

EFFECT OF MOISTURE STRESS AT DIFFERENT GROWTH STAGES OF TOMATO PLANT (*Lycopersicon esculentum* Mill.) ON YIELD AND QUALITY OF FRUITS

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ABSTRACT

There is a need to utilize the water efficiently and effectively because water availability is scarce in the dry zone of Sri Lanka. An experiment was conducted to determine the changes in fruit quality of tomato cv. KC-1 with moisture stress viz., determine the vitamin C, total soluble solids (TSS) and acid contents of tomato fruits during fruit ripening stage. Also, investigated in the present study was to find out the most critical stage/s of the plant growth to moisture stress in order to sustain the yield by efficient water management. Experiment was conducted at the agronomy farm of the Faculty of Agriculture, Eastern University, Sri Lanka. The experimental design was randomized complete block design with five treatments and four replications. Moisture stress was imposed during vegetative, flowering, early fruiting and fruit ripening stages of tomato for a period of four days in each growth stages. The control plants were watered daily to the field capacity. The stress cycle was single in which water was withheld completely at once. The result showed that moisture stress at fruit ripening stage reduced the vitamin C contents of fruits. The TSS and acid contents of the fruits were slightly affected by moisture stress when the stress was imposed during the fruit ripening stage but they were not significant. Vitamin C, TSS and acid contents of fruits were unaffected by moisture stress given during vegetative, flowering and early fruiting stages. Moisture stress reduced the yield of tomato and the stress during the flowering stage showed the highest yield reduction compared to the other growth stages. Hence, the flowering stage is the most critical stage of growth of tomato to moisture stress for the fruit yield.

Keywords: Tomato, Growth stages, Moisture stress, Fruit quality, Yield.

INTRODUCTION

Tomato is an important solanaceous vegetable crops of widespread and popularity. It is a rich source of health building substances particularly vitamins and minerals. Vitamin C, total soluble solids (TSS) and acid contents are commonly considered as fruit quality determining properties in tomato. Vitamin C is a principal nutrient of tomato fruit. Although the vitamins only account for a small proportion of the total dry matter of tomato fruit, they are highly significant from the nutritional point of view. Soluble solids include mainly the sugars such as glucose, fructose and sucrose. In tomato fruit, organic acid with sugars make a major contribution to the taste of the fruit. Most variation in flavour can be related to differences in the sugars and acids contents of the fruits. Although the cultivar has a dominant influence on the quality determinant properties, the environment in which it grows also has a significant impact on quality characters (Purseglove *et al.*, 1981).

Fruit quality mainly total soluble solids, vitamin C and acid contents are changed by moisture stress (Kozłowski, 1972). Moisture stress not only affects the quality of fruits but also inhibits crop yield in semi-arid and arid regions. The major constraint to expand tomato cultivation in the dry zone of Sri Lanka is the variety of environmental stresses such as drought and high temperature. These stresses constitute some of the most serious limitations to tomato growth, productivity and distribution. For high yield and good quality, the tomato needs a controlled supply of water throughout the growing period (FAO, 1996). The damaging effect of drought depends on its severity and also the development stage at which it occurs. The effects of water stress on the growth and yield of tomato vary with the stage of crop growth during which stress occurs (Sionit & Kramer, 1977).

Efficient water management in relation to critical periods of stress is essential to optimize yield with available moisture. There are many reports showing that water deficit limits yield while irrigation increases yield (Mahendran & Bandara, 2000). Present study was conducted with the objectives of determining the changes in the internal fruit quality of tomato with moisture stress and find out the effect of moisture stress on yield of tomato to determining the most critical stage/s of growth of tomato plant to moisture stress.

MATERIALS AND METHODS

A quantity of 10 g tomato seeds (cv. KC-1) was treated with 'Captan' solution (2 g l⁻¹). The seeds were then sown by row seeding to a depth of 0.5-1 cm. The seedlings

were managed in the nursery beds according to the recommended practices of the Department of Agriculture (Anon., 2005). This experiment was conducted in the agronomy farm of the Eastern University, Sri Lanka which is situated at 100 m above the mean sea level. The climate was warm (28° C - 32 ° C) with an annual rainfall ranging from 1800 mm to 2100 mm.

In the field (sandy regosol soil), 20 plots, each of 5m x 5m size were prepared. A distance of 1 m was maintained between the plots to minimize the seepage of water from one plot to the other during irrigation. Rain shelters were constructed to prevent the entry of rainwater into the experimental field during rainy days. In addition, drainage channels were constructed around each plot to minimize the percolation of water. Polyethylene sheets were inserted around each plot to a depth of 50 cm to prevent the run off of water during irrigation. The 25 days old vigorous and uniform seedlings were selected and transplanted on the main field at a spacing of 80 cm x 50 cm (Anon., 2005).

This experiment had five treatments (T₁- T₅) as follows:

- | | | |
|----------------|---|--|
| T ₁ | = | Control- Regular watering to Field Capacity |
| T ₂ | = | Moisture stress for 4 days during the vegetative stage |
| T ₃ | = | Moisture stress for 4 days during the flowering stage |
| T ₄ | = | Moisture stress for 4 days during the early fruiting stage |
| T ₅ | = | Moisture stress for 4 days during the fruit ripening stage |

The experimental design was a randomized complete block design (RCBD) with four replicates and all five treatments were randomly assigned to each block. The stress cycle was single in which water was withheld completely at once for a period of four days (Fig. 1). The experiment was managed in accordance with the recommended cultural practices (Anon., 2005).

Determination of vitamin C, Total Soluble Solids (TSS) and acid contents

Five fruits were randomly plucked from each replicate of all the treatments during the fruit ripening stage. These fruits were blended by a blender and the juice was extracted. The fruits were collected on the 5th day from the commencement of the stress and were analyzed for vitamin C, TSS and acid content by using standard methods of analysis (AOAC, 1998).

Regular watering (control)

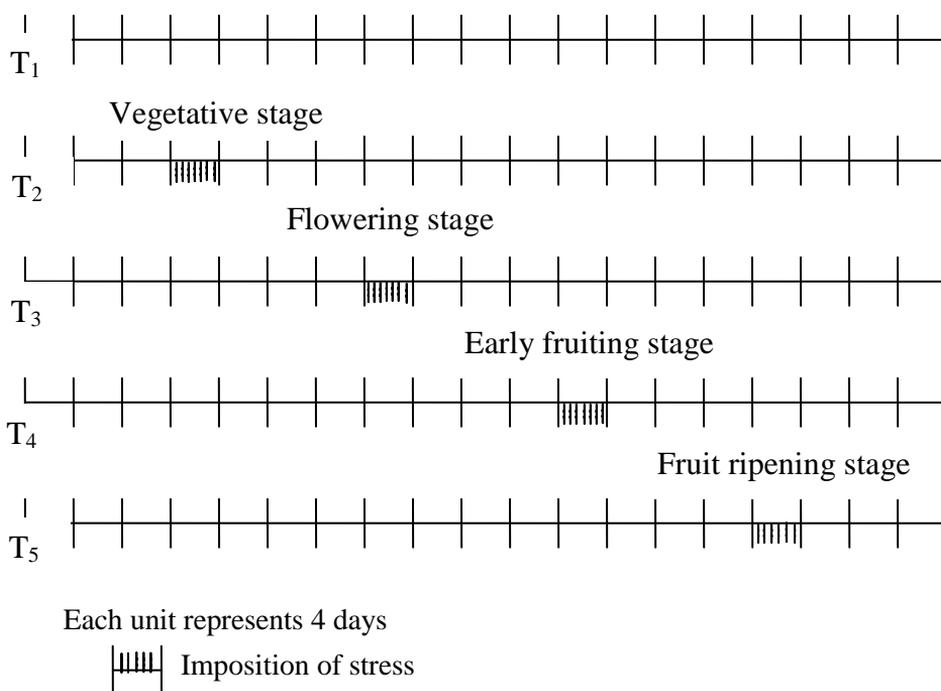


Figure 1: The diagrammatic representation of the manner in which moisture stress was imposed at different growth stages of tomato

Vitamin C: It was determined by oxidizing vitamin C in acid medium using 2, 6 – dichlorophenol indophenols dye to dehydroascorbic acid. For standardizing purpose, an amount of 0.01 g ascorbic acid was dissolved in 100 ml metaphosphoric acid and was titrated against 2, 6 - dichlorophenol indophenols dye until a faint pink colour persisted for a few seconds. An amount of 5 g juice was taken and volumerized to 100 ml using metaphosphoric acid. A quantity of 25 ml from the volumerized juice was taken into the conical flasks and was titrated against the dye until a pink colour persisted for a few seconds.

TSS: It was measured by a hand refractometer (model, ATAGO, S-28E). A drop of fruit juice was placed in the refractometer and the brix value was recorded by adjusting the eyepiece.

Acid content: An amount of 5 g juice was taken and volumerized to 100 ml by distilled water. A quantity of 25 ml from the volumerized sample was taken into a conical flask and a few drops of phenolphthalein indicator was added. This was titrated

against 0.1 N NaOH. The acid content of the fruit sample was calculated based on the volume of 0.1 N NaOH used for neutralizing the acid content in the sample.

Yield

Five plants were randomly selected from the middle area of each replicate of the treatments in order to eliminate boarder effects. The fruits from these plants were harvested manually in five pickings at two day intervals. These fruits were weighed and the yield was determined.

Analysis of data

The collected data were statistically analyzed using the analysis of variance (ANOVA) and the differences between treatments were compared by Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Vitamin C

There were significant differences ($p < 0.05$) between treatments in the vitamin C content of tomato fruits (Table 1). Moisture stress reduced the vitamin C content of tomato fruits when the stress was imposed during the fruit ripening stage. The average value of the vitamin C content of the control plants was $15.9 \text{ mg } 100 \text{ g}^{-1}$ while the vitamin C content of $8.9 \text{ mg } 100\text{g}^{-1}$ was observed when the stress was imposed during the fruit ripening stage. Atherton & Rudich (1986) repored that the vitamin C content of tomato fruits might range from 8-119 $\text{mg } 100 \text{ g}^{-1}$, which may vary among tomato cultivars and species. Purseglove *et al.* (1981) stated that, although the cultivar has a dominant influence on the quality determinant properties, the environment in which it grows also has a significant role in the quality characters.

Table 1: The effects of moisture stress on the vitamin C content of tomato fruits at different growth stages

Treatments	Vitamin C (mg 100g ⁻¹)
T ₁	15.9 ^a
T ₂	15.2 ^a
T ₃	15.2 ^a
T ₄	14.6 ^a
T ₅	8.9 ^b

Values in the same column followed by the same letter do not differ significantly (P<0.05).

Values are the means of 20 fruits in 4 replications.

Mahendran & Bandara (2000) reported that moisture stress reduced the vitamin C content of chilli fruits. The proposed route for vitamin C synthesis commences from D – glucose (Counsel & Horning, 1981). When plants experience moisture stress, stomata close followed by a decline in the CO₂ fixation. A reduction in the D – glucose synthesis would have occurred during the period of stress, which in turn may have reduced the synthesis of vitamin C. Moisture stress may have reduced the substrate concentration for vitamin C synthesis. Reduction in the substrate may possibly be due to reduced photosynthetic rate.

Another possibility of reduction in the vitamin C content is due to increased leaf temperature. The increase in leaf temperature may be due to lowering of transpirational cooling with the onset of stress. Vitamin C is very sensitive to changes in environmental conditions. It gets oxidized very rapidly when exposed to high temperatures (Davies *et al.*, 1991). The leaf temperature progressively builds up as a consequence of moisture stress and contributes towards the reduction of vitamin C (Mahendran & Bandara, 2000).

Non-significant differences in the vitamin C content of fruits when the stress was imposed during the vegetative (T₂), flowering (T₃) and early fruiting (T₄) stages indicated that moisture stress given during these stages did not have any effect on the vitamin C content of fruits.

TSS and Acidity

TSS and acid content are also quality characteristics of tomato fruits. It was found that there were no significant differences in the TSS and acid content of tomato fruits when the stress was imposed during the vegetative, flowering, early fruiting and fruit ripening stages of tomato (Table 2). A slight increase in the TSS and acid content was observed when the plants were subjected to moisture stress during the fruit ripening stage. The reason for the non-significant differences in the TSS and acid content of the fruits may be due to the short period (4 days only) of moisture stress experienced by these plants.

Table 2: The effects of moisture stress on the TSS and acid contents of tomato fruits at different growth stages

Treatments	TSS (% Brix)	Acid content (mg 100g⁻¹)
T ₁	5.5 ^a	0.77 ^a
T ₂	5.5 ^a	0.77 ^a
T ₃	5.5 ^a	0.77 ^a
T ₄	5.5 ^a	0.78 ^a
T ₅	6.0 ^a	0.81 ^a

Values in the same column followed by the same letter do not differ significantly (P<0.05).

Values are the means of 20 fruits in 4 replications.

From the present study, it could be pointed out that four days moisture stress did not alter the quality of the fruit with regard to taste and aroma. Sugar, acids and their interactions are important for sweetness, sourness and overall flavor intensity in tomatoes and they make a major contribution to the taste of the fruit (Atherton & Rudich, 1986).

Yield

It was observed that there were significant differences (P<0.05) between treatments in the yield of tomato (Fig. 2). Moisture stress reduced the yield of tomato. The yield reduction was highest when the stress was imposed during the flowering

stage. The plants stressed during the vegetative stage showed the next highest yield reduction. The plants, which underwent moisture stress during the early fruiting and fruit ripening stages also produced significantly lower yield than the control treatment. The amount of injury caused by water stress depends to a considerable extent on the stage of plant development at which it occur (Kramer, 1983).

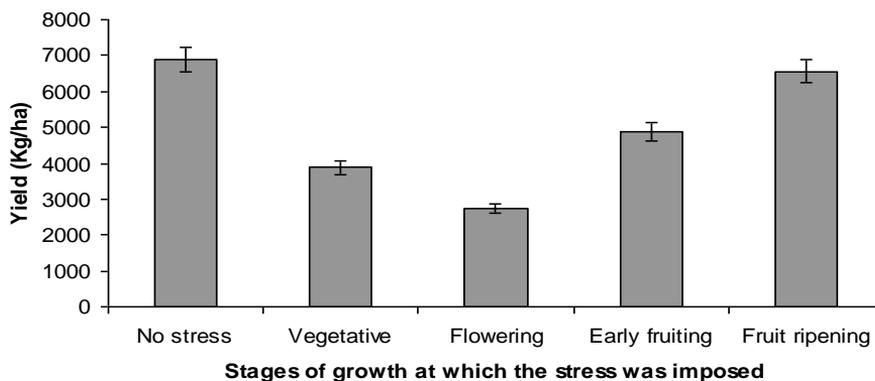


Figure 2: The effects of moisture stress at different growth stages on the yield of tomato cv. 'KC-1'

The final yield of the crop is the result of the combined effects of stress on growth, photosynthesis, respiration, metabolic processes, reproduction and other processes. Water deficit can reduce photosynthesis by decrease in chlorophyll content, reduction in leaf area, closure of stomata and decrease in the efficiency of carbon fixation. As stated by Ramadasan *et al.* (1993), chlorophyll content is positively correlated with growth and yield. Another possible reason for the reduction in yield is reduced nutrient uptake by crops during moisture stress.

The highest reduction in the yield of tomato when the plants experienced moisture stress during the flowering stage indicates that the flowering stage is the most critical stage of growth of tomato compared to the other growth stages. Salter & Goode (1967) demonstrated that yield was affected most adversely when water stress occurred during periods of internode elongation just before flowering and flower opening. During the flowering stage, most of the water is required for the development of reproductive organs. Growth of the flower and fruit involves rapid accumulation of dry matter and water (Kozłowski, 1972). Water deficit during this stage would have

reduced the number of flowers produced. There are ample evidences that even slight water deficit can reduce the rate of appearance of floral primordia.

Limitation of water at flowering stage not only reduces flower formation but also increases flower shedding. Mahendran & Bandara (2000) observed that when plants were exposed to moisture stress at the flowering stage, a severe drop in flowering occurred in chilli. Sionit & Kramer (1977) found that subjecting soybeans to water stress during flower induction shortened the flowering period and caused flower abortion. As stated by Kozlowski (1972), flowering stage largely determines the number of ripe fruits which will be produced. Reduction in flower number reduces the amount of final yield. Hence, moisture stress during the flowering stage may have resulted in the highest reduction in yield.

The plants which were exposed to moisture stress during the vegetative stage showed the next highest yield reduction. The yield reduction in the plants when treated at the vegetative stage was due to reduced development of leaves, twigs and branches. The reduction in the vegetative parts of these plants during the vegetative stage would have considerably affected leaf flower bud formation and development in tomato. The plants which experienced moisture stress during the vegetative stage were stunted, the leaves were severely wilted and showed wrinkled appearance. The leaf area was small compared to the control plants. The reduction in the leaf area may mainly be due to decreased turgidity of the cells and tissues. This appearance of the plants would have caused reduced photosynthetic rates in these leaves. As a result, low carbohydrate production would have occurred for the formation of fruits in these plants. Turner *et al.* (1978) gave ample examples of reduction in cell enlargement and vegetative growth caused by water stress. Thus, there is likely to be a serious reduction in the photosynthetic area of the stressed plants and the rates of photosynthesis per unit leaf area.

The yield reduction in the plants, when they experienced moisture stress during the early fruiting stage, would have been due to reduced fruit size and fruit number. The fruits of plants treated at this stage were smaller than those of the control. The reduction in the fruit number was due to dropping of immature fruits. During the period of fruit enlargement, considerable amounts of carbohydrates and water are transported to the fruits. Therefore, size of the fruit largely depends on this phase (Kozlowski, 1972). Fruit size is reduced by water stress mainly because of shorter fruit

growth period (Salter & Goode, 1967). Water stress can accelerate the abscission process, leading in some cases to premature dropping of fruits (Kozłowski, 1972).

CONCLUSIONS

The above study determined the extent to what moisture stress affected the quality of tomato fruits with regard to vitamin C content, total soluble solids and acidity. Immediate moisture stress reduced the vitamin C content of fruits and did not have any effect on the total soluble solids and acidity. Moisture stress imposed during the vegetative, flowering and early fruiting stages did not have any effect on the quality characteristics of the fruits.

Moisture stress during the flowering stage showed the highest yield reduction. Hence, it could be stated that this is the most critical stage of growth of tomato for moisture stress compared to the other growth stages. The timing of irrigation thus could be adjusted so that no moisture stress is experienced by tomato plants during the flowering stage in order to sustain the yield.

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