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Short communication

Impact of Temperature and Water Stress on Growth Yield and Related Biochemical Parameters of Okra

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ABSTARCT. *The main aim of this research is to compare the physical and biochemical parameters of okra when subjected to heat and water stress and to determine how heat shock or water deficit, either individually or in combination, affect the growth and yield of okra species. Experiments were conducted in three growing seasons in the low country wet zone as a replicated trial. The plants were grown in pots under temperature-controlled polytunnels. Main plot included two different wetting applications (no water stress, 50 % water stress from the field capacity) and sub plots contained 3 different temperature regimes (34 °C maximum temperature polytunnel / 32 °C maximum temperature polytunnel / ambient temperature). Individual water stress showed highly significant effect on growth, and yield parameters of okra. High yield reduction was shown in the water stressed plants. Further temperature stress has especially affected the pod quality parameters such as fibre and pectin content. Harvesting time of okra under ambient temperature was not suitable for the high temperature conditions due to rapid pod growth rate and break down of the calcium pectate, 5 to 6 days after full blooming. Results indicated that okra has high yield when it is grown under high temperature environment with no water stress. Therefore by maintaining irrigation at field capacity level even at high temperature stress conditions, it is possible to achieve a good yield by harvesting okra pods 5 to 6 days after full blooming without significant yield reduction.*

Keyword: *Water deficit, wetting temperature, pectin, environment*

INTRODUCTION

Studies in Sri Lanka based on HadCM3 general circulation model has revealed that the temperature will increase in the coming years and in 2050s the highest temperature increase by 2^0 C is predicted in Anuradhapura compared to the baseline temperature during the period of 1961-1990. Further the rainfall during northeast monsoon is predicted to decrease in the dry zone area. 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). Hence, this research is aimed to determine the effect of high temperature and water stress on growth, yield and quality parameters (physical and biochemical) of okra variety Haritha.

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MATERIALS AND METHODS

The study was conducted at the Open University of Sri Lanka, Nawala, Nugegoda from September 2009 to April 2011 for three consecutive seasons. Recommended okra cultivar Haritha was planted in pots filled with reddish brown soil. Two temperature regulated polytunnel houses were constructed in order to maintain the stipulated temperature conditions by means of a thermostat and air circulation fans. One of the polytunnels was maintained at 32 °C (maximum) while the other one was maintained at 34 °C. When the temperature increases above the respective maximum temperature (set point), the fans automatically start to operate and keep on operating until the temperature comes down to the set point of that particular polytunnel. Each polytunnel was separated into two to represent the temperature replication.

The trial was laid out as a split plot experiment based on complete randomized design (CRD) with ten replicates for the main plot treatment. Main plot included two different soil moisture conditions such as field capacity (no water stress) and 50 % of the field capacity level (with imposed water stress) and sub plots contained 3 different temperature regimes such as 34 ºC maximum temperature, 32 °C maximum temperature and ambient temperature. Soil moisture regimes were maintained using tensiometers. Plant growth parameters of okra were investigated during the vegetative and reproductive periods. Chemical parameters like soluble solid, calcium pectate (Rangnna, 1976) and fibre (Gould, 1977) were analyzed in the laboratory. All extraction runs and analyses were carried out at least in duplicate and in randomized order with the mean values being reported. Analysis of variance (ANOVA) of the results was performed using general linear model procedure of SPSS (Software Version 19). Multiple comparison of the various means were carried out by LSD (Least Significant Difference) test at probability levels of 5 % and 1 % ($p= 0.05$ and $p= 0.01$).

RESULTS AND DISCUSSION

Temperature and water stress on physiological parameters of okra

Availability of water was statistically significant ($p <0.01$) for the germination of okra seeds irrespective of the temperature (Table 1). The seedling emerging rate was significantly reduced by water stress in all temperature regimes at two weeks after seeding. In addition, effect of temperature stress has a significant influence on the germination (at $p=0.05$). However, an interaction effect for seed germination was not statistically significant. Individual effects of both water stress and temperature stress had significant adverse effects ($p < 0.01$) on plant height together with a combination (at $p = 0.05$). Higher temperature leads to an increase in plant height due to elongation of internodes.

The okra variety Haritha started to flower 34 days after sowing. The number of flowers/plant was counted up to 3 weeks from the first flowering. The highest number of flowers was observed at 34 ºC temperature without water stress condition. There was no significant treatment interaction with respect to number of flowers. But the individual effect on both water and temperature stress has significant influence on flowering. It is interesting to note that water stress has a negative influence on flowering while temperature stress has a positive influence.

The diameter of the pods rapidly increased until 9 days after full blooming. Then the rate of increase gradually decreased before reaching a plateau. When plants were exposed to 34 ºC maximum temperature and no water stress the diameter of the pods had rapid growth and reached the maximum. Both individual stress as well as interactive stress had a highly significant influence ($p<0.01$) on the pod diameter (Fig. 1).

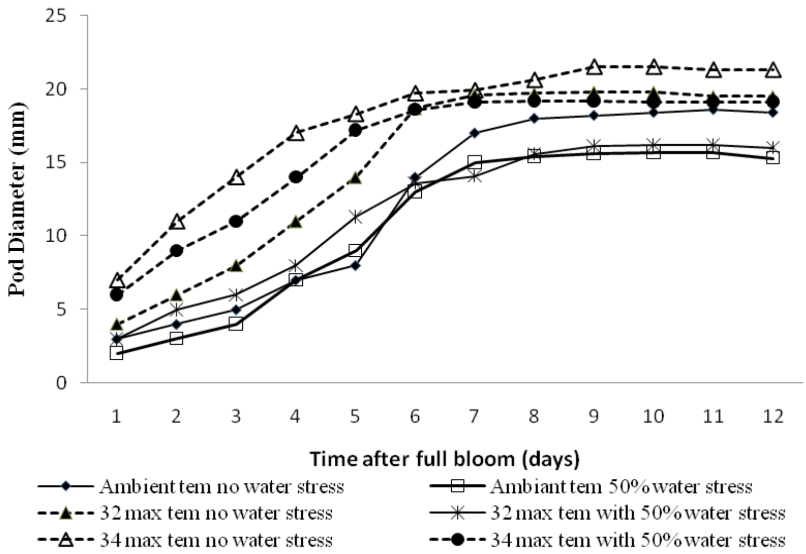

Fig. 2. Effect of treatments on temporal variation of pod diameter

The treatments are highly significant on the fresh weight of okra pods under both stresses as well as in the interactive stress condition ($p<0.01$). In case of dry matter of the fruit, the maximum weight was observed at the 34 ºC temperature under no water stress condition. Even the combined effect of high temperature and water stress had a substantial effect on the fruit weight of okra compared to the other treatments. Water stress in combination with temperature stress had less negative effects on growth parameters compared to other water stress treatments. Even at high temperature stress (34 ºC maximum temperature) if the plants are maintained without any water stress (at field capacity soil water condition), it significantly enhanced the weight of the pod.

Temporal variation of fresh weight represents a sigmoid shaped curve. Rapid growth was shown in early days after full bloom and the maximum growth rate was achieved at 34 ºC with no water stress and the lowest pod weight was found in water stressed treatments at 32 ºC temperature. The plants grown in 34 ºC with water stress condition also showed higher pod weight compared to the other treatments.

According to Table 1, water stress condition significantly ($p<0.01$) affected the number of fruits/plant. Further, the highest temperature stress with adequate soil moisture at field capacity level has significantly increased the number of fruits/plant compared to the other treatments ($p<0.01$). Highest number of fruits/plant was found in high temperature (34 ºC) without water stress condition followed by 32 ºC temperature without water stress condition. The number of fruits/plant was the lowest when okra was subjected to water stress condition. However, it is interesting to note that even at the highest temperature and water stress condition, the number of fruits/plant were higher compared to other treatments. It shows that the combination effect of temperature and water has less negative effect on number of fruits/ plant in okra when compared to individual water stress treatments.

Table 1. Variations of plant physiological characters of okra under stress condition

Treatments	Germination (%)	Flowers/ plant	Plant height (cm)	Pods/ plant	Fruit diameter (mm)	Fresh pod weight	Length (cm)
Ambient Tem. No water stress	82	7	65.75	6	14.4	20.34	17.02
Ambient Tem. 50% water stress	55	5	42	4	13.8	15.89	13.93
32 ºC Max. Tem. No water stress	89	7	68.25	6	18.8	22.13	17.75
32 ºC Max. Tem. 50% water stress	76	5	42.4	3	13.7	12.23	11.72
34 ºC Max. Tem. No water stress	92	8	136.6	7	19.7	25.32	18.72
34 ºC Max. Tem. 50% water stress	53	5	102.1	5	18.6	18.47	14.46
MS of Main plot trt (WS)	2403.55**	23.12**	3536.405**	25.56**	22.15**	224.55**	89.6**
MS of Sub plot trt (TS)	246.22*	3.06**	8388.27**	2.56**	38.46**	37.4*	5.23**
MS of interaction WS*TS	53.55	0.9	48.69*	0.78**	9.11**	11.18**	3.29**

** significant different at 0.01 probability level; * significant different at 0.05 probability level MS – mean square

Biochemical parameters of okra

Soluble solids of the okra pericarp slowly increased and reached a maximum on the 7th day under 32 ºC temperature treatment and on the 6th day under 34 ºC temperature treatment. But under the ambient temperature, soluble solids reached the maximum on the 8th day and then decreased steadily (Fig. 2).

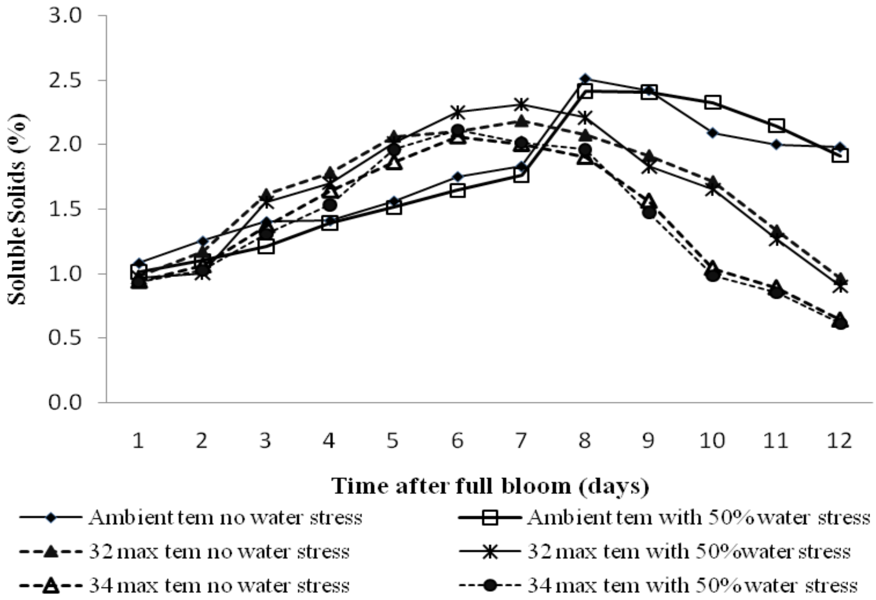

Fig. 2. Effect of treatments on temporal variation of soluble solid concentration

Temperature stress enhances the okra pods to reach the maximum soluble solids level compared to the ambient temperature conditions. The slow increase of soluble solids in the pericarp during the early development may be due to the presence of chlorophyll in the pericarp which has a capacity for photosynthesis (Crafts & Crisp, 1971; Singh and Pandey, 1980).

Fibre content of the pericarp steadily increased during the development of pod after full bloom (Fig. 3). Similarly, Ketsa and Chutichudet (1994) showed that fibre content of the pericarp steadily increased during development of the pod.

Higher temperature treatments have enhanced higher fibre content in the pericarp compared to the ambient temperature treatments. The toughness of the okra pod is caused by the development of fibre in the pericarp which steadily increases after full bloom.

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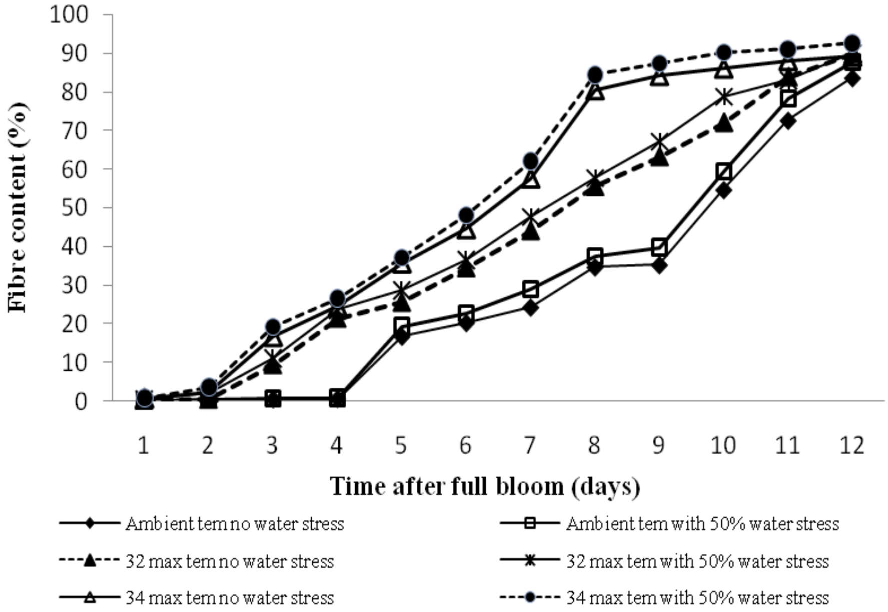

Fig. 3. Temporal variation of fibre content of the pod days after full blooming

Fig. 4 shows the temporal variation of calcium pectate content of the okra pericarp under different temperature stress treatments without any water stress. It was very high at early stage of the pod development and then rapidly decreased after full bloom. This showed a continuous decrease of calcium pectate in the pericarp, which may be due to loss of calcium pectate from cell walls by the action of pectinesterase (Leopold, 1964). The activity of pectinesterase has a greater influence on the calcium pectate content, as the pods mature. However, the decrease in calcium pectate varies with different temperature and water stress treatments. Accordingly the decreasing rate is slower in higher temperature stress treatments than the ambient temperature treatments.

The decrease in the calcium pectate and increase in fibre content in the pericarp as the pod matures results in less crispness of the pod. According to the fibre content, calcium pectate and weight gain, it is possible to establish the optimum time for harvesting of okra pods. Dry zone farmers usually harvest around 7 to 8 day after full blooming. Similarly, Culpepper and Moon (1941) observed that the edible quality of okra increased up to 6th day after pollination and then declined, so that 10 day-old pods were unsuitable for consumption. Singh *et al.* (1974) recommended harvesting okra 6 days after pod set so as to ensure good quality.

The results of the this study indicate that the optimum time for harvesting okra pods growing under ambient temperature is 7-8 day after full blooming. When there is a temperature stress such as 32 ºC and 34 ºC, okra pods could be harvested at 5 and 6 days after full bloom respectively, provided that the plants are grown under no water stress conditions. This study has showed even the pods were harvested earlier than normal 7-8 days after full bloom, the yield was 27% higher with compared to the pods grown under ambient temperature. This may be due to the vigorous growth and development which take place during high temperatures conditions. As the global warming may not be mitigated, adaptation by careful planning of okra cultivation with adequate water supply (at field capacity) will increase the yield irrespective of the stress due to high temperature. Further, the okra pods will be 2-3 inches in size which could be suitable to avoid postharvest losses on transport. This study reveals a valuable adaptation measure for cultivating okra under global warming situations**.**

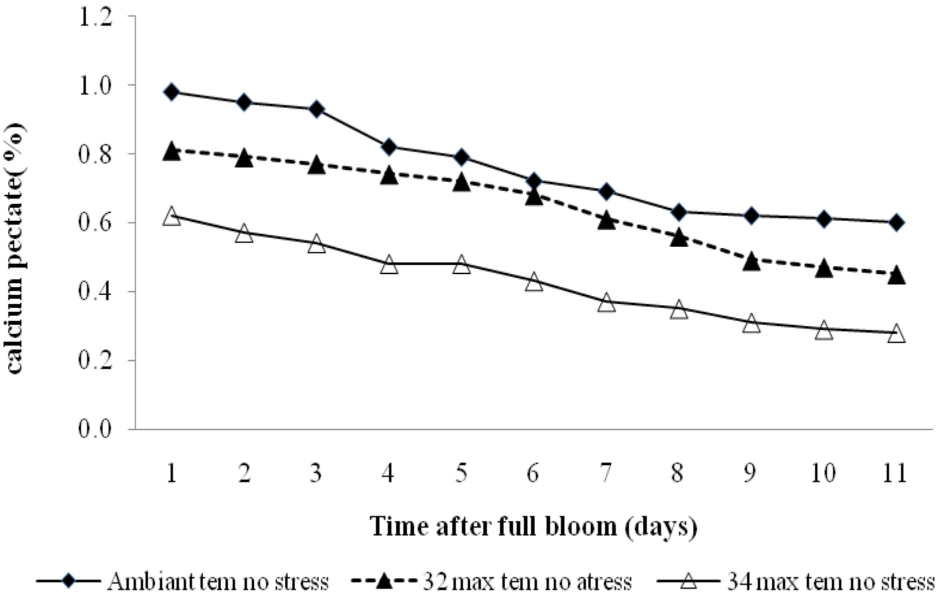

Fig. 4. Temporal variation of calcium pectate content in okra pericarp

CONCLUSIONS

There is a significant effect of individual stress of water and temperature and their combination on the physical parameters such as plant height, fresh weight and pod diameter of okra. Water and temperature stress in combination had less negative effects on growth parameters compared to individual water stress conditions. The high temperature stress in combination with no water stress situation can increase the yield of okra significantly compared to the other treatments. Further, it can be concluded that in high temperature situations with no water stress, pods can be harvested earlier (on the 5^{th} day after full bloom, instead of 7-8 days) to obtain a higher yield and quality. Therefore, this study can be used as a pilot study for adaptation to global warming. Further, this study has some important messages for farmers and extension services .

REFERENCES

Crafts, A.S. and Crisp, C.E. (1971). Phloem Transport in Plant. W.H. Freeman, San-francisco, 481.

Culpepper, C.W. and Moon, H.H. (1941). The growth and composition of fruits of okra in relation to its eating quality. USDA Cir. *595*, 1-17.

De Silva, C.S., Weatherhead, E.K., Knox, J.W. and Rodrihuez-Diaz, J.A. (2007). Predicting the impacts of climate change-A case study of paddy irrigation water requirements in Sri Lanka. Agricultural Water Management. *93*, 19-29.

Gould, W.A. (1977). Food quality Assurances. AVI publishing Co., Inc., Westport, CT. 314p.

Kaiser, W.M. (1987). Effects of water deficit on photosynthetic capacity. Physio. Plantarum *71*, 142-149.

Ketsa, S. and Chutichudet, B. (1994). Pod growth development biochemically changes and maturity indices of okra cv. small scale vegetable production and economics. Acta Horti. *369*, 44 – 48.

Leopold, A.C. (1964). Plant Growth and Development. Mc Graw–Hill Book Co., New York 466p.

Ranganna, S. (1978). Manual of Analysis Fruits and Vegetable Products. Tata McGraw – Hill publishing Co.Ltd., New Delhi. 340p.

Singh, B.K. and Pandey, R.K. (1980). Production and distribution of assimilate in chick pea (*Cicer arietinum* L.) Aust. J. Plant physiol. *7*, 725-735.

Singh, P., Tripathi, R.D. and Singh, H.N. (1974) Effect of age of picking on chemical composition of the fruits of okra. Indian J. Agric. Sci .*44*, 22-26.