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Impact of flooding on growth of tomato (*Solanum lycopersicum* L.)

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Abstract
Tomato (*Solanum lycopersicum* L.,) is one of the most popular vegetables and an essential source of antioxidants including, lycopene, phenolics, and vitamin C in the human diet which is widely grown in temperate and tropical regions of the world. Usually, plants are vulnerable to various abiotic stresses, and one of the significant abiotic stresses is flooding to which tomato is considered to be most sensitive. Exposure of tomato plants to flooding would cause reduced plant growth. Hence, a study on the impact of flooding on the growth of tomato was conducted. The observation on plant height, the number of leaves, leaf area, relative growth rate were significantly reduced under flooding compared to control, but the genotypes like LE 523, LE 828, and LE 102 has recorded nearest lower value compared to their control. Among all the genotypes LE 523 has recorded higher plant height (43.20cm), the number of leaves (46), leaf area (184.27 cm^2) and relative growth rate (7.29mg $g^{-1}day^{-1}$) followed by LE 828. On the other hand, the genotypes, PKM 1 and CO 3 had decreased plant height, the number of leaves, leaf area, and relative growth rate, revealing that it is susceptible to flooding stress.

Keywords: Plant height, number of leaves, leaf area, relative growth rate, flooding, tomato

Introduction

Tomato (*Solanum lycopersicum* L.) is an herbaceous plant, belongs to the family Solanaceae. It is one of the most important and widely grown vegetable crops in both temperate and tropical regions of the world. Tomato is the second important vegetable after potato and sweet potato both in area and production. Tomato is a day-neutral plant, so widely grown in any season. Worldwide, tomato ranks seventh in production after maize (*Zea maize*), rice (*Oryza sativa*), wheat (*Triticum aestivum*), potatoes (*Solanum tuberosum*), soybeans (*Glycine max*), and cassava (*Manihot esculenta*) (Anon., 2015) [1]. Tomatoes also contribute to a healthy, well-balanced diet as it is a rich source of minerals, vitamins, lycopene, beta-carotene, flavonoids, vitamin C, hydroxyl cinnamic acid derivatives, essential amino acids, sugars, dietary fibers, and vitamin B. Therefore, tomato is considered as "protective foods". In India, the major tomato producing state is Andhra Pradesh, Karnataka, Madhya Pradesh, West Bengal, Odissa, Uttar Pradesh, Maharashtra, Assam, and Bihar. The total production of tomato in Tamil Nadu was about 26.41 thousand MT from 365.77 thousand hectares of land (Anon., 2015) [1], which is very low compared to the other states. India is the second-largest producer of tomato after China in the world (Anon., 2015) [1], however, the production of tomato lags behind the demand. As per the IPCC report, it is predicted that in future there is more likely to get an increased frequency of heavy rainfall, eventually resulting in flood stress (IPCC, 2014) [2]. Current data indicates that more than one-third of the world's irrigated area may likely to get waterlogged, due to heavy rainfall, faulty irrigation, unleveled land, poor drainage, heavy soil texture, and flooding is a severe constraint to crop growth and productivity in many regions and situations.

In tropical and subtropical regions, excessive rainfall is the major constraint for crop production. India is quite susceptible to cyclones and floods due to its geographical location surrounded by water on three sides, and regularly 10 million hectares of land in India and Bangladesh are affected by flood in monsoon. The flood-affected areas in India are West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, and Gujarat. Currently, flooding has become an important global crop production constraint causing significant yield reduction in several crops that affect about 16% of production areas worldwide (Boyer, 1982) [3]. Flooding affects the physiological functioning, vegetative, and reproductive growth of plants is affected by flooding (Kozlowski, 1984; Gibbs and Greenway, 2003) [4, 5].

Soil is considered to be waterlogged only if there is freestanding water on the soil surface at least 20% higher than the field capacity (Aggarwal *et al*., 2006) [6]. Waterlogging may result in a yield loss of upto 10% and 40% in severe cases.

The negative impact of waterlogging on plant growth and development is mostly the consequence of the slow diffusion rates of gases in water as compared with air and the relatively low solubility of oxygen in water (Vartapetian and Jackson, 1997) [7]. In the plant rhizosphere, waterlogging can severely impair the performance of terrestrial plants, where morphological and physiological responses are disturbed. Flooding stress negatively influences the plant growth, retardation of shoot growth in flooded plants is caused by the inhibition of nitrogen (N) uptake, and the consequent redistribution of nitrogen within the shoot. The decrease in the shoot nitrogen content will lead to chlorosis and consequently reduces the shoot growth, root growth, dry matter accumulation, and final yield. Tomato production is complicated in hot and humid lowland areas of tropics during monsoon months due to waterlogging. Moreover, very few studies have been done on flooding stress in tomato, so a better insight is required in knowing the impact of flooding stress on tomatoes. Hence, a study on the impact of flooding on the growth of tomato is required to screen or develop tomato genotypes for flooding tolerance. With this background, a study was conducted to screen tomato genotypes for flooding stress based on the impact on growth.

Materials and Methods

The research was conducted at the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore (11° N latitude, 77° E longitude; 426.7 MSL), Tamil Nadu, India. The seeds of 15 genotypes were treated with carbendazim @ 0.5g kg-1 of seeds for protection against seed borne diseases. The seeds were sown uniformly in the well prepared coir pith media containing portrays maintaining a thin film of water. After thirty five days of sowing, uniform seedlings were transplanted to the submergence tank. The submergence tank was divided into four quarters where two quarters of submergence tank plants were maintained under controlled condition and the other two quarters for flooding treatment for each genotype. A set of plants were subjected to flooding treatment after 10 DAT. Five cm of water was maintained from the ground surface for seven days. The morphological responses of 15 tomato genotypes (LE 2, LE 3, LE 5, LE 102, LE118, LE 125, LE 150, LE 184, CO 3, HN 2, PKM 1, LE 411, LE 523, LE 812 and LE 828) to flooding stress were evaluated. The recommended dose of fertilizers and standard package of practices were followed. Each genotype was replicated three times. The experiment was designed in a factorial completely randomized block design. A set of plants were subjected to flooding treatment after 10 DAT. The morphological observations such as plant height, number of leaves, leaf area and relative growth rate were recorded after seven days of flooding treatment from each replication. Five plants were selected in random and tagged to measure plant height from each replication. The height of the plant was measured from the base of the shoot to the apical portion of the plant, and the mean was expressed in cm. The number of leaves was counted from the randomly selected and tagged plants on the seventh day after treatment. The tagged plants were uprooted and the leaf area per plant was measured using a leaf area meter (LICOR, Model LI 3000) and expressed as cm^2 per plant. Relative growth rate is the measure of the rate of increase of dry weight per unit time. Gardner *et al.* (1985) [8]. suggested the following formula for RGR and it was expressed as mg g^{-1} day^{-1}.

$$\text{RGR} = \frac{W_2 - W_1}{T_2 - T_1}$$

Where, W_1= Total plant dry matter at time T_1; W_2= Total plant dry matter at time T_2; T_1= Time of first observation and T_2= Time of second observation.

Results and Discussion

In the present study, tomato genotypes were exposed to flooding stress for seven days at vegetative stage. There was a significant difference among the genotypes and between the treatments. Plant height decreased under flooding condition for all genotypes compared to control (Table 1). Among the 15 genotypes, the genotype LE 2 had greater plant height in both control (46.67 cm) and flooded condition (44.57 cm) (Table 1) followed by LE 828 (45.80and 43.20 cm respectively). On the other hand, PKM 1 recorded significantly lower plant height of 28 cm under control and 17.90 cm under flooded condition followed by CO3. Plant height was considered to be the maximum sensitive character to flooding stress, because under waterlogged condition, gibberellic acid (GA) deficiency or ethanol transport to shoot from anaerobic roots may occur (Kuo, 1993) [9].

Across the genotypes, the leaf number was decreased under flooding condition. The genotype LE 523 recorded a more significant number of leaves (49) followed by LE 828(45) whereas PKM 1 recorded the lowest number of leaves (18) under flooding condition (Table 1). This was similar to the results found by Tek Prasad Gotame (2006) [10]. and Vincent *et al*. (2010) [11]. in tomato. All genotypes under flooding stress not only had less leaf production but also had reduced overall plant growth compared to the control plants. The negative effect of flooding on plant growth, leaf length, and the number of leaves across the genotype might be due to a reduction in their photosynthetic rate. Reduced plant growth due to flooding was also observed in *Annona* species which was due to the decrease in shoot extension, leaf production of seedling and reduced net CO_2 assimilation rates that resulted in 20±80% tree mortality (Nunez-Elisea *et al*., 1999) [12]. *Paspalum dilatatum*is another vegetable crop most sensitive to excessive soil moisture (Vasellati, 2001) [13]. Under anaerobic conditions waterlogged soils incompletely oxidized intermediates and end products that are toxic to plants, such as methanol and organic acids, can accumulate, and potentially toxic substances such as H_2S are produced in soils at low redox potentials (Kludze *et al*., 1994) [14]. When the plants were not able to evade unfavorable soil conditions by inducing adventitious roots, deterioration progressed fast.

Leaf areais an important parameter for yield attributes, and it has significantly decreased under the flooding condition in all the genotypes. The genotype LE 523 recorded significantly higher leaf area of 217.05 cm^2 under control and 184.27 cm^2 under flooding condition, and it was followed by LE 828. The lowest leaf area was recorded for the genotype PKM 1(64.03 cm^2) and CO 3(7.68 cm^2) under the flooding condition (Fig 2). Restricted nitrogen supply and increased ethylene production were attributed to leaf growth reduction (Adhikari, 1992) [15]. Similar results were observed by Bange (2003) [16]. in cotton were a considerable reduction in leaf area, and specific leaf weight resulted in decrease dry matter production.

Relative growth rate represents the increase of total dry weight per unit time per unit of existing total dry weight. In the present study, the genotype LE 523 has a significant higher relative growth rate of 8.34 mg g^{-1} day^{-1}in control and 7.29 mg $g^{-1}$$day^{-}$under flooding condition (Fig. 1). The lowest relative growth rate of 5.12 mg g^{-1} $day^{-1}$and 3.62 mg g^{-1} $day^{-1}$was recorded in PKM 1 under control and flooding condition, respectively. Any changes in plant growth were mainly due to the altered water relation, carbohydrate content, mineral nutrients, hormonal relations, and accumulation of toxic substances (Adhikari and Paje, 1993) [17]. Drew and Sisworo (1977) [18]. also observed the inhibition of nitrogen uptake, and the consequent redistribution of nitrogen within the shoot. The inhibition in mineral uptake in flooded soils resulted from the depletion of $NO_3^-$and accumulation of Fe^{2-}, Mn^{2+}, NH^{4-} and S^{2-} in the flooded soil (Ponnamperuma. 1984; Tiedje *et al*., 1984) [19, 20]. An excessive amount of NO_3 in the flooded soils may lead to accumulation of NH_4 by the process of NO_3 reduction. Increase of NH_4 in the soil to a considerable extent may cause a reduction in plant growth and toxic effects on plant metabolism (Mengel and Kirkby, 1987; Marschner, 1995) [21, 22]. Similar results were observed in *Paspalum dilatatum* and tomato seedlings (Vasellati *et al*., 2001; Walter *et al*., 2004) [23, 24]. This study explicitly shows a reduction in relative growth rate in all the genotypes under flooding condition that result from reduced nutrient uptake.

Conclusion

The study elucidates that among all the genotypes evaluated LE 523 was the best tolerant genotype followed by LE 828 for flooding condition by showing its superior morphological characters namely plant height, the number of leaves, leaf area, relative growth rate over other selected genotypes. On the other hand, PKM 1 and CO 3 showed its poor performance by being very sensitive to flooding stress with lower performance under flooding stress.

Table 1: Effect of flooding stress on plant height (cm) and number of leaves $plant^{-1}$in tomato genotypes

S. No	Genotypes	Plant height (cm)		Mean	Number of leaves $plant^{-1}$		Mean
		Control	Flooding stress		Control	Flooding stress	
1	LE – 2	39.67	33.67	36.67	36	34	35.00
2	LE – 3	43.40	37.87	40.64	41	37	39.00
3	LE – 5	33.00	28.52	30.76	33	27	30.00
4	LE – 102	37.67	34.83	36.25	47	42	44.50
5	LE – 118	39.20	33.00	36.10	45	32	38.50
6	LE – 125	33.06	29.10	31.08	30	27	28.50
7	LE – 150	28.52	26.36	27.44	28	25	26.50
8	LE – 184	44.34	39.87	42.11	44	41	42.50
9	CO 3	25.30	21.24	23.27	38	21	29.50
10	HN 2	42.05	39.40	40.73	34	24	29
11	PKM 1	28.00	17.90	22.95	29	18	23.50
12	LE – 411	32.40	28.53	30.47	36	30	33.00
13	LE – 523	46.67	44.57	45.62	49	46	47.50
14	LE – 812	24.84	21.40	24.62	24	22	23.00
15	LE – 828	45.80	43.20	44.50	45	43	44.00
Mean		36.26	32.16	34.21	37.27	31.47	34.26
SEd		G 0.52	T 0.19	GxT 0.73	G 0.39	T 0.14	GxT 0.55
CD (P=0.05)		1.03	0.38	1.46	0.78	0.29	1.11

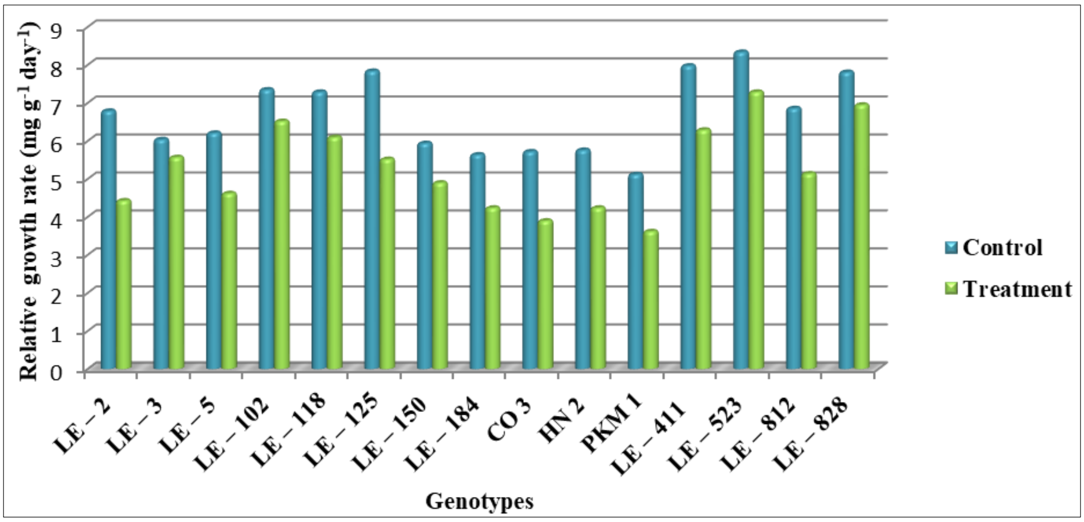

Fig 1: Effect of flooding stress on Relative Growth Rate (mg g^{-1} day^{1}) in tomato genotypes

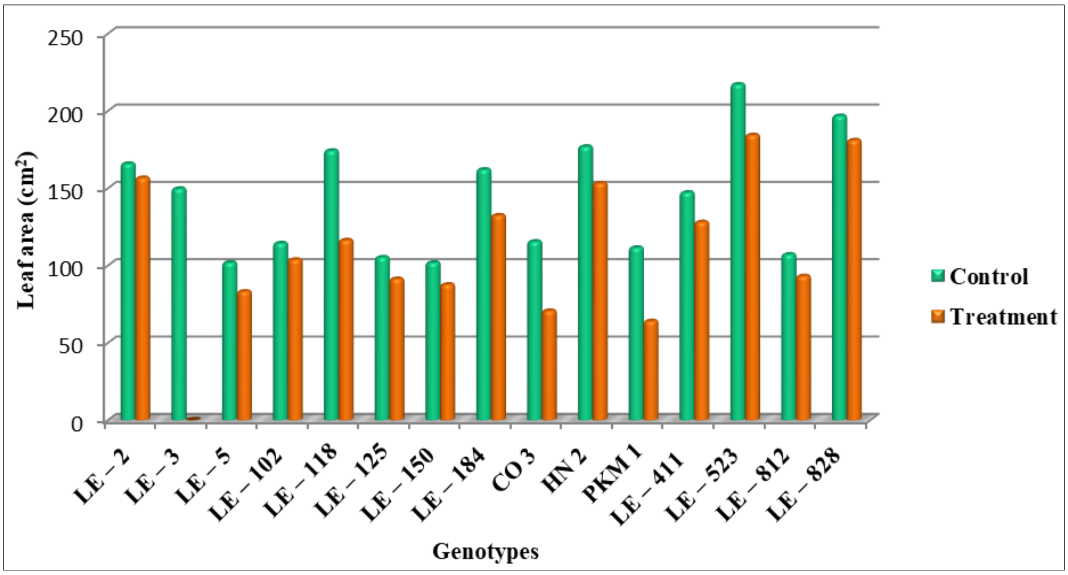

Fig 2: Effect of flooding stress on leaf area (cm^2) in tomato genotypes

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