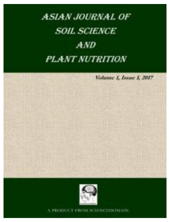

Asian Journal of Soil Science and Plant Nutrition

2(1): 1-8, 2017; Article no.AJSSPN.36861
ISSN: 2456-9682

Fruit Quality and Osmotic Adjustment of Four Tomato Cultivars under Drought Stress

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Authors' contributions

This work was carried out in collaboration between both authors. Author KN designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author SMU managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2017/36861
Editor(s):
(1) Tancredo Souza, Department of Life Sciences, Centre for Functional Ecology, University of Coimbra, Portugal.
Reviewers:
(1) E. G. Oboho, University of Benin, Benin.
(2) Kürşat Çavuşoğlu, Süleyman Demirel University, Turkey.
(3) Martín Maria Silva Rossi, Argentina.
Complete Peer review History: http://www.sciencedomain.org/review-history/21513

Original Research *Article*

Received 20th September 2017
Accepted 15th October 2017
Published 23rd October 2017

ABSTRACT

A field experiment was conducted on loam soil to study the effect of drought stress on fruit quality and osmotic adjustment in four tomato cultivars in Bangladesh. The water stress treatments were imposed at 82-100% (T0), 69-85% (T1), 53-67% (T2), and 40-50% (T3) of the field capacity. Under stress, the quality of fruits was improved as a result of the synthesis of different acids like ascorbic acid, citric acid and malic acid. The response of solute accumulation in relation to water stress revealed significant increase in glucose, fructose and sucrose in fruits and proline contents in leaves, showed the conspicuous tendency of tomato plants to adjust osmotically against water stress.

An increase of 100% (glucose), 30% (fructose) 72% (sucrose) and 345% (proline) were found at T3 treatment compared with T0. The concentration of citric acid, malic acid and ascorbic acid increased with increasing water deficit in the plants. Water stress increased sugar and different acids and consequently improved the fruit quality. No physical damage due to stress was observed in fruits, which were over 90% red.

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Keywords: Tomato; drought stress; Bangladesh; fruit quality; osmotic adjustment.

1. INTRODUCTION

Vegetable crops play a vital role in human nutrition. Tomato (*Lycopersicon esculenturn* Mill) is one of the most important and widely cultivated vegetable crop all over the world. It is one of the most popular salad vegetables in the row state and is made into soups, pickles, ketchups, sauces and other products. Of more than 100 species of vegetable crops selected for intensive study in representative Asian countries, tomato ranked first [1]. People of Bangladesh especially in the rural areas suffer from malnutrition because of imbalanced diet. Besides majority of the people of Bangladesh suffer from nutritional deficiency particularly of vitamin A & C, iron, calcium and riboflavin.

It is also a respectable source of some key nutrients such as vitamin A, vitamin C, sugar, ascorbic acid, some protein and iron. It also possesses valuable medicinal properties and it is an excellent purifier of blood, so the crop has very diverse functions in humans.

World-wide, tomato was the seventh most valuable commodity crop in 2013, with a gross production value of over $60 billion [2]. The average consumption of vegetable in Bangladesh is only 82 g per head per day as against the required level of 235 g [3].

Tomato is sensitive to a number of environmental stresses, especially extreme temperature, inadequate moisture and environmental pollution, salinity, drought and there is a need to develop varieties that can withstand such environmental stresses [4]. Water availability has substantial impact on the chemical composition and physical properties of plant tissues, which in turn have decisive significance on the quality and yield of plants [5]. Water deficits in tomato compromise fruit yield and also quality [6,7,8].

Water deficit by climate change in Bangladesh is a common phenomenon during summer and winter periods. Due to the reduction of moisture levels in this period, the growth of agriculture suffers. To this adds population problem which needs production of more food to feed for 160 million people within an area of 147570 square kilometers [9].

If there were adequate supply of uncontaminated water during this period, Crops can be ensured. Practically winter is the safest period for crop production where there is little chance of crop failure due to climatic reasons but unfortunately our crops suffer from drought during this period. Crops production could be enhanced either by supplying adequate water or by growing drought resistant crops. This could be overcome by selecting crops which have less demand for water or have root systems sufficient to utilize subsurface water.

Water Potential is the physiochemical availability of the water to participate in plant functions and determines the tendency for net water movement within the system. The Overall water potential of the tomato plant is a function of the combined effect of environmental factors and plant characteristics [10,11].

Generally in hot regions the amount of water necessary for obtaining a given quantity of fresh fruit (Tomato) is five times greater than in humid and cool regions. The difference becomes even greater when one considers the farming profitability of the use of water in greenhouses, where the water consumption decreases even more and the efficiency per mm of water rises further, to the point of doubling the crop per unit of water [12]. The judicious use of water needs to be made to obtain maximum efficiency when their supply is limited.

In this experiment we have selected tomato crop because it is less susceptible to drought and has extensive root system.

The aim of the present study was to find out a suitable drought resistant tomato variety out of four varieties commonly cultivated in Bangladesh, also to evaluate fruit quality and osmotic adjustment with minimum use of water.

2. MATERIALS AND METHODS

Field experiment was conducted in Dhaka, Bangladesh, geographical location is 20° 34’N-26°38’N and 88° 01’E-92°41’E, mean humidity 79.5%, annual rainfall (average) 2000 mm and maximum annual temperature 36°C and minimum 12°C. The annual precipitation varies from 1500 mm in the north to 5700 mm in the northeast [13] and during the periods from (November-March).

The experiment was conducted to evaluate the fruit quality and osmotic adjustment in tomato plants due to water stress. Four varieties of tomato plants namely, BR-1, BR-2, BR-4 and BR-5 were the test crops.

The seeds of four varieties namely BR-1, BR-2, BR-4 and BR-5 from Bangladesh Agriculture Research Institute (BARI) at Gazipur.

The soil used in the field experiment was of Tejgaon series under Madhupur tract (According to Reconnaissance Soil Survey report of Dhaka District, 1965 reviewed in 1987). For physical and chemical analysis soil samples were collected at a depth of 0-15 cm from experimental station of Bangladesh Agriculture Research Institute at Tejgaon, Dhaka.

Tejgaon soil has a wide range of crop potentialities and is best suited to producing dry land crops. This soil can be successfully used to study the effect of moisture levels on different cultivars of tomato.

The collected soil samples were air-dried ground to pass through 2 mm sieve and then mixed thoroughly to make a composite sample. Dry grasses and other vegetative residual parts were discarded from the soil.

The general physical and chemical characteristics of the soil were:

Textural class of soil-loam, sand - 35.80%, silt - 40.20%, clay - 24.00, Moisture at field - 32%, Moisture at wilting-10%, Maximum water holding capacity-45%, Hygroscopic moisture-1.73%, Bulk density-1.39 g/cc, Particle density-2.63g/cc, Porosity-47%, pH- 5.1, EC-90 µS, OM-1.1%, CEO- 14.88 meq / 100 g soil, and N-0.07%.

The experiment was carried out in a randomized complete block design with four treatments and three replications for each cultivar. Unit plot size was 1 mX1 m with four plants per plot.

The land was prepared well by harrowing followed by laddering. The grasses, weeds and other vegetative residual parts were removed from the land. In this experiment spacing were 75 cm between plots, 50 cm between rows and 45 cm between plants.

Cow dung was applied at the rate of 6t/ha at the time of final land preparation. N, P_20_5 and K_20 were applied at the rate of 260-200-150 kg/ha, respectively.

The entire amount of phosphate, potash and half of the nitrogen were mixed at the time of the preparation of land. The rest half of the nitrogen was applied in two splits, one at 21 days after sowing of plants during vegetative stage and another at flowering stage.

Seeds were sown at BADC (Bangladesh Agriculture Development Corporation) and after 25 days of germination, healthy seedlings of uniform size were transplanted in the field. After transplantation, Plants had been shaded for 4 days to protect them from sunlight.

Twenty one days after transplantation, each row of tomato plant was supported with bamboo stick to prevent lodging. Weeding in the plots were done when necessary.

As growth progressed, the tomato plants were attacked by insects. It was therefore, necessary to spray the plants with Malathion (1 ml in 1 L water) as insecticide. The insecticide was sprayed as and when required.

The stress period with the cultivars commenced from 28 days after transplantation. The water stress treatments were imposed at 82-100% (T0), 69-85% (T1), 53-67% (T2), and 40-50% (T3) of the field capacity, respectively, in order to investigate the fruit quality and osmotic adjustment of plant. Soil samples were collected at 6 days intervals for measuring the soil moisture percentages from the plots and were measured gravimetrically by drying the soil samples at 105°C for 24 hours. To maintain the above mentioned moisture levels, the soil was irrigated with the amount of water lost by evaporation and transpiration. By addition of irrigation water after six days, the soil moisture levels were within the following ranges: 26-32% (T0), 22-27% (T1), 17-21% (T2), 13-16% (T3).Water was added weekly to maintain soil moisture at 40-50%, 53-67%, 69-85% and 82-100% of the field capacity throughout the experimental period.

After the end of the experiment, the ripening of the tomatoes were observed and recorded.

Young and fresh leaves were taken for biochemical analysis. Three leaves of tomato plants of each plot wrapped in aluminum foil and stored in the deep freeze. These were done just after plucking the leaves from the plants.

The riped tomatoes were harvested from time to time. After the harvest of the riped tomatoes, fresh weight was recorded and visual quality and physical damage of tomatoes were determined according to the rating, scale of [14]. Three tomatoes from each plot were cut into pieces for application of the rating scale for internal tissue damage due to bruising, the rest of the fruits used for other biochemical investigations.

Organic solutes like Glucose, fructose, sucrose, malic acid, L-ascorbic acid and citric acid in tomatoes were determined by enzymatic methods described by [15]. Proline in leaves was estimated by the method outlined by [16].

Three tomatoes from each plot were minced separately by an electric mixture and extracted with water (60°C). In the extract the contents of glucose, fructose, sucrose, (with carrez - solutions) citric acid and malic acid were analyzed by enzymatic methods [15]. For the assay of ascorbic acid, fruit samples were well minced with an electric mixer and homogenized in metaphosphoric acid (15% w/v). The pH of the mixture was adjusted to 3.7 with KOH and ascorbic acid was determined by enzymatic methods (Boehringer- Mannheim 1989). Proline was estimated by the method outlined by [16].

For determination of proline in tomato leaves, Purified Proline was used to standardize the sample values.

2.1 Reagents

Acid ninhydrin was prepared by warming 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6M phosphoric acid, with agitation, until dissolved Kept cold (Stored at 4°C) the reagent remains stable for 24 hours.

2.2 Procedure

(a) Approximately 0.5 g of plant material was homogenized in 10 ml of 3% aqueous sulfosalicylic acid and the homogenate filtered through whatman # 2 filter paper.
(b) Two ml of filtrate was reacted with 2 m 1 acid ninhydrin and 2 m 1 of glacial acetic acid in a test tube for 1 hour at 100°C and reaction terminated in an ice bath.
(c) The reaction mixture was extracted with 4-ml toluene, mixed vigorously with a test tube stirrer for 15-20 sec.
(d) The chromophore containing toluene was aspirated from the aqueous phase, warmed to room temperature and the absorbance read at 520 nm using toluene for a blank.
(e) The proline concentration was determined from a standard curve and calculated on a fresh weight basis.
(f) To evaluate the quality parameters of plant, enzymatic methods were used [15].

For determination of glucose, fructose, sucrose, malic acid and citric acid in tomato fruits, following techniques are used for sample preparation.

The sample was homogenized using a mortar, A well mixed sample was accurately weighed and extracted with hot water (60°C). The extract was transferred quantitatively to a volumetric flask and filled up to the mark with redistilled water. Filtered and used the clear solution for the assay. For clarification (glucose, fructose and sucrose) the following solutions are used 5 ml carrez-1 solution (3 60g potassium hexacyanoferrate-II, K_4 [Fe (CN) $_6$] $3H_2O$/100 ml. 5 ml carrez-II solution (7.20 g of $ZnSO_4$, $7H_2O$/100 ml and 10 ml NaOH (0.1 mol/L).

L. Ascorbic acid: For the assay of ascorbic acid the tomatoes were well minced with an electric mixture and homogenized with metaphosphoric acid (1 5%WN). After mincing the pH of the mixture was adjusted to 3.7 with KOH solution.

Finally the results were analyzed statistically employing the Duncan's New Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

Effect of water stress on Concentrations of Proline, Glucose, Fructose, Sucrose, Malic acid, Citric acid and L-Ascorbic acid (osmotic adjustment and quality parameters).

3.1 Results

Results of these parameters among varieties and treatments are given in Tables 1-2.

3.1.1 Proline

The proline contents in tomato leaves showed significant difference among the cultivars. It was the highest in BR-2 and the lowest in BR-5. There was no significant difference between BR-4 and BR-1 (Table 1). The concentration of proline increased significantly with increasing water stresses. The highest concentration of 9.16% was observed at T3, which was about

345% higher than that of control (T0) treatment. (Table 2).

3.1.2 Concentration of glucose

The glucose concentration of fruits among the cultivars differed significantly and was found the highest in BR-2 followed by BR-4, BR-5 and BR-1 (Table 1). The contents of glucose in tomato fruits increased significantly with the increase in water stress (Table 2). There was about 100% increase in glucose contents at T3 compared with T0 treatment.

3.1.3 Concentration of fructose

Like glucose, fructose contents in tomato fruits were also affected by water stresses. The lowest concentration of fructose was observed at T0 (Table 2), which had about 30% lower fructose content than that of T3 treatment.

Concentration of fructose is also dependent on variety and was found the highest in BR-2 and the lowest in BR-5. There was no significant difference between BR-1 and BR-4 (Table 1).

3.1.4 Concentration of sucrose

The result of this experiment demonstrated that the sucrose contents in fruits were much higher than glucose and fructose. The concentration was highest in BR-2. However there was no significant variation among the three varieties (Table 1).

The results also revealed that water stress increased the concentration of sucrose than glucose and fructose. The highest concentration was measured at T3 and the lowest at T0 treatment (Table 2). More than 72% increase in sucrose was notice at T3 compared with that on the control (T0).

3.1.5 Malic acid concentration

Malic acid concentration of fruits among the cultivars differed significantly. The highest concentration was found in BR-4 followed by BR-5. There was no significant difference between BR-2 and BR-1 (Table 1). Malic acid concentration was also affected by water stresses. Increased water stress also increased the synthesis of malic acid. The highest concentration was observed at T3 and the lowest was measured at T0 treatment (Table 2). An increased of 100% malic acid concentration was observed at T3 compared with T0 treatment.

3.1.6 Ascorbic concentration

The result of ascorbic acid concentration showed that there was no significant different among the cultivars (Table 1). However the treatments differed significantly. Its concentration increased with increasing water stress.

The highest amount of ascorbic acid was found at T3 treatment, while the lowest was at T0 treatment (2). Water deficit significantly increased acid contents in tomato fruits to more than 175% at T3 compared with T0 treatment.

Table 1. Content of organic solutes in different cultivrs

Cultivars	% Proline	% Glucose	% Fructose	% Sucrose	% Ascorbic acid	% Malic acid	% Citric acid
BR-1	5.21ab	0.66b	0.93ab	1.11b	0.049a	0.32c	0.66a
BR-2	5.79a	0.92a	0.97a	1.84a	0.050a	0.36c	0.70a
BR-4	5.53ab	0.80ab	0.91ab	1.29b	0.051a	0.50a	0.70a
BR-5	4.69b	0.71b	0.86b	1.22b	0.053a	0.45b	0.68a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 2. Effect of different water stress treatments on organic solutes content in plants

Treatment	% Proline	% Glucose	% Fructose	% Sucrose	% Ascorbic acid	% Malic acid	% Citric acid
T0	2.06d	0.53c	0.79b	0.99b	0.028c	0.26d	0.42d
T1	3.89c	0.67c	0.97a	1.84a	0.050a	0.36a	0.70a
T2	6.12b	0.83b	0.93a	1.47ab	0.059b	0.47b	0.81b
T3	9.16a	1.06a	1.03a	1.71a	0.077a	0.54a	0.94a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

3.1.7 Citric acid concentration

Citric acid concentrations in tomato fruits showed that there was no significant difference among the cultivars, but the treatments differed significantly from each other.

The highest concentration was found at T3 while the lowest was at T0 treatment. There was an increase of about 124% at T3 compared with T0 treatment. The results also indicate that tomato fruits accumulated more citric acid than malic and ascorbic acids (Table 1).

Ripeness classes of tomatoes were also determined according to [14]. The tomatoes were red over 90%, classified as red scored 6 of Grierson and Kader's Table 6.5 in all treatments.

Regarding the internal tissue damage due to bruising, no degree to severity and no visible internal tissue damage were observed (Score Table 6.6 of [14]. in all treatments. Overall visual quality of the fruits was found excellent and essentially no symptoms of deterioration were noticed - Score 9 of Table 6.7 [14] in all treatments. No symptom of physical damage in any of the treatments could be detected (Score 1 of Table 6 [14]. Ripening and fruit quality studies showed that none of the stress treated tomatoes deteriorated in quality (Plates 1-4). On the other hand water stress enhanced the sweetness of the tomatoes by increasing their glucose, fructose, and sucrose contents and improved the quality by increasing the amount of important acids such as ascorbic acid, malic acid and citric acid.

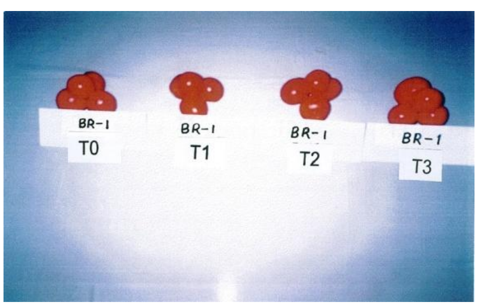

Plate 1. Colour of tomatoes (BR-1) at different moisture stress level

It was found that the plants had a tendency to adjust against drop in potential in soil by producing organic solutes such as glucose, fructose, sucrose and proline. An increase of 100% (glucose), 30% (fructose) 72% (sucrose) and 345% (proline) was found at T3 treatment compared with T0. The quality of fruits was improved as a result of the synthesis of ascorbic acid, citric acid and malic acid. No physical damage due to stress was observed in fruits, which were over 90% red.

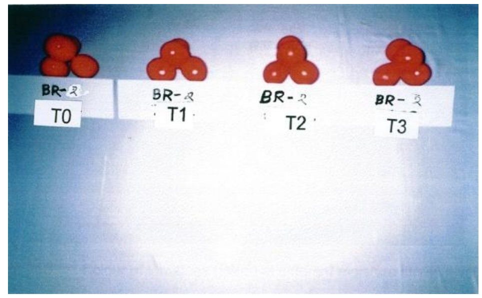

Plate 2. Colour of tomatoes (BR-2) at different moisture stress level

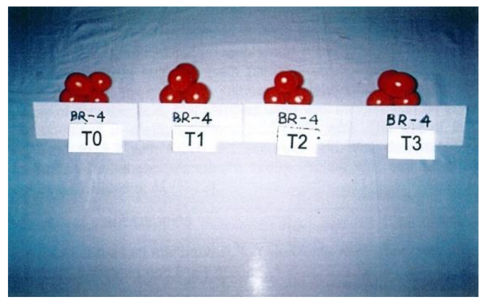

Plate 3. Colour of tomatoes (BR-4) at different moisture stress level

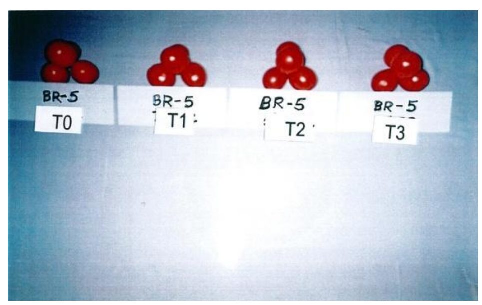

Plate 4. Colour of tomatoes (BR-5) at different moisture stress level

3.2 Discussion

Osmotic adjustment is a key mechanism by which plants adapt to water shortages resulting from an increased solute concentration of cells in order to maintain the water potential gradients needed to ensure continued uptake of water during the stress period. In addition, osmotic adjustment allows cell to maintain the turgor, which is essential for plant growth and various other physiological processes.

According to [17,18,19,20,21,22,23,24,25,26]. Plants synthesize and accumulate organic molecules such as glucose, fructose, proline etc, which act as osmotica and play important role in osmotic adjustment in plants at reduced potential.

In this experiment, the proline concentration in tomato leaves increased with increasing water stress. This result is in agreement with others [27,28,29,30,31] who reported that proline accumulation during water stress was the greatest in tomato varieties.

In this experiment, the content of glucose, fructose, sucrose, ascorbic, malic and citric acid in tomato increased significantly with water stress. This result with the findings of [21,22,23] who reported a significant increase in glucose, fructose, in some cases sucrose, acids and proline contents in faba beans and tomato by salt stress improving fruit quality.

Ripeness classes of tomatoes were determined according to [14]. The tomatoes were red over 90%, classified as red scored 6 of Grierson and Kader's table 6.5 in all treatments. Regarding the internal tissue damage due to bruising, no degree to severity and no visible. internal tissue damage was observed (Score table 6.6 of [14]. in all treatments. Overall visual quality of the fruits was found excellent and essentially no symptoms of deterioration were noticed (Score 9 of table 6.7 [14]. No symptom of physical damage in any of the treatments could be detected (Score 1 of table 6. [14]. Ripening and fruit quality studies showed that none of the stress treated tomatoes deteriorated in quality. On the other hand water stress enhanced the sweetness of the tomatoes by increasing their glucose, fructose, and sucrose contents and improved the quality by increasing the amount of important acids such as ascorbic acid, malic acid and citric acid.

4. CONCLUSION

From the experiment it can be concluded that drought stress reduced soil water potential which affected metabolic and physiological functions of the plants and showed a tendency to adjust against drop in potential in soil by producing organic solutes and different acids.

It is believed that drought resistant cultivars have wide adaptation and internal physiological process during stress by producing organic solutes and acids. A significant increase in organic solutes showed a tendency of the plants to adjust osmotically to survive under stressed condition and the synthesis of different acids increases the sweetness and hence improves the quality of fruits. Also no physical and internal tissue damages in fruits were detected due to stress and the fruits were red over 90%.

Finally we can conclude from the result that it is possible to use water stress tolerance a selection criteria in tomato breeding program for drought resistance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Asian Vegetable Research and Development Center. Pre-and post-harvest vegetable technology in Asia, Shanhua, Taiwan, Roc; 1977.
2. FAOSTAT. FAOSTAT data base; 2013 production. Avalable:http://faostat3.fao.org/home/E.2014
3. Anonymous. Yearbook of agricultural statistics division, ministry of food. Govt. of Bangladesh. Dhaka; 1990.
4. Kalloo G. Genetic improvement of vegetable crops in tomato. Kallo G, Bergh BO. (ed.), Pergamon Press, New York. 1993;645-666.
5. Kramer PJ. Water relations of plants. Academic Press, New York, London; 1983.
6. Patane C, Cosentino SL. Effects of soil water deficiton yield and quality of processing tomato under a Mediterranean climate. Agr. Water Manage. 2010;97:131–138.
7. Nahar K, Ullah SM. Morphological and physiological characters of tomato (*Lycopersicon esculentum* Mill) cultivars under water stress. Bangladesh Journal of Agricultural Research. 2012;37(2):355-360.
8. Kuşcu H, Turhan A, Demir AO. The response of processing tomato to deficit irrigation at various phonological stages in a sub-humid environment. Agr. Water Manage. 2014;133:92–103.
9. Anonymous. Statistical pocket book. Bangladesh Bureau of Statistics; 1993.
10. Waister PD, Hudson JP. Effects of soil moisture regimes on leaf water deficit, transpiration and yield of tomatoes. J. Hort Sci. 1970;45:359-370.

11. Turner NC. Techniques and experimental approaches for the measurement of plant water status. Plant and Soil. 1981;58:339-366.
12. Rendom-poblete E. Effect of soil water status on yield, quality and root development of several tomato genotypes. PhD Dissertation. University of California, Davis; 1980.
13. Hussain MS. Soil classification with special reference to the soils of Bangladesh. University of Dhaka; 1992.
14. Grierson D, Kader AA. Fruit ripening and quality. In: The tomato crop (Atherton. J.G and J. Rudich eds). Chapman and Hall. London/New York. 1986;241-280.
15. Boehringer Mannheim. Methods of biochemical analysis and food analysis, Sandhofer Stra Be 116 6800 Mannheim 31, W. Germany.1989;2-122.
16. Bates LS, Waldren RP, Teare ID. Rapid determination of free proline for water stress studies. Plant and Soil. 1973;39: 205-207.
17. Greenway H, Munns R. Mechanisms of salt tolerance in nonhalophytes. Annual Review of Plant Physiol. 1980;31:149-90.
18. Flowers TJ, Troke PF, Yeo AR. The mechanism of salt tolerance in halophytes. Ann. Rev. Plant physiol. 1977;28:89-121.
19. McCree KJ. Whole plant carbon balance during osmotic adjustment to drought and salinity stress. Aust. J. Plant Physiol. 1986; 13:33-43.
20. Torrecillas A, Guillaume C, Alarcon JJ, Ruiz-Sanchez MC. Plant Science (Ireland). 1995;105(2):169-176.
21. Ullah SM, Soja G, Gerzabek MH. Ion uptake, Osmoregulation and plant water relations in faba bean (*Vicia faba*) under salt stress. Die Bodenkultur. 1993;44:291-301.
22. Ullah SM, Gerzabek MH, Soja G. Effect of sea-water and soil salinity on ion uptake, yield and quality of tomato (fruit). Die Bodenkultur. 1994;45(1):1- 8.
23. Ullah SM, Chamon AS, Chowdhury MS, Rahman MM, Mondol MM. Ion uptake, yield and quality of tomato (fruits) under simulated seawater salinity stress. Dhaka Univ. J. Biol. Sci.1997;6(2):195-204.
24. Nahar K, Gretzmacher R. Effect of water stress on nutrient uptake, yield and quality of tomato (L.e) under subtropical conditions Die Bodenkultur. Austrian Journal of Agricultural Research. 2002;53: 45-51.
25. Nahar K, Ullah SM, Islam N. Osmotic adjustment and quality response of five tomato cultivars (*Lycopersicon esculentum* Mill) following water deficit stress under subtropical climate. Asian Journal of Plant Sciences. 2011;10(2):153-157.
26. Dekoum VM, Marius A, Liyun L, Akihiro U, Toshinori N, Hirofumi S. Effects of drought stress on growth, solute accumulation and membrane stability of leafy vegetable, huckleberry (*Solanum scabrum* Mill.) Journal of Environmental Biology. 2016; 37(1):107-14.
27. Aloni B, Rosenstein G. Proline accumulation: A parameter for evaluation of sensitivity of tomato varieties to drought sensitivity of tomato varieties to drought stress. Physiologic – Planetarium. 1984; 61(2):231-235.
28. Nahar K. Effect of water stress on nutrient uptake, osmotic adjustment and root development in different tomato cultivars. Lulu Publisher; 2014.
ISBN: 978- 1-312-59237-7
29. Nahar K, Ullah SM, Gretzmacher R. Influence of soil moisture stress on height, dry matter and yield of seven tomato cultivars. Canadian Journal of Scientific and Industrial Research. 2011;2:4.
30. Nahar K, Ullah SM, Gretzmacher R. Influence of soil moisture stress on height, dry matter and yield of seven tomato cultivars. Canadian Journal of Scientific and Industrial Research. 2011;2(4):160-163.
31. Nahar K, Ullah SM. Effect of water stress on moisture content distribution in soil and morphological characters of two tomato (*Lycopersicon esculentum* Mill) cultivars. Bangladesh Journal of Scientific Research. 2011;3(3):677-682.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/21513