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Original scientific article

THE EFFECT OF YEAR AND GENOTYPE ON PRODUCTIVITY AND QUALITY OF POTATO

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The study presents results of a three-year experiment of variability of different potato varieties in Montenegro: early maturity varieties (Riviera), medium early (Almera, Aladin and Bounty) and medium late (Agria, Margarita, Kennebec and Desiree). The research was conducted during 2015, 2016 and 2017, in acid, brown soil and three different climatic locations: Nedakusi (556 m a.s.l.), Sutivan (680 m a.s.l.) and Orahovica (900 m a.s.l.). Field experiments were set up using standard methodology in random block design in three repetitions. The analysis of variance suggest that number of tubers per plant, mean tuber weight, yield of small tubers, marketable and total yields were significantly fluctuating depending on genotype (G), year (Y) and the location (L). In addition to individual influences of different factors, their interactions were also pronounced (G x Y, G x L, Y x L, G x Y x L). In the three-year period average, the highest total yield was recorded in Nedakusi (31.41 t ha^{-1}), followed by Sutivan (21.35 t ha^{-1}), while the lowest average yield (17.36 t ha^{-1}) was recorded in Orahovica. As expected, on the three-year average, the highest percentage of dry matter was found in late varieties Agria - 25.46%, then Desiree - 25.33%, followed by Kennebec with 25.13%, while the lowest percentage of dry matter was found in medium early variety Almera - 20.82%. The highest average yield of tubers in the three-year period was recorded in the Aladin variety, followed by Agria and Desiree, while the lowest average yield was recorded in the variety Riviera. Obtained results show that the highest yields over observed locations were recorded in

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medium early varieties that formed high number of tubers per plant (Aladin) and medium late varieties (Desiree and Agria) give satisfactory and stable yields.

Keywords: potato, genotype, productivity, dry matter, starch

INTRODUCTION

Potato (*Solanum tuberosum* L.) is cultivated in about 160 countries in the world and consumed every day by over a billion people (CAMIRE *et al.,* 2009; BISHWOYONG and SWARNIMA, 2016). Used for food more than 10,000 years potatoes have high industrial and forage importance (DONNELLY and KUBOW, 2011). 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 23% (http://www.monstat.org). 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-Bjelopavlici 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 (JOVOVIC *et al.,* 2012). Potato yield depends on the variety and its genetic potential, agro-ecological conditions, the level of applied cropping practices, tuber viability, seed tuber size, the number of stems per plant and the number of tubers per plant (BUS and WUSTMAN, 2007; POŠTIĆ *et al.,* 2012; POŠTIĆ *et al.,* 2013; MOMIROVIĆ *et al.,* 2016). Among the environmental factors, soil water is a major limiting factor in the production and quality of potatoes (POŠTIĆ *et al.,* 2012; MONNEVEUX *et al*., 2013; MOMIROVIĆ *et al.,* 2016). Compared to other species, potato is sensitive to drought (HASSANPANAH *et al*., 2008) due to shallow root system (IWAMA, 2008). Drought stress negatively affects in phase of tuber initiation and early development stage of tubers increased involvement rough an deformed tubers, which significantly reduces the yield of potatoes, while the lack of water during the stage of bulking tubers, in addition to reducing yields, negatively affects its quality (MONNEVEUX *et al*., 2013; POŠTIĆ *et al*., 2012).

The quality of potato tubers and their chemical composition are influenced by genetics factors, soil fertility, weather conditions and chemical treatments that are applied (RYTEL *et al.,* 2013). Potato tubers quality is often referred to as external and internal quality. The internal quality is determined by many traits of which the most important are dry matter content, type and amount of starch, sugar, and protein content (VAN ECK, 2007). Dry matter content and starch content are the two overriding factors governing the quality of potato varieties (KIRKAM, 2007). According to the requirements of quality features of potato fit for direct consumption, tubers should contain 18-22% of dry matter and 12-16% of starch, while potato tubers intended for chips 20-22% of dry matter and 14-17% of starch, and for crisps 20-25% of dry matter and 16-20% of starch (GRUDZINSKA *et al.,* 2016). Some potato genotypes have the ability to achieve very stable yields under very different environmental conditions (JOVOVIC *et al.,* 2012; MOMIROVIĆ *et al.,* 2016). Stability represents a very low genotype response to changed environmental conditions and it is considered a desirable characteristic in agricultural production. Varieties with low interactions under different agro-ecological conditions reach stabile yields (DIMITRIJEVIC *at al.*, 2011), 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 developed genotypes have high yields in a wide environmental array (JOVOVIC *et al.,* 2012; MOMIROVIĆ *et al.,* 2016). 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 favorable environmental conditions, but also if the genotype cannot resist to their adverse effect (JOVOVIC *et al.,* 2012). 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 agrotechnology). The potato yields in Montenegro are very unstable and very susceptible to the influence of meteorological conditions (JOVOVIC *et al.,* 2012).

With proper varieties selection it is possible to overcome the adverse effects of vegetation factors, especially the water and air soil regime, and high temperatures during vegetation season in northern Montenegro. For these reasons, the aim of this study was to examine the productivity of different genotypes in agro-ecological conditions of the northern Montenegro in order to find the genotypes that will give satisfactory and stable yields.

MATERIALS AND METHODS

The study of genetic yield potential of eight potato varieties was carried out during 2015, 2016 and 2017 at three sites in northern part of Montenegro. The objects of research were early maturity varieties (Riviera), medium early (Almera, Aladin and Bounty) and medium late (Agria, Margarita, Kennebec and Desiree). Experiments were carried out in different environmental conditions and on same soil types: Nedakusi (556 m altitude, acid, brown soil), Sutivan (680 m altitude, acid, brown soil) and Orahovica (900 m altitude, acid, brown soil). Tests were carried out using field trials in a randomized block design with 3 replications. The plot size was 16 m^2. Planting of potatoes was done manually with 70 cm between row distance and 40 cm within row plant distance respectively, achieving the density of 35714 plants per hectare. Planting material belonged to the category of original (certified seeds), fractions 35-55 mm, and the average weight of mother tuber was 60±5 g. Properly pre-sprouted seed material was used for planting. The sowing was conducted in all locations at the end of April. Growing practices were as usual for potato production in the continental part of Montenegro, and irrigation was not applied. Recommended plant protection products were used to control diseases and pests.

Table 1. Chemical properties of soil in the experimental plots

Depth (cm)	Location	pH		$CaCO_3$	Humus	Soluble mg/100 g	
		H_2O	nKCl	%	%	P_2O_5	K_2O
30	Nedakusi	5.00	4.41	2.57	2.77	5.27	8.33
	Sutivan	5.17	4.57	2.60	5.04	3.53	25.13
	Orahovica	4.63	4.03	2.47	3.62	3.17	24.60

All cultivars except the late ones were harvested in the second week of September in all seasons. The medium late cultivars Agria, Margarita, Kennebec and Desiree were harvested 7-10 days later to allow the tuber skin to be fully developed. After the harvest the number of tubers

per plant, average tuber weight, yield of small tubers, marketable tuber yield and total yield were precisely determined. The potato yield in the experiment was determined by measuring the tubers at each elementary plot, then the yield per hectare was calculated.

Table 2. Meteorological conditions in the course of experiment

Year	Location	Month						Average
		April	May	June	July	August	September	
		Air temperature (°C)						
	Nedakusi	9.7	16.9	18.9	23.4	22.6	18.7	18.37
2015	Sutivan	9.0	16.4	18.3	22.9	21.8	18.2	17.77
	Orahovica	8.4	15.8	17.9	22.5	21,2	18.0	17.30
	Nedakusi	13.6	13.9	20.5	21.5	19.8	16.6	17.65
2016	Sutivan	12.9	13.4	19.9	21.0	19.1	16.0	17.05
	Orahovica	12.3	12.9	19.5	20.4	18.4	15.7	16.53
	Nedakusi	10.3	15.3	20.0	21.3	21.9	16.7	17.58
2017	Sutivan	9.7	14.7	19.4	20.8	21.0	16.2	16.97
	Orahovica	9.2	14.1	18.8	20.3	21.5	15.8	16.62
		Precipitation sum (mm)						Total
	Nedakusi	53.5	35.5	90.4	15.5	30.7	59.0	284.6
2015	Sutivan	56.1	38.4	34.0	8,2	22.3	63.8	222.8
	Orahovica	61.4	42.5	47.1	20,3	16.7	48.6	236.6
	Nedakusi	48.2	120.0	86.0	76,0	85.3	74.6	490.1
2016	Sutivan	50.6	126.1	90.3	79.8	88.1	78.2	513.1
	Orahovica	53.0	132.8	95.1	89,2	97.3	82.5	549.9
	Nedakusi	49.0	78.9	75.4	102.4	44.8	19.4	369.9
2017	Sutivan	51.4	83.0	79.8	106.7	47.5	22.4	390.8
	Orahovica	60.5	89.6	87.2	117.3	53.0	25.8	433.4

Harvested tubers were grouped into two size categories: (i) <70 g -small tubers and (ii) >70 g - marketable tuber. Data were converted into the tons per ha. Dry matter content (DMC) was determined at harvest, the samples were made by mixing tubers of different sizes for each cultivar. DMC was determined by drying tubers at 105°C.The starch content in tubers was determined by method VRAČAR (2001) at the Faculty of Technology in Novi Sad. Soil on which the experiments were carried out, as well as the most of the soils in the northern region of Montenegro, are characterized by favorable water and air properties and high humus content. On the other hand these soils are high acidic pH, poor in phosphorus and calcium and with low (Nedakusi) to high potassium content (Sutivan and Orahovica) Table 1.

As shown in Table 2 meteorological data were significantly different on all studied sites and between years as well. Average air temperatures were decreasing with higher altitude, while the precipitations 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 2015 at locations Sutivan and Orahovica, which resulted in significantly reduced marketable and total yields.

Obtained results were analysed by the analysis of variance (ANOVA, F-test; P≤ 0.05, P≤ 0.01 and P≤ 0.001) and effect of factors (year, genotype, locality and their interaction). Tukey's multiple range test and coefficients of variation (CV, %) were used to determine the differences among varieties. Correlations between observed parameters were determined by Pearson correlation coefficients (r). Data were processed by program STATISTICA, version 8 (StatSoftInc, Tulsa, OK, USA).

RESULTS AND DISCUSSION

The F test, in the complex three factorial analysis (Table 3), showed a significant effect ($p<0.001$) of the year and location on average tuber weight, marketable and total yield. An effect of the variety (genotype) on all traits productivity was also significant ($p<0.01$). Interaction of studied factors were significant among all the factors and for all the traits ($p<0.01$) or ($p<0.001$).

Table 3. The influence of mean values on the properties by application *F test*

Source	d.f.	Number of tubers	Mean tuber weight (g)	Yield small tubers (t ha^{-1})	Marketable yield (t ha^{-1})	Total yield (t ha^{-1})
Genotype (G)	7	**	**	**	**	**
Year (Y)	2	**	***	***	***	***
G*Y	14	**	**	**	**	**
Location (L)	2	**	***	**	***	***
G*L	14	**	**	**	**	**
Y*L	4	**	***	**	***	***
G*Y*L	28	*	*	**	**	*

G-genotype;Y-year; L-location; ^{ns}=P>0.05,*=P<0.05,**=P<0.01,***=P<0.001

The largest number of tubers per plant was recorded in all locations in 2016 (Table 4), as a result of the favourable distribution rainfall (Table 2). Deficit water supply leads to poor plant growth and reduced tuber number resulting low yield (HASSANPANAH *et al*., 2008). Result indicated that soil moisture due to good distribution of rainfall in 2016 favourable for plants led to an increase of the number of tubers. Present results agree with previous studies of many authors (HASSANPANAH, 2010; ABDULLAH-AL-MAHMUD *et al*., 2014; MOMIROVIĆ *et al.*, 2016). The lowest number of tubers per plant was determined at location Nedakusi in 2017 (Table 4), while at the locations Sutivan and Orahovica the lowest number of tubers per plant was recorded in 2015. Observed by locations in the three-year average all genotypes formed a significantly higher number of tubers per plant 10.06 at location Nedakusi, compared to 8.10 number tubers per plant at other two locations. On the three-year average, the highest number of tubers per plant at all localities was formed by medium early varieties Aladin and Bounty, while the lowest number of tubers per plant was recorded in the medium late Kennebec.

Analysing the results of the mean tuber weight in the three-year period (Table 5), we noticed that the highest mean tuber weight were achieved at locality Nedakusi (87.98 g), then locality Sutivan (71.44 g), and lowest at Orahovica (59.60 g).

Table 4. Average tuber number per plant

Locality	Nedakusi			
Genotype	Year			
	2015	2016	2017	Average
Riviera	10.33ab	8.92a	8.25bc	9.17
Almera	9.50ab	9.22a	8.20bc	8.97
Aladin	12.28a	13.28a	12.61a	12.72
Bounty	11.36ab	11.61a	10.94ab	11.30
Agria	8.81ab	11.56a	10.51ab	10.29
Margarita	11.00ab	10.78a	10.11abc	10.63
Kennebec	7.78b	7.81a	6.80c	7.46
Desiree	11.08ab	9.39a	9.39abc	9.95
Average	10.27	10.32	9.60	10.06
CV (%)	14.42	17.37	19.13	
Locality	Sutivan			
Riviera	10.39a	6.25d	5.92e	7.52
Almera	6.86ab	9.42abc	8.75bcd	8.34
Aladin	8.22ab	10.72ab	11.39a	10.11
Bounty	4.38b	11.08a	10.42ab	8.63
Agria	6.38ab	8.53abcd	7.86cde	7.59
Margarita	6.00b	9.81abc	9.14bc	8.32
Kennebec	5.06b	6.86cd	6.53de	6.15
Desiree	7.74ab	8.08bcd	8.61bcd	8.14
Average	6.88	8.84	8.58	8.10
CV (%)	27.71	19.65	21.33	
Locality	Orahovica			
Riviera	6.17a	6.22c	6.22cd	6.20
Almera	6.72a	10.64ab	9.29ab	8.88
Aladin	8.08a	9.72abc	10.39ab	9.40
Bounty	6.45a	12.03a	11.03a	9.84
Agria	5.89a	9.86abc	9.19abc	8.31
Margarita	7.95a	8.36abc	8.02bcd	8.11
Kennebec	5.80a	6.78c	6.11d	6.23
Desiree	7.64a	7.67bc	8.23abcd	7.85
Average	6.84	8.91	8.56	8.10
Total average	8.00	9.36	8.91	8.76
CV (%)	13.55	22.41	20.83	

* Means that columns followed by the same letter are not significantly different according to Tukey Method confidence (P=0.05)

Table 5. Average tuber weight (g)

Locality	Nedakusi			
Genotype	Year			
	2015	2016	2017	Average
Riviera	104.38a	64.45d	63.00c	77.28
Almera	123.50a	70.81cd	66.52bc	86.94
Aladin	93.16a	81.81abcd	78.51abc	84.49
Bounty	85.75a	65.77d	59.12c	70.21
Agria	110.80a	90.36abc	89.51ab	96.89
Margarita	115.36a	74.59bcd	69.14bc	86.36
Kennebec	112.60a	97.87ab	97.50a	102.66
Desiree	99.51a	104.17a	93.30ab	98,99
Average	105.63	81.23	77.08	87.98
CV (%)	11.75	18.38	19.19	
Locality	Sutivan			
Riviera	43.04a	96.06ab	90.71a	76.60
Almera	46.73a	85.16ab	81.40a	71.10
Aladin	34.24ab	100.25ab	85.95a	73.48
Bounty	24.24b	74.13b	68.52a	55.63
Agria	35.86ab	100.57ab	97.00a	77.81
Margarita	29.25ab	88.18ab	84.68a	67.37
Kennebec	34.46ab	101.01a	91.27a	75.58
Desiree	31.50ab	105.44a	85.02a	73.99
Average	34.92	93.85	85.57	71.44
CV (%)	20.68	11.20	9.87	
Locality	Orahovica			
Riviera	38.46b	71.29ab	64.50ab	58.08
Almera	50.43ab	60.88bc	60.55ab	57.29
Aladin	44.60ab	72.51ab	60.08ab	59.06
Bounty	40.24ab	43.66c	43.88b	42.59
Agria	57.52a	74.07ab	70.41a	67.33
Margarita	46.42ab	74.45ab	72.83a	64.57
Kennebec	43.88ab	70.00ab	71.77a	61.88
Desiree	38.61a	86.94a	72.47a	66.01
Average	45.02	69.23	64.56	59.60
Total average	65.19	81.43	75.74	74.12
CV (%)	14.44	18.14	15.28	

* Means that columns followed by the same letter are not significantly different according to Tukey Method confidence (P=0.05)

In 2015, all varieties formed a significantly higher average tuber weight at locality Nedakusi, compared to Sutivan and Orahovica localities. The drought stress during June, July and August in Sutivan and Orahovica had a negative effect on the average tuber weight of tested genotypes (Table 2 and 5). Deficit water supply leads poor plant growth and reduced tuber size resulting low yield (HASSANPANAH *et al*., 2008; RYKACZEVSKA, 2015; MOMIROVIĆ *et al.*, 2016).

Highest average tuber weight in three-year study was measured in variety Kennebec (102.66 g) in Nedakusi location, and the lowest in variety Bounty (42.59 g) in Orahovica. The highest average tuber weight in Nedakusi locality was achieved in 2015, while the lowest was recorded in 2017. At localities Sutivan and Orahovica, the highest average tuber weight was achieved in 2016, while the smallest one was formed in 2015.

The results of yield of small tubers in the three-year period show that the highest average unmarketable yield (2.00 t ha^{-1}) were achieved in Nedakusi location, followed by Sutivan (1.67 t ha^{-1}), and Orahovica (1.59 t ha^{-1}) (Table 6). The observed maximum yield of small size of tubers might be due to the presence of more number of tubers as well as, varietal character and adaptability or establishment effect of other growth attributes (KUMAR *et al*., 2007). The highest yield of small tubers at all localities was recorded in 2017. The lowest average yield of small tubers at the locality Nedakusi was established in 2016, i.e. 2015 at localities Sutivan and Orahovica.

The highest number of small tubers at Nedakusi locality was formed on average by the variety Margarita, followed by Aladin and Almera, while the lowest one was formed by Kennebec variety. At Sutivan locality, the highest average yield of small tubers was measured by Almera and Riviera varieties, followed by Desiree, while the smallest yield of small tubers was formed by Agria. At Orahovica locality, the highest yield of small tubers was found in Agria cultivar, then in Almera, followed by Desiree, while the smallest tubers were found on the plot with Bounty cultivar. Variation among genotypes of yield of small tubers could be attributed to their genetic make-up which influenced tuber size.

With regard to locations, the highest three-year average yield of marketable tubers (29.22 t ha^{-1}) was recorded at Nedakusi location, then at Sutivan (19.85 t ha^{-1}), while the lowest marketable tuber yield was established in Orahovica (15.79 t ha^{-1}) (Table 7). Differences of marketable yields between the localities were statistically significant. Records of the three-year average marketable tuber yield at all the three locations show that the medium early Aladin and medium late Agria varieties were the top yielding genotypes. The lowest yield of marketable tubers in the three-year average at Nedakusi and Orahovica locations showed the early variety Riviera, while in Sutivan the lowest yield of marketable tubers was recorded in the variety Kennebec.

The highest average marketable yield at Nedakusi locality was achieved in 2015, while the lowest one was recorded in 2017. At the localities of Sutivan and Orahovica, the highest marketable yield was established in 2016, while the lowest yield of marketable tubers was achieved in 2015. Lower marketable yield in Sutivan and Orahovica locations is a consequence of drought and unfavourable distribution of precipitation during June, July and August the vegetation period in 2015. In 2015 the largest coefficient of variation at location Sutivan was also determined (Table 7). These results are also in accordance with the researches of many authors (POŠTIĆ *et al*., 2012; MOMIROVIĆ *et al.*, 2016), and all these authors stated that the lack of

water in the soil during the tuber bulking was causing the increase in the number of small tubers, or the decrease in the number of larger tubers.

Table 6. Yield of small tubers (t ha^{-1})

Locality	Nedakusi			
Genotype	Year			
	2015	2016	2017	Average
Riviera	1.89a	1.22a	2.83ab	1.98
Almera	2.34a	1.64a	2.38ab	2.12
Aladin	1.51a	1.41a	3.57a	2.16
Bounty	1.80a	1.18a	2.85ab	1.94
Agria	1.95a	1.22a	2.62ab	1.93
Margarita	2.19a	1.27a	3.05ab	2.17
Kennebec	1.75a	1.57a	2.00b	1.77
Desiree	2.03a	1.35a	2.39ab	1.92
Average	1.93	1.36	2.71	2.00
CV (%)	13.46	12,60	17,70	
Locality	Sutivan			
Riviera	1.33a	1.50ab	3.00ab	1.94
Almera	1.42a	1.50ab	3.32a	2.08
Aladin	1.09a	1.82a	1.93c	1.61
Bounty	1.56a	1.14b	2.20bc	1.63
Agria	0.98a	1.27b	1.50c	1.25
Margarita	1.02a	1.29b	2.41abc	1.57
Kennebec	0.96a	1.55ab	2.23bc	1.58
Desiree	1.03a	1.76ab	2.20bc	1.66
Average	1.17	1.48	2.35	1.67
CV (%)	19.56	16.07	24.54	
Locality	Orahovica			
Riviera	0.92a	1.09a	2.29a	1.43
Almera	1.39a	1.05a	2.81a	1.75
Aladin	0.99a	1.37a	2.66a	1.67
Bounty	0.95a	0.82a	2.16a	1.31
Agria	1.06a	1.27a	3.11a	1.81
Margarita	1.05a	1.09a	2.57a	1.57
Kennebec	1.20a	1.06a	2.08a	1.45
Desiree	0.98a	1.18a	2.96a	1.71
Average	1.07	1.12	2.58	1.59
Total average	1.39	1.32	2.55	1.75
CV (%)	14.65	14.71	14.62	

* Means that columns followed by the same letter are not significantly different according to Tukey Method confidence (P=0.05)

In the three-year period average, the highest total yield was recorded in Nedakusi (31.41 t ha^{-1}), followed by Sutivan (21.35 t ha^{-1}), while the lowest average yield (17.36 t ha^{-1}) was recorded in Orahovica (Table 8). Statistical data analysis of the average tubers yield tested in different locations shows significant differences between Nedakusi 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 (HASSANPANAH, 2010; JOVOVIC *et al.*, 2012; MOMIROVIĆ *et al*., 2016).

Genotypes reacted differently on investigation locality. Research results showed that in the agro-ecological conditions of north part of Montenegro at localities Nedakusi, Sutivan and Orahovica average the highest three-year total yield was recorded in medium early varieties forming high number of tubers (Aladin) and medium late varieties Desiree and Agria. The lowest total yield was recorded for variety Riviera at all three localities. Some varieties due to the ability of the fast growth, good ground cover, early formation of tubers (Desiree) easier tolerate critical growing phases that reduces adverse environmental effect (RYKACZEVSKA, 2015; MOMIROVIĆ *et al*., 2016).

This conclusion was confirmed in our research as well. The distribution of the total yield (Table 8) by localities and years has the same trend as the marketable yield (Table 7). The highest total yields (38.51 t ha^{-1}) were recorded in 2015 at locality Nedakusi, while the lowest total yields (26.25 t ha^{-1}) were recorded in 2017. Differences of the tuber yields between the years were statistically significant.

At the localities Sutivan and Orahovica, the highest total yield was established in 2016, while the lowest was achieved in 2015. Drought stress during June, July and August in 2015 at localities Sutivan and Orahovica reduced development of potato plants and lead to the shorter growing season of potato crops. As a consequence, the total yield of potatoes in 2015 were significantly lower than in 2016 at these localities. To achieve high yields it is necessary to provide well developed aboveground mass and its activity in the longer period. Sufficient precipitation in 2016 at localities Sutivan and Orahovica resulted in slightly longer vegetation period of potatoes, and therefore higher total yields.

Dry matter content of eight cultivars in three-year ranged from 18.41-25.39% in Nedakusi, 21.08-27.84% in Sutivan and 20.05-27.43% in Orahovica (Table 9). The presence of wide variations among varieties for dry matter and starch contents indicated the genetic factor was important to influence the tuber internal quality traits. The observed differences are a good opportunity for the producers to select the varieties for production that fit the market demand. Dry matter content and starch content, like any genetic characters, are a function of hereditary factors and the environment working together (KOOMAN *et al*., 1996; BROĆIĆ *et al*., 2016).

As expected, on a three-year average, the highest percentage of dry matter was found in late varieties 25.46% Agria, then Desiree 25.33%, followed by Kennebec with 25.13%, while the lowest percentage was found in medium early variety Almera - 20.82%. Tuber dry matter content is a varietal characteristic and depends on the conditions in growing season, as a rule level of tuber dry matter content in early cultivar is lower, compared to late cultivar. These results agree with other studies reporting decreased tuber dry matter content under drought (SCHITTENHELMA *et al*., 2006; SINGH and LOVEDEEP, 2009; SANCHEZ-RODRIGUEZ *et al*., 2010).

Table 7. Marketable yield (t ha⁻¹)

Locality	Nedakusi			
Genotype	Year			
	2015	2016	2017	Average
Riviera	36.19a	19.37d	15.73c	23.76
Almera	40.68a	21.59d	17.11c	26.46
Aladin	38.96a	37.35a	31.79a	36.03
Bounty	33.83a	25.56cd	20.26c	26.55
Agria	32.08a	35.99ab	30.98a	33.02
Margarita	43.13a	26.89bcd	21.92bc	30.65
Kennebec	32.29a	25.71cd	18.11bc	25.37
Desiree	33.71a	33.14abc	28.90ab	31.92
Average	36.36	28.20	23.10	29.22
CV (%)	11.37	23.42	28.14	
Locality	Sutivan			
Riviera	19.69a	19.69c	16.18c	18.52
Almera	9.87b	27.25bc	22.12bc	19.75
Aladin	9.16bc	36.46a	33.04a	26.22
Bounty	2.17c	28.01abc	23.30abc	17.83
Agria	7.20bc	29.28ab	25.73ab	20.74
Margarita	5.61bc	29.48ab	25.24abc	20.11
Kennebec	5.22bc	23.05bc	19.06bc	15.78
Desiree	7.05bc	28.49abc	23.93abc	19.82
Average	8.25	27.71	23.58	19.85
CV (%)	63.18	17.74	21.17	
Locality	Orahovica			
Riviera	7.75a	14.73a	12.50a	11.66
Almera	10.59a	22.00a	17.28a	16.62
Aladin	12.06a	24.37a	20.38a	18.94
Bounty	8.33a	17.81a	15.13a	13.76
Agria	10.78a	24.82a	20.00a	18.53
Margarita	12.43a	21.56a	18.29a	17.43
Kennebec	8.03a	15.95a	13.58a	12.52
Desiree	9.70a	22.57a	18.36a	16.88
Average	9.96	20.48	16.94	15.79
Total average	18.19	25.46	21.21	21.62
CV (%)	18.17	18.69	17.20	

* Means that columns followed by the same letter are not significantly different according to Tukey Method confidence (P=0.05)

Table 8. Total yield (t ha^{-1})

Locality	Nedakusi			
Genotype	Year			
	2015	2016	2017	Average
Riviera	38.10a	20.58d	18.56b	25.75
Almera	41.73a	23.06d	19.48b	28.09
Aladin	40.48a	38.76a	35.36a	38.20
Bounty	34.96a	26.11ab	23.09b	28.05
Agria	34.02a	37.22ab	33.60a	34.95
Margarita	45.32a	28.16bcd	24.95b	32.81
Kennebec	34.04a	27.28cd	23.67b	28.33
Desiree	39.43a	34.50abc	31.29a	35.07
Average	38.51	29.46	26.25	31.41
CV (%)	10.50	22.58	24.34	
Locality	Sutivan			
Riviera	15.93a	21.19c	19.18b	18.77
Almera	11.29ab	28.75bc	25.45ab	21.83
Aladin	10.24abc	38.27a	34.95a	27.82
Bounty	3.73c	29.15abc	26.13ab	19.67
Agria	8.18bc	30.55ab	27.23ab	21.99
Margarita	6.63bc	30.77ab	27.64ab	21.68
Kennebec	6.19bc	24.59bc	21.28b	17.35
Desiree	8.78abc	30.26abc	26.14ab	21.73
Average	8.88	29.19	26.00	21.35
CV (%)	41.89	17.05	18.01	
Locality	Orahovica			
Riviera	8.67a	15.81a	14.79a	13.09
Almera	11.98a	23.05a	20.09a	18.37
Aladin	13.04a	25.35a	23.02a	20.47
Bounty	9.33a	18.63a	17.28a	15.08
Agria	11.83a	26.09a	23.11a	20.34
Margarita	13.48a	22.64a	20.86a	18.99
Kennebec	9.24a	17.00a	15.66a	13.97
Desiree	10.68a	23.75a	21.30a	18.58
Average	11.03	21.54	19.51	17.36
Total average	19.42	26.73	23.92	23.36
CV (%)	16.56	18.02	16.52	

* Means that columns followed by the same letter are not significantly different according to Tukey Method confidence (P=0.05)

Table 9. Dry matter content (%) in potato tubers during 2015, 2016 and 2017 years

Locality	Year	Genotype								Average
		Riv	Alm	Ala	Bou	Agr	Mar	Ken	Des	
Nedakusi	2015	20.48	20.12	23.05	24.54	25.39	22.41	24.35	24.57	23.11
	2016	20.83	18.41	22.48	24.32	22.61	23.58	22.82	22.08	22.14
	2017	21.32	20.83	23.56	23.18	24.60	23.01	23.05	23.31	22.86
	Average	20.88	19.79	23.03	24.01	24.20	23.00	23.41	23.32	22.70
Sutivan	2015	21.08	21.09	24.73	25.53	23.38	22.09	25.08	26.53	23.69
	2016	24.72	20.48	25.38	26.32	27.35	24.48	27.45	27.84	25.50
	2017	20.41	21.33	25.17	24.41	26.21	23.72	25.01	24.35	23.83
	Average	22.07	20.97	25.09	25.42	25.65	23.43	25.85	26.24	24.34
Orahovica	2015	22.34	23.61	24.35	26.47	27.43	26.08	26.54	26.83	25.46
	2016	20.81	20.05	20.39	21.82	25.35	21.31	26.48	26.58	22.85
	2017	21.50	21.47	25.13	24.34	26.78	23.52	25.35	25.91	24.25
	Average	21.55	21.71	23.29	24.21	26.52	23.64	26.12	26.44	24.19
Total average		21.50	20.82	23.80	24.55	25.46	23.36	25.13	25.33	23.74

In the group of early maturity, the highest amounts of dry matter (Table 9) and starch (Table 10) were accumulated by Bounty 24.55% and 19.70%, respectively. The other potato varieties of early maturity, such as Riviera and Almera, had lower accumulation of dry matter and starch. In the group of the medium late maturity, the highest content of dry matter had Agria (25.46%), while Desiree had the highest content of starch (19.57%). The content of dry matter and starch also depends on the size of tubers, but also on the climatic conditions. Larger tubers generally have a lower dry matter and starch content, but the smallest tubers usually have a higher dry matter and starch content (GVOZDEN, 2016).

Observed by localities in the three-year average, the highest content of dry matter and starch (24.34% and 18.90%, respectively) were recorded at the locality Sutivan, then at Orahovica (24.19% and 18.37%, respectively), while the lowest amount were found at the locality Nedakusi (22.70% and 16.60%, respectively). At the localities Nedakusi and Orahovica, the highest amount of dry matter and starch was recorded in 2015, while the lowest was recorded in 2016. At Sutivan site, the content dry matter and starch had the opposite tendency. On a three-year average, the highest percentage of starch in tubers 19.70% was recorded in the middle early variety Bounty, followed by the late varieties Desiree - 19.57% and Kennebec - 19.12%, while the lowest was found in the early variety Almera - 15.38%. The result suggested the importance of testing potato varieties across locations and seasons to identify wide adaptable varieties that could produce tubers with uniform dry matter and starch content in all environments since it benefit producers, processors and consumers.

On the basis of correlation analysis and gained correlation coefficients (Table 11) very high dependences ($p \leq 0.01$ to $p \leq 0.001$) are noticed between number tubers per plant, average tuber weight, marketable and total yield, while the correlation between the number of tubers per plant and the yield of small tubers has not been established. Further, average tuber weight correlated ($p \leq 0.01$ to $p \leq 0.001$) with marketable, total yield and yield of small tubers. The yield

of small tubers correlated ($p \leq 0.05$ to $p \leq 0.01$) with marketable and total yield. Based on the correlation analysis, correlations between traits of quality (dry matter and starch content) and traits of productivity has not been established. A very high correlation ($p \leq 0.001$) between dry matter and starch content was determined (Table11).

Table 10. Starch content (%) in potato tubers during 2015, 2016 and 2017 year

Locality	Year	Genotype								Average
		Riv	Alm	Ala	Bou	Agr	Mar	Ken	Des	
Nedakusi	2015	15.12	15.46	17.19	19.27	17.67	16.83	19.97	19.17	17.59
	2016	13.29	12.11	16.89	19.36	14.55	15.99	15.70	14.78	14.96
	2017	16.24	15.02	17.42	18.05	18.32	17,24	17.69	18.04	17.25
	Average	14.88	14.20	17.17	18.89	16.85	16.69	17.79	17.33	16.60
Sutivan	2015	15.34	15.21	18.75	19.74	14.99	16.16	19.81	20.25	17.53
	2016	20.31	15.17	20.12	24.05	21.56	19.68	20.40	21.99	20.54
	2017	16.43	16.89	19.31	18.84	19.73	18.52	19.63	19.71	18.63
	Average	17.36	15.76	19.39	20.88	18.76	18,12	19.95	20.65	18.90
Orahovica	2015	16.43	18.75	19.22	22.42	22.52	20.74	20.14	20.65	20.11
	2016	13.87	12.59	14.82	16.34	17.99	13.53	19.14	21.66	16.24
	2017	15.65	17.24	20.08	19.21	20.42	18.17	19.56	19.85	18.77
	Average	15.32	16.19	18.04	19.32	20.31	17.48	19.61	20.72	18.37
Total average		15.85	15.38	18.20	19.70	18.64	17.43	19.12	19.57	17.96

Table 11. The correlation coefficients between the observed traits (n=72)

Traits	Total yield	Yield small tubers	Mean tuber weight	Number tubers per plant	Dry matter	Starch content
Marketable yield	0.993***	0.254*	0.849***	0.731***	-0.126 ns	-0.109 ns
Total yield	-	0.325**	0.866***	0.721***	-0.118 ns	-0.095 ns
Yield small tubers		-	0.329**	0.214 ns	-0.144 ns	-0.017 ns
Mean tuber weight			-	0.315**	-0.039 ns	-0.022 ns
Number tubers per plant				-	-0.193 ns	-0.063 ns
Dry matter					-	0.906***
Starch content						-

Pearson correlation coefficient: *** $P \leq 0.001$, ** $P \leq 0.01$, * $P \leq 0.05$, respectively

Hence, on the basis of the mentioned relationships it can be concluded that four productivity traits - number of tubers per plant, average tuber weight, marketable and total yields had the highest interdependence of the selected genotypes. The results agree with previous findings (TACIO and TAD-AWAN, 2005).

The hierarchical cluster analysis (Figure 1) clearly shows three groups (clusters) of genotypes which differentiated on the basis of the similarity of productive traits.

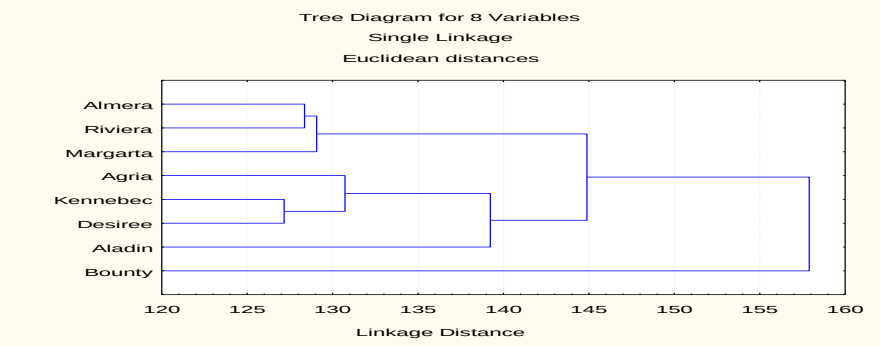

Figure 1. Dendrogram of productive traits in 8 potato varieties

The genotypes were very good clustered according to their analysed traits, the early maturity varieties Almera and Riviera as well as medium late Margarita clearly distinguishes from remaining in the first cluster, while medium late Agria, Kennebec and Desiree and medium early Aladin distinguishable in the second cluster. In the third cluster, the genotype Bounty has unrelated traits with other genotypes.

CONCLUSION

According to the three-year research results on variability of eight potato varieties under different agro-ecological conditions in north Montenegro, the following can be concluded:

- Different locations and years individually and by their interactions significantly affected the productive and quality properties of studied genotypes;
- High correlation between the number of tubers per plant, average tuber weight, marketable yield and total yield of potatoes were determined;
- A very high correlation ($p \leq 0.001$) between dry matter and starch content was established;
- Based on the marketable and total yields of all eight genotypes observed in different locations, can be recommended the growing medium early maturity varieties (Aladin), as well as medium-late maturity varieties (Desiree and Agria), especially for growing in favourable weather conditions.

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UTICAJ GODINE I GENOTIPA NA PRODUKTIVNOST I KVALITET KROMPIRA

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Izvod

U radu su predstavljeni rezultati trogodišnjih istraživanja varijabilnosti različitih sorti krompira u u severnoj Crnoj Gori: Riviera (rana), Almera, Aladin i Bounty (srednje rane) i Agria, Margarita, Kennebec i Desiree (srednje kasne). Ispitivanja su izvedena tokom 2015, 2016 i 2017. godine, na tri klimatski različita lokaliteta: Nedakusi (556 m n.v.), Sutivan (680 m n.v.) i Orahovica (900 m n.v.). Poljski ogledi su izvedeni po standarnoj metodologiji u potpuno slučajnom blok sistemu u 3 ponavljanja. Analiza varijanse je pokazala da su broj krtola po biljci, prosečna masa krtole, prinos tržišnih krtola i ukupan prinos značajno varirali u zavisnosti od genotipa, ispitivane godine i lokacije. Pored individualnih uticaja proučavanih faktora značajno su ocenjene i njihove interakcije (genotip x godina, genotip x lokalitet, godina x lokalitet, genotip x godina x lokacija). U trogodišnjem proseku najveći ukupan prinos krtola utvrđen je na lokalitetu Nedakusi (31,41 t ha^{-1}), zatim u Sutivanu (21,35 t ha^{-1}), dok je najmanji prosečan prinos zabeležen na lokalitetu Orahovica (17,36 t ha^{-1}). Najveći prinos krtola u trogodišnjem proseku ustanovljen je kod sorte Aladin, zatim kod sorte Agria i Desiree, dok je najmanji prinos krtola konstatovan kod sorte Riviera. Kao što je očekivano, najveći sadržaj suve materije utvrđen je kod kasnih sorti 25,46% Agria, zatim kod Desirea 25,33%, odnosno kod sorte Kennebec 25,13%, dok je najmanji sadržaj suve materije 20,82%. zabeležen kod srednje rane sorte Almera. Rezultati ovih istraživanja su pokazali da na ispitivanim lokalitetima najveće prinose postiže srednje rana sorta (Aladin) koja formiraju veliki broj krtola po biljci, kao i srednje kasne sorte (Agria i Desiree) koje su ostvarile zadovoljavajući i stabilan prinos.

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