Effect of Simulated Temperature and Water Stress on Growth, Physiological and Yield Parameters of Tomato [*Lycopersicon esculentum* var: *Thilina*] Grown with Mulch

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Abstract

Understanding the effect of temperature stress on growth and yield of crops, and also identifying suitable management options to sustain the productivity under different changes in the natural environment are of timely importance. The main aim of this research is to compare the growth, yield and quality parameters of Tomato (*solanum lycopersicum*) variety Thilina grown with mulch when subjected to temperature and water stress if there is global warming. The plants were grown in pots under temperature-controlled poly tunnels. Main plot included two different irrigation applications (no water stress by irrigation to field capacity moisture level and, water stress by irrigating only up to the 50% of the available water capacity). Coir dust and saw dust were used as mulch and sub plots contained 3 different temperature regimes (34°C maximum temperature poly tunnel/32°C maximum temperature polytunnel/Open space-ambient temperature). The treatments were set up in a completely randomized design with 3 replicates. To make sure of the temperature replication, the trials were repeated 3 times. According to the results, there is significant effect of mulch on growth parameters of Tomato plants exposed to water and temperature stresses. Individual water stress showed a highly significant effect on growth, and yield parameters of Tomato. High yield reduction was shown in the high temperature (34°C) and water stressed plants. Mulching of saw dust and coir dust improved the yield even at 34 °C temperature treatment. Therefore, Tomato variety Thilina would not be a successful crop in open field condition due to temperature and water stress if there is global warming, but mulching will help to improve the situation.

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Introduction

Studies in Sri Lanka based on HadCM3 general circulation model have revealed that the temperature will increase in the coming years. It was also reported that in 2050, the highest temperature increase by 2°C is predicted in Anuradhapura compared to the baseline temperature during the period of 1961-1990 (De Silva *et al.*, 2007). Further, the rainfall during northeast monsoon is predicted to decrease in the dry zone area (De Silva *et al.*, 2007). Therefore, the decrease in rainfall and increase in temperature will increase the evapotranspiration and soil moisture deficits. Accordingly, agricultural activities in the dry zone may be affected by predicted climate change in Sri Lanka (De Silva *et al.*, 2007). A significant change in climate on a global scale will impact agriculture and consequently affect the world's food supply. Temperature stress is becoming the major concern for plant scientists worldwide due to the global warming as a result of climate change. The conservation of soil moisture may help in preventing the loss of water through evaporation from the soil facilitating maximum utilization of moisture by the plants. Mulching is a method by which soil moisture can be conserved (Sandal and Acharya, 1997). Moreover, mulching regulates the soil temperature and improves the soil physical properties.

Agricultural crops are affected by global warming due to the relationship between crop development, growth, yield, with atmospheric CO₂ concentration and climatic conditions. Temperature related extreme indices have increased over most locations in Sri Lanka. Annual average rainfall over Sri Lanka has been decreasing for the last 57 years at a rate of about 7 mm per year (Ranasinghe *et al.*, 2014). The coefficient of variation of rainfall distribution between 1931 and 1960 is greater during the Northeast monsoon and Second inter monsoon period (*Maha Season*) when compared to the period from 1961-1990. Southwest monsoon rainfall has not shown any significant change during these two periods. However, variability has decreased during 1961-1990 compared to 1931-1960 period (Ranasinghe *et al.*, 2014). When temperature exceeds the optimum for biological processes, crops often respond negatively with a steep drop in net growth and yield (Chynthia and Hillel, 1995). Some reports show that an increase in temperature by a single degree above normal can lead to a significant reduction in growth and yield (Pastori and Foyer, 2002).

Yield is positively related to the amount of incoming solar radiation intercepted by the plants in a long season crop. Termination of growth of small fruits is sometimes induced by high temperatures and high light conditions. Tomato is one of the major fruit vegetables in the world. In Sri Lanka it is annually cultivated more than 220 ha, producing approximated 3400 metric tons (Ranasinghe *et al.*, 2014). However, the average productivity of Tomato in Sri Lanka (2 metric ton/ha) is much lower than the world average, may be due to the seasonal weather changes which adversely affect the average productivity. Meantime, a shortage in the month of peak rain fall (May and November) and a production glut in the month of harvesting (March to May and September to October) lead to a dichotomy in the distribution of annual Tomato production.

Therefore, this research is focused on the evaluation of the effect of temperature and water stress on growth and yield of Tomato (*solanum lycopersicum*, var: Thilina) grown with the application of a mulch.

Methodology

The experiment was set up in the agricultural field poly tunnels of the Open University at Nawala.

Nursery management was initiated and the Tomato seedlings were transplanted into individual plastic pots (1 plant/ pot according to the Department of Agriculture recommendation for Tomato variety Thilina. The pots were filled with a compost and sandy loam soil mixture at the ratio of 1:1. Two mulching treatments namely coir dust and saw dust (mixture of timber species especially, teak and jak) were used. Un- mulched treatment was considered as control.

Two mulches were added for 5cm thickness until the surface of the compacted soil was within 1.5 cm of the rim. Initial height of the Tomato seedlings was 12 cm. These Tomato plants were grown at 3 different temperature conditions; 34°C and 32°C maximum air temperature in poly tunnels and ambient temperature in open space out side the poly tunnel. Poly tunnels were made with temperature regulation and ventilation fans. When the temperature is set at the poly tunnel for 34°C and if the temperature rose above that set temperature, the ventilation fans automatically start in operation until the temperature is brought down to the set temperature. Open space on the top of the poly tunnel facilitates the free air circulation.

A two factor factorial experiment was carried out in three replicates. Pots are arranged according to the complete randomized design (CRD), resulting in a total of 54 pot-grown plants. Temperature and mulches were taken as factors. Experiment was repeated thrice in order to fulfill the temperature replication instead of having three poly tunnels for each temperature. Physiological, morphological, yield and quality parameters of Tomato were investigated during the growing and reproductive periods. Analysis of variance (ANOVA) was performed using the statistical program Minitab (version 14, Minitab Inc.). Significant differences specified were all at ($p < 0.05$).

Growing conditions

In the management of Tomato plants, cultural practices recommended by the Department of Agriculture for fertilizing, weeding etc. were adopted except water management. A basal dressing was applied at the transplanting, and top dressing was applied at 3rd and 6th week after planting. Chemical controls of diseases were done by application of “C-CRON PROFENOFOS” 6th and 8th week after planting. Irrigation management was done according experimental designing. Every day the soil moisture of the pots was measured and the water was applied to the field capacity level for the no water stress treatments plants. Water stress treatment plants were watered with half the volume of the water applied for the no water stress treatment plants. However, water stress develops during the day due to evaporation and transpiration.

Water management

Field capacity (θ_{fc}) and permanent wilting point (θ_{pw}) were determined using the pressure plate method. Calculated field capacity and permanent wilting point moisture contents were 44% and 13% respectively. Above values were used in computing the percentage depletion of plant available water (PAW) for the water stress treatments. Treatments under water stress of 50% soil moisture deficit level (50% depletion of plant available water from the soil moisture at field capacity), the plants received irrigation only when PAW was depleted by 50% or more, i.e. below,

$$44 - [0.50 \times (44 - 13)] = 28.5 \text{ soil moisture}$$

All the no water stress treatment pots were watered up to field capacity level every day in the morning. However, the water stress develops during the day due to evaporation and transpiration.

Climatic data

All the climatic data such as rainfall, temperature and relative humidity were collected from Meteorological Department, Colombo. Air temperature inside the tunnel, temperature in the soil and mulch were measured using a digital thermometer with an electric sensor.

Crop physiological data collection

The leaf relative water content

The leaf relative water content was determined in the fully expanded top most leaf of the main shoot. The fresh weight of the sample leaves was recorded and the leaves were immersed in distilled water in a Petri dish. After 2 hrs, the leaves were removed, the surface water was blotted-off and the turgid weight was recorded. Samples were then dried in an oven at 70 °C to constant weight. Leaf relative water content was calculated using the following formula.

$$\text{LRWC (\%)} = [(F.W - D.W) / (T.W - D.W)] \times 100$$

Where: F.W. = Fresh weight; D.W. = Dry weight;

T.W. = Turgid weight.

Leaf chlorophyll content

SPAD-502 chlorophyll meter (Minolta Camera Co., Osaka, Japan), was used *in situ* to estimate chlorophyll content. The SPAD-502Plus performs quick measurements of the chlorophyll content of leaves without damaging the leaf. Three leaves were selected single plant to form one sample. The Whole healthy leaves were sampled randomly from the plant. The SPAD reading of each tomato leaf was obtained at three locations: (a) about one-third of the leaf length from the petiole, (b) at the midpoint of leaf, and (c) about one-third of the leaf length from the apex. At each location, a measurement was taken on both sides of the leaf vein. The six SPAD readings were averaged to provide a single reading per leaf.

Crop morphological data collection

Crop morphological data were collected on plant height, stem diameter, leaf area, branches, number of flowers per plant, and the number of leaves per plant on a regular basis. Plant height was measured from 30 days after transplanting (DAT) till 105 DAT on 15 days interval. To evaluate the effect of water stress on the

parameters of the plant, stem diameter was measured with calipers. The accuracy of the caliper was ± 0.02 mm « 100mm). Fruit diameter is also measured by caliper (in cm).

Crop Growth stages

Four growth stages were identified in this study for Tomato variety Thilina. Growth stage 1 is from the establishment to 1st flower stage of 15-30 days, Growth stage 2 is from first flower to first fruit set of about 30 days, Growth stage 3 is from Fruit ripening stage to first harvest of 30 days and the Growth stage 4 is from first harvest to the end of harvest of 30 days. Reading of every 15 days interval within each growing stage was calculated for analysis.

Results and Discussion

Temperature and water stress on growth parameters of Tomato

Plant height

The plant height varied due to different mulches and temperature at different growth stages irrespective of water stress condition. Mulching has contributed to the moisture conservation in water stress treatments. Therefore, there was no significant difference in the plant height between water stress and no water stress treatments. Figure 1 shows the plant height during fruit ripening stage and the mulching treatment has a significant effect on plant height compared to the no mulched treatments. Coir mulch in 34 °C maximum temperature treatment showed the superior performance in plant height than the control without mulched, indicating mulches had a positive effect on the growth and development of Tomato variety Thilina. The increased plant height in mulched plants may be possibly due to better availability of soil moisture and by reducing the effect of higher temperature.

The slope of the line in the interaction plot for the no mulch condition is steeper than others. It shows that the effect of mulching on plant height was significant ($p < 0.05$) in 32°C maximum temperature in fruit ripening stage.

NS = No water stress **WS** = 50% Water stress of FC **FC** = Field Capacity

Figure.1. Effect of temperature and water stress on average plant height during fruit ripening stage of Tomato variety Thilina grown with two types of mulches.

Leaf area

The mulches had a significant effect on the leaf area of the plant (Figure 3). The leaf area continually increased with plant age. All the mulches had the positive effect on generating and retaining higher leaf area per plant. The highest leaf area per plant was observed in saw dust mulch in no water stress treatment of (AT °C) ambient temperature. Plants grown in saw dust mulch showed the significantly highest leaf area in both ambient and 32 °C maximum temperature respective of water availability. Plants in control treatment showed the lowest leaf area in both temperature and water stress treatments. It showed that the mulching effect has a significant role in leaf area as the slope of the interaction plot is steeper in no mulch treatments (Figure 4). Favorable weather conditions and moisture of the soil are the important parameters affecting the leaf area of plant. It was reported (Barrs, 1968) that mulched Tomato plants had more leaf area and branches than that of plants without mulch, which supported the present results.

Figure.2. Interaction of mulch and temperature plot for plant height in 32 °C maximum temperature in fruit ripening stage.

Figure 3. Effect of temperature and water stress on average leaf area of Tomato variety Thilina grown with two types of mulches

Leaf chlorophyll content

Chlorophyll concentration has been known as an index for evaluating source strength thus, its decrease under drought stress can be regarded as a non-stomata limiting factor. There are research findings showing the decrease in chlorophyll under drought stress (Kulshreshta *et al.*, 1987). The effect of mulch on leaf chlorophyll content of plants during the fruit ripening stage of Tomato variety Thilina is presented in Figure 5. Results revealed that the plants in mulched treatments have more chlorophyll content than no mulched treatment plants. It is also revealed by the slope of the interaction plot of no mulch treatment (Figure 6) for the 32°C temperature during the fruit ripening stages ($p < 0.05$). Kirnak *et al.*, (2001) showed that the total chlorophyll content in high water stress was

reduced by 55% compared to the control which agrees with present results.

Figure 4. Interaction plot for mulch effect on leaf area (cm²) in 32°C maximum temperature in fruit ripening stage.

Figure 5. Effect of temperature and water stress on chlorophyll content (LCC) of Tomato variety Thilina grown in two types of mulches.

Figure.6. Interaction plot for leaf chlorophyll content in 32°C maximum temperature in fruit ripening stage of Tomato variety Thilina.

Relative Water Content (RWC)

Measurements of water content expressed on a tissue fresh or dry mass basis have been mostly replaced by measurements based on the maximum amount of water a tissue can hold. These measurements are referred to as Relative Water Content (Barrs, 1968). These results show that organic surface mulches can significantly improve the internal water status irrespective of temperature and water stress (Figure 7). No mulch treatments showed the lowest relative water content in all the treatments.

Figure 7. Effect of mulch on average relative water content

Temperature and water stress on yield parameters of Tomato

Fruit size

High temperatures, however, often result in smaller fruits (Newton and Sahraoui, 1999). Under ambient temperature with mulching condition in water stress and no water stress treatment (Figure 8a) the average fruit size was larger than the other temperature condition. In 32 °C temperature under no mulch condition with no water stress (Figure 8.b), the average size of the tomato fruit had become smaller. Under 34°C temperature with mulch condition and no water stress (Figure 8.c), the average size of the fruit was the smallest of all. Fruit growth and yield are, like most other developmental processes, primarily dependent on temperature.

Figure 8. Temperature and water stress on fruit size (a) ambient temperature with mulching (b) 32°C temperature under no mulch condition with no water stress (c) 34°C temperature with mulch condition and no water stress

Fruit weight

Fruit weight decreased with increase in temperature irrespective of water availability. Plants grown in an ambient temperature without a water stress showed the highest fruits weight (Figure 9). Fruit weight statistics showed that there is a significantly higher ($p < 0.05$) impact in outdoor ambient temperature compared to 32°C and 34°C temperature ranges inside the poly tunnel. High temperatures, however, often result in smaller fruits. But significant result fruit weight was shown in plants grown with saw dust mulching in all three temperatures. Even the interactive plot on the effect of mulching showed a remarkable effect on the fruit weight of Tomato compared to the other treatments (Figure 10). Sawdust mulch performed well in both water stressed and no water stressed

condition irrespective of temperature. However, fruit weight was lowest in 34°C treatments.

Plants grown in an ambient temperature without a water stress showed the highest fruits weight. Fruit weight statistics showed that there is significantly low fruit weight ($p < 0.05$) at 34°C temperature.

Figure 9. Effect of temperature and water stress on average fruit weight during fruit ripening stage of Tomato variety Thilina grown with two types of mulch.

Figure 10. Interaction plot for fruit weight in 34°C maximum temperature in Fruit ripening stage.

Fruit yield

Figure 11 showed that the highest mean yield (1.752 kg/plant) in plant grown in outdoor ambient temperature without water stress and saw dust mulching condition, followed by outdoor grown plant with a imposed water stress and without mulch, showed the lowest mean yield (1.175 kg/plant). The vegetative growth is higher in the controlled environment condition, at 32°C temperature; the yield was reduced from 1.560 kg/plant to 0.215 kg/plant with water stresses and without mulching condition. Further, the yield obtained at 34°C temperature was 0.653 kg/plant and with imposed water stress and without mulch it was further reduced to (0.110 kg/plant). But in the previous research, without mulching only 0.16 kg/plant yield was obtained at 34°C with no water stress (Gunawardena *et al.*, 2011). This study proves that the yield (0.653 kg/plant to 0.570 kg/plant) can be improved with mulching even when the temperature increased up to 34°C due global warming if the plants are maintained with no water stress.

Figure 11. Effect of temperature and water stress on average fruit yield during fruit ripening stage of Tomato variety Thilina grown with two types of mulches.

Conclusion

Conclusions and Recommendations

According to the results, there is a significant effect of mulch on growth parameters of Tomato plants exposed to water and temperature stresses. Higher temperature treatments with saw dust mulch showed significantly higher plant height. Higher leaf area was shown on 32°C with no water stress condition. The water stress

resulted in significant decreases in chlorophyll content and the leaf relative water content. High temperature stress of 32-34°C could be minimized by using mulches such as saw dust and coir dust. There were significant good growth parameters under saw dust mulch in maximum temperature of 32°C and under coir mulch in 34°C maximum temperature. Agronomic management practices like mulching will help the crop to adjust to the temperature stress due to global warming in the dry zone of Sri Lanka.

There is a significant effect of water and temperature on yield parameters such as fruit weight, fruit yield etc. According to the results, there is little difference between the water stress and no water stress treatment as the mulching has resisted the effect of temperature by conserving moisture in the soil. Therefore, the yield per plant has improved with coir dust mulch compared to the previous study without mulch at 34°C maximum temperature. This study showed that Tomato variety Thilina will not be a successful crop in open field conditions if the temperature rises above 34°C due to global warming. Therefore Tomato variety Thilina could be cultivated in green houses by providing optimum temperature. However, small scale farmers may be able to cultivate Tomato in open field with mulches such as saw dust and coir dust. These findings could be an adaptation measure for farmers growing tomato if the temperature increases due to global warming.

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