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Influence of economically important diseases and pests on the yield of pepper varieties and breeding lines (*Capsicum annuum* L.) grown in organic conditions

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Abstract

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The pepper crop is attacked by a number of diseases and pests during the growing season which decrease the quality of production and cause significant yield losses, depending on the degree of attack.

The aim of the study was to determine the impact of economically important diseases and pests on the yield of pepper varieties and breeding lines grown in conditions of organic production. Five genotypes have been studied in four organic production systems compared to conventional one. The following traits were reported: damaged fruits (%) by cotton bollworm (*Helicoverpa armigera* Hubn.) and damaged plants (%) by *Alternaria* spp., *Phytoplasma solani* and viruses. The traits – total yield (kg da^{-1})*, yield of healthy fruits (kg da^{-1}) and yield of damaged (infested) fruits (kg da^{-1}) had been also studied.

The lowest infestation by *Helicoverpa armigera* Hubn. in organic production systems was established in the genotypes for grinding – from 2.86% to 4.08% for variety IZK Kalin and from 3.43% to 3.47% for line P1059/10. Higher susceptibility to infestation by cotton bollworm was found in the cultivar Sofiyska kapia (10.84%). Of the studied pepper varieties and breeding lines, with the lowest sensitivity to *Alternaria* spp., *Phytoplasma solani* and viruses showed the genotypes for grinding (variety IZK Kalin and line P1059/10), which makes them suitable for inclusion in organic production systems due to their general expressed tolerance to the tested pathogens.

In all studied genotypes in the systems of organic production lower yields were found compared to the conventional method of cultivation, as the yield of healthy fruits took a larger part of the total yield.

Keywords: Capsicum annuum; Helicoverpa armigera; Alternaria spp.; *Phytoplasma solani;* viruses, infestation

Introduction

Pepper (*Capsicum* spp.) is one of the main vegetable crops grown worldwide.

It belongs to the genus *Capsicum*, which includes 36 species, five of which are cultivated forms – *Capsicum annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. pubescens* (Eshbaugh, 2012). The great importance and spread of this crop are due to the high biological value of its fruits, which possess valuable nutritional, dietary and taste qualities and have healty effects. Adaptation of pepper in the conditions of organic production requires studies related to the use of organic fertilizers (Berova et al., 2013; Vlahova & Popov, 2014; Vlahova, 2015a; Vlahova, 2020), for application of plant protection products to diseases and pests (Yankova et al., 2009; Cwalina-Ambroziak & Czajka, 2010; Machi-

*1 da = 1000 m^2

al, 2010; Yankova & Todorova, 2011; Masheva & Yankova, 2012) and last but not least, with the productive capabilities of genotypes and significant morphological, and biochemical traits (Szafirowska & Elkner, 2008; Flores et al., 2009; Todorova et al., 2013).

Organic vegetable production is increasingly looking for local varieties, accessions and breeding lines that are adapted to certain conditions and have the specific taste qualities preferred by consumers (Panayotov, 2003). In recent years, there has been an increase in pepper consumption, and maintaining this trend requires the development and establishment of new sustainable and high-yielding varieties (Parisi et al., 2020). The choice of varieties with the application of appropriate production practices in cultivation would contribute to the successful organic production of high quality pepper (Bicikliski et al., 2018).

As one of the intensive vegetable crops, pepper had been attacked by a number of diseases and pests during the growing season, which led to a deterioration in production quality and lower yields, depended to the degree of the pest infestation (Vasileva & Todorova, 2020; Yankova et al., 2020). Crop production can be compromised by different types of pests – thrips, cicadas, aphids, owlet moths, viral, fungal and other patogens, caused damages to the leaves, flowers and fruits directly or indirectly. Some vectors transmitted viral and mycoplasmal diseases, which further determined the need for effective plant protection against them (Sorenson, 2009). Only a few are identified as economically important, and the management of these pests is critical to successful pepper production (Boucher & Ashley, 2001). Peach aphid colonies (*Myzus persicae* Sulz) and fruit damage from the larves of the *Helicoverpa armigera* Hubn. are often observed in crops (Yankova & Todorova, 2011; Yankova, 2012).

The cotton bollworm (*Helicoverpa armigera* Hubn.) is one of the pests that caused significant damage to pepper fruits. Its larvae are typical polyphagous. In Bulgaria, the cotton bollworm is widespread, found both outdoors and in cultivation facilities. In recent years, there had been an increase of the pest population, which is probably due to changed biotic and abiotic factors (Yankova et al., 2020; Yankova et al., 2021).

The losses caused by the *H. armigera* infestation could be significant if adequate control measures are not taken. Penetration of the larva in the fruit makes its control very difficult, hence preventive measures are needed to avoid pest penetration into the fruit (Sannino et al., 2004b).

The economic consequences of pests and diseases in organic farming systems vary considerably depended on the region, and in some cases the yields are highly reduced. Optimization of organic production can be supported if yield stability is enhanced through better control of diseases and pests (Lammerts van Bueren, 2003).

The aim of the study was to determine the impact of economically important diseases and pests on the yield of pepper varieties and breeding lines grown in organic production. The research was part of organic breeding of genotypes with increased resistance/tolerance to pests.

Material and Methods

The study was conducted in three consecutive years (2011 – 2013) in the experimental field of the Maritsa Vegetable Crops Research Institute (Maritsa VCRI), Plovdiv.

Plant material

The subject of the study were five pepper genotypes: from the Kapia varietal type – Sofiyska kapia, Kurtovska kapia 1 and breeding line 1238/09, and for grinding – variety IZK Kalin and breeding line P1059/10. All genotypes were developed in Maritsa VCRI.

Seed germination, transplanting, and plant growth period

The setting of the experiment, the seedling production, the growing during the vegetation, the applied agro-technical activities and the period of their implementation were in accordance with the technology for mid-early open field production, as plants, in the control variant were grown according to the accepted technology of Todorova et al. (2014). The seeds of the studied genotypes were planted in an unheated greenhouse in the middle of March. The experiments were set in the open field, on a profiled area, on a high flat bed by randomized block design in five production systems with four replications (each with 30 plants), transplanting was carried out in the second half of May, with a planting scheme 100 + 60/15 cm.

Systems of organic production:

- S1 – conventional system (control);
- S2 – non-fertilizer and non-plant protection system;
- S3 –system with Lumbrikal fertilization, without plant protection;
- S4 – system without fertilization, with biopesticides plant protection;
- S5 – system with Lumbrikal fertilization and with biopesticides plant protection.

Fertilization doses were determined after an agrochemical analysis of the soil's nutrient supply and a recommendation prepared in accordance with the biological requirements of pepper. Lumbrical fertilization was performed twice during the growing season in the systems S3 and S5. The first treatment was carried out 10 days after planting with a rate of 100 ml/plant, and the second – 30 days later with a rate of 150 ml/plant. Fertilization in the control variant (S1) was carried out with mineral fertilizers.

The aplication with plant protection products were carried out during the vegetation period – from seedling production to the end of harvesting, depending on the degree of pest infestation found during preliminary inspections. Plant protection in organic systems S4 and S5 was carried out with the following biopesticides:

- Timorex 66 EC 0.5 and 1% (a.i. extract of *Melaleuca alternifolia*);
- Pirethrum FS EC 0.05% (a.i. pyrethrum, extract of *Chrysanthemum cinerariefolium*);
- Piros 0.08% (a. i. pyrethrum, extract of *Chrysanthemum cinerariefolium*);
- Neem Azal T / S 0.3% (a. i. azadirachtin, a product of *Azadirachta indica*);
- Bioneem Plus 1.5 EC 0.25% (a. i. azadirachtin, product of *Azadirachta indica*).

The plant protection in the control variant S1 was performed with the following chemical products:

- Score 250 EC 0.04% (a. i. difeconazole);
- Funguran ON 50 WP 0.15% (a. i. copper hydroxide);
- Dithane M – 45 0.2% (a. i. mancozeb);
- Ridomil Gold MZ 68 WG 0.25% (a. i. metalaxil + mancozeb);
- Fastac new 100 EC 0.03% (a. i. alpha-cypermethrine);
- Nurelle D 50 ml/da (a. i. chlorpyrifos-ethyl + cypermethrin);
- Decis 2.5 EC 50 ml/da (a. i. deltamethrin);
- Mospilan 20 SP 25 g/da (a. i. acetamipride).

Subject of research

Assessment of pests against a natural background of attack in field conditions

During the vegetation, visual route inspections were carried out for the infestation of significant pest on the pepper, the trait of damaged fruit (%) of cotton bollworm (*Helicoverpa armigera* Hubn.) was reported. Damaged plants (%) of the phytopathogens *Alternaria* spp., *Phytoplasma solani* and viruses (*Tobacco mosaic virus* – TMV, *Cucumber mosaic virus* – CMV, *Tomato spotted wilt virus* – TSWV, etc) were also analyzed. The detected virus infestation was performed by visual assessment of symptomatic signs of plants. Three records were made at a natural background of infestation during the period of active growth and fruiting: during the first ten days of July, August and September.

Fruit yield

Varieties and breeding lines were also evaluated by:

- total yield (kg da^{-1})
- yield of healthy fruit (kg da^{-1})
- yield of infested or damaged fruit (kg da^{-1})

Yield was recorded at botanical maturity of the fruit in all tested genotypes. Three harvests were made for the genotypes of the Kapia varietal type and one for the grinding ones.

The obtained results were statistically processed according to the Duncan's method (Steele & Torie, 1980) through the program "R studio" (R Core Team, 2020), using the packages "agricolae" (Mendiburu, 2021), "readxl" (Wickham, 2019), "Rcpp" (Eddelbuettel & Balamuta, 2018) and "rstatix" (Kassambara, 2021).

Results and Discussion

Infestation by cotton bollworm (*Helicoverpa armigera* Hubn.). In the three-year study, the damaged fruits of the tested genotypes of this pest ranged from 2.86% to 10.84% average, but the amplitude between the minimum and maximum value was large – from 0.00% to 22.22% (Table 1). In Serbia, Keresi & Petrak (2013) monitored on organic produced tomato and sweet pepper the occurrence of cotton bollworm. Apperantly, sweet pepper was less atractive to this pest, as well as low fruit damage on sweet pepper around 15%. Serious damage was observed in Italy in field and glasshouse crops. Sannino et al. (2004a) state that the unusually warm summer weather caused Plant Protection Service (NL) and Central Science Laboratory (UK) joint Pest Risk Analysis for *Helicoverpa armigera* population levels to increase above average levels. In the spring of 2003, *H. armigera* was a serious problem on pepper crops in the Metaponto region in Italy. 30% of the pepper fruits and 70-80% of the pepper plants were damaged. The larvae fed on leaves, flowers and fruits, with fruits recording the most serious damage (Sannino et al., 2004b).`

In our study the lowest infestation of *H. armigera* was found in the genotypes for grinding: variety IZK Kalin in the system without fertilization, with biopesticides plant protection (S4) – 2.86% and the system with application of Lumbrical and biopesticides (S5) – 4.08%. In breeding line P1059/10 in systems with biopesticides treatment, the lowest impact was reported in system S4 (3.43%), followed by system S5 (3.47%). It is noteworthy that for both genotypes the lowest infestation is in the systems for organic production using biopesticides (S4 and S5), followed by the control variant (S1), and the largest is the infestation in the variants of organic production without plant protection (S2 and S3).

Table 1. Infestation by *Helicoverpa armigera* Hubn. in pepper genotypes grown in different systems of organic production

Genotype	System	Damaged fruits, %				
		Mean	Relative %	SD	Min	Max
Sofiyska kapia	S1	5.55 b	100,00	5,00	0,00	12,50
	S2	8.96 ab	161,44	5,19	3,03	17,17
	S3	10.84 a	195,32	6,33	3,03	21,21
	S4	8.55 ab	154,05	5,52	3,03	16,67
	S5	5.82 b	104,86	4,58	0,00	12,12
Kurtovska kapia 1	S1	5.97 ab	100,00	6,26	0,00	15,83
	S2	7.61 ab	127,47	3,21	3,03	12,12
	S3	9.76 a	163,48	4,56	0,00	14,14
	S4	4.14 b	69,35	3,16	0,00	8,08
	S5	5.42 b	90,79	4,16	0,00	11,11
1238/09	S1	5.55 ab	100,00	4,24	0,00	10,83
	S2	10.37 a	186,85	6,02	3,03	18,18
	S3	9.83 a	177,12	8,29	0,00	22,22
	S4	4.61 b	83,06	3,08	0,00	9,09
	S5	4.91 b	88,47	5,19	0,00	14,14
IZK Kalin	S1	4.59 ab	100,00	4,83	0,00	12,50
	S2	7.34 a	159,91	6,21	3,03	17,17
	S3	5.99 ab	130,50	4,23	3,03	14,14
	S4	2.86 b	62,31	3,30	0,00	7,07
	S5	4.08 ab	88,89	4,27	0,00	10,10
P1059/10	S1	3.89 b	100,00	3,73	0,00	9,17
	S2	4.85 ab	124,68	2,47	0,00	8,08
	S3	6.50 a	167,10	3,43	3,33	13,13
	S4	3.43 b	88,17	2,36	0,00	6,06
	S5	3.47 b	89,20	1,98	0,00	6,06

Legend: S1 – conventional system (control); S2 – system use of natural soil fertility without plant protection; S3 – fertilization with Lumbrical without plant protection; S4 – natural soil fertility use with biopesticides application; S5– system with application of Lumbrical and biopesticides plant protection;
a, b – Duncan's multiple range test ($p < 0.05$).

For the variety IZK Kalin the differences were statistically significant (at $p < 0.05$) only between organic systems with the lowest values in the *H. armigera's* infestation (S4) and the highest value of damaged fruit (S2), and for the breeding line – between the three systems with the lowest values (S4, S5, S1) and system with Lumbrikal fertilization without plant protection (S3).

In the Kapia genotypes, the plants grown in organic production systems with biopesticides application, the lowest infestation was established in Kurtovska kapia 1 in the system of natural soil fertility use with biopesticides application (S4) by 4.14%, followed by the system with application of Lumbrical and biopesticides (S5) with 5.42%. The differences were statistically non-proven at $p < 0.05$. The highest percentage of damaged fruits in the systems with biopesticides (S4 and S5), compared to the control (S1), was reported in the variety Sofiyska kapia 5.82% in the S5 system and 8.55% in the S4 system, statistically non-proven at $p < 0.05$. In pesticide-free systems, the lowest infestation was again observed in the genotypes for grinding. For variety IZK Kalin from 5.99% for fertilization with Lumbrical without plant protection (S3) to 7.34% for the system with natural soil fertility without plant protection (S2), and for line P1059/10 – 6.50% in the S3 system, statistically signifinant and 4.85% for S2, non-proven statistically. The highest values in these systems were found at Sofiyska kapia variety from 8.96% (S2) to 10.84% (S3). Higher values were also reported for line 1238/09 – 9.83% (S2) and 10.37% (S3), statistically non-proven at $p < 0.05$ (Table 1). In screening of different pepper accessions including some varieties for infestation by pests in field conditions, Yankova et al. (2020, 2021) did not detect an infestation from cotton bollworm in the varieties IZK Kalin (CAPS-67), CAPS-110 and CAPS-110A.

Infestation by phytopathogens and viral diseases. Observation of the infestation by *Alternaria* spp., the lowest infestation was found in the control variants with conventional growing system (S1) – from 1.25% for line P1059/10 to 3.69% for line 1238/09 (Table 2).

A high degree of infestation was recorded in all tested genotypes in the system with natural soil fertility without plant protection (S2). The highest attack was in the variety IZK Kalin – 8.46%, statistically proven at $p < 0.05$, which is 286.30% higher than the control (S1). In systems with the application of biopesticides (S4 and S5) the lowest infestation by *Alternaria* spp. observed in the variety IZK Kalin (3.19% in S4 and 3.64% in S5, statistically non-proven in $p < 0.05$) and breeding line P1059/10 (3.08% in S4 and 4.64% in S5, statistically significant in $p < 0.05$).

The lowest level of infestation by *Phytoplasma solani* was recorded in the control variants grown under conventional production conditions including fertilization with mineral fertilizers and treatment with chemical plant protection products. From all tested varieties and lines, the lowest degree of infestation in this variant (S1) was found in variety Kurtovska kapia 1 – 14.58%, followed by line P1059/10 – 15.97% and line 1238/09 – 16.11% (Table 2). In organic production systems, less infestation was determined for the genotypes for grinding, variety IZK Kalin (from 29.80% in system S3 to 36.53% in system S2) and line P1059/10 (from 31.55% in S2 to 33.64% in S4 statistically proven at $p < 0.05$). In the genotypes of Kapia varietal type the weakest infestation in all four systems of organic farming was established in Kurtovska kapia 1 – from

Table 2. Infestation by *Alternaria* spp., *Phytoplasma solani* and viruses (*Tobacco mosaic virus* – TMV, *Cucumber mosaic virus* – CMV and *Tomato spotted wilt virus* – TSWV) in pepper grown in diferent systems of organic production

Genotype	System	*Alternaria* spp.		*Phytoplasma solani*		Viruses	
		damaged	%	damaged	%	damaged	%
Sofiyska kapia	S1	2.64 c	100,00	17.92 b	100,00	4.44 a	100,00
	S2	6.33 ab	239,77	44.91 a	250,61	4.98 a	112,16
	S3	6.56 ab	248,48	32.93 ab	183,76	4.84 a	109,01
	S4	4.31 bc	163,26	44.58 a	248,77	2.73 a	61,49
	S5	7.22 a	273,48	41.28 a	230,36	3.37 a	75,90
Kurtovska kapia 1	S1	1.58 c	100,00	14.58 b	100,00	4.03 a	100,00
	S2	6.67 b	422,15	32.59 a	223,53	4.98 a	123,57
	S3	9.46 a	598,73	33.43 a	229,29	2.36 a	58,56
	S4	5.48b	346,84	32.83 a	225,17	4.64 a	115,14
	S5	7.44ab	470,89	39.49 a	270,85	3.23 a	80,15
1238/09	S1	3.69 b	100,00	16.11 b	100,00	3.75 a	100,00
	S2	7.95 a	215,45	45.22 a	280,70	7.10 a	189,33
	S3	6.49 a	175,88	41.17 a	255,56	3.37 a	89,87
	S4	3.81 b	103,25	35.99 a	223,40	4.48 a	119,47
	S5	6.72 a	182,11	35.86 a	222,59	3.87 a	103,20
IZK Kalin	S1	2.19 b	100,00	17.22 b	100,00	5.28 a	100,00
	S2	8.46 a	386,30	36.53 a	212,14	4.88 a	92,42
	S3	4.76 b	217,35	29.80 ab	173,05	4.24 a	80,30
	S4	3.19 b	145,66	33.87 a	196,69	3.37 a	63,83
	S5	3.64 b	166,21	31.00 ab	180,02	2.12 a	40,15
P1059/10	S1	1.25 c	100,00	15.97 b	100,00	7.64 a	100,00
	S2	4.25 ab	340,00	31.55 a	197,56	2.26 ab	29,58
	S3	5.21 a	416,80	32.56 a	203,88	3.50 ab	45,81
	S4	3.08 b	246,40	33.64 a	210,64	2.49 ab	32,59
	S5	4.64 ab	371,20	32.83 a	205,57	1.38 b	18,06

Legend: S1 – conventional system (control); S2 – system use of natural soil fertility without plant protection; S3 – fertilization with Lumbrical without plant protection; S4 – natural soil fertility use with biopesticides application; S5– system with application of Lumbrical and biopesticides plant protection; a, b, c – Duncan's multiple range test ($p < 0.05$).

32.59% in S2, to 39.49% in S5, which is from 123.53% to 170.85% increase, compared to the control. The differences were statistically significant at $p < 0.05$. In the systems with application of biopesticides S4 and S5 the highest degree of infestation was reported in variety Sofiyska kapia – 41.28% for S5 and 44.58% for S4, statistically proven at $p < 0.05$. Vlahova (2015b) in conditions of organic production of the variety Sofiyska kapia reports an infestation by *P. solani* up to 8.2% of infected plants.

The lowest virus infestation in studied genotypes was reported at line P1059/10 – 1.38% in the system with application of Lumbrical and biopesticides (S5), statistically proven at $p < 0.05$, 2.26% at S2, 2.49% at S4 and 3.50% in system S3, the differences being statistically non-significant at $p < 0.05$ (Table 2). In the systems with biopesticides S4 and S5 a lower infestation compared to the control variant was reported in varieties IZK Kalin (3.37% and 2.12%) and Sofiyska kapia (2.73% and 3.37%), but the differences were statistically non-proven. This is probably due to the good biological activity in the use of bioinsecticides to these pests (aphids and thrips) vectors of viral diseases, there is still no resistance. The highest percentage of infected plants in organic systems was observed in line 1238/09 – 7.10% in the system of use of natural soil fertility without plant protection (S2), non-proven statistically, which is 89.33% more than the control variant.

Establishing the mechanisms for resistance and overcoming the resistance in the populations of pests to insecticides intensively used in vegetable production would contribute to the creation of breeding planting material and its inclusion in the systems of organic production of pepper genotypes with pest resistance.

Evaluation of pepper genotypes by yield. The highest values of healthy fruit yields for all pepper varieties and

Table 3. Evaluation of pepper genotypes by total yield, yield of healthy fruits and yield of damaged fruits

Genotype	System	Yield of healthy fruits		Yield of damaged fruits		Total yield	
		kg da^{-1}	%	kg da^{-1}	%	kg da^{-1}	%
Sofiyska kapia	S1	2938.67 a	100,00	213.98 a	100,00	3152.65 a	100,00
	S2	1158.55 b	39,42	155.03 a	72,45	1313.58 b	41,67
	S3	1356.65 b	46,17	324.73 a	151,76	1681.38 b	53,33
	S4	1329.25 b	45,23	292.16 a	136,54	1616.54 b	51,28
	S5	1420.16 b	48,33	267.49 a	125,01	1687.65 b	53,53
Kurtovska kapia 1	S1	3935.54 a	100,00	341.01 ab	100,00	4276.55 a	100,00
	S2	1834.55 b	46,61	173.01 b	50,73	2007.56 c	46,94
	S3	2095.09 b	53,24	293.92 ab	86,19	2389.02 bc	55,86
	S4	2116.54 b	53,78	224.38 b	65,80	2340.92 bc	54,74
	S5	2758.28 b	70,09	484.31 a	142,02	3242.58 b	75,82
1238/09	S1	3163.96 a	100,00	233.31 b	100,00	3397.27 a	100,00
	S2	1277.16 b	40,37	268.41 ab	115,04	1545.57 d	45,49
	S3	1807.00 b	57,11	349.11 ab	149,63	2156.89 cd	63,49
	S4	2701.78 a	85,39	319.35 ab	136,88	3021.13 ab	88,93
	S5	1855.00 b	58,63	465.41 a	199,48	2320.41 bc	68,30
IZK Kalin	S1	1703.97 a	100,00	38.90 a	100,00	1742.87 a	100,00
	S2	845.99 b	49,65	11.01 b	28,30	857.00 b	49,17
	S3	752.69 b	44,17	13.74 b	35,32	766.43 b	43,97
	S4	1090.28 b	63,98	5.51 b	14,16	1095.79 b	62,87
	S5	964.80 b	56,62	10.21 b	26,25	975.01 b	55,94
P1059/10	S1	1574.47 a	100,00	39.93 a	100,00	1614.41 a	100,00
	S2	587.31 b	37,30	8.82 b	22,09	596.13 b	36,93
	S3	796.89 b	50,61	11.43 b	28,63	808.32 b	50,07
	S4	631.77 b	40,13	7.17 b	17,96	638.94 b	39,58
	S5	905.26 b	57,50	12.39 b	31,03	917.65 b	56,84

Legend: S1 – conventional system (control); S2 – system use of natural soil fertility without plant protection; S3 – fertilization with Lumbrical without plant protection; S4 – natural soil fertility use with biopesticides application; S5– system with application of Lumbrical and biopesticides plant protection; a, b, c, d – Duncan's multiple range test ($p < 0.05$).

breeding lines were reported in control variant (S1) from 1574.47 kg da^{-1} for line P1059/10 to 3935.54 kg da^{-1} for variety Kurtovska kapia 1 (Table 3). In the organic production systems, the highest yields of healthy fruits were found in variety Kurtovska kapia 1 in the system of natural soil fertility use with biopesticides application (S4) 2758.28 kg da^{-1} (statistically significant at $p < 0.05$) and 2701.78 kg da^{-1} at line 1238/09 in the system with application of Lumbrical and biopesticides (S5), statistically non-significant at $p < 0.05$.

The lowest yields in the systems with application of biopesticides (S4 and S5) were reported for the variety Sofiyska kapia (1329.25 kg da^{-1} and 1420.16 kg da^{-1}), and the differences were statistically non-proven at $p < 0.05$. In the genotypes for grinding, in the systems with application of biopesticides the highest yield was found in variety IZK Kalin in the system of natural soil fertility used with biopesticides application (S4) – 1090.28 kg da^{-1} and line P 1059/10 in the system with application of Lumbrical and biopesticides (S5) – 905.26 kg da^{-1}. The differences were statistically significant at $p < 0.05$.

The lowest values for the yield of damaged fruits in organic farming systems were found for pepper genotypes for grinding (Table 3). Yields from 5.51 kg da^{-1} in natural soil fertility use with biopesticides application (S4) to 13.74 kg da^{-1} in fertilization system with Lumbrical without plant protection (S3) were recorded for IZK Kalin variety. For line P1059/10 the yield of diseased fruits is from 7.17 kg da^{-1} in the system of natural soil fertility use with biopesticides application (S4) to 12.39 kg da^{-1} in the system with application of Lumbrical and biopesticides (S5). The differences were statistically proven at $p < 0.05$. The highest yields of damaged fruits in the systems with the application of biopesticides were found in the genotypes of Kapia varietal type. Most damaged fruits in the system with application of Lumbrical and biopesticides (S5) were observed in line 1238/09 – 465.41 kg da^{-1} (99.48% more than the control), followed by variety Kurtovska kapia 1 – 484.31 kg da^{-1} (42.02% more than the control) and variety Sofiyska kapia with 267.49 kg da^{-1} (25.01% more than the control). The differences were not statistically proven at $p < 0.05$.

The highest values, taking into account the total yield of all tested genotypes, were found in the control systems (S1) – from 1614.41 kg da^{-1} for line P1059/10 to 4276.55 kg da^{-1} for variety Kurtovska kapia 1. In the organic systems with application of biopesticides (S4 and S5), higher yields were realized for line 1238/09, respectively 3021.13 kg da^{-1} in system S4, statistically non-proven at $p < 0.05$, and 2320.41 kg da^{-1} in system S5, statistically proven at $p < 0.05$ (Table 3). The lowest values in all four organic production systems were reported for breeding line P1059/10, as the decrease in yield in different systems ranged from 43.16% (917.65 kg da^{-1}) in system S5 to 63.07% (596.13 kg da^{-1}).) in system S2, lower than the control. The differences were statistically proven at $p < 0.05$ (Table 3).

The decrease of the total yield compared to the control for the variety IZK Kalin in the systems S4 (1095.79 kg da^{-1}) and S5 (975.01 kg da^{-1}) was 37.13% to 44.06% lower. Among the genotypes of the Kapia varietal type, the lowest total yield in all four organic test systems was reported for the Sofiyska kapia variety from 1687.65 kg da^{-1} in system S5 to 1313.58 kg da^{-1} in system S2. The differences were statistically significant at $p < 0.05$ (Table 3). Our results confirmed the established lower total yields in organic production of all studied genotypes compared with conventional cyctem (Todorova et al., 2013). In a previous study, we found differences in the total yield of the studied pepper genotypes grown in organic production systems (Todorova & Filyova, 2014). In it, again, genotypes for grinding had the lowest yields compared to the conventional cultivation variant, while Stryama variety which was for green pepper production had a proven higher total yield in all organic systems. Gragera-Facundo et al. (2012) also reported that the organic system let to be obtain the same yield as the conventional one in two from three tested pepper varieties as they specified in the organic system three manual weeding and a higher number of phytosanitary treatments were necessary.

Conclusions

The Sofiyska kapia variety had a relatively high susceptibility to infestation by *Helicoverpa armigera* Hubn., while the Kurtovska kapia 1 variety, the IZK Kalin variety and the P1059/10 line showed relatively good unreceptiveness to natural population pests density and suitable for growing in organic conditions using biopesticides.

From all studied pepper varieties and breeding lines for organic production, the lowest susceptibility to *Alternaria* spp., *Phytoplasma solani* and viruses, showed variety IZK Kalin and line P1059/10, which made them suitable for inclusion in organic production systems due to their lower complex unreceptiveness to tested pathogens.

In the case of genotypes for grinding, variety IZK Kalin and line P1059/10, the lowest values of yield of damaged fruits were reported in the organic studied systems.

For all assessed genotypes, the yield of healthy fruit occupied a larger part of the total yield in all evaluated organic production systems.

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