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IMPACT OF TEMPERATURE AND WATER STRESS DUE TO GLOBAL WARMING ON GROWTH AND YIELD OF TOMATO (*Lycopersicon esculentum*)

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INTRODUCTION

Temperature and soil moisture are significant factors in determining plant growth and productivity (Chapin *et al.*,1987). In the context of present discussions on global climatic change, agriculture is expected to be very sensitive to global climatic change (Adams *et al.*, 1990). Scientists predict that the climatic factors such as temperature, soil moisture and atmospheric CO_2 concentration will vary from present day averages in decades to come. Unprecedented rise in environmental temperature in the next few decades is expected to introduce and disseminate many serious infectious diseases among humans (Patz *et al.*, 1996) as well as crops (Arnell, 1999). Therefore any changes in the climatic factors can bring major shifts in the world's food production. Tomato is an important vegetable crop grown throughout the year in both *Maha* and *Yala* seasons in the dry zone of Sri Lanka. Tomato is widely cultivated by a considerable portion of farming communities in all agro-ecological zones of Sri Lanka. Therefore it is important to study the effects of global warming, especially the effects of temperature and water stress on the growth and yield of these vegetables. Studies in Sri Lanka based on HadCM3 general circulation model has revealed that the temperature will increase in coming years and in 2050s the highest temperature increase by 2^0C is predicted in Anuradhapura compared to the baseline temperature of 1961-1990 (De Silva et al 2007). Therefore this research aimed to determine the effect of high temperature and water stress on growth, yield and quality parameters (Physical and Biochemical) of tomato (*Lycopersicon esculentum*) variety Rajitha.

METHODOLOGY

This study was conducted during the period from September 2009 to August 2010, an experiment was set up in temperature regulated poly tunnels constructed in the Agricultural field of the Open University of Sri Lanka, Nawala, Nugegoda. Experimental design is Randomized Complete Block Design (RCBD) with three temperature regimes, two water management condition and 10 replicates resulting in a total of 160 pot-grown plants. Upper limit of the temperature was maintained at the maximum day time temperature in Anuradhapura (32^0C) and 1998 – 2008 Monthly variations considered for the temperature regulation (Meteorological Department) in one poly tunnel. Upper temperature limit was maintained at 2 ^{0}C higher than day time maximum temperature of Anuradhapura (34^0C) in the second poly tunnel. Open space experiment was conducted as a control experiment at the Colombo ambient temperature. The plants were grown in pots and half of the samples were subjected to water stress (50% from field capacity) and rest of sample kept at field capacity level of soil moisture. Physiological parameters of plants and fruits were measured and data were subjected to an analysis of variance (ANOVA), and the mean differences were compared by least significant difference (LSD) test at probability level of $P< 0.05$.

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Table 1. Growth and Yield Parameters of Tomato

Treatment	Transplant success	Plant Height (cm)		Leaf Number		No of flower DAP			Moisture	weight	fruit /	yield	Soluble	P^H	Fruit	Fruit
	% 3WAP	3 WAP	6 WAP	3 WAP	6 WAP	90	100	110	%	(g/fruits)	plant	kg/plant	Solid (0Brix)		Shape	Cracks
Ambient tem. No water stress	90.60	18.69	46.83	17.00	32.00	90.60	18.69	46.8	42.00	40.62	37.00	1.56	4.5	4.6	0.94	NS*
Ambient tem. 50% water stress	77.80	17.63	51.43	16.00	28.00	77.80	17.63	51.4	28.00	28.16	35.00	0.99	5.2	4.5	0.67	NS
32^{0}C max. tem No water stress	93.34	18.11	57.87	26.00	44.00	93.34	18.11	57.9	62.00	19.67	13.00	0.26	6.8	4.3	0.58	NS
32^{0}C max tem 50% water stress	72.60	16.25	40.56	19.00	26.00	72.60	16.25	40.6	31.00	13.16	9.00	0.12	8.3	4.1	NS	0.54
34 ^{0}C max tem No Water stress	91.80	19.12	52.68	34.00	41.00	91.80	19.12	52.7	61.00	4.36	6.00	0.26	10.6	4.2	NS	0.65
34^{0}C max temp 50% Water stress	70.10	16.89	38.94	14.00	28.00	70.10	16.89	38.9	26.00	3.98	5.00	0.19	12.8	3.8	NS	0.76
50% water stress	73.5 a	16.92	43.64	16.33	27.33	73.5 a	16.92	43.6	28.33 a	15.10	16.33	0.43	7.6	4.2		
without Water stress	91.91 b	18.64	52.46	25.67	39.00	91.9 b	18.64	52.5	55 b	21.55	18.67	0.69	7.6	4.0		
Ambient Tem	84.20	18.16	49.13	16.50	30.00	84.20	18.16	49.1	35.00	34.39	36 a	1.273 a	8.76 a	4.1		
30 -32^{0}C	82.97	17.18	49.22	22.50	35.00	82.97	17.18	49.3	46.50	16.42	11 b	0.188 b	7.3 a	4.4		
32 - 34^{0}C	80.95	18.01	45.81	24.00	34.50	80.95	18.01	45.8	43.50	4.17	5.5 b	0.225 b	4.85 b	4.6		
	Transplant success	Plant Height (cm)		Leaf Number		No of flower DAP			Moisture	weight	fruit /	yield	Soluble	P^H	Fruit	Fruit
	% 3WAP	3 WAP	6 WAP	3 WAP	6 WAP	90	100	110	%	(g/fruits)	plant	kg/plant	Solid (0Brix)		Shape	Cracks
Water stress effect	77.8 b	17.63	51.43 b	16 b	28 b	77.8 b	17.63	51.4 b	28 b	28.156 a	35 a	0.986 a	5.2 a	4.5 b	0.67	NS
Temperature stresss effect	91.8 a	19.12	52.68 b	34 a	41 a	91.8 a	19.12	52.7 b	61 a	4.36 b	6 b	0.26 b	10.6 b	4.2 b	NS	0.65
Interctive effect stresses	70.1 b	16.89	38.94 a	14 b	28 b	70.1 b	16.89	38.9 a	26 b	3.98 b	5 b	0.19 b	12.6 b	3.8 a	NS	0.76

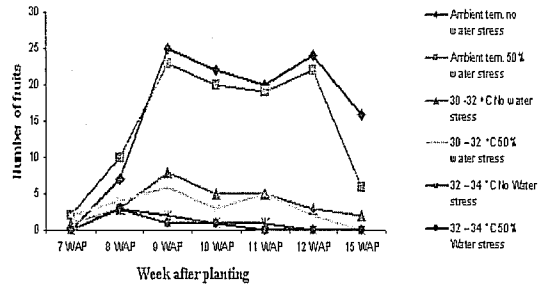

Figure 1. Number of fruits harvested in different stress treatment

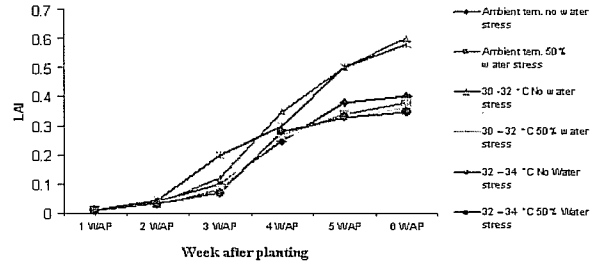

Figure2. Variations of leaf area index of tomato under stress conditions

RESULTS AND DISCUSSION

The highest transplant success (93%) was reported in 32^{0}C maximum temperature maintained poly tunnel with no water stress treatment. However, the transplant success showed a significant decline with imposed water stress while the combination of water and temperature stresses resulted in the lowest transplant success due to enhancement of the plant stress. A similar trend could be observed with respect to plant height and leaf number.

The effect of water stress condition on leaf number and leaf area index (LAI) (Figure 2) was significant through the vegetative phase (p>=0.05). Significantly higher LAI (during 3WAP) and leaf number were seen in 34 ^{0}C maximum temperature poly tunnel with no water stress treatment. At the 6WAP 34 ^{0}C maximum temperature poly tunnel with no water stress treatment and 32^{0}C maximum temperature maintained poly tunnel with no water stress treatment were shown significant high value (p>=0.05) of LAI than the other treatment plants (Figure 1). Although there is no water stress in ambient temperature in outdoor it was shown low LAI due to outdoor environment barriers. Similarly, Weerakkody and Peries (1996) explained the suppression of leaf growth due to dry weather and that can be reduced by the indoor culture and improved technology.

Table 1 illustrates the number of flowers formed 90, 100, and 110 days after planting. Early flowering was observed in the highest temperature poly tunnel treatment which agrees with a similar study of Weerakkody and Peries (1996) where early flowering of tomato in the indoor culture was a result of the vigorous vegetative growth of the plants. Although there was early flowering, there was no significant variation (p>=0.05) of number of flower/plant among the treatments.

Plants grown in an ambient temperature outdoor condition without water stress showed the highest yield. This outdoor environment gave the highest fruit yield was the significant (p>=0.05) number during the entire fruit development (Figure 1).

Results showed that the highest mean yield obtained (1.56kg/ plant) in plant grown in ambient temperature with no water stress treatment and the second highest yield obtained in ambient temperature with water stress (0.9 kg/plant) treatment. The potential yield of tomato with the application of recommended chemical fertilizer is 20 to 30 t/ha (Department of Agriculture Techno-guide). Therefore, the above yield of tomato in ambient temperature with no water stress is in the potential yield range of tomato. Although the vegetative growth is higher in the controlled environment condition, at 32^{0}C temperature, the yield was low (0.256kg/plant) and with water stress it was further reduced to 0.12kg/plant. Meanwhile the yield obtained at 34^{0}C maximum temperature poly tunnel was 0.26kg/plant and with imposed water stress it was further reduced to 0.19kg/plant. There was no significant difference of flowering among the treatments. But yield statistics showed that there is significantly higher (p = 0.05) yield in outdoor ambient temperature compared to 32^{0}C and 340C maximum temperature poly tunnels. The lowest yield was received in the high temperature chamber irrespective of the level of water stress. Etanpressman *et al.* (2002) demonstrated that continuous exposure of tomato 'Trust' to high temperatures markedly reduced the number of pollen grains per flower and decreased viability. The effect of heat stress on pollen viability was associated with alterations in carbohydrate metabolism in various parts of the anther during its development.

The maximum temperature, i.e. 34^{0}C with water stress produced the smallest fruits. Fruit grew heavier in plants grown with adequate soil moisture during stages of vegetative growth and fruit setting. Similarly Molla Md.et.al (2003) showed that the water stress throughout the growing season significantly reduced yield and fruit size.

Fruits of the no water stress condition were more round in shape than those in water stressed condition. Among different treatments tested, concentric fruit cracks were observed in all treatments except ambient temperature with no water stress. It was significantly higher ($p= 0.05$) at 34 ^{0} C maximum temperature in poly tunnel for both water stress and no water stress condition. Diurnal temperature difference and relative humidity influence the fruit cracking (Patz, 1996). Therefore fluctuation of soil temperature could be the primary reason for differences in fruit cracking.

Both treatment at 34^{0}C poly tunnel was showed significant effect ($p>0.05$) on the soluble solids (0 Brix) of tomato fruit (Table 1). But soluble solids were 20.7% greater under 50% water stress fruits in high temperature poly tunnels. Water stress and high temperature combinations had significant effect ($p>0.05$) on pH and acidity of fruits during this study.

CONCLUSIONS/RECOMMENDATIONS

Temperature stress and water stress of the tomato reduced the fruit number although there was no significant reduction of flowering. Higher temperature conditions lead to the high vegetative growth but do not support the reproductive growth (fruit production). Combine stressed conditions (temperature and water) lead to improve the taste of the tomato but appearance and size were not good for marketing.

The experiment revealed that the selected tomato cultivar was unable to produce marketable good yield with the combined stresses of temperature and water. Therefore Tomato will not be profitable to cultivate in farmer's field if there is both temperature and water stress. This study might serve to select suitable crop to cultivate as an adaptation measure for global warming.

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