 (1.18 g).

Tab.5. Grain weight per spike (g) in different two-rowed barley landraces

Barley landrace	Year		$\bar{X} \pm SD$ for landraces
	2011	2012	
AM1	0.94 ± 0.05	1.13 ± 0.04	1.04 ± 0.10
AM2	0.99 ± 0.08	1.35 ± 0.06	1.17 ± 0.18
AM3	0.99 ± 0.02	1.14 ± 0.05	1.06 ± 0.08
AM4	1.01 ± 0.03	1.14 ± 0.02	1.07 ± 0.06
AM5	1.03 ± 0.06	1.14 ± 0.03	1.09 ± 0.06
$\bar{X} \pm SD$ for years	0.99 ± 0.02	1.18 ± 0.04	–
$F_{\text{landraces}} = 2.3325^{\text{ns}}$; $F_{\text{years}} = 41.4763^{**}$; $F_{\text{landraces} \times \text{years}} = 2.3222^{\text{ns}}$ ns not significant (P > 0.05), * (P ≤ 0.05), ** (P ≤ 0.01)			
LSD	0.05		0.01
years	0.06		0.08

Relatively higher values of grain weight per spike in 2012 can be explained by a better water supply to plants. More precisely, the 2012 rainfall of 398.8 mm was more favourable in comparison to 2011 (284.2 mm), which reflected in higher values of grain weight per spike in 2012.

Conclusions

This research aimed at increasing the knowledge of barley landraces in the Republic of Srpska, with contribution to the possibility of their utilization as genetic resources in the future. Analysed spring barley landraces differed in all traits tested, except in the grain weight per spike. Two-rowed barley landrace AM2 achieved the highest average values for most of the observed traits, therefore it can be characterized as a promising landrace in the future research. Relatively higher values of all tested traits were achieved in the second growing season (2012) which contributed by a better water supply for plants.

References

Akgun, N., Topal, A., Akcura, M. (2012). Evaluation of central Anatolian barley landraces for crop improvement. *Romanian Agricultural Research*, 29: 87-93.

Al-Nashash, A., Migdadi, H, Saou, H., Masoud S. (2005). Evaluation of Jordanian barely (*Hordeum vulgare* L.) landraces collected from diverse environments. *Dirasat Agricultural Sciences*, 32(2): 163-171.

Badr, A., Muller, K., Schafer-Pregl, R., El Rabey, H., Effgen, S., Ibrahim, H.H., Pozzi, C., Rohde, W., Salamini, F. (2000). On the origin and domestication history of barley (*Hordeum vulgare*). *Molecular Biology and Evolution*, 17: 499-510.

Bothmer, R.V., Sato, K., Knüpffer, H., Hintum, T.V. (2003). Barley diversity, an introduction. *Dev. Plant Genet. Breed.*, 7: 31.

Camacho Villa, T.C., Maxted, N., Scholten, M., Ford-Loyd, B (2005). Defining and identifying crop landraces. *Plant Genetic Resources*, 3: 373-384.

Ceccarelli, S. (1987). Yield potential and drought tolerance of segregation localities of barley in contrasting environments. *Euphytica*, 36: 265-273.

Chalak, L., Mzid, R., Rizk, W., Hmedeh, H., Kabalan, R., Breidy, Hamadeh, B., Machlab, H., Rizk, H., Elhajj, S. (2015). Performance of 50 Lebanese barley landraces (*Hordeum vulgare* L. subsp. *vulgare*) in two locations under rainfed conditions. *Annals of Agricultural Sciences*, 60(2): 325-334.

Dotlačil, L., Hermuth, J., Stehno, Z., Dvoraček, V., Bradova, J., Leišova, L. (2010). Many modern cultivars, in wheat and in other crops as well, are often genetically similar, with a rather narrow genetic base. *Czech J. Genet. Plant Breed.*, 46 (Special Issue): S70–S74.

Heyland, K.U. and Werner, A. (2002). Barley (*Hordeum vulgare* L.). Lehrstuhl fuer Speziellen Pflanzenbau und Pflanzenzuechtung, University of Bonn, German, 7 pp.

Jovović, Z., Šilj, M., Velimirović, A., Pržulj, N., Mandić, D. (2017). Genetički resursi ječma (*Hordeum sativum* Jess.) u Crnoj Gori. XXII Savetovanje o biotehnologiji. Čačak, 10-11. mart 2017, Zbornik radova, Knjiga 1, str. 109-114.

Komatsuda, T., Pourkheirandish, M., He, C., Azhaguvel, P., Kanamori, H., Perovic, D., Stein, N., Graner, A., Wicker, T., Tagiri, A., Lundqvist, U., Fujimura, T., Matsouka, M., Matsumoto, T., Yano, M. (2007). Six-rowed barley originated from a mutation in a homeodomain-leucine zipper I-class homeobox gene. *Proceedings of the National Academy of Sciences*, 104: 1424-1429.

Madić, M., Đurović, D. Paunović, A. (2004). Genetička analiza komponenti prinosa u ukrštanjima dvorednih i šestorednih ječmova. X Simpozijum o krmnom bilju Srbije i Crne Gore sa međunarodnim učešćem. *Acta Agriculturae Serbica*, IX(17): 157-164.

Madić, M., Paunović, A., Knežević, D., Zečević, V. (2009). Grain yield and yield components of two-row winter barley cultivars and lines. *Acta Agriculturae Serbica*, XIV(27): 17-22.

Madić, M., Knežević, D., Paunović, A., Đurović, D. (2012). Genetic analysis of spike traits in two- and multi-rowed barley crosses. *Genetika*, 44(3): 475-482.

Madić, M., Knežević, D., Paunović, A., Đurović, D. (2016). Plant height and internode length as components of lodging resistance in barley. *Acta Agriculturae Serbica*, XXI(42): 99-106.

Madić, M., Paunović, A., Jelić, A., Knežević, D., Đurović, D. (2017). Prinos i komponente prinosa zrna ozimog dvoredog ječma gajenog na kiselom zemljištu. XXII Savetovanje o biotehnologiji, Čačak, 10-11 mart 2017, Zbornik radova, Knjiga 1, str. 195-200.

Miletić, A., Panković, D., Zorić, M., Pržulj, N., Momirović, G., Jovanović, M., Radisavljević, B., Perović, D. (2018). Fenotipska varijabilnost osobina klasa i genetička struktura populacije u kolekciji jarih ječmova. *Selekcija i semenarstvo*, 24(2): 49-58.

Noworolnik, K. (2010): Effect of sowing rate on yields and grain quality of new cultivars of spring barley. *Polish Journalof Agronomy*, 3: 20-23.

Spunar, J., Blumel, H., Fouquin, G. (2008). Global warming impact – Winter barley as reserve crop for brewing industry in the traditional European countries declaring exclusive or dominant spring malting barley utilization. In: Proceedings of the 10th International Barley Genetics Symposium, Alexandria, Egypt, 5-10 April 2008; pp. 395-405.

Špunar, J., Vaculova, K., Špunarova, M., Nesvadba, Z. (2002). Comparison of important parameters of spring and winter barley cutivated in sugar beet production area of Czech Republic. *Rostlinna vyroba*, 48(6): 237-242.

Морфолошке карактеристике локалних популација јарог двореда јечма (*Hordeum sativum* ssp. *distichum* L.) поријеклом из Херцеговине

Иван Ковачевић[1], Ђурађ Хајдер[2], Данијела Кондић[2], Драган Мандић[1], Десимир Кнежевић[3]

[1] *Пољопривредни институт Републике Српске, БиХ*
[2]*Универзитет у Бањој Луци, Пољопривредни факултет, Република Српска, БиХ*
[3]*Пољопривредни факултет, Универзитет у Приштини, Лешак, Косово и Метохија, Србија*

Сажетак

Јечам је стрна житарица толерантна на високе температуре и сушу. Због ове особине, може се окарактерисати као перспективан усјев за производњу у сушним условима. Истраживање пет јарих локалних популација двореда јечма трајало је двије експерименталне године (2011-2012) у агро-еколошким условима Бање Луке. У експерименту је примјењена стандардна ратарска пракса, без наводњавања. Оглед је постављен по принципу потпуно случајног блок система са четири понављања. Сва мјерења су извршена на 10 биљака по понављању. Испитиване су сљедеће морфолошке карактеристике: висина биљке (cm), дужина класа (cm), број зрна по класу и маса зрна по класу (g). У обради података примјењена је двофакторијална анализа варијансе са локалном популацијом и годином као основним факторима. Значајни ефекти третмана и интеракције су даље анализирани Фишеровим LSD-тестом, који се често користи као тест вишеструких поређења парова аритметичких средина. Код свих испитиваних особина, максималне просјечне вриједности добијене су код локалне популације АМ2, односно висина биљке (86,89 cm), дужина класа (8,90 cm), број зрна по класу (24,74) и маса зрна по класу (1,17 g). С обзиром на дате чињенице, локална популација двореда јечма АМ2 може се издвојити као најпродуктивнија у овом истраживању, носећи притом потенцијал за различите оплемењивачке сврхе.

Кључне ријечи: јечам, локална популација, карактеризација, евалуација, продуктивност

Danijela Kondić
E−mail*: danijela.kondic@agro.unibl.org*

Received: November 7, 2018
Accepted: April 17, 2019