Climate Smart agriculture with drought resistant tomato (*Solanum Lycopersicum*) cultivars under subtropical climate.

Abstract

Climate smart agriculture focus on crop production under climate stress. Climate change adaptation potential was investigated to study the effect of drought/water stress on different varieties of tomato plants. The stress levels were (T0), (T1), (T2) and (T3) of the field capacity. In the experiment, under stress no significant influence was observed in dry matter production of plants and increased soluble sugars and important acids and consequently improved the fruit quality. Water stresses also showed insignificant effect on height, yield and increased in BR-5, probably due to its tolerance to water stress.
Overall visual quality of the fruits showed that none of the stress- treated tomatoes deteriorated. No bruising and internal tissue damages in fruits were detected due to stress and fruits were red over 90%. Water stresses 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 citric acid, malic acid and ascorbic acid.

Key words: Climate change, Adaptation, Tomato, Drought stress, Yield, Fruit quality.

1. INTRODUCTION

Concept of climate smart agriculture focus on crop production under abiotic stresses. Agriculture is extremely sensitive to climate and weather conditions. Abiotic stresses are one of the major constraints to crop production and food security worldwide. Heat and drought are undoubtedly the two most important climate stresses having huge impact on growth and productivity of the crops. Several developing countries are at the risk of losing about 280 million tons of potential cereal production as a result of climate change factor, particularly increasing temperatures and prolonged dry periods [1].
. Crop yields and nutritional security are extremely dependent on the climatic conditions projected for the future, and consequently, most of the food produced for human consumption is under its menace, particularly in developing countries. Despite efforts to increase global food availability, a key requirement for food and nutrition security, the global burden of malnutrition and micronutrient deficiencies remains alarming and closely linked to climate changes, particularly in low-income communities [2][3]

Climate Change, is a multifactorial stress [4] will project to have significant impacts on the growth, yields, fruit quality, root development and other projection factors. In order to adequately adapt to these impacts, we must first model the impacts of projected Climate Change on various crop species in order to identify which varieties and treatments are most suitable for the projected climatic stressed conditions. in the last decades, plants

have experienced significant environmental fluctuations and these environmental changes are likely to worsen, and their frequency of occurrence is likely to increase in the upcoming decades Therefore, in the coming decades climate change will present a major challenge to agriculture, natural ecosystems, and global economies, for producing enough and nutritious food, which has been reflected in a sustainable intensification of agricultural systems [5] Without adaptation strategies, these changes will have a cumulative effect as time progresses [6] So adaptation to climate change is a major issue in the current food security discourse [7][8]
Drought due to climate change is expected to significantly increase by the end of this century ([9][10] [11]. So, Crop adaptation, switching to more drought-tolerant crop species or varieties, is an important adaptation strategy within a diverse portfolio of livelihood responses to climatic stress [12].

Vegetable crops play a vital role in human nutrition. People of low-income countries especially in the rural areas suffer from malnutrition because of imbalanced diet.
Tomato (*Solanum Lycopersicum*) is an herbaceous plant and a member of the solanaceae family is one of the most important and widely cultivated popular vegetable crop in the world and has the greatest area under cultivation compared to other vegetables [13] with an annual value exceeding 90 billion USD [14]. Of more than 100 species of vegetable crops selected for intensive study in representative Asian countries, tomato ranked first [15]. It is also a respectable source of some key nutrients such as vitamin A, vitamin C, sugar, ascorbic acid, some protein and iron.
In a subtropical country like Bangladesh, it occupies an area of about 10919 hectares with a total production of 81,005 tons. The average yield being only 7.42 tons per hectare which is very low as compared with that in other tropical countries of the world. Livelihoods of the country depending on agriculture are particularly vulnerable to changes in the mean and variability of climate, and due to the reduction of moisture levels in the soils, the growth of agriculture suffers. To this adds population problem which needs production of more food to feed for 180 million people within an area of 147570 square kilometers [16], and the need for crop adaptation strategies (changing to crop species or varieties that are resistant to climatic stress) is among the most cited adaptation measures [17][18].

Tomato is sensitive to a number of environmental stresses, especially extreme temperature, drought, salinity, inadequate moisture and environmental pollution, and there is a need to develop varieties that can withstand such environmental stresses [19].

Deficit irrigation is an agricultural water management strategy by which crops are exposed to a level of drought stress either during a certain period of time or during the entire growing season [20], deficit irrigation for tomato have shown mixed results in terms of fruit yield and quality. [21] found that drought stress resulted in a drastic reduction in dry mass yield, while other studies reported no adverse effects on yield and fruit quality for a field-grown processing cultivar [22][23]. [24] showed that tomato yield was mainly affected by drought stress that occurred throughout the course of fruit growth and maturation, but quality was sensitive to drought stress during the fruit ripening stage. To the best of our knowledge, to date only a limited number of experiments have studied the effect of deficit irrigation on fruit yield and qualitative characteristics at various species. Therefore, it is essential to understand the requirements for the timing of irrigation to meet the demand for tomato production.

Osmotic adjustment occurs in plants in response to drought as well in response to salinity and is currently the focus of much research interest. Solute accumulation caused due to drought [25] [26] leads to a lowering of osmotic potential during stress. Recovery and partial or complete maintenance of turgor under stress conditions are termed osmotic adjustment [27]. The organic molecules (glucose, fructose, sucrose, proline etc) act as osmotica and play an important role in osmotic adjustment [28] [29][30] [31] [32].

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.
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 cultivar out of four varieties commonly cultivated in Bangladesh, for climate change adaptation and also to evaluate fruit quality and sustain optimum yield with minimum use of water.

The overall goal of this study was to investigate the quantitative relationship among the cultivars. Specific objectives were to evaluate the effect of deficit irrigation/ water stress on growth, yield, and quality and to identify the drought resistant cultivars and quality traits.

2. MATERIALS AND METHOD

Field experiment was conducted to evaluate the height, yield, fruit quality, and osmotic adjustment of four tomato cultivars due to water stress, in Dhaka, Bangladesh, with 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 5700mm in the northeast [33].

2.1. Soil type, collection and the experimental crop

The textural class of the soil used in the experiment was loam, under Tejgaon series of Madhupur tract.
For physiochemical analysis of the soil, samples were collected at a depth of 0-6 inches from Tejgaon, Dhaka (Bangladesh Agriculture Research Institute), were air-dried, ground to pass through 2mm sieve and make a composite sample by mixing thoroughly. The test crops used in the field trial were four Tomato cultivars namely, BARI-1, BARI-2, BARI-4 and BARI-5

2.2. Physiochemical properties of the soil

Table 1: Physiochemical properties of the soil

Physical properties	Chemical properties
Texture: Loam; Sand:35.80%, Silt: 40.20%, Clay: 24.00%	pH: 5.1
Moisture at field:32%; Moisture at wilting: 10%,	EC: 90µS/cm
Maximum water holding capacity: 45%; Hygroscopic moisture: 1.73%	CEC:14.88 meq/100g soil
Porosity: 47%, Bulk density: 1.39g/cc, Particle density: 2.63g/cc	N%: 0.07%
Organic matter:1.1%	

2.3. Experimental design and preparation of land

The experiment was arranged in a completely randomized block design with three replications and four treatments. Size of the unit plot was 1m x1m, having 4 plants per plot, with spacing 75cm between plots, 50 cm between rows and 45cm between plants. Cow dung was used as organic fertilizer at the rate of 6t/ha at the time of final land preparation after harrowing and laddering. Chemical fertilizers, N, P_2O_5, K_2O were applied at the rate 260-200-150kg respectively. Half of the nitrogen and the whole amount of potash and phosphate were added at the time of final prepation of the land. The remaining half of the nitrogen fertilizer was added in two splits, one (25%) at 21 days after sowing the plant (vegetative stage) and remaining (25%) at flowering stage.

2.4. Sowing of seeds and transplantation

Seeds were sown and after 25 days of germination, seedlings of healthy and uniform size were transplanted in the experimental field. Plants had been shaded for 3/4 days, after transplantation to protect young seedling from sunlight. Three weeks after transplantation, each row of tomato plant was supported with bamboo stick to prevent the lodging. Weeding in the plots were done when needed and the insecticide was sprayed as and when required to protect the plant from insects.

2.5. Application of water stresses at different percent of field capacities.

From four weeks after transplantation, the stress period commenced with 4 levels of irrigation regimes. 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, to evaluate the effect of different moisture regimes on growth, yield, fruit quality and osmotic adjustment of different tomato cultivars. Every after one week of intervals the soil samples were collected for measuring the soil moisture percentages from the plots 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 evapotranspiration. By addition of water after seven days, the soil moisture levels were within the following ranges: 26-32% (T0), 22-27% (T1), 17-21 % (T2), 13-16% (T3) throughout the experimental period

2.6. Growth measurement of plants

Data were recorded on the plant height, dry matter and the fresh weight of the tomatoes. The ripening classes of the tomatoes were also observed and recorded. The data in the table are the average of three replications.

2.6.1. Harvesting, yield and biochemical analysis of Plants

a. Collection of tomato fruit: -

After the harvest of the ripened tomatoes time to time, fresh weight was recorded. The total fresh weight of the tomatoes was calculated by summing up the fresh weight of all the harvests. Visual quality and physical damage of tomatoes were determined according to the rating scale [34].
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 were frozen for other investigations. To evaluate the quality parameters of plant, enzymatic methods were used [35].

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

2.6.2. Biochemical analysis:

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

Preparation of sample:

Frozen tomatoes (3) 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 (Boehringer- Mannheim 1989). For the assay of ascorbic acid, fruit samples were well minced with an electric mixer and homogenized in metaphosphoric acid (15% w/v), pH was adjusted to 3.7 with KOH and ascorbic acid was determined by enzymatic methods

3. RESULTS AND DISCUSSION:

3.1. Water stress effect on shoot development of plants:

Data recorded on height and dry matter production of plants at the end of the experimental period.

Plant heights and dry matter production in different cultivars and at different stressed condition were present in tables 2 and 3.

3.1.1. Height of plants:

The result recorded on plants height indicated that among the four cultivars, the plants showed the following sequence: BARI-5 > BARI-2, BARI-1 > BARI-4. (Table 2).

Table-2: Plant heights in different cultivars.

Tomato cultivars	Plant Height (cm)
BARI-1	77.03b
BARI-2	83.15b
BARI-4	65.30c
BARI-5	88.40a

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

Table-3: Water stress effects on height of plants.

Treatments	Plant Height (cm)
(T0)	74.33a
(T1)	72.00a
(T2)	72.17a
(T3)	73.67a

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

The height of the plants ranged from 72.0 to 74.33 cm but statistically no significant difference was observed at T3, T2, T1 and T0 treatment. (Table 3) So the result revealed that water stress had statistically insignificant effect on plant height.

This result did not confirm the findings of reduced height due to water stress [36]
The height of the plants were not drastically declined due to stress as the quantity and quality of plant growth depend on cell division, enlargement and differentiation which are affected by water deficits but not necessarily to the same extent [37]. After a short period of stress when water becomes available, growth of plant is very rapid for a short time, so due to stress no net reduction in tomato occurs [38].

3.2. Dry matter production of plants:

The dry matter production of plants is presented in table 4-5.

Table-4: Production of Dry matter in different cultivars

Tomato cultivars	Dry matter g/m^2
BARI-1	298.7.0a
BARI-2	226.10b
BARI-4	331.90a
BARI-5	308.00a

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

Table-5: Water stress treatments effect on dry matter production of plants.

Treatments	Dry matter g/m^2
T0	288.88a
T1	269.90a
T2	275.07a
T3	310.75a

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

There is no significant differences among the cultivars in dry matter production, except BARI-2 (Table 4).
The result presented in table 5 shows the maximum dry matter yield was contributed at T3 treatment. But statistically insignificant results were found among the treatments (Table 5)

The result of reduced dry matter production due to water stress, is not in agreement with others [39] [40], but consistent with [41] [42], who noticed dry matter production was unaffected by the water stress treatments. The ability of the cultivars to produce dry matter under depleted soil moisture regimes might be due to the effect of osmotic adjustment [43] and the ability of the varieties to withstand at higher water stress condition.

3.3. Water stress effect on yield of tomatoes:

The yield parameters of tomato plants are presented in tables 6-7. The tomato varieties had different abilities to yield tomato plants.

Table-6: Yield of tomatoes in different cultivars of tomato plants

Tomato cultivars	Yield g/m^2
BARI-1	3535 b
BARI-2	3345 b
BARI-4	4114 b
BARI-5	5291 a

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

Table-7: Water stress treatments effects on yield of tomatoes.

Treatments	Yield g/m^2
T0	4221 a
T1	4169 a
T2	3970 a
T3	3924 a

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

The results mentioned in the table 6 clearly demonstrate that the yield difference among the cultivars there was no significant difference in yield except in BARI-5.

The highest yield was obtained from BARI-5, however the data presented in table 7 indicate that there was no significant difference in yield among the treatments. Which gave the lowest yield and different significantly from all other treatments.
In the experiment, highest yield was obtained in BARI-5. Yield was reduced due to stress but statistically no significant difference was observed (Table 7). Water stresses also showed statistically insignificant effect on height and dry matter production of plants.

This result is not agreeing with other researchers, who reported a change in moisture tension from 2 to 4 bars caused a significant reduction in the yield of tomato [44]; but consistent with others [45] [46] [47][48], those who noticed that there was insignificant yield under moisture stress conditions. Yield of tomatoes was found highest at soil moisture tension of 2 bar [49]. Considering the overall performance BR-2 and BR-5 contributed the best performance probably due to drought tolerance by virtue of their partitioning ability of assimilates toward fruit development. The accumulations of assimilates towards fruit development are glucose and fructose developing osmotic adjustment in the fruit production [50] [51].

3.4. Water stress effects on osmotic adjustment and quality parameters.

3.4.1. Concentrations of organic solutes and acids

Results among varieties and treatments are given in table 8 - 9

Table-8: Organic solutes in different cultivars

Tomato cultivars	Glucose (%)	Fructose (%)	Sucrose (%)	Ascorbic acid (%)	Malic acid (%)	Citric acid (%)
BARI-1	0.66b	0.93ab	1.11b	0.049a	0.32c	0.66a
BARI-2	0.92a	0.97a	1.84a	0.050a	0.36c	0.70a
BARI-4	0.80ab	0.91ab	1.29b	0.051a	0.50a	0.70a
BARI-5	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-9: **Water stress effects on organic solutes content in different cultivars**

Treatments	Glucose (%)	Fructose (%)	Sucrose (%)	Ascorbic acid (%)	Malic acid (%)	Citric acid (%)
T0	0.53c	0.79b	0.99b	0.028c	0.26d	0.42d
T1	0.67c	0.97a	1.84a	0.050a	0.36a	0.70a
T2	0.83b	0.93a	1.47ab	0.059b	0.47b	0.81b

T3	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

Concentration of Glucose:

The glucose concentration of fruits was found the highest in BARI-2 followed by BARI-4, BARI-5 and BARI-1 (Table 8). Among the cultivars concentration of glucose differed significantly but the content increased significantly with the increase in water stress (Table 9). There was about 100% increase in glucose contents at T3 compared with control (T0) treatment.

Concentration of Fructose:

Like glucose, fructose contents in tomato fruits were also highest at BARI-2 followed by BARI-1, BARI - 4 and the lowest at BARI -5 and affected by water stresses. The lowest concentration of fructose was observed at T0 (Table 9), which had about 30% lower fructose content than that of T3 treatment. There was no significant difference between BR-1 and BR-4 (Table 8). Also, no significant difference was observed at T1, T2, T3 but reduced at T0 (Table 9)

Concentration of sucrose:

Water stress increased the concentration of sucrose than glucose and fructose. The lowest concentration was measured at T0 treatment and the highest at T3. More than 72% increase in sucrose was notice at T3 compared with that on the control (T0). The concentration was highest in BARI-2, however there was no significant variation among the three varieties (Table 8 and 9).

Malic acid concentration:

The highest concentration of malic acid was noticed in BARI-4 followed by BARI-5. However, there was no significant differences was observed between BARI-2 and BARI-1 (Table 8). But the concentration is affected by water stresses. The highest concentration of malic acid was found at T3 and the lowest was measured at T0 treatment (Table 9). An increase of 100% malic acid concentration was observed at T3 compared with T0 treatment.

Ascorbic concentration:

In case of ascorbic acid, there was no significant different among the cultivars (Table 8). But the concentration increased with increasing stress.

The lowest amount was found at T0 treatment, while the highest was at T3 treatment (Table 9). Water stress significantly increased the mentioned acid contents to more than 175% at T3 compared with T0 treatment.

Citric acid concentration:

Citric acid concentrations showed that there was no significant difference among the cultivars, but the treatments differed significantly from each other (Table 8 and 9)

Like other acids, the lowest concentration was found at T0 treatment while the highest was at T3 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 8).

Discussion:

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Plants accumulate organic molecules such as glucose, fructose, sucrose, proline etc, which act as osmotica and play a vital role in osmotic adjustment at reduced water potential [52][53]. Therefore, a significant increase in organic solutes showed a tendency of the plants to adjust and survive under stressed condition

Osmotic adjustment is an important mechanism to adapt plants under water shortage/stress condition by increasing the solute concentration of cells in order to maintain the water potential gradients needed to ensure continued uptake of water during the stress period. Besides, osmotic adjustment allows cell to maintain the turgor, which is required for various important physiological functions and ultimately plant growth and development.

The contents of glucose, fructose, sucrose, ascorbic, malic and citric acid in tomato increased significantly in this experiment with water stress. This result agrees with the findings of [54] [55][56][57][58][59][60], who reported a significant increase in glucose, fructose, in some cases sucrose and acids contents in faba beans and tomato under water stress /salt stress and improving the quality fruits.

In this experiment the overall visual quality of the fruits was found excellent and essentially no symptoms of deterioration were noticed (Score 9 of Table 6.7; 34). No symptom of physical damage in any of the treatments could be detected (Score 1 of Table 6., 34). 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 34). in all treatments. Ripeness classes of tomatoes were red over 90%, classified as red scored 6 [34] table 6.5 in all treatments. Also the fruit quality studies showed that none of the stress treated tomatoes deteriorated in quality. On the other hand, water stress enhanced the sweetness by increasing their glucose, fructose, and sucrose contents and improved the quality of fruits by increasing the amount of important acids such as ascorbic acid, malic acid and citric acid.

4. CONCLUSIONS

It is believed that drought resistant cultivars have wide adaptation and internal physiological process during stress by producing solutes and acids.

The amount of published literature on water shortage/drought stress due to climate change and its impact on agriculture is increasing, but there is little effort to analyze and develop strategies to adapt small farm holders to climate change at a landscape level, particularly in developing countries. Adaptation research and practice often overlooks the wider context within which climate change is experienced. This study fills the gap and will serve as a valuable source of information for those who intend to conduct research or develop climate change adaptation strategies under drought stress for any crop cultivating in Bangladesh.

The results show how with minimum supply of water, the quality of fruits could be improved to consider as adaptive measure to cope up with climate change for future field trials

Finally we can conclude from the finding that BARI-5 considered as drought resistant cultivars among the other 4 entities.

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