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EVALUATION OF THE QUALITY OF TOMATO SEED POPULATIONS FROM THE ORGANIC PRODUCTION SYSTEM DURING AGING

OCENA KVALITETA SEMENA POPULACIJA PARADAJZA IZ ORGANSKE PROIZVODNJE TOKOM STARENJA

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ABSTRACT

A total of six tomato seed populations, collected in the autumn of 2016 at different locations in Serbia (West (3), South (1), North (1) and East (1)), were enrolled in this study. Seeds of the tomato populations considered were produced in the organic growing system in the area of Zaovice (76 m a.s.l., chernozem), Stara Pazova, Northern Serbia (44˚ 47 '19.6" N, 20˚ 27' 56.2" E) in 2017. Analyses of the germination parameters of the tomato seed populations examined (namely the germination energy, total germination, abnormal seedlings and dead seeds of the tomato seeds considered) indicated significant ($p < 0.01$) differences according to the production year (A) and the tomato seed population (B). The impact interactions ($p < 0.01$) of these factors (A × B) proved significant only relative to dead seeds. A highly significant positive correlation was found between the germination energy and the total germination of the seeds considered ($r = 0.8711$, $p < 0.001$), as well as between the amounts of their abnormal seedlings and dead seeds ($r = 0.92297$, $p < 0.001$). The germination energy and the total germination of the tomato seeds considered were found to decrease with the increasing seed age, in contrast to the numbers of their abnormal seedlings and dead seeds which continued to increase with seed aging.

Key words: *tomato, germination seeds, population/variety.*

REZIME

Seme šest populacija/sorti paradajza prikupljeno je u jesen 2016. sa različitih lokaliteta iz Srbije: zapadne (3 populacije), južne (1), severne (1) i istočne (1). Proizvodnja semena populacija paradajza u organskom sistemu gajenja izvedena je 2017. godine na lokaciji zapadne Srbije u Staroj Pazovi, potes Zovice (76 m n.v.) 44˚ 47 '19.6" N, 20˚ 27' 56.2" E. Cilj istraživanja je bio da se izvrši ocena uticaja godine i populacije na pokazatelje kvaliteta semena paradajza tokom 2017, 2018. i 2019.. Seme je čuvano u skladištu upakovano u pvc-kesama na temperaturi ispod 15ºC, RH 50%.

Analiza energije klijanja, ukupne klijavosti, neneormalnih klijanaca i mrtvog semena paradjza pokazala je visoko značajne razlike ($p<0,01$) pod uticajem faktora godina (A) i populacija semena (B). Veoma značajna interakcija ($p<0,01$) ispitivanih faktora u pogledu mrtvog semena paradajza dobijena je samo kod međusobnog uticaja faktora A × B. Zabeležena je visoko značajna korelacija ($p\leq0.001$) između energije klijanja i ukupne klijavosti, i između broja neneormalnih klijanaca i mrtvog semena. Energija klijanja i ukupna klijavost sa povećanjem starosti semena opadaju, dok broj nenormalnih klijanaca i mrtvog semena raste. Rezultati ovog rada treba da daju doprinos u shvatanju značaja autohtonih populacija/sorti ne samo paradajza, već i autohtonih sorti semena ostalog povrća; odnosno da ukažu na značaj očuvanja genetičkih resursa za organsku poljoprivredu.

Ključne reči: *paradajz, klijavost semena, populacija/sorta.*

INTRODUCTION

Seeds are one of the basic preconditions of successful agricultural production and regular yields of high quality. Therefore, the identification and testing of seed quality, i.e. vigor, is of paramount importance to crop production (*Poštić et al., 2019*). Vigor or biological viability is used to describe the physiological properties of seeds responsible for their ability to germinate rapidly in the soil (*Tabaković et al., 2013*). There is a deficit in organic seeds both in Serbia and worldwide, which is being increasingly compensated for by conventional non-treated seeds. However, the EU experts have announced that organic production will not be able to use untreated seeds from conventional production as of 2021. Over the past twenty years, the global organic production has rapidly expanded due to growing concerns about human health and a great demand for "healthy" food (*Postic et al., 2018*). Organic farming and organic tomato production have recently been receiving increased attention in Serbia. However, there are no accurate data on the organic production of tomatoes in Serbia to date.

Nowadays, a 0.9 % share of the total agricultural land in the world is devoted to organic agriculture. However, the largest share of 6.2 % of the agricultural land devoted to organic farming is recorded in Europe. As many as eight EU countries have an average of more than 10 % of their agricultural land devoted to organic farming. However, only a 0.4 % share of the total agricultural land is devoted to organic farming in Serbia. A total of 13,423 ha were devoted to organic production in Serbia in 2017, or 0.4 % of the total Serbian arable land, with 6,022 registered organic producers (FiBL, 2020). Tomatoes are one of the most common and economically significant vegetable crops in Serbia, grown in the open field or in protected areas. The conventional production of tomatoes in Serbia approximates to 180,000 t, covering a land area of 20,000 ha. Owing to the lack of organic seeds in the market, domestic producers use seeds from their own production and/or local seed populations adapted to the agroecological conditions in Serbia (*Ugrenović et al., 2015*).

A continuous decrease in the number of well-established local seed populations in Serbia poses a great threat to the local biodiversity and genetic resources. In the face of increasing production issues caused by climate change, it is necessary to collect and preserve as many well-established local seed populations and plant varieties as possible because they carry many genes for resistance to various adverse environmental conditions and plant diseases (pathogens). The purpose of this study is to evaluate the effects of production year and seed population on the most significant indicators of the quality of organic tomato seeds. The results obtained emphasize the overriding importance of domestic seed populations and plant varieties of tomatoes and other vegetable crops for organic agriculture.

MATERIAL AND METHOD

Production of tomato seeds in the organic farming system. A total of six tomato seed populations, collected in the autumn of 2016 at different locations in Serbia (West (3), South (1), North (1) and East (1)), were enrolled in this study. Seeds of the tomato populations considered were produced in the organic growing system in the area of Zaovice (76 m a.s.l., chernozem), Stara Pazova, Northern Serbia (44˚ 47 '19.6" N, 20˚ 27' 56.2" E) in 2017. The soil properties are shown in Table 1.

Seed sowing was performed using containers in early April, whereas planting in the open field was carried out in mid-May (at a distance of 0.4 × 0.7 m and in a plot area of 10 m^2). Crop management was conducted according to the commonly accepted recommendations for growing tomatoes in the organic production system. Tomatoes were harvested at full physiological maturity during August and September, followed by seed extraction and 24-hour seed fermentation. Seed drying was performed in the shade at room temperature. The seeds were stored in PVC bags at a temperature below 15ºC, RH 50%. The data on meteorological conditions are shown in Table 2.

Table 1. Properties of the soil at the experimental location

Depth (cm)	Type of soil	CaCO3 %	PH		Humus %	mg/100g soil	
			H2O	nKCl		P2O5	K2O
0-30	Chernozem	6.32	-	7.70	5.86	28.09	17.71

Table 2. Air temperature and precipitation conditions in Northern Serbia during the tomato growing season of 2017 and the period 2008-2016

Month	2017		2008-2016	
	ºC	mm	ºC	mm
March	11.5	30.2	8.7	55.4
April	12.4	47.1	14.4	36.3
May	18.6	49.2	18.5	79.7
Jun	24.4	39.0	22.3	71.6
July	25.5	26.7	24.5	54.6
August	25.8	23.7	24.2	39.8
September	18.4	36.6	19.6	48.9
Average-sum	18.1	252.5	18.9	386.3

Seed quality assessment. The evaluation of tomato seed quality (namely the germination energy, total germination, abnormal seedlings and dead seeds of the tomato seeds considered) was conducted in 2017, 2018 and 2019 at the Laboratory for Seed and Planting Material Testing of the Institute for Plant Protection and the Environment in Belgrade.

The germination testing of six seed populations considered was performed using a standard laboratory method involving filter paper moistened with a 0.2 % aqueous KNO_3 solution at 4 × 100 seeds. The seeds were incubated for 14 days at a temperature of 20-30 °C and a relative air humidity of 95 %. The germination energy after 5 days of incubation, the total germination and the numbers of abnormal seedlings and dead seeds after 14 days of incubation of the tomato seeds considered were determined according to the Rules on the Quality of Seeds of Agricultural Plants ("Official Gazette of SFRY ", no. 47/87), which are in accordance with the ISTA Rules (ISTA, 2002-2018). **Statistical analysis.** The experimental data obtained were processed using the statistical package STATISTICA 8.0 for Windows. Differences between the treatments were determined using the analysis of variance (ANOVA), whereas the least significant difference (LSD) test was used for individual comparisons. Correlations between the parameters observed were determined using the Pearson correlation coefficient (r).

RESULTS AND DISCUSSION

Analyses of the germination parameters of the tomato seed populations examined (namely the germination energy, total germination, abnormal seedlings and dead seeds of the tomato seeds considered) indicated significant differences ($p < 0.01$) according to the production year (A) and the tomato seed population (B). The results obtained in the present study are consistent with the results of *Stanisavljević et al., (2018)*. The impact interactions ($p < 0.01$) of these factors (A × B) proved significant only relative to dead seeds.

Table 3. F-values for the factors observed

Factors	Germination energy	Total germination	Abnormal seedlings	Dead seeds
Year (A)	**	**	**	**
Population (B)	**	**	**	**
A × B	ns	ns	ns	**

** - significant at 0.01; * - significant at 0.05; ns - not significant

The germination energy of the tomato seed populations considered ranged from 72 % to 92 % (Table 4). As expected, the highest average germination energy of 89 % was determined in 2017, followed by 85 % in 2018 and 79 % in 2019. After harvest (2017), the decreases in the germination energy of the tomato seed populations considered ranged on average from 4 % in 2018 to 10 % in 2019. The results obtained are consistent with the results of Poštić et al. (2011).

The total germination of the tomato seed populations considered ranged from 81 % to 98 % (Table 5). As expected, the highest average total germination of 94 % was determined in 2017, followed by 88 % in 2018 and 84 % in 2019. After harvest (2017), the decreases in the overall germination of the tomato seed populations considered ranged on average from 6 % in 2018 to 10 % in 2019. The results obtained are consistent with the results of Poštić et al., (2011). Lower variability was found in the germination energy (Table 4) and the total germination (Table 5) of the tomato seeds considered, ranging from 3.15 % to 11.43 %. The number of abnormal seedlings of the tomato seeds considered was found to increase with the increasing age of tomato seeds, ranging from 0 % in the first year to 9 % in the third year (Table 6). The smallest average number of abnormal seedlings of 3.33 % was observed in the Jabučar East population (Negotin), whereas the largest number of abnormal seedlings of 7.33 % was observed in the Jabučar West population (Šabac).

The number of dead seeds of the tomato seeds considered increased with seed aging, ranging from 2 % in the first year to 10 % in the third year (Table 7). High variability was found for abnormal sprouts (Table 6) and dead seeds (Table 7), ranging from 13.32 % to 91.65 %.

The coefficients of correlation (r) computed express the interdependence between the seed quality parameters observed (Table 6). As expected, a highly significant positive correlation was found between the germination energy and the total germination of the tomato seeds considered (r = 0.8711, p < 0.001), as well as between the numbers of their abnormal seedlings and dead seeds (r = 0.92297, p < 0.001). The results obtained are consistent with the results of *Stanisavljević et al., (2017)*.

Table 4. Effects of the production year and seed population on the germination energy (%)

Population (B) / Origin	Year (A)			Average	CV (%)
	2017	2018	2019		
Jabučar / West (Badovinci)	90aA	86aB	72cC	82.7	11.433
Jabučar / West (Šabac)	84bA	80cB	75dC	79.7	5.660
Volovsko srce / West (Šabac)	91aA	85abB	81aC	85.7	5.875
Jabučar / South (Pirot)	92aA	88aB	83aC	87.7	5.144
Sant pjer / North (Sombor)	84bA	83bA	79bB	82.0	3.227
Jabučar / East (Negotin)	90aA	87aB	82aC	86.3	4.681
Average (A)	88.5	84.8	78.7	84.0	

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

Table 5. Effects of the production year and seed population on the total germination (%)

Population (B)/Origin	Year (A)			Average	CV (%)
	2017	2018	2019		
Jabučar / West (Badovinci)	96aA	89abB	85aC	90.0	6.186
Jabučar / West (Šabac)	86cA	85cA	81bB	84.0	3.150
Volovsko srce / West (Šabac)	96aA	88bB	84aC	89.3	6.840
Jabučar / South (Pirot)	96aA	90aB	85aC	90.3	6.097
Sant pjer / North (Sombor)	90bA	86cB	82bC	86.0	4.651
Jabučar / East (Negotin)	98aA	91aB	86aC	91.7	6.576
Average (A)	93.7	88.2	83.8	88.6	

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

Table 6. Effects of the production year and seed population on the number of abnormal seedlings (%)

Population (B)/Origin	Year (A)			Average	CV (%)
	2017	2018	2019		
Jabučar / West (Badovinci)	2bC	4abB	6abA	4.00	50.00
Jabučar / West (Šabac)	6aB	7aB	9aA	7.33	20.830
Volovsko srce / West (Šabac)	1bC	5aB	7aA	4.33	70.501
Jabučar / South (Pirot)	2bB	5aA	6abA	4.33	48.038
Sant pjer / North (Sombor)	4aC	6aB	9aA	6.33	39.736
Jabučar / East (Negotin)	0bC	4abB	6abA	3.33	91.652
Average (A)	2.50	5.17	7,33	5.00	

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

Table 7. Effects of the production year and seed population on the number of dead seeds (%)

Population (B)/Origin	Year (A)			Average	CV (%)
	2017	2018	2019		
Jabučar / West (Badovinci)	2bC	7aB	9aA	6.0	60.093
Jabučar / West (Šabac)	8aB	8aB	10aA	8.67	13.323
Volovsko srce / West (Šabac)	3bC	7aB	9aA	6.33	48.238
Jabučar / South (Pirot)	2bC	5bB	9aA	5.33	65.848
Sant pjer / North (Sombor)	6aB	8aA	9aA	7.67	19.924
Jabučar / East (Negotin)	2bC	5bB	8aA	5.00	60.00
Average (A)	3.83	6.67	9.0	6.50	

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

Table 8. The correlation coefficient for the traits observed (n =16)

Traits	Germina. energy	Total germina.	Abnormal seedlings	Dead seeds
Germinat. energy	-	0.8711***	- 0.82930***	- 0.87727***
Total germinat.		-	- 0.97903***	- 0.98202***
Abnormal seedlings			-	0.92297***
Dead seeds				-

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

The strongest negative correlation was found between the germination energy of the tomato seeds considered and the numbers of their abnormal seedlings (r = -0.82930, p < 0.001) and dead seeds (r = -0.87727, p < 0.001), as well as between the total germination of the tomato seeds considered and the numbers of their abnormal seedlings (r = -0.97903, p < 0.001) and dead seeds (r = -0.98202, p < 0.001).

CONCLUSION

Production year, seed population and plant variety exerted strong effects on the quality of organic tomato seeds (namely the germination energy, total germination, abnormal seedlings and dead seeds of the tomato seeds considered). The tomato seed populations examined exhibited lower variability in the germination energy and the total germination with seed aging. However, high variability was observed in the numbers of their abnormal seedlings and dead seeds. A highly significant positive correlation was found between the germination energy and total germination of the tomato seeds considered (r = 0.8711, p < 0.001), as well as between the numbers of their abnormal seedlings and dead seeds (r = 0.92297, p<0.001). The germination energy and the total germination of the tomato seeds considered were found to decrease with the increasing seed age, in contrast to the numbers of their abnormal seedlings and dead seeds which continued to increase with seed aging.

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