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Impact of Drought on Growth Characters and Yield of Contrasting Tomato Genotypes

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Drought is a major problem in arid and semi-arid regions and is the primary cause of crop loss worldwide, reducing average yields for most of the crop plants by more than 50%. Tomato cultivation is concentrated in semi-arid zones, where water stress is frequent. It is important to ascertain its response, while selecting cultivars that are tolerant and productive. Therefore, eighteen tomato genotypes were used to assess the impact of drought on various growth traits such as plant height, number of leaves, leaf area, TDMP and yield by adopting 100 and 50% field capacity. The results indicated 53% yield reduction under drought compared to 100% field capacity. As the stress increased from 100 to 50% field capacity, significant reduction in growth traits associated with yield were noticed. However, slight increment of root length and root volume were observed at 50% field capacity. The genotypes LE 114, LE 57, LE118 and LE 27, which showed significantly less reduction in plant height, leaf area, TDMP and yield during drought were considered as drought tolerant. Genotypes LE 1, LE 3, LE 20 and COTH 2, which recorded the highest reduction in plant height, leaf area, TDMP and ultimately poor yield were considered as drought susceptible.

Key words: Drought, Tomato, Root length, Leaf area, Yield

One of the most important abiotic factors limiting crop growth and productivity is water stress brought about by drought and salinity (Almansouri *et al.,* 2001). Water shortage is a worldwide problem for which the only solution is to make efficient use of water in agriculture and also breed drought tolerant varieties (Wang *et al.,* 2009). Rainfed vegetable production is need of the day to cope up with increasing demand for vegetable crops. The reduction in growth, yield and quality by water stress has been well documented (Barrs and Weatherley, 1962), although different physiological processes have been put forward to account for this reduction in different species. Drought is one of the most widespread environmental stresses and affects almost all the plant functions. The onset of stress may initially cause a loss of cell turgor and reduce leaf elongation, which in turn reduces plant height and leaf area since both are turgor-dependent processes. The result will be a decrease in growth rate, which in turn is a function of leaf area (Chartzoulakis *et al.,* 1993).

Tomato is very sensitive to number of environmental stresses, especially drought, high temperature and salinity (Kalloo and Bergh, 1993). In India, lack of irrigation and drought tolerant genotypes are the central problems for tomato cultivation. There are several growth and physiological traits contributing to the drought tolerance of horticultural crops. However, large number of tomato genotypes have not been screened for drought tolerance or exploited for their cultivation under drought situation. To breed drought tolerant genotypes, it is necessary to identify growth traits of plants, which contribute to drought tolerance. Therefore, the present investigation was carried out to study the growth traits at different stages to facilitate the screening and selection of contrasting tomato genotypes for drought tolerance.

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Materials and Methods

Experiments were conducted to study the effect of drought on growth parameters in contrasting tomato genotypes in pot culture at Rainout Shelter, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore.

The experiment was conducted with 18 tomato genotypes *viz.,* LE 1, LE 3, LE 5, LE 13, LE 14, LE 18, LE 20, LE 23, LE 27, LE 57, LE 100, LE 114, LE 118, LE 125, CO 3, PKM 1, TNAU THCO 3 and COTH 2 and two treatments *viz.,* 100% FC and 50% FC with three replications adopting completely randomized block design.

Seeds of selected genotypes were sown in trays filled with vermicompost for nursery. Uniform size (38 cm width and 32 cm height) pots were filled with 25 kg of soil and saturated with water and the field capacity of the soil was recorded. Twenty-five days old seedlings were transplanted and one plant was maintained in each pot. Drought was imposed from 0^{th} day onwards after transplanting by maintaining soil moisture at 50% field capacity by gravimetric method. Crop was supplied with fertilizers (2 g urea, 7 g SSP and 1.5 g MOP per pot as basal and 2 g urea at 30

DAT) and other cultivation operations including plant protection measures (foliar spray of dimethioate @ 2 ml per litre at 40 DAT) as per recommended package of practices of Tamil Nadu Agricultural University, Coimbatore. All the observations were recorded on physiologically active leaf at 60 DAT.

Plant height was measured from the ground level to the tip of the growing point and expressed as cm. The plant was uprooted and the root was taken with minimum damage and the length from the cotyledonary node to the root tip was measured as root length and expressed as cm. The root volume was estimated by water displacement method. Individual plant roots were immersed in known volume of water and the amount of water displaced was measured and expressed in cubic centimeter. Numbers of leaves were determined by counting the leaves from the base to tip of the plant in each pot of each replication were worked out and mean value expressed in numbers. Leaf area per plant was measured using a Leaf Area Meter (LICOR, Model LI 3000) and expressed as cm^2 $plant^{-1}$.

Uprooted plant samples, after washing the root portion, were first shade dried and then oven dried at 80ºC for 48 hrs. The total dry matter production of the whole plant was recorded and expressed as g $plant^{-1}$. Yield was calculated by the total weight of fruits harvested from each plants of all picking were added and average yield per plant was worked out and expressed in g $plant^{-1}$. Later the yield per hectare was calculated and expressed as t ha^{-1}. The data collected were subjected to statistical analysis in completely randomized block design following the method of Gomez and Gomez (1984).

Results and Discussion

Effect of drought on plant height

Plant height is an important trait for growth, since increased plant height would allow greater biomass production and yield potential in crops (Zhang *et al*., 2004). Notably higher plant height of 85.0 was recorded in the genotype LE 18, followed by LE 114 (83.5), CO 3 and LE 118 (80.0) at 50% FC and the lower value was recorded in LE 3 (53.0) and LE 5 (60.0) (Table. 1). Therefore, water deficit in the early stages of tomato showed a greater effect on reduction in plant height as observed by Gladden *et al*. (2012).

Table 1. Effect of drought on plant height and root characters of tomato genotypes

Genotypes	Plant height (cm)			Root length (cm)			Root volume (cm^3)		
	100% FC	50% FC	Mean	100% FC	50% FC	Mean	100% FC	50% FC	Mean
LE 1	94.3	72.6	83.5	23.5	24.5	24.0	115.0	113.2	114.1
LE 3	70.2	53.0	61.6	21.6	21.1	21.4	105.9	103.4	104.7
LE 5	78.4	60.0	69.2	19.7	19.6	19.6	96.3	95.8	96.1
LE 13	89.9	72.8	81.4	23.4	25.0	24.2	114.7	122.4	118.6
LE 14	84.5	70.7	77.6	22.2	25.9	24.1	108.8	126.8	117.8
LE 18	94.5	85.0	89.8	20.8	24.2	22.5	102.1	118.7	110.4
LE 20	100.1	72.7	86.4	21.4	22.6	22.0	104.9	110.6	107.8
LE 23	96.6	77.0	86.8	18.8	17.6	18.2	92.3	86.3	89.3
LE 27	83.5	77.3	80.4	20.7	25.3	23.0	101.2	114.1	107.7
LE 57	89.0	82.4	85.7	23.0	28.7	25.8	112.6	125.9	119.3
LE 100	83.9	64.7	74.3	18.8	17.6	18.2	92.3	92.4	92.4
LE 114	94.7	83.5	89.1	24.4	27.0	25.7	119.3	132.2	125.8
LE 118	85.1	80.0	82.6	21.1	28.8	24.9	103.2	141.0	122.1
LE 125	95.0	74.3	84.7	18.5	16.5	17.5	90.4	90.4	90.4
CO 3	91.2	80.0	85.6	20.1	23.2	21.6	98.4	113.6	106.0
PKM 1	76.7	71.1	73.9	19.7	23.0	21.4	96.6	112.8	104.7
THCO 3	87.1	67.5	77.3	22.3	22.3	22.3	109.0	109.1	109.1
COTH 2	94.5	74.2	84.4	23.1	23.8	23.4	113.0	116.4	114.7
Mean	88.3	73.3	80.8	21.3	23.1	22.2	104.2	112.5	108.4
	G	T	G x T	G	T	G x T	G	T	G x T
SEd	2.09	0.70	2.95	0.59	0.20	0.84	2.88	0.96	4.07
CD (0.05)	4.16	1.39	5.88	1.18	0.39	1.67	5.73	1.91	NS

These findings were in conformity with the results of Adam and Barakbah (1990), which revealed that the inhibiting effect of water stress on plant height of banana was more pronounced in susceptible cultivars than in tolerant ones. Therefore, plant height can be considered as an important trait for determining drought tolerance under water stress condition. As reported by Bhatt and Rao (2005) and Manivannan *et al*. (2007), the reduction in plant height was associated with a decline in the cell enlargement and more leaf senescence under water stress. The reduction in plant height might be due to turgor loss under drought. Hence, cell elongation is highly sensitive process and extremely affected by drought leads to reduction in plant height.

Effect of drought on root characters

Root length plays a major role in absorption of water and minerals thereby increase growth and development of plants. Root growth defines the extent to which a plant explores soil for water and mineral nutrients. Therefore, an extensive root system is advantageous to support plant growth during the early crop growth stage and extract water from shallow soil layers that is otherwise easily lost by evaporation. There are controversial evidences on the effect of drought stress on root growth. However, the root growth was not substantially inhibited under water stress in maize (Sacks *et al*., 1997). LE 118 performed with the longest root length of 28.8, followed by LE 57 (28.7) (Table 1). The varieties and the hybrids also exhibited better root systems with longer roots at 50% FC as considered as tolerant. While the genotypes showed less increment of root length under drought is considered as susceptible. Shimshi *et al*. (1982) also postulated that drought tolerant plants possess morphological or metabolic properties that enable them to maintain a high degree of tissue hydration even under limited water supply.

Table 2. Effect of drought on leaf characters and TDMP of tomato genotypes

Genotypes	Number of leaves			Leaf area (cm^2 $plant^{-1}$)			TDMP (g $plant^{-1}$)		
	100% FC	50% FC	Mean	100% FC	50% FC	Mean	100% FC	50% FC	Mean
LE 1	42.5	29.8	36.1	1767.80	1116.20	1442.00	25.38	14.35	19.86
LE 3	43.3	31.3	37.3	1800.70	1175.49	1488.09	25.85	15.20	20.52
LE 5	39.7	26.8	33.2	1651.68	1047.98	1349.83	23.71	14.72	19.22
LE 13	42.6	32.8	37.7	1772.39	1141.38	1456.89	25.44	16.39	20.91
LE 14	43.6	34.6	39.1	1814.42	1168.54	1491.48	26.05	16.78	21.41
LE 18	39.5	33.7	36.6	1642.52	1294.25	1468.38	23.58	17.93	20.76
LE 20	36.7	22.7	29.7	1526.81	906.91	1216.86	21.92	12.02	16.97
LE 23	38.5	27.0	32.7	1601.30	1069.47	1335.39	22.99	15.35	19.17
LE 27	40.9	33.7	37.3	1702.87	1339.63	1521.25	24.45	18.94	21.69
LE 57	43.3	37.3	40.3	1800.70	1521.99	1661.34	25.85	19.30	22.57
LE 100	38.5	25.0	31.8	1603.80	1032.75	1318.28	23.02	13.83	18.42
LE 114	37.8	29.5	33.6	1573.43	1172.99	1373.21	22.59	16.19	19.39
LE 118	36.0	32.3	34.1	1499.74	1157.06	1328.40	21.53	17.61	19.57
LE 125	37.5	23.3	30.4	1559.27	1004.06	1281.67	22.38	13.41	17.90
CO 3	30.3	25.3	27.8	1487.90	1114.70	1301.30	18.13	13.77	15.95
PKM 1	32.5	24.7	28.6	1350.72	908.06	1129.39	19.39	13.04	16.21
THCO 3	33.7	26.6	30.1	1775.24	1017.45	1396.34	24.12	14.61	19.36
COTH 2	34.5	25.1	29.8	1880.09	961.61	1420.85	23.59	13.80	18.69
Mean	38.4	29.0	33.7	1656.19	1119.47	1387.83	23.33	15.40	19.37
	G	T	G x T	G	T	G x T	G	T	G x T
SEd	0.87	0.29	1.23	15.58	5.19	22.03	0.49	0.17	0.70
CD (0.05)	1.73	0.58	2.45	31.05	10.35	43.92	0.99	0.33	1.40

Thakur (1989) also noticed a similar trend of root and shoot dry matter production in tomato under water deficit condition. Among the genotypes, LE 118 was statistically superior showing higher root volume of 141.0 at 50% FC followed by LE 114 (132.2) and LE 57 (125.9.) while the lowest value was recorded by LE 23 (86.3) (Table. 1). In the present study, the increment of root length and volume under drought might be due to increment of osmotic pressure by the accumulation of compatible osmolytes like proline which keeps the leaf water potential lower than that of soil water potential which leads ultimately induce the root growth for search of water. The present study corroborates with the earlier findings of Djibril *et al*. (2005). Rana and Kalloo (1989) observed profused root system with longer and thicker roots in resistant genotypes of *L. pimpinelifolim*, whereas susceptible genotype, Sel-5 had restricted root system.

Effect of drought on leaf characters

The results of leaf numbers as influenced by two irrigation levels exhibited significant differences. However, at 50% FC, the genotype LE 57 maintained in superiority with the highest number of leaves (37.3) followed by LE 14 (34.6), LE 18 and LE 27 (33.7). The varieties and hybrids also performed better with the leaf number ranging from 24.7 to 26.6 at this water deficit level (Table 2).

Leaf area is a fundamental determinant of the total photosynthesis of a plant. Leaf area always shows a positive relationship with net photosynthetic activity, because leaf enlargement is attributed to increase in number and width of grana and also high degree of stacking of grana (Fortun *et al.*, 1985). Leaf area development is based on the length and width of leaf, in general, was very sensitive to water deficit as reported by Rawson and Turner (1982).

In the present study, drought stress caused 30% reduction in leaf area especially at the time of flowering. The reduction in leaf area under drought could be due to loss of turgidity ultimately affects the cell enlargement.

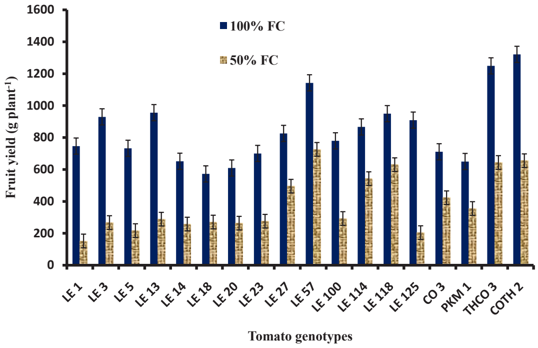

Fig. 1. Impact of drought on fruit yield of contrasting tomato genotypes

The genotypes LE 57 (15.5%), LE 18 (21.2%), LE 27 (21.3%) and LE 118 (22.8%) showed the lowest reduction in leaf area (Table. 2). LE 57 showed its superiority with less reduction of leaf area. These results are in close with the findings of Rana and Kalloo (1989), which indicates that susceptible genotypes of tomato showed significant reduction in leaf area as compared to resistant genotypes.

Total leaf area in stress imposed plants of tomato was lower than well-watered plants as observed by Tahi *et al*. (2008). This was also in confirm with the present study, that reduction in leaf area might be an adoptive mechanism under drought for survival, by reducing transpiration but larger leaf area reduction affects the capturing of light ultimately photosynthesis and yield.

Effect of drought on dry matter production

An adverse effect of water stress on crop plants is the reduction in total dry matter production. Patel *et al.* (2012) showed that total dry weight of the plant was decreased significantly by drought stress in chickpea. It was observed in the present study that drought stress (50% FC) caused reduction of 40% TDMP compared to 100% FC. COTH 2 maintained its superiority and recorded a maximum dry matter production of 139.61 at 100% FC (Table. 2). Drought (50% FC) treatment significantly affects the total dry matter production of all the genotypes. Between the genotypes, performance of LE 57 was statistical superior showing higher TDMP of 19.30 at 50% FC. Drought significantly affects the total dry matter production of all the genotypes, but greater adverse effect on TDMP was registered in LE 20, PKM 1and LE 125.

The tolerant genotype LE 118 maintained higher TDMP throughout the growth thus showing lesser reduction under drought stress condition. The hybrids COTH 2 and THCO 3 showed their susceptible nature with greater reduction in dry matter production. Reduction of total dry matter production in drought conditions might be due to reduction in leaf area and net photosynthesis and an increase in photorespiration rates eventually (Terbea *et al*., 1995).

Impact of drought on yield

Water deficit at various stages of crop growth may adversely affect the final yield of the crop. Effect of drought on the yield depends on duration and severity of the stress. Drought may cause abortion of embryonic sac, dehydration of style and pollen and hence interference in pollination (Mohammmad *et al*., 1996). Drought stress resulted in the overall yield loss tomato fruits up to 55%. Under 50% FC level, LE 57 documented significantly superior fruit yield of 726.00 which was closely followed by COTH 2 (654.80), THCO 3 (643.65) and LE 118 (630.00) (Fig. 1). The per cent yield reduction was smaller in the genotype LE 118 (33.64) followed by LE 57 (36.46) and LE 114 (37.38). The per cent yield reduction was higher in LE 1 (79.62) followed by LE 125 (77.53).

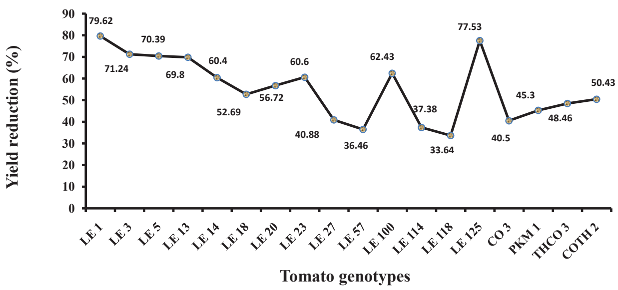

Fig. 2. Impact of drought on percentage of yield reduction in contrasting tomato genotypes

The highest yield loss of 70 to 80% was shown by LE 1, LE 125, LE 3 and LE 5. The varieties and hybrids showed a reduction of fruit yield from 40.5 to 50.4% over control. A significantly lesser reduction of 35 to 40% was exhibited by LE 118, LE 57, LE 114 and LE 27 showing their somewhat tolerance nature to drought stress (Fig. 2) Therefore, it could be clearly revealed that water deficit as the result of drying soil caused a major adverse effect on yield and yield components even in tolerant genotypes. The reduction in fruit yield and related parameters under drought probably due to reduction of water content in plant which disrupting leaf gas exchange properties which limited the source size and activity (photosynthesis) and partitioning of photo assimilates to fruits (sink size and activity). The present study confirms the early findings of Farooq *et al*. (2009) and Manjunatha *et al*. (2004).

Conclusion

From the study on performance of the genotypes based on various growth parameters and yield, the genotypes *viz.,* LE118, LE 57 and LE 114 showed less yield reduction under drought. These genotypes can be successfully used in breeding programmes for further exploitation.

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