Turkish Journal of Agricultural and Natural Sciences
Special Issue: 1, 2014

TÜRK
TARIM ve DOĞA BİLİMLERİ
DERGİSİ

TURKISH
JOURNAL of AGRICULTURAL
and NATURAL SCIENCES

www.turkjans.com

Evaluation of Pepper Genotypes in Different Organic Production Systems

[a]Velichka TODOROVA*, [a]Penka FILYOVA
[a]Maritsa Vegetable Crops Research Institute, Plovdiv, Bulgaria,
*Corresponding author: todorova_vili@abv.bg

Abstract

The aim of this study was to be estimated the response of eight pepper varieties, accessions and breeding lines with different fruit shape and direction of usage in four systems of organic production and conventional variant used as a control. The field experiments were carried out during the period 2008-2010 at the Maritsa Vegetable Crops Research Institute, Plovdiv, Bulgaria. The total yield and some morphological characters of the fruit - length, diameter at the base and fruit weight were analyzed. The influence of the sources of variation on these characters was also determined. An organic production system with identical behavior of all studied pepper materials concerning the analyzed traits was not outlined during the whole experimental period. The variety Buketen 50 and accession K558 showed very good results by most studied characters of the fruit in the growing systems with bio pesticides use. Variety Stryama realized its yield potential in all organic production systems that confirmed its good adaptability. The exceeding towards the control variant of growing was with 19.49% in the system with Lumbrical (vermicompost) use without plant protection and up to 45.32% in system with Lumbrical fertilization and bio pesticides application. Breeding line 1186/06, kapia type, also demonstrated higher total yield in most organic system but it was with worse fruit characters than in conventional conditions of growing.

Keywords: *Capsicum annuum*, yield, fruit, variance

Introduction

Organic farming is a modern way of agriculture management, not using any chemical plant protection and mineral fertilization which have negative effects on the environment, human and animal health. It is both a philosophy and a system of agricultural production. Its roots are to be found in certain values that closely reflect the ecological and social realities. Organic agriculture is a production method that takes into account the traditional knowledge of farmers and integrates the scientific progress in all agricultural disciplines, answering the social concerns of the environment and providing high quality products to consumers (Costel and Vasile, 2012).

An increasing interest in organic agriculture for food production is seen throughout the world. According to the study of World of Organic Agriculture, seven of the first ten countries of the world, ranked by the highest shares of organic agricultural land and six - by the highest increase of organic land are in the European Union (FiBL and IFOAM, 2014 https://www.fibl.org/fileadmin/documents/shop/1636-organic-world-2014.pdf). In response to this fact in Bulgaria the studies for investigations on the manifestation of various vegetable crops genotypes as tomatoes (Boteva and Cholakov, 2011), garden pea (Kalapchieva et al., 2011), head cabbage (Antonova et al., 2012), pepper (Todorova et al., 2013) and potatoes (Nacheva et. al, 2013) in conditions of organic farming are increased and also the effect on them of different bio fertilizers (Vlahova et al., 2011, Boteva et al., 2012; Dintcheva 2014) and bio pesticides (Yankova and Markova, 2009; Masheva and Yankova, 2012).

The pepper is a traditional vegetable crop for Bulgaria and Balkan countries, where it

is characterized with large diversity of fruit shape, colour and attitude, directions of production, processing and consuming (Krasteva et al., 2012). In organic farming it is required to be estimated native varieties, accessions and populations, adapted to local environment conditions and possessing specific taste characteristics which are preferred by consumers (Panajotov, 2003).

The aim of this study was to evaluate pepper varieties, accessions and breeding lines in conditions of different organic production systems by total yield and some fruit characters.

Materials and Methods

Eight pepper genotypes - two varieties, one accession and five breeding lines were estimated in four different systems for organic farming in the "Maritsa" Vegetable Crops Research Institute, Plovdiv during the period 2008-2010. Conventional system was used as a control. The genotypes included in the study were with different fruit shape, attitude and direction of usage: variety Stryama with conical fruits; accession K558, breeding lines 1264/07 and 1265/07 (now - variety Kaloyan) from *Grossum* group; lines 1186/06 and 1266/07 – kapia type of the fruit and variety Buketen 50 and line P708/08 suitable for ground red pepper. The varieties and breeding lines were developed in the Institute. All materials were grown by technology for mid-early field production. The sowing was carried out at the end of March and planting - in the middle of May. The experiments were performed on a furrows profiled area (500 m^2) by randomized block design in five production systems with four replications each in planting scheme 70/15 cm.

The systems of production were: 1 – conventional, with standard mineral fertilization and plant protection with application of pesticides with chemical origin; 2 - free of fertilization and plant protection; 3 – fertilization with Lumbrical without plant protection; 4 – without fertilization but with bio pesticides for plant protection and 5 - with Lumbrical use and plant protection by bio pesticides. Fertilization in corresponding organic systems was conducted with bio product Lumbrical (trade name of vermicompost, produced by *Lumbricus rubellus*) ten days after planting with 150-170 ml per plant. The fertilization rates were determined in agrochemical laboratory of the Maritsa Vegetable Crops Research Institute on the base of soil analysis, according to the content nutrient elements in the soil and the biological requirements of pepper crop. The plant protection was carried out with bio pesticides: Timorex 66 EC 0.5 and 1% (a.i. extract from *Melaleuca alternifolia*); Pirethrum FS EC 0.05% (a.i. pirethrum, extract from *Chrysanthemum cinerariefolium*); Piros 0.08% (a. i. pirethrum, extract from *Chrysanthemum cinerariefolium*); Neem Azal T/S 0.3% (a. i. azadirachtin, product from *Azadirachta indica*) and Bioneem Plus 1,5 EC 0.25% (a. i. azadirachtin, product from *Azadirachta indica*). The characters total yield (kg da^{-1}), fruit length (cm), fruit diameter (cm) and fruit weight (g) were analyzed. The fruits from Stryama, K558, 1264/07 and 1265/07 were harvested before maturity but from others genotypes in maturity stage when fruits reached a shining green or red color, respectively. Biometrical measurements for determining of fruits characters were done with 5 fruits from each replication immediately after each harvest.

The obtained data were statistically processed by three-way analysis of variance (Lidanski, 1988). The influence (η, %) of the variation factors also was evaluated. Comparisons of means between production systems separately for each genotype were carried out using Duncan's multiple range test at $p<0.05$ (1955).

Results and Discussion

The results by three-way analysis of variance for the variability of total yield showed that all variation sources had proved effect on phenotypic expression of the character (Table 1). The genotype exerted the biggest influence (50.81%) followed by years of growing (28.87%) and the interaction genotype x year (10.56%). The rest sources were with total effect below 10%.

The evaluated varieties, accession and breeding lines did not possess one-valued response by total yield in investigated growing systems. Four of evaluated genotypes - K558, 1266/07 and materials for ground pepper, realized the highest total yield in conventional conditions of growing (Table 2). For accession K558 and lines 1264/07 the differences between growing systems were not significant. Khalaf (2007) has established insignificantly higher total yield - about 12% for the organic production compared to the conventional.

Szafirowska and Elkner (2008) have reported different cultivar manifestations to organic farming.

Significantly lower values were determined in breeding line P708/08, for ground pepper, in all systems for organic production. The biggest decrease, for unexplainable reasons, was observed in system with Lumbrical and bio pesticides application as the yield reached only 53.78% of those in control variant. Similar reduction of total yield was established in our previous study with variety IZK Rubin, also suitable for ground pepper, (Todorova et al., 2013). Our results confirmed the determined significantly lower yield (above 20%) from five bell pepper varieties in organic system compared to integrated nutrient management one by Gopinath et al. (2008).

During the whole investigation period, variety Stryama successfully realized its yield potential in all conditions of organic production, which indicated its good adaptability. The exceeding was from 19.49% in system with Lumbrical use and without plant protection to 45.32% in that with application of Lumbrical and bio pesticides. According to Buczkowska (2005) an organic fertilization may increase the sweet pepper yield by 30-40% From breeding materials kapia type, line 1186/06 was with the highest yield in two systems with Lumbrical use and in those without plant protection the exceeding compared to the control was the biggest (17.66%)..

Table 1. Three-way analysis of variance on total yield and fruit weight

Factors of variation	Degree of freedom	Total yield		Fruit weight	
		Mean square	Influence	Mean square	Influence
	df	MS	%	MS	%
Genotype (A)	7	1.08E+08***	50.81	50804.78***	85.16
System of production (B)	4	729481.4***	0.20	1644.86***	1.58
Year (C)	2	2.14E+08***	28.87	717.54***	0.34
Interaction A x B	28	1255637***	2.37	203.41***	1.36
Interaction A x C	14	11197098***	10.56	300.92***	1.01
Interaction B x C	8	2568498***	1.38	1177.60***	2.26
Interaction A x B x C	56	1111631***	4.19	142.61***	1.91
Residual	360	67341.24***		74.00***	

* p<0.05, ** p<0.01, *** p<0.001, ns – non significant

Breeding line 1265/07 (now - variety Kaloyan) also had good performance in most organic systems. In this one with Lumbrical fertilization and bio pesticides use variety Buketen 50 unproved reduced its yield – only 6.49% compared to the conventional system. Berova et al. (2010) reported proved higher yield from Buketen 50 grown with Lumbrical use than in soil without this bio fertilizer.

All systematic sources were proved responsible for variability of the fruit weight but the genotype differences had dominant influence – 85.16% (Table 1).

During the experimental period most studied genotypes formed heavier fruits in conventional production - using of fertilizers and pesticides with chemical origin. Exceptions were recorded in materials for ground pepper (Table 2). Stryama variety was with insignificant differences by this character in all growing conditions, while lines 1265/07, 1186/06 and 1266/07 formed fruits with proven less weight than in the control variant. The cultivation in organic production systems had the most negative effect by this character on line 1265/07 - the deviation was from 23.71% to 26.99% compared to the control. In systems with application of bio pesticides variety Buketen 50 demonstrated heavier fruits but excess was significant only by using natural soil fertility (16.51%). Khalaf (2007) reported for irregular trend for fruit fresh weight, with an insignificant difference between organically and conventionally grown hot pepper, while Berova et al., (2010) revealed significant differences in fruit weight of variety Buketen 50 grown in soils with different Lumbrical fertilization rates and ones without biofertilizer application. Szafirowska and Elkner (2009) also established that organic fruits distinguished themselves with higher mean fruit weight as compared to conventional fruits.

Table 2. Estimation of sweet pepper genotypes by total yield an fruit weight

Genotype		Toatal yield		Fruit weight	
		kg da $^{-1}$	%	g	%
Stryama	1	3416 d	100.00	70.14 ns	100.00
	2	4828 ab	141.32	68.77 ns	98.05
	3	4082 c	119.49	62.54 ns	89.16
	4	4630 b	135.54	66.34 ns	94.58
	5	4964 a	145.32	63.40 ns	90.39
	Mean value	4384		66.24	
K558	1	3754 ns	100.00	100.28 a	100.00
	2	3522 ns	93.83	80.73 c	80.50
	3	3679 ns	98.01	86.21 bc	85.97
	4	3323 ns	88.53	91.43 abc	91.17
	5	3649 ns	97.20	96.68 ab	96.41
	Mean value	3585		91.07	
1264/07	1	3899 ns	100.00	75.67 a	100.00
	2	3881 ns	99.54	71.11 ab	93.97
	3	3904 ns	100.13	67.93 b	89.77
	4	3770 ns	96.69	65.67 b	86.78
	5	4000 ns	102.60	69.77 ab	92.20
	Mean value	3891		70.28	
1265/07	1	3764 b	100.00	81.50 a	100.00
	2	3826 b	101.64	62.18 b	76.29
	3	3345 c	88.85	60.54 b	74.28
	4	3644 b	96.82	59.50 b	73.01
	5	4059 a	107.83	61.25 b	75.15
	Mean value	3728		65.00	
1186/06	1	2935 c	100.00	75.26 a	100.00
	2	2423 d	82.57	61.50 b	81.72
	3	3453 a	117.66	58.98 b	78.37
	4	3049 c	103.89	59.41 b	78.94
	5	3213 b	109.50	61.84 b	82.17
	Mean value	3014		63.40	
1266/07	1	3565 a	100.00	79.12 a	100.00
	2	2871 c	80.53	64.78 c	81.88
	3	3176 b	89.09	64.99 c	82.14
	4	3160 b	88.64	67.3 bc	85.06
	5	3196 b	89.67	70.23 b	88.76
	Mean value	3193		69.28	
P708/08	1	1388 a	100.00	9.20 a	100.00
	2	819 cd	59.00	7.88 bc	85.65
	3	940 bc	67.71	8.11 b	88.15
	4	1009 b	72.69	9.41 a	102.28
	5	747 d	53.78	7.18 c	78.04
	Mean value	981		8.36	
Buketen 50	1	941 a	100.00	12.96 b	100.00
	2	712 b	75.73	12.54 b	96.76
	3	694 b	73.82	12.29 b	94.83
	4	701 b	74.52	15.10 a	116.51
	5	880 a	93.51	14.14 ab	109.10
	Mean value	786		13.41	

Legend: 1 – conventional system (control); 2 – use of natural soil fertility without plant protection; 3 – fertilization with bioproduct and without plant protection; 4 – natural soil fertility use with bio pesticides application; 5 – system with application of bio product and bio pesticides

a, b, c, ns - Duncan's multiple range test ($p<0.05$)

All factors were with proven role on the phenotypic expression of the fruit length but the genotype exerted decisive influence - 66.11% (Table 3). The influence of other factors and the interaction between them was less than 6% and total of them it reached 19.69%.

Five genotypes - breeding lines 1186/06 and 1266/07 (kapia type), 1265/07, K558 (*Grossum* group) and variety Stryama (conical type) were with the longest fruit in conventional production but the differences in all studied farming systems were not significant at genotypes K558, 1264/07 and P708/08 (Table 4). The most considerable decrease was in line 1265/07 - from 15.98% to 17.60%. In the ranks of the growing systems these ones with bio pesticides use followed control variant for lines kapia type and K558 and they demonstrated better results than conventional for Buketen 50. On the base of conducted three-way analysis of variance it was established that only factor of production system was with an unproven effect on the variability of fruit diameter (Table 3). Genotypic differences were with dominant influence - 90.58%, while the remaining factors – with slight but proven impact.

Throughout the experimental period in seven of studied varieties, accession and lines it was determined that the differences by diameter at the base of the fruit were not considerable in all systems of production (Table 4). Only Buketen 50 was characterized with higher absolute values in all systems for organic farming compared to the control variant. The increase was statistically significant in systems using bio pesticides and in this with Lumbrikal application without plant protection - from 11.31% to 16.07%. Kir and Mordogan (2010) also reported the highest measurements for fruit length and width in organically produced red pepper compared to the conventional.

Table 3. Three-way analysis of variance on the length and diameter of the fruit

Factors of variation	Degree of freedom	Length		Diameter	
		Mean square	Influence	Mean square	Influence
	df	MS	%	MS	%
Genotype (A)	7	166.33***	66.11	197.52***	90.58
System of production (B)	4	12.58***	2.86	0.16 ^{ns}	-
Year (C)	2	46.23***	5.25	20.48***	2.68
Interaction A x B	28	1.61***	2.56	0.20 *	0.37
Interaction A x C	14	2.41***	1.91	1.77 ***	1.63
Interaction B x C	8	8.77***	3.98	1.04***	0.55
Interaction A x B x C	56	0.99*	3.13	0.23**	0.84
Residual	360	0.69		0.14	

* p<0.05, ** p<0.01, *** p<0.001, ns – non significant

Conclusion

As a result of the study it was found that the genotype had a predominant influence on the variability of analyzed quantitative characters. The studied pepper varieties, accession and breeding lines haven't the same response in none of the applied organic system. All systems for organic production have negative effect in breeding lines 1265/07, 1186/06 and 1266/07 toward the length and weight of the fruits. Variety Buketen 50 and accession K558 were revealed very successfully by most studied fruit characters in systems with application of bio pesticides.

Variety Stryama demonstrated a higher total yield (from 19.49% to 45.32%) in all organic systems and the differences by weight and diameter of the fruits were unproven. Line 1186/06 also demonstrated_significant higher yield in most organic systems but it was with lower values toward the fruit characters.

It could be summarized that genotypes with different fruit shape, attitude and direction of producing, processing and consuming were identified and could be used as an initial material for future organic breeding.

Table 4. Estimation of sweet pepper genotypes by length and diameter of the fruit

Genotype		Length		Diameter	
		cm	%	cm	%
Stryama	1*	11.71 a	100.00	4.41 ns	100.00
	2	11.22 ab	95.82	4.32 ns	97.96
	3	10.66 b	91.03	4.21 ns	95.46
	4	11.05 b	94.36	4.20 ns	95.24
	5	10.85 b	92.66	4.30 ns	97.51
	Mean value	11.09		4.28	
K558	1	8.42 ns	100.00	6.61 ns	100.00
	2	8.00 ns	95.01	6.24 ns	94.40
	3	7.92 ns	94.06	6.08 ns	91.98
	4	8.34 ns	99.05	6.51 ns	98.49
	5	8.34 ns	99.05	6.51 ns	98.49
	Mean value	8.20		6.39	
1264/07	1	9.18 ns	100.00	5.31 ns	100.00
	2	9.00 ns	98.04	5.34 ns	100.56
	3	8.59 ns	93.57	5.21 ns	98.12
	4	9.28 ns	101.09	4.99 ns	93.97
	5	8.91 ns	97.06	5.20 ns	97.93
	Mean value	8.99		5.21	
1265/07	1	9.26 a	100.00	5.65 ns	100.00
	2	7.63 b	82.40	5.49 ns	97.17
	3	7.78 b	84.02	5.50 ns	97.35
	4	7.76 b	83.80	5.41 ns	95.75
	5	7.69 b	83.05	5.41 ns	95.75
	Mean value	8.02		5.49	
1186/06	1	12.88 a	100.00	4.79 ns	100.00
	2	11.34 b	88.04	4.55 ns	94.99
	3	11.28 b	87.58	4.68 ns	97.70
	4	11.95 b	92.78	4.47 ns	93.32
	5	11.35 b	88.12	4.77 ns	99.58
	Mean value	11.76		4.65	
1266/07	1	12.86 a	100.00	4.52 ns	100.00
	2	10.68 c	83.05	4.64 ns	102.65
	3	11.42 bc	88.80	4.51 ns	99.78
	4	11.52 bc	89.58	4.66 ns	103.10
	5	11.76 b	91.45	4.60 ns	101.77
	Mean value	11.65		4.59	
P708/08	1	9.80 ns	100.00	1.03 ns	100.00
	2	10.02 ns	102.24	1.03 ns	100.00
	3	9.78 ns	99.80	1.14 ns	110.68
	4	9.98 ns	101.84	1.08 ns	104.85
	5	9.59 ns	97.86	1.08 ns	104.85
	Mean value	9.83		1.07	
Buketen 50	1	7.91 ab	100.00	1.68 c	100.00
	2	7.47 ab	94.44	1.83 bc	108.93
	3	7.32 b	92.54	1.87 b	111.31
	4	7.96 a	100.63	2.04 a	121.43
	5	8.01 a	101.26	1.95ab	116.07
	Mean value	7.74		1.88	

Legend: 1 – conventional system (control); 2 – use of natural soil fertility without plant protection; 3 – fertilization with Lumbrical without plant protection; 4 – natural soil fertility use with bio pesticides application; 5 – system with application of Lumbrical and bio pesticides

a, b, c, d, ns - Duncan's multiple range test ($p<0.05$).

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