Available online at www.notulaebiologicae.ro

Print ISSN 2067-3205; Electronic 2067-3264

Not Sci Biol, 2013, 5(4):508-512

Effect of Prior Heat Stress on the Early Growth of *Carica papaya*

Gideon Olarewaju OKUNLOLA*, Adekunle Ajayi ADELUSI

*Department of Botany, Obafemi Awolowo University Ile- Ife, Osun State, Nigeria; lanrog01@yahoo.com (*corresponding author)*

Abstract

The experiment was carried out to determine the effects of heat stress on some growth parameters like shoot height, leaf area, fresh weight, dry weight as well as the accumulation of chlorophylls in *Carica papaya*. Seedlings of *C. papaya* were exposed to prior heat stress at 40 °C. A group of plants was placed in a Gallenkamp oven for four hours; another group of plants was placed in the oven for eight hours while the third group of plants was placed in a dark cupboard for the period of eight hours. Sampling was carried out at weekly intervals starting from seven days after treatment. Plants were randomly picked from each of the three treatments. Three replicates were used for each parameter. The results obtained from the study showed that there was an increment in the shoot height, leaf area, fresh weight and dry weight from the beginning to the end of the experimental period. However, the accumulation of chlorophylls did not follow a particular pattern. The analysis of variance carried out on the data obtained showed that heat stress had a significant effect on the petiole length, shoot height, leaf length, leaf width, leaf area, fresh weight and dry weight. Heat stress, however, did not produce a significant effect on the accumulation of chlorophylls *a* and *b* and total chlorophyll.

Keywords: chlorophyll, growth, heat, papaya, stress

Introduction

Heat stress is often defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development. It is a complex function of intensity (temperature in degrees), duration and rate of increase in temperature. In tropical climates, excess of radiation and high temperatures are often the most limiting factors affecting plant growth and final crop yield. High temperatures can cause considerable pre- and post-harvest damages, including scorching of leaves and twigs, sunburns on leaves, branches and stems, leaf senescence and abscission, shoot and root growth inhibition, fruit discoloration and damage, and reduced yield (Guilioni *et al.*, 1997; Ismail and Hall, 1999; Vollenweider and Gunthardt-Goerg, 2005). Similarly, in temperate regions, heat stress has been reported as one of the most important causes of reduction in yield and dry matter production in many crops (Giaveno and Ferrero, 2003).

In many crop plants, early maturation is closely correlated with smaller yield losses under high temperatures, which may be attributed to the engagement of an escape mechanism (Adams *et al.*, 2001). Plant's immobility limits the range of their behavioral responses to environmental cues and places a strong emphasis on cellular and physiological mechanisms of adaptation and protection. Also, plants may experience different types of stress at different developmental stages and their mechanisms of response to stress may vary in different tissues (Queitsch *et al.*, 2000).

The pawpaw plant is a native of South America, where it was cultivated since Pre-Columbian times and It belongs to a small family of only four general and 27-30 species; the famous of which is *C. papaya* which has its center of diversification in the lowlands of Central America and southern Mexico, possibly the West Indies (Caribbean) (Crane, 2005). The ripe fruits are rich in vitamins A, B and *C. papaya* (*Carica papaya* L.) is herbaceous, but its stature is not that of a typical herbaceous plant. Papaya plants may reach heights of 9 m, and are thus described as giant herbs (Maloand Campbell, 1986). The plants have a rapid growth rate, are usually short-lived, but can produce fruit for more than 20 years (Malo and Campbell, 1986). Commercial papaya cultivation is restricted to tropical and subtropical areas due to chilling damage at temperatures above freezing (Yadava *et al.*, 1990). Understanding the interaction of papaya with environmental factors such as light, wind, temperature, relative humidity, soil water, and soil physical and biological characteristics, is necessary to maximize yield and quality limiting effects of these factors on the photosynthetic process. Knowledge of how papaya responds to environmental factors provides a scientific basis for the development of management strategies to optimize fruit yield and quality (Schaffer and Anderson,

Received 23 August 2013; accepted 23 October 2013

1994). Concern about temperature increases on a global level has sparked research in quantifying plant responses to heat stress. This has become of particular interest to a wide range of scientists and disciplines as evidence suggests that increased temperatures such as that associated with global warming will have widespread adverse effects on species diversity (Davis *et al.*, 1998), food-web and ecosystem structuring (Cao and Woodward, 1998), dominant vegetation (Harte and Shaw, 1995), plant physiology and development (Sato *et al.*, 2000) climate (McCarty, 2001), and phenology (Menzel and Fabian, 1999). The objectives of this research work are therefore to determine the effects of prior heat stress on some growth parameters of *C. papaya* and also to study the response of photosynthetic pigments of the plants to prior heat stress.

Materials and methods

This work was carried out at the Department of Botany, Obafemi Awolowo University Ile Ife, Osun State, Nigeria. Topsoil was collected from the Campus of Obafemi Awolowo University Ile Ife. The soil sample was thoroughly mixed to obtain homogeneity. It was later sieved to remove the particles other than soil. The soil was later soaked in 1N HCl to kill the germs that might be present. At the end of this, the acid was drained and the soil washed with tap water and later distilled water until the pH of the decantable water was between 6 and 7. Three wooden pots of approximately 30 cm x 30 cm were filled with soil. The seeds of *C. papaya* were sown at the rate of two hundred seeds per wooden pot at a depth of about 1 cm. After the seed had been sown, each pot was supplied with 250 ml of water to soak the soil before the periodic watering with 250 ml of water twice daily. The seedlings were allowed to grow outdoor before they were incubated. The three pots were divided into three regimes. The seedlings were incubated four weeks after germination in the Gallenkamp illuminated cooled incubator. The first regime was incubated for four hours while the second was incubated for eight hours. The control regime was kept in a dark cupboard throughout the period of incubation. At the end of the incubation period, all the three wooden pots were transferred outdoor. Sixty plastic pots were filled with the topsoil. Holes were bored at the base of each plastic pot to ensure drainage of excess water. The pots were divided into three regimes. Each of the regimes had twenty pots. The incubated plants as well as the controlled plants were then transplanted at the rate of three seedlings per plastic pot. The sixty plastic pots were then arranged according to their respective treatments. The twenty pots for each treatment were divided into two rows of ten pots. The first ten pots were used for physical measurements while the second ten pots were used for destructive analysis i.e. determination of fresh and dry weight as well as chlorophyll determination. Sampling was carried out at weekly intervals starting from seven days after treatment. Plants were randomly picked from each of the three treatments. Three replicates were used for each parameter. Metric rule was used to measure the following parameters: shoot height; leaf length and width; petiole length. Leaf area was calculated using the formula of Hoyt and Brand (1962) as A= LxWx0.75, where: A= Area of the leaf in cm^2; L= Length of the leaf in cm; W= Width of the leaf and 0.75 is a correction factor used in correcting for the shape of the leaf. For the fresh weight determination, plants were carefully uprooted and the soil attached to the roots washed off with tap water. The fresh weight was then determined on the Mettler Toledo PB 153 digital balance after which it was dried in a Gallenkamp drying oven until a constant weight was achieved. After cooling, the dry weight was determined. In order to extract the chlorophyll, 80% acetone was used and the optical density of the extracted chlorophyll pigments was determined on a CAMSPEL visible linear readout spectrophotometer at 647 nm and 664 nm wave lengths, respectively. Chlorophyll *a*, Chlorophyll *b* and total Chlorophyll were later determined using the formula by Coombs *et al.* (1985):

Chl a= 13.19A_{664}-2.57A_{647}

Chl b= 22.1A_{647} - 5.26A_{664}

Total chlorophyll = 7.93A_{664}+ 19.53A_{647}.

The data obtained from the study were first tested between normality and assumption of constant variance. A one-way analysis of variance (ANOVA) was carried out considering the factor (Heat) as source of variation to investigate the effects 4 hours of prior heat stress, 8 hours of prior heat stress and no prior heat stress(control) on the parameters studied. The data obtained was also subjected to Duncan multiple range test to separate the means at probability level of 0.05.

Result

The shoot height of the pawpaw plants under the different heat treatments is shown in Fig. 1. There was an increment in the shoot height in all the treatments from the beginning to the end of the experimental period. The shoot heights of the plants in all the treatments were approximately equal throughout the experimental period.

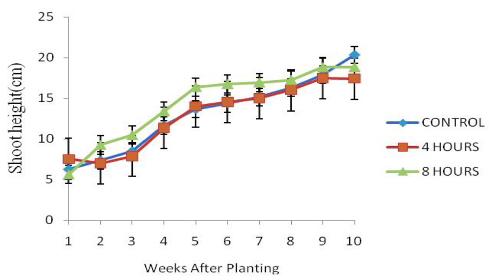

Fig. 1. Effect of prior heat stress on the shoot height of *C. papaya*

The results of the ANOVA analysis showed that there was no significant effect of prior heat stress on the shoot height of the *C. papaya* ($p<0.05$)(Tab. 1). The leaf area of the plants is shown in Fig. 2.

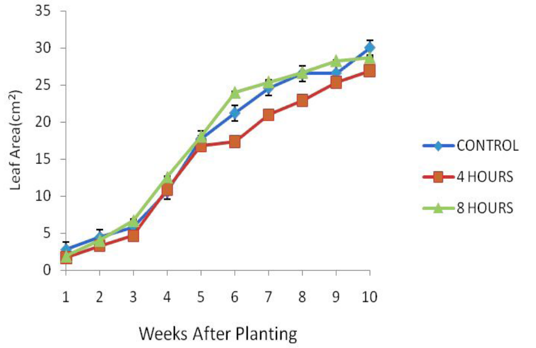

Fig. 2. Effect of prior heat stress on the leaf area of *C. papaya*

The leaf areas of the plants in the three treatments were approximately equal throughout the experimental period. The leaf area increased gradually throughout the experimental period. The control plants recorded the highest leaf area at the end of the experimental period, while the leaf area of both the 4 hours and 8 hours plants were approximately equal. There was no significant difference of prior heat on the leaf area ($p>0.05$).The fresh weight and dry weight of plants under different heat treatments are shown in Fig. 3 and 4 respectively. Both the fresh and dry weight were observed to follow the same patterns. For a greater part of the experimental period, the control plants were observed to record the highest fresh and dry weights. At the end of the experiment, the plants that were stressed for 8 hours were observed to record the highest fresh and dry weights followed by the control plants, while the plants that were stressed for 8 hours recorded the lowest fresh and dry weight. The results of the ANOVA analysis showed that there was a significant difference between the control plants and the stressed plants. It however showed that there was no significant difference between the stressed plants (4 hours and 8 hours).

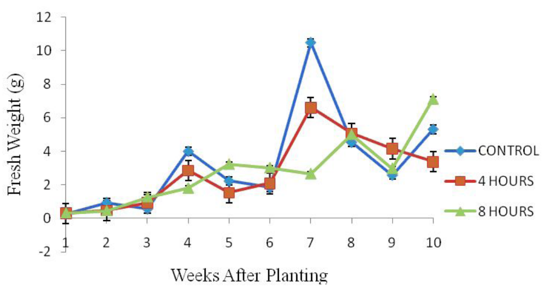

Fig. 3. Effect of prior heat stress on the fresh weight of *C. papaya*

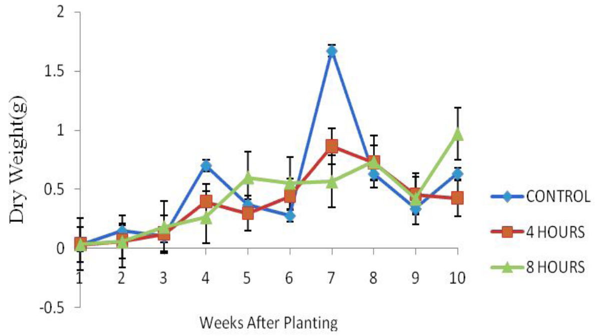

Fig. 4. Effect of prior heat stress on the dry weight of *C. papaya*

The accumulation of chlorophylls *a, b* and total chlorophyll in the plants did not follow a particular trend as can be seen in Figs. 5, 6 and 7. The results of the ANOVA analysis showed that there was no significant difference in chlorophylls a, b and total chlorophyll in the different heat treatments.

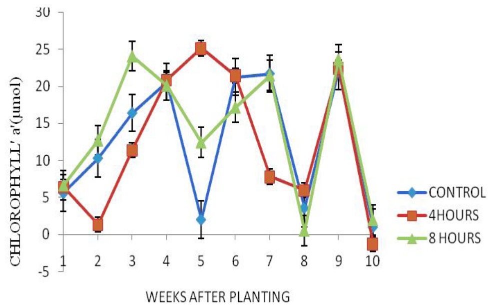

Fig. 5. Effect of prior heat stress on the accumulation of chlorophyll *a* in *C. papaya*

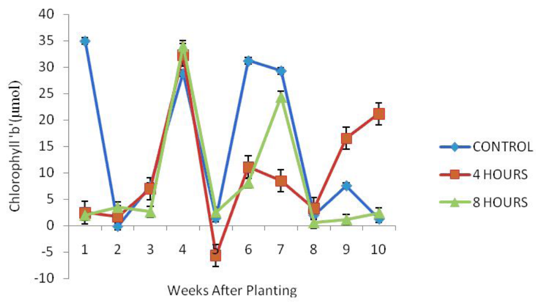

Fig. 6. Effect of prior heat stress on the accumulation of chlorophyll *b* in *C. papaya*

Result of Duncan Multiple Range Test (DMRT) for the parameters measured

Treatments	Shoot Height (cm)	Leaf Area (cm^2)	Fresh Weight (g)	Dry Weight (g)	Chlorophyll *a*	Chlorophlll *b*	Total Chlorophyll
Control	13.15±1.05[a]	17.03±1.2[a]	3.27±0.25[a]	0.49±0.05[a]	12.44±2.51[a]	14.34±0.6[a]	26.83±3.32[a]
4 Hours	12.82±2.53[b]	15.07±0.0[b]	2.73±0.6[b]	0.26±0.1[b]	12.37±1.01[a]	14.36±2.1[a]	26.73±2.61[a]
8 Hours	14.36±1.12[c]	17.64±0.0[c]	2.78±0.1[b]	0.44±0.22[c]	12.47±2.03[a]	14.29±1.01[a]	26.76±3.24[a]

Mean ± (SE) values followed by the same letter within each column are not significantly different at 0.05(ANOVA and Duncan's multiple range test)

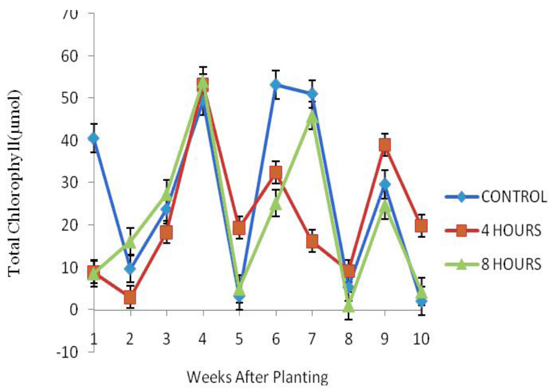

Fig. 7. Effect of prior heat stress on the accumulation of total chlorophyll in *C. papaya*

Discussion

The shoot height and leaf area were found to be highest in the control plants followed by the eight hour stressed plants and least in the four hour stressed plants. This is in an agreement with earlier findings that heat stress reduces growth in plants. Such retardation is found in the hypocotyls of cowpea, melon and tomato seedlings (Onwueme, 1974) and of the coleoptiles in wheat following heat stress at 45 °C for 10 hours or less. In this study however, heat stress of a longer duration led to enhancement of the above parameters as against heat stress of a shorter duration. This shows the tolerance level of *C. papaya* to heat stress since the expectation is that a longer duration should cause a higher level of reduction in the parameters mentioned. The early reduction in fresh and dry weight of the plants in all the treatments was expected as plants are known to show retardation following exposure to high but non-lethal temperatures (Adelusi and Lawanson, 1978).

This higher dry weight of the control plants compared to the stressed plants is also in agreement with the findings of Ashraf and Hafeez, 2004. High temperatures caused significant declines in shoot dry mass, relative growth rate and net assimilation rate in maize, pearl millet and sugarcane (Wahid, 2007)

Since there was no significant difference in the chlorophyll *a*, chlorophyll *b* and total chlorophyll content of both the stressed and control plants, it can be said to be in contrary to the work of previous workers such as Yiwei and Bingru (2001) who reported that turf quality, leaf relative water content and chlorophyll content decreased with prolonged drought, heat and combined stresses for both species of *Festuca arundinacea* and *Poa pratensis*, but this severity of decline varied with stress type and duration. The higher chlorophyll a, chlorophyll b and total chlorophyll content of the plants at the early part of the experiment can be attributed to the fact that the other treatments were trying to adjust to the initial heat stress at that stage.

Conclusion

Prior heat stress caused an increase in the shoot height, leaf area, fresh weight and dry weight from the beginning to the end of the experimental period. However, the accumulation of chlorophylls did not follow a particular pattern.

References

Adams SR, Cockshull KE, Cave CRJ (2001). Effect of temperature on the growth and development of tomato fruits. Ann Bot 88:869-877.

Adelusi AA, Lawanson AO (1978). Heat-induced quantitative changes in dry weight, leaf size and number of chloroplasts per cell in maize and cowpea shoots. J Agric Sci 91:349-357.

Ashraf M, Hafeez M (2004).Thermotolerance of pearl millet and maize at early growth stages: growth and nutrient relations. Biol Plant. 48:81-86.

Cao M, Woodward FI (1998). Dynamic responses of terrestrial ecosystem carbon cycling to global climate change. Nature 393:249-252.

Coombs J,Hind G, Leegood RC, Tieszen LL, Vonshak A(1985). Analytical Techniques. In: Techniques in Bioproductivity and photosynthesis 2nd edition. (Eds) J Coombs, DO Hall, SP Long, JMO Scurlock. p. 219-220, Pergamon Press.

Crane JH (2005). Papaya growing in the Florida Home Landscape. University of Florida. IFAS Extension. p. 8.

Davis AJ, Jenkinson LS, Lawton JH, Shorrocks B (1998). Making mistakes when predicting shifts in species range in response to global warming. Nature 391:783-786.

Giaveno C, Ferrero J (2003). Introduction of tropical maize genotypes to increase silage production in the central area of Santa Fe, Argentina. Crop Breed Appl Biotechnol 3:89-94.

Guilioni L, Wery J, Tardieu F (1997). Heat stress-induced abortion of buds and flowers in pea: is sensitivity linked to organ age or to relations between reproductive organs? Ann Bot 80:159-168.

Harte J, Shaw R (1995). Shifting dominance within a montane vegetation community:Results of a climate-warming experiment. Science 267:876-880.

Hoyt P, Bradfield R (1962). Effect of varying leaf area defoliation and density on dry matter production of corn. Agronomy Journal 54:523-525.

Ismail AM, Hall A.E (1999). Reproductive-stage heat tolerance, leaf membrane thermostability and plant morphology in cowpea. Crop Sci 39:1762-1768.

Malo SE, Campbell CW (1986). The papaya. University of Florida, Cooperative Extension Service Fruits CropsFact Sheet FC-11. Gainesville.

McCarty JP (2001). Ecological consequences of recent climate change. Conserv Biol 15:320-331.

Menzel A, Fabian P (1999). Growing season extended in Europe. Nature 397:659.

Onwueme IC (1974). Retardation of hypocotyls growth by prior heat stress in seedlings of cowpea, melon and tomato. JAgric Sci(Camb) 83:409-413.

Queitsch C, Hong SW, Vierling E, Lindquest S (2000).Heat shock protein plays a crucial role in thermotolerance in Arabidopsis. Plant Cell 12:479-492.

Sato S, Peet MM, Thomas JF (2000). Physiological factors limit fruit set of tomato (*Lycopersicon esculentum* Mill.) under chronic, mild heat stress. Plant Cell Environ 23:719-726.

Schaffer B, Andersen PC (1994). Introduction. In: SchafferB, Andersen PC (ed) Handbook of Environmental Physiology of Fruit Crop. CRC Press, Boca Raton, p.1-2.

Vollenweider P, Gunthardt-Goerg MS (2005). Diagnosis of abiotic and biotic stress factors using the visible symptoms in foliage. Environ Pollut 137:455-465.

Wahid A (2007). Physiological implications of metabolite biosynthesis for net assimilation and heat-stress tolerance of sugarcane (*Saccharum officinarum*) sprouts. J Plant Res 120:219-228.

Yadava UL, Burris AJ, McCrary D (1990). Papaya: a potential annual crop under middle Georgia conditions. In: Janick J, Simon JE (eds), Advances in New Crops, p. 364-366. Timber Press, Oregon.

Yiwei J, Bingru H (2001). Drought and heat stress injury to two cool season turf grasses in relation to anti oxidant metabolism and lipid peroxidtion. Crop Sci 41(2):436-2.