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Effect of water stress on the growth and some yield parameters of *Solanum lycopersicum* L.

Gideon Olarewaju OKUNLOLA[1*], Adekunle Ajayi ADELUSI[2],
Ezekiel Dare OLOWOLAJU[2], Ojo Michael OSENI[2] and Gideon Love AKINGBOYE[2]

[1]*Department of Biological Sciences, Faculty of Basic and Applied Sciences, Osun State University, Osogbo, Osun State, Nigeria.*
[2] *Department of Botany, Faculty of Science, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.*
[*]*Corresponding author, E-mail: gideon.okunlola@uniosun.edu.ng; Tel: +2348033870696*

ABSTRACT

An investigation aimed at a better understanding of the normal water requirement for the optimum growth and yield of *Solanum lycopersicum* was carried out. Seeds of *S. lycopersicum* were sown in 32 plastic pots and after germination the seedlings were allowed to grow for a period of 2 weeks within which they were well watered and kept under optimum conditions of the environment. The plants were then subjected to different levels of water applications. Plants in the first group (W1) were supplied with 200 ml of water everyday; plants in the second group (W2) were supplied with 200 ml of water once every 3 days; plants in the third group (W3) were supplied with 200 ml of water once in every 5 days while the fourth group (W4) were supplied with 200 ml of water once in every 10 days. The results obtained showed that water stress caused a significant ($p<0.05$) reduction in some of the morphological parameters studied. Some yield parameters were unaffected by the water stress.

Keywords: Tomato, crop, morphology, biomass, Leaf area, physiology.

INTRODUCTION

Any change in the environment that results in plant response that is less than the optimum might be considered stressful. These changes could be produced both by abiotic and biotic factors such as -freeze, chill, heat, drought, flood, salt, pest and air pollution, etc. (Hopkins et al., 2000). Plants are subject to many forms of environmental stress, some are abiotic or density independent such as temperature, drought and fire, or physicochemical such as air pollution. Other sources of stress are biotic or density dependent, such as competition, herbivory, disease, and parasitism (Pessarakli, 2001).

Stresses such as drought reduce the yield of cultivated plants or affect the quality of the harvested products (Arafa et al., 2009). Drought stress tolerance is seen in almost all plants but its extent varies from species to species and even within species (Caeruty et al., 2009). The ability to recognize early symptoms of water stress is crucial to maintaining the growth of plants. Plants experience water stress either when the water supply to their roots becomes limiting, or

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when the transpiration rate becomes intense. However, water stress is primarily caused by a water deficit, such as a drought or high soil salinity (FAO, 2011). Water stress does not only affect the morphology but also severely affects the metabolism of the plant. The extent of modification depends upon the cultivar, growth stage, duration and intensity of stress (Mark et al., 2005).

Current world production of tomato is about 152 million tonne of fresh fruit from about 4.4 million ha. Tomato is the second most valuable vegetable crop next to potato (FAO, 2011). The cropped area increased 1.4 million ha (+40 percent) in the period 1997-2007, but total fruit production, including fresh market tomato, increased by only 20 million tonne (15 percent). More than 38 million tonne per year are grown for the processing industry, making it the world's leading vegetable for processing. Fruit production for processing increased even more in proportion, by 11 million tonne (+49 percent), while only 0.5 million ha (+10 percent) were cropped with processing tomato (WPTC, 2011). Global tomato consumption increased by an average of 4.5 percent per year between 1990 and 2004. Tomato producers are mainly located between subtropical and temperate zones, the main cropping countries being China, the United States, India, Turkey, Egypt, Italy, Iran, Spain, Brazil and Mexico. Nigeria is not among the top 20 producers of the crop in the world(FAO,2011) and most farmers have stopped its cultivation due to little yield they experience, which invariably causes shortage in revenue and a gross net loss in income.

Although there is a lot of information in the literature on the effect of water stress on food crops, e.g rice, maize and sorghum, little attention is being paid to vegetable crops which actually require a lot of water use. This work was therefore aimed at determining the effect of different levels of water stress on some morphological parameters of the plant; determine the effect of different levels of water stress on some growth parameters of the plant as well as determine the effect of different level of water stress on the yield of the plant.

MATERIALS AND METHODS

Seedlings of *Solanum lycopersicum* (Ife No 1 Variety) were utilized in this experiment. Seeds were collected from the Osun State Ministry of Agriculture, Osogbo, Osun State, Nigeria. Top soil was collected from the Department of Botany re-forestation project site, Obafemi Awolowo University, Ile Ife, Nigeria**.** The soil was air-dried and transferred into thirty-two plastic pots in which holes have been bored to allow the drainage of excessive water. Each pot was 21 cm in depth and 32 cm in diameter containing the treated sand filled to the brim. The experiment was carried out within a screen house to minimize extraneous materials from interfering with the experiment. After a period of 3 weeks, the 32 pots were divided into four groups of 8 pots each. The four different groups were as follows:

W1- plants were supplied with 200 ml of water daily.

W2 - plants were supplied with 200 ml of water once in three days.

W 3 - plants were supplied with 200 ml of water once in every three days.

W4 - plants were supplied with 200 ml of water once in every ten days.

The light intensity under the screen house was measured with a digital luxmeter TCX100 and the average light intensity during the experiment was 8800LUX.

Sampling was taken every week. The following morphological parameters were taken, shoot height, leaf area, number of leaves was counted. Fresh and dry weights of plants were also determined. Leaf area ratio (LAR) was also calculated from the morphological parameters studied as follows:

Leaf Area Ratio (LAR) = LA/Ws- (West et al., 1920).

Where, LA = Leaf Area; Ws = Dry weight

Where, W_2 and W_3 are shoot and root dry weight respectively, the unit is g^{-1}.

The total number of flowers per plant in each group was counted. At fruiting, the total number of fruits in each group was also counted. The length and diameter of each fruit was measured accurately with a micrometer screw gauge. The weight of the fruit was measured with a weighing balance. The fresh weight of the fruits were taken after which they were left in the oven at 72 °C for 42 hours. After this period, the dry weight was measured with a weighing balance. The data obtained from the study was subjected to analysis of variance (ANOVA) with the aid of the software SPSS 16. Significant means were separated by Least Significance Difference (LSD) at the 95% probability level.

RESULTS

There was a general increase in the shoot heights of the plants in the different water treatments from the beginning to the end of the experiment (Table 1). There was no significant (P>0.05) different in the shoot height of the stressed plants and the unstressed plants from the beginning of the experiment to the third day of the experiment. From the fourth day to the end of the experiment, the unstressed plants were significantly (P<0.05) higher in shoot height than the stressed plants (W3 and W4). The stressed and the unstressed seedlings recorded a gradual but steady increase in the number of leaves from the beginning to the end of the experiment (Table 2). There was no significant (P>0.05) difference in the number of leaves from the beginning to the 4th week of the experiment. From the 5th week to the end of the experiment however, plants treated with W1 and W2 were significantly (p<0.05) higher than those treated with W3 and W4 in the number of leaves.

Plants treated with W1 and W2 recorded an increase in the dry weight from the beginning to the end of the experimental period (Table 3). Plants treated with W3 and W4 however did not follow a consistent pattern from the beginning to the end of the experiment. There was no significant difference in the dry weights of the plants in the W1 and W4 treatment from the beginning to the 4th week of the experiment. From the 5th week to the end of the experiment, plants treated with recorded a significantly (p<0.05) higher dry weight than those treated with W4. There was a general increase in the leaf area of the plants in the different treatments from the beginning to the experiment (Table 4). From the 2nd week to the end of the experiment, plants treated with W1 recorded a significantly (p<0.05) higher leaf area ratio than those treated with W4. For a greater part of the experimental period, there was no significant (p>0.05) difference in the leaf area ratio of the plants (Table 5). There was no significant (p>0.05) difference in the number of flower produced by the plants in the different water treatments. The number of fruits was significantly (p<0.05) higher in plants in the W1 treatment than those in the W4 treatment. The fruit length of the unstressed plants (W1) was also not significantly (p>0.05) different from the fruit length of the stressed plants (W3 and W4). The fruit diameter of the plants in the W1 treatment was significantly (p<0.05) higher than the fruit diameter of the plants in the W3 and W4 treatment. The fruit fresh weight of the plants in the W1 treatment was significantly (p<0.05) higher than those of the stressed seedlings. For the fruit dry weight, plants in the W1 treatment recorded a significantly (p<0.05) lower root dry weight than those in the W3 and W4 treatment.

Table 1: Shoot height of *Solanum Lycopersicum subjected* to different water treatments.

Water regimes	**Weeks after treatments**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
W1	13.10[a]	22.50a	27.40a	52.30a	72.10a	77.40a	96.50a	96.70a
W2	11.40[a]	22.10a	29.20a	50.90a	70.60a	74.80a	91.40a	92.10a
W3	11.90[a]	20.20a	24.50a	48.60ab	66.70ab	70.40b	75.80b	75.70b
W4	12.59[a]	19.30a	22.30a	45.30b	59.60b	61.70b	70.30b	70.70b

Means within the same column with the same superscript are not significantly different ($p>0.05$); W1- plants were supplied with 200 ml of water every day; W2- plants were supplied with 200 ml of water once in three day; W3- plants were supplied with 200 ml of water once in five days ; W4- plants were supplied with 200 ml of water once in ten days.

Table 2: Number of leaves of *Solanum lycopersicum* subjected to different water treatments.

Water regimes	**Weeks after treatments**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
W1	8.00a	12.00a	16.00a	19.00a	25.00a	26.00a	30.00a	30.00a
W2	9.00a	12.00a	18.00a	22.00a	28.00a	27.00a	31.00a	32.00a
W3	9.00a	11.00a	17.00a	20.00a	26.00ab	21.00b	22.00b	23.00b
W4	8.00a	12.00a	19.00a	19.00a	20.00b	23.00b	23.00b	21.00b

Means within the same column with the same superscript are not significantly different ($p>0.05$); W1- plants were supplied with 200 ml of water every day; W2- plants were supplied with 200 ml of water once in three day; W3- plants were supplied with 200 ml of water once in five days; W4- plants were supplied with 200 ml of water once in ten days.

Table 3: Dry weights of *Solanum lycopersicum* subjected to different water treatments.

Water regimes	**Water treatments**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
W1	0.45a	0.65a	0.87a	1.20a	2.01a	2.11a	3.16a	3.88a
W2	0.54a	0.57a	0.77a	0.90a	1.98a	2.23a	3.08a	3.18a
W3	0.46a	0.67a	0.99a	1.10a	1.77a	1.12b	0.95b	1.14b
W4	0.44a	0.59a	0.88a	0.80a	0.78b	0.96b	0.89b	0.98b

Means within the same column with the same superscript are not significantly different ($p>0.05$)

W1- plants were supplied with 200 ml of water everyday

W2- plants were supplied with 200 ml of water once in three day

W3- plants were supplied with 200 ml of water once in five days

W4- plants were supplied with 200 ml of water once in ten days

Table 4: Leaf area of *Solanum lycopersicum* subjected to different water treatments.

Water regimes	Water treatments							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
W1	89.90a	120.20a	150.20b	179.32a	228.56a	232.30a	235.37a	235.65a
W2	90.30a	115.90a	170.38a	180.30a	215.90a	220.70b	225.60a	229.45a
W3	85.50a	90.98b	110.30c	115.89b	130.22b	142.50c	150.30b	153.45b
W4	95.20a	93.74b	100.50c	120.23b	122.30b	127.40d	135.55c	136.32c

Means within the same column with the same superscript are not significantly different (p>0.05); W1- plants were supplied with 200 ml of water every day; W2- plants were supplied with 200 ml of water once in three day; W3- plants were supplied with 200 ml of water once in five days; W4- plants were supplied with 200 ml of water once in ten days.

Table 5: Leaf area ratio of *Solanum lycopersicum* subjected to different water treatments.

Water regimes	Water treatments							
	1	2	3	4	5	6	7	8
W1	180.00a	300.00a	90.90c	85. 30a	33.50a	35.60a	23.70a	23.50a
W2	162.50a	145.70b	138.30b	91.70.70a	60.30b	48.40a	28.60a	29.50a
W3	244.30a	175.40b	145.40b	83.70a	23.20a	47.30a	29.30a	28.50a
W4	223.40a	162.30b	233.10a	57.60b	33.70a	39.20a	27.90a	31.20a

Means within the same column with different superscript are significantly (p>0.05) different; W1- plants were supplied with 200 ml of water every day; W2- plants were supplied with 200 ml of water once in three day; W3- plants were supplied with 200 ml of water once in five days; W4- plants were supplied with 200 ml of water once in ten days.

Table 6: Yield parameters of *Solanum lycopersicum* subjected to different water treatments.

Water Regime	Number of flowers	Number of fruits	Fruit length(mm)	Fruit Diameter(mm)	Fruit Fresh Weight(g)	Fruit Dry Weight(g)
W1	52.00a	28.00a	23.70a	32.86a	16.71a	0.42c
W2	61.00a	23.00a	27.86a	29.64a	13.57b	0.97b
W3	45.00a	16.00b	25.75a	20.76b	6.36c	1.24a
W4	42.00a	16.00b	28.40a	21.42b	13.85b	0.91b

Means within the same column with the same superscript are not significantly different (p>0.05); W1- plants were supplied with 200 ml of water every day; W2- plants were supplied with 200 ml of water once in three day; W3- plants were supplied with 200 ml of water once in five days; W4- plants were supplied with 200 ml of water once in ten days.

DISCUSSION

During the course of this experiment, all the plants were subjected to the same conditions of the environment that were necessary for the normal growth and development of the plants, except that some were water stressed while some were given normal water supply. Therefore, any differences observed in the plants could be attributed to the different levels of water to which the plants were subjected to.

The reduction in the shoot height of *S. lycopersicum* plants subjected to water stress was in consonance with the findings of (Aderolu, 2000) who found similar reduction in plant height in response to soil water deficit in cowpea. The reduction in plant height in maize seedling due to drought was reported by

Del Rosario et al. (2003). Results from this study are also similar to those found by Kinark et al. (2001) where plant height and stem diameter of water stressed plants were smaller than the equivalent component in the well-watered plants. The decrease in plant height under extreme water stress may have been due to reduced turgor, which affected cell division and expansion since growth involves both cell growth and development. Mwai (2002) reported that cell growth and development is a process consisting of three stages; cell division, enlargement and differentiation. Morphologically, seedling height is perceived as an increase in plant size as indicated by parameters such as seedling height, moisture content and root length while development involves tissue and organ formation. Therefore, reduced growth rate under water stress can be qualitatively related to reduced cell turgor or a reduction in the extensibility of the cell wall. Cell turgor reduces with any dehydration-induced decrease in cell water potential. The result of this study showed that the number of leaves produced was significantly reduced by water stress at the latter part of the experimental period. This is in line with the findings of Aderolu (2000) and Abubakar (2004) who found that water stress affected number of leaves for cowpea, maize and soybean respectively. Water stress leads to decreased in the rate of leaf initiation and reduction in leaf area of already formed leaves. This will result to lower photosynthetic activity in the affected leaves. The reduction in leaf area in the tomato plants under severe water stress is a mechanism adapted to avoid higher rate of transpiration and reduced surfaces for radiation due to water deficit. Plants develop strategies for maintaining turgor through increasing root depth or having an efficient rooting system to maximize water uptake, and by reducing water loss through reduced stomatal conductance, reduced absorption of radiation by leaf rolling and reduced evapo-transpiration (Singh, 2003).

The reduction in number of fruits in the plants that were water stressed occurred due to poor flower bud formation and development of fruit. Birhanu and Tilahun (2010) reported a decreased number and sizes of tomato fruits from plants subjected to moisture stress. The same observation of water stress on tomato yield parameters was also reported by Zotarelli et al. (2009). This reduction in number of fruits was, however, compensated by the increase in the fruit fresh weight to some extent. The decrease in fruit fresh weight of the stressed plants of *C. frutescence* subjected to water stress at the matured might be due to the competition between vegetative and reproductive organs which ultimately reflected on the yield.

The number of fruits per plant, fruit length and diameter, individual fruit fresh weight and fruit dry weight were affected by the water stress. In *C. annuum* and *C. frutescence*, the number of fruits per plant showed sensitivity to water stress imposed at flowering stage.

The fruit of the water stressed plants recorded small diameters and weights. When the rate of photosynthesis is reduced as a result of reduced amount of water, the sensitive phytochrome pigments (chlorophyll pigmentation) that intercepts light for the process is affected, and then plants subjected to drought stress should be expected to have small and light fruits weights. The results also indicated that no significant difference existed in the mean fruit length.

Conclusion

In this study of the effect of water stress on the growth and yield of tomato, it was noticed that water stress had no significant effect on the growth and morphological parameters of tomato. The results clearly showed that some of these parameters were even favored by mild water stress rather than excess water or normal water; however, water stress had a remarkably significant effect on the yield of tomato. When tomato is grown and watered daily, it was observed that the number of fruits obtained is increased compared to any other wetting regime but the fruits were somewhat smaller than fruits in the group of plants subjected to stress.

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