International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Potassium Management for Improving Growth and Yield of Tomato Under Moisture Deficit Condition

Redoan Hossain[1], Tania Sultana[2], Zannatul Firdaus Binte Habib[3], Fatematuj zohura[4], Anika Tabassum[5] and Nazmun Naher[6*]

[1,2,3,4,5,6]Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207.

*** Email: nazmunsau@yahoo.com**

ABSTRACT

The production of tomato is expected to reduce due to climate change induced major abiotic stresses like drought. So, the objectives of this study were to explore the influences of drought on morphology and yield attributes of tomato applying different potassium fertilizer doses. A pot experiment was laid out in a Randomized Complete Block Design with three replications. The treatments were T_1(Control), T_2(0.63g K/pot + 40ml water/kg soil), T_3(0.5g K/pot + 40 ml water/kg soil), T_4(1g K/pot + 40 ml water/kg soil), T_5(0.5g K/pot + 70 ml water/kg soil), T_6(1g K/pot + 70 ml water/kg soil), T_7(0.5g K/pot + 100 ml water/kg soil) and T_8(1g K/pot + 100 ml water/kg soil). Drought levels directly reduced the plant growth attributes such as; plant height, leaf area, fresh and dry matter yield, relative water contents, leaf water potential, photosynthesis rate, fruit weight per plant and yield whereas; application of K+ fertilizer progressively alleviated deleterious effects of drought stress on plant growth. T_8 revealed the highest plant height at maturity stage (69.67cm), fruit number (42), fruit diameter (4.67cm), fruit weight (80.17gm) and fruit yield (3.3 Kg per pot). This study informs that an incremental increase yield by increasing levels of K on drought in case of tomato leading to improve the cultivated variety of tomato and fertilizer management.

Keywords: Moisture stress, Potassium management, Tomato, Growth, Yield.

INTRODUCTION

Bangladesh has been experiencing significant changes in environmental conditions over the last 30 years due to the effects of climate change. Bangladesh currently ranks as one of the world's foremost disaster-prone country. Ensuring food security for all is one the major challenges that Bangladesh faces today. Nowadays, the main limiting natural resource is widely considered to be water. Drought is the most complex but least understood of all-natural hazards in Bangladesh. Drought stress is responsible for water scarcity in plants (Hasanuzzaman *et al*., 2014). Every year, generally from mid-September through mid-November, this crisis occurs. People call the period Mora Kartik, meaning the month of death and disaster. Too little rainfall creates drought situations. Drought is a major factor limiting productivity in agriculture and have caused a collapse in food production by reducing uptake of water and nutrient (Du *et al.,* 2010). Despite important achievement in food grain production and food availability, food security at national, household, and individual levels remains a matter of main concern for the government mainly due to drought (Kashem and Faroque, 2013). Drought is being considered as the main cause which hampers the estimated agricultural production, here in Bangladesh over the last few decades (Dey *et al.,* 2011). Tomato (Lycopersicon esculentum Mill.) belongs to Solanaceae (nights hade) family and considered as one of the most important, popular, and nutritious vegetables that has achieved tremendous popularity around the world (FAOSTAT, 2014). Tomato is a warm season horticultural crop that is sensitive to cold (Afshari *et al.,* 2014) and can be grown both in the wet and dry seasons with an annual rainfall of 60-150 cm. Tomato is rich source of minerals and vitamins, its distinctive nutritional attributes play an important role in reducing risk of cardiovascular and associated diseases through their bioactivity in modulating disease process pathways (Dias, 2012. According to the Bangladesh Bureau of Statistics, tomato production in Bangladesh was around 4.4 million metric tons in 2020. Potassium (K) is a key element for crops growth and productivities (Munns, 2002) and plant growth is limited if the Potassium supply is interrupted, such as excessive potassium outflow caused by increasing of cellular membrane permeability (Tomemori *et al.*, 2002). Plants deficient in potassium are less resistant to drought, excess water, and high and low temperatures. They are also less resistant to pests, diseases and nematode attacks. Potassium affects quality factors such as size, shape, color and vigor of the seed or grain. Potassium builds cellulose and reduces lodging and activates at least 60 enzymes involved in growth. It helps in photosynthesis for food formation, translocate sugars and starches and improves grains starch, protein content of plants, maintains turgor pressure and reduces water loss and wilting. Drought can occur in any climate of the world and cause harmful impacts on human beings and natural ecosystems (Saadati *et al.,* 2009). Drought may be meteorological (problematic weather patterns), hydrological (lack of rain), agricultural (low commodity production) and socio-economic (low incomes and social consequences) explanations; that it is drought's impact on people and their activities (Wangai, 2013).

MATERIALS AND METHODS

A pot experiment was conducted at Agroforestry and Environmental Science Field Lab, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during the period of November 2021 to March 2022. The soil of the experimental site was collected from SAU Field which was sandy loam. Topsoil was collected from the experimental field. The soil was thoroughly mixed with compost (1/4th of the soil volume) and 1.2 g urea, 0.9g TSP, 0.6g Mop per pot were incorporate uniformly into the soil. Each pot was then filled with 14 kg previously prepared growth media (soil and cow dung mixture). Healthy and uniform 30 days old seedlings were transplanted in the experimental pots in the afternoon of 28 November 2021.The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. In this experiment BARI Tomato 8 was used. BARI Tomato 8 variety was treated under drought condition with different dose of potassium. Water was applied in different amount after 5 days interval except control condition. Eight treatments were used in the experiment. Treatments such as T1= control condition, T2= (0.63g K/pot + 40ml water/kg soil), T3= (0.5g K/pot + 40 ml water/kg soil), T4= (1g K/pot + 40 ml water/kg soil), T5 = (0.5g K/pot + 70 ml water/kg soil), T6 = (1g K/pot + 70 ml water/kg soil), T7 = (0.5g K/pot + 100 ml water/kg soil), T8 = (1g K/pot + 100 ml water/kg soil) were applied in plant. Weeding and mulching were accomplished when necessary. As a preventive measure against as the insect pest Malathion 57 EC was applied @ 2 ml L-1. To prevent plants from fungal infection. Dithane M-45 was applied @ 2 g/L at the early stage against late blight of tomato. Harvesting was started from 23 February 2022 and was continued up to 19 March 2022. Plant height, leaf and branch number were measured at vegetative, reproductive and maturity stages. Chlorophyll (Chl) content in terms of SPAD (soil plant analysis development) values was recorded using a portable SPAD 502 Plus meter (Konica-Minolta, Tokyo, Japan. Soil moisture content was measured with moisture meter at flowering stage. Plant yield parameters such as cluster number, fruit number, diameter and size and yield were measured. Collected data were statistically analyzed using Statistic 10 software. Mean for every treatment were calculated and analysis by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

1. Effects of drought and potassium levels on plant morphological parameters

1.1 Effects of drought and potassium levels on plant height of tomato

Plant heights of tomato variety were measured at 45, 60 and 85 days after transplanting (DAT). At vegetative stage tallest plant was found from T4 (1g K/pot + 40 ml water/kg soil). At T1 (Control), T5(0.5g K/pot + 70 ml water/kg soil), T6(1g K/pot + 70 ml water/kg soil), T7(0.5g K/pot + 100 ml water/kg soil), T8(1g K/pot + 100 ml water/kg soil) the plant height was statistically similar which was about 29 cm. The smallest plant (28cm) was recorded from T2(0.63g K/pot + 40ml water/kg soil). At flowering and maturity stages there was also significant difference among the treatments. The tallest plant was found from T1 which was 60.33 cm. There were similar plant heights at T4, T6, T7) and T8. The smallest plant was found from T2 and T3. At maturity stage tallest plant (69.67cm) was found from T8 and smallest from T2 which was 63.00 cm.

Khan *et al.* (2015) found that plant height of tomato variety was lower in drought stress condition compared to stress free condition. Khan *et al.* (2020) resulted that tomato plant height decreases in drought condition. Zhou *et al.* (2017); Ragab *et al.,* (2007) and Whab *et al.,* (2011) found similar result in tomato plant at drought condition. Quddus *et al.,* (2019) found application of different levels of potassium increased the plant height of mungbean plant. Sultana *et al.,* (2015) found use optimum level of potassium (K) for maximum height of tomato. Lester *et al.,* (2005) found available K improve the physical quality of plants. Chapagain and Wiesman (2004), found Potassium increases tomato plant growth. Drought stress condition interferes plant physiological activities and causes gradual decrease of plant height (Conti *et al.,* 2019; Lisar *et al.,* 2012). Application of Potassium fertilizer on drought condition improve plant height. Potassium ensured the availability of other essential nutrients. As a result, maximum growth and plant height was occurred.

Table 1. Effects of drought with potassium levels on plant height

Treatments	**Plant height(cm) at different days after transplanting (DAT)**		
	45	**60**	**85**
T1	29.67 a	60.33 a	67.67 ab
T2	28.67 ab	56.00 c	63.00 d
T3	27.67 b	56.00 c	64.00 cd
T4	30.00 a	59.00 ab	66.67 b
T5	29.33 a	57.67 bc	65.67 bc
T6	29.67 a	58.33 ab	66.67 b
T7	29.00 ab	59.00 ab	64.00 cd
T8	29.00 ab	58.67 ab	69.67 a
CV (%)	3.05	2.23	1.78
LSD	NS	2.26	2.05

1.2. Effects of drought and potassium levels on Number of branches plant-1

At 35 DAT, the highest number of branches (4) were obtained from T6 treatment and the lowest number of branches (3) were recorded from T2. At 55 DAT, there is no significant difference among the treatments. The highest number of branches (4.66) were obtained from T1 and the lowest number of branches (3.66) were recorded from T3. At 80 DAT, there is significant difference among the treatments, the highest number of branches (6) were found from T1. At T4, T6, T7, T8 which were 5.33 and the lowest number of branches (4.66) were recorded from T3.

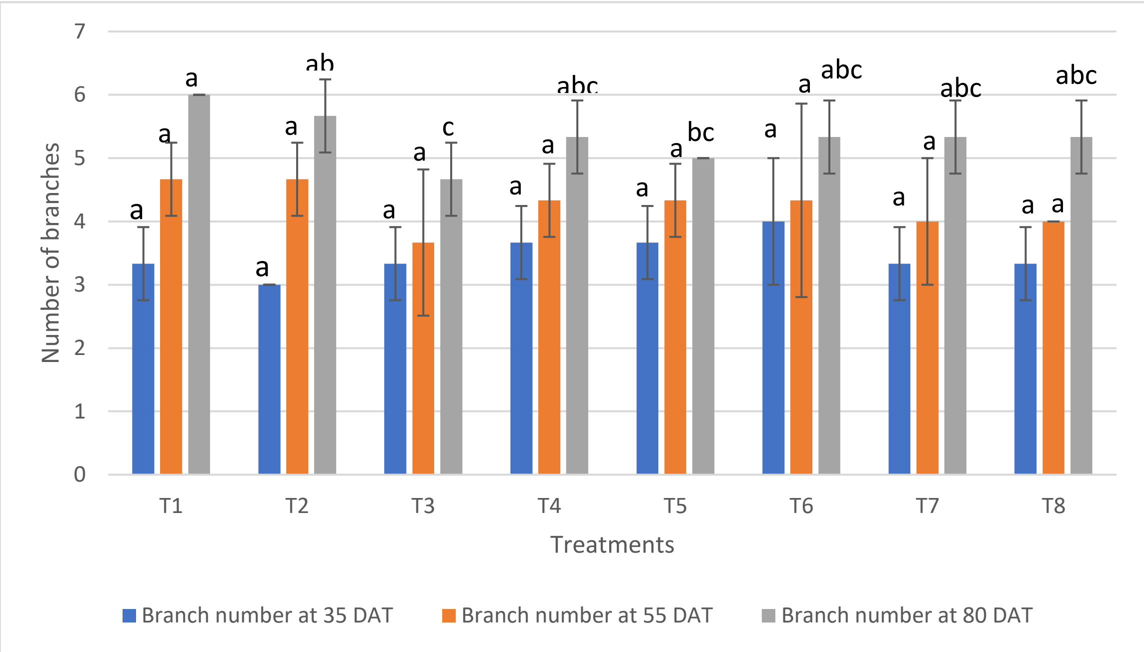

Figure 1. Effect of drought and potassium levels on number of branches per plant at different days after transplanting

1.3. Effects of drought and potassium levels on Number of leaves plant^{-1}.

At 65 DAT, highest number of leaves per plant (34.667) was recorded from T1 and the similar results about 31.66 were found from T4, T5, T6, T7 treatment. The lowest number of leaves per plant (25) was recorded from T2 and T3 treatment. Weershinghe *et al.* (2003) Found same result in case of check pea. Ibrahim (1990) reported similar findings for chickpea in case of drought. Ragab *et al*., (2007) and Whab *et al.*, (2011) found similar results in tomato plant in case of drought condition. Hossain *et al.* (2009) who found that increasing potassium fertilizer levels increased number of leaves per plant and shoot fresh weight in carrot. Akand, *et al.*, (2016) found that application of potassium fertilizer improves leaf number per plant. Potassium protects leaves from dehydration by inducing accumulation of solute such as proline, thus lowering osmotic potential that maintains plant cell turgor under osmotic stress (Egilla, *et al.*, 2005).

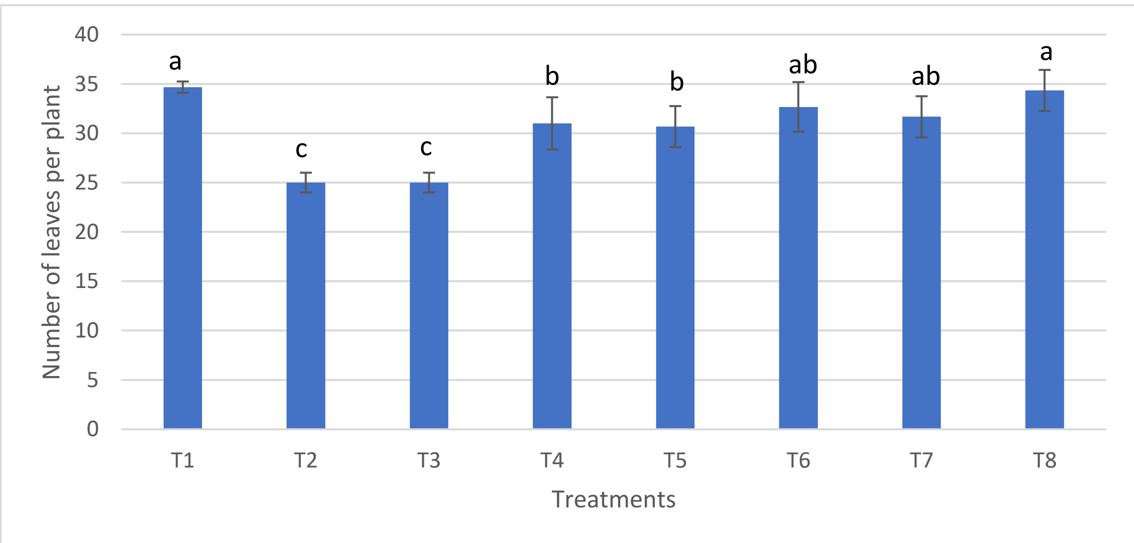

Figure 2. Effect of drought and potassium on number of leaves per plant at LSD $_{(0.05)}$ 3.32 with CV 6.19%

2. Effects of drought and potassium levels on plant physiological parameters

2.1. Effects of drought and potassium levels on SPAD Value

At 65 DAT, the highest SPAD value (36.63) was obtained from T2 and the lowest SPAD value (32.47) was recorded from T8 condition and all other treatments gave the more or less similar results. At 70 DAT, the highest SPAD value (40.3) was obtained from T4 treatment. The lowest SPAD value (37.13) was recorded from T2 condition. Sakya *et al.* (2018) reported drought stress decrease total chlorophyll content. Zhou *et al.* (2017) found similar finding in case of drought. Khan *et al.* (2020) found maximum chlorophyll content found in case of drought condition in tomato plant. Similar type of result was also found by Salama *et al.* (2017) in case of drought condition. A reason for decrease in chlorophyll content as affected by water deficit is that drought stress by producing reactive oxygen species (ROS), such as O^{2-} and H_2O_2, can lead to lipid peroxidation and consequently chlorophyll destruction (Foyer *et al.*, 1994; Hirt and Shinozaki, 2004). (Havlin *et al*., 2005; Prajapati and Modi, (2012). It has been reported that adequate supply of potassium in soil improves the water relations of plant and photosynthesis, helps in osmotic regulation of plant cell, assists in opening and closing of stomata, activates the enzymes, nodulation and synthesizes the protein (Yang *et al.*, 2004).

Table 1. Effects of drought with potassium levels on chlorophyll content of tomato plants

Treatments	**Chlorophyll content (SPAD units) at different days after transplanting**	
	50	**70**
T1	33.300 a	39.833 ab
T2	34.633 a	37.133 d
T3	34.100 a	37.500 cd
T4	33.867 a	40.300 a
T5	33.200 a	39.633 ab
T6	33.433 a	39.200 abc
T7	33.600 a	38.700 abcd
T8	32.467 a	37.933 bcd
CV (%)	6.75	2.88
LSD $_{(0.05)}$	NS	1.95

3. Effects of drought and potassium levels on plant yield parameters

3.1. Drought and potassium levels effects on Number of clusters plant^{-1}

At flowering stage 70 DAT, highest number of clusters per plant (11.67) was recorder from T7 and T8 condition. Similar data was found from T4, T5, T6 treatment. which was about 10.33. The lowest number of clusters per plant (8.33) was recorded from T3 condition. Mohan Ram and Rao (1984) reported that drought stress significantly interferes with flowering period, nectar production, flower opening mode and turgor maintenance of floral organs. Sivakumar and Srividhya (2016) found early flower production in case of drought condition in tomato plant. Akter *et al.* (2019) found similar findings in case of drought. Ragab *et al*., (2007) found flowering decreased in drought condition. Sultana *et al.*, (2015) found maximum flowering in case of application of K fertilizer. Clarke (1944) found little effect of potassium application on flower production Akand, *et al*., (2016) found similar finding application of potassium and gibberellic acid in tomato plant. Flowering stage of tomato is highly sensitive to drought condition (Samarah *et al.*, 2009c; Zinselmeier *et al*., 1999, 1995). Potassium plays roles in flowering, phenological development, physiological maturity was delayed due to the lower application of K (Fan, *et al.*, 2001; Iqbal, *et al*., 2016). (Sadiq and Jan 2001).

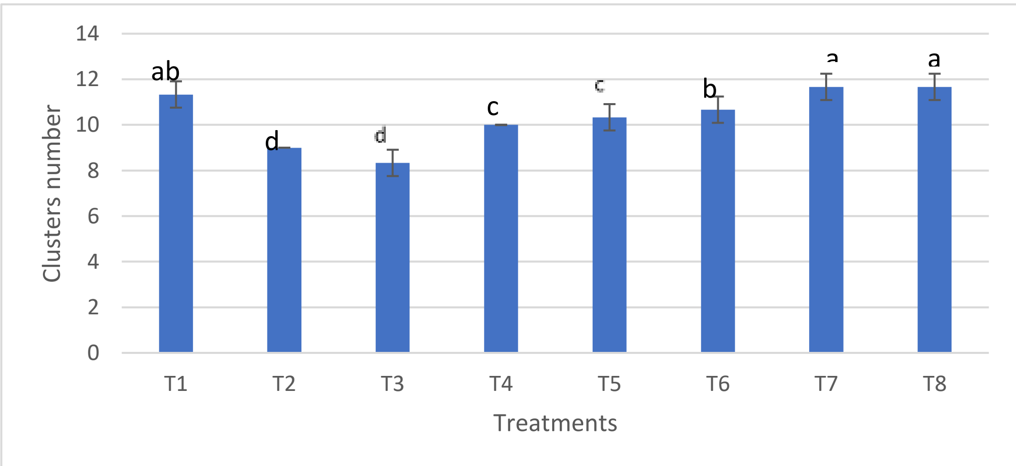

Figure 3. Effect of drought and potassium levels on number of clusters per plant at different days after transplanting at LSD $_{(0.05)}$ 0.844 with CV 4.64%

3.2. Drought and potassium levels effects on Number of Fruits plant^{-1} and Fruit diameter

At fruiting stage highest number of fruits (42) were obtained from T8 condition. The lowest number of fruits (24.67) were recorded from T3 condition. Akter *et al.* (2019) reported that highest number of fruits produce in control condition lowest number found in drought condition. Weershinghe *et al.* (2003) found that fruit number per tomato plant decreased in drought condition. Ragab *et al*., (2007) found similar result drought condition of tomato plant. Mazed, *et al.,* (2015) resulted that application of potassium fertilizer improve the Number of fruits per plant. Sultana *et al.,* (2015) resulted that optimum level of potassium use increase fruits per plant but Excess level of potassium use reduces the fruit production. Quddus *et al.,* (2019) found application of different levels of potassium showed significant increased number of pods per plant in mungbean. Akand, *et al.,* (2016) found potassium and gibberellic acid use in tomato plant increase number of fruits per plant. Pervez *et al*., (2013) who confirmed that excessive doses of K have negative impacts on potato tubers per plant. Besides, balance potassium fertilizer improved tomato production. (Zia-ul-Hassan, 2016).

At fruiting stage 100 DAT, highest fruit weight (80.17g) was found from T8 condition and lowest fruit weight (41.20g) was recorded from T3 condition. Similar data was found from T4 treatment which was about 67.37g. Techawongstein *et al*., (1992). Sakya *et al.,* (2018) showed that tomato fruit weight in the drought conditions decreased from 3-148% yield. Botrini *et al.,* (2000) observed increased fruit production and fruit quality of tomato in response of potassium. Sakya *et al.,* (2018) in the drought conditions tomato fruit weight decreased. Again Weershinghe *et al.* (2003) found that drought stress condition induces tomato yield reduction through reducing fruits per plant. Rahman *et al.* (1999) found that fruit weight per plant was decreased in drought condition. Mazed, *et al.,* (2015) resulted that application of potassium fertilizer improve the weight of individual fruit. Akand, *et al.,* (2016) found potassium and gibberellic acid increase average fruit weight. Hossain *et al.*, (2009) resulted that the potassium increase tomato fruit weight. Quddus *et al.*, (2019) found the similar result in case of mung bean. Ghourab *et al*., (2000) stated that application of adequate K increases fruit weight by increasing translocation of photosynthates to fruit and water use efficiency.

Table 3. effects of drought with potassium levels on number of fruits plant^{-1} and Fruit diameter

Treatments	**Number of fruits plant^{-1} at days after transplanting**	**Fruit diameter at days after transplanting (DAT)**
		100
T1	41.000 ab	4.4667 ab
T2	26.000 d	3.1667 e
T3	24.667 d	3.4667 d
T4	35.333 c	4.1333 c
T5	36.333 c	3.9667 c
T6	39.000 b	4.3667 b
T7	40.667 ab	4.5000 ab
T8	42.000 a	4.6667 a
CV (%)	4.03	3.10
$LSD_{(0.05)}$	2.52	0.22

3.3. Drought and potassium levels effects on Fruit Weight

At fruiting stage 100 DAT, highest fruit weight (80.17g) was found from T8 condition and lowest fruit weight (41.20g) was recorded from T3 condition. Similar data was found from T4, T5 which was about 67.37g. Techawongstein *et al.*, (1992). Sakya *et al.,* (2018) showed that tomato fruit weight in the drought conditions decreased from 3-148% yield. Botrini *et al.,* (2000) observed increased fruit production and fruit quality of tomato in response of potassium. Sakya *et al.,* (2018) in the drought conditions tomato fruit weight decreased. Again Weershinghe *et al.* (2003) found that drought stress condition induces tomato yield reduction through reducing fruits per plant. Rahman *et al.* (1999) found that fruit weight per plant was decreased in drought condition. Rao *et al.,* 2000; were found Similar results in case of tomato. Mazed, *et al.,* (2015) resulted that application of potassium fertilizer improve the weight of individual fruit. Akand, *et al.,* (2016) found potassium and gibberellic acid increase average fruit weight. Hossain et al. (2009) resulted that the potassium increase tomato fruit weight. Quddus *et al.,* (2019) found the similar result in case of mung bean. Ghourab *et al*., (2000) stated that application of adequate K increases fruit weight by increasing translocation of photosynthates to fruit and water use efficiency. But excess use of potassium reduced fruit production.

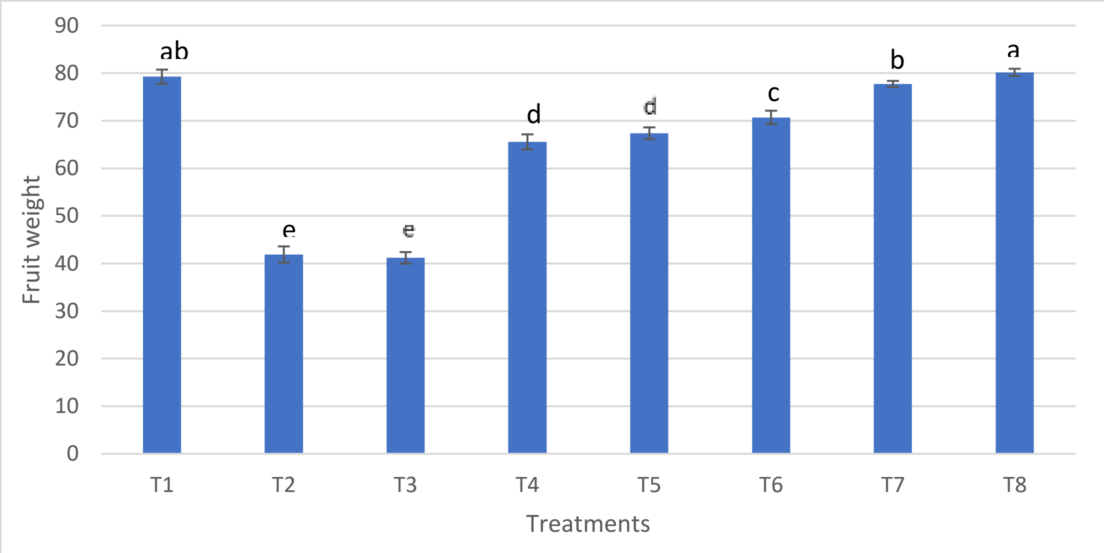

Figure 4. Effect of drought and potassium levels on fruit weight at days after transplanting at LSD $_{(0.05)}$ 2.075 with CV 1.81%

3.5. Drought and potassium levels effects on Yield per plant

Total yield per plant was measured on at 110 DAT. At 110 DAT, highest yield (3.3kg) was obtained from T8 condition. Similar results were found from T4, T5 treatment which were 2.27kg and 2.40kg respectively. The lowest yield (0.97 kg) was recorded from T3 condition. Drought stress shows very complex effect on plant growth and development process (Zlatev and Lidon, 2012). Sibomana and Aguyoh (2013) found similar findings. Ragab *et al.*, (2007) found same result in different vegetables. Sultana *et al.*, (2015) found potassium increase the tomato production but excess fertilizer reduce production. Mazed, *et al.*, (2015) resulted that application of potassium fertilizer increase the yield. Quddus *et al.*, (2019) reported that potassium increases mungbean yield. Khan *et al*., (2005) found increased tomato yield by increasing levels of potassium. Javaria *et al.*, (2012) found an incremental increase yield by increasing levels of K. while Iqbal *et al*., (2011) found maximum yield found potassium application. Elmer *et al*., (2012) reported similar result.

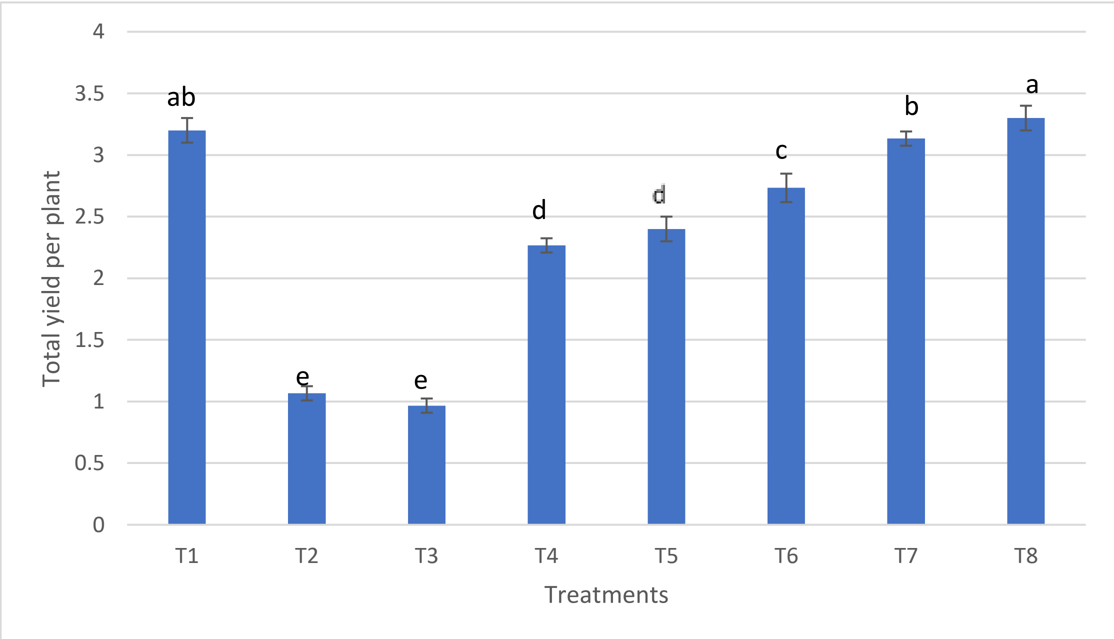

Figure 5. Effects of drought and potassium levels on total yield at LSD $_{(0.05)}$ 0.14 with CV 3.36%

CONCLUSION

Drought is a major factor limiting productivity in agriculture and have caused a collapse in food production by reducing uptake of water and nutrient. In short, the results from current study ensured the recovery effect of K^+ on tomato plants during drought stress situation.

- At morphological growth, physiological and yield component, 1g K/pot + 100 ml water/kg soil treatment showed the highest performance than other treatments.
- Highest performance found in recommended doses of fertilizer + 100ml water/kg soil and 1g K/pot + 40 ml water/kg soil for leaf, branch number and chlorophyll content.
- In case of flower per plant, cluster no per plant, fruit no per plant, fruit diameter, fruit weight, fruit yield per plant control, 0.5g K/pot + 100 ml water/kg soil, 1g K/pot + 100 ml water/kg soil treatment shows the best performance and 0.5g K/pot + 40 ml water/kg soil treatment shows the lowest results.

ACKNOWLEDGMENTS

Sher-e-Bangla Agricultural University Research System provided funding for this research.

REFERENCE

Afshari, M.; Afsharmanesh, G.H.R. and Yousef, K. (2014). The effect of enriched organic fertilizer and Methanol Spray on the greenhouse-tomato yield. Journal of Agricultural Science., 6(11):14-20.

Akand M. H., Mazed K. H. E. M., Bhagat S.K., Moonmoon J. F. and Moniruzzaman M. (2016) Growth and yield of tomato as influenced by potassium and gibberellic acid. *Bull. Inst. Trop. Agr., Kyushu Univ*.**39**: 83-94

Akter, R., Haq, M.E., Begum, B. and Zeba, N. (2019). performance of tomato (Solanum lycopersicum L.) genotypes based on agro-morphogenic traits under drought condition. Asian j. biotechnol. 2(4): 1-10.

BBS, 2012.Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of The People's Republic of Bangladesh, Dhaka. p.108.

Botrini, L., Lipucci, P.M., and Graifenberg. A. (2000) Potassium affects sodium content in tomato plants grown in hydroponic cultivation under saline-sodic stress. *Hort. Sci.* **35**(7):220–222.

Chapagain, B. P., and Wiesman. Z. (2004). Effect of potassium magnesium chloride in the fertigation solution as partial source of potassium on growth, yield and quality of greenhouse tomato. *Int. J. Hortic. Sci.* **99**:279–288.

Conti, V., Mareri, L., Faleri, C., Nepi, M., Romi, M., Cai, G. and Cantini, C. (2019). Drought stress affects the response of Italian local tomato (*Solanum lycopersicum* L.) varieties in a genotype-dependent manner Plants. **8**: 336.

Clarke E J. 1944. Studies on tomato nutrition. I. The effect of varying concentrations of potassium on the growth and yield of tomato plants. *J. Dept. Agric*., **41**: 53-81

Dias, J.S. (2012). Nutritional Quality and Health Benefits of Vegetables: A Review. Food and Nutrition Sciences, 3, 1354-1374. http://dx.doi.org/10.4236/fns.2012.310179

Dey, N. C, Alam, M. S., Sajjan, A. K., Bhuiyan, M. A., Ghose, L., Ibaraki, Y., and Karim, F., (2011). Assessing Environmental and Health Impact of Drought in the Northwest Bangladesh, *J. Environ. Sci. Nat. Resour.*, **4**(2): 89-97.

Du, N. W. Guo, X. Zhang and R. Wang. (2010). Morphological and physiological responses of Vitex negundo L. var. heterophylla (Franch.) Rehd. to drought stress. Acta Physiol Plant, 32:839–848

Egilla, J. N., Davies, F. T. and Boutton, T. W. (2005) Drought stress influences leaf water content, photosynthesis, and water-use efficiency of *Hibiscus rosa-sinensis* at three potassium concentrations. *Photosynthetica* .**43**:135-140.

El-nemr, M.A., Abd El-Baky, M.M.H., Salman S.R., and El-Tohamy. W.A. (2012). Effect of Different Potassium Levels on the Growth, Yield and Quality of Tomato Grown in Sand-Ponic Culture. *Aust. J. Basic & Appl. Sci*. **6**(3): 779-784

Fan, L., Wang, Y., Wang, H., Wu, W. (2001). In vitro Arabidopsis pollen germination an characterization of inward potassium currents in Arabidopsis pollen grain protoplasts. *J. Exp. Bot*, *52*, 1603–1614.

FAOSTAT. (2016). Food and Agriculture Organization of the United Nations, Statistics Division.

Foyer, C.H., Descourvieres, P. and Kunert, K.J. (1994). Photo oxidative stress in plants. *Plant Physiol*. **92**: 696-717.

Ghourab, M.H.H., Wassel, O.M.M. and Raya, N.A.A. (2000). Response of cotton plant to foliar application of (Pottasin-P) TM under two levels of nitrogen fertilizer. *Egypt J. Agric. Res.* ***78***:781-793

Gomez, K.A., and Gomez, A.A. (1984). Comparison between treatment means. In: Statistical Procedures for Agricultural Research. 2nd Edition. John Wiley and Sons, NY, USA

Hasanuzzaman M, Nahar K, Gill SS, Fujita M. (2014). Drought stress responses in plants, oxidative stress, and antioxidant defense. Climate change and plant abiotic stress tolerance. 2013 Dec 18:209-50.

Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L. (2005). Soil Fertility and Fertilizers: an introduction to nutrient management. Pearson Edu. Inc. USA.

Hirt, H. and Shinozaki, K. (2004). Plant responses to abiotic stress. Berlin: Springer.

Hossain, A. K. M. M., Islam, M. R., Bari, M. S., Amin M. H. A., and Kabir, M. A., (2009). Effects of mulching and levels of potassium on growth and yield of carrot. Bangladesh Research Publications Journal. **3** (2): 963-970.

Ibrahim, A.K. (1990). Studies on growth and yield of chickpea. A Ph.D. thesis, Univ. of Wales, Bangor, U.K.

Iqbal, M., Niamatullah, M., Yousaf, I., Munir, M. and Khan, M.Z. (2011). Effect of nitrogen and potassium on growth, economical yield and yield components of tomato. *Sarhad J. Agric., **27***(4): 545-548.

Iqbal, A.; and Hidayat, Z. (2016). Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress condition. Science Report.

Javaria, S., Khan, M. Q., and Bakhsh. I., (2012). Effect of potassium on chemical and sensory attributes of tomato fruit. *J. of Anim. Plant Sci.***22** (4):1081-1085.

Kashem, M.A. and Faroque, M.A.A. (2013). A country scenarioes of food security and governance in Bangladesh. *J. Sci. Found*. **9**(1-2), 41-50.

Khan, A., Khatri, A. S., Nizamani, M.A., Siddiqui, S. R., and Dabar, N., (2005). Effect of NPK fertilizer on the growth of sugar cane Clone AEC. 86-347. Developed by NIA Tandojam Pakistan. *pak. J. Bot.*, **37**(2): 355-360.

Khan, H., Basit, A., Alam, M., Ahmad, I., Ullah, I., Alam, N., Ullah, I., Khalid, M.A., Shair, M. and Ain, N.U. (2020). Efficacy of chitosan on performance of tomato (*Lycopersicon esculentum* L.) plant under water stress condition. *Pak. J. Agric. Sci.* **33**(1): 27-41.

Lester, G.E. (2006). Environmental regulation of human health nutrients (ascorbic acid, β-carotene and folic acid) in fruits and vegetables. *Int. J. Hortic. Sci.* **41**(1): 59-64.

Lisar, S.Y.S., Motafakkerazad, R., Hossain, M.M. and Rahman, I.M.M. (2012). Water stress in plants causes, effects and responses. In**:** Water stress. Rahman, I.M.M., (ed.). New York, USA.

Mazed, K.H. E. M., Akand, H.M., Haque, M. N., Pulok, M.A. I. and Partho, S. G. (2015) Yield and Economic Analysis of Tomato (Lycopersicon Esculentum mill.) as Influenced by Potassium and Stem Pruning. *Int. J. Sci. Res*. **5**: 1

Mohan-Ram, H.Y. and Rao, I.V. (1984). Physiology of flower bud growth and opening. *Proc. Indian National Sci. Acad* **93**: 253-274.

Munns, R. (2002) Comparative physiology of salt and water stress. *Plant Cell Environ*.**25**: 239-250.

Pervez, M.A., Ayyub, C.M., Shabeen, M.R. and Noor, M.A. (2013). Determination of Physio morphological Characteristics of Potato Crop Regulated by Potassium Management. *Pak. J. Agri. Sci. **50***(4): 611-615.

Prajapati, K. and Modi, H.A. (2012). The Importance of Potassium in Plant Growth – a Review. *Indian J. of Plant Sci.* **1**: 177-186.

Quddus, M.A., Hossain, M.A., Naser, H.M., Anwar, B., Siddiky, M.A., and Ali, M.R., (2019). Influence of Potassium Addition on Productivity, Quality and Nutrient Uptake of Mungbean (Vigna radiata L.). *J. Agric. Stud.* **7**: 1

Ragab, A.R., Abdel-Raheem, A.T., Kasem, Z.A., Omar, F.D. and Samera, A.M. (2007). Evaluation of R1 tomato somaclone plants selected under Polyethylene Glycol (PEG) treatments. *Afr. Crop Sci. j.* **8**: 2017-2025.

Rahman, S. M. L., Nawata, E. and Sakuratani, T. (1999). Effect of water stress on growth, yield and eco-physiological responses of four (*Lycopersicon esculentum* Mill.) tomato cultivars. *J. Japan. Soc. Hort.* **68**(3): 499-504.

Rao, N.K.S., Bhatt, R.M. and Sadashiva, A.T. (2000). Tolerance to water stress in tomato cultivars. *Photosynthetica.* **38**(3): 465-467.

Saadati, S. S., Soltani, S., and Eslamian, S. S. (2009). Statistical analysis of return period of drought conditions in Isfahan province using the standardized precipitation index. *IJNRR.* **62**(2), 257-269.

Sadiq, S.A. and Jan, A. (2001). Effect of Graded Application of Potash on Kharif Maize Sown at Different Fertility Levels. M. Sc (Hons) Thesis, Department of Agron, KPK Agricultural University, Peshawar, Pakistan.

Sakya, A.T., Sulistyaningsih, E. Indradewa, D. and Purwanto, B.H. (2018). Physiological characters and tomato yield under drought stress. IOP Conf. Ser.: Earth Environ. Sci. p. 200.

Salama, A.A., nashwa, A.I.A. and El-Sayed, H.E. (2017). Effect of deficit irrigation levels and NPK fertilization rates on tomato growth, yield and fruits quality. *Middle East J. Agric. Res.* **6**(3): 587-604.

Samarah, N.H., Mullen, R.E. and Anderson, I. (2009c). Soluble sugar contents, germination and vigor of soybean seeds in response to drought stress. *J. New Seeds*. **10**: 63-73.

Sibomana, I. C. and Aguyoh, J. N. (2013), Water stress affects growth and yield of Container Grown Tomato (*Lycopersicon esculentum Mill*) Plants. *Global J. Biosci. Biotech.* **2**(4): 461-466.

Sivakumar, R and Srividhya, S. (2016). Impact of drought on flowering, yield and quality parameters in diverse genotypes of tomato (*Solanum lycopersicum* L.). *Adv. Hort. Sci.* **30**(1): 3-11.

Sultana, R., Dilruba., Parvin., and Islam, A. (2015). Effect of Potassium on Growth and yield of Tomato (Lycopersicon esculentum Mill.) *Eco-friendly Agril. J.* **8**(06): 77-80.

Techawongstein, S., Nawata, E. and Shigenaga, S. (1992). Effect of water stress at various stages of plant development on growth and yield of chili pepper. *Japanese J. Trop. Agric.* **36**: 275-280

Tomemori, H., Hamamura, K., and Tanabe, K. (2002). Interactive effects of sodium and potassium on the growth and photosynthesis of spinach and komatsuna. *Plant Prod. Sci* **5**: 281-285.

Wahb-Allah, M.A., Abdullah, A.A. and Abdullah, A.I. (2011). Drought tolerance of several tomato genotypes under greenhouse conditions. *World Appl. Sci. J.* **15**(7): 933-940.

Wang, M.; Zheng, Q.; Shen, Q.; Guo, S. (2013) The critical role of potassium in plant stress response. *Int. J. Mol. Sci.* ***14*:**7370–7390

Weershinghe, O.R., Costa, W.A.J.M. and Perera A.L.T. (2003). Evaluation of different genotypes of tomato under well-watered and well stressed conditions on the basis of yield and some selected physiological parameters. *Trop. Agric. Res*. **15**: 144-156.

Yang, X. E., Wang, W. M., andHe, Z. (2004). Physiological and genetic characteristics of high nutrient efficiency of plants in acid soils, 78-83.

Zlatev, Z., and Lidon, F. C. (2012). An overview on drought induced changes in plant growth, water relations and photosynthesis. *Emir J. Food and Agric.* **24**(1): 57-72.

Zhou, R., Yu, X., Ottosen, C., Rosenqvist, E., Zhao L., Wang, Y., Yu, W., Zhao, T. and Wu, Z. (2017). Drought stress had a predominant effect overheat stress on three tomato cultivars subjected to combined stress. *BMC Plant Biol*. **17**: 24.

Zia-ul-Hassan, Kubar., K.A., Chhajro, M.A., Kandhro, M.N., Jamro, G.M., Talpur, K.H. and Talpur, N. (2016). Response of Tomato (Lycopersicon esculentum L.) at Varying Levels of Soil Applied Potassium. *J. Basic Appl. **12**:* 198-201.

Zinselmeier, C., Lauer, M.J. and Boyer, J.S. (1995). Reversing drought induced losses in grain-yield; sucrose maintains embryo growth in maize. *Crop Sci.* **35**: 390-1400.

Zinselmeier, C., Jeong, B.R. and Boyer, J.S. (1999). Starch and the control of kernel number in maize at low water potential. *Plant Physiology.* **121**: 25-35.