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Effects of water stress and nutrient management on the performance of tomato

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***Abstract*— *Management of nutrient and water scarcity are very important for getting higher yield of tomato specially in winter season in Bangladesh. The application of different fertilizer and manures increase the availability of nutrients which to stimulate plant growth that lead to enhance stress tolerance. Therefore, the main aim of this study is to investigate how different nutrients management practices improves growth by reducing impacts of water stress. Tomato plants were grown in field condition and different growth parameters such as height, root dry weight and shoot dry weight were measured. Yield and yield attributes of tomato were also determined. Recommended fertilizers along with organic manures application improve the growth and yield of tomato plants. On the other hand, growth and yield of tomato was lowest for no fertilization and manures treatment. This study improves our understanding about how nutrient management in water stress increase the growth and yield of tomato plant.*

***Keywords*— tomato, nutrients, water stress, yield, manures**

I. INTRODUCTION

Climate change is recognized as a great threat to sustainable development of agricultural expansion thereby alarming for agricultural productivity. Global warming has direct impact on enhancement in evapotranspiration rates, and escalates water stress frequency and intensity with a rise from 1 to 30% in acute dry land by 2100 (Fischin *et al.*, 2007). The severity of water scarcity is unpredictable as it depends on many factors such as occurrence and distribution of rainfall, evaporative demands and moisture storing capacity of soils.

The aggressive exploitation of natural resources has endangered water resources, biodiversity and soil quality globally. Although it is notable that less than 1 % of the worlds fresh water (or about 0.007 % of all water on earth) is allowable for human consumption. It is anticipated that more than 1.8 billion peoples of the world will suffer absolute water scarcity and two thirds of the world community could be under water stress conditions by the year 2025 (Haji, 2011). Depletion of this valuable water resource accelerates failure of water safeguard for world community and trigger poverty and malnutrition.

Arable lands are facing serious water scarcity due to climate change and available resources are depleting at an alarming rate, which necessitate efficient use of water for agriculture. Water deficit or drought is the most common stress condition globally and is increasingly of concern worldwide (Mahajan & Tuteja, 2005). Water scarcity has to be considered one of the major abiotic stresses that hinder the plant growth and development (Yang *et al.*, 2010). On an average drought and/or water scarcity instigate more than 50% crop yield loss worldwide (Bray *et al.*, 2000). Numerous alterations in morphological, metabolic, or/and physiological traits are induced by the water scarcity or drought stress in plant. At plant growth and development stage, water stress adversely affected plant elongation and growth expansion (Shao *et al.*, 2008). Water scarcity affected the leaf growth and leaf area and a greater root/shoot ration in several species (Jaleel *et al.*, 2009).

Severe water stress poses injurious effects on plant water relations, photosynthesis, ion uptake, and nutrient metabolism and assimilates partitioning (Jaleel *et al.*, 2009, Saud *et al.*, 2016). Stomatal closure and turgor losses under water stress are deemed to be the core cause of decreasing photosynthetic activity and crop production. (Farooq *et al.*, 2009). Under water stress plant response are extremely intricate and fluctuate among plant species and growth phases and water limitation duration (Fahad *et al.*, 2015).

During stress condition plant develop many adaptive strategies including escape, avoidance and tolerance mechanisms (Chaves *et al.*, 2003). Morphological plasticity, water physiological integration or gene regulation of plants could be possible acclimation mechanism at water stress condition (Jackson *et al.*, 2000). Under water scarcity conditions, plants alter metabolic and physiological function to minimize negative impacts and maximize survival (Thapa *et al.*, 2011). However, application of nutrition through fertilization increases the availability of limited nutrients, and then could alter system properties, which might be a potentially practical way to stimulate plant growth, enhance stress tolerance.

Like, optimal nitrogen application plays a crucial role in combating water stress (Marschner, 1995). N nutrition and drought tolerance are interrelated, with increased external N supply improving physiological status and growth in response to low soil water availability (Drenovsky *et al.*, 2012). Nitrogen is an essential structural constituent of protein, rubisco, nucleic acid, chlorophyll and some hormones and its application in the form of fertilizer accelerated the agronomic responses of crops (Ata-ul-Karim *et al.*, 2016). Nitrogen addition drives proper photosynthetic activity of the leaf (Brennan, 1992). Effective plant nutrition levels have also alleviated drought stress damage by sustaining the metabolic activities under water-restricted condition and at reduced leaf water potential. Thus, an adequate evaluation of water scarcity stress on the morpho-physiological traits under nitrogen fertilizer might deliver valuable understanding of tomato performance (Abid *et al.*, 2016).

However, organic manure might be another way for altering water stress (Forouzandeh *et al.*, 2015) and the storehouse of both micro and macronutrients and also act as natural mulch for conserving soil moisture and reducing moisture stress of soil. The soil-based application of organic amendments added humic substances to soil might have an ameliorating effect on water stressed to field grown crops (Zhang and Ervin, 2004). Thus, nutrient conservation through organic and inorganic fertilizer might be an approach for restoration of dry land agriculture to combat drought stress.

Tomato is most susceptible horticultural plant to drought stress because of its wide range of transpiring leaf surface, high stomatal conductance, having a shallow root system (Mohammed *et al.*, 2018). In Bangladesh tomato is grown mainly during the dry season (October-March) of the year, when the evapotranspiration is very high. Thus, understanding drought stress impact and searching its alleviating ways become urgent for dry land agriculture. However, a very little attempts was taken to combat the dry land tomato cultivation for future food security of Bangladesh. Based on the importance of dry land agriculture and combat to climate change induced food scarcity the present study is investigate the effects of water stress and nutrient management on the growth and yield of tomato.

II. MATERIALS AND METHODS

Study site and soil properties

The experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. The experimental soil is terrace soils, which is nearly equivalent to Ochrept sub-order under the order Inceptisol of USDA Soil Taxonomy and belongs to the general soil type Shallow Red Brown Terrace Soil (Brammer, 1971; Saheed, 1984). The soil is friable clay loam with acidic in nature. The physico-chemical properties of studied soil are shown in Table 1.

Table 1 Physico-chemical characterization of experimental terrace soil surface layer (at the depth of 15 cm)

Soil Characteristics	Analytical Value	Soil Characteristics	Analytical Value
Physical properties		Chemical properties	
Particle size distribution		Soil pH	5.34
Sand	17.30%	Total N (%)	0.07
Silt	45.80%	Organic C (%)	0.63
Clay	36.90%	C: N ratio	9.0
Textual class	Silty clay loam	Available P (ppm)	9.3

Bulk density	1.38g/cm^3	Exchangeable K (meq/100g)	0.09
Particle density	2.63 g/cm^3	Exchangeable Ca (meq/100g)	5.34
Porosity (%)	47.4	Exchangeable Mg (meq/100g)	1.45
Hydraulic conductivity (cm sec^{-1})	4.6 x 10^{-4}	Exchangeable Na (meq/100g)	0.58
Field capacity (% by weight)	30.7	Available Sulphur (ppm)	13
-	-	Zinc content (ppm)	0.97
-	-	Boron content (ppm)	0.16

Planting materials

Seedlings of 30 days of BARI Tomato-9 (Lalima) were used as planting material. BARI Tomato-9, a high yielding prolific bearer and bacterial wilt tolerant variety was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. The potential yield of the variety is 90-95 t/ha.

Experimental Design and Treatments

The two factors experiment was laid out in factorial Randomized Complete Block Design (RCBD) with three replications. Three different water stresses were considered as Factor A and four different nutrient management practices were studied as Factor B.

The experiment consisted of two factors:

Factor A: Different levels of Water stress-

i. D_1 = Irrigation at 90% Field capacity (FC) (control)

ii. D_2= Irrigation at 70% Field capacity (FC)

iii. D_3= Irrigation at 50% Field capacity (FC)

Factor B: Different nutrient managements-

i. N_0 = Control (No nutrient application)

ii. N_1 = Soil test based fertilizers (STB) ($N_{145.0}$ $P_{41.5}$ $K_{75.0}$ $S_{11.6}$ $Zn_{0.9}B_{1.0}$ kg ha^{-1})

iii. N_2 = STB + 50% N,

iv. N_3 = STB + 6 t ha^{-1} poultry manure.

There were 12 (3 × 4) treatments combination such as: D_1N_0, D_1N_1, D_1N_2, D_1N_3, D_2N_0, D_2N_1, D_2N_2, D_2N_3, D_3N_0, D_3N_1, D_3N_2 and D_3N_3.

The unit plot size was 1.5 m × 1.5 m and maintain a 0.5 m drainage to separate one plot to another plot. One-month-old (accumulated in a pit and collected after month) poultry manure was procured from local poultry farm. Physical and chemical properties of poultry manure are presented in Table 2.

Raising of seedlings

Tomato Seedlings were raised in one seedbed on a relatively high land at the research field of the department of Soil Science, BSMRAU. The size of the seedbed was 3 m× 1 m. The soil was well prepared with spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and 5 kg well rotten cowdung was applied during seedbed preparation. Germination was visible at 3 days after sowing of seeds. Heptachlor 40 WP was applied @ 4 kg ha^{-1} around each seedbed as precautionary measure against ants and worm. Necessary shading by banana leaves was provided over the seedbed to protect the young seedlings from scorching sun. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in this seedbed.

Table 2 Physioco-chemical characterization of poultry manure

Organic matter	Moisture (%)	pH (1/2.5)	Organic carbon (%)	Total N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)
Poultry manure	37.43	8.22	34.20	2.22	0.97	1.18	1.51	0.51	178.10	31.1

Land preparation

The land was prepared well by deep plowing with a tractor followed by harrowing and laddering. The weeds and stubbles were removed and the 36 plots were prepared according to the layout of factorial RCBD design. Drains were made around each plot and excavated soil was used for making dikes around each plot for restricting the lateral runoff of irrigation water.

Uprooting and transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental plots and maintaining two seedlings in each hill and row to row and plant to plant spacing of (75 cm × 50 cm).

The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to roots with ensuring maximum retention of roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedlings from the strong sunlight. Shading and watering in moderate quantity were continued till the seedlings were established properly. The dead and very weak seedlings were replaced by the fresh and healthy ones soon after detection.

Manure and Fertilization:

The crop was fertilized with 145.0 kg N, 41.5 kg P, 75.0 kg K, 11.6 kg S, 0.9 kg Zn and 1.0 kg B ha^{-1} as a soil test based fertilizer from urea, TSP, MoP, Gypsum, zinc sulphate and boric acid respectively. The applied nutrient in the different nutrient management are presented in Table 3

Table 3 Applied amounts of nutrients (kg ha^{-1}) in different management treatments

Nutrient management	N	P	K	S	Zn	B	Poultry manure
N_0 (control)	-	-	-	-	-	-	-
N_1	145.0	41.5	75.0	11.6	0.90	1.0	-
N_2	217.5	41.5	75.0	11.6	0.90	1.0	-
N_3	145.0	41.5	75.0	11.6	0.90	1.0	6 t ha^{-1}

Half of the poultry manure and full amount of phosphorus, sulphur, zinc and boron from urea, TSP, MoP, Gypsum, zinc sulphate and boric acid respectively were applied at final land preparation. The remaining poultry manure was applied in pits before planting the seedlings. Nitrogen and potassium were applied in two equal splits at 15 and 35 days after transplanting under moist soil condition and were mixed thoroughly immediately after application.

Application of water stress

Tomato plants were exposed to the different water stress treatment two weeks after the seedling transplantation. The amount of water applied at different water stress was applied considering the field capacity of the soil. Keeping the depletion of water, applied stress required amounts of irrigation water at 90% FC, 70%FC and 50% was calculated and administered at 7 days intervals by using measured water can along with sprinkler from 14 days after transplanting to harvest.

Physico-chemical characterization of soil

Soil sample from each plot were collected considering the 0-15 cm depth at before treatment exposure and after harvest. The physico-chemical properties of the initial and residual soil samples were done by following suitable standard protocols.

Harvesting

Fruits were harvested at 4 days interval during early ripe stage when they developed slightly red color.

Plant height (cm)

Five-plant height was measured from plant of each unit plot from the ground level to the tip of the longest stem and mean value was calculated. Plant height was recorded at 50% flowering stages.

Shoot and root dry weight

After final fruit plucking, five pre-selected plants in each plot were uprooted, chopped with sharp knife for portioning shoot and root, air-dried in the laboratory and finally oven-dried for 72 hours at 65℃. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken.

Number of fruits plant^{-1}

The number of fruits per plant was counted from five plants of each unit plot and the average number of fruits per plant was recorded.

Yield plant^{-1} (kg)

Yield of tomato per plant was recorded as average value of the whole fruit per plant harvested in different time and was expressed in kilogram.

Yield (t ha^{-1})

Yield per hectare of tomato fruits was calculated by converting the weight of total plant yield into hectare on the basis of total plant population of tomato per hectare and expressed in ton.

Statistical analysis:

The data were statistically analyzed by using Statistix Version 10.0 software to find out the significance of variation between treatments. The differences between the treatment means were judged by least significance difference (LSD) Test.

III. RESULTS AND DISCUSSION

Effects of water stress and nutrient management on the growth of tomato plant

Effects of water stress and nutrient management singly and or in combination on tomato plant growth parameters is represent in the table 4, 5 and 6.

Plant height

The results showed that water stress significantly affected the plant height at both flowering stages (50% and 90%) (Table 4). The tallest plant at both 50% and 100% flowering stage (64.12 and 86.65 cm, respectively) were recorded from D_1 treatment with watering at 90% field capacity (FC), which was statistically similar with D_2 at 70% of FC. The shortest plant at both 50% and 100% flowering stage (59.95 and 78.15 cm, respectively) were found from the most water deficit D_3 treatment with 50% of FC. Thus, deficit irrigation with 50% FC significantly decreased the plant height of tomato at 50% and 100% flowering stage by approximately 15.9% and 16.7% respectively. Data revealed that well watered plot exhibited the healthy growth but the drought stress reduced the morphological parameters such as plant height of tomato. The diminishment in plant height could likewise be credited to declining in the cell extension and more leaf senescence in the plant prone to stress (Manivannan *et al.*, 2007). Pervez *et al.* (2009) found that significant results toward water stress signifying drought effects were registered on plant height of tomato plant. Ubaidullah *et al.* (2002) also found the similar result.

Significant variation was recorded for different levels of nutrient management on plant height of tomato at 50% and 100% flowering stage (Table 5). Data revealed that at 50% and 100% flowering stage, the tallest plant (72.34 and 97.58 cm, respectively) was found from N_3 treatment of STB based fertilizer along with 6-t/ha poultry manure, which was statistically similar with N_2 treatment. While, the shortest plant at 50% and 100% flowering stage (45.45, and 58.25 cm, respectively) was recorded from N_0 treatment.

Combined effect of different levels water stress and nutrient management showed significant differences on plant height of tomato at 50% and 100% flowering stage (Table 6). The tallest plant at both 50% and 100% flowering stage (73.73 and 100.57 cm, respectively) was found from D_1N_3 treatment combination that was statistically similar with D_1N_2, D_2N_2, D_2N_3, D_3N_2 and D_3N_3. While, the shortest plant (41.66 and 53.73 cm, at 50% and 100% flowering stage respectively) was found from D_3N_0 treatment combination, which was statistically similar with D_1N_0 and D_2N_0 treatments. The present data reveals that nutrient management with STB based fertilizer along with 6 t/ha poultry manure significantly ameliorate the adverse effects of moisture stress on plant height of tomato. Similar trends were also observed in the treatment combination of STB fertilizer along with 50% more nitrogen. This might be due to higher manure application rate improved soil physical, chemical, and biological properties (Farhad, 2018). Application of poultry manure might be improved the porosity and protect the soil moisture depletion favor the growth and development of tomato plant. Moreover, N addition encourages the plant growth, which helps to ameliorate the adverse effects of water stress (Arun *et al.*, 2012).

Table 4 Effect of water stress on the growth parameters of tomato plant

Treatments	Plant height (cm)	Root DW Plant^{-1} (g)	Shoot DW Plant^{-1} (g)
D_1	64.12a	1.80a	12.38a
D_2	61.29ab	1.79ab	11.37a
D_3	59.95b	1.63b	9.33b
CV (%)	7.95	5.67	12.20
SE (±)	2.005	0.041	0.61
LSD $_{(0.05)}$	4.15	0.085	1.27

Table 5 Effect of nutrient management on the growth parameters of tomato plant

Treatments	Plant height (cm) (50%F)	Root DW Plant^{-1} (g)	Shoot DW Plant^{-1} (g)
N_0	44.45c	1.42d	7.05c
N_1	61.90b	1.70c	12.627b
N_2	68.46a	1.86b	14.16a
N_3	72.34a	2.11a	15.62a
SE (±)	2.31	0.047	0.7111
LSD (0.05)	4.80	0.098	1.47

Table 6 Combined effects of water stress and nutrient management on the growth parameters of tomato plant

Treatments	Plant height (cm) (50%F)	Root DW Plant^{-1} (g)	Shoot DW Plant^{-1} (g)
D_1*N_0	47.50e	1.39e	7.32e
D_1*N_1	64.96bcd	1.66d	13.16cd
D_1*N_2	70.30ab	1.71d	14.11abcd
D_1*N_3	73.73a	2.06abc	16.20a
D_2*N_0	44.20e	1.28e	6.087e
D_2*N_1	61.16cd	1.71d	12.97cd
D_2*N_2	68.83abc	1.90c	13.27bcd
D_2*N_3	70.96ab	2.17a	15.75ab
D_3*N_0	41.66e	1.04e	5.53e
D_3*N_1	59.54d	1.73d	11.74d
D_3*N_2	66.26abcd	1.96bc	15.11abc
D_3*N_3	72.33ab	2.11ab	14.91abc
SE (±)	4.01	0.082	1.23
LSD (0.05)	8.316	0.17	2.55

Root dry weight

Root dry weight was significantly affected by different moisture stress. Irrigation at 90% filed capacity at D_1 treatment showed the maximum root weight (1.80 g), which was statistically similar with the D_2 treatment maintaining 70% FC (Table 4). Irrigation at 50% filed capacity significantly reduced the root dry mass of the tomato plant. Thus, root dry mass was linearly decreased with decreased amount of irrigation water added to the trial.

Nutrient management was also significantly influencing the root dry mas of tomato plant. (Table 5). Significantly higher amount of root dry mass was found in the N_3 treatment of STB fertilizer along with 6-t/ha poultry manure (2.11g). The lower amount of root dry matter was detected in the control treatment (1.42g). Application of organic amendments improves the physical, chemical and biological properties of soil that helps proper root growth and development of tomato plants (Jones *et al.*, 2007).

The interaction effects of water stress and nutrient management had provided a significant response on the root dry weight production (Table 6). In the present study, the highest roots dry weight (2.17g) was found in the treatment combination of D_2N_3, which was statistically identical with D_3N_3 and D_1N_3. Thus, the study summarized that nutrient addition of STB fertilizer along with 6 t ha^{-1} poultry manure overcome the adverse effect of water stress on tomato roots. Addition of organic and inorganic amendment helps to improve the nutrient uptake mechanisms and osmotic balance that may provide the ameliorative effects of water stress of tomato plant (Farhad *et al.*, 2018)

Effects water stress and nutrient management on yield and yield attributes of tomato

Effects of water stress and nutrient management singly and/ or in combination on reproductive stage traits of tomato plant is represent in the Table 7, 8 and 9.

Number of fruits plant^{-1}

Significant variation was recorded in terms of number of fruits plant^{-1} of tomato due to different levels of moisture under the present trial (Table 7). The highest number of fruits plant^{-1} (39.54) was recorded from D_1, which was statistically similar with D_2. While, the lowest number (23.93) was found from D_3 (Table 7). Pervez *et al.* (2009) and Ubaidullah *et al.* (2002) also found the similar results and they showed significant results toward drought stress signifying drought effects on the number of fruits plant^{-1} of tomato.

Number of fruit plant^{-1} of tomato showed significant difference due to different nutrient management (Table 8). The highest number of fruits plant^{-1} (51.60) was recorded from N_3 treatment administered with 6 t ha^{-1} poultry manure along with the STB fertilizer. However, control treatment (N_0) provided the lowest fruit number plant^{-1} (10.99). Wu *et al.*, (2018) explained that nutrient uptake plays an important role on transfer of carbon assimilates and fruit settling.

Interaction effect of water stress and nutrient management significantly affected the fruit number plant^{-1} (Table 9). The present data indicated that the maximum fruit number plant^{-1} (53.41) was accredited against the treatment combination of D_1N_3, which was statistically identical with D_1N_2, D_2N_3, and D_3N_3. The lowest fruit number plant^{-1} (7.75) production was subjected to the treatment combination upholding the irrigation with 50% FC along with no fertilization (D_3N_0) treatment which was statistically similar with the D_1N_0 and D_1N_0. The data of the present study reveal that the adverse effect of water stress on fruit number plant^{-1} in tomato plant might be due to the ameliorative effects of organic matter along with STB fertilizer. Wu *et al.*, (2018) found similar findings that the effects of the interaction between water and fertilization on fruit settling were significant. Liu *et al.*, (2019) also found that various soil moisture and potassium administration provides a significant impact on fruit settling of tomato. They also suggested that addition of potassium might play an important role on minimizing the impact of water stress on fruit settling. Forhad *et al.*, (2018) also found similar finding that composted poultry manure was able to partially alleviate the effect of water stress on maize.

Fruit weight plant^{-1} (g)

Weight of plant^{-1} of tomato varied significantly due to effects of different levels of moisture (Table 7). The highest fruit weight per plant (3.51kg) was found from D_1, which was similar with the data of D_2. On the other hand, the lowest (0.93) was observed from D_3 (Table 7). Significant variation was recorded for different levels of nutrient management on fruit weight of plant^{-1} (Table 8). The highest fruit weight per plant (3.36 kg) was recorded from N_3, whereas the lowest weight (0.46) was attained from N_0. These results suggested that nutrient management contribute in the enrichment of fruit weight. Combined effect of water stress and nutrient management significantly affected the fruit weight of plant^{-1} (Table 9). The present data signified that the maximum fruit weight of plant^{-1} (3.51 kg) was attained in the treatment combination of D_1N_3, which was statistically identical with D_1N_2, D_2N_3 and D_3N_3. The lowest fruit weight of plant^{-1} (0.32kg) was D_3N_0 treatment that was statistically similar with the D_1N_0 and D_1N_0. Thus the data reveal that the adverse effect of water stress on single fruit weight in tomato plant might be due to the ameliorative effects of organic matter along with the STB fertilizer.

Table 7 Effect of water stress on yield and yield attributes of tomato

Treatments	Fruit No. plant^{-1}	Fruit Weight (Kg plant^{-1})	Yield (t ha^{-1})
D_1	39.54a	2.46a	65.63a
D_2	35.48ab	2.22b	59.22b
D_3	30.82b	1.93b	49.23c
(%) CV	14.77	12.24	12.24
SE (±)	2.16	1.12	3.44
LSD $_{(0.05)}$	4.49	1.12	7.13

Table 8 Effect of nutrient management on yield and yield attributes of tomato

Treatments	Fruit No. plant^{-1}	Fruit Weight (Kg plant^{-1})	Yield (t ha^{-1})
N_0	10.99d	0.46d	12.39d
N_1	36.91c	2.29c	60.99c
N_2	44.28b	284b	75.60b
N_3	51.60a	3.36a	89.63a
SE (±)	2.50	1.29	3.44
LSD $_{(0.05)}$	5.19	2.68	7.13

Table 9 Combined effects of water stress and nutrient management on yield and yield attributes of tomato

Treatments	Fruit No. plant^{-1}	Fruit Weight (Kg plant^{-1})	Yield (t ha^{-1})
D_1*N_0	13.79e	0.59f	15.83f
D_1*N_1	43.36bc	2.69cd	71.86cd
D_1*N_2	47.60ab	3.05abc	81.36abc
D_1*N_3	53.41a	3.51a	93.47a
D_2*N_0	11.45e	0.49f	12.94f
D_2*N_1	35.92cd	2.25de	59.98de
D_2*N_2	42.18bc	2.74bc	73.07bc
D_2*N_3	52.38a	3.41a	90.90a
D_3*N_0	7.75e	0.32f	8.40f
D_3*N_1	31.46d	1.92e	51.12e
D_3*N_2	43.07bc	2.71bc	72.38bc
D_3*N_3	49.02ab	3.17ab	84.52ab
SE (±)	4.33	0.223	5.96
LSD (0.05)	8.99	0.463	12.36

Fruit yield (t ha^{-1})

Different level of water stress significantly the fruit yield of tomato (Table 7). The highest fruit yield of tomato (65.63 t ha^{-1}) was found from D_1 irrigation at 90% FC. On the other hand, the lowest (49.23) was observed from D_3 treatment (Table 7). These results suggest that fruit yield of tomato was severely affected by water stress. Similarly, Ullah *et al.*, (2016), explained that water stress restricts the nutrient availability and cell division and nutrient translocation process which hinder the yield of tomato under water scarcity.

Significant variation was recorded for different levels of nutrient management on fruit yield of tomato (Table 8). The highest fruit yield of tomato (89.63 t ha^{-1}) was recorded from N_3, whereas the lowest weight (12.39 t ha^{-1}) was attained in N_0. These results suggested that nutrient management contribute in the fruit yield of tomato. Such finding might be explained that, nutrient availability provides a significant role on the photosynthetic activity and carbon assimilation and translocation in the fruit (Wu *et al.*, 2018).

Combined effect of water stress and nutrient management significantly affected the fruit yield of tomato (Table 9). The present data signified that the maximum fruit yield of tomato (91.47 t ha^{-1}) was attained in the treatment combination of D_1N_3, which was statistically identical with D_1N_2, D_2N_3 and D_3N_3. The lowest fruit yield 8.40 t ha^{-1} was recorded in D_3N_0 treatment that was statistically similar with the D_1N_0 and D_1N_0. Thus the data reveal that the adverse effect of water stress on single fruit weight in tomato plant might be due to the ameliorative effects of organic matter along with STB fertilizer. Under water stress condition, organic matter increased the water holding capacity (Wang *et al.*, 2016). Li *et al.*, (2012) and Mahama *et al.*, (2016) also reported that nitrogen and water required for photosynthesis and transpiration also increase the capacity of cereals to mobilize and translocate photosynthates for grain formation and fruit formation which significantly increased the fruit yield.

IV. CONCLUSIONS

The maximum biomass and fruit yield of tomato plant was obtained from the treatment receiving irrigation at 90% FC. Irrigation at 70% FC also provided the similar trends. Water scarcity (irrigation at 50% FC) severely affected the plant growth, yield and yield attributes of tomato. The highest biomass and fruit yield of tomato plant was ensured in the treatment N_3 receiving STB fertilizer along with 6 t ha^{-1} poultry manure. Nutrient deficient condition (N_0; control) severely demolishes the plant growth and yield of tomato. Combined effects of irrigation at 90% FC and nutrient management by STB fertilizer + 6 t ha^{-1} poultry manure (D_1N_3) showed greater biomass and fruit yield of tomato plant. Thus, nutrient management with STB fertilizer + 6 t ha^{-1} poultry manure might be ameliorating the adverse effects of water stress on growth and yield of tomato.

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