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Original scientific paper

THE PRODUCTIVE TRAITS OF DIFFERENT POTATO GENOTYPES IN MOUNTAINOUS REGION OF MONTENEGRO

Zoran JOVOVIĆ[1], Željko DOLIJANOVIĆ[2], Dušan KOVAČEVIĆ[2], Ana VELIMIROVIĆ[1], Milan BIBERDŽIĆ[3]

[1]University of Montenegro, Biotechnical Faculty Podgorica, Montenegro
[2]University of Belgrade, Agricultural Faculty, Belgrade, Serbia
[3]University of Priština, Faculty of Agriculture Lešak, Serbia

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The results of three-year study of productivity for the five leading potato varieties in Montenegro: Riviera and Tresor (early), Kennebec (medium-early), Aladin and Agria (medium-late) are presented. The research was conducted during 2009, 2010 and 2011, on three highly diverse, related to the pedological and climatic conditions, locations in mountainous region of Montenegro: Nikšić (800 m.a.s.l.), Kolašin (900 m.a.s.l.) and Žabljak (1450 m.a.s.l.). Field experiments were set up using standard methodology in random block design in four repetitions.

Corresponding author: Zoran Jovović, University of Montenegro, Biotechnical Faculty Podgorica, Mihaila Lalića1, 81000 Podgorica, Montenegro, e-mail: jovovic@t-com.me

The analysis of variance suggested that there were highly significant differences among genotypes (G), investigated years (Y) and locations (L) for potato yield. Apart from individual influence of the factors, their interactions (G x Y, G x L, Y x L, G x Y x L) were also highly significant for investigated trait. In average the highest yield (28.9 t/ha) was established at Kolašin locality. The highest yield of all investigated varieties and localities was measured at variety Agria (30.0tha^{-1}), while the lowest at Riviera (24.6 t ha^{-1}). In this investigation Agria variety was favourable for yield of potato tuber.

Key words: genotype-environment interaction, mountainous region, potato, yield

INTRODUCTION

According to the planted area, potato represents the leading agricultural crop in Montenegro. In the production structure of the arable land, potato accounts for more than 20%. Zoning of the potato production is closely related to the nature, primarily climatic conditions. The production of early potatoes, intended for fresh consumption, is mainly located in the Zeta-Bjelopavlići plain and the coastal zone with a share in the total production of 16.8%. Production of potatoes intended for the storage is a dominant type of production (83.2%) and is related to the central and mountainous area (http://www.monstat.org). The mountain area is very interesting in terms of seed production as well. Environmental conditions (primarily altitude) have a crucial impact on growth and development of potato crops. At higher altitudes, the sunlight intensity is higher (HAVERKORT, 2007) as well as the utilization of solar radiation (PEREIRA *et al*., 2008), changed spectral composition of light, lower daily air and soil temperatures, which delays maturation and prolongs vegetation which is favourable for obtaining good quality tubers with high biological power (MOMIROVIĆ *et al.,*2000). The mountainous region of Montenegro is considered as the lowest southern zone in Europe where it is still possible to produce high quality seed potato. Plenty of sunlight and low cloudiness make this area ideal for seed potato production (JOVOVIĆ *et al.,* 2012).

The systematic study of different genotypes at numerous sites is of high importance as the selection of varieties adapted to the specific conditions increases (YANG, 2002). Vegetation factors have significant impact of potato yield along with the genotype. The reaction of genotypes in different agro-ecological conditions is caused by their genetic characteristics and interaction with the external environment. Knowledge of these characteristics is very important when choosing varieties as it enables high yields and stable production and the maximum utilization of genetic resources (PETROVIĆ *at al.*, 2010). One of the ways to reduce the negative impact of the interaction between genotype and the environment is the identification and cultivation of stable genotypes (MONDAL, 2003; YAN and KANG, 2003). Some potato genotypes have the ability to give very stable yields either on higher or lower level in very different environmental conditions (ANNICCHIARICO, 2002). Stability represents a very small genotype reaction on changed environmental conditions and it is

considered as a desirable characteristic in agricultural production. Through these small interactions of genotype uniform yields in relatively different agro-ecological conditions are insured (DIMITRIJEVIĆ *at al.*, 2010), thus the genotypes with a minimum yield variation are considered stable (SABAGHNIAA *et al.,* 2006). In all selection programs genotype stability has a high priority as it is desirable that newly created genotypes have high yields in a wide environmental conditions range (ABALO *et al.,* 2003).

Environmental conditions in specific potato growing areas are very different, thus the reactions of some genotypes in these conditions are different as well. Genotype productivity is significantly reduced if it's unable to use the full capacity of favourable environmental conditions, but also if the genotype cannot resist to their adverse effect (GRAY, 1999). It is well known that all the varieties were selected for specific agro-ecological conditions and only in such conditions it is possible to utilize their maximum genetic potential (with the use of optimal agro-technology).

The potato yields in Montenegro are very unstable and very susceptible to the influence of meteorological conditions (JOVOVIĆ *et al.,* 2002). With proper varieties selection it is possible to overcome the adverse effects of vegetation factors, especially the water and air soil regime, high temperatures and short vegetation season in the mountains. For these reasons, the aim of this study was to examine the productivity of different genotypes in agro-ecological conditions of the north part of Montenegro, at higher altitudes and to find the genotypes that will give satisfactory and stable yields.

MATERIALS AND METHODS

The study of genetic yield potential of the five leading potato varieties in Montenegro was carried out during 2009, 2010 and 2011 at three sites in the mountainous region of Montenegro. Early varieties tested were Riviera and Tresor, middle early Kennebec and middle late Aladin and Agria. Experiments were carried out in very different environmental conditions and on different soil types: Nikšić (800 m altitude, acid, brown soil), Kolašin (900 m altitude, alluvial soil) and Žabljak (1450 m altitude, mountain black soil).

Tests were carried out using field trials in a randomized block design with 4 replications. The plot size was 21 m^2. Planting of potatoes was done manually with 70 cm between row distance and 33 cm within row plant distance respectively, achieving the density of 43300 plants per hectare. Standard agricultural practice for the potato crop was applied. Potato harvesting was done after full maturation of canopy. The potato yield in the experiment was determined by measuring the tubers at each elementary plot, then the yield per hectare was calculated. The analysis of variance was calculated according to randomize complete block design with three factors: Genotype (G), Year (Y) and Locality (L). The significant differences among the means were evaluated according to least significant difference (*lsd*) test (MALETIĆ, 2005).

Table 1. Chemical properties of acid-brown soil in the experiment field

Depth (cm)	Locality	pH		$CaCO_3$	Humus	Soluble mg/100 g	
		H_2O	nKCl	%	%	P_2O_5	K_2O
40	Nikšić	6.57	5.97	1.75	3.05	9.3	17.3
	Kolašin	6.29	5.55	1.1	4.53	2.4	16.0
	Žabljak	5.91	4.85	2.05	7.32	6.2	23.5

Table 2. Meteorological conditions in the course of experiment

Year	Locality	Month					Average
		May	June	July	August	September	
		Air temperature (^{0}C)					
2009	Nikšić	17	18.2	21.8	22.3	17.5	19.4
	Kolašin	13	15.1	18.1	17.6	13.8	15.5
	Žabljak	10.2	12.1	15.3	14	8.8	12.1
2010	Nikšić	14	18.6	22	23.3	16.1	18.8
	Kolašin	11.6	15.9	18	18.3	12.6	15.3
	Žabljak	9.2	14.1	16.0	17.1	10.7	13.4
2011	Nikšić	15.6	18.5	21.8	22.8	18.1	19.4
	Kolašin	11.3	16.2	17.6	18	15.6	15.7
	Žabljak	8.8	13.9	15.9	16.5	14.1	13.8
		Amount of rainfall (mm)					Total
2009	Nikšić	73	158	81	51	48	411
	Kolašin	86	167	44	71	64	432
	Žabljak	62	166	68	93	46	435
2010	Nikšić	157	220	39	23	210	649
	Kolašin	202	103	34	12	117	468
	Žabljak	163	93	35	20	82	393
2011	Nikšić	135	56	40	29	140	400
	Kolašin	148	72	70	40	101	431
	Žabljak	162	43	76	53	113	447

Soil on which the experiments were carried out, as well as the most of the soils in the mountainous region of Montenegro, are characterized by favourable water and air properties and high humus content. On the other hand these soils are poor in phosphorus and calcium and with moderate potassium content (Table 1). As shown in Table 2 meteorological data were significantly different on different sites and between years as well. Average air temperatures were decreasing with higher altitude, while the precipitation during the potato vegetation period were unevenly distributed, with a deficit in the period of intensive tuber growth. This deficit was the most dominant in 2010, which resulted in significantly reduced yields.

RESULTS AND DISCUSSION

The average potato yield in investigation years showed considerable dependence on the genotype, locality and their interaction (table 3). Highest yield in three-year study was measured in variety Tresor (40.7 tha^{-1}) in Žabljak location in 2011, and the lowest in variety Aladin (18.3 tha^{-1}) in the same location in 2010. Average yield of potato ranged from 24.6 tha^{-1} (Riviera) to 30.0 tha^{-1} (Agria). Differences in achieved yield among all tested potato varieties were statistically very significant, except between varieties Agria and Kennebec. Lower yield of variety Agria were only in Žabljak location (26.1 tha^{-1}), as a consequence of lower and unfavourable distribution of precipitation during the vegetation period in 2010. Genotype effect on potato yield have also been reported by JOVOVIĆ *et al.* (2012a) and BROĆIĆ *et al.* (2000) who found that there were significant differences in the genetic bases among the studied potato varieties. Research results showed that in the agro-ecological conditions of north part of Montenegro highest yields had middle late varieties forming average number of tubers (Agria), and the lowest middle late varieties forming high number of tubers (Aladin). Some varieties due to the ability of the fast growth, good ground cover, early formation of a small number of tubers (Kennebec) easier tolerate critical growing phases that reduces adverse environmental effect (BUGARČIĆ *et al.,* 2000).This conclusion was confirmed in our research as well.

Genotypes reacted differently on investigation locality. The best results of tuber yields were obtained in Žabljak (32.8 t/ha^{-1}) in 2011, and lowest (22.1 tha^{-1}) in 2010 in Žabljak as well. Taking into account that the temperatures between 16 and 19 ° C are considered optimal for tuber initiation (BARKLEY, 2005) and intensive tubers growth in the early stages of budding and flowering (STRUIK, 2007) it is obvious that during these research, the temperature conditions were favourable for the potato crop. When the location is considered, the highest yield of potato for all genotypes was achieved in Kolašin (28.9 tha^{-1}), while the lowest in Nikšić (27.9 tha^{-1}). Statistical data analysis of the average tubers yield tested in different location shows significant differences between Kolašin and the other two sites, while difference between last two locations wasn't statistically significant. This strong influence of environment on yield of potato is in agreement with results of previous investigations (JOVOVIĆ *at al*, 2012b; HASSANPANAH, 2011).

Analysing the results of the potato yields in the three-year period, we noticed that the highest yields were achieved in 2009 (29.7 t ha-1), then in 2011 (28.8 t ha-1), and lowest in 2010 (26.5 t ha-1). Differences of tuber yields between the years were statistically significant. Bearing in mind that the research was conducted in the mountainous region of Montenegro, where the winters are long and cold and the summers short and cool, the achieved yields can be considered as satisfactory.

To achieve high yields it is necessary to provide well developed above ground mass and its activity in the longer period. The favourable temperature conditions and sufficient precipitation in 2009 and 2011 resulted in slightly longer vegetation period of potatoes, and therefore higher yields. High amount of

precipitation at the beginning of the vegetation period in 2010, followed by slightly lower air temperatures, caused the weaker vegetative growth of potato crops. In addition, a severe drought occurred during tuber filling. As a consequence, the yield of potatoes in 2010 was significantly lower than in 2009 and 2011.

Table 3. Average yield of potato (tha^{-1}) and analysis of variance

Genotype (G)	Locality (L)												Average (G)
	Nikšić				Kolašin				Žabljak				
	2009	2010	2011	Average	2009	2010	2011	Average	2009	2010	2011	Average	
G_1	25.1	23.6	26.1	24.9	24.3	22.8	22.2	23.1	26.4	21.3	29.4	25.7	**24.6^{d}**
G_2	26.5	24.1	24.9	25.2	35.0	24.2	32.2	30.5	28.4	24.5	40.7	31.2	**28.9^{bc}**
G_3	35.6	26.6	27.9	30.0	29.6	26.7	27.1	27.8	34.9	23.3	33.7	30.6	**29.5^{ab}**
G_4	26.2	34.4	25.2	28.6	28.5	33.1	27.2	29.6	30.3	18.3	34.8	27.8	**28.7^{c}**
G_5	28.8	37.4	25.7	30.6	36.4	33.4	30.1	33.3	29.8	23.3	25.3	26.1	**30.0^{a}**
Average	28.4	29.2	25.9	**27.9^{b}**	30.8	28.0	27.8	**28.9^{a}**	29.9	22.1	32.8	**28.3^{b}**	**28.3**

				lsd	
Source	d.f.	MS	F	0.05	0.01
Genotype (G)	2	14.73	5.849*	0.741	1.268
Year (Y)	2	170.14	67.576***	0.574	0.982
G*Y	4	276.98	110.005***	1.284	2.196
Location (L)	4	169.45	67.299***	0.574	0.982
G*L	8	82.69	32.843**	1.284	2.196
Y*L	8	88.27	35.059**	0.994	1.701
G*Y*L	16	43.78	17.386**	2.224	3.804

G-genotype (G_1 Riviera; G_2 Tresor; G_3 Kennebec; G_4 Aladin; G_5 Agria); L-locality

^{nsz}=P>0.05 *=P<0.05 **=P<0.01 ***=P<0.001

* Means that columns followed by the same letter are not significantly different according to Fisher's protected LSD values (P=0.05)

In addition to the effect of the main factors, their interactions (G*Y, G*L, Y*L, G*Y*L) were also high significant for investigation trait. The strong effect on potato yield was determined for locality (F=67.299), for year (F=67.576) and especially for interaction G*Y (F=110.005).

Environmental factors through different years strongly influenced the yield of potato, even though there was also a significant genotype effects shown by analysis of variance. Productivity is a function of the adaptability of variety to environmental conditions, thus it is very important to create varieties that will be able to provide consistently high yields in a wide range of environmental factors (HALDAVANKAR *at al.,* 2009). This large difference in variance between environmental and genotypic influences clearly demonstrates the importance of impact of meteorological conditions on yield of tested potato genotypes. Phenotypic variability of the major yield components (number of tillers per plant, number of

tubers per stem, and their size) is primarily caused by differences between the genotypes of the cultivars, while the variation of their products (tuber number and yield per plant) mainly depends on the interaction between genotype and environmental factors (NACHEVA, 2006). To ensure high and stable production, which means maximum utilization of genetic resources, it is necessary to provide as much information about the different types of genotype x environment interactions as possible. This means that evaluation of genotypes of several environments would give a more accurate estimate of their productive potential.

CONCLUSION

The three-year research results of investigation of productive properties of different potato genotypes in mountainous region of Montenegro allow us to conclude:

- Localities and years of research, individually and in the interaction, had a major influence on the yield of potato tubers of different genotypes;

- Based on the tubers yield of five investigated genotypes of potato in the north of Montenegro, we recommend three of them (Agria, Kenebec and Tresor) especially for growing in favourable weather conditions, as it was year 2011.

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PRODUKTIVNE OSOBINE RAZLIČITIH GENOTIPOVA KROMPIRA U PLANINSKOM REGIONU CRNE GORE

Zoran JOVOVIĆ[1], Željko DOLIJANOVIĆ[2], Dušan KOVAČEVIĆ[2], Ana VELIMIROVIĆ[1], Milan BIBERDŽIĆ[3]

[1]Univerzitet Crne Gore, Biotehnički fakultet Podgorica, Crna Gora
[2]Univerzitet u Beogradu, Poljoprivredni fakultet Zemun, Beograd, Srbija
[3]Univerzitet u Prištini, Poljoprivredni fakultet Lešak, Srbija

U radu su predstavljeni rezultati trogodišnjih proučavanja produktivnosti pet vodećih sorti krompira u Crnoj Gori: Riviera i Tresor (rana), Kennebec (srednje rana) i Aladin i Agria (srednje kasna). Istraživanja su sprovedena tokom 2009, 2010 i 2011. godine, na 3 pedoklimatski veoma različita lokaliteta u planiskom predjelu Crne Gore: Nikšić (800 m.n.v.), Kolašin (900 m.n.v.) i Žabljak (1450 m.n.v.). Poljski ogledi su postavljeni po standardnoj metodologiji, u potpuno slučajnom blok sistemu, u 4 ponavljanja.

Analiza varijanse je pokazala da je prinos krompira značajno varirao u zavisnosti od genotipa, ispitivane godine i lokacije. Pored individualnog uticaja proučavanih faktora, visoko značajnim ocijenjene su i njihove interakcije (genotip x godina, genotip x lokalitet, godina x lokalitet, genotip x godina x lokalitet).U trogodišnjem prosjeku najveći prinos krtola postignut je u Kolašinu (28,9 th^{-1}), najprinosnija sorta bila je Agria (30th^{-1}), dok su najniži prinosi izmjereni kod Riviere (24.6th^{-1}). Rezultati ovih istraživanja su pokazali da u brdsko-planinskom rejonu Crne Gore najbolje prinose daju srednje kasne sorte koje formiraju srednji broj krtola (Agria).

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