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Influence of the water deficit on growth indexes and pests infestation of pepper mutant lines

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Abstract

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Scarcity of water is a severe environmental limit to plant productivity. The plants were grown in a glasshouse as a substrate culture with two watering regimes. The biometric values decrease as a result of a reduced in the water regime. That effect is mostly expressed in the mass of fruits of first quality, where it varies from 27.1% to 69.5%. The most sensitive to the water stress was line C45 and entirely the best tolerance had line C41. The average fruit mass and the fruit mass of the fruits from first quality weren't influenced by reducing the water regime in line No.1928. During the vegetation, an attack of green peach aphid, thrips and cotton bollworm was observed. In full irrigation, there were no differences in thrips attack between pepper genotypes. In plants with reduced water regime, an increase in the density of the thrips was observed as the highest rate of infestation in line C45 was reported. The lowest percentage of damaged cotton bollworm fruits was observed in pepper genotype 1930 in both irrigation modes.

Keywords: pests infestation; mutant lines; pepper; peach aphid; bollworm

Introduction

Pepper is a traditional and economically important vegetable culture in Bulgaria (Boteva et al., 2012). In order to increase and stabilize yields and quality in the country, in-depth studies have been conducted on optimization of fertilization. Nutrition in modern agriculture is an important stage of production technology (Dintcheva et al., 2008; Boteva & Cholakov, 2011; Vlahova et al., 2011; Boteva & Georgieva, 2013; Boteva, 2014). At present, in Bulgaria the yields of vegetable crops are significantly lower than those of the countries with developed agriculture due to the climatic conditions, frequent natural anomalies (low and high temperatures, droughts, salinization, etc.), distinguishes its continental climate from that of other parts of Europe. Environmental conditions have a substantial impact on the yield and quality of tomato, pepper and eggplant grown under cover or in the field, not only because of their effect on assimilation, but also due to their influence on the reproductive processes leading to successful pollination, fertilization, fruit set and yield (Karapanos et al., 2008).

Drought stress is a major environmental factor that limits crop production and it is important to develop crop varieties with higher yield under water scarcity (Penella et al., 2014). Pepper is one of the most susceptible crops to water stress, mainly due to its large surface area and high stomatal conductance of water vapour (Alvino et al., 1994; Delfine et al., 2002). In the production of pepper, drought necessitates a tremendous reduction in yield and crop quality with significant economic losses of up to 70% (Delfine et al., 2002; De Pascale et al., 2003; Fernandez et al., 2005). In this connection, irrigation is essential for the production of pepper as these plants are particularly sensitive to the stressed stress during flowering and fruit conditions (Bosland & Votava, 2000). Thus, reduced yields and smaller berries are often recorded under stress conditions from moisture and furthermore, limiting the water applied to the peppers during the rapid growth period reduces the final yield according to Beese et al. (1982).

Various pests can damage pepper, among them are green peach aphid (*Myzus persicae*), western flower thrips (*Frankliniella occidentalis*), onion thrips (*Thrips tabaci*), cotton bollworm (*Helicoverpa armigera*), two spotted spider mites (*Tetranychus urticae* Koch). Colonies of green peach aphid and fruit damages by caterpillar of cotton bollworm are frequently observed (Yankova & Todorova, 2011; Yankova et al., 2011).

Various factors such as water stress, soil moisture and host plant can affect population of pests (Smith, 2005; Showler, 2012). Drought stress has adverse effects on plant growth and indirectly might increase population and damage of pests through changes in nutritional value of plant (Khederi et al., 2016). Moderate stress is known to improve the nutritional value of some plant tissues and sap, in some instances to reduce concentrations of plant defence compounds that help reduce pest populations to economically tolerable levels, each of them can lead to greater pest damages (Smitley and Peterson, 1996; Popov et al., 2006; Showler, 2012). The optimal water regime of the plant also affects the reduction of damage caused by the pests. In the drought stress, the attack of thrips and spider mites is greater (Bahariev et al., 1992).

The current study aim is to investigate the drought influence over indexes that characterize the productivity in mutant pepper forms.

Materials and Methods

The experiments were conducted in glasshouse Venlo type in the MVCRI, Plovdiv. Bulgaria with four pepper (*Capsicum annuum* L.) genotypes – cultivar Zlaten Medal №7 (№ 1928) and three mutants line No1930, № C 41 and № C45. The plants will be cultivated as a substrate culture (PE bag 16 L) without heating. The trial will be put by the block method in three repetitions as in each repetition there will be by four plants. During the bud formation-blossoming period the plants were exposed in two watering regimes. The first regime – Control 100% watering norm (the number of the watering will correspond to the perceived for that production technology) and the second regime – drought 50% watering norm (the number of the watering will be reduced with 50% towards the perceived for that production technology).

Of all the plants on each repetition reported the following indicators of yield components: Fruit diameter; Fruit length; Fruit length/fruit diameter; Pericarp thickness; Number of seeds per plant; Yield first quality; Total yield; The average fruit weight from first quality;

Monitoring on the four pepper lines in both irrigation regimes was carried out to determine pest species and the degree of infestation. The following test pests and indices have been recorded:

– Green peach aphids (*Myzus persicae* Sulz.) – percentage of damaged plants and degree of infestation on 5 rating scale. depending on the number of aphids (0 – no aphids; 1–5 aphids / plant; 2–6 to 25 aphids / plant; 3–26 to 50 aphids / plant; 4 – over 50 aphids / plant) (Leclant and Remaudiere. 1970);

– Thrips (*Frankliniella occidentalis* Perg. and *Thrips tabaci* Lindeman) – percentage of damaged plants and degree of infestation on five rating scale, depending on the symptoms (0 – no or minimal symptoms; 4 – severe symptoms) (Fery and Schalk 1991);

– Cotton bollworm (*Helicoverpa armigera* Hubn.) – percentage of damaged plants and percentage of damaged fruit.

Statistical analysis

The results are statistically processed by Duncan's Multiple range Test and Paired-Samples T-Test with ANOVA.

Results and Discussion

Fruit length/fruit diameter at base. In relation with the index fruit length to fruit diameter in the base between the separate genotypes significant differences were found. With highest correlation between the two parameters characterizing the fruit form amongst the control variants were found in line C41, where it reached up to 3.50. The smallest values of that index were reported in variants C45 – 2.02 cm/cm (Table 1).

The results in the treated plants were one way with those in the controls. Comparing line C41 it outlined with significantly elongated fruits in comparison with the rest of the variants (3.13 cm/cm). In the drought plants, also line C45 had lowest correlation of fruit length to fruit diameter in the base – 1.58 cm/cm. From the results that were obtained we could conclude that the water deficit did not exert significant influence over the fruit form.

No statistically proven differences were found towards the index correlation of length/fruit diameter in the base in comparison between the controls and the treated plants except for variant C45 where the value of that index decreased with 21.6% (Table 1).

Pericarp thickness. The statistical processing of the results obtained in the non-treated plants proved that the peppers from variant 1928 (5.12 mm) had provenly thicker peri-

Table 1. Fruit length/Fruit diameter at base in control and drought genotypes

Genotype	Fruit length/Fruit diameter at base, cm/cm		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	2.58 c	2.65 b	-0.07	0.35	0.18	n.s.	-2.5
1930	2.90 b	2.61 b	0.30	0.31	0.16	n.s.	10.2
C 41	3.50 a	3.13 a	0.37	0.28	0.14	n.s.	10.6
C 45	2.02 d	1.58 c	0.44	0.26	0.13	+	21.6

carp in comparison to lines C41 (4.28 mm) and C45 (4.26 mm). In the treated plants variant 1928 (4.37 mm) had distinct higher values of that index in comparison to the rest of the mutant forms. There was the thinest pericarp (3.90 mm) amongst the drought plants of line C45. The results that were obtained did not gave us a reason to claim that the water stress influenced significantly that index as a comparative morphological characteristics between the separate genotypes.

Treating with water deficit occurred negative influence over the thickness of the pericarp in variants 1928 and 1930 as in the drought plants the values of that index decreased with 14.7% and 14.0% respectively towrds the controls (Table 2). The same effect was observed in the rest of the variants but it was not statistically significant.

Number of seeds per plant. Concerning the index number of seeds per plant significant differences between the separate genotypes were not found as in the controls as well as in the treated plants. The values of that index vary from 206.9 number/ plant to 227.8 number/ plant in the drought and from 144.7 number/plant to 193.8 number/ plant in the drought peppers (Table 3).

The number of seeds was not significantly influenced as a result of the drought in line C45 only. The treatment with water deficit in the rest of the genotypes exerted negative effect as it decreased the seeds number in the treated plants from 22.6% in variant C41 to 30.0% in line 1930 (Table 3).

Yield first quality. The mathematical analysis of the obtained results in the control plants distributed the data defining the first quality production in two statistical groups. The variants 1928 (493.8 g/plant) and 1930 (478.3 g/plant) get into the first statistical group as they had proven higher values from the mutant lines C41 (307.4 g/plant) and C45 (289.7 g/plant) (Table 4). Statistically important differences were found in the plants treated with water deficit. The highest quantity first quality production was obtained in 1928 variety (292.7 g/plant) and the lowest in line C45 (88.4 g/plant).

Comparing the production from first quality in the control plants with the one gained from the corresponding treated variants, significant differences were found. The control plants are significantly superior the treated genotype analogues by that index. The negative effect expressed as a result of the water deficit was the weakest in the plants from line C41. The production quantity from first quality in the treated plants was with 83.3 g/plant lower in that line. The registered values of that index decreased with 27.1%. The strongest negative reaction by that index was observed in the treated plants from line 1930 where the production decreasing from first quality was with 279.69 g/plant in comparison with the control variant

Table 2. Pericarp thickness in control and drought genotypes

Genotype	Pericarp thickness, mm		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	5.12 a	4.37 a	0.75	0.19	0.09	++	14.7
1930	4.68 ab	4.02 bc	0.66	0.84	0.42	+	14.0
C 41	4.28 b	4.14 b	0.14	0.37	0.18	n.s.	3.3
C 45	4.26 b	3.90 c	0.35	0.40	0.20	n.s.	8.3

Table 3. Number of seeds per plantin control and drought genotypes

Genotype	Number of seeds per plant		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	208.1 n.s.	152.8 n.s.	55.4	11.6	5.8	+++	26.6
1930	206.9 n.s.	144.8 n.s.	62.2	24.7	12.3	++	30.0
C 41	207.4 n.s.	160.4 n.s.	47.0	9.8	4.9	++	22.7
C 45	227.8 n.s.	193.8 n.s.	34.0	55.6	27.8	n.s.	14.9

Table 4. Yield first quality g/plant in control and drought genotypes

Genotype	Yield first quality, g/plant		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	493.8 a	292.7 a	201.0	13.1	6.6	+++	40.7
1930	478.3 a	198.7 c	279.7	113.4	56.7	++	58.5
C 41	307.4 b	224.1 b	83.3	11.9	6.0	+++	27.1
C 45	289.7 b	88.4 c	201.3	13.4	6.7	+++	69.5

from the same line. The values reduction in percentage in that index was highest in line C45 where it decreased with 69.5% in the drought plants (Table 4).

Total yield. Significant differences were found in the total yield between the separate lines in the non-treated plants. The highest quantity of production was gained in variant with line 1928 – 850.2 g/plant and lowest in plants from line C45 – 499.9 g/plant. The results in the drought plants were analogue. The mutant form 1928 exceeded the rest of the variants by that index also as it registered yield from 579.2 g/plant. Line C45 was with the weakest productive qualities – 283.5 g/plant.

The comparative analysis of the yield in the treated plants in comparison with the controls determined statistically argumented differences in all variants. The decreasing of the productive behaviours as a result of the treating with water deficit was weakest in the variants C41 and 1928 where in the treated plants the yield decreased with 28.1% and 31.9% respectively, in the rest two lines it was lower with about 45%. The gained results were proved also from the investigation of Mafakheri et al. (2010) and Keyvan (2010), they found yield reducing as a result of treating with water deficit (Table 5).

The average fruit weight from first quality. The average fruit mass from first quality in the control plants was highest in the plants from variety 1928 – 44.7 g but it statistically superior the variant C45 – 40.8 g only (Table 6). More significant differences by that index between the separate genotypes were found in the treated variants. The values of that index get into four statistical groups of prove as they vary from 33.4g in line C45 to 47.0 g in variant 1928. The good results of Line No1928*ms*$_8$ (a mutant line with nuclear male sterility) grounded one more time the wide involving of the male sterile line in the breeding programs of Maritsa VCRI. In that connection it was repeatedly examined and highly evaluated and it takes a major role in developing of new hybrid varieties, combining genetic male sterility and heterosis effect (Tomlekova et al., 2014; Todorova & Arnaoudova, 2014).

The average fruit mass in the treated variant of 1928 variety superior with 4.9% the one of its control analogue but the difference was statistically insignificant (Table 6). The values of that index in the rest of the mutant forms in the non-treated plants were proven higher as a negative influence of the water stress vary from 18.1% in line C45 to 35.4% in variant 1930.

The average fruit weight. The average fruit mass in the control plants vary as mathematically significant differences were found between the separate variants. The highest value of that index was measured in line C41 – 40.7 g (Table 7). The control plants from variant C45 formed fruits with the

Table 5. Total yield (g/plant) in control and drought genotypes

Genotype	Yield first quality, g/plant		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	850.2 a	579.3 a	271.0	53.1	26.6	++	31.9
1930	687.2 b	370.9 c	316.3	9.5	4.8	+++	46.0
C 41	581.1 c	417.7 b	163.4	10.9	5.4	+++	28.1
C 45	499.9 d	283.5 d	216.4	19.5	9.8	+++	43.3

Table 6. The average fruit weight from 1-st quality in control and drought genotypes

Genotype	The average fruit weight from 1-st quality, g		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	44.7 a	47.0 a	2.3	3.1	1.6	n.s.	4.9
1930	42.6 ab	27.5 d	15.1	2.3	1.2	+++	35.4
C 41	43.9 a	30.7 b	13.3	2.7	1.4	++	30.2
C 45	40.8 b	33.4 c	7.4	1.5	0.8	++	18.1

Table 7. The average fruit weight (g) in control and drought genotypes

Genotype	The average fruit weight, g		Difference	Std. Deviation	Std. Error Mean	Sig.	%
	Control	Drought					
1928	33.7 c	32.6 a	1.1	3.2	1.6	n.s.	3.3
1930	36.6 b	28.1 b	8.6	0.6	0.3	+++	23.4
C 41	40.7 a	34.4 a	13.3	2.7	1.4	++	15.5
C 45	29.7 d	25.2 c	4.5	1.4	0.7	++	15.1

lowest average mass – 29.7 g. The variants C41 and 1928 in the treated mutant forms the average fruit mass was 34.4 g and 32.6 g, respectively which significantly exceeded the one of the other two variants.

The water deficit exerted negative effect over the fruit size in the tested variants except of 1928 variety. The negative influence of the wter deficit was highest expressed in the plants from line 1930 where it reached up to 23.4%. In the rest two genotypes it was in the range 15.1% – 15.5% (Table 7).

Pests infestation. During the vegetation of the pepper genotypes, an infestation of green peach aphid, thrips and cotton bollworm was observed. In 100% irrigation, the lowest degree of infestation by *Myzus persicae* (0.40) was recorded in pepper line 1928 while the highest attack of the green peach aphid was established in mutant line C45 (0.80). There was no significant difference in the aphid infestation between lines 1930 and C41. Percentage of damage plants ranges from 10% to 25% as the lowest value was found in pepper line 1928. There were no significant differences in degree of infestation by green peach aphid between the pepper lines under the reduced water regime (Table 8).

In full irrigation, differences in thrips infestation between pepper genotypes were not established. In plants with reduced water regime, the lowest degree of infestation was observed in pepper line 1930 (0.25), followed by pepper line 1928 (0.75). An increase in the density of the thrips was observed with the highest degree of infestation from thrips was reported in accession C45 (1.50) (Table 8).

The percentage of damaged plants by cotton bollworm at 100% irrigation ranges from 25% to 65%. The lowest percentage of damaged fruits was observed at pepper line 1930. No damage on the fruits in pepper line 1930 was found at the reduced water norm (Table 8).

Conclusion

The water deficiency has no significant effect on the size of the fruit and the thickness of the pericarp, the decrease of these parameters being on average by 10.1% and by 9.9%, respectively. With high sensitivity line 1930 stands out, where the reduction of the irrigation rate by 50% reduces the number of seeds by an average of 30.0% and of the fruits – 46%. The decline in production as a result of drought is most pronounced in terms of fruit quality, with first-quality production decreasing on average by 48.9% in the genotypes studied.

At 50% reduced water regime, a reduction in the population of green peach aphids and cotton bollworm and an increase in the thrips population were observed.

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Table 8. Damages from pests in pepper genotypes grown under different irrigation modes

Genotypes	Aphids		Thrips		Cotton bollworm	
	Damaged plants, %	Degree of infestation	Damaged plants, %	Degree of infestation	Damaged plants, %	Damaged fruits, %
Control						
1928	10	0.40 b*	10	0.25 n.s.	25	10
1930	15	0.55 ab	0	0.00 n.s.	55	5
C41	25	0.75 ab	25	0.50 n.s.	40	10
C45	20	0.80 a	40	0.75 n.s.	65	15
Drought						
1928	5	0.25 n.s.	30	0.75 bc	10	5
1930	10	0.50 n.s.	15	0.25 b	25	0
C41	5	0.40 n.s.	55	1.00 ab	20	5
C45	5	0.40 n.s.	60	1.50 a	40	10

*Means followed by the same letter in each column are not significantly different ($P < 0.05$) according to Duncan's Multiple Range Test

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