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YIELDING OF DIFFERENT MATURITY GROUPS POTATOES AT THREE SITES AND TUBER QUALITY DURING STORAGE*

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Summary: *Two-year field trials (2001-2002) were conducted with aim to investigate the effect of growing site and maturity group of ten potato cultivars on yielding and changing of tuber quality during long-term storage. The biggest number of tubers per plant and highest mean tuber weight were obtained in Čačak, what gave the highest yields in both seasons; the lowest values were obtained in Guča. Favourable soil characteristics had more important role than weather conditions on potato field performance. Early cultivars gave the smallest number of tubers per plant and highest mean tuber weight, while opposite to this was recorded in mid-late to late cultivars (ML-L). The share of tubers >55 mm was consistently high in early cultivars. ML-L maturity group gave the highest yields at all sites and the highest initial tubers dry matter (DM), >20% in 2001 and >21% in 2002, while it was <20% in early cultivars overall experiment. Constant increase in DM content and decrease in starch content in tubers DM was recorded after two-month and seven-month storage under conditions with ventilation system without control of humidity. The effect of site on tuber DM was significant at mid-early to mid-late (ME-ML) and ML-L in 2002, when it was the highest in tubers originated from Sombre; there was no effect on starch content. Presented study showed that high yields can be achieved by growing potato cultivars of different maturity groups and Čačak has been shown to be the site with good agro ecological conditions; ME-ML (with exemption of cv. Condor) and ML-L groups gave the highest yields of tubers with DM content sufficient for processing for French fry and chips.*

Key words: *potato cultivars, maturity groups, storage, dry matter, starch.*

INTRODUCTION

Storage capacities for both seed and ware potato are limited in Serbia, still less than 10% of total potato production (Broćić and Stefanović 2012). In comparison with developed countries, storage losses for both ware and seed potato are much higher due to lack of control of air temperature and humidity. Storage conditions should

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provide good quality potato suitable for processing. Various properties of tubers change during storage, causing losses (for review see Wustman and Struik, 2007). During storage starch is converted into sugars and temperatures below 4°C have been shown to enhance this process. Also, losses are affected by duration of storage.

In Serbia, large number of potato cultivars of different origin and quality are grown in regions differing in agroecological conditions. Potato breeding is very intensive and continuous, so newer cultivars are present in Serbia, too. Due to limited and inadequate storage capacities there is lack of results showing the effect of storage on the post harvest quality of potato grown in Serbia. The origin of tubers was mainly investigated as a potential source of biological viability in seed potato Poštić et al. (2012), while Milošević et al. (2012) indicated that production site might have significant impact on seed potato quality.

The aim of presented study was to investigate productivity of potato cultivars of different maturity groups grown at three sites, as well as changing in tubers dry matter (DM) and starch content during 7-month storage.

MATERIAL AND METHODS

Ten potato cultivars of different maturity groups: early (Jaerla, Cleopatra); mid-early to mid-late – ME-ML (Frisia, Red Star, Kondor); mid-late to late – ML-L (Bintje, Desiree, Van Gogh, Asterix, Agria) were grown at three experimental sites in Serbia: Sombor (85 m asl), Čačak (240 m asl) and Guča (370 m asl) in 2001 and 2002. Crops were grown on loam soil (chernozem) in Sombor, sandy loam (alluvium) in Čačak and clay loam (pseudoglay) in Guča. Seed material was pre-sprouted; planting dates were April 10th at Sombor and Čačak and April 20th at Guča in both seasons. Planting pattern was 70 x 35 cm and size of the plots was15 m^2, with two border rows were. Experiment was established as randomized completely block design with three replications. There was no irrigation and basic soil properties at 0-20 cm depth were: in Sombor (pH_{KCl}–7.5, P_2O_5– 23.5 mg 100 g^{-1}, K_2O–27.9 mg 100 g^{-1}, $CaCO_3$–7.6%, organic matter 3.4%, total –0.25%); in Čačak (pH_{KCl}– 5.9, P_2O_5–30.2 mg 100 g^{-1}, K_2O –19.6mg 100 g^{-1}, $CaCO_3$–1.5%, organic matter 2.9%, total N–0.2%); in Guča (pH_{KCl}– 4.3, P_2O_5–3.5 mg 100 g^{-1}, K_2O – 23.7mg 100 g^{-1}, $CaCO_3$–0.1%, organic matter 2.0%, total N – 0.3%). All plots were fertilized with NPK mineral fertilizer (15:15:15): 150 kg ha^{-1} N, 150 kg ha^{-1} $P_2O_5$and 150 kg ha^{-1} K_2O. In Sombor and Čačak early and ME-ML cultivars were harvested during the first week of September and at third week of September in Guča in both seasons. ML-L cultivars were harvested 7-10 days later with aim their tubers skin to be fully developed. Number of tubers, mean tuber weight per plant and tuber size were determined at the harvest using ten plants.

Data on weather conditions recorded at three sites during two potato growing seasons are given in Table 1. In 2001, at Sombor and Čačak rainfall sum was lower in comparison to 30-year average, due to lower rainfall recorded in May, June and September. In 2002, in Sombor due to high rainfall in July (108 mm) higher rainfall sum was recorded in comparison 30-year average. In Guča amount of rainfall recorded in both seasons was similar but still lower than 30-year average. In 2002, slightly higher temperatures were recorded at all sites in June, July and August and the rest of data for the growing season was consistent with long-term data.

After harvest the tubers originating from the three sites were stored in the facility situated in Guča. The store was equipped with ventilation system with air recilculated through floor, without control of humidity. Air temperature was maintained at 3-4^{o}C. The samples for dry matter (DM) content in tubers and starch content in DM determination were made by mixing tubers of different sizes. Measurements were determined at harvest, two-month (2-m) and seven-month (7-m) after storage, with three replications. Tuber DM content was determined by drying tubers at 105^{o}C. Starch in tuber DM was determined by Ewers' polarimetric method based on the partial HCl hydrolysis of starch, followed by measurement of the optical rotation of the gelatinized starch (specific rotation factor of 185.7^o) (Thybo et al., 2006).

One-way ANOVA was performed to evaluate the effect of cultivar within each site and the effect of site within each cultivar. Means were compared by LSD test ($p<0.05$). Costat software package was used for processing obtained data.

Table 1. Weather conditions during potato growing season in Sombor (S.), Čačak (Č.) and Guča (G.) for 2001 - 2002 and 30 years mean data

Month	Monthly sum of rainfall (mm)									Mean monthly temperature (°C)								
	S.	Č.	G.	S.	Č.	G.	S.	Č.	G.	S.	Č.	G.	S.	Č.	G.	S.	Č.	G.
	2001			2002			30 years mean			2001			2002			30 years mean		
IV	55	44	108	45	23	32	45	58	77	7.7	7.2	5.7	12.6	13.0	11.2	11.6	10.2	9.5
V	24	42	60	58	50	96	60	75	60	17.2	16.2	16.0	16.0	14.2	14.9	17.1	15.2	14.0
VI	81	37	27	69	110	51	82	88	136	20.4	19.4	19.0	19.0	20.1	19.5	20.2	18.3	18.5
VII	79	50	98	106	39	50	66	76	102	20.2	19.6	20.5	20.5	21.2	21.1	21.9	20.0	20.2
VIII	45	98	93	74	11	42	53	60	56	20.6	19.6	20.5	20.5	21.2	20.4	21.3	19.5	19.5
IX	46	2	45	82	96	137	54	66	69	16.9	15.2	14.4	14.4	14.9	15.0	16.5	15.1	11.7
Mean/Sum	330	272	427	434	329	408	360	423	500	16.9	16.0	15.7	15.7	17.4	17.0	18.1	16.4	15.6

RESULTS

Number of tubers was significantly higher in ME-ML and ML-L in comparison to early cultivars overall experiment ($p < 0.05$) (Table 2). In early cultivars there were 9.2 tubers over three sites in both seasons, while ML-L gave the biggest numberper plant (12.3 and 11.9, respectively). Only at Sombor in 2002, ME-ML cultivars gave bigger number of tubers than ML-L (11.7 and 10.8, respectively). In both seasons, cultivars of all maturity groups grown in Čačak had the biggest number of tubers. The effect of site within maturity groups was significant in both seasons ($p < 0.05$). Early cultivars gave the biggest tubers over all sites in both season (on average >90 g), while the smallest mean tuber weight was recorded in ML-L cultivars (average over three sites in both seasons around 75 g) (Table 3). The smallest mean tuber weight over three maturity groups was recorded in Guča in both seasons (81.1 g and 74.7 g, respectively), while it was the highest in Čačak (97.3 g and 92.6g, respectively). The effects of maturity group and site within each maturity group were significant ($p < 0.05$). Mean two-year results showed that early cultivar Jaerla had consistent share >50% of >55mm tubers, mid-early to mid-late Kondor had >60% when grown in Sombor and Guča (Figure 3). Mid-late to late cultivar Agria had the highest share of >55 mm tubers, while tubers of 35-55 mm were dominating in this maturity group. The share of <35 mm tubers was less than 10% overall experiment; it was the lowest in early cultivars (1-3%). The highest tuber yields in all maturity groups were recorded in Čačak in both seasons, on average 38.8 t ha^{-1} and 40.4 t ha^{-1} (Table 4). Yields obtained in Sombor and Guča were similar in both seasons and significantly lower in comparison to Čačak within all maturity groups. Over three sites, ML-L group gave slightly higher yields than early and ME-ML ones in both seasons (34.6 t ha^{-1} and 34.3 t ha^{-1}, respectively). The effect of maturity group on tubers yield was significant overall experiment ($p < 0.05$), with exemption of Sombor in 2001. In Guča in 2001 the highest yield was obtained in early cultivars, while for the rest of the experiment this was the case with ML-L.

Table 2. Number of tubers per plant of potato cultivars of different maturity groups grown in Sombor, Čačak and Guča in 2001 and 2002

Maturity group (A)	Site (B)							
	2001				2002			
	Sombor	Čačak	Guča	Mean (A)	Sombor	Čačak	Guča	Mean (A)
Early	8.5a[b]	9.5b	9.5b	9.2	7.5a	11.0b	9.0a	9.2
ME-ML	12.3a	12.3a	10.7b	11.8	11.7a	12.3a	10.7a	11.6
ML-L	12.4a	12.6a	11.8a	12.3	10.8a	12.8b	12.2b	11.9
Mean (B)	11.1	11.5	10.7	11.1	10.0	12.0	10.6	10.9
$LSD_{0.05}$[a]	0.6	1.0	0.8		1.0	1.3	1.0	

[a] LSD test – comparison between individual means of cultivars within each site; [b]– different letters in a row indicate significant difference between sites at $p < 0.05$; LSD test.

Table 3. Mean tuber weight of potato cultivars of different maturity groups grown in Sombor, Čačak and Guča in 2001 and 2002

Maturity group (A)	Site (B)							
	2001				2002			
	Sombor	Čačak	Guča	Mean (A)	Sombor	Čačak	Guča	Mean (A)
Early	89a[b]	102b	94c	95	92a	104b	81c	91.8
ME-ML	73a	99b	77 a	83	98a	89b	76c	87.7
ML-L	73a	91b	72a	78	70a	85b	68a	74.6
Mean (B)	97.3	97.3	81.1	85.6	86.7	92.6	74.7	84.7
$LSD_{0.05}$[a]	11.1	8.2	10.3		7.1	16.1	ns	

[a] LSD test – comparison between individual means of cultivars within each site; [b]– different letters in a row indicate significant difference between sites at $p < 0.05$; LSD test.

Table 4. Tuber yield (t ha^{-1}) of potato cultivars of different maturity groups grown in Sombor, Čačak and Guča, 2001 and 2002

Maturity group (A)	Site (B)							
	2001				2002			
	Sombor	Čačak	Guča	Mean (A)	Sombor	Čačak	Guča	Mean (A)
Early	30.4a[b]	36.2b	35.4b	33.9	27.3a	40.8b	28.9a	32.3
ME-ML	30.8a	37.5b	31.5a	33.3	31.0a	39.0b	29.7a	33.3
ML-L	31.9a	42.8b	29.0a	34.6	30.5a	41.3b	31.2a	34.3
Mean (B)	31.0	38.8	31.9	33.9	29.6a	40.4b	29.9a	33.3
$LSD_{0.05}$[a]	ns	1.2	1.3		1.3	1.2	1.7	

[a] LSD test – comparison between individual means of cultivars within each site; [b]– different letters in a row indicate significant difference between sites at $p < 0.05$; LSD test.

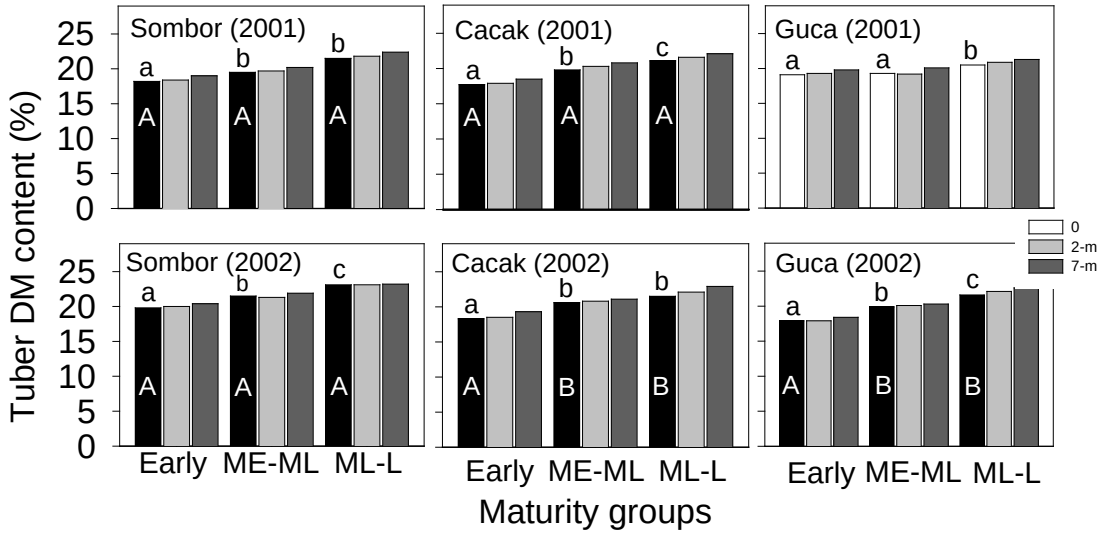

Figure 1.Tuber DM content (%) at harvest and during storage of potato cultivars of different maturity groups grown in Sombor, Čačak and Guča in 2001 and 2002. Measurements were performed at harvest (0), two months (2-m) and seven months (7-m) after storage. ME-ML (mid-late to late cultivars), ML-L (mid-late to late cultivars). Significant differences in initial tuber DM content between different maturity groups are indicated by different low case letters and between sites by different capital letters ($p < 0.05$).

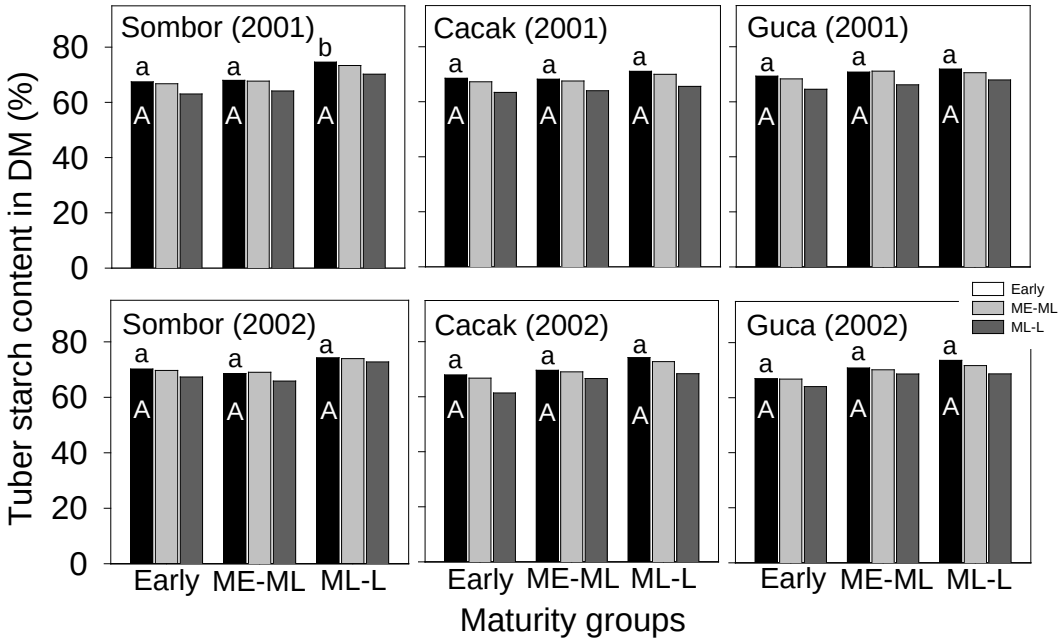

Figure 2.Tuber starch content in DM (%) at harvest and during storage of potato cultivars of different maturity groups grown in Sombor, Čačak and Guča in 2001 and 2002. Measurements were performed at harvest (0), two months (2-m) and seven months (7-m) after storage. ME-ML (mid-late to late cultivars), ML-L (mid-late to late cultivars). Significant differences in initial tuber DM content between different maturity groups are indicated by different low case letters and between sites by different capital letters ($p < 0.05$).

Initial tuber DM content of ML-L cultivars originated from three sites was >20% in 2001 and >21% in 2002, while it was <20% in early cultivars overall experiment; ME-ML cultivars gave tubers with DM content ≥20% in 2002 (the exemption was cv. Kondor, with DM<20%, data not shown) (Figure1). The effect of maturity group on initial DM content was significant overall experiment ($p < 0.05$). Constant increase in DM content was recorded overall experiment during storage. After 7-month storage DM content was increased 0.7 – 1.5% overall experiment. On average overall maturity groups, the lowest initial and final DM content were recorded at tubers originating from Guča in both seasons. In 2002, slightly higher values were recorded for Sombor in comparison to Čačak at all measurements in all maturity groups. The effect of site was significant at ME-ML and ML-L in 2002.

There was no significant effect of maturity group and site on initial starch content in DM in both seasons ($p < 0.05$) (Figure 2). Initial starch content <70% was recorded in early cultivars overall experiment. In ME-ML cultivars values >70% were obtained at plants grown in Guča in 2002, while in ML-L this was the case at all sites and both seasons. After 2-month and again after 7-month storage starch content was decreased in all groups and sites. During 7-m storage, starch content was decreased overall experiment for 2-6% without clear pattern. Values obtained for three sites were similar, showing the same trend of decrease of starch content in DM.

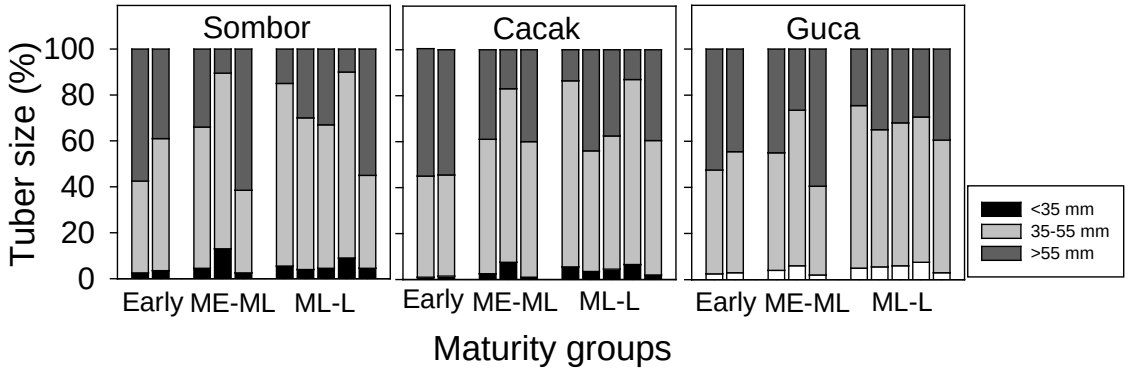

Figure 3. Size of tubers of ten potato cultivars of different maturity groups grown in Sombor, Čačak and Guča. Shown results are mean values for 2001 and 2002. ME-ML (mid-late to late), ML-L (mid-late to late). Each column represents a cultivar; the order of cultivars is as listed in Materials and methods.

DISCUSSION

Presented results showed that high tuber yields, much higher than 14.2 t ha^{-1}, which is average potato tuber yield for Serbia (Statistical Year Book of the Republic of Serbia, 2014) could be achieved by growing early, ME-ML and ML-L cultivars (Table 4). At the same time, the highest yields in all maturity groups were recorded in Čačak. Rainfall sum recorded in Čačak was much lower than in Sombor and Guča in both seasons, indicating that weather conditions did not have strong effect on yielding over two-year study. As suggested by Ilin et al. (2000), rainfall sum of 460-480 mm for potato growth season is considered as sufficient. During our study, lower rainfall sum than proposed was recorded at all sites in 2001 and in 2002 it was higher only in Sombor (Table 1). It could be taken under consideration that high rainfall recorded in Čačak in June 2002 contributed to obtaining higher yields than in 2001. Although some authors highlighted that number of tubers per plant is determined by cultivar (Broćić et al., 2000; Đorđević, 2000) seems that soil characteristics played an important role for obtaining the biggest number of tubers per plant of all tested maturity groups in Čačak in both seasons (Table 2); sandy loam soil had good texture and high level of ground water.

In Sombor, loam soil also had good texture, but due to its dark colour it warms up quickly. It is known that optimal temperature for tuber formation is 20^{o}C (Broćić and Stefanović 2012). The effect of temperature depends upon cultivar and part of the plant affected. In presented study, in Guča, poor soil conditions such as texture might be associated with small number of tubers in some cases and lower mean tuber weight in comparison to other sites (Table 2, Table 3). According to Firman (2008) number of tubers per stem is generally lower on clay soils than average number on coarse loams. Haverkort and Anisimov (2007) also stated that even in clay soils the majority of tubers were of 40-80 mm size class at soils with better texture and 40-60 mm size class was dominating at soils with less favourable physical properties, but this was not the case in all tested cultivars in presented study (Figure 3). Cultivars such as Kondor and Red Star which gave the smallest and biggest number of tuber, respectively (data not shown) had slightly higher share of >55 m tubers in Guča in comparison to other sites (Figure 3). Tubers size is one of the main characteristics of potato cultivar, but it could be also affected by growing practices, number of tubers per plant, length of stolons, etc; this is why data on share of different tubers size is presented for each cultivar.

Quality of potato tubers, such as DM content is of great importance for processing industry. For French fries processing 19-23% DM is needed, while for crisps it is 22-24% (Kabira and Berga 2003). Presented results clearly showed that ME-ML and ML-L cultivars give the best quality tubers at harvest while tested early cultivars are not suitable for processing (Figure 1). Our results are in agreement with findings by Zhang et al. (2002) who stated that DM content differs between potato cultivars, while Alva et al. (2007) found similar In presented study, the lowest DM content at harvest overall sites was recorded in Guča in both seasons. This could be a results of the highest rainfall sum recorded in Guča among all sites in 2001 (Table 1) and also the highest attitude. Long shape tubers and oval-long shape tubers, with diameter >55 mm are used for French fries processing and oval tubers with size 40-60 mm are used for chips. Our results showed that ML-L high quality cultivar Agria which is used for French fries processing gave >50% of tubers with >55 mm diameter over two seasons when grown in Sombor and 40% in Čačak

and Guča (Figure 3). Also, ML-L cultivars Van Gogh and Asterix which are suitable for chips processing gave good quality tubers under different agroecological conditions, which is confirmed by our study (Fig 1).

Asmamaw et al. (2010) reported significant interaction of cultivar and growing environment with respect to DM content. In contrast to this, our results showed that effect of site was not significant (Figure 1). Constant increase in DM content was observed during long-term storage overall experiment (Figure 1).

In presented study initial starch concentration in DM was around 70% overall experiment. During storage starch content decreased in all maturity groups, but it was maintained over 60% after 7-m storage. Content of the starch is determined by cultivar (Jansen et al., 2001) but various environmental factors also affect it (Morrison et al., 2000). In our study, the highest initial starch content in tubers DM was recorded in ML-L cultivars in both seasons, with significant effect recorded only in Sombor in 2001 (Figure 2). On the other hand, it has been shown that potato cultivars might differ significantly in starch content (Casañas Rivero et al., 2003).

CONCLUSIONS

Growing potato cultivars of different maturity groups under different agroecological conditions can give high yields of good quality tubers. Among three tested sites Čačak has been shown to be the most suitable for growing of tested cultivars. Early cultivars had the biggest mean tuber weight and the highest share tubers >55 mm diameter. ME-ML (with exemption of cv. Kondor) and ML-L gave the highest yields of tubers with DM content sufficient for processing for French fry and chips. High quality cultivars which are used for processing also had high share of tubers of desirable size. As it was expected, DM content was increased and starch content in tuber DM was decreased while during long-term storage.

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PRINOS SORTI KROMPIRA RAZLIČITIH GRUPA ZRENJA GAJENIH NA TRI LOKACIJE I KVALITET KRTOLA TOKOM SKLADIŠTENJA

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Izvod: Dvogodišnja istraživanja (2001-2002) su izvođena sa ciljem da se prouči uticaj lokacija (Sombor, Čačak, Guča) na kojima je gajen krompir i grupe ranostasnosti deset sorti na prinos i promene kvaliteta krtola tokom višemesečnog skladištenja. Najveći broj krtola po biljci i najveća prosečna masa krtola zabeleženi su u Čačku, što je dalo i najviše prinose u obe godine istraživanja, dok su najmanje vrednosti zabeležene u Guči. Povoljne osobine zemljišta u Čačku imale su značajniju ulogu nego klimatski uslovi na porast i prinosnost krompira. Ranostasne sorte su dale najmanji broj krtola po biljci i najveću prosečnu masu krtola, dok su suprotni rezultati zabeleženi kod srednje-kasnih do kasnih sorti. Najveći udeo krtola kod kojih je najveća dužina >55 mm bio je konzistentno visok kod ranostasnih sorti. Na sve tri lokacije najveći prinos zabeležen je kod srednje-kasnih do kasnih sorti, kao i sadržaj suve materije (SM) na početku skladištenja (>20% u 2001, >21% u 2002), dok je kod ranostasnih bila <20% na nivou celog eksperimenta. Nakon dva i sedam meseci skladištenja sa ventilacijom i bez kontrolisane vlažnosti, zabeleženo je kontinuirano povećanje SM i smanjenje sadržaja skroba u suvoj materiji krtole. Uticaj lokacije na kojoj je gajen krompir bio je značajan 2002. godine, u okviru srednje-ranih do srednje-kasnih i srednje-kasnih do kasnih sorti, kada je najveći sadržaj SM zabeležen kod krtola biljaka gajenih u Somboru; uticaj na sadržaj skroba nije bio značajan. Razultati prikazanih istraživanja pokazali su da se gajenjem sorti sa različitom dužinom vegetacionog perioda na različitim lokacijama mogu postići visoki prinosi, a među njima Čačak ima agroekološke uslove koji najviše pogodiju proizvodnji krompira. Gajenjem srednje-ranih do srednje kasnih sorti (sa izuzetkom sorte Kondor) i srednje-kasnih do kasnih sorti postižu se najveći prinosi sa odgovarajućim sadržajem SM potrebnom za preradu u pomfrit i čips.

Ključne reči: sorte krompira, grupa zrenja, skladištenje, suva masa, skrob.

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