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Original scientific article

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

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Potato (*Solanum tuberosum* L.) is characterized by specific temperature requirements and develops best at about 20°C. High temperatures during the growing season cause an array of changes in potato plants, which affect its development and may lead to a drastic reduction in economic yield. Under natural conditions, drought and heat stress are two different types of abiotic stresses that occur in the field simultaneously or separately, especially in conditions without irrigation in potato production. This study aimed to examine the productivity of nine potato varieties in agro-ecological conditions of western Serbia and to find the genotypes that will give satisfactory and high yields. The field experiment was carried out with varieties: Cleopatra, Anuschka, Presto, Kuroda, Omega, Dita, Desiree, Roko and Jelly. The impact year and genotype on potato plants were tested during a four-year period (2010-2013). The final harvest was performed after the full maturity of plants in September. Our studies confirmed that potato marketable yield and total yield are greatly reduced at temperatures higher than optimal and deficit precipitation during the growing season. Here we demonstrated that the tested potato cultivar's response to heat stress and drought in the growing season is dependent on the longer the adverse effects and the growth stage. The earlier a heat and drought occurs, the

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more negative the impact on the growth and productive traits of potatoes. The results obtained in this study indicate that among the tested cultivars Cleopatra was the most tolerant to heat and drought stress acting on the plants during the growing season. Our research shows that the total yield was not the only indicator of potato tolerance to abiotic stress during the growing season, but the assessment should also take into account the occurrence of secondary tuberization and physiological defects of tubers. These studies confirm that Cleopatra had the largest share (82%) of market tubers in relation to the total yield and to have the best predisposition for the highest economic yield of tubers. Our experiment showed that heat and drought tolerant potato cultivars could be used to mitigate the effects of global warming in Serbia and wider Western Balkans regions.

Key words: High temperature, drought, tuber, yield

INTRODUCTION

There is broad consensus that climate change represents a major threat to agricultural production and food security (ALEXANDRATOS and BRUINSMA, 2012; CHALLINOR *et al.,* 2014; GODFRAY *et al.,* 2010; IPCC, 2014; LOBELL *et al.,* 2008; WHEELER and VON BRAUN, 2013). According to forecasts of the International Food Policy Research Institute (IFPRI), the four major food sources in the world - wheat, rice, corn and potatoes will be steadily total yields decreased up to 2050. The negative effects of climate change on crop production are likely to be even more severe in the future as global temperatures are predicted to increase from 2.6 to 4°C before the end of this century (ROGELJ *et al.,* 2016). HIJMANS (2003) estimates indicate that an increase of 1.6-3°C could reduce global potato yields by 18–32%. Decreases in the production of potato and other staple crops represent a major challenge to food security, especially in the case of rapid population growth (ALEXANDRATOS and BRUINSMA, 2012). Almost all relevant studies agree that least developed and developing countries, are mostly affected by these changes to which the countries of the Western Balkans also belong. In the coming years, it is expected an increased frequency of droughts, especially in the southern parts of Europe, and therefore in the western Balkans (JOVOVIĆ *et al.,* 2016). The area of the Western Balkans is characterized by the Mediterranean and continental climate with long moderate winters and long warm summers. Among the environmental factors, soil water is a major limiting factor in the production and quality of potatoes (BAO-ZHONG *et al*., 2003). Excet for Albania, which irrigates 54% of arable land, other countries irrigated only 1-3% of arable land, which makes agriculture in these countries very vulnerable to drought stress (FAOSTAT, 2018). Compared to other species, potato is sensitive to drought (VAN LOON, 1981; FRUSCIANTE *et al.,* 1999; HASSANPANAH *et al.,* 2008; NASIR and TOTH, 2022) due to shallow root system (IWAMA, 2008). Drought stress negatively affects the phase of tuber initiation and early development stage of tubers increased involvement rough and deformed tubers, which significantly reduces the yield of potatoes, while the lack of water during the bulking tubers, in addition to reducing yields, negatively affects its quality (MACKERRON and JEFFERIES, 1986; TOMASIEWICZ *et al.,* 2003; MONNEVEUX *et al.,* 2013; POŠTIĆ, 2013; MUTHONI and SHIMELIS, 2020; ÁVILA-VALDES *et al.,* 2020). Growth, yield and quality responses of potato cultivars to drought stress significantly differ (MACKERRON and JEFFERIES, 1986; CABELLO *et al.,* 2012; POŠTIĆ, 2013; NASIR and TOTH, 2022). LAHLOU *et al.* (2003) stated that drought may reduce tuber yield even by 11 to 53%. The phenomenon of stress caused by high soil temperatures, a lack of soil moisture, high bulk density, and lack of air permeability, have resulted in secondary growth of tubers (BEUKEMA and VAN DER ZAAG, 1979), which could reduce market value and quality of yield. According to POŠTIĆ *et al.* (2015) soil temperatures over 27ºC in the surface 10 cm soil layer in the phenophase of tuber bulking, play a key role in the reduction of yields and quality of potato tubers. Under high temperature conditions (heat stress), tuberization is significantly inhibited and photoassimilate partitioning to tubers is greatly reduced (EWING, 1981; HAYNES *et al.,* 1989; KRAUSS and MARSCHNER, 1984; LAFTA and LORENZEN, 1995; ÁVILA-VALDES *et al.,* 2020; MUTHONI and SHIMELIS, 2020). Heat stress due to increased temperature is an agricultural problem in many areas of the world (BIRCH *et al.,* 2012). Transitory or constant high temperatures cause an array of morpho-anatomical, physiological and biochemical changes in plants, which affect plant growth and development and may lead to a drastic reduction in economic yield (WAHID *et al.,* 2007). In natural conditions drought and heat stress are two different types of abiotic stresses that occur generally in the field simultaneously (RYKACZEWSKA, 2015). Bearing in mind, there is not much information on the effect of heat and drought stress at different stages of potato tuber growth (LEVY, 1985; LEVY and VEILLEUX, 2007; RYKACZEWSKA, 2015). In the farming system under non-irrigated conditions potato yields in Serbia are very unstable and very susceptible to the influence of meteorological conditions (POŠTIĆ *et al.,* 2015). With proper variety 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 Western Serbia. For these reasons, the aim of this study was to examine the productivity of different genotypes in agro-ecological conditions of Western Serbia and to find the genotypes that will give satisfactory and stable yields.

MATERIAL AND METHOD

Fild Location and Tested Cultivars

The field experiment was carried out during four-year period (2010-2013) in Western Serbia in village Badovinci (75 m a.s.l., recent alluvium) (44˚ 80' 05" to 44˚ 81' 17"N - 19˚ 35' 39 to 19˚ 36' 41"E). Potato crops were grown in crop rotation, winter wheat as the pre-crop each year. The following varieties were tested: Cleopatra, Anuschka, Presto (early), Kuroda, Omega, Dita (middle early) and Desiree, Roko, Jelly (middle late). Four-generation pedigree of all cultivars is presented in Table 3. Planting material seed tubers category of original (certified seeds 35-45 mm, approx 60 g each, all cultivars from Ltd. Co. Solanum Komerc, Guča, Serbia). The basic soil properties are presented in Table 1.

Table 1. Soil chemical analysis at the four years in the experimental plot

Year	Depth (cm)	pH (KCl)	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})	$CaCO_3$ (%)	Organic matter (%)	N (%)
2010	0-30	6.53	19.84	15.00	0.00	2.97	0.19
2011		6.08	20.32	14.57	0.00	2.85	0.17
2012		6.21	18.97	16.06	0.00	3.02	0.21
2013		6.37	19.13	15.32	0.00	3.19	0.18

Agrotechnical measures

The experimental design was a randomized complete block system with four replications. Row spacing was 0.7 m, with 0.3 m between plants within the row. Each plot was 12.6 m^2, with 60 plants (4 rows with 15 plants per row). Plants from border rows were not harvested and 26 plants were harvested. Properly pre-sprouted seed material was used for planting. The pre-planting soil cultivation involved two passages with a rotary harrow to the depth of 20 cm in spring. Planting dates were 5, 1, 6 and 8 April, in 2010, 2011, 2012 and 2013 respectively. The planting of tubers was carried out manually. Along with planting the tubers in the rows, insecticide chlorpirifos against the soil pests was applied (Radar Versus G, manufacturer and supplier: Galenika-Fitofarmacija, Belgrade, Serbia). NPK compound mineral fertilizer (15:15:15) was applied and all plots received the same amounts of basal nutrients, as calculated per hectare: 150 kg N, 150 kg P_2O_5 and 150 kg K_2O. Potato crops were grown in natural water regime. The field was protected against weeds by spraying the herbicide metribuzin once in the third decade of April (Velton WG, manufacturer and supplier: Galenika-Fitofarmacija, Belgrade, Serbia). In the second decade of May of each year, manual hoeing and earthing up was carried out manually hoeing and earthing up. When the critical number of Colorado potato beetles per plant was exceeded (0.07 beetle/plant, MAILLOUUX *et al*., 1995) and the weather conditions were favorable for the development of fungal diseases, all potatoes were sprayed with fungicides/insecticides. In the second decade of June, the potatoes were treated with the insecticide deltamethrin (Pollux, producer and supplier: Galenika-Fitofarmacija, Belgrade, Serbia), on the third decade of June and on the first decade of July, we sprayed them with the fungicides propamokarb hydrochloride and chlorothalonil (Fuzija, producer and supplier: Galenika-Fitofarmacija, Belgrade, Serbia), fluazinam (Kardinal, producer: Galenika-Fitofarmacija, Belgrade, Serbia), mancozeb and metalaxyl-m (Alijansa, producer and supplier: Galenika-Fitofarmacija, Belgrade, Serbia). In the third decade of July, we applied the fungicides Alijansa and Kardinal and the insecticide thiamethoxam (Asterija, producer and supplier: Galenika-Fitofarmacija, Belgrade, Serbia) to the potatoes. The insecticide was used when the critical larvae L1/L2 value, 4 specimens/stalk, was exceeded (BINNS *et al.,* 1992). The crop was dehaulmed 20 days before harvesting using piraflufen-etil (Kabuki 2,5 EC, producer: Nichino Europe, Cambridge, United Kingdom; supplier: Galenika-Fitofarmacija, Belgrade, Serbia).

The occurrence of diseases and pests by years: Late blight (Phytophthora infestans, Mont. de Bary) in 2010 and 2013 symptoms appeared on the plants (12^{th}, 15^{th} June, respectively), in 2011 and 2012 symptoms appeared later at the end of June (23^{rd}, 26^{th} respectively); Early blight (Alternaria solani, Ellis & G. Martin L.R. Jones & Grout) symptoms appeared in all four years in the period of mid-July, and it was more intensive infection in 2011 and 2012 compared with 2010 and 2013; and Colorado potato beetle (Leptinotarsa decemlineata, Say) appeared in all years in mid-May, the highest pressure of these pests was recorded in dry 2012.

Weather Conditions

The meteorological data during the potato growing period were obtained from the bulletin ‘Meteorological yearbook’, which is published annually by the Republic Hydro-meteorological Institute of Serbia. Climatic conditions at the experimental field are mild continental, with hot and dry summers and cold winters. As shown in Table 2 meteorological data were very different between years. The average temperature of air for a vegetation period of potato crop was a bit higher in 2010 (18.4ºC), 2013 (18.5ºC), 2011 (19.2ºC) and especially in 2012 (20.1ºC), compared to the long-term data (17.6ºC), which indicates very hot summers in all years of examination. The drought was severe especially in 2012, since the precipitation amount was much lower than average (350.1 mm). Very limited precipitation (236.7 mm), following very high temperatures in June (22.7ºC), July (24.9ºC) and August (23.7ºC) have caused considerable water deficit and resulted in significantly reduced yields. During the 2010 and 2011 average air temperatures were closer to long-term average values, and the precipitation distribution was better in Jun and July.

Table 2. Mean values of air temperature and precipitation during the potato growing season (2010, 2011, 2012 and 2013) and the long-term data (1975-2006) for the area western Serbia

Year	Decade	Month						Mean	Sum
		April	May	June	July	August	September		
Mean temperature (ºC)									
2010	I	10.6	18.6	18.7	21.4	22.0	16.9		
	II	11.3	13.9	24.0	25.4	23.0	16.9		
	III	14.6	18.5	18.3	21.4	20.5	14.6		
	mean	12.2	17.0	20.3	22.7	21.8	16.2	18.4	2865
	min	3.2	8.1	9.2	13.1	10.2	7.6		
	max	26.7	29.6	34.6	34.4	37.7	30.2		
2011	I	13.4	12.8	20.5	22.1	22.1	21.9		
	II	10.8	16.7	20.2	25.3	22.3	21.8		
	III	15.4	20.3	21.1	19.3	22.8	17.1		
	mean	13.2	16.6	20.6	22.2	22.4	20.3	19.2	2906
	min	3.6	2.8	10.1	10.0	10.4	9.5		
	max	25.0	29.7	33.6	37.4	38.2	35.2		
2012	I	10.7	18.9	21.3	27.5	25.4	21.2		
	II	11.4	15.4	22.7	24.2	22.1	17.5		
	III	16.6	17.0	23.9	23.1	23.7	19.8		
	mean	12.9	17.1	22.7	24.9	23.7	19.5	20.1	3099[a]
	min	-2.1	5.6	9.4	12.6	10.9	4.3		
	max	29.1	30.6	35.9	37.9	41.0	34.5		
2013	I	7.0	18.8	17.0	20.8	25.4	17.4		
	II	13.7	17.6	22.9	21.6	23.2	15.2		
	III	18.3	15.0	20.1	24.0	20.2	15.1		
	mean	13.0	17.4	20.0	22.1	22.9	15.9	18.5	2900
	min	0.9	7.4	11.2	10.4	12.1	5.3		
	max	30.6	33.0	35.5	39.0	38.7	29.1		

Table 2 continued

Year	Deacade	Month							
		April	May	June	July	August	September	mean	sum
Long-term data (1975-2006)		11.1	16.7	19.9	20.9	20.7	16.3	17.6	2731
Monthly sum of precipitation (mm)								Sum	
2010	I	11.1	3.4	43.0	36.8	25.4	28.9		
	II	32.9	62.4	12.4	4.6	16.0	35.2		
	III	10.8	43.2	71.7	35.4	31.7	13.3		
	sum	54.8	109.0	127.1	76.8	73.1	77.4	518.2	
2011	I	3.2	41.3	55.1	19.8	3.0	1.2		
	II	15.2	19.8	3.6	2.3	1.4	2.4		
	III	1.6	2.2	11.4	71.4	1.7	15.2		
	sum	20.0	63.3	70.1	93.5	6.1	18.8	271.8	
2012	I	38.3	5.4	8.2	2.8	0.0	1.2		
	II	30.2	24.0	14.2	1.2	0.0	7.4		
	III	17.1	41.7	4.4	35.6	0.4	4.6		
	sum	85.6	71.1	26.8	39.6	0.4	13.2	236.7	
2013	I	17.9	30.1	26.5	31.1	0.0	0.0		
	II	4.2	41.5	17.5	6.3	2.4	43.9		
	III	9.8	47.4	18.0	7.3	15.9	17.0		
	sum	31.9	119.0	62.0	44.7	18.3	60.9	336.8	
Long-term data (1975-2006)		48.5	53.4	81.9	63.3	46.8	56.2	350.1	

Data Collected

Stems were counted 65 days after planting. Five plants of each cultivar were sampled in the middle of August, tubers were harvested manualy and transported to the lab for measurements. It was done regarding the presence of physiological defects in the tubers, mainly deformations (elongated tubers, bottlenecks, chain-tuberization) and sprouting were determined as a percentage of the total mass of tubers. All cultivars except the late ones were harvested in the first week of September in all seasons. The moderately late cultivars Desiree, Roko and Jelly were harvested 7 - 10 days later to allow the tuber skin to be fully developed. Yield and number of stems and tubers per plant were recorded. The number of tubers per stem and average tuber weight was calculated. Harvested tubers were grouped into two size categories: (i) <70 g yield small tubers and (ii) >70 g marketable tuber yield. Data were converted into tons per hectare. Dry matter content (DMC) was determined at harvesting, the samples were made by mixing tubers of different sizes, with three replicates for each variety. DMC was determined by drying tubers at 105°C (BROĆIĆ *et al.,* 2016).

Data Analyses

The ANOVA (F test) was applied to determine the effect of factors. The Tukey's multiple range test ($p \leq 0.05$) and the coefficient of variance (CV%) were used to test environmental effects. The Pearson's correlation between examined parameters was calculated using simple correlation coefficients (r). Hierarchical cluster analysis was used to group the genotype into classes or clusters based on their similarities. Acquired experimental data were processed using the freeware software package Minitab (https://www.minitab.com/en-us/). Index represents the % ratio between the largest average value and other mean of the evaluated properties.

Table 3. Four generation pedigree of cultivars

CLEOPATRA	ZPC 50-35	SASKIA	RODE EERSTERLING
			HEROLD
		SIRTEMA	DORST H 123A
			FRUHMOLE
	DESIREE	URGENTA	FURORE
			KATAHDIN
		DEPESCHE	DUKE OF YORK
			IMPOSANT
ANUSCHKA	LEYLA	7338/812	
		CULPA	CLIVIA
			HYDRA
	MARABEL	NENA	GRANDIFOLIA
			52/72/2206
		MA 75-364	AM 66-42
			BIRANCO
PRESTO	MV 982.034-87	KORETTA	1-67.254/13N
			ADRETA
		5.132.017-80N	5.73.228/129N
			LIBELLE
	MARABEL	NENA	GRANDIFOLIA
			52/72/2206
		MA 75-364	AM 66-42
			BIRANCO
KURODA	AR 76-199-3	GE 64-491	
		VAKON	VACUNA
			VK 64-56
	KONST 80-1407	KONST 75-1122	STANIA
			KONST 69-864
		AUSONIA	WILJA
			KONST 63-665
OMEGA	H 277-58		
	TONDRA	AQUILA x BRA 9089	AQUILA
			BRA 9089
		seedling	

DITA	MARIELLA	EVA	EARLY SUNRISE
			ERSTE VON FROMSDORF
		SCHWABLE	AQUILA
			CAPELLA
	BU 58.80/15 x WE.58.42/9N	BU 58.80/15	
		WE.58.42/9N	LU.55.1198/12N
			SCHWABLE
DESIREE	URGENTA	FURORE	RODE STAR
			ALFA
		KATAHDIN	USDA 40568
			USDA 24642
	DEPESCHE	DUKE OF YORK	EARLY PRIMROSE
			KING KIDNEY
		IMPOSANT	INDUSTRIE
			PEPO
ROKO	ALWARA	290/76	CORDIA
			228/64
		DESIREE	URGENTA
			DEPESCHE
	MA 81-536		
JELLY	MARABEL	NENA	GRANDIFOLIA
			52/72/2206
		MA 75-364	AM 66-42
			BIRANCO
	L 173/87/4476	L 246/83/3500	L 258/77/2615
			LINDA
		L 783/87/4476	

RESULTS AND DISCUSSION

According to the analysis of variance (ANOVA), our results showed a significant effect ($p<0.001$) of the year on the mean tuber weight and marketable yield, while for the other observed traits (stems number per plant, number of tubers per plant, number tubers per stem and yield small tubers) showed significant effects on the level $p<0.01$ (Table 4). This can be explained by different climatic conditions in which potato crops were grown. Furthermore, a significant effect ($p<0.01$) of the genotype on all investigated characteristics was determined. Interaction of studied factors Y × G was significant for all the traits ($p<0.05$) or ($p<0.01$).

Stem Number per Plant

The main effects of year, genotype and their interaction effects on the stem number per plant varied significantly (Table 4). Average maximum stem number per plant in the four-year period was found in Desiree (4.62), followed by Jelly (4.53), and the lowest was measured in Kuroda (3.70) (Table 5). Reduced adverse environmental effect was noted in Desiree variety due to the ability of its fast growth and good canopy development, as well as the early formation of an average number of tubers with higher tolerance in critical growing phases. In an earlier study RYKACZEWSKA (2015) a similar founding for variety Desiree was characterized by the relatively high tolerance of the aboveground part of plants to high temperature. Cultivar Desiree has very high adaptability to the environment (EPCD, 2008). The stem number per plant is mainly determined by the size of the seed tuber (HASSANPANAH, 2010; POŠTIĆ, 2013) and its condition and by soil properties and soil moisture at planting. The number of stem per plant is an extremely important morphological property, because it affects the development of aboveground mass and assimilation area (STRUIK, 2007; ÁVILA-VALDES *et al.,* 2020), the number of seeded tubers per plant, and total yield (KHAN *et al.,* 2004; POŠTIĆ *et al.,* 2012; MOMIROVIĆ *et al.,* 2016). Drought stress reduces assimilate production and canopy growth (MILLER and MARTIN, 1985; JEFFERIES, 1989; GREGORY and SIMMONDS, 1992; ÁVILA-VALDES *et al.,* 2020). The lowest average number of stem per plant (3.98) was found in 2012, as a result of high air temperature accompanied by severe drought during June when the potato plants were in the phase of intensive vegetative development (Table 2 and 5). Mean reduction in the number of stem per plant in years varied in a very narrow range 6.57% (2012) to 3.05% (2011) in severe drought and slightly weaker favorable conditions compare to good growing conditions in 2010 (Table 2 and 5). Similar findings showing the effects of drought on the number of shoots per plant were also reported earlier by many authors (WURR, 1974; BARAKAT *et al.,* 1994; DEBLONDE and LADENT, 2001; MOMIROVIĆ *et al.,* 2016). Results are consistent with results obtained by other authors (WURR *et al.,* 2001; KHAN *et al.,* 2004; POŠTIĆ *et al.,* 2012), who stated that the number of stem per plant varied considerably depending on the variety and the production conditions. Based on our results, a greater number of stems in favorable ecological conditions provide higher yields.

Table 4. The significance level of tested factors - from the analysis of variance

Factors	Stem number per plant	No. of tubers per plant	No. of tubers per stem	Mean tuber weight	Yield small tubers	Marketable yield	Total yield
Year (Y)	**	**	**	***	**	***	**
Genotype (G)	**	**	**	**	**	**	**
Y × G	*	*	*	**	*	**	**

Y-Year (Ecological conditions); G - Genotype; ^{ns}=P>0.05,*=P<0.05,**=P<0.01, ***=P<0.001

The Number of Tubers per Plant

The main effects of year, genotype and their interaction effects for tuber number per plant varied significantly (Table 4). It was shown that a high amount of precipitation cause soil moisture favorable for plants and led to an increase in the number of tubers (Table 2 and 5). The highest number of tubers per plant was produced by Jelly (13.58), followed by Desiree (13.50), and the lowest by Kuroda (10.83), due to the ability formation of the average number of tubers (Table 5).

Table 5. Effect of year and genotype on stem number per plant and number tubers per plant in 2010, 2011, 2012 and 2013 years

	Stem number per plant				Average	
Year	2010	2011	2012	2013	Variety	Maturity
G1	4.59abA	4.48aA	4.38abcA	4.30abA	4.45ab	
G2	4.43abcA	4.20abAB	3.95bcdB	3.95bB	4.13bc	4.21
G3	4.40abcA	4.20abAB	3.80cdB	3.85bB	4.06bc	
G4	3.60dB	3.73bAB	3.55dB	3.90bA	3.70c	
G5	4,05bcdA	3.83bB	3,78dB	3.80bB	3.87c	3.80
G6	3.88cdAB	4.05abA	3.68dB	3.73bB	3.84c	
G7	4.68aA	4.63aA	4.58aA	4.60aA	4.62a	
G8	3.83dA	3.78bA	3.63dA	3.73bA	3.74c	4.30
G9	4.75aA	4.28aB	4.50abB	4,58aAB	4.53a	
Average	4.26A	4.13AB	3.98B	4.05AB	4.11	
Index (%)	100	96.95	93.43	95.07		
CV (%)	9.79	7.58	9.97	8.67		
	Number tubers per plant					
G_1	13.5aA	12.4abcAB	11.7bcB	12.4abcAB	12.50ab	
G_2	12.2abA	12.6abA	11.5bcB	12.1bcAB	12.10ab	11.84
G_3	10.7bA	10.7bcA	10.9cA	11.4cA	10.93b	
G_4	11.2bA	10.5cA	10.4cA	11.2cA	10.83b	
G_5	12.1abA	11.8abcA	10.6cB	11.5cAB	11.50b	11.33
G_6	12.1abA	11,6abcA	11.4bcA	11.5cA	11.65b	
G_7	14.0aA	13.6aAB	12.9abB	13.5aAB	13.50a	
G_8	12.5abA	12.3abcA	11.6bcB	12.4abcA	12.20ab	13.09
G_9	13.5aA	13.6aA	13.5aA	13.7aA	13.58a	
Average	12.42A	12.12AB	11.61B	12.19AB	12.09	
Index (%)	100	97.58	93.48	98.15		
CV (%)	8,79	9,10	8,77	7,48		

G-genotype (G1 Cleopatra; G2 Anuschka; G3 Presto; G4 Kuroda; G5 Omega; G6 Dita; G7 Desiree; G8 Roko; G9 Jelly); Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% Confidence; Index represents the % ratio between the largest average value and other mean of the evaluated properties.

Table 6. Effect of year and genotype on number tubers per stem and mean tuber weight (g) in 2010, 2011, 2012 and 2013 years

	Number of tubers per stem				Average	
Year	2010	2011	2012	2013	Variety	Maturity
G_1	2.95abA	2.76abAB	2.68aB	2.87bA	2.82b	
G_2	2,76bcA	3.01abA	2.91aA	3.06abA	2.94ab	2.82
G_3	2.44cB	2.54bAB	2.87aAB	3.00A	2.70b	
G_4	3.12abA	2.82abB	2.94aAB	2.87bB	2.94ab	
G_5	2.99abAB	3.08aA	2.82aB	3.04abA	2.98ab	2.99
G_6	3.13abA	2.88abB	3.09aAB	3.10abAB	3.05a	
G_7	2.99abA	2.94abA	2.83aA	2.95bA	2.93ab	
G_8	3.28aAB	3.26aAB	3.21aB	3.47aA	3.31a	3.07
G_9	2.85bcA	3.0abA	3.02aA	3.0bA	2.97ab	
Average	2.95A	2.92A	2.93A	3.04A	2.96	
Index (%)	97.04	96.05	96.38	100		
CV (%)	8,31	7,03	5,41	5,91		
	Mean tuber weight (g)					
G_1	53.1bcAB	56.1abA	46.0aB	47.8aB	50.75a	
G_2	56.1bcA	53.7abAB	44.6aB	48.1aB	50.63a	50.98
G_3	61.9abA	59.7aA	40.7abB	43.9abB	51.55a	
G_4	64.1aA	58.8aA	44.1aB	45.0abB	53.00a	
G_5	58.5abA	47.8bB	39.2abcC	40.6bcC	46.53ab	47.63
G_6	52.1cA	45.5bB	33.6bcC	42.2abB	43.35b	
G_7	58.3abA	52.7abA	40.4abB	40.3bcB	47.93ab	
G_8	56.8bcA	50.9abB	34.2bcC	34.2dC	44.03b	45.39
G_9	58.5abcA	50.8abA	32.2cB	35.3cdB	44.20b	
Average	57.71A	52.89A	39.44B	41.93B	47.99	
Index (%)	100	91.65	68.34	72.66		
CV (%)	6,60	9,00	12,93	11,75		

G-genotype (G1 Cleopatra; G2 Anuschka; G3 Presto; G4 Kuroda; G5 Omega; G6 Dita; G7 Desiree ; G8 Roko; G9 Jelly); Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% Confidence; Index represents the % ratio between the largest average value and other mean of the evaluated properties.

Deficit water supply leads to poor plant growth and reduced tuber number resulting in low yield (MILLER and MARTIN, 1985; HASSANPANAH *et al.,* 2008; ARSLANOVIĆ-LUKAČ *et al.,* 2021). The highest number of tubers per plant (12.42) was found in 2010, followed by 2013 (12.19), and lowest in 2012 (11.61). The number of tubers per plant is a characteristic of the variety, but it linearly depends on the number of stems per plant, agroecological conditions and production technology (TADESSE *et al.,* 2001; POŠTIĆ *et al.,* 2012; RYKACZEWSKA, 2015; ARSLANOVIĆ-LUKAČ *et al.,* 2021). Mean reduction in tuber number per plant in years varied in very narrow interval 6.52 (2012) to 1.85% (2013) in severe drought and slightly low favorable conditions compare to good growing conditions in 2010 (Table 2 and 4). Results indicated that soil moisture due to good distribution of rainfall in 2010 favorable for plants led to an increase of the number of tubers. Present results agree with previous studies of many authors (HAVERKORT *et al.,* 1990; LEVY, 1992; HASSANPANAH, 2010; ABDULLAH-AL-MAHMUD *et al.,* 2014; ARSLANOVIĆ-LUKAČ *et al.,* 2021).

The lowest average number of tubers per plant was determined in all varieties in 2012, as a result of a small number of stems per plant, due to severe drought and heat stress in the phase of tuber initiation in 2012 (Table 2 and 4). The results agree with previous findings of many authors (FABEIRO *et al.*, 2001; WAKWORT and CARLING, 2002; TOMASIEWICZ *et al.,* 2003; POŠTIĆ *et al.,* 2012; RYKACZEWSKA, 2015; MOMIROVIĆ *et al.,* 2016; ARSLANOVIĆ-LUKAČ *et al.,* 2021)**,** who stated that the deficit of rainfall and higher air temperatures during the stolon formation and tuber initiation reduces the number of tubers per plant. The largest number of tubers per plant in all varieties studied was achieved in the years when the largest number of stems per plant was obtained, and this coincides with results achieved by many authors (ZEBARTH *et al.,* 2006; KNOWLES and KNOWLES, 2006; BUSSAN *et al.,* 2007; POŠTIĆ *et al.,* 2012; MOMIROVIĆ *et al.,* 2016). These authors found that the number of tubers per plant varied according to changes in the number of stems per plant. Results indicated that the number of tubers per plant adversely affected by deficit water and high air temperature.

The Number Tubers per Stem

Main effects of year and genotype and their interaction on number of tubers per stem varied significantly (Table 4).The average number of tubers per stem of nine varieties in studied years varied in a very narrow interval ranging from 2.92 (2011) to 3.04 (2013). The highest average number of tubers per stem was found in the variety Roko (3.31), followed by Dita (3.05), while the lowest (2.70) was found in Presto (Table 6). The number of tubers per stem might be due to stems number per plant (Table 5). The number of tubers per stem and plant is determined by genotype, but linearly dependent on the number of stems per plant, weather conditions and technology cultivation (TADESSE *et al.,* 2001; POŠTIĆ *et al.,* 2012).

Mean Tuber Weight (g)

In the study presented highly significant effect of year and cultivar and their interaction on the tuber size were found (Table 4). The significance of the year × genotype interaction suggests different mean tuber weight performance of cultivars as dependent upon weather conditions: mean tuber weight in the 2010 years was significantly higher than that in 2011, 2012 and 2013 for varieties Omega, Dita and Roko (Table 4 and 6). The high temperature and drought stress during the growing season had a negative effect on the mean tuber weight of tested cultivars (Table 2 and 6). Analyzing the results of the mean tuber weight in the four-year period, the highest mean tuber weight was achieved in 2010 (57.71 g), then in 2011 (52.89 g), and lowest in 2012 (39.44 g). As a shown in table 6 highest variability of mean tuber weight depending on the weather conditions was determined in 2012 (CV = 12.93%) and the lowest in 2010 (CV = 6.60%). The average reduction in mean tuber weight in years varied in a wide range 31.66 (2012) to 8.35% (2011) in severe drought and slightly weaker favorable conditions compare to good growing conditions in 2010 (Table 2 and 6). The deficit in water supply leads to poor plant growth and reduced tuber size, resulting in low yield (MILLER and MARTIN, 1985; HASSANPANAH *et al.,* 2008; ÁVILA-VALDES *et al.,* 2020; ARSLANOVIĆ-LUKAČ *et al.,* 2021). In potatoes, the weight of tubers has an important role in yield. In the present study, maximum mean tuber weight was recorded for Kuroda (53.00 g), as a result of the genetic potential of the variety to form a medium number of larger tubers. However, Dita gave the lowest average tuber weight (43.35 g) Table 6. The variation might be attributed to genetic variation among potato varieties and environmental factors on tuber bulking. The duration and rate of tuber bulking vary among varieties and depend on environmental conditions (LEVY, 2007). The research results demonstrated high significance effect year and cultivar on the tuber size. BUSSAN *et al.* (2007) stated that the tubers were smaller in the year when a larger number of stems per plant were and this is not in accordance with our results. Potato tuber size is an important attribute of potato for consumers and retailers.

Yield of Small Tubers (Unmarketable Yield) (t ha^{-1})

In the results of the yield of small tubers in the four-year period, we noticed that the highest average unmarketable yield was achieved in 2010 (6.72 t ha^{-1}), then in 2011 (6.53 t ha^{-1}), and lowest in 2012 (5.30 t ha^{-1}) Table 7. In the present study a significant effect of year and genotype and their interaction on the tuber size were found (Table 4). The average reduction in yield of small tubers varied in a wide range 21.13 (2012) to 2.83% (2011) in severe drought and slightly less favorable conditions compare to favorable growing conditions in 2010 (Table 2 and 7). The share of the yield of small tubers in the total yield was highest in 2012 (24.65%), followed by 2013 (22.87%), then 2011 (21.64%) while the lowest share was recorded in 2010 (19.72%). The highest share of unmarketable yield in total yield in 2012 was due to more unfavorable conditions (air temperature higher than the optimal and low amount of precipitation especially during June, July and August) for potato development (Table 2 and 7). The observed maximum yield of small size tubers might be due to the presence of more tubers as well as, varietal characteristics and adaptability or determined impact of other growth attributes (KUMAR *et al.,* 2007). Middle late cultivars had the highest yield of small tubers (6.99 t ha^{-1}) or 21.3% larger compared to (5.5-5.6 t ha^{-1}) the early and middle early cultivars (Table 7). Variation among genotypes of yield small tubers could be attributed to their genetic make-up which influenced tuber size. Desiree gave the highest yield of small tubers (8.13 t ha^{-1}) followed by Jelly (6.76 t ha^{-1}) which might be due to the higher number of tubers produced by these varieties. The lowest yield of small tubers (5.17 t ha^{-1}) was recorded for variety Cleopatra and it is statistically similar with Dita (5.33 t ha^{-1}) Table 7. The result in the present work is in line with the findings of HAILE *et al.* (2015), who reported the effects of the genotype that significantly influence unmarketable tuber yield.

Table 7. Effect of year and genotype on yield of small tubers (t ha^{-1}) and marketable yield (t ha^{-1}) in 2010, 2011, 2012 and 2013 years

	Yield small tubers (t ha^{-1})				Average Variety	Index (%) in total yield	Average Maturity
Year	2010	2011	2012	2013			
G_1	4.85cA	5.53cA	5.33bA	4.98bA	5.17c	17.16	
G_2	5,68bcA	6.38bcA	5.48abA	6.05abA	5.90b	20.10	5.53
G_3	6.08bcA	6.10bcA	4.83bA	5.08bA	5.52bc	21.00	
G_4	7.0bA	5.95bcAB	5.20bB	5.48bB	5.91b	21.74	
G_5	6.20bcA	5.63cA	4.88bA	4.85bA	5.39bc	21.07	5.54
G_6	6.15bcA	5.58cAB	4.38bB	5.20bAB	5,33c	22.04	
G_7	9.05aA	9.10aA	6.95aC	7.40aBC	8.13a	26.31	
G_8	7.0bA	7.13bcA	4.98bB	5.18bB	6.07b	23.64	6.99
G_9	8.50aA	7.33bAB	5.68abB	5.53bB	6.76b	24.07	
Average	6.72A	6.53AB	5.30B	5.53B	6.02	21.91	
Index (%)	100	97.17	78.87	82.29			
CV (%)	19,91	17,86	13,76	14,26			
	Marketable yield (t ha^{-1})						
G_1	29.2abA	27.4aA	20.1aC	23.0aB	24.93a	82.84	
G_2	28.0abcA	25.6abB	18.8abD	21.5aC	23.48a	79.90	23.06
G_3	25.6cdA	23.8bcB	15.0deD	18.7bC	20,78bc	79.00	
G_4	27.1abcA	23.1cdB	16.4cdD	18.5bC	21.28b	78.26	
G_5	27.4abcA	21.1deB	14.9deD	17.3bC	20.18bc	78.93	20.10
G_6	23.9dA	19.6eB	13.8eC	18.0bB	18.83c	77.96	
G_7	29.7aA	25.7abB	17.8bcC	18.5bC	22.93ab	73.69	
G_8	26.8bcA	22.7cdB	13.9eC	15.0cC	19.60c	76.36	21.29
G_9	29.0abA	23.7bcB	15.1deD	17.5bC	21.33b	75.93	
Average	27.41A	23.63B	16.20D	18.67C	21.48	78.09	
Index (%)	100	86.21	59.10	68.11			
CV (%)	6,75	10,17	13,80	12,56			

G-genotype (G1 Cleopatra; G2 Anuschka; G3 Presto; G4 Kuroda; G5 Omega; G6 Dita; G7 Desiree; G8 Roko; G9 Jelly); Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% Confidence; Index represents the % ratio between the largest average value and other mean of the evaluated properties.

Marketable Yield (t ha^{-1})

Analysing the results of the marketable yields in the four-year period, the highest marketable yields were achieved in 2010 (27.41 t ha^{-1}), then in 2011 (23.63 t ha^{-1}) followed 2013 (18.67 t ha^{-1}), and lowest in 2012 (16.20 t ha^{-1}). Differences in marketable yields between the years were statistically very significant. The highest variability of marketable yield depending on the year was determined in 2012 (CV=13.80%) and the lowest in 2010 (CV=6.75%) (Table 7).

Table 8. Effect of year and genotype on total yield tubers (t ha⁻¹) and dry matter content (%) in 2010, 2011, 2012 and 2013 years

	Total yield tubers (t ha⁻¹)				Average	
Year	2010	2011	2012	2013	Variety	Maturity
G_1	34.1aA	33.0abA	25.4aC	28.0aB	30.13a	
G_2	33.7aA	31.9bcA	24.3aC	27.5aB	29.35a	28.59
G_3	31.6aA	29.9cdA	19.9bcdC	23.7bcB	26.28b	
G_4	34.1aA	29.1deB	21.6bD	23.9bcC	27.18b	
G_5	33.6aA	26.7efB	19.8bcdD	22.2cdC	25.58bc	25.65
G_6	30.1aA	25.2fB	18,2dC	23.2cB	24.18c	
G_7	38.2aA	34.8aB	24.7aC	25.9abC	30.90a	
G_8	33.8aA	29.8cdB	18.9cdC	20.2dC	25.68bc	28.22
G_9	37.5aA	31.1bcdB	20.7bcC	23.0cC	28.08ab	
Average	34.08A	30.17B	21.50D	24.18C	27.48	
Index (%)	100	88,52	63,08	80,15		
CV (%)	7,42	9,90	12,42	10,44		
	Tuber dry matter content (%)					
G_1	20.3	19.5	18.2	18.6	19.15	
G_2	20.7	20.6	20.0	20.4	20.43	19.88
G_3	20.3	20.5	19.6	19.8	20.05	
G_4	20.8	21.1	20.0	20.5	20,60	
G_5	20.1	20.5	19.3	19,8	19.93	20.12
G_6	20.0	20.3	19.4	19.6	19.83	
G_7	20.4	20,9	19.1	19.7	20.03	
G_8	19.6	20.2	19.3	19.8	19.73	20.25
G_9	21.5	21.8	20.0	20.7	21.00	
Average	20.41	20.60	19.43	19.88	20.08	
CV (%)	2,67	3,10	2,97	3,13		

G-genotype (G1 Cleopatra; G2 Anuschka; G3 Presto; G4 Kuroda; G5 Omega; G6 Dita; G7 Desiree; G8 Roko; G9 Jelly); Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% Confidence; Index represents the % ratio between the largest average value and other mean of the evaluated properties.

The analysis of the year × genotype interaction reveals significant differences between the marketable yield of cultivars as dependent upon weather conditions: marketable yield in 2010 was significantly higher compared to 2011, 2012 and 2013 at all cultivars exception variety Cleopatra (Table 4 and 7).The heat stress and drought during the growing season average reduced the marketable yield of nine tested potato cultivars from 40.90 (2012) to 13.79% (2011) in severe drought and slightly low favorable conditions compare to good growing conditions in

2010 (Table 2 and 7). Heat stress due to increased temperature effects plant growth and development and lead to the drastic reduction in economic yield (WAHID *et al.,* 2017; ARSLANOVIĆ-LUKAČ *et al.,* 2021). The best results of average marketable yield (23.06 t ha^{-1}) were obtained in the early varieties, comparing to the middle late varieties (21.29 t ha^{-1}), and lowest (20.10 t ha^{-1}) was recorded in middle early varieties (Table 7). More favorable weather conditions in 2010 and 2011, compared to 2012 and 2013 resulted in significantly higher marketable yields (Table 2 and 7), which coincides with the results of other research (LAHLOU *et al.,* 2003; WAHID *et al.,* 2017; MOMIROVIĆ *et al.,* 2010; POŠTIĆ *et al.,* 2012; MOMIROVIĆ *et al.,* 2016; ARSLANOVIĆ-LUKAČ *et al.,* 2021). The research results showed that in the agro-ecological conditions of the West part of Serbia highest marketable yields (24.93 t ha^{-1}) had early variety Cleopatra, followed by Anuschka (23.48 t ha^{-1}) and middle late Desiree (22.93 t ha^{-1}) Table 7. The lowest marketable yield (18.83 t ha^{-1}) was recorded for variety Dita. From the aspect of decrease in marketable yield, the most tolerant varieties among all tested were Cleopatra and Anuschka, due to their increased tolerance to drought. Some varieties due to the ability of the fast growth, good ground cover, the early formation of a forming average number of tubers (Desiree) easier tolerate critical growing phases that reduces the adverse environmental effect (POŠTIĆ *et al.,* 2012; MOMIROVIĆ *et al.,* 2016; ARSLANOVIĆ-LUKAČ *et al.,* 2021). This conclusion was confirmed in our research as well. It is possible that variety Cleopatra inherited good resistance to dry conditions from one of the parents that are shared with variety Desiree (Table 3), which is moderately tolerant to the heat drought stress during the growing season.

Total Yield (t ha^{-1})

The high temperature and drought during the growing season had a negative effect on the total yield of tested cultivars. The effect on the plants was strongest when the heat and drought occurred in the second decade of June and lasted during July and August. Analysis of the results of the potato yields in the four-year period, we noticed that the highest yields were achieved in 2010 (34.08 t ha^{-1}), then in 2011 (30.17 t ha^{-1}), and lowest in 2012 (21.50 t ha^{-1}). Differences in total yields between the years were statistically significant. It was discerned that in less favorable conditions (Table 2) varieties exhibited higher variability per years 2012 (CV=12.42%), 2013 (CV=10.44%), 2011 (CV=9.90%) and 2010 (CV=7.42%) Table 8. The significance of the year × genotype interaction suggests different total yield performance of cultivars as dependent upon weather conditions: total yield in 2010 was significantly higher than that in 2011, 2012 and 2013 at all middle early and early cultivars (Table 4 and 8). The heat stress and drought during the growing season average reduced the total yield of nine tested potato cultivars from 36.92% (2012) to 11.48% (2011) in severe drought and slightly less favorable conditions compare to good growing conditions in 2010 (Table 2 and 8). Present results agree with previous studies, that limited soil moisture on potato decreases yield by 24-33% (KARAFILLIDIS *et al.,* 1996) and 11-53% (LAHLOU *et al.,* 2003) respectively. Bearing in mind that the research was conducted in the region of Western Serbia, where the winters are cold and the summers are long, dry and hot, the achieved yields can be considered satisfactory. The more favorable air temperature and sufficient precipitation in 2010 and 2011 resulted in a longer growing season of potatoes, and therefore higher yields. To achieve high yields it is necessary to provide well developed above ground mass and its activity in a longer period (JOVOVIĆ *et al.,* 2012). Severe drought stress during June, July and August in 2012 and July and August in 2013, followed by higher air temperatures, reduced development of potato plants and lead to the shorter growing season of potato crops. As a consequence, the yield of potatoes in 2012 and 2013 was significantly lower than in 2010 and 2011. The best of result average total yield was determined in early varieties (28.59 t ha^{-1}), then in middle late (28.22 t ha^{-1}), while the lowest was found in middle early varieties (25.65 t ha^{-1}) (Table 8). These results are in accordance with the results gained by POŠTIĆ (2013) and MOMIROVIĆ *et al.,* (2016) who found out that early varieties can achieved higher yields, compared to later varieties, because of early tuberisation and faster tuber bulking. The results are consistent with previous results whereby production conditions significantly affects total yield of potatoes (TOMASIEWICZ *et al.,* 2003; MOMIROVIĆ *et al.,* 2010; POŠTIĆ *et al.,* 2012; RYKACZEWSKA, 2013a; FLIS *et al.,* 2014; ARSLANOVIĆ-LUKAČ *et al.,* 2021; NASIR and TOTH, 2022). High air temperature during the phase of tuber bulking significantly limits the development of the plants and potato yield (POŠTIĆ, 2013). The highest total yield (Table 8) was determined in the Desiree (30.90 t ha^{-1}), followed by Cleopatra (30.13 t ha^{-1}), while the lowest was measured in Dita (24.18 t ha^{-1}). Among the most tolerant from the viewpoint of decrease in yield were Desiree, Cleopatra, Anuschka and Jelly. The results obtained were normal differences between varieties, which are probably the result of their ability to produced higher yield in a given environment. Biochemical studies of the relationship between thermotolerance and heat-shock protein expression in potato, conducted by AHN *et al.* (2004) indicate a lack of high tolerance of cultivar Desiree to high temperature during the growing season. Likewise, many authors (POŠTIĆ, 2013; HANCOCK *et al.,* 2014; MOMIROVIĆ *et al.,* 2016; ARSLANOVIĆ-LUKAČ *et al.,* 2021) used a variety of Desiree in their research as a cultivar with moderate resistance to heat stress. RYKACZEWSKA *et al.* (2015) stated that Desiree was characterized by the relatively high tolerance of the aboveground part of plants to high temperature, but also a tendency to secondary tuberization and a decrease in the size of tubers in the total yield. Recent studies show that the application of PGP-rhizobacteria stimulates better root development, better seed germination and higher yield (BRUTTI *et al.,* 2015). TRDAN *et al.* (2019) indicate that increased resilience to drought in potato tubers treated with a mixture of bacteria prior to planting, enabled a higher yield (17-31%) of potato in the dry year. This was found in all three varieties (TRDAN *et al.,* 2019).

Dry Matter Content (%)

Dry matter content (DMC) of nine cultivars ranged from 19.6-21.5% in 2010, 19.5-21.8% in 2011, 18.2-20.0% in 2012 and 18.6-20.7% 2013 (Table 8). As expected, the lowest DMC in tubers was found in early varieties, and DMC grew by increasing the length of the vegetation period. Jelly (21.00%), Kuroda (20.60%) and Anuschka (20.43%) had similarly high tuber DMC, while Desiree (19.73%) and Cleopatra (19.15%) had comparatively lower DMC. Tuber dry matter content is a varietal characteristic and it depends on the conditions in the growing season, and its lower in early variety compared to late cultivar. These results agree with other studies reporting decreased tuber DMC under drought (SCHITTENHELMA *et al.,* 2006; SANCHEZ-RODRIGUEZ *et al.,* 2010; MUTHONI and SHIMELIS, 2020; ARSLANOVIĆ-LUKAČ *et al.,* 2021). The highest mean tuber weight (Table 6) was determined in the early cultivars and mean tuber weight decreases with the duration of the vegetation period, while the tuber DMC (Table 8) had the opposite tendency.

From the conducted studies it appears that the DMC of tubers was different by years (Table 8). The lowest DMC was obtained in the dry growing season of 2012, in which the precipitation sum was 236.7 mm, being lower than the mean sum from the multi-year period by 86.4 mm. However, a higher DMC was recorded in the growing seasons of 2011 and 2010, in which atmospheric conditions were more favorable and precipitation distribution in June, July and August for the growth and development of potato plants in comparison with the other studied years. The results are in accordance with the research of GUGALA and ZARZECKA (2010), RYMUZA *et al.* (2015) who proved that weather conditions in individual research years, especially the amount of precipitation, were the factor differentiating the content of dry matter and starch in potato tubers. A lower accumulation of DMC in tubers was observed in 2012 with the lowest amount of precipitation than in other research years.

Tuber Physiological Defects (%)

High temperature occurring and drought stress in subsequent stages of plant development had a adverse effect on tubers defects and tubers sprouting in the soil before harvest (Table 2 and 9). The reaction of cultivars was differentiated. Results of the experiment obtained by RYKACZEWSKA (2013b) are similar. Cultivars Cleopatra, Kuroda, Omega and Jelly have demonstrated good resistance to physiological deformations of tubers (Table 9).

Table 9. Physiological deformations (%) of tubers of individual cultivars on high temperature and drought during the growing season

Cultivar	Year				Average
	2010	2011	2012	2013	
Cleopatra	0	3	7	5	3.75
Anuschka	1	5	17	10	8.25
Presto	2	6	23	12	10.50
Kuroda	1	2	9	3	3.75
Omega	0	1	11	4	4.0
Dita	3	9	30	19	15.25
Desiree	4	11	39	25	19.75
Roko	0	3	13	5	5.25
Jelly	0	1	9	3	3.25
Average	1,22	4.55	15.11	11.11	7.99
CV (%)	121,20	77,69	62,60	82,09	

Cultivars Desiree, Dita, Presto and Anuschka have shown susceptibility to second growth, especially in years 2012 and 2013 with low amount precipitation and high air temperature, particularly in July and August (Table 2). Environmental factors (heat and drought stress) promoting the secondary growth of tubers have been known for a long time (LUGT *et al., 1964*). All these deformed tubers are not suitable for the fresh market and also not adequate for the processing industry (POŠTIĆ *et al.,* 2017). ZAAG (1992) pointed that high temperature and drought break the dormancy of tubers resulting in sprouting and second growth. In the case of tubers' deformation the largest share of these tubers in the final yield occurred when the highest air temperature followed also a low amount of precipitation in 2012 (Table 2 and 9).

The results of an experiment conducted by BODLAENDER *et al.* (1964) also clearly show that high temperatures induce second-growth in potato tubers. In the case of sprouting tubers in the soil before harvest, the response of plants to high temperature and drought was also dependent on the time of occurrence, but the biggest negative impact had a when high-temperature stress and deficit rainfall was in the during of July and August (Table 2).

The hierarchical cluster analysis (Figure 1) clearly shows three groups (clusters) of genotypes that differed on the basis of the similarity of morphological and productive traits. The genotypes were very good clustered according to their analysed traits, the early maturity varieties Cleopatra, Anuschka clearly distinguishes from remaining in the first cluster, while Presto, Omega, Roko, Jelly, Dita and Desiree distinguishable in the second cluster. In the third cluster, the genotype Kuroda has unrelated traits with other genotypes.

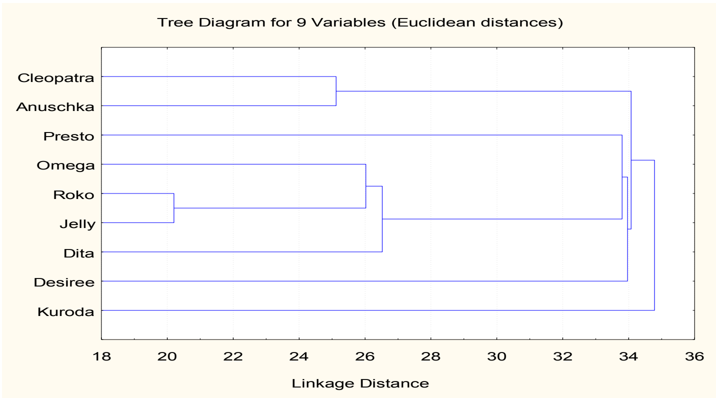

Figure 1. Dendrograms obtained from the hierarchical cluster analysis six morphological and productive traits of growth of potato genotypes in Western Serbia

On the basis of correlation analysis and gained correlation coefficients (Table 10 and 11) very high ($p \leq 0.01$ to $p \leq 0.001$) dependences are noticed between mean tuber weight, marketable and total yield in all genotypes. Further, yield small tubers correlated ($p \leq 0.05$ to $p \leq 0.001$) with marketable and total yield in all genotypes with exceptions cultivars Cleopatra and Anuschka. Also, the mean tuber weight correlated ($p \leq 0.05$ to $p \leq 0.001$) with yield small tubers in all genotypes with exceptions cultivars Cleopatra and Anuschka. This can be explained due to the ability of the fast growth, good ground cover, the early formation of a medium number of tubers (Cleopatra and Anuschka) easier tolerate critical growing phases that reduce the adverse environmental effect. The number of tubers per plant significantly correlated ($p \leq 0.05$) with marketable and total yield only at cultivars Omega and Dita.

Table 10. The correlation coefficients (r) between the investigated traits

Variety	Traits	Total yield	Yield small tubers	Mean tuber weight	No. tubers per plant	No. tubers per stem	Stem number per plant
	Market. yield	0.997***	-0.227	0.894*	0.874	0.667	0.833
	Total yield	-	-0.152	0.926*	0.835	0.611	0.832
	Yield sm. tub.		-	0.222	-0.665	-0.850	-0.140
Cleopatra	Mean tu. weight			-	0.567	0.301	0.719
	No. tubers				-	0.914*	0.742
	No. tu. per stem					-	0.914*
	St. No. per plant						-
	Market. yield	0.997***	0.343	0.998***	0.770	-0.467	0.949*
	Total yield	-	0.414	0.999***	0.816	-0.399	0.925*
	Yield sm. tub.		-	0.386	0.863	0.655	0.058
Anuschka	Mean tu. weight			-	0.798	0.429	0.938*
	No. tubers				-	0.193	0.549
	No. tu. per stem					-	0.712
	St. No. per plant						-
	Market. yield	0.999***	0.972**	0.977**	-0.544	-0.901*	0.961**
	Total yield	-	0.980**	0.984**	-0.570	0.912*	0.964**
	Yield sm. tub.		-	0.994***	-0.681	-0.941*	0.951*
Presto	Mean tu. weight			-	-0.703	-0.963**	0.977**
	No. tubers				-	0.847	-0.707
	No. tu. per stem					-	-0.973**
	St. No. per plant						-
	Market. yield	0.999***	0.974**	0.980**	0.419	0.543	-0.156
	Total yield	-	0.980**	0.978**	0.427	0.566	-0.173
	Yield sm. tub.		-	0.930*	0.519	0.710	-0.235
Kuroda	Mean tu. weight			-	0.234	0.472	-0.256
	No. tubers				-	0.468	0.448
	No. tu. per stem					-	-0.579
	St. No. per plant						-
	Market. yield	0.999***	0.971**	0.993***	0.883*	0.446	0.948*
	Total yield	-	0.976**	0.994***	0.878*	0.439	0.947*
	Yield sm. tub.		-	0.984**	0.805	0.364	0.902*
Omega	Mean tu. weight			-	0.825	0.351	0.959**
	No. tubers				-	0.809	0.728
	No. tu. per stem					-	0.187
	St. No. per plant						-

Pearson correlation coefficient: *** P≤ 0.001, ** P≤ 0.01, * P ≤ 0.05, respectively

The number of tubers per stem correlated (p≤0.05 to p≤0.01) with the number tubers per plant only at cultivars Cleopatra and Desiree. Cultivars Cleopatra and Desiree due to the ability of the fast growth and good ground cover formed the highest stems number per plant and number tubers per plant (Table 5) and as a consequence of that these varieties formed the smallest number tubers per stem (Table 6). The number stem per plant significant correlated ($p \leq 0.05$ to $p \leq 0.01$) with marketable and total yield only at cultivars Anuschka, Presto, Omega, Desiree and Roko.

Table 11. The correlation coefficients (r) between the investigated traits

Variety	Traits	Total yield	Yield small tubers	Mean tuber weight	No. tubers per plant	No. tubers per stem	Stem number per plant
Dita	Market. yield	0.999***	0.993***	0.996***	0.930*	0.022	0.603
	Total yield	-	0.994***	0.997***	0.926*	0.007	0.615
	Yield sm. tub.		-	0.999***	0.885*	-0.083	0.677
	Mean tu. weight			-	0.897*	-0.042	0.646
	No. tubers				-	0.252	0.411
	No. tu. per stem					-	0.775
	St. No. per plant						-
Desiree	Market. yield	0.996***	0.947*	0.998***	0.858	0.725	0.968**
	Total yield	-	0.969**	0.995***	0.857	0.731	0.953*
	Yield sm. tub.		-	0.948*	0.833	0.736	0.873
	Mean tu. weight			-	0.825	0.683	0.952*
	No. tubers				-	0.974**	0.927*
	No. tu. per stem					-	0.819
	St. No. per plant						-
Roko	Market. yield	0.998***	0.949*	0.995***	0.655	-0.253	0.910*
	Total yield	-	0.963**	0.997***	0.652	-0.260	0.909*
	Yield sm. tub.		-	0.965**	0.611	-0.290	0.865~~ns~~
	Mean tu. weight			-	0.594	-0.332	0.876~~ns~~
	No. tubers				-	0.559	0.908*
	No. tu. per stem					-	0.162~~ns~~
	St. No. per plant						-
Jelly	Market. yield	0.999***	0.979**	0.993***	-0.29	-0.859	0.296
	Total yield	-	0.986**	0.995***	-0.32	-0.856	0.284
	Yield sm. tub.		-	0,985**	-0.46	-0.842	0.254
	Mean tu. weight			-	-0.31	-0.803	0.192
	No. tubers				-	0.430	-0.254
	No. tu. per stem					-	-0.734
	St. No. per plant						-

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

No significance (p>0.05) was determined for varieties Cleopatra, Kuroda and Jelly in the correlation between stems number per plant and number tuber per plant, between stems number per plant and number tubers per stem and between number tubers per plant and number tubers per stem.

On the basis of the mentioned relationships it can be concluded that three productivity traits mean 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).

CONCLUSION

Our studies on the impact of year and genotype on the productivity of potato confirm the view that its yield and quality is greatly reduced at unfavorable conditions. It was demonstrated here, however, that potato cultivars' response to deficit water and high air temperature during the growing season is dependent on the ability to tolerate abiotic stress. The longer it lasts, the more negative its impact on the yield and quality of potatoes. Here we show that the combined heat and drought stress which occurred in the second decade of June and lasted during July and August affects potato plants during the tuber bulking may reduce the total yield of potato cultivars by 36.9 %. The results obtained in this study indicate that among the tested cultivars Cleopatra was the most tolerant to heat stress and drought acting on the plants during the growing season. This cultivar was characterized by a relatively small decrease in the marketable and total yield in relation to other variety, by a low level of tuber deformations and lack of tendency for sprouting in the soil before harvest. A similar reaction was seen in cultivar Anuschka. Our research shows that the total yield is not the only indicator of potato tolerance to high air temperatures and drought stress during the growing season, but the assessment should also take into account the occurrence of secondary tuberization and physiological defects of tubers. In this study the moderate tolerance of cultivar Desiree to the heat and drought stress during the growing season has been confirmed. Likewise, this cultivar has characterized a tendency to secondary tuberization and a decrease in the size of tubers and an increase in the share of small tuber yields in the total yield. Our study has shown that heat and drought tolerant potato cultivars could be used to mitigate the effects of global warming in Serbia and wider Western Balkans regions.

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UTICAJ GODINE I GENOTIPA NA PRODUKTIVNOST I KVALITET KROMPIRA

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Izvod

Krompir (*Solanum tuberosum* L.) karakteriše se specifičnim zahtevima prema temperaturi vazduha, a najbolje se razvija na temperaturama oko 20°C. Visoke temperature vazduha tokom vegetacionog perioda uzrokuju niz promena u biljkama krompira, koje utiču na njegov razvoj i mogu dovesti do drastičnog smanjenja prinosa krtola. Suša i toplotni stres su dve različite vrste abiotskog stresa, koje se u prirodnim uslovima javljaju istovremeno ili odvojeno i predstavljaju veliki problem u proizvodnji krompira naročito uslovima prirodnog vodnog režima. Cilj ovog istraživanja bio je da se utvrdi produktivnost devet sorti krompira u agroekološkim uslovima zapadne Srbije i da se pronađu genotipovi koji će ostvariti zadovoljavajuće i visoke prinose. Poljski ogled izveden je sa sledećim sortama: Cleopatra, Anuschka, Presto, Kuroda, Omega, Dita, Desiree, Roko i Jelly. Uticaj godine i genotipa na varijabilnost krompira ispitivani su tokom četvorogodišnjeg perioda (2010-2013). Rezultati našeg rada potvrdili su da se tržišni i ukupni prinos krompira znatno smanjuje usled temperature vazduha viših od optimalnih i pri deficit padavina tokom vegetacionog perioda. Dobijeni rezultati ukazuju da produktivnost ispitivanih sorti u uslovima toplotnom stresa i suše tokom vegetacionog perioda zavisi od dužine trajanja negativnog uticaja i feno faze razvoja krompira. Što je ranija pojava toplotnog stresa i suše u toku vegetacionog perioda to je negativniji uticaj na rast i ravoj biljaka i produktivne osobine krompira. Rezultati iz ovih istraživanja ukazuju da je među ispitivanim sortama, sorta Cleopatra bila najtolerantnija na toplotni stres i sušu, koji su delovali tokom vegetacionog perioda. Ukupni prinos krtola nije jedini pokazatelj tolerancije krompira prema abiotskom stersu tokom vegetacionog perioda, već bi procena takođe trebala da uzme u obzir pojavu sekundarne tuberizacije krtola i deformisanih krtola. Kod sorte Cleopatra konstatovan najveći udeo (82%) tržišnih krtola u ukupnom prinosu i da poseduje najveću predispoziciju za postizanje najviših prinosa. Naš poljski ogled je pokazao da tolerantne sorte krompira prema toplotnom stersu i suši se mogu koristiti za ublažavanje efekata globalnog zagrevanja u Srbiji i širem regionu zapadnog Balkana.

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