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Evaluation of pepper (*Capsicum annuum* L.) accessions for infestation by pests

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Abstract

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The pepper is attacked by various types of pests during the vegetation. In recent years, changes in population density and species composition are observed and it was established that green peach aphid (*Myzus persicae* Sulz.), thrips (*Frankliniella occidentalis* Perg., *Thrips tabaci* Lindeman) and cotton bollworm *(Helicoverpa armigera* Hubn) are economically important pests. The infestation by these pests leads to a deterioration in the production quality and a reduction of the yields. Aphids and thrips are vectors of virus diseases. Chemical treatments are not always effective enough. The studies are aimed at developing species and varieties with increased resistance to pests, as an element of integrated plant protection systems. In this regard, tests to determine the response of 79 pepper accessions to infestation by these pests conducted on a natural background of infestation and under controlled conditions were conducted during the period 2018-2019 in the "Maritsa" Vegetable Crops Research Institute – Plovdiv. Three of them, CAPS-110A, CAPS-138 and CAPS-174, combined a relatively weak infestation by the three pests. A comparative characteristic of the infestation by the studied pests was made depending on the variety type, as well as on the presence of hotness in the fruits.

Keywords: Capsicum annuum; Myzus persicae; Frankliniella occidentalis; Thrips tabaci; Helicoverpa armigera; resistance

Introduction

Pepper (*Capsicum* spp.) is one of the major vegetable crops grown worldwide largely appreciated for its economic importance and nutritional value. This crop belongs to the large *Solanaceae* family, which, among more than 90 genera and 2500 species of flowering plants, includes commercially important vegetables such as tomato and eggplant. The genus includes over 30 species, five of which (*C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. pubescens*) are domesticated and mainly grown for consumption as food. The main challenges for vegetable crop improvement are linked to the sustainable development of agriculture, food safety, the growing consumers' demand for food. Furthermore, demographic trends and changes to climate require more efficient use of plant genetic resources in breeding programs. Increases in pepper consumption have been observed in the past 20 years, and for maintaining this trend, the development of new resistant and high yielding varieties is required (Parisi et al., 2020).

During the vegetation, pepper is attacked by various types of pests. In recent years changes in population density and species composition are observed and green peach aphids (*Myzus persicae* Sulz.), thrips (*Frankliniella occidentalis* Perg., *Thrips tabaci* Lindeman) and cotton bollworm (*Helicoverpa armigera* Hubn) are economically important. The infestation by these pests results in a deterioration in the production quality and a yield reduction. Aphids and thrips are vectors of virus diseases. The chemical treatments are not always effective enough due to the appearance of resistance to commonly used insecticides. The studies are aimed at developing of species and varieties with increased resistance to pests, as an element of integrated plant protection systems. Tests were performed with different pepper accessions to determine their response to pest infestation (Maris et al., 2003; Maharijaya et al., 2011; Maharijaya et al., 2012; Mdellel & Kamel, 2014). Sources of resistance are looking for in the rich gene pool that nature offers us as a selection method for control. Various indicators are used to evaluate pepper accessions. They give information about the response of the host plant on the one hand and on the other hand about its effect on the pest. Such are the biological parameters – population density, infection rate, relative growth and generation time (La Rossa et al., 2013; Mdellel & Kamel, 2014). Indicators of the degree of infestation, number of larvae or adults per plant, percentage of damaged fruits and plants (Fery & Schalk, 1991) are used to assess damage. Work is underway to uncover the mechanisms of resistance, which can be antibiosis or antixenosis. Free choice and forced non-choice host tests are performed to assess the response of the plant (Tanpure et al., 2017).

Conventional use of insecticides risks the development of resistance and damage to beneficial insects, while the availability of resistant pepper varieties offers an effective, economical and environmentally friendly management strategy. However, a green peach aphid resistance gene has not yet been identified in pepper. A study was conducted in greenhouse conditions and field screening for resistance to green peach aphid in 24 pepper varieties. The varieties ZDC as highly resistant and DYJJ as highly susceptible are included. Inheritance analyzes using these cultures as parents have been performed. The results show that pepper resistance to green peach aphid is probably controlled by a dominant gene. The highly resistant variety ZDC may be a possibility for including of resistance in future breeding programs after further studies (Chen et al., 2020).

In the "Maritsa" Vegetable Crops Research Institute – Plovdiv, the maintaining, studying and enrichment of a rich collection of local and foreign pepper accessions is an integral and important part of the breeding work in this crop (Todorov & Todorova, 2002). In recent years, one of the focuses of scientific research has been on a more in-depth and comprehensive study of the local pepper resources from Albania, Bulgaria, Greece, Macedonia, Serbia and Romania, with the majority (63.33%) coming from Bulgaria that are collected and kept at the Institute for decades (Nankar et al., 2020). The whole or part of the collection was evaluated for phenotypic, agronomic, morphological (Todorova et al., 2019) and biochemical traits (Denev et al., 2019; Tringovska et al., 2019), as well as for response to virus (Nankar et al., 2020) and fungal diseases (Vasileva et al., 2019). In this regard, 98 of these accessions were studied towards pest infestation by green peach aphid (*M. persicae*), thrips (*F. occidentalis*, *T. tabaci*) and cotton bollworm (*H. armigera*) (Yankova et al., 2020).

The aim of the study was to establish the infestation by important pests of other pepper accessions with origin from the Balkan Peninsula and to summarize the results of the search for sources of resistance to these pests.

Material and Methods

The studies were conducted in the "Maritsa" Vegetable Crops Research Institute – Plovdiv during the period 2018-2019. The remaining 79 pepper accessions were tested in a natural background of infestation by pests: green peach aphid (*Myzus persicae* Sulz.), thrips (*Frankliniella occidentalis* Perg. and *Thrips tabaci* Lindeman), and cotton bollworm (*Helicoverpa armigera* Hubn.). The seedling production of the materials was carried out in unheated greenhouses from the middle of March to the middle of May. The experiments in open field conditions were set by the block method in 3 replications, each with 10 plants according to the scheme 100 + 60/15 cm. In cultivation of the materials was applied medium early field production technology (Todorova et al., 2014).

Assessment in a natural background of an infestation in field conditions

- Green peach aphid (*Myzus persicae* Sulz.), percentage of damaged plants and degree of infestation of 5 rating scale, depending on the number of the pest (0 – no aphids, 1 – up to 5 aphids/ plant, 2 – from 6 to 25 aphids/plant, 3 – from 26 to 50 aphids/plant, 4 – over 50 aphids/plant) (Leclant & Remaudiere, 1970);
- Thrips (*Frankliniella occidentalis* Perg. and *Thrips tabaci* Lindeman), percentage of damaged plants, degree of infestation on 5 rating scale, depending on the symptoms (0 – no symptoms, 1 – minimal symptoms, 2 – poorly expressed symptoms, 3 – average expressed symptoms, 4 – strongly expressed symptoms) (Fery & Schalk, 1991);
- Cotton bollworm (*Helicoverpa armigera* Hubn.), percentage of damaged fruits (30 fruits from 10 plants).

The readings are performed at a natural background of infestation during the fruitage period.

Assessment in an artificial background of infestation in the laboratory conditions

Representatives from the core-collection, evaluated as resistant/tolerant at a natural background of infestation, were infected with green peach aphid (*M. persicae*) under laboratory / controlled/ conditions in pot experiments. Five plants per accession were infected, and 10 aphids per plant were imported. The total number of aphids in each accession was reported. Reporting was made 7, 14 and 21 days after the infestation of aphids.

Software products used for the investigation are "MS Excel Analysis Tool Pak Add-Ins" (https://support.office.com) and "R-3.1.3" in combination with "RStudio-1.1.447" and installed package "agricolae 1.2-2" (Mendiburu, 2015).

Results and Discussion

An assessment of 79 pepper accessions for infestation by pests was made. Basically, the accessions were tested in open field conditions and natural background of infestation, as some of the materials that showed resistance were also tested in artificial background of infestation by green peach aphids.

The results obtained by us show that there is a significant variation in the resistance of pepper accessions to infestation by these pests.

– Green peach aphid (*Myzus persicae* Sulz.)

In the tested accessions, no green peach aphid infestation was found in 74.68% of the materials. The percentage of damaged plants reaches 7.56% in the CAPS-160 accession. The degree of infestation varies from 0.00 to 0.55 in the CAPS-146 accession (Table 1).

Table 1. Infestation by pests in pepper accessions, grown in open field conditions

Accession	Varietal type	Pests				
		Green peach aphid		Thrips		Cotton bollworm
		Average % damaged plants	Average degree of infestation	Average % damaged plants	Average degree of infestation	Average % damaged fruit
CAPS-101	*ratundum*	1.11 bc	0.11 bc	34.81 n.s.	0.89 abcd	11.11 n.s.
CAPS-102	*kapia*	1.11 bc	0.11 bc	22.22 n.s.	1.00 abcd	3.33 n.s.
CAPS-103	*ratundum*	3.33 bc	0.22 abc	48.25 n.s.	1.11 abcd	12.22 n.s.
CAPS-104	*ratundum*	0.00 c	0.00 c	38.89 n.s.	1.00 abcd	14.44 n.s.
CAPS-105	*ratundum*	0.00 c	0.00 c	37.95 n.s.	1.11 abcd	23.33 n.s.
CAPS-107	*ratundum*	0.00 c	0.00 c	49.06 n.s.	1.00 abcd	13.33 n.s.
CAPS-108	*conical*	0.00 c	0.00 c	41.46 n.s.	1.22 abcd	15.56 n.s.
CAPS-109	*shipka*	0.00 c	0.00 c	62.22 n.s.	1.11 abcd	13.33 n.s.
CAPS-110	*cerasiforme*	0.00 c	0.00 c	35.56 n.s.	0.78 bcd	0.00 n.s.
CAPS-110A	*like shipka*	0.00 c	0.00 c	19.57 n.s.	0.67 cd	0.00 n.s.
CAPS-111	*shipka*	0.00 c	0.00 c	44.60 n.s.	0.67 cd	10.00 n.s.
CAPS-112	*like fish*	0.00 c	0.00 c	46.11 n.s.	0.89 abcd	10.00 n.s.
CAPS-113	*shipka*	0.00 c	0.00 c	39.58 n.s.	1.00 abcd	13.33 n.s.
CAPS-114	*small pumpkin*	0.00 c	0.00 c	31.81 n.s.	1.00 abcd	11.11 n.s.
CAPS-115	*cerasiforme*	0.00 c	0.00 c	44.95 n.s.	1.33 abcd	7.78 n.s.
CAPS-116	*shipka*	0.00 c	0.00 c	47.46 n.s.	1.00 abcd	18.89 n.s.
CAPS-117	*conical*	0.00 c	0.00 c	41.11 n.s.	1.11 abcd	13.33 n.s.
CAPS-117A	*conical*	3.33 bc	0.33 abc	47.22 n.s.	1.11 abcd	14.44 n.s.
CAPS-118	*corniforme*	0.00 c	0.00 c	41.75 n.s.	1.11 abcd	10.00 n.s.
CAPS-119	*conical*	0.00 c	0.00 c	51.53 n.s.	1.33 abcd	18.89 n.s.
CAPS-120	*corniforme*	0.00 c	0.00 c	43.33 n.s.	1.33 abcd	8.89 n.s.
CAPS-121	*corniforme*	0.00 c	0.00 c	33.06 n.s.	0.77 bcd	13.33 n.s.
CAPS-121A	*blocky*	1.11 bc	0.11 bc	49.52 n.s.	1.33 abcd	10.00 n.s.
CAPS-122	*kapia*	2.35 bc	0.44 ab	35.06 n.s.	0.89 abcd	6.67 n.s.
CAPS-123	*conical*	0.00 c	0.00 c	44.44 n.s.	1.00 abcd	10.00 n.s.
CAPS-124	*shipka*	0.00 c	0.00 c	33.66 n.s.	1.11 abcd	25.56 n.s.
CAPS-125	*shipka*	0.00 c	0.00 c	25.19 n.s.	0.89 abcd	15.56 n.s.
CAPS-126	*cerasiforme*	0.00 c	0.00 c	63.33 n.s.	0.89 abcd	5.56 n.s.
CAPS-127	*ratundum*	0.00 c	0.00 c	45.56 n.s.	1.11 abcd	10.00 n.s.
CAPS-128	*cerasiforme*	0.00 c	0.00 c	37.36 n.s.	1.44 abcd	10.00 n.s.

Table 1. Continued

CAPS-129	*kapia*	3.33 bc	0.11 bc	48.10 n.s.	1.33 abcd	8.89 n.s.
CAPS-130	*like fish*	0.00 c	0.00 c	45.19 n.s.	1.33 abcd	8.89 n.s.
CAPS-131	*ratundum*	1.11 bc	0.11 bc	46.11 n.s.	1.00 abcd	6.67 n.s.
CAPS-132	*corniforme*	0.00 c	0.00 c	36.11 n.s.	1.00 abcd	12.22 n.s.
CAPS-133	*blocky*	0.00 c	0.00 c	42.22 n.s.	0.89 abcd	6.67 n.s.
CAPS-133A	*kapia*	0.00 c	0.00 c	46.67 n.s.	1.11 abcd	15.56 n.s.
CAPS-134	*blocky*	0.00 c	0.00 c	44.92 n.s.	1.22 abcd	12.22 n.s.
CAPS-135	*blocky*	0.00 c	0.00 c	63.33 n.s.	1.00 abcd	2.22 n.s.
CAPS-135A	*ratundum*	0.00 c	0.00 c	52.22 n.s.	1.67 a	4.44 n.s.
CAPS-136	*blocky*	0.00 c	0.00 c	49.60 n.s.	0.78 bcd	21.11 n.s.
CAPS-137	*shipka*	0.00 c	0.00 c	15.87 n.s.	0.78 bcd	11.11 n.s.
CAPS-138	*kapia*	0.00 c	0.00 c	6.67 n.s.	0.55 d	4.44 n.s.
CAPS-139	*shipka*	0.00 c	0.00 c	44.65 n.s.	0.78 bcd	2.22 n.s.
CAPS-140	*kapia*	0.00 c	0.00 c	44.29 n.s.	1.33 abcd	12.22 n.s.
CAPS-141	*kapia*	3.33 bc	0.22 abc	26.98 n.s.	1.33 abcd	10.00 n.s.
CAPS-142	*kapia*	1.11 bc	0.11 bc	42.11 n.s.	1.33 abcd	11.11 n.s.
CAPS-143	*blocky*	3.51 bc	0.33 abc	46.84 n.s.	1.11 abcd	8.89 n.s.
CAPS-143A	*kapia*	1.11 bc	0.11 bc	42.22 n.s.	1.33 abcd	5.56 n.s.
CAPS-144	*corniforme*	0.00 c	0.00 c	37.52 n.s.	0.78 bcd	11.11 n.s.
CAPS-145	*kapia*	0.00 c	0.00 c	40.00 n.s.	1.66 ab	11.11 n.s.
CAPS-146	*blocky*	4.85 ab	0.55 a	40.81 n.s.	1.33 abcd	18.89 n.s.
CAPS-147	*blocky*	0.00 c	0.00 c	35.00 n.s.	1.22 abcd	10.00 n.s.
CAPS-148	*blocky*	2.08 bc	0.33 abc	41.94 n.s.	0.89 abcd	7.78 n.s.
CAPS-149	*corniforme*	0.00 c	0.00 c	46.67 n.s.	1.00 abcd	6.67 n.s.
CAPS-149A	*corniforme*	0.00 c	0.00 c	53.70 n.s.	0.89 abcd	5.00 n.s.
CAPS-150	*kapia*	0.00 c	0.00 c	35.56 n.s.	1.11 abcd	13.33 n.s.
CAPS-151	*kapia*	0.00 c	0.00 c	37.25 n.s.	0.67 cd	11.11 n.s.
CAPS-151A	*ratundum*	0.00 c	0.00 c	42.14 n.s.	1.11 abcd	11.11 n.s.
CAPS-151B	*kapia*	1.19 bc	0.33 abc	36.98 n.s.	1.33 abcd	2.22 n.s.
CAPS-152	*shipka*	0.00 c	0.00 c	46.30 n.s.	1.11 abcd	8.89 n.s.
CAPS-153	*corniforme*	0.00 c	0.00 c	46.58 n.s.	1.33 abcd	6.67 n.s.
CAPS-154	*conical*	0.00 c	0.00 c	43.06 n.s.	1.00 abcd	14.44 n.s.
CAPS-155	*corniforme*	0.00 c	0.00 c	34.80 n.s.	1.11 abcd	13.33 n.s.
CAPS-156	*conical*	0.00 c	0.00 c	32.22 n.s.	1.44 abcd	15.56 n.s.
CAPS-157	*kapia*	1.11 bc	0.11 bc	47.14 n.s.	1.33 abcd	23.33 n.s.
CAPS-158	*conical*	0.00 c	0.00 c	31.21 n.s.	0.89 abcd	15.56 n.s.
CAPS-159	*kapia*	0.00 c	0.00 c	39.26 n.s.	1.55 abc	11.11 n.s.
CAPS-160	*blocky*	7.56 a	0.44 ab	39.33 n.s.	1.11 abcd	14.44 n.s.
CAPS-161	*blocky*	0.00 c	0.00 c	52.64 n.s.	1.22 abcd	8.89 n.s.
CAPS-162	*kapia*	4.44 abc	0.22 abc	32.72 n.s.	0.89 abcd	12.22 n.s.
CAPS-163	*ratundum*	3.33 bc	0.11 bc	46.06 n.s.	1.22 abcd	7.78 n.s.
CAPS-164	*ratundum*	1.11 bc	0.11 bc	45.56 n.s.	1.44 abcd	4.44 n.s.
CAPS-165	*ratundum*	0.00 c	0.00 c	43.17 n.s.	1.00 abcd	13.33 n.s.
CAPS-166	*corniforme*	0.00 c	0.00 c	38.97 n.s.	1.44 abcd	10.00 n.s.
CAPS-168	*kapia*	0.00 c	0.00 c	23.33 n.s.	1.11 abcd	7.78 n.s.
CAPS-169	*ratundum*	0.00 c	0.00 c	47.17 n.s.	1.00 abcd	8.89 n.s.
CAPS-171	*kapia*	0.00 c	0.00 c	34.44 n.s.	0.78 bcd	18.89 n.s.
CAPS-173	*kapia*	0.00 c	0.00 c	38.89 n.s.	0.78 bcd	16.67 n.s.
CAPS-174	*shipka*	0.00 c	0.00 c	18.57 n.s.	0.55 d	5.56 n.s.

With some of the accessions showing no infestation by green peach aphid in field conditions, tests were performed on an artificial background of infection. A small number of aphids was found 21 days after infestation and no population growth in CAPS-110 and CAPS-110A accessions, followed by CAPS-113. In accessions CAPS-110 and CAPS-110A, the population began to decrease significantly on the 7th day after infestation. This suggests that these accessions are an unsuitable host for green peach aphid (Figure 1).

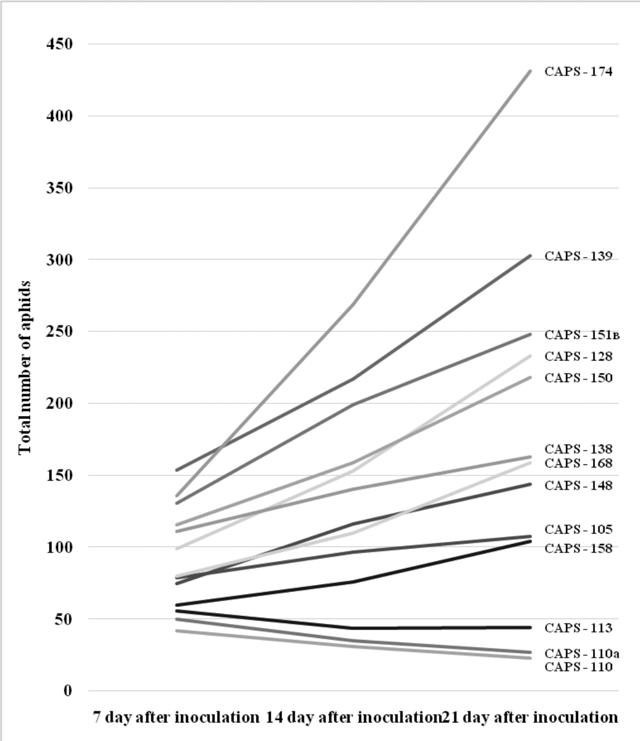

Fig. 1. Status of the aphid's population *Myzus persicae* Sulz. in pepper accessions in an artificial background of infestation

– Thrips (*Frankliniella occidentalis* Perg. and *Thrips tabaci* Lindeman)

In all tested pepper accessions, an infestation of thrips was found. There is a variation in both the percentage of damaged plants and the degree of infestation. The infestation of thrips (*Frankliniella occidentalis* Perg. and *Thrips tabaci* Lindeman) varies from 6.67% damaged plants in accession CAPS-138 to 63.33% damaged plants in accession CAPS-126 and CAPS-135. The degree of infestation varied from 0.55 in accessions CAPS-138 and CAPS-174 to 1.44 in accessions CAPS-128, CAPS-156 and CAPS-164 (Table 1).

– Cotton bollworm (*Helicoverpa armigera* Hubn.)

In the cotton bollworm, the percentage of damaged fruits ranges from 0% in accession CAPS-110 and CAPS-110A to 25.56% in accession CAPS-124, followed by CAPS-105 and CAPS-157 with 23.33% damaged fruit. Accessions CAPS-135, CAPS-139 and CAPS-151B (Table 1) also stand out with a relatively low percentage of damaged fruits (2.22%).

In the CAPS-110A, CAPS-138 and CAPS-174 accessions, a relatively weak infestation was found by the three pests. These three accessions are of Bulgarian origin and have shown susceptibility towards the infestation by tobam-

Table 2. Evaluation of pest infestation according to varietal type and pungency of studied accessions

Grouping of accessions	Number of accessions	Green peach aphid		Thrips		Cotton bollworm
		Average % damaged plants	Average degree of infestation	Average % damaged plants	Average degree of infestation	Average % damaged fruits
total	79	0.65	0.06	40.63	1.08	10.89
pungent	36	0.09	0.01	40.87	1.00	10.88
sweet	43	1.12	0.10	40.42	1.15	10.90
blocky	11	1.74	0.16	46.01	1.10	11.01
cerasiforme	4	0.00	0.00	45.30	1.11	5.83
conical	8	0.42	0.04	41.53	1.14	14.72
corniforme	10	0.00	0.00	41.25	1.08	9.72
kapia	19	1.00	0.09	35.78	1.13	10.82
like fish	2	0.00	0.00	45.65	1.11	9.44
shipka	11	0.00	0.00	36.15	0.88	11.31
ratundum	14	0.51	0.03	44.26	1.15	10.40

oviruses (Nankar et al., 2020). Both CAPS-110A and CAPS-174 produce small fruits with a hot taste, while CAPS-138 is characterized by sweet kapia type fruits. These accessions are of interest for the next breeding programs for resistance to the tested pests.

Averaging the results obtained for all 79 accessions, it demonstrated the infested plants and the degree of aphid infestation was lower, respectively 0.65% and 0.06, while the infested thrips plants were on average 40.63% with a degree of infestation 1.08 (Table 2). Fruits damaged by a cotton bollworm are on average 10.89%. Examining the infestation by these pests after grouping the accessions, there are some differences in the presence of hotness in the fruit or variety-type.

The plants of the accessions with hot fruits are infested significantly less than aphids (0.09%) and the degree of infestation is very low (0.01) compared to those with sweet fruits. In the other studied pests, no differences were observed between the two groups. Comparing the available eight varietal types to which the studied accessions belong, it is found that in the accessions of four varietal types – *cerasiforme*, *corniforme*, *like fish* and *shipka* no infested aphid plants were identified. The materials of the type *kapia* and *shipka* have the least infested plants, respectively 35.78% and 36.15%, as the degree of infestation in the first is 1.13, and in the second – 0.88. The infestation of cotton bollworm showed the greatest variation between the different varieties – from 5.83% damaged fruit for the accessions from *cerasiforme* to 14.72% damaged fruit for those of the *conical* variety type.

Conclusions

In the studied materials CAPS-110 and CAPS-110A was established that there are no infestation by *Myzus persicae* Sulz in open field conditions while in an artificial background the infection is weak.

Accessions CAPS-138 and CAPS-174 are characterized with a weak infestation by thrips (*Frankliniella occidentalis* Perg. and *Thrips tabaci* Lindeman).

In CAPS-110 and CAPS-110A, no infestation by the cotton bollworm (*Helicoverpa armigera* Hubn.) on the fruits was found.

The studied materials CAPS-110A, CAPS-138 and CAPS-174 showed a relatively weak infestation by the three pests and could be used in breeding programs for resistance to these pests.

A comparative characteristic of the infestation by the studied pests was made depending on the presence of hotness in the fruits, as well as according to the varietal type.

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