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Fruit selection of NS tomato-shaped pepper lines

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Summary: Pepper is one of the most important vegetable species in Serbia. The use of pepper fruits is very often determined by their type. Tomato-shaped pepper is a fruit type suitable for the pickle processing industry because of its thick pericarp. In this study, several lines of light-yellow tomato-shaped peppers were evaluated in the open field with the aim to develop new variety with appropriate fruit characteristics and without anthocyanin colouration. Eight of selected lines originated from two crosses while two lines originated from variety Novosađanka. Fruit weight, fruit length, fruit width, fruit index, pericarp thickness, number of locules, and Brix were measured in technological maturity. According to the obtained data, lines 17 and 24 will be used for further selection process. Line 17 was chosen because of the highest pericarp thickness and high fruit weight and line 24 because of the high content of total soluble solids.
Key words: anthocyanin, breeding, breeding lines, Capsicum, pepper fruit traits, tomato-shaped pepper

Introduction

Pepper (*Capsicum annuum*) is one of the major vegetable crops in Serbia. In different parts of Serbia, people consume pepper fruits in various shapes, sizes and colours. Pepper genotypes with oblate fruit shape in a longitudinal section are called tomato pepper (Başak, 2021). In Serbia, this fruit type is called "paradajz paprika" (tomato pepper), while the name of the same type in Hungary is „alma paprika" (apple pepper) and in Bulgaria, "pumpkin shape". Novosađanka is the only tomato-shaped pepper variety in the assortment of the Institute of Field and Vegetable Crops, Novi Sad (IFVCNS), Serbia (Danojević et al., 2017). Although Novosađanka is a good, high-quality and widely grown variety, during the autumn period undesirable purple colouration appears on their fruits which originates from the pigment anthocyanin. Purple patches caused by the influence of environmental factors have a negative impact on fruit appearance (Liu, 2016). Production and market forces increasingly demand that breeders establish identities in the marketplace, through supplying unique, high-quality products (Mcavoy & Ozores-Hampton, 2007). Consumers base their first impression about fruits and vegetables on shape, color and size, considering those that deviate from the standard physical appearance as undesirable (Bitner 1992, Bloch 1995, Aschemann-Witzel et al., 2015). Because of this reason, a breeding program that started in 2013 aimed to develop a new tomato pepper variety with appropriate fruit characteristics and without anthocyanin colouration on the fruit pericarp.

In order to select genotypes with above mentioned characteristics, the aim of this study was to evaluate 10 pepper lines of light-yellow tomato shape pepper fruit type. Although there are a lot of lines of this type with green fruits in IFVCNS pepper breeding collection, such genotypes were not used in this study because consumers in Serbia prefer red or light-yellow and yellow fruits more than green (Danojević et al., 2021a).

Materials and Methods

Plant material and field trial. After several years of selection, ten tomato-shaped pepper lines originating from two crosses and one variety, were chosen for further breeding (Table 1). Lines 21 and 22 were used as controls because they originated from a variety Novosađanka.

Table 1. Code and origin of pepper line

Line code	Origin
15	38/12
16	38/12
17	38/12
18	38/12
19	695/17
20	38/12
21	Novosađanka
22	Novosađanka
23	695/17
24	695/17

Sowing was done on 28 March 2019 in a greenhouse without heating. Plants were transplanted on 30 May 2019 in the open field of the Institute of Field and Vegetable Crops Novi Sad (Rimski Šančevi), Serbia. Per each genotype, 30 plants were transplanted (10 plants in three replications). The distance between rows was 70 cm and between plants within row was 25 cm. Common agricultural practices for peppers were applied and plants were irrigated by sprinkling. Twenty-five fruits per line were harvested in technological maturity. According to da Silva et al. (2015), a sample of 22 fruits is considered suitable for estimating the mean of pepper fruit traits. Fruit weight (FWe), fruit length (FL), fruit width (FWi), fruit index (FI), number of locules (NL), pericarp thickness (PT) and total soluble solids (TSS) were evaluated. Data were collected according to Descriptor for *Capsicum* (IPGRI, AVRDC, CATIE 1995). Total soluble solids - Brix (TSS) were measured for each fruit by Digital Refractometer (Kruss).

Statistical analysis. Minimum and maximum values for all traits were presented. Mean values, coefficient of variation (C.V.) and Bonferroni multiple test interval at 0.05 probability level were calculated. Pearson correlation coefficients were determined at the 0.05 and 0.01 probability levels. The principal component analysis (PCA) was programmed according to the NIPALS algorithm and was used for grouping genotypes on the biplot. Data were processed in the software Statistica 13.2 (Dell Inc., USA).

Results and Discussion

Smith & Basavaraja (2005) and Bharadwaj et al. (2007) singled out fruit weight, length and diameter as very important yield-related traits in pepper selection. Field-evaluated cultivars of tomato pepper have shown variation in the estimated traits. Fruit weight (FWe) is one of the most important fruit characteristics in the breeding process. The highest FWe was found in lines 17 (Figures 1 and 2) and 24 (97.11 g and 95.18 g, respectively), while line 22 had the lowest FWe (65.61 g) (Table 2.). Typical FWe of tomato pepper fruits in Hungary usually ranged from 80 to 120 g (Sebesi 2016). Previous results showed that the variety Novosađanka had FWe 80-110 g (Gvozdenović & Vasić, 1997). Lines 21 and 22 had lower FWe than variety Novosađanka due to several years of self-pollination (Figures 3

and 4). The longest fruits (4.46 cm) were found in line 17, while the fruit length (FL) of other lines ranged from 3.62 to 4.38 cm. The widest fruits were found in lines 24 (7.60 cm) and 19 (7.52 cm), followed by line 23 (7.26 cm) (Figures 5 and 6). Those three lines (19, 23, and 24) originated from the same genotype 695/17 and also had the highest TSS. Total soluble solids content as a quality trait is relevant for fresh consumption and processing. According to Başak (2021), genotypes of tomato pepper fruit type had FL of 5.2 cm and FWi 6.4 cm. In Bulgaria, the fruits of pumpkin-shaped pepper fruits are thicker and wider with a flattened shape with an average FL of 3.92 cm, FWi of 5.44 cm and FWe of 111 g (Nankar et al., 2020). Pericarp thickness (PT) is a very important commercial trait that determines the usefulness of fruits for preservation and freezing (Rożek et al. 2012). Line 17 had the highest PT (8.21 mm), followed by two lines 18 and 20 with PT of 7.67 mm.

Figure 1. Plant and fruits of Line 17

Figure 2. Fruits of Line 17 (Origin 38/12)

Figure 3. Plant and fruits of Line 21

Figure 4. Fruits of Line 21 (Origin Novosađanka)

Figure 5. Plant and fruits of Line 23

Figure 6. Fruits of Line 23 (Origin 695/17)

Among all the lines, there was no significant difference in the number of locules. Number of locules ranged from 2.72 to 3.0. FL, FWi and FI had the lowest CV (around 10%) which indicates a high stability of those traits (Table 2). Previous results reported by Todorova (2007) and Danojević et al. (2021b), showed the lowest CV in fruit width which indicates that this trait is more influenced by heritable factors than environmental factors. The highest CV was recorded for TSS (23.24%) and FWe (23.16%), which indicates high variability for those traits. However, in a previous study Danojevic et al. (2018) found lower heritability for PT and TSS. Probably those traits in tested pepper genotypes were more influenced by environmental factors.

Table 2. Mean, minimum, maximum values, and coefficient of variation (CV) of several fruit traits in tomato-shaped pepper lines (25 fruits/line)

Line code	FWe (g)	FL (cm)	FWi (cm)	FI	NL	PT (mm)	TSS Brix (%)
15	73.63^{bcd}	3.98^{cd}	6.65^{cde}	0.60^{ab}	3.00^{a}	7.01^{bc}	4.87^{b}
16	87.18^{ab}	4.09^{bc}	7.1^{abc}	0.58^{bc}	2.88^{a}	7.45^{ab}	4.62^{b}
17	97.11^{a}	4.46^{a}	7.21^{ab}	0.62^{ab}	2.88^{a}	8.21^{a}	4.66^{b}
18	87.68^{ab}	4.38^{ab}	6.85^{bcde}	0.64^{a}	2.76^{a}	7.67^{ab}	4.79^{b}
19	90.41^{a}	4.04^{bc}	7.52^{a}	0.54^{c}	3.04^{a}	6.25^{c}	5.88^{a}
20	83.78^{abc}	4.15^{abc}	6.90^{bcd}	0.60^{ab}	3.16^{a}	7.67^{ab}	4.74^{b}
21	69.47^{cd}	3.68^{de}	6.46^{de}	0.57^{bc}	2.72^{a}	6.71^{bc}	4.48^{b}
22	65.61^{d}	3.62^{e}	6.33^{e}	0.57^{bc}	2.84^{a}	6.87^{bc}	4.77^{b}
23	85.58^{ab}	3.98^{cd}	7.26^{ab}	0.55^{c}	2.96^{a}	6.70^{bc}	6.02^{a}
24	95.18^{a}	4.10^{bc}	7.60^{a}	0.54^{c}	3.00^{a}	6.20^{c}	6.20^{a}
Mean	83.56	4.04	6.98	0.58	2.92	7.07	5.10
Minimum	43.80	3.00	5.40	0.44	2.00	3.60	3.80
Maximum	139.10	5.40	8.90	0.76	4.00	11.10	8.70
CV(%)	23.16	10.88	10.03	10.15	17.54	17.95	23.24

Different letters show significant difference according to Bonferroni test p<,05000;
FWe- Fruit Weight; FL- Fruit Length; FWi- Fruit Width; FI-Fruit Index; NL-Number of Locules; PT- Pericarp Thickness; TSS-Total Soluble Solids

In order to determine the degree of relationship between the evaluated traits, researchers usually use a simple correlation analysis (Cankaya & Kayaalp, 2007). In our study positive correlations were found between FWe and all evaluated traits, except TSS (Tab. 3). The strongest correlation was recorded between FWe and FWi (0.86). A positive correlation was recorded between FL and FWi, PT. Lannes et al. (2007) also found positive correlation between FW and PT in *C. chinense* emphasising its importance for the selection of varieties intended for fresh market sale since fruits with higher PT are more resistant to injuries during postharvest storage and shipping. Previous results of Rêgo et al. (2011) showed that fruit width, fruit weight and dry matter content were positively correlated with the pepper yield. According to Cankaya et al. (2010), PT and FWi could be used in selection for increasing pepper yield per plant. The lowest significant correlation in our research was noted between TSS and FWi. That positive correlation was probably caused by high TSS and wide fruit of lines 19, 23, and 24 which are from the same origin 695/17.

Table 3. Pearson correlation coefficients between fruit traits of tomato-shaped pepper lines (N=250 fruits)

Trait	FL	FWi	NL	PT	TSS
FWe	0.70**	0.86**	0.18**	0.32**	0.12
FL		0.53**	0.02	0.20**	0.02
FWi			0.18**	0.12	0.15*
NL				0.02	0.07
PT					-0.12

* and **are significant at p< .05000; p< .01000

FWe- Fruit Weight; FL- Fruit Length; FWi- Fruit Width; NL-Number of Locules; PT- Pericarp Thickness; TSS-Total Soluble Solids

For clearer visual presentation of the results, PCA analysis was performed in the form of one PCA biplot (Figure 7). PCA biplot showed that the highest divergence was recorded in lines (15, 16, 17, 18 and 20) originated from 38/12. Lines (21 and 22) from Novosađanka and lines (19, 23 and 24) from 695/17 crossing were more uniform among each other.

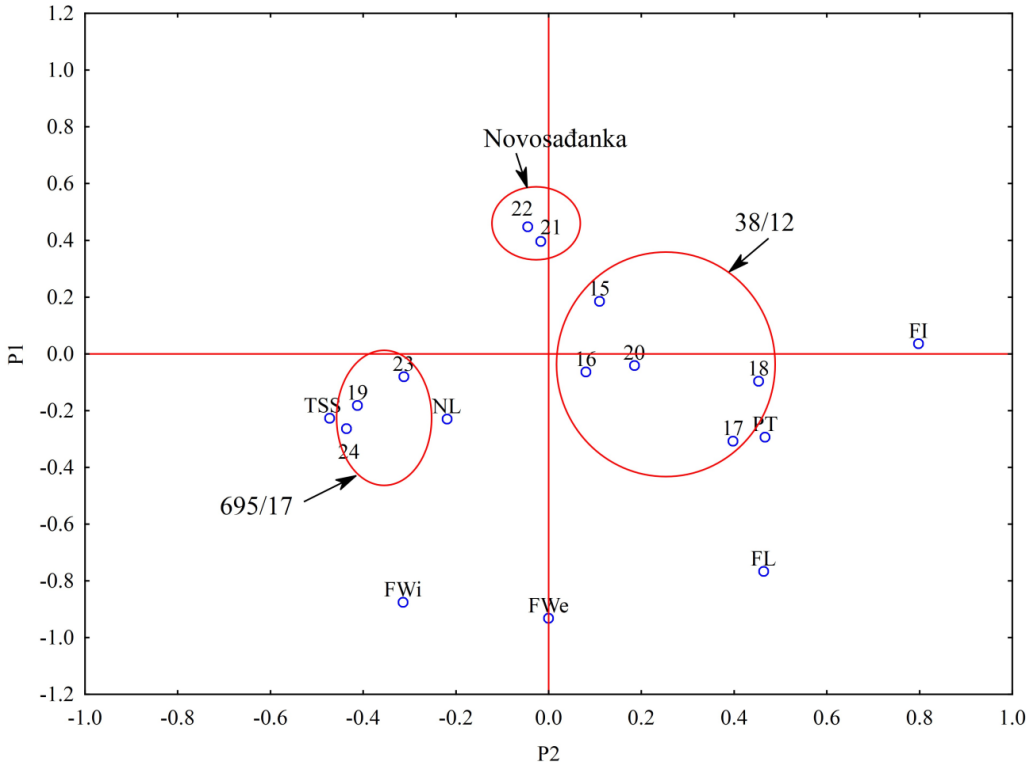

Figure 7. Biplot of fruit traits, codes and origin of evaluated tomato-shaped pepper lines

Additionally, according to PCA, traits such as FI, PT and TSS showed distinctive variations among three different origins of pepper lines.

Conclusions

Tested pepper lines have shown variation in the estimated traits, and they were separated into three groups according to PCA. Based on the results, for further breeding process two lines were selected. Line 17 is promising for creation of high yield variety because of the thicker pericarp and high fruit weight, while line 24 will be used as a source of the high TSS, fruit width and fruit weight.

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Selekcija plodova NS linija paprike (tip paradajz paprike)

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Sažetak: Paprika je jedna od najvažnijih povrtarskih vrsta u Srbiji. Upotreba plodova paprike je vrlo često određena tipom ploda. Paradajz paprika se dosta koristi za industrijsku preradu zbog debelog perikarpa, a i kao svež plod u salatama. Cilj ovog istraživanja bio je da se ispita nekoliko linija paradajz paprika svetložute boje koje su gajene na otvorenom polju. U tehnološkoj zrelosti mereni su: masa ploda, dužina ploda, širina ploda, indeks ploda, debljina perikarpa, broj komora i suva materija. Prema dobijenim podacima, za dalji proces selekcije koristiće se linije 17 i 24. Linija 17 zbog najveće debljine perikarpa i mase ploda, a linija 24 zbog većeg sadržaja suve materije.

Ključne reči: antocijan, *Capsicum*, oplemenjivačke linije, oplemenjivanje, osobine ploda paprike, paradajz paprika