Published with Open Access at Journal BiNET
Vol. 02, Issue 01: 44-50

Asian Journal of Crop, Soil Science and Plant Nutrition

Journal Home: https://www.journalbinet.com/ajcsp-journal.html

Waterlogging stress adversely affects growth and development of Tomato

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Article received: 12.12.2019; Revised: 28.01.2020; First published online: 10 February 2020.

ABSTRACT

Waterlogging is serious abiotic stress which affects plant growth and development dueto a reduced amount of oxygen supplied to submerged tissues. A pot experiment was conducted to look into the adverse effect of flooding stress on tomato cultivar, Pusharubi at Jute Agriculture Experimental Station, Jagir, Manikganj from September to December, 2018. Thirty days old healthy tomato plants were subjected to continuous flooding stress of different durations, 0, 3, 6, 9 and 12 days. Earthen pots with healthy tomato plants were placed inside a larger concrete chamber and irrigated with tap water so that the waterlogging depth was maintained within 4-5 cm throughout the experimental period. Morphological parameters recorded include plant height, number of leaves, stem base diameter, leaf area, dead plant %, days to flowering and number of fruits per plant. Pusharubi cultivar was heavily affected by the deleterious effect of waterlogging on all the parameters studied. Therefore Pusharubi genotype can be treated as a waterlogging sensitive genotype. For all these reasons Pusharubi may not be recommended for cultivation in low land areas or where water stagnation is prominent. This experiment identified some agronomic traits associated with flood-tolerance for vegetable crops.

Key Words: *Tomato, Flooding stress, Growth parameters, Yield and yield components*

Cite Article: Tareq, M. Z, Sarker, M. S. A., Sarker, M. D. H., Moniruzzaman, M., Hasibuzzaman, A. S. M. and Islam S. N. (2020). Waterlogging stress adversely affects growth and development of Tomato. Asian Journal of Crop, Soil Science and Plant Nutrition, 02(01), 44-50.
Crossref: https://doi.org/10.18801/ajcsp.020120.07

I. Introduction

Tomato (*Lycopersicon esculentum*) belongs to the family Solanaceae, is one of the most important nutritious palatable and mostly winter vegetable grown in Bangladesh. In the human diet, tomato plays an important role because of its higher amount of vitamins and minerals (Lorenz, 1997). Among all vegetables, tomato is ranked first in terms of its nutritional contribution to the human diet (Splittstoesser, 1990). In Bangladesh tomato itself provides more than 7% of total vitamin-C of vegetable origin (BBS, 2008). Tomato contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). The antioxidant lycopene present in tomato helps human body to fight against different types of cancers (prostate, breast), atherosclerosis, coronary artery diseases, myocardial infarction and reduce blood cholesterol levels (Kohlmeier et al., 1997; Rao and Agarwal, 2000; Kerkhofs et al., 2005; Xianquan et al., 2005; Rao and Rao, 2007). Research studies have shown that tomatoes contain enzymes or a factor (dubbed P3) that inhibits platelets in the blood from clumping together and forming blood clots (Lazarus et al., 2004). It is also rich in Ca, P and Fe (Islam et al., 1996).

Waterlogging is a global phenomenon and focal abiotic stress which affects crop growth and yield (Linkemer et al., 1998; Setter and Waters, 2003; Lone et al., 2018). As a consequence of Global climate change waterlogging events to be more frequent, severe, and unpredictable (Jackson and Colmer 2005). In the United States, Waterlogging affects 16% of the soils, 10% of the agricultural lands of Russia and irrigated crop production areas of India, Pakistan, Bangladesh, and China (Yaduvanshi et al., 2014; FAO, 2015). About 10-15 million ha of wheat are affected globally by waterlogging which annually causes yield loss of 20-50% (Hossain and Uddin 2011). Waterlogging also causes yield losses in other grain crops such as barley, canola, lupins, field peas (Bakker et al., 2007; Romina et al., 2018), lentils and chickpeas (Solaiman et al., 2007). Due to the special geographical location and backdrop of climate change in recent years, waterlogging is one of the most pressing concerns now a day in Bangladesh. Therefore, exploring the best adaptation practices is time demanded with the prevention and mitigation of waterlogging in the region.

Winter tomato is mostly cultivated all over Bangladesh for its wide range of adaptability with respect to soil and climate (Ahmed, 1995); and it ranks fourth on the basis of production and third on the basis of area (BBS, 2006). Considering annual production in the world tomato places sixth (FAO, 2011). The cultivated area under tomato in Bangladesh is 6.81%, average yield 5451 kg/acre, total production of 368000 tons (BBS, 2016). Although tomato is a winter crop (January-March) in our country, it has great demand throughout the year. As a result of its greatest demand tomato is known a profitable, less risky, relatively short production cycle and labor-intensive cash crop compared with many field crops (Islam, 2005). Farmers in Bangladesh are now started to produce summer tomato, but there is still a long way to go for successful commercial production due to a number of limitations. Waterlogging as a result of excessive rainfall during the rainy season is the prime barrier to cultivating summer tomato in Bangladesh (Zaman et al., 2006). From the above facts, the experiment was designed to study the waterlogging effect on growth and yield of tomato.

II. Materials and Methods

An experiment was conducted at Jute Agriculture Experimental Station, BJRI, Manikganj during the period from September to December, 2018 in pot culture to find out the waterlogging effect on growth and yield of tomato. The crop was sown on 18th September, 2018. Seeds of tomato cultivars were surface sterilized by keeping the seeds in 1% $HgCl_2$ solution for 2 min, followed by rinsing thoroughly with distilled water. Twenty-five seeds were sown per pot (15 inches in height and 16 inches in diameter) containing 40 kg soil. The atmospheric temperature fluctuated within a range of 29-31 ^{0}C at day and 18-27 ^{0}C at night. The relative humidity fluctuated between 71 and 83% at day and night, respectively. Waterlogging induced at 30 DAG (Days after germination).

A tomato variety `Pusharubi' with five different i.e. 0, 3, 6, 9 and 12 days of waterlogging were used as treatments. Waterlogging depth was 4-5cm from the base of the plant. Crop was harvested at the period of horticultural maturity. Completely Randomized Design (CRD) with a single factor and three replications were used in this experiment. There were five plants per pot and 3 pots were considered as a replication. Each replication contains 15 plants. The collected data on different growth and yield related characters were subjected to statistical analysis following ANOVA technique. Differences among treatment means were adjusted by Duncan's Multiple Range Test with the help of a computer based statistical package program MSTAT-C (Gomez and Gomez, 1984).

III. Results and Discussion

Plant height

Tomato plants responded negatively to Waterlogging showing a stunted growth compare to control. The highest plant height was recorded (67.33cm) in T_0 (control) treatment and was subsequently decreased as the T_2 (28.79), T_3 (26.50) and the lowest one was recorded (20.62cm) in T_4 treatment (Figure 01).

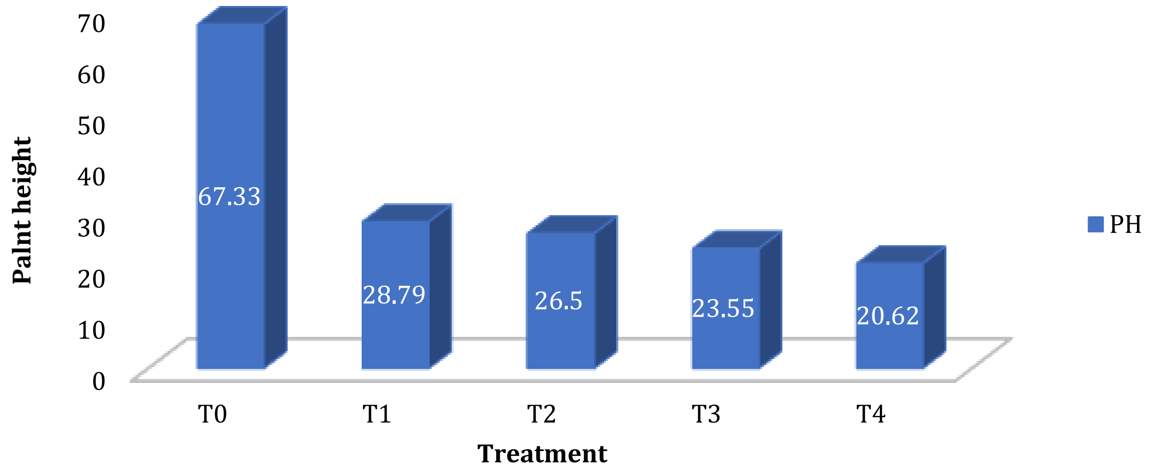

Figure 01. Effect of waterlogging on plant height of tomato

Number of leaves

Number of leaves per plant varied significantly compared to control and follows a decreasing pattern. The highest number of leaves per plant was recorded (11.00) in T_0 (control) treatment and the lowest was recorded (3.33) in T_4 treatment. T_1 (6.33), T_2 (5.67) and T_3 (5.00) remain in the middle position (Table 01).

Base diameter

There was decrease in base diameter as the days of flooding increased and significantly differed when compare to the control. The highest base diameter was recorded (8.28mm) in T_0 (control) treatment and the lowest was recorded (3.70mm) in T_4 treatment. T_1 (6.33), T_2(5.67) and T_3 (5.0) are statistically insignificant (Table 01).

Leaf area

Waterlogging has pronounced an obstructive effect on leaf area of tomato. The highest leaf area was recorded (46.88) in T_0 (control) treatment and the lowest was recorded (4.63) in T_4 treatment which is statistically identical with T_3 (6.42) treatment. T_1 (21.33) and T_2 (13.25) remain in the middle position (Table 01).

Table 01. Effect of waterlogging on growth and yield of tomato

Treatments	PH	NL	BD	LA	Dead plant (%)	Days to flowering	Number of fruits/plants
T_0	67.33a	11.00a	8.28a	46.88a	0.00c	35.67e	8.58a
T_1	28.79b	6.33b	6.05b	21.33b	17.86b	59.67d	3.92b
T_2	26.50bc	5.67b	5.61b	13.25c	33.15b	64.33c	2.97b
T_3	23.55cd	5.00bc	5.24b	6.42d	51.48a	67.00b	2.00b
T_4	20.62d	3.33c	3.70c	4.63d	66.87a	71.00a	1.30b
LSD	3.720	1.867	1.531	2.272	17.66	2.254	3.498
CV	5.92	15.82	14.08	6.52	27.69	2.01	49.52
Level of sig.	**	**	**	**	**	**	**

Dead plant percent

Waterlogging exhibits a remarkable co-relation with number of dead plant percent of tomato. The highest dead plant percent was recorded (66.87) in T_4 treatment which is statistically identical with (51.48) T_3 treatment and the lowest was recorded (0.00) in T_0 treatment. T_1 and T_2 remain in the middle position (Table 01).

Days to flowering

Table 01 shows that, waterlogging poses a notable difference on days to flowering of tomato. The highest days to flowering was recorded (71.00) in T_4 treatment and the lowest was recorded (35.67) in T_0 (control) treatment. T_1 (59.67), T_2 (64.33) and T_3 (67.0) remain statistically identical (Table 01).

Number of fruits per plant

The number of fruits per plant presented in the table 01, appreciably affected by Waterlogging. The highest number of fruits per plant was recorded (8.58) in T_0 (control) treatment and the lowest was recorded (1.30) in T_4 treatment which is statistically identical with T_1 (2.97), T_2 (2.0) and T_3 (1.3) treatments (Table 01 and Figure 02).

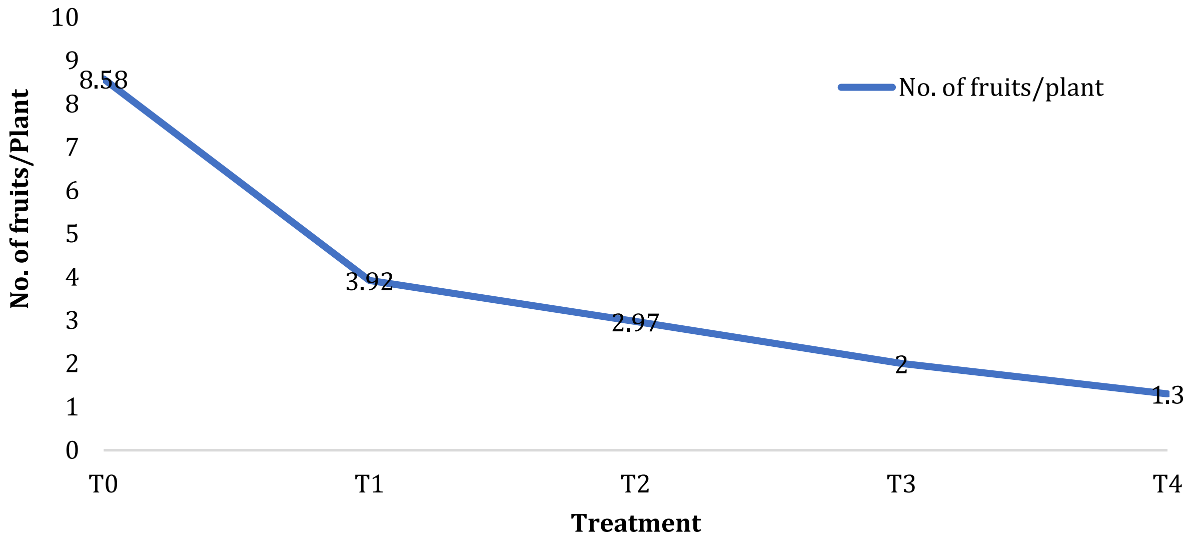

Figure 02. Effect of waterlogging on number of fruits per plant

IV. Discussion

Tomato, an important vegetable worldwide exerts a sensitivity to waterlogging (Iden, 1956; Bray et al., 2001). It has been suggested that paucity of oxygen, the key result of waterlogging is associated with this problem (Armstrong, 1979; Jackson and Drew, 1984; Kozlowski, 1984). Roots get oxygen from air pockets of the soil. When roots are submerged with excess water, the anoxic (absence of oxygen) condition hinders root growth and send signal to the rest of the plant to reduce shoot growth and plant productivity. Rice, having a well-developed aerenchyma tissue both in root and stem can withstand the brunt of waterlogging.

Plant height, numbers of leaves, leaf area from flooded genotype remarkably differ when compared to the control plants. The data obtained indicates that Pusharubi genotype is adversely affected by flooding conditions. The negative effect of flooding in plant growth, number of leaves and leaf area from Pusharubi genotype could be due to reduction of photosynthetic rate. Cessation of plant growth due to flooding was also observed in *Annona* species (Nunez-Elisea, 1999), *Panicum antidotale* (Ashraf, 2003), *Paspalum dilatatum* (Vasellati, 2001) and tomato (Walter, 2004; Ezin et al., 2010). All of these plant species showed growth reduction to varying extents in waterlogged conditions.

The treated genotype pusharubi exhibited some adventitious root above soil surface compared to control. This could be due to the prowess to confront the cynical effect of waterlogging. It also assists to augment water as well as mineral uptake and expiate for loss of the original roots. Hsiao (1973) reported that flooding stress reduces plant absorption of inorganic nutrients. Formation of adventitious root may play an important role in its adaptation to flooding conditions. The noteworthiness of adventitious root formation during flooding has been previously reported for barley (Stanca et al., 2003) and Italian ryegrass (Tase and Kobayashi, 1992). In a similar study on tomato, Walter et al. (2004) reported that tomato had the most vigorous adventitious root growth compared to cucumber, zucchini and bean. Dicotyledonous plants (e.g. soybean and tomato) generally form taproot system but develop adventitious roots under flooding conditions (Mano and Omori, 2007; McNamara and Mitchell, 1990; Bacanamwo and Purcell, 1999). This feature permits the root system to obtain oxygen directly from the air.

The data obtained in this experiment indicates that the ultimate fate of prolonged waterlogging is the death of tomato plant. We hypothesize that the yellowing of the plant followed by the death of the treated plants might be due to toxic substances moving from the soil through roots to the leaves.

According to Kramer (1951) yellowing and henceforth death of the lower leaves of tomato is due to desiccation, but most likely resulting from poisoning by toxic substances moving up from the dying roots. Microbes on the roots or in the soil and dying cells may evade these substances. He further stated that nitrites and sulphides which are toxic to roots and leaves produce profusely under anaerobic i.e. waterlogging condition may cause dead of plant.

Based on the data obtained from this study, it is revealed that the impediment of photosynthesis and the inauspicious effect of flooding conditions may results the significant reduction in number of flowers and fruits. This is compatible with Ezin et al. (2010) and Kozlowski (1997) that flooding of soil often halts flower bud initiation, anthesis, fruit set, and fruit enlargement in flood-intolerant species. Early abscission of flowers and fruits also impel owing to flooding. Ezin et al. (2010) reported that, the extent of the alteration of reproductive growth varies with plant species and genotype and with the time and duration of flooding. Reductions in yield were also associated with fewer and smaller fruits. It could be linked to fruit shed plant before harvest. Abbott and Gough (1987) reported that fruit set in flooded *V. corymbosum* was decreased by 45%.

V. Conclusion

The findings of this work divulged that, flooding put forth an immense jolt on the growth, development and yield of the treated tomato genotype Pusharubi. Hence it should not be put forward to cultivate in the flood prone areas. The current knowledge of the morpho-physiological basis of flood tolerance, coupled with breeding approaches followed by genetic engineering of tomatoes may lead to a more complete understanding to experiencing a notable success in enhancing waterlogging stress tolerance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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HOW TO CITE THIS ARTICLE?

MLA
Tareq et al. "Waterlogging stress adversely affects growth and development of Tomato". Asian Journal of Crop, Soil Science and Plant Nutrition, 02(01), (2020):44-50.

APA
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Tareq, MZ, Sarker, MSA, Sarker, MDH, Moniruzzaman, M, Hasibuzzaman, ASM and Islam SN. Waterlogging stress adversely affects growth and development of Tomato. Asian Journal of Crop, Soil Science and Plant Nutrition, February 2020 02(01), 44-50.