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RESEARCH PAPER

The effects of climatic change mediated water stress on growth and yield of tomato

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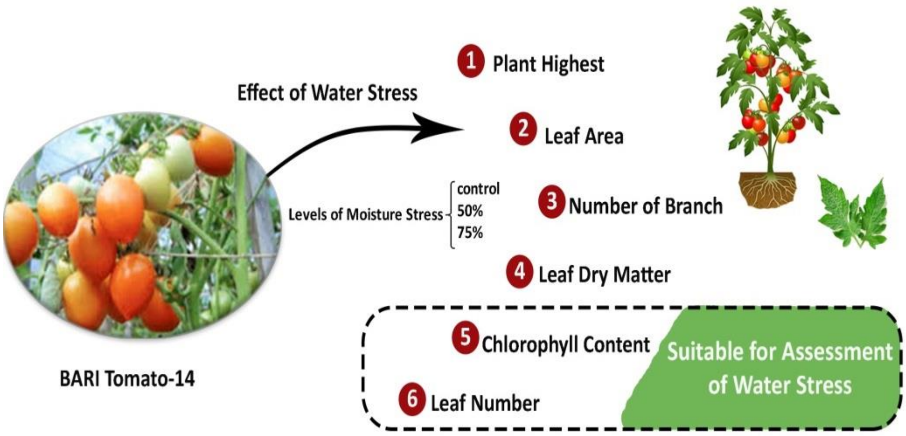
Highlights

- Water stress affects the crop productivity in many regions.
- A noteworthy and positive connection exists between natural product yield and development and physiological parameters.
- Chlorophyll content is suitable index for assessment of water stress and tomato genotypes tolerant.

Graphical Abstract



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Abstract

Climate change especially water stress affect the crop productivity in many regions of the world. The current paper survey the effect of water weight on development and organic product yield of tomato. Winter cultivar (BARI Tomato-14) was grown under different levels of moisture stress (control, 75 and 50% evapotranspiration moisture) in pot experiment using randomized total square plan with three replications. The investigation results appeared that increased moisture stress progressively reduced plant height (92.73, 90.06, and 75.58 cm), leaf area (198.69, 187.56, and 176.66 cm^2), chlorophyll content (47.41, 40.87 and 38.10), leaf dry matter (18.07, 16.27, and 12.24), number of branch (13.55, 12.06 and 10.00) and leaf number (22.93, 22.44, and 20.34) under control 100, 75, and 50% of evapotranspiration conditions, respectively. The outcome additionally indicated a noteworthy and positive connection between organic product yield and development and physiological parameters. The most elevated connection was seen between organic product yield and leaf number (r2=0.97) trailed by chlorophyll content (r2=0.95). Consequently, leaf number and chlorophyll content is a suitable index for assessment of water stress and tomato genotypes tolerant.

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1. Introduction

The productivity of crops is not increasing in parallel with the food demand due to changing environmental factors, both biotic and abiotic. Various abiotic environmental stresses such as drought, high or low temperature, salinity, flooding, metal toxicity, etc., lead to a serious threat to world agriculture. Dampness stress is a significant abiotic natural hindering of plants' physiological and metabolic procedures, which may prompt smothering plant development and advancement, diminishing yield efficiency or plant demise (Gonzalez et al., 2010). Nonetheless, water pressure is essentially brought about by a water shortage, for example, dry season. Plants adapt to drought stress by inducing various morphological responses such as escaping dehydration by completing their lifecycle before soil dehydration, reducing transpiration by closing stomata, decreasing leaf area and leaf rolling (Farooq et al. 2009; Conesa et al. 2016; Li et al. 2017; Mathobo et al. 2017). Many investigators reported a decreased net photosynthetic rate and stomatal conductance upon exposure to water stress (Zhang et al. 2013; Luo et al. 2016; Tombesi et al. 2018). Production of compatible solutes acting both in osmotic adjustment and as osmoprotectants and antioxidant compounds are considered to be among the most critical physiological and biochemical mechanisms for coping with water deficit conditions (Ashraf et al. 2011). Significantly, the optimal strategies for dealing with drought stress differ significantly between species. Moreover, even within the same species, such a strategy may differ, depending on the severity of drought stress, stress duration, and plants' growth and developmental stages (Gonzalez et al. 2010; Zhang et al., 2017).

Tomatoes (*Solanum Lycopersicum* L.) has a place with the Solanaceae family, which are of the most significant and financially significant vegetable harvests in Bangladesh and around the globe (Lahoz et al. 2016). The congenial atmosphere is preserved during tomato production in the low-temperature winter season in Bangladesh. Water deficit or moisture stress or drought occurs during this season, especially in northwestern regions. Impediment of water flexibly has an immediate negative effect on water use proficiency in the plant. Therefore, it virtually affects photosynthesis, plant development, and organic product creation (Jiang et al. 2017). Drought reduces crop production on 25% of arable land throughout the world (Farooq et al., 2009; Zahoor et al., 2017).

However, the more drought stress progresses, the more stomata close, and often leaves are rolled and making the measurements impossible in practical terms. SPAD chlorophyll meters are often used for rapid and cost-effective assessments of drought tolerance (Filek et al. 2015). Plants uncover water pressure when the water gracefully to their underlying foundations gets restricting, or when the transpiration rate gets exceptional. Water pressure doesn't just influence the morphology yet additionally seriously affects the digestion of the plant. The examination point was to evaluate the reaction of various development and yield parameters after water worry of tomato plants and their relationship with natural product yield.

2. Materials and Methods

2.1. Plant material and growing conditions

Tomato seeds (BARI Tomato 14) were developed in a plastic plate, and a month after germination, single seedling tomatoes were transplanted into a singular pot loaded up with a pre-prepared preparing blend. Each pot was 35 cm (14 inches) in measurement and 30 cm (12 inches) in stature. Two weeks after transplanting, plants were started to treat with different levels of moisture stress. The investigation was done in Randomized Complete Block Design (RCBD) by three replications. Additionally, the analysis region was isolated into three equivalent squares. Each block contained 12 pots, where four plants were placed in each treatment. Thirty-six pots were all together in this experiment. The plants were grown in a poly house at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, between October 2015 and April 2016. The average temperature was 23 °C in daytime and 15°C at night, with a relative humidity of 65 to 80%.

2.2. Moisture treatment

Tomato plants were treated with different moisture stress levels: W_1=100% evapotranspiration moisture, W_2= 75% evapotranspiration moisture, W_3= 50% evapotranspiration moisture; Where water was added to each pot to make it a well-saturated condition. The difference between the two weights is the evaporation rate. Pot with soil was allowed for two days tying with a polythene sheet. After two days, the plastic pot with wet soil was weighted. The loss of water = (weight of pot soil in saturated water–weight of pot soil after allowing two days). During the two days, the amount of water loss was recovered completely by irrigation, for control (100%) pots only. Other pots received 75 and 50% of the water added to the control plants (Bhandari et al., 2017).

2.3. Morphological traits

Plant tallness, number of branches, number of leaves, and leaf zone were recorded at the blossoming stage. Plant stature was estimated from the top edge of the pot to the shoot tip of the plant. Leaf area (LA) was determined from the middle portion of the plant by measuring the leaf's length and breadth using the scale at the flowering stage.

2.4. Chlorophyll content

The SPAD meter is a hand-held gadget generally utilized for the fast, precise and non-ruinous estimation of leaf chlorophyll focuses. Chlorophyll content of leaf was determined from plant samples by using an automatic SPAD meter. SPAD was recorded at the flowering stage.

2.5. Dry matter content of leaves (%)

At the blossoming stage, arbitrarily chose 100 g leaf test was cut into extremely meager pieces and put into the wrap and kept up in stove at 60°C for 72 hours. The example was then moved into desiccators and permitted to chill off at room temperature. The last weight of the sample was taken. The accompanying recipe figured the dry issue substance of leaf:

$$\%\ \text{Dry matter content of leaf} = \frac{\text{Dry weight of leaf (g)}}{\text{Fresh weight of leaf (g)}} \text{x } 100 \qquad (1)$$

2.6. Yield traits and yield

The number of fruit per plant was counted from the plant of each unit pot, and the average number of fruits per plant was recorded. The yield of tomato per plant was recorded as the whole fruit per plant harvested at different times and expressed in kilograms (kg).

2.7. Data analysis

Information was examined utilizing SPSS 20.0 programming. Three medicines mean (the estimations of 100, 75%, and half evapotranspiration dampness plants) were exposed to combined t-test. The worth was viewed as factually noteworthy when $P< 0.05$. All outcomes were given mean ± SE from the reproduces. The importance of the connections between various parameters is controlled by bivariate relationships dependent on Pearson's relationship (two-followed).

3. Results and Discussion

3.1. Plant height (cm)

The tomato plant height varied significantly for different moisture levels at the flowering stage under the present trial. The tallest plant (92.73 cm) was recorded from W_1, which was statistically different from W_2 (90.06 cm) and W_3 (75.42 cm) (Fig. 1A). Plant height was significantly (R^2= 0.90; $P> 0.05$) correlated with fruit yield (Table 1). Data revealed that the drought stress reduced the morphological parameters such as plant height of tomato. The significant reduction of plant height under drought pressure compared to control signifying drought effects was registered on tomato plant height.

Table 1. Correlation between relative fruit yield and different growth and yield traits of tomato.

Traits	Relative fruit yield
Relative Plant height	0.90*
Relative leaf area	0.69
The relative number of branches/plants	0.88*
The relative number of leaves/plants	0.97**
Relative chlorophyll content	0.95**
Relative dry matter of leaf (%)	0.84*
The relative number of fruits/plants	0.92**

*: significant at 0.05 level **: significant at 0.01 level.

3.2. Leaf area (cm2)

Statistically, significant variation was recorded for leaf area due to different moisture levels at the flowering stage. The maximum leaf area (198.69) was recorded from W_1, which was statistically different from W_2 (187.56). However, the minimum leaf area (176.66) was found from W_3, which was statistically different from W_1 and W_2 (Fig. 1B). The outcomes showed that the distinctive water pressure medications brought about a slow diminishing in leaf territory as the pressure increments in tomato plants. In the wheat plant, the leaf region diminished with expanded water pressure (Boutraa et al. 2010). The plant leaf region is diminished submerged worry by decreasing the cell extension component that lessens cell size and, in this way, leaf region (Schuppler et al. 1998).

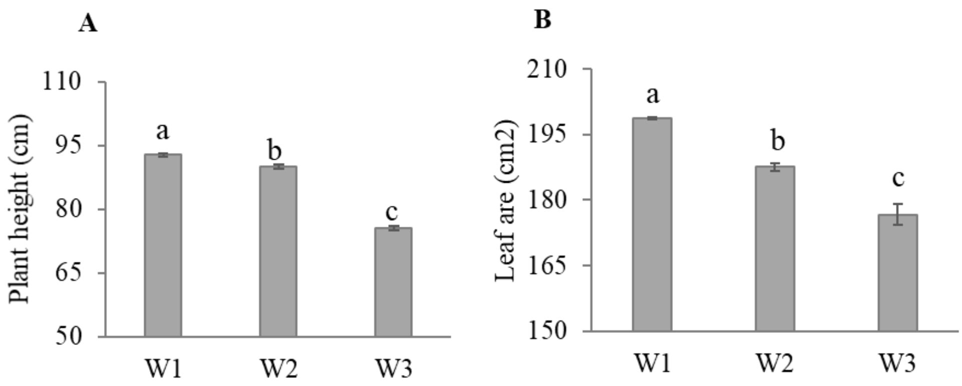

Fig. 1. Average plant height (cm). (A) and leaf area (cm2), (B) in the water stress, and control tomato plants at the flowering stage. Whereas, W_1=100% evapotranspiration moisture, W_2 = 75% evapotranspiration moisture and water stress W_3 = 50% evapotranspiration moisture. Mean ± SE (n=12).

3.3. Number of branches plant^{-1}

Different levels of moisture varied significantly in terms of the number of branches plant^{-1} of tomato at the flowering stage under the present trial (Fig. 2A) and showed a significant ($P > 0.05$) correlation with the fruit yield (Table 1). The maximum number of branches plant^{-1} was recorded from W_1 (13.55), and the minimum number of units plant^{-1} was recorded from W_3 (10.0) followed by W_2 (12.06). In another study, it was found that drought stress caused severe depression in the production of the number of branches of tomato (Pervez et al., 2009).

3.4. Number of leaves plant^{-1}

The highest number of leaves (29.93) was recorded from W_1, which was statistically similar to W_2 (22.4), whereas the shortest plant was recorded from W_3 (20.34), which was statistically different from W_1 and W_2 at the flowering stage (Fig. 2B). Leaves number Plant^{-1} was significantly (R^2 = 0.97; $P > 0.01$) correlated with fruit yield (Table 1). Leaves have different strategies when they are under drought stress. Leaf rolling, leaf shedding or low stomatal conductance were the leaf's main responses to drought stress (Hu et al., 2006). At another study Found that significant results toward drought stress signifying drought effects were registered on the number of leaves of tomato plant^{-1} (Pervez et al., 2009).

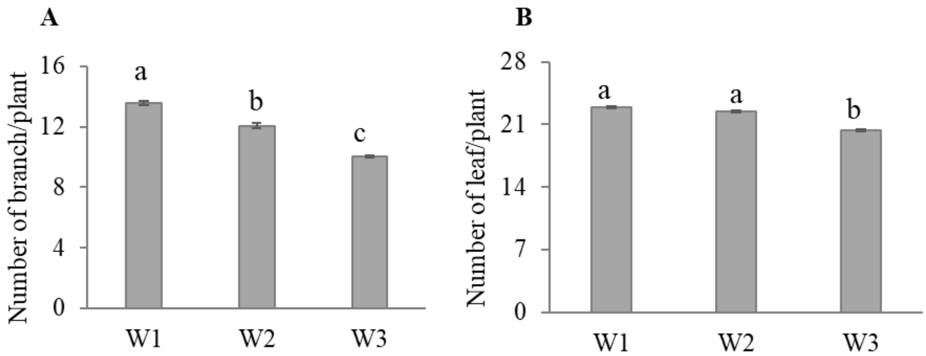

Fig. 2. The number of branches/plants in the. (A) and the number of leaf/plant, (B) in the water stress, and control plants of tomato at the flowering stage. Whereas, W_1=100% evapotranspiration moisture, W_2= 75% evapotranspiration moisture and W_3= 50% evapotranspiration moisture. Mean ± SE (n=12).

3.5. Chlorophyll content

A significant variation was observed for tomato plants' SPAD values due to different moisture levels at the flowering stage (Fig. 3A). The highest SPAD values (47.13) were recorded in W_1, whereas the lowest SPAD values were recorded in W_3 (38.10), followed by W_2 (41.29). Chlorophyll content was significantly (R^2= 0.95; P> 0.01) correlated with fruit yield (Table 1). Extreme dry season pressure also restrains plants' photosynthesis by causing changes in chlorophyll content by influencing chlorophyll parts and harming the photosynthetic mechanical assembly (Iturbe-Ormaetxe et al., 1998).

3.6. Dry matter of leaf (%)

Dry matter content of leaf in tomato plant species varied significantly for different levels of moisture under the present trial (Fig. 3B). The highest dry matter content of leaf in the plant was found from W_1 (18.07), whereas the lowest was observed from W_3 (12.24), followed by W_2 (16.27). Leaf dry matter (%) was significantly (R^2= 0.84; P> 0.05) correlated with fruit yield (Table 1). In the other study similarly found that the dry weight reduced significantly under the drought stress (Birhanu and Tilahun, 2010). Cell elongation and expansion are inhibited by drought stress (Jaleel et al., 2009), consequently reducing plant height and growth. Leaf area reduction resulted in a decrease in net assimilate production; thus, photosynthesis per unit area might remain changed. This may be the reason for reduced dry matter accumulation under water stress.

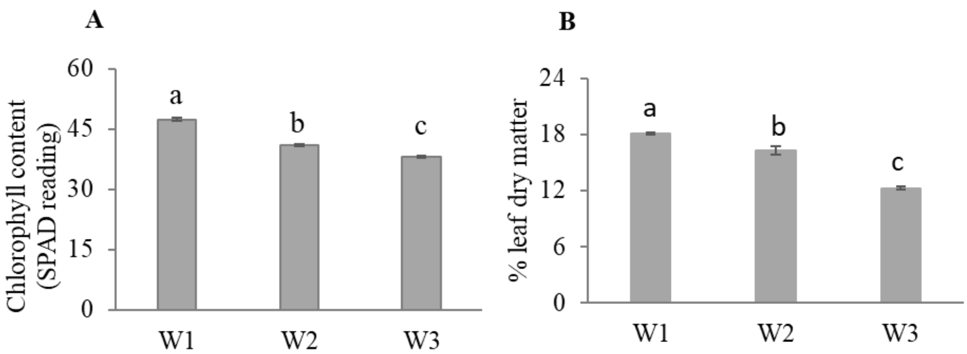

Fig. 3. Chlorophyll content. (A) and leaf dry matter (%), (B) in the water stress, and control plants of tomato at the flowering stage. whereas, W_1=100% evapotranspiration moisture, W_2= 75% evapotranspiration moisture and W_3= 50% evapotranspiration moisture. Mean ± SE (n=12).

3.7. Number of fruits plant^{-1}

Significant variation was recorded in terms of the number of fruits plant-1 of tomato due to differing moist levels under the present trial (Fig. 4A). The highest number of fruits plant^{-1} (34.73) was recorded from W_1, and the lowest number (23.82) was found from W_3 (Fig 4A).Fruits number Plant^{-1} was significantly (R^2= 0.92; P> 0.01) correlated with fruit yield (Table 1). The founder's results and dedicated huge outcomes toward dry spell pressure connoting dry season impacts on the quantity of organic products plant^{-1} of tomato (Pervez et al., 2009).

3.8. Yield plant^{-1} (kg)

Various degrees of dampness fluctuated essentially as far as yield plant-^{1} of tomato under the current preliminary. The best return plant^{-1} (2.28 kg) was recorded from W1, while the most minimal yield (1.33 kg) was found from W3 (Fig. 4B).

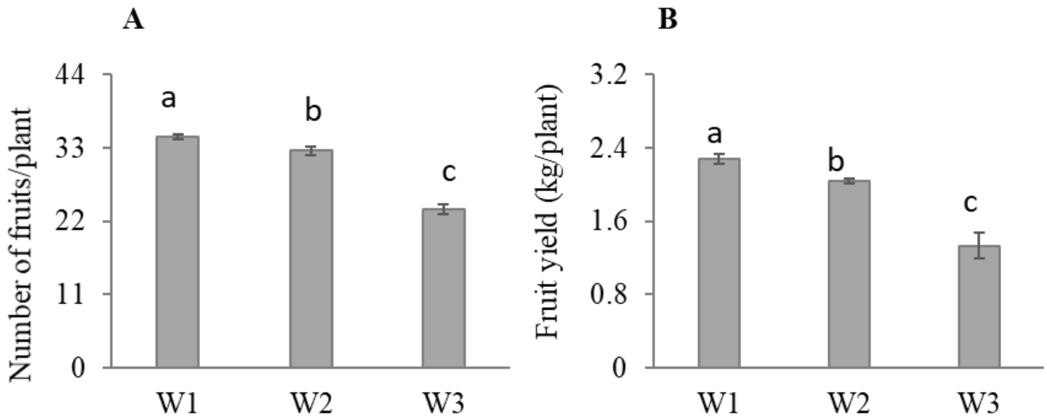

Fig. 4. The number of fruits/plant. (A) and fruit yield (kg/plant), (B) in the water stress, and control plants of tomato, whereas. W_1=100% evapotranspiration moisture, W_2= 75% evapotranspiration moisture and water stress W_3 = 50% evapotranspiration moisture. Mean ± SE (n=12).

4. Conclusions

The current investigation recommends that plant tallness, number of branches and leaves per plant, chlorophyll content, % dry matter of plate, and number of organic products per plant submerged pressure could all be utilized as reference pointers for choosing dry spell open-minded genotypes. In any case, chlorophyll content is moderately basic and fast; hence, it will probably be increasingly productive in screening countless genotypes.

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