Screening of Tomato Genotypes for Tolerance of Reduced Irrigation

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***Abstract*—**Screening and selection of tomato accessions under conditions of 50% reduced irrigation was performed in the current study. The experiment was conducted at the Maritsa Vegetable Crops Research Institute with 10 determinate tomato accessions (five large-fruited and five for processing) in two consecutive years (2016-2017). The productivity per plant, number and average fruit weight was recorded for two harvest periods – in the end of July and mid of August. The data indicated that reduced irrigation during growing season influenced more strong productivity per plant especially in the second harvest period. The decrease of the yield in two studied tomato groups was 59.3% and 54.2% respectively. In the first harvest period the reduction of yield was 46.3% and 27.2%. Moreover the applied stress had the weaker negative effect on average fruit weight. In both studied tomato groups, the reduction of fruit weight below 30% was observed. The studied large-fruited tomato accessions showed low drought tolerance compared to the tomato accessions for processing. Three-way analysis of variance showed that watering regime influenced mainly the productivity per plant and fruit set while the average fruit was affected by genotype. Based on the present study tomato accessions BG 985 and BG Solaris suitable for breeding of drought stress were selected.

***Keywords*—**Tomato, reduced irrigation, productivity, harvest period.

I. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely grown and consumed vegetables in the world. This fact is due to the high biological value of the fruits (high content of dry substance, vitamin C, minerals, carotenoids, phenols etc.) and their use for both fresh consumption and processing. A creation of a large number of genetically close varieties, because of domestication and breeding work in tomato is one of the reasons for the loss of genetic diversity and it increases the sensitivity of varieties to biotic and abiotic stress [1]. Among the abiotic stresses drought and high temperature are the main factors limiting the crop development and productivity. Drought often accompanies heat especially in summer [2].

Tomato plants are very sensitive to water stress and show high correlation between duration of the drought and crop yield [3]. The most sensitive stages after transplanting are the flowering and fruit development [4]. According to some authors the water stress at earlier stage of growth (20 day stage) is more inhibitory compared to the later stage (30 day stage) as a consequence which decreased growth and development caused by reduced photosynthesis [5], [6]. Reduced irrigation decrease fruit number because of flower abortion and fruit shedding but fruit size was a limiting factor to fruit production in tomato [7]. In many cases the market yield reduction can reach over 50% [8]–[10].

In this regard breeding for drought-tolerant tomato varieties is an important and urgent task due to the increased frequency and duration of droughts caused by climatic change. There has been much research aiming to development of tolerant tomato varieties but the process is slow and difficult due to the complex and multigenic control of drought tolerance [11], [12]. The approaches to breeding drought-resistant included: 1. screening of available germplasm for drought tolerant/adapted varieties; 2. hybridization with wide species distinguished by enhance drought tolerance; 3. genetic transformation [13], [14]. In order to achieve the develop of genotypes with enhanced tolerance to water stress it is essential to combine the knowledge required to agronomical, physiological, biochemical and genetic basis of water tolerance.

The aim of the present study is to establish tomato genotypes that despite stressful conditions - high temperatures and reduced irrigation retain a relatively constant yield and quality.

II. Materials And Methods

The experimental work was carried out during the two summer seasons of 2016 and 2017 at the field of the Maritsa Vegetable Crops Research Institute in Plovdiv. The plant material consisted of 10 determinate tomato genotypes divided into two groups: large-fruited tomato for fresh consumption and industrial processing in juices and pulps - BG 252, BG 2040, BG Milyana, BG Marti, BG Solaris and for processing in peeled tomato - BG 985, BG 2086, BG K1, BG Kapri and BG Venera. The seeds of selected accessions were sown at the beginning of April in an unheated greenhouse. At the beginning of May five weeks' old tomato seedlings were transplanted into a field. Tomato plants were grown according to the technology for mid-season production of determinate tomatoes under two conditions of water availability – optimum

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(well-watered) and 50% reduced irrigation (water-stressed). The experiment was conducted in a randomized complete block design with two replications by 10 plants (area 2.4 m^2). A micro-flow drip irrigation method was used with dripping wings and distributors giving 2 L h^{-1}, spaced 20 cm apart and placed along the row. Observations were recorded on five individual plants for each replication for productivity per plant (g), average fruit weight (g) and fruits per plant (number). The evaluation was performed in two periods – in the end of July (first harvest) and in the mid of August (second harvest).

Weather data were collected from June to August in 2016 and 2017. Air minimum and maximum temperature (°C), air humidity (%), rainfalls (l/m^2) and soil moisture at 15 and 30 cm depth (kPa) were recorded by weather station Caipos Wave (Caipos GmbH, Austria).

The results were given as means of ten independent (biological) replications. To compare differences among accessions grown in two watering regimes Duncan's multiple range tests were used. The decrease percentage ($D_{\%}$) was also calculated. Three-way analysis of variance was applied to show the effect of genotype, watering regime and period of harvesting on productivity, average fruit weight, fruit number and interaction between them (SPSS software).

III. Results And Discussion

Significant differences in temperature between two studied years were not observed (Table 1). In the period of 2016 and 2017 the daily mean temperature from June to August was 25°C ranged between 19.78 ºC and 28.80 ºC as well as 17.10 ºC and 32.02ºC respectively. The highest value of maximum temperature was recorded in June and July with peaks over 37ºC and 40 ºC in 2016 and 2017 respectively. The minimum temperature for the period June-August were from 10.07 ºC to 21.34 ºC in 2016. In 2017 the minimum temperature varied from 8.66 ºC to 22.88 ºC.

TABLE I
Temperatures and rainfalls during the experimental period of 2016 and 2017

Year		June	July	August
	Temperature (°C)			
2016	Mimimum	18.39 (14.84-21.16)	17.93 (14.29-21.34)	17.01 (10.07-21.21)
	Maximum	32.81 (27.08-37.30)	33.61 (28.77-37.33)	32.59 (24.12-37.61)
	Daily mean	25.36 (19.78-28.80)	25.42 (20.16-28.08)	24.35 (19.80-28.11)
2017	Mimimum	17.18 (13.07-22.88)	17.64 (12.76-21.24)	16.92 (8.66-21.60)
	Maximum	32.79 (22.60-42.23)	32.85 (20.23-40.45)	34.12 (24.75-39.20)
	Daily mean	24.91 (17.63-32.02)	25.17 (17.10-30.32)	25.28 (20-28-29.75)
	Rainfalls (l/m^2)			
2016		31.5	38.0	64.5
2017		19.5	52.5	4.5

During the first experimental year the total rainfalls were 134 l/m^2 more than the second one (76.5 l/m^2) (Table 1). The period of 2017 was distinguished by lack of rainfalls in August except for 4.5 l/m^2 while in the 2016 it was the month with the most rainfalls. The weather in June 2017 was also dry with only 19.5 l/m^2 total rainfalls.

The response to water stress was mainly dependent on the genotype. The traits defining the yield (fruit number and average fruit weight) were influenced by the stress conditions and confirmed the sensitivity of the tomato varieties. The flowering passed normally when reduced irrigation was applied in June but stress conditions affected the fruit formation because of increases the flower shedding. Reduced watering combined with high temperatures in July had a significant impact on the number and quality of tomato fruits in the studied accessions (Table 2, 3).

TABLE II
Impact of water deficit on fruit number, average fruit weight and productivity per plant in large-fruited tomato accessions

Genotype		First harvest			Second harvest		
		FN	***FW***	***Yield***	***FN***	***FW***	***Yield***
BG Milyana	O	17.5^{a}	122.9^{bc}	2151^{a}	11.2^{cd}	111.2^{b}	1241^{cd}
	R	10.5^{c}	103.0^{cde}	1082de	7.0^{d}	92.2^{bc}	646^{e}
$D_{\%}$		**40.0**	**16.2**	**50.0**	**37.5**	**17.1**	**47.9**
BG Marti	O	13.0^{b}	132.7^{abc}	1727^{c}	16.5^{ab}	96.5^{bc}	1593^{bc}
	R	10.0^{c}	98.3^{de}	983^{e}	10.0^{cd}	77.7^{d}	777^{e}
$D_{\%}$		**23.1**	**25.9**	**43.1**	**39.4**	**19.5**	**51.2**
BG Solaris	O	10.0^{c}	147.4^{ab}	1474^{cd}	13.0^{bc}	115.5^{a}	1502^{bc}
	R	9.0^{c}	112.8c^{d}	1015de	8.5^{d}	107.1^{b}	910de
$D_{\%}$		**10.0**	**23.5**	**31.1**	**34.6**	**7.3**	**39.4**
BG 252	O	12.2^{b}	135.2^{abc}	1644^{c}	19.8^{a}	109.9^{b}	2180^{a}
	R	8.5^{c}	85.8^{e}	730^{e}	9.5^{cd}	91.8^{bc}	872de
$D_{\%}$		**30.3**	**36.6**	**55.6**	**52.0**	**16.5**	**60.0**
BG 2040	O	14.0^{b}	150.5^{a}	2107^{ab}	17.0^{ab}	109.0^{b}	1869^{ab}
	R	9.0^{c}	119.7^{cd}	1077^{dc}	7.0^{c}	93.9^{bc}	657^{e}
$D_{\%}$		**35.7**	**20.4**	**51.3**	**58.8**	**13.9**	**64.8**
Average $D_{\%}$		29.5	24.6	46.3	45.8	14.6	53.9

a,b,c…- Duncan's Multiple Range ($p \leq 0.05$)
O - optimum irrigation; R- reduced irrigation

The large-fruited determinate tomato accessions demonstrated low drought tolerance with significant reduction of fruit number and fruit weight (Table 2). Depending on the harvest period the reduction of yield was 46.3% and 53.9% respectively compared to the well-watered plants. Only one accession (BG Solaris) showed a decrease of productivity below 50%. The studied determinate tomatoes for processing were more tolerant to applied stress especially in the first harvest period (Table 3). The reduction of yield was 27.2% and 54.9% respectively. Accession BG 985 distinguished by slight reducing of productivity per plant by 16.7% and 31.4%

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respectively. A decrease of productivity per plant in other accessions of this group varied from 16.6% to 48.7% for the first harvest period and from 30.0% to 66.8% for the second one. The same results with an overall yield loss in drought stress up to 55% were observed by other authors [8], [9], [15]. The yield loss reached to 70-80% in the most susceptible genotypes [9].

TABLE III
IMPACT OF WATER DEFICIT ON FRUIT NUMBER, AVERAGE FRUIT WEIGHT AND PRODUCTIVITY PER PLANT IN TOMATO ACCESSIONS FOR PROCESSING

Genotype		First harvest			Second harvest		
		FN	***FW***	***Yield***	***FN***	***FW***	***Yield***
BG 985	O	10.5^{cd}	86.6^{a}	910^{cd}	15.8^{cd}	78.9^{a}	1249^{c}
	R	9.5^{cd}	79.8^{ab}	758d^{e}	13.5^{de}	63.4^{bc}	857^{d}
D$_{\%}$		**9.5**	**7.8**	**16.7**	**14.6**	**19.6**	**31.4**
BG Kapri	O	14.3^{bc}	50.8^{cd}	728de	15.0^{cd}	53.8^{de}	807^{d}
	R	12.3^{bcd}	49.2^{d}	607^{e}	8.7^{e}	37.1^{f}	322^{e}
D$_{\%}$		**14.0**	**3.1**	**16.6**	**42.0**	**31.0**	**60.1**
BG Venera	O	20.8^{a}	75.9^{b}	1582^{a}	31.5^{a}	77.0^{ab}	2425^{a}
	R	24.2^{a}	50.9^{d}	1231^{b}	19.3^{bc}	41.6^{ef}	804^{d}
D$_{\%}$		**-16.3**	**32.9**	**22.2**	**38.7**	**46.0**	**66.8**
BG 2086	O	11.5^{bcd}	83.3^{ab}	958b^{cd}	22.0^{b}	80.7^{a}	1275^{b}
	R	9.0^{d}	78.4^{ab}	706de	12.7^{de}	67.5^{bc}	855^{d}
D$_{\%}$		**21.7**	**5.9**	**26.3**	**42.3**	**16.4**	**51.8**
BG K1	O	15.3^{b}	79.1^{ab}	1213^{bc}	13.7^{cde}	80.0^{a}	1094^{cd}
	R	10.3^{cd}	60.1^{c}	622^{e}	13.7^{cde}	56.2^{cd}	768^{d}
D$_{\%}$		**32.7**	**24.0**	**48.7**	**0.0**	**30.0**	**30.0**
Average D$_{\%}$		9.8	15.3	27.2	30.7	28.2	54.9

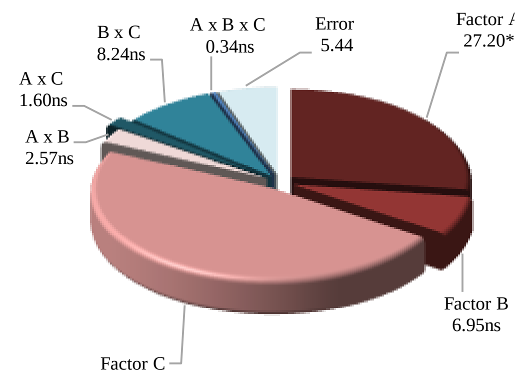
a,b,c…- Duncan's Multiple Range (p≤0.05)
O - optimum irrigation; R- reduced irrigation

Drought stress had negative effects on the fruit formation. In the condition of reduced watering the number of fruits at the first harvest decreases with 29.5% in large-fruited tomatoes and 9.8% in the tomatoes for processing (Table 2, 3). The decrease recorded for the fruit number at the second harvest period was significantly higher with 45.8% and 30.7% respectively.

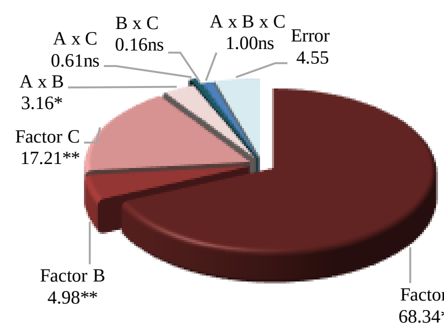
The accessions showed a lower decrease of the average fruit weight under conditions of 50% reduced irrigation. Regarding the period of harvesting in the conditions of water stress the fruit weight reduced by 24.6% and 14.6% in the group of large-fruited tomato and with 15.3% and 28.2% in tomato for processing. Among the genotypes the lowest decrease of average fruit weight below 20% was established in two accessions for processing (BG 2086 and BG 985) and in two large-fruited accessions (BG Milyana and BG 2040).

The results were consistent with those established by other authors who found a decrease of number and weight of tomato fruits as a result of water deficit [7], [9]. Water stress decreases the number of ovules per floret and this is the main reason for the increased percentage of flower abortion in stressed plants [6]. Limiting of water at flowering stage not only reduces flower formation but also increases flower shedding [16].

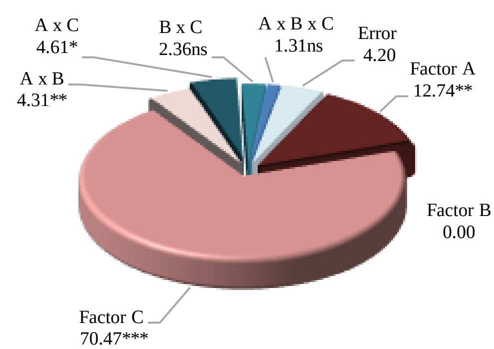
The three-way analysis of variance indicated that the watering regime mainly influenced the productivity per plant (63.94%) and fruit number (35.57%) (Fig. 1a, c) while fruit weight was affected by genotype (68.34%) (Fig. 1b).



a.



b.



c.

Fig. 1. Three-way analysis of variance and power of influence of genotype (Factor A), period of harvesting (Factor B) and watering regime (Factor C); (a) fruit number, (b) fruit weight, (c) productivity per plant

IV. Conclusion

Water deficit combined with high temperature during the vegetative period (flowering phase) reduced the yield in tomato plants as a result of decrease of fruit set and average fruit weight. Large-fruited tomato accessions were more sensitive to applied drought stress compered to accessions for processing. The results showed that the watering regime influenced mainly the productivity per plant and fruit number while average fruit weight depended on genotype. Additionally, the number of fruits per plant was the most strongly affected by reduced irrigation and could be used as an indicator for the selection of tolerant genotypes. Among the genotypes tomato accessions BG 985 and BG Solaris were selected as tolerant to reduced irrigation and could be a base for the development of new varieties less sensitive to the drought stress.

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