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PLANT PHYSIOLOGY

Deciphering the Impact of Water-stress on Plant Growth and Yield Attributes in Tomato Genotypes

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ABSTRACT

The adverse effect of water-stress on growth and yield parameters of tomato (*Solanum lycopersicum)* genotypes *viz.*, plant height, days to 50% flowering, number of branches per plant, number of flower per truss, number of flower truss per plant and fruit setting percentage was investigated under field conditions in rainout shelter. The drought condition was imposed 25 days after transplanting by withhold water supply. Experimental trial was carried out with nine genotypes adopting complete randomized design (CRD) with three replications and two treatments *viz.,* well-watered and withhold water supply. The water-stress caused reduction in all plant growth and yield parameters. The genotypes Arka Vikas showed significantly less reduction in plant height, number of flower per truss and number of flower truss per plant, while EC179083 showed minimum reduction in days to 50% flowering, number of branches per plant and fruit setting percentage during drought so both genotypes were considered as drought tolerant. Genotypes EC160885 and EC 249508 represented the maximum reduction in all morphological parameters among all genotypes, hence considered as drought susceptible.

HIGHLIGHTS

- Effect of water stress on growth and yield attributes of tomato genotypes
- Identifying best genotype among unexplored and explored tomato genotypes under water stress conditions.

Keywords: tomato genotypes, drought, plant height, days to 50% flowering, fruit setting percentage

Tomato (*Solanum lycopersicum* L.) is the second most important fruit or vegetable crop next to potato (*Solanum tuberosum* L.), with approximately 180.7 million tons of tomato fruits produced on 50.31 million hactare each year (FAOSTAT, 2020). Asia accounts for 61.1% of global tomato production, while Europe, America, and Africa produced 13.5%, 13.4%, and 11.8% of the total tomato yield, respectively. It is one of the most popular and widely consumed vegetable crops all over the world. Tomato has been recently gaining attention in relation to the prevention of some human diseases. The nutritional importance of tomatoes is largely explained by their various health-promoting compounds, including vitamins, carotenoids, and phenolic compounds (Li *et al.* 2018). The bioactive compounds have a wide range of physiological properties, including

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anti-inflammatory, anti-allergenic, antimicrobial, vasodilatory, antithrombotic, cardio-protective, and antioxidant effects (Raiola *et al.* 2014). Particularly lycopene, which is an unsaturated alkylic compound, appears to be an active compound in the prevention of cancer, cardiovascular risk and in slowing down cellular aging (Gerster 1997).

Tomato production is challenged by several problems around the world, including the scarcity of water resources, soil salinization, and other abiotic stresses (Fahad *et al.* 2017; Zhou *et al.* 2019). Drought stress can affect plant growth, development and yield. It has been estimated that up to 45% of world agricultural lands are subjected to drought (Bot *et al*. 2000). Its cultivation is mainly concentrated in semiarid zones, like the Mediterranean, where it needs to be cultivated under irrigation (Rivelli *et al.* 2013), and where drought events associated with climate change are expected to be more frequent (Nankishore and Farrell 2016). Thus, water shortage caused by drought periods can have important consequences for tomato production, and might produce yield reduction up to 50% in case of equivalent reduction in irrigation (Cantore *et al.* 2016).

The challenges of abiotic stress on plant growth and development are emerging ecological impacts of climate change and thus constraints to crop production. These constraints towards global food supply and a balanced environment encourage research and development of climate-smart crops, resilient to climate change (Pereira 2016). Both vegetative and reproductive processes of modern tomato cultivars can be severely compromised by drought stress, which inhibits seed development, reduces vegetative growth and compromises reproduction (Bartels and Sunkar 2005; Nuruddin *et al.* 2003).

Therefore, the present investigation was undertaken with the aim of characterizing and assessing morphological variability of tomato genotypes collected from diverse sources. In this study, morphological characters such as plant height, days to 50% flowering, number of flower truss^{-1}, number of flower truss plant^{-1} and fruit setting percentage were used to distinguish the tomato genotypes response to water limiting conditions.

MATERIALS AND METHODS

Experiment location and weather data

The experiment was conducted at a research field under rain out shelter of Field Laboratory and Experiment Station under Department of Agricultural Biotechnology, SVPUA&T, Meerut, India, during *Rabi* season (2019-2020). The experimental site located in the semi-arid environment and agro-climatic plain zone of Uttar Pradesh state lies at North West Plain Zone, India, 28.99°N latitude and 77.7° E longitude with an altitude of 220 m above the mean sea level. The climate of the experimental site is sub-tropical and having extreme weather conditions, i.e., extremely hot summer and cold winter. The meteorological data were recorded by an automatic weather station of Indian Institute of Farming System and Research (IIFSR), Modipuram, Meerut, India. Graphical representation of weather data are shown in Fig. 1.

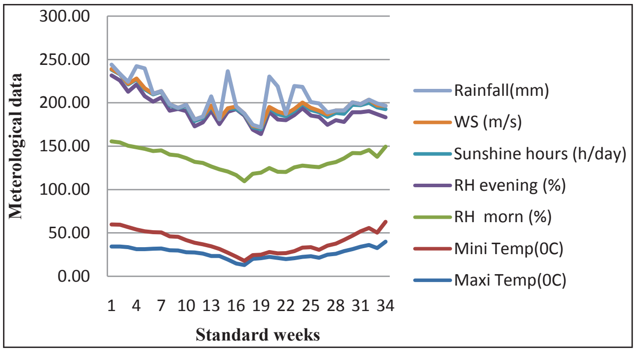

Fig. 1: Meteorological variables during experimental field trial

Experimental design

Nine tomato germplasms were procured for the study (Table 1), out of which, five genotypes procured from ICAR-National Bureau of Plant Genetic resources (ICAR-NBPGR), New Delhi while others were released varieties.

Seeds of each genotype were sown for nursery preparation in mid September in medium sized germination trays having mixture of cocopeat and vermicompost. Twenty five days old seedlings were transplanted in the large cemented pots in field following Complete Randomized Design (CRD) in replicates of each treatment (Fig. 2). Water stress was imposed by water-withholding at late vegetative stage after 25 days after transplanting (DAT) while

Table 1: Description of tomato genotypes used under study

Sl. No.	Genotypes	Growth Type	Collection source
1	EC249508	Determinate	ICAR-NBPGR, New Delhi
2	EC164677	Determinate	ICAR-NBPGR, New Delhi
3	EC 165690	Determinate	ICAR-NBPGR, New Delhi
4	EC160885	Semi – determinate	ICAR-NBPGR, New Delhi
5	EC179083	Indeterminate	ICAR-NBPGR, New Delhi
6	Arka Vikas	Semi – determinate	ICAR-IIHR, Bangalore
7	Pusa Sadabahar	Determinate	ICAR-IARI, New Delhi
8	Pusa Gaurav	Determinate	ICAR-IARI, New Delhi
9	Pusa Rohini	Determinate	ICAR-IARI, New Delhi

control plants maintained well-watered. Pots in the water stress treatment were protected from any possible rain water by placing under rainout shelter. Observations of different morphological characters were recorded for three replicates of each genotype. Stress was relieved by re-watering and plants were maintained stress free till harvest. Various morphological characters were observed viz. days to 50% flowering, plant height, number of primary branches, number of flower truss per plant, number of flower per truss and fruit setting percentage. Quantitative data were statistical analyzed. A Student's t-test was performed to determine significant differences between control and drought treatment and differences among genotypes under both conditions (irrigated as well as drought stress) were analysed by one-way analysis of variance (ANOVA).

Fig. 2: Experimental field trial at research field under rain out shelter

RESULTS AND DISCUSSION

Plant growth attributes

Results of morphological characters viz. plant height and number of branches per plant are shown in Table 2. Plant height of drought stressed plants were in the range of 59-132.67cm while that of control plants ranged between 71-158.67cm indicating a compelling reduction in plant height plant^{-1} under water-stress in all the nine genotypes. Under well-watered conditions genotype EC179083 (158.67cm ± 3.21) recorded the maximum plant height plant^{-1} while minimum plant height plant^{-1} was observed in Pusa Sadabahar (71.67cm ± 1.53). Under water-stress condition again genotype EC179083 (132.67cm ± 20.53) showed the maximum plant height plants^{-1} while the minimum plant height plant^{-1} was recorded in EC165690 (59cm ± 3.61). The present results were in accordance with Zhou *et al.* (2017) who observed growth reduction in tomato cultivars height under water-stress conditions compared to controlled conditions. Elizabeth *et al.* (2018) also observed reduced plant height in drought conditions in comparison to well-watered conditions. They obtained results in the range of 77-75 cm for drought stressed plants. The results reported by EL-Mansy *et al.* (2021) also showed similar differences in plant height under abiotic stress. Blanchard-Gros *et al.* (2021) reported the impact of water-stress on plant height in tomato populations of *Solanum chilense* and *Solanum lycopersicum*. Water-stress impaired mitosis and cell elongation that resulted in poor growth (Hussain *et al.* 2008) and limited the cell growth processes largely due to the loss of turgor (Taiz and Zeiger 2010). Both the factors play an important role in growth reduction.

The number of branches plant^{-1} were in the range 8.67-19.00 in control plants where as the value for drought stressed plants ranged between 7.00-15.00. So the observations showed compelling reduction in branches plant^{-1} under water-stress conditions in all

Table 2: Variations in morphological characters of nine tomato genotypes exposed to drought stress

Characters→ Genotypes↓	Plant Height (cm)		Number of Branches Plant^{-1}	
	Control	Drought	Control	Drought
	Mean	Mean	Mean	Mean
EC249508	120.00±5.00	82.00±6.08	9.00±1.00	7.00±1.00
EC164677	139.00±5.29	114.00±6.00	10.33±1.53	8.33±0.58
EC 165690	72.67±5.03	59.00±3.61	13.33±2.08	10.67±1.53
EC160885	132.00±20.66	99.67±13.05	11.00±2.00	7.67±1.15
EC179083	158.67±3.21	132.67±20.53	8.67±1.53	7.33±1.15
Arka Vikas	85.33±4.51	79.67±4.51	17.67±2.52	14.67±1.53
Pusa Sadabahar	71.67±1.53	64.33±4.04	19.00±2.65	15.00±2.65
Pusa Gaurav	78.33±2.08	69.33±5.03	14.67±2.52	12.00±2.00
Pusa Rohini	98.67±4.04	69.33±5.51	13.33±2.08	10.67±2.52
Mean	106.26±5.71	85.56±7.60	13.00±1.99	10.37±1.57
C.V.%	5.37	8.88	15.30	15.11
CD@5%	10.43	12.26	2.60	2.13
SE(d)	2.34		0.51	
CI 95%(d)	15.96 - 25.45		1.59 - 3.67	

the nine genotypes. Under well-watered conditions genotype Pusa Sadabahar (19 ± 2.65) recorded the maximum branches plant^{-1} while minimum branches plant^{-1} was recorded in EC179083 (8.67 ± 1.53). Under water-stress conditions also genotype Pusa Sadabahar (15 ± 2.65) showed the maximum branches plants^{-1} while the minimum branches plant^{-1} was recorded in EC249508 (7 ± 1.00). In general the number of branches per plant under drought stress was lesser than that of control. The differences within the genotypes may be due to the genetic composition. Varied supply of water also affects the number of branches per plant. Results reported by Ilakiya *et al.* (2017) showed observations on branching in the range of 13.30-20.00 in 100% field capacity (FC) where as in 50% FC observations were in the range of 12.31-17.36. Similarly Parveen *et al.* (2019) reported the less number of branches plant^{-1} in drought condition (5.33-14.33) as compared to control conditions (7.33-19).

In all the nine genotypes, a reduction was observed in plant growth attributes under water stress conditions as compared to control (normal irrigation). When this decrease was compared in terms of percent reduction within the various genotypes (Fig. 3), Arka Vikas was found to perform the best among all under stress conditions followed by EC179083.

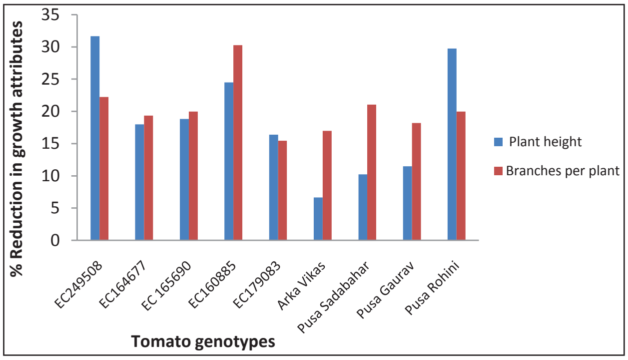

Fig. 3: Percent reduction in plant growth attributes of tomato genotypes under water stress conditions

Yield attributes

The data on yield attributing characters of nine tomato genotypes is presented in Table 3. The days to 50% flowering were in the range of 31-48 days under controlled conditions while 28-38 days under drought conditions. Under control conditions, among all genotypes Pusa Gaurav took maximum number of days (48 days) for 50% flowering while genotypes EC179083 took minimum number of days (31 days). In controlled conditions observations of present study were in accordance to Khaled *et al.* (2015) which showed a period of 37-42 days for 50% flowering. Under drought conditions also Pusa Gaurav (38 days) showed maximum number of days taken for 50% flowering among all genotypes

Table 3: Variations in yield attributing characters of nine tomato genotypes exposed to drought stress

Characters→ Genotypes↓	Days to 50% flowering		Number of Flower truss^{-1}		Number of flower truss Plant^{-1}		Fruit Setting %	
	Control	Drought	Control	Drought	Control	Drought	Control	Drought
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
EC249508	41.67±5.69	31.33±3.51	7.33±0.58	5.33±0.58	32±3.61	26.00±3.61	45.24±14.87	31.11±10.18
EC164677	44.67±3.51	36.00±2.65	7.33±0.58	6.33±0.58	20.67±2.08	17.67±1.53	31.55±5.15	26.19±8.58
EC 165690	37.33±7.09	29.67±2.52	7.67±0.58	6.33±0.58	25.67±3.21	21.67±4.16	33.33±8.25	26.19±8.58
EC160885	42.67±5.03	31.00±2.65	7.67±0.58	5.67±0.58	21.00±3.61	16.33±3.21	35.12±9.16	23.33±8.82
EC179083	31.33±1.53	28.33±1.53	7.67±0.58	6.67±0.58	20.33±2.08	18.00±2.00	26.19±2.06	24.60±6.87
Arka Vikas	33.67±2.52	29.33±2.08	6.67±0.58	6.33±0.58	24.33±2.52	22.00±2.65	30.16±2.75	25.40±15.12
Pusa Sadabahar	36.00±2.65	30.00±1.00	7.33±0.58	6.67±0.58	27.00±2.00	23.33±2.52	54.17±10.15	40.48±10.91
Pusa Gaurav	47.67±2.52	38.33±5.13	8.00±1.00	6.67±1.15	25.33±4.73	21.67±4.51	33.13±4.47	25.00±8.33
Pusa Rohini	37.33±1.53	31.67±1.53	7.67±0.58	6.33±0.58	22.67±3.06	19.00±2.65	26.19±2.06	21.43±10.38
Mean	39.15±3.56	31.74±2.51	7.48±0.62	6.26±0.64	24.33±2.99	20.63±2.98	35.01±6.55	27.08±9.75
C.V.%	9.10	7.91	8.34	10.25	12.28	14.45	18.70	36.02
CD@5%	5.24	3.49	0.84	0.88	4.02	3.98	9.52	9.52
SE(d)	0.94		0.18		0.85		2.43	
CI 95%(d)	5.51 - 9.31		0.86 – 1.58		1.98 – 5.42		2.99 – 12.86	

where as genotype EC179083 showed minimum period (28 days). This early flowering under drought may be attributed to rapid phenological development in order to complete the life cycle under unfavourable environmental conditions. Maximum change in days for 50% flowering under two conditions was observed in EC160885 (11 days) while the minimum change was recorded in EC179083 (3 days). Results were in agreement with the observations of Sivakumar and Srividhya (2016), where they reported 4 days earlier flowering in drought-stressed plants than control plants.

The number of flower truss^{-1} (Table 3) were in the range of 5.33-6.67 in drought stressed plants while control plants showed a range of 6.67-8.00 suggesting a compelling reduction in number of flower truss^{-1} under water-stress conditions in all the nine genotypes. Under well-watered conditions, genotype Pusa Gaurav recorded the maximum (8 ± 1.00) number of flower truss^{-1}, while minimum (6.67 ± 0.58) number of flower truss^{-1} was recorded in Arka Vikas. However under water-stress conditions genotype Pusa Sadabahar (6.67±0.58) showed the maximum number of flower truss^{-1} and minimum number of flower truss^{-1} were recorded in EC249508 (5.33±0.58). Earlier reports of Ilakiya *et al.* (2017) were also in conformity to present results where observations on number of flower truss^{-1} were in the range of 4.56-6.89 in 100% FC and 4.13-5.92 in 50% FC. Findings of Parveen *et al.* (2019) also showed that number of flower truss^{-1} varied from 4.33-7.33 under control conditions while under drought stress condition, it varied from 2.00-4.33. Among all the nine genotypes studied least difference for number of flower truss^{-1} was found in genotype Arka Vikas while Pusa Gaurav seemed to be most affected showing maximum difference under two conditions.

The number of flower truss plant^{-1} (Table 3) were in the range of 16.00-26.00 in drought stressed plants while in control plants the value ranged between 20.33-32.00 showing a clear compelling reduction in number of flower truss plant^{-1} under water-stress conditions in all the nine genotypes. Under well-watered conditions genotype EC249508 (32±3.61) recorded the maximum number of flower truss plant^{-1}, while minimum number of flower truss plant^{-1} was recorded in EC179083 (20.33±2.08). Under water-stress conditions again genotype EC249508 (26±3.61) showed the maximum number of flower truss plant^{-1} but minimum number of flower truss plant^{-1} was recorded in EC160885 (16.33±3.21). Results were well in accordance with those of Ilakiya *et al.*, (2017) whose observations were in the range of 19.39-29.00 and 13.33-20.00 for 100% FC and 50% FC, respectively.

Fruit setting percentage plant^{-1} (Table 3) was in the range of 21.43%-40.48% in drought stressed plants while for control plants it was in the range of 26.19%-54.17% , thus again indicating a reduction in fruit setting percentage under water-stress conditions in all the nine genotypes. Under well-watered conditions genotype Pusa Sadabahar (54.17±10.15) recorded the maximum fruit setting percentage while minimum fruit setting percentage was recorded in EC179083 (26.19±2.06). For water-stress conditions also, genotype Pusa Sadabahar (40.48±10.91) showed the maximum fruit setting percentage but the minimum fruit setting percentage was recorded in Pusa Rohini (21.43±10.38). Wahb-Allah *et al.* (2011) also reported a higher fruit setting percentage (56%) under control condition in comparison to drought conditions (46%). Similarly findings of Parveen *et al.* (2019) also observed that fruit setting percentage varied from 7.01%-48.14% under control conditions while under drought stress conditions it varied from 2.86%-43.85%. Our observation also confirms that fruit setting percentage in all the genotypes was higher in control plants than stressed ones.

Comparison of percent reduction under water stress conditions in different yield attributes for nine genotypes is shown in Fig. 4. The results clearly indicated that minimum reduction was experienced in Arka Vikas and EC179083. Arka Vikas is a released variety and known for its thermal and moisture resistance thus performs good under water stress conditions, but EC179083 is still unexplored.

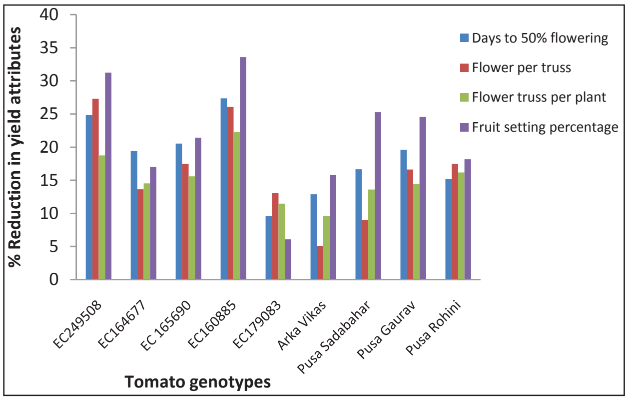

Fig. 4: Percent reduction in yield attributes of tomato genotypes under water stress conditions

Our results suggested that its performance under water stress conditions was at par with Arka Vikas, thus further studies or trials in this direction must be conducted to release it as a variety suitable for drought prone areas.

CONCLUSION

It can be concluded that tomato genotypes could respond differently against drought stress to enhance their ability to combat with adverse conditions. It is possible that morphological traits such as such as plant height, days to 50% flowering, number of flower truss^{-1}, number of flower truss plant^{-1} and fruit setting percentage could be altered in a way that make plants better adapted to drought conditions and help in completing phenological development within short time to complete the life cycle under unfavourable environmental conditions. This variation could be used as an effective mechanism for drought tolerance. Results demonstrated that on the basis of morphological parameters, which are very useful tools in initial screening of drought tolerance, tomato genotypes Arka Vikas and EC179083 showed a promise for drought resistance.

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