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GROWTH, PHYSIOLOGY AND YIELD RESPONSES OF FOUR ROCK MELON (*CUCUMIS MELO* VAR. *CANTALOUPENSIS*) CULTIVARS IN ELEVATED TEMPERATURE

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ABSTRACT

Rock melon is a high value greenhouse crop. Reduction of economical crop yield in high temperature stress due to global warming is an emerging issue with Rock melon. Therefore, this study was conducted for evaluate the growth, physiology and yield of different Rock melon cultivars grown under high temperature stress. Four cultivars of rock melon (Lady-gold, Lady-green, Himalai-99 and Glamour) were evaluated for their physiological behaviors under two temperature ($42\pm 3^{\circ}\text{C}$ and $47\pm 3^{\circ}\text{C}$) regimes. In four cultivars of rock melon, leaf area, specific leaf area, relative growth rate, chlorophyll content, photosynthesis rate, stomatal conductance, intercellular carbon dioxide concentration, transpiration rate, malondialdehyde content and fruit yield of Rock melon were significantly differ in each temperature regime. Temperature significantly affects the fruit position in main branch. When temperature increases, Rock melon fruits shifts in to upper branches. While Lady-green and Glamour shown similar attributes in extreme temperature, most susceptible cultivar was the Lady-gold and most tolerant cultivar was the Himalai-99. This study identified the issues of extreme temperature related to the economical yield of rock melon cultivars which can be use in future crop modification and breeding.

Keywords: elevated temperature, cultivars, greenhouse, leaf gas exchange, malondialdehyde, fruit position.

INTRODUCTION

Rock melon, *Cucumis melo* var. *cantalupensis* called as Cantaloupe, Muskmelon or Netted Melon (Baloglu, 2018; Lim, 2016). Global Rock melon market has been broadened because of high consumer preference due to its nutritive values, taste and texture (The World's Healthiest Foods, 2019; Laur and Tian, 2011). Rock melon is an economical and popular greenhouse crop in all over the world which sensitive to high temperature (Azmi *et al.*, 2019 and Zhang *et al.*, 2013). Optimum seed germination and plant growth for Cucurbits was reported at 22-32°C. Maximum thermal limits were reported as 39°C - 45°C for melon (Kurtar, 2010). Hartz *et al.* (2008), mentioned that Rock melon can tolerate the temperature higher than 40 °C. Observed drastic reduction in femaleness of cucumber due to high temperature stress by Lai *et al.* (2018). Temperatures above the optimum are termed as heat stress which disturbs the cellular homeostasis increase of extreme temperature is becoming a major limiting factor for the plant growth and plant productivity. Global warming reduces the crop yield in tropical regions very prominently than the temperate. In many locations of the temperate regions, crop yield recorded

decrease even in moderate warming (Nadeem *et al.*, 2018; Challinor *et al.*, 2014; Easterling, 2010). Atmospheric temperature has increased by 30% within the 20th century and is expected to be increased by 1.8–4.0 °C by the end of the 21st century (Bita & Gerats, 2013; Srinivasan, 2009). According to Lobell & Asner (2003), 17% yield reduction per 1°C temperature increment is the main negative effect of impact of gradual increment of temperature on crop yield.

High temperature significantly effects on photosynthesis mechanism followed by crop yield. Causes for reduction of photosynthesis are decrease of maximum carboxylation rate of Rubisco, the maximum potential rate of electron transport contributed to RUBP, relative quantum efficiency of Photosystem-II photochemistry, carboxylation efficiency and lipid peroxidation (Sharkey, 2005 and Ogweno *et al.*, 2008). When production of Reactive Oxygen Species (ROS) exceeded the plant capacity, lipid peroxidation in biological membranes increases. The decomposition of polyunsaturated fatty acid in membranes generates Malondialdehyde (MDA) content. MDA is one of the final most abundant aldehydic lipid breakdown products (Labudda, 2013; Sharma *et al.*, 2012).

Cucurbit plant responses for extreme temperatures vary with the plant cultivar, growth stage and the degree of the temperature increment (Bita and Gerats, 2013; Hasanuzzaman *et al.*, 2013; Mirza Hasanuzzaman, 2012; Wien, 2004). In cucurbit plant growth curve, floral induction, differentiation and pollination reported as the most important growth stage. (Hatfield and Prueger, 2015; Albert *et al.*, 2008). Cucurbits can adjust photosynthesis, carbohydrate content, anti-oxidative metabolism and osmolyte accumulation to adapt to short-term heat shock (Ding *et al.*, 2016) but the impacts of elevated temperature throughout the growth cycle for Rock melon not reported yet.

Many researches have been done and doing their researches on climate change and temperature extremities on temperate plants. Majority of experiments in higher temperature are short term experiments for seedlings. Rock melon not yet tested for their physiological behavior in higher than 42 °C. Novelty of this study is evaluating different Rock melon cultivars under greenhouse conditions in 47±3 °C. In this research work, we have maintained plants in the optimal agronomic management conditions i.e. irrigation, fertilizer application, pest and disease control, plant training, pruning and pollination for observe the actual high temperature responses of plants and its impacts for final yield. Therefore, this study was conducted with the objectives of evaluating the growth, physiological responses and yield of different Rock melon cultivars grown under optimum elevated temperature in green house.

MATERIALS AND METHODS

This study was conducted in two greenhouses at field 15, Faculty of Agriculture, Universiti Putra Malaysia (2.9917°N, 101.7163°E). Both greenhouses were gutter shape, with connected side walls, covered with UV polythene and size was 20ft x 10ft in length and width. Temperature controlled by exhaust and axial fans. Popular three Rock melon cultivars among Sri Lankan farmers; Lady-green, Lady-gold, Himalai-99 and most popular cultivar in Malaysia; Glamour were used in this study. Ten days old seedlings from nursery trays were transplanted into 16×16 cm sized polybags which contained coco-peat. Data on atmospheric temperature and CO₂ were monitored by data logger in every 5 minutes. The plants were fertigated five times per day in drip irrigation system (0800, 1030, 1200, 1430 and 1700) using Dosatron fertigation system. Modified Cooper formulation was used as the fertilizer source and fertilizer level was manipulated by adjusting electrical conductivity. Plants were pruned at 6 feet height and only one fruit per plant was maintained by pruning other side branches. After fruit set, leaves below the fruit were pruned. Four cultivars of Rock melon were evaluated for their in two temperature regimes in two greenhouses; GH-1 maintain at maximum day temperature 42±3°C; ambient temperature (AT) and GH-2 maintain at maximum day temperature 47±3°C; elevated temperature (ET). Nested design was used with four replicates and two sub samples. Cultivar (nested factor) was nested in temperature (main factor with fixed effect). Hygienic practices were followed to minimize pest and disease infestations and pest and disease were controlled with recommended chemicals where necessary.

Dry weight of plant leaves, stem and roots were obtained after oven dried for 72 hours in 70 °C. Relative growth rate (RGR) of plant parts were determined in every growth stage. RGR was calculated by the following

formula. W_1 – Plant dry weight at time t_1 , W_2 – Plant dry weight at time t_2 .

$$RGR = \frac{(\ln W_2 - \ln W_1)}{t_2 - t_1}$$

Total leaf area (LA) was measured by using leaf area meter (LI 3100A Lincoln Inc. Nebraska, USA). The specific leaf area was calculated according to the following formula.

$$SLA = \frac{\text{Leaf Area (cm}^2\text{)}}{\text{Leaf Dry Matter (g)}}$$

Third fully mature leaf was used in the analysis and data recording. MDA content was analyzed according to the method described by Ozdimir *et al.* (2004) at fruit mature stage. Chlorophyll (Ch) Content was determined with use of method described by Coombs *et al.* (1986). Photosynthesis rate (PR), stomatal conductance (SC), intercellular CO₂ concentration (GS) and transpiration rate (TR) were measured by using portable photosynthesis system (Li 6400, Li-Cor, USA) between 0830-1030 hours of the day. In all plots, fruits were harvested at the commercial harvesting stage of each cultivar. The Total Soluble Solid (TSS) were measured for each sample of fruit in three replications using digital refractometer (Atago Co. Ltd., Japan) and expressed as °Brix. Firmness was measured by texture analyzer (Instron – 5543, USA).

Data were analyzed and analysis of variance (ANOVA) was done using statistical software R-studio 1.4.1106. LSD at 5% significant level was used for mean separation. For analyze the correlation between parameters, Pearson Correlation method was used.

RESULTS

Plant react to high temperatures by adopting morphological or functional characters and it depend on extent and duration of temperature increase and plant type (Bita and Gerats, 2013). The physiological responses to ET are dynamic research areas which leads to finding remedies for the impacts of global warming i.e. produce heat tolerant cultivars, environmental modifications, optimization of treatments like hormone and anti-transparent (Nadeem *et al.*, 2018).

Hourly mean atmospheric temperature and CO₂ concentration during crop growth period at both greenhouses were given in figure 01. The differences of atmospheric [CO₂] and temperature between AT and ET were recorded as 5-8 ppm and 5°C during 9 am to 5.59pm hours and 9-11ppm and 1°C during 6pm to next day 8.59 am.

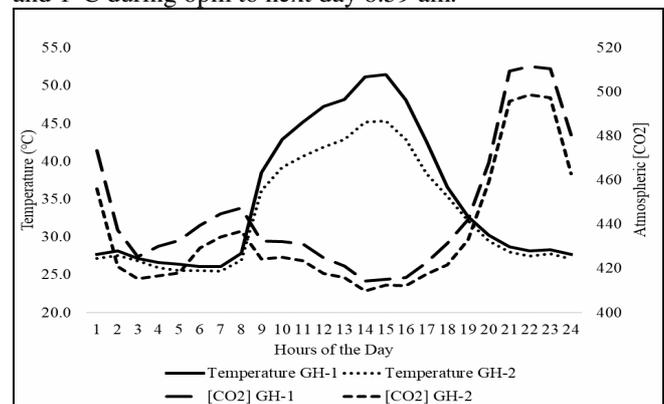


Fig. 01 : Average hourly temperature and [CO₂] during the experimental period in two greenhouses; GH-1 (elevated temperature) and GH-2 (ambient temperature).

Relative growth rate is the mathematical interpretation of relative increase of plant dry weight per day and RGR reveals the relative impact of environment on plant growth (Gent, 2017 and Sonstebly, *et al.*, 2016). Plant RGR analysis data in vegetative phase, had no significant difference between varieties but had a significance difference between two temperature regimes. In flowering and fruit development stages, both between cultivars and temperature regimes recorded a significant difference (figure 02). In higher temperature than the ambient, Plant RGR was significantly lower in vegetative and fruit development phases. RGR was significantly higher in HT than AT in flowering phase. When temperature increases, RGR has been decreased by 0.38-7.46% in vegetative phase and by 8.70-15.78% in fruit development phase. RGR has been increased by 15-24.48% in flowering phase. Plants seems more sensitive and performances are differ in their flowering and fruit development phases. Conesa *et al.*, (2017) studied on wild tomato genotypes and reported that RGR differ according to

climate and plant biomass allocation approaches related on originated climates of plant species. As similar to RGR records in this experiment, heat stress was highly observed in plant growth retardation together with decrease of shoot dry weight and total RGR were observed by Wahid, (2007), in sugarcane sprouts. He described that the increase net assimilation capacity with increase of temperature but there were high temperature damages i.e. root and shoot growth retardation. High temperature alters plant internal morphology i.e. reduces cell size, increase stomatal density, increase trichomatous densities and enlarge xylem vessels. The most observed effect of heat stress on plants is the retardation of growth (Mirza Hasanuzzaman, 2012). Farrar and Williams (2000), explained that plants make their own alterations on shoot and root growth rates towards the high temperature and thoes alterations are independent within a cultivar. Rai *et al.* (2018), observed significant decrease in growth and plant biomass in high temperature stress of Lebab plants at 37-42 °C.

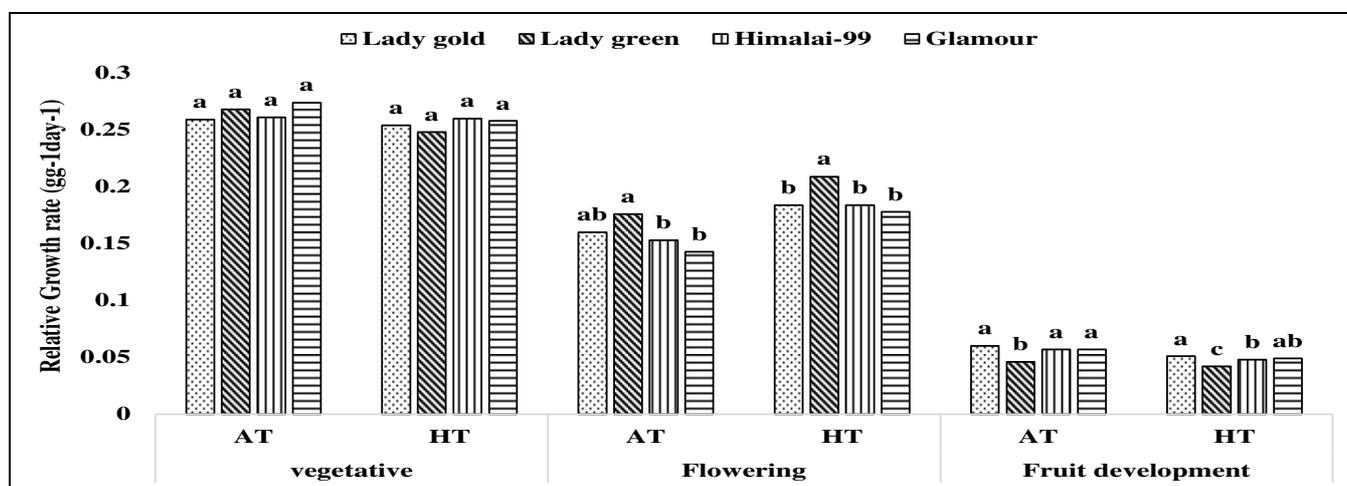


Fig. 02 : Relative growth rate (RGR) of four Rock melon cultivars in three growth stages. Mean values with the same letter between cultivars within a temperature regime, are not significantly difference at $P \leq 0.05$.

Data relevant to LA and SLA are present in Table 01. In each growth stage, in each temperature regime, LA reported a significant difference between cultivars. And also, there was a significant difference between two temperature regimes in each growth stage. At higher environmental temperature, LA of vegetative phase has been decreased. LAs of all four cultivars were higher in flowering phase at ET. In fruit development phase, at ET, LA of all four cultivars were low than AT. SLA of vegetative phase has no significant difference between cultivars and two temperature regimes. Flowering phase had significant difference between cultivars and no significant difference between two temperature regimes. In fruit development stage, there was a significant difference between temperature regimes and cultivars. At ET, SLA of Himalai-99 significantly lowest in flowering phase. SLA of Lady-green was higher in flowering and fruit development stages. Similar to our observations on LA, Zhang *et al.* (2014), observed a significant reduction in leaf area of melon seedlings at 4 leaf stage at 42 °C. Specific leaf area is a key feature which highly correlates with plant growth and it has a great ecological importance (Liu *et al.*, 2017). Except ET in flowering stage, Himalai-99 recorded significantly higher SLA. SLA is often use in plant growth analysis because it correlate temperature condition of the living environment and

reflects plant responses towards the climatic changes (Rosbakh *et al.*, 2015). According to Auger and Shipley, (2013), SLA explains the intraspecific feature variation and environmental variation up to 28% out of the total variation of a species.

Data obtained relevant to total chlorophyll (Ch) content were presented in Table 02. There was no significant difference between cultivars in vegetative and flowering phases but had difference between temperature. There was a significant cultivar and temperature difference in fruit development stage. Hou *et al.* (2016), Purnama *et al.* (2018), Zhao *et al.* (2011), Djanaguiraman *et al.* (2011) and Balal *et al.* (2016) reported significant decrease of chlorophyll contents in their experiments in sea grass, watermelon, soybean and cucumber at 38-42°C heat stress. Chlorophyll content decrease mainly due to the chlorophyll biosynthesis, changes in the chloroplast shape and ultrastructure, including grana lamellae extrusion, severe chloroplast deformations, starch granule and osmiophilic particle accumulation (Liwei Wang *et al.*, 2018; Purnama *et al.*, 2018). Heat shock stress significantly decreased the level total Chlorophyll content (90.68%) of cucumber in 42 °C compared to 28 °C (Liwei Wang *et al.*, 2018), but reference on effect of elevated temperature on chlorophyll content of cucurbits not available.

Data pertained to PR, SC, GS and TR are revealed in table 03. PR, SC, GS and TR recorded a significant difference between cultivars in each temperature regimes in each growth stage except TR in vegetative stage. It was observed a significant effect by elevated temperature in three growth stages for PR, SC, GS and TR. In two temperature regimes, in three growth phases, cultivar Himalai-99 recorded significantly higher photosynthesis rate. Compared to AT, photosynthesis rate was decreased in each growth phase at ET. When atmospheric temperature increases SC of four cultivars was decreased in each growth phase. When temperature increases from AT to ET, GS has been significantly increased in all cultivars in three growth phases. TR was significantly decreased when temperature increased up to ET. Islam (2015) observed same results with poplar plants in 42 °C as increase temperature decrease the photosynthesis rate, stomatal conductance and transpiration while increase the inter cellular [CO₂]. Similar results of decrease photosynthesis rate of cucumber in high temperature (42 °C) were obtained by Chen *et al.* (2017) and Wang *et al.* (2018). Djanaguiraman *et al.* (2020) recorded that photosynthesis rate decreased in wheat by 17 and 25% when temperature increased by 12 °C, compare to AT. Part of the light absorbed in Photosynthesis II antennae, use as energy for photosynthesis and this “energy utilized in photosynthesis” reflects the capacity of photosynthesis in the entire PSII. Energy utilized in photosynthesis significantly decrease in the high temperature stress and therefore photosynthesis rate decrease in high temperature conditions (Chen *et al.*, 2017). Inhibition of photosynthesis with increase of environmental temperature also occur due to the damage cause to the photosynthesis mechanism mainly by production of ROS. ROS are removed by thylakoid lipids. At high temperatures, amounts of ROS produced and removal, changes occur in protein, MDA and chlorophyll, damages to photosynthesis sites of plant cells and senescence of plant cells significantly determines the photosynthesis rate (Zhao *et al.*, 2011 and Djanaguiraman *et al.*, 2018). MDA is a highly recognized biochemical marker to measure the oxidative stress where extreme high temperatures tend to produce high amount of reactive oxygen species. In current research work, SC seems more sensitive to atmospheric temperature increment and it was not having a uniform pattern between cultivars throughout the plant growth stages.

Plant responses in different growth phases by decreasing PR, water use efficiency, nutrient use efficiencies phase and increasing evaporation rates are different and plant sensitivity also differ according to the growth stage (Mohanty, 2017 and Wahid, 2007). But they are highly susceptible to high temperature within gametogenesis and flowering. Duration of exposure to high temperature within a cropping season express different levels of responses. High temperature stress along the cropping season decrease biomass production and crop yield (Prasad and Jagadish, 2015). In extremely higher temperatures, intercellular CO₂ increases, stomata close and photosynthesis decreases (Lindgreen and Lindgreen, 2004).

In this study, there was a significant effect by elevated temperature for the MDA content and significant deference between cultivars (Table 04). Lady-gold had the significantly highest MDA content which means, cultivar Lady-gold is highly sensitive to the high temperature stress. MDA content has been increased when environmental temperature increases and it was increased by 42.5% in Himalai-99,

72.8% in Lady-gold and 25.2% in Lady-green and by 43.9% in glamour. It was 1.3-1.7 folds higher in ET compared to AT. Ahammed *et al.* (2019), observed that at the 40 °C, MDA of tomato leaves was significantly increased by 5 folds than in 25°C. Balal *et al.* (2016), observed that at 40 °C, MDA was increased by 91 % in leaves and 77 % in roots with compared to 28°C in cucumber. Rai *et al.* (2018) recorded significant increase in MDA at 40 °C in Lablab and the extent of lipid peroxidation was different between cultivars.

Female flower immergence and fertilization highly vary according to the environmental temperature. In this study, fruit position in main branch was observed as highly affected in ET. In every cultivar, fruit position in main node was significantly higher in ET than NT (table 04). Days after transplant (DAT) to female flowering was observed as; at AT, 24 DAT in Lady-green and Himalai-99, 25 DAT in glamour and 28 DAT in Lady-gold. In ET, it was 30 DAT in average of four cultivars. At ET, fruit position of Himalai-99 was observed lower than the other cultivars. According to the previous research experiences, sex expression and flower bud initiation of cucurbits delay under high temperature conditions in green house environment. Lina Wang *et al.* (2014), suggest that sugar playing a major role in regulating cucumber female flower initiation and fruit development. Reason for male female sex alteration and fruit development/abortion in high temperature stress condition was identified as the competition for photo-assimilation between sink and source. Therefore, alteration of competition will lead to increase female flower initiation and reduce fruit abortion. In cucurbits, first fruit development in main stem expressed by the main stem node number and it can be influenced by the atmospheric temperature. High temperature initiate male flowers, subpress the initiation of female flowers and abort female flowers. Increase of atmospheric temperature lifts the fruits in to upper nodes and it reduce the final yield because fruits getting smaler. In *Cucurbita pepo*, it was observed that node shifted from 17th to 26th resulted yield reduction by 74%. This character of shifting fruiting node was significantly difference between melon cultivars and most prominent in early cultivars and late cultivars (Wien *et al.*, 2004; Bouzo and Küchen, 2012 and Maynard, 2007). Fruiting node effect the melon senescence, fruit weight and fruit characters. As well as, composition of chlorophyll content, proteins, MDA, peroxidase are differ between the plants having different number of fruiting node due to the temperature in a same cultivar (LI Bin *et al.*, 2012).

There is a significant effect on yield by temperature on each cultivar and relevant data presented in table 04. Cultivar Himalai-99 given the highest fruit weight followed by Glamour, Lady-green and Lady-gold in both temperature regimes. Compared to AT, average fruit weight of Lady-gold, Lady-green and Glamour were significantly lower in ET. But in Himalai-99, average fruit weight was significantly higher in ET. In Lady-green and glamour, yield reduction was 8.5 and 13.2% and in Lady-gold it was 12.5%. Compared to AT, Yield of Himalai-99 was recorded 7.7% yield increment in ET. There is no significant effect by temperature on the TSS and fruit firmness values of Rock melon cultivars in this research. But there is a significant different between cultivars (Table 04). Cultivar Lady-green given significantly higher TSS value in normal temperature. In elevated temperature, cultivars Lady-green and Himalai-

99 showed highest TSS values and no significant difference between two cultivars. TSS content of Glamour and firmness of Himalai-99 were the lowest among tested four cultivars. High temperature adversely effects on different mechanisms in crop growth and development which leads the reduction of final crop yield. Plants grown in elevated temperature decrease the final crop yield because it adversely effects on plant vegetative growth, reproductive growth, photosynthesis and flowering. Amount of crop reduction depend on degree of temperature variation and crop genotype (Mirza Hasanuzzaman, 2012). Reduction in chlorophyll content, photosynthesis rate, female flower initiation, sink-source relationship and plant growth, as well as cell damage, assimilation of ROS and metabolites due to heat stress will reduce the fruit set, fruit growth and yield related parameters

(Sato *et al.*, 2006; Bitu and Gerats, 2013; Challinor *et al.*, 2014 and Rai *et al.*, 2018).

Table 05 revealed the data pertain to the correlation between parameters considered in this study. Here, data in fruit development stage was taken in to consideration. Fruit fresh weight had positive significant correlation with PR, MDA and fruit node. PR was positively and significantly correlated with SC, TR, LA and total RGR, while having negative significant correlation with GS and SLA, MDA and fruit node. Strong negative correlation was observed between MDA content and PR. Increment of GS significantly inhibits the PR and as well as it leads to close stomata and significantly reduce the SC followed by decrease the final crop yield.

Table 01 : Leaf Area (LA) and Specific Leaf Area (SLA).

	Cultivar	Vegetative		Flowering		Fruit development	
		AT	ET	AT	ET	AT	ET
LA (cm ²)	Lg	880 ^b	780 ^c	3819 ^d	5007 ^b	6524 ^b	5397 ^{bc}
	Lgr	1281 ^a	965 ^b	6416 ^a	7246 ^a	5980 ^c	5152 ^c
	Him	1086 ^b	1036 ^{ab}	4840 ^c	5702 ^b	6144 ^c	5884 ^b
	Gla	1332 ^a	1208 ^a	5425 ^b	6712 ^a	8679 ^a	7119 ^a
SLA (cm ² g ⁻¹)	Lg	309.66 ^a	303.89 ^b	296.24 ^b	290.85 ^c	129.00 ^{bc}	151.18 ^b
	Lgr	336.2 ^a	348.85 ^a	308.78 ^b	359.78 ^a	183.04 ^a	220.49 ^a
	Him	309.67 ^a	331.38 ^{ab}	388.69 ^a	284.26 ^c	144.32 ^b	187.95 ^{ab}
	Gla	298.32 ^a	334.54 ^{ab}	327.14 ^b	329.93 ^b	111.04 ^c	118.6 ^c

Note: Lady-gold (Lg), Lady-green (Lgr), Himalai-99 (Him), Glamour (Gla). Mean values with the same letter between cultivars within a temperature regime, are not significantly difference at P≤0.05.

Table 02 : Chlorophyll content.

Cultivar	Total chlorophyll content (mg cm ⁻²)					
	Vegetative		Flowering		Fruiting	
	AT	ET	AT	ET	AT	ET
Lg	6.414 ^{ab}	5.571 ^a	7.935 ^a	6.618 ^a	9.724 ^{ab}	8.846 ^a
Lgr	5.931 ^b	5.73 ^a	7.606 ^a	5.922 ^{ab}	9.862 ^a	8.389 ^a
Him	7.054 ^a	6.036 ^a	8.282 ^a	6.004 ^{ab}	8.631 ^b	7.594 ^b
Gla	6.34 ^{ab}	5.667 ^a	7.786 ^a	5.667 ^b	9.289 ^{ab}	7.440 ^b

Note: Lady-gold (Lg), Lady-green (Lgr), Himalai-99 (Him), Glamour (Gla). Mean values with the same letter between cultivars within a temperature regime, are not significantly difference at P≤0.05.

Table 03 : Leaf gas exchange.

	Cultivar	Leaf Gas Exchange					
		Vegetative		Flowering		Fruit development	
		AT	ET	AT	ET	AT	ET
PS (μmol m ⁻² s ⁻¹)	Lg	29.6 ^b	28.3 ^{ab}	28.8 ^{ab}	25.8 ^{ab}	28.4 ^{ab}	23.3 ^b
	Lgr	31.1 ^b	28.4 ^{ab}	27.7 ^b	25.3 ^b	28.1 ^b	25.7 ^a
	Him	33.6 ^a	30.0 ^a	31.2 ^a	28.1 ^a	29.9 ^a	27.0 ^a
	Gla	30.3 ^b	28.2 ^b	29.1 ^{ab}	25.3 ^b	28.6 ^{ab}	26.3 ^a
SC (mol m ⁻² s ⁻¹)	Lg	4.41 ^{ab}	1.32 ^{ab}	0.38 ^b	0.34 ^{ab}	4.99 ^a	0.81 ^a
	Lgr	4.26 ^b	1.34 ^b	0.30 ^c	0.27 ^c	4.39 ^a	1.09 ^a
	Him	4.90 ^a	1.67 ^a	0.49 ^a	0.39 ^a	4.37 ^{ab}	1.60 ^a
	Gla	4.38 ^{ab}	0.84 ^{ab}	0.47 ^a	0.32 ^b	4.38 ^b	1.3 ^{ab}
GS (μmol mol ⁻¹)	Lg	316.4 ^a	324.7 ^a	298.7 ^a	330.9 ^a	353.6 ^b	365.0 ^a
	Lgr	310.6 ^{ab}	318.2 ^{ab}	303.0 ^a	321.1 ^a	343.2 ^b	355.3 ^a
	Him	304.3 ^b	310.2 ^b	272.3 ^b	318.2 ^a	352.1 ^b	362.4 ^a
	Gla	301.1 ^b	309.4 ^b	301.4 ^a	328.5 ^a	349.0 ^b	361.4 ^a
TR (mmol m ⁻² s ⁻¹)	Lg	5.76 ^a	4.30 ^b	7.84 ^b	6.34 ^b	4.74 ^a	2.74 ^a
	Lgr	5.48 ^a	4.16 ^{ab}	8.32 ^{ab}	6.86 ^{ab}	4.48 ^{ab}	2.56 ^a
	Him	6.08 ^a	4.26 ^{ab}	8.44 ^a	7.03 ^a	4.30 ^b	2.66 ^a
	Gla	5.54 ^a	3.76 ^b	8.44 ^a	6.78 ^{ab}	4.47 ^{ab}	2.61 ^a

Note: Photosynthesis rate (PR), Stomatal conductance (SC), Intercellular [CO₂] (GS) and Transpiration rate (TR) Lady-gold (Lg), Lady-green (Lgr), Himalai-99 (Him), Glamour (Gla). Mean values with the same letter between cultivars within a temperature regime, are not significantly difference at P≤0.05.

Table 04 : Malondialdehyde content (MDA), fruit position, fruit fresh weight, brix of fruit pulp and fruit flesh firmness.

Cultivar	MDA ($\mu\text{M g}^{-1}$ FW)		Fruit position (Node number)		Fruit fresh weight (g)		Brix (%)		Firmness (N)	
	AT	ET	AT	ET	AT	ET	AT	ET	AT	ET
Lg	5.26 ^b	9.17 ^a	15.0 ^a	20.5 ^a	1239 ^c	1084 ^c	14.43 ^c	14.57 ^c	12.3 ^{ab}	12.8 ^a
Lgr	4.87 ^c	6.80 ^c	14.0 ^b	19.5 ^b	1445 ^b	1323 ^b	16.17 ^a	15.67 ^a	11.4 ^{ab}	13.5 ^a
Him	4.52 ^d	5.66 ^d	12.0 ^c	17.5 ^d	1603 ^a	1734 ^a	15.27 ^b	15.03 ^b	11.2 ^b	10.2 ^b
Gla	5.37 ^a	7.71 ^b	13.5 ^d	18.5 ^c	1541 ^{ab}	1338 ^b	12.37 ^d	12.73 ^d	13.4 ^a	14.0 ^a

Note: Lady-gold (Lg), Lady-green (Lgr), Himalai-99 (Him), Glamour (Gla). Mean values with the same letter between cultivars within a temperature regime, are not significantly difference at $P \leq 0.05$.

Table 05 : Pearson correlation analysis.

	FW	Ch-tot	PR	SC	GS	TR	LA	SLA	RGR	MDA
Ch-tot	-0.23	--								
PR	0.53*	0.33	--							
SC	0.23	0.6**	0.83**	--						
GS	-0.22	-0.58**	-0.72**	-0.75**	--					
TR	0.13	0.7**	0.75**	0.98**	-0.74	--				
LA	0.04	0.25	0.5*	0.46*	-0.55	0.44*	--			
SLA	-0.23	-0.1	-0.43*	-0.42*	0.4	-0.37*	-0.54	--		
RGR	0.12	0.4*	0.45*	0.61**	-0.41	0.61**	0.45	-0.72**	--	
MDA	-0.63**	-0.33	-0.85**	-0.8**	0.65**	-0.73**	-0.23	0.41*	-0.5*	--
Node	-0.36*	-0.54*	-0.82**	-0.96**	0.7**	-0.94**	-0.37*	0.36*	-0.62**	0.84**

Note: FW= Fruit fresh weight, PR= Photosynthesis rate, SC= Stomatal conductance, GS= Intercellular CO_2 concentration, TR= Transpiration rate, Ch = Total chlorophyll content, LA= Leaf area, RGR= Relative growth rate of plant, SLA= Specific leaf area, MDA= Malondialdehyde content. * and ** significant difference at $P \leq 0.05$ and 0.001

CONCLUSIONS

According to the results and forgone discussion of current study, high temperature stress has significantly affected flowering and fruit development stages of plant growth and plant physiological functions which finally affect the yield of rock melon. Degree of high temperature stress impact vary according to the cultivar of rock melon and the environmental temperature. Rock melon cultivars can function in higher temperature elevation. When all the other factors i.e. water, fertilizer, pest and disease control are optimized, fruit firmness and TSS not significantly affected by high temperature stress. Cultivar Himalai-99 was tolerance to increase of atmospheric temperature by 5°C and most susceptible cultivar was the Lady-gold. Lady-green and Glamour shown approximately similar attributes towards the increasing temperature. Female flower emergence was affected by elevated temperature. When temperature increases, fruit appear in upper branches and giving smaller fruits.

REFERENCES

- Albert Liptay, Ron A. Salzman, J.H.S. & M.D.O. (2008). *Overcoming high temperature inhibition of flower formation and fruit production without bees*. Nature proceedings. <https://doi.org/hdl:10101/npre.2009.3707.1>
- Auger, S. and Shipley, B. (2013). Inter-specific and intra-specific trait variation along short environmental gradients in an old-growth temperate forest. *Journal of Vegetation Science*, 24(3): 419–428.
- Azmi, W.A.; Wan Sembok, W.Z.; Yusuf, N.; Mohd Hatta, M.F.; Salleh, A.F.; Hamzah, M.A.H. and Ramli, S.N. (2019). Effects of Pollination by the Indo-Malaya Stingless Bee (Hymenoptera: Apidae) on the Quality of Greenhouse-Produced Rockmelon. *Journal of Economic Entomology*, 112(1): 20–24.
- Balal, R.M.; Shahid, M.A.; Javaid, M.M.; Iqbal, Z.; Anjum, M.A.; Garcia-Sanchez, F. and Mattson, N.S. (2016). The role of selenium in amelioration of heat-induced oxidative damage in cucumber under high temperature stress. *Acta Physiologiae Plantarum*, 38(6): <https://doi.org/10.1007/s11738-016-2174-y>
- Baloglu, M.C. (2018). Genomics of Cucurbits. In *Genetic Engineering of Horticultural Crops*, 9930: 413–432.
- Bitá, C.E. and Gerats, T. (2013). Plant tolerance to high temperature in a changing environment: Scientific fundamentals and production of heat stress-tolerant crops. *Frontiers in Plant Science*, 4(JUL): 1–18.
- Bouzo, C.A. and Küchen, M.G. (2012). Effect of temperature on melon development rate. *Agronomy Research*, 10(1–2): 283–294.
- Challinor, A.J.; Watson, J.; Lobell, D.B.; Howden, S.M.; Smith, D.R. and Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, 4(4): 287–291.
- Chen, Q.; Zhao, X.; Lei, D.; Hu, S.; Shen, Z.; Shen, W. and Xu, X. (2017). Hydrogen-rich water pretreatment alters photosynthetic gas exchange, chlorophyll fluorescence, and antioxidant activities in heat-stressed cucumber leaves. *Plant Growth Regulation*, 83(1), 69–82.
- Cho, U.H. and Seo, N.H. (2005). Oxidative stress in *Arabidopsis thaliana* exposed to cadmium is due to hydrogen peroxide accumulation. *Plant Science*, 168(1): 113–120.
- Conesa, M.; Muir, C.D.; Roldán, E.J.; Molins, A.; Perdomo, J.A. and Galmés, J. (2017). Growth capacity in wild tomatoes and relatives correlates with original climate in arid and semi-arid species. *Environmental and Experimental Botany*, 141(January): 181–190.
- Daryono, B.S.; Hadi, R.; Sidiq, Y. and Maryanto, S.D. (2015). Phenotypic Characters Stability of Melodi Gama-3 Melon (*Cucumis melo* L.) Cultivar in Rainy

- Season Based on Multilocation Test. *IPTEK Journal of Proceedings Series*, 0(1): 550–554.
- Ding, X.; Jiang, Y.; Hao, T.; Jin, H.; Zhang, H.; He, L.; Zhou, Q.; Huang, D.; Hui, D. and Yu, J. (2016). Effects of heat shock on photosynthetic properties, antioxidant enzyme activity, and downy mildew of cucumber (*Cucumis sativus* L). *PLoS ONE*, 11(4): 1–15.
- Djanaguiraman, M.; Boyle, D.L.; Welti, R.; Jagadish, S.V.K. and Prasad, P.V.V. (2018). Decreased photosynthetic rate under high temperature in wheat is due to lipid desaturation, oxidation, acylation, and damage of organelles. *BMC Plant Biology*, 18(1): 1–17.
- Djanaguiraman, M.; Narayanan, S.; Erdayani, E. and Prasad, P.V.V. (2020). Effects of high temperature stress during anthesis and grain filling periods on photosynthesis, lipids and grain yield in wheat. *BMC Plant Biology*, 20(1): 268.
- Djanaguiraman, M.; Prasad, P.V.V. and Al-Khatib, K. (2011). Ethylene perception inhibitor 1-MCP decreases oxidative damage of leaves through enhanced antioxidant defense mechanisms in soybean plants grown under high temperature stress. *Environmental and Experimental Botany*, 71(2): 215–223.
- Easterling, W.E. (2010). Guidelines for Adapting Agriculture to Climate Change. In *Handbook of Climate Change and Agroecosystems: Impacts, Adaptation and Mitigation, ICP Series on Climate Change Impacts, Adaptation, and Mitigation* (Issue 1990, pp. 269–286). Imperial College Press.
- Farrar, J.F. and Williams, M.L. (2006). The effects of increased atmospheric carbon dioxide and temperature on carbon partitioning, source-sink relations and respiration. *Plant, Cell and Environment*, 14(8): 819–830.
- Gent, M.P.N. (2017). Factors affecting relative growth rate of lettuce and spinach in hydroponics in a greenhouse. *HortScience*, 52(12): 1742–1747.
- Hartz, T.; Cantwell, M.; Mickler, J.; Mueller, S.; Stoddard, S. and Turini, T. (2008). Cantaloupe Production in California. *UC Agriculture & Natural Resources*, 7218: 1–5.
- Hasanuzzaman, M.; Nahar, K.; Alam, M.M.; Roychowdhury, R. and Fujita, M. (2013). Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. *International Journal of Molecular Sciences*, 14(5): 9643–9684.
- Hatfield, J.L. and Prueger, J.H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes*, 10: 4–10.
- Hou, W.; Sun, A.H.; Chen, H.L.; Yang, F.S.; Pan, J.L. and Guan, M.Y. (2016). Effects of chilling and high temperatures on photosynthesis and chlorophyll fluorescence in leaves of watermelon seedlings. *Biologia Plantarum*, 60(1): 148–154.
- Islam, M.D.T. (2015). Effects of high temperature on photosynthesis and yield in mungbean. *Bangladesh Journal of Botany*, 44(3): 451–454.
- Kurtar, E.S. (2010). Modelling the effect of temperature on seed germination in some cucurbits. *African Journal of Biotechnology*, 9(9): 1343–1353.
- Labudda, M. (2013). Lipid peroxidation as a biochemical marker for oxidative stress during drought. An effective tool for plant breeding. *E-Wydawnictwo, Polland, October*, 1–12.
- Lai, Y.S.; Shen, D.; Zhang, W.; Zhang, X.; Qiu, Y.; Wang, H.; Dou, X.; Li, S.; Wu, Y.; Song, J.; Ji, G. and Li, X. (2018). Temperature and photoperiod changes affect cucumber sex expression by different epigenetic regulations. *BMC Plant Biology*, 18(1): 1–13.
- Laur, L.M. and Tian, L. (2011). Provitamin A and vitamin C contents in selected California-grown cantaloupe and honeydew melons and imported melons. *Journal of Food Composition and Analysis*, 24(2): 194–201.
- LI Bin, WU Guo-li, ZHANG Yue-jian, YE Li-hua, ZHANG Yue-hua, M.L. (2012). Effects of fruiting nodes on physiological characteristics, fruit weight and total soluble solid content of muskmelon. *China Academic Journal*, 02: 4–6.
- Lim, T.K. (2016). *Cucumis melo* L. (*Cantalupensis* Group) ‘Charentais.’ In *Edible Medicinal and Non-Medicinal Plants*, 10: 1–659.
- Lindgreen, A. & Lindgreen, A. (2004). Corruption and unethical behavior: report on a set of Danish guidelines. *Journal of Business Ethics*, 51(1): 31–39.
- Liu, M.; Wang, Z.; Li, S.; Lü, X.; Wang, X. and Han, X. (2017). Changes in specific leaf area of dominant plants in temperate grasslands along a 2500-km transect in northern China. *Scientific Reports*, 7(1): 1–9.
- Lobell, D.B. and Asner, G.P. (2003). Climate and management contributions to recent trends in U.S. agricultural yields. *Science*, 299(5609): 1032.
- Maynard, L. (2007). Cucurbit Crop Growth and Development. *2007 Indiana CCA Conference Proceedings*, 495–505.
- Mirza Hasanuzzaman, K.N. and M.F. (2012). Extreme Temperature Responses, Oxidative Stress and Antioxidant Defense in Plants. In *Abiotic Stress - Plant Responses and Applications in Agriculture: Vol. i* (pp. 169–189).
- Mohanty, J.N.; Nayak, S.; Jha, S. and Joshi, R.K. (2017). Transcriptome profiling of the floral buds and discovery of genes related to sex-differentiation in the dioecious cucurbit *Coccinia grandis* (L.) Voigt. *Gene*, 626: 395–406.
- Nadeem, M.; Li, J.; Wang, M.; Shah, L.; Lu, S.; Wang, X. and Ma, C. (2018). Unraveling Field Crops Sensitivity to Heat Stress : Mechanisms, Approaches, and Future Prospects. *Agronomy*, 8(7): 128.
- Ogweno, J.O.; Song, X.S.; Shi, K.; Hu, W.H.; Mao, W.H.; Zhou, Y.H.; Yu, J.Q. and Nogués, S. (2008). Brassinosteroids alleviate heat-induced inhibition of photosynthesis by increasing carboxylation efficiency and enhancing antioxidant systems in *Lycopersicon esculentum*. *Journal of Plant Growth Regulation*, 27(1): 49–57.
- Ozdimir, F.; Bor, M.; Demiral, T. and Turkan, I. (2004). Effects of 24-epibrassinolide on seed germination , seedling growth , lipid peroxidation , proline content and antioxidative system of rice (*Oryza sativa* L.) under salinity stress. *Plant Growth Regulation*, 42(Fujioka 1999), 203–211.
- Prasad, P.V.V. and Jagadish, S.V.K. (2015). Field Crops and the Fear of Heat Stress – Opportunities, Challenges and Future Directions. *Procedia Environmental Sciences*, 29(Agri): 36–37.
- Purnama, P.R.; Purnama, E.R.; Manuhara, Y.S.W.; Hariyanto, S. and Purnobasuki, H. (2018). Effect of

- high temperature stress on changes in morphology, anatomy and chlorophyll content in tropical seagrass *Thalassia hemprichii*. *AACL Bioflux*, 11(6): 1825–1833.
- Rai, K.K.; Rai, N. and Rai, S.P. (2018). Response of *Lablab purpureus* L. to high temperature stress and role of exogenous protectants in mitigating high temperature induced oxidative damages. *Molecular Biology Reports*, 45(5): 1375–1395.
- Rosbakh, S.; Römermann, C. and Poschlod, P. (2015). Specific leaf area correlates with temperature: new evidence of trait variation at the population, species and community levels. *Alpine Botany*, 125(2): 79–86.
- Sato, S.; Kamiyama, M.; Iwata, T.; Makita, N.; Furukawa, H. and Ikeda, H. (2006). Moderate increase of mean daily temperature adversely affects fruit set of *Lycopersicon esculentum* by disrupting specific physiological processes in male reproductive development. *Annals of Botany*, 97(5): 731–738.
- Sharkey, T.D. (2005). Effects of moderate heat stress on photosynthesis: importance of thylakoid reactions, rubisco deactivation, reactive oxygen species, and thermotolerance provided by isoprene. *Plant, Cell and Environment*, 28: 269–277.
- Sharma, P.; Jha, A.B.; Dubey, R.S. and Pessarakli, M. (2012). Reactive Oxygen Species, Oxidative Damage, and Antioxidative Defense Mechanism in Plants under Stressful Conditions. *Journal of Botany*, 2012: 1–26.
- Sønsteby, A.; Solhaug, K.A. and Heide, O.M. (2016). Functional growth analysis of 'Sonata' strawberry plants grown under controlled temperature and daylength conditions. *Scientia Horticulturae*, 211: 26–33.
- Srinivasan, J. (2009). Climate change, greenhouse gases and aerosols. *Resonance*, 13(12): 1146–1155.
- The World's Healthiest Foods. (2019). *Cantaloupe: What's New and Beneficial About Cantaloupe*. <http://www.whfoods.com/genpage.php?tname=foodspice&dbid=17>
- Wahid, A. (2007). Physiological implications of metabolite biosynthesis for net assimilation and heat-stress tolerance of sugarcane (*Saccharum officinarum*) sprouts. *Journal of Plant Research*, 120(2): 219–228.
- Wang, Lina, Yang, X.; Ren, Z. and Wang, X. (2014). The Co-Involvement of Light and Air Temperature in Regulation of Sex Expression in Monoecious Cucumber (*Cucumis sativus* L.). *Agricultural Sciences*, 05(10): 858–863.
- Wang, Liwei, Zhou, H.; Guo, S.; An, Y.; Shu, S.; Lu, N. and Sun, J. (2018). Exogenous spermidine maintains the chloroplast structure of cucumber seedlings and inhibits the degradation of photosynthetic protein complexes under high-temperature stress. *Acta Physiologiae Plantarum*, 40(3).
- Wien, H.C.; Stapleton, S.C.; Maynard, D.N.; McClurg, C. and Riggs, D. (2004). Flowering, sex expression, and fruiting of pumpkin (*Cucurbita* sp.) cultivars under various temperatures in greenhouse and distant field trials. *HortScience*, 39(2): 239–242.
- Zhang, Y.P.; He, J.; Yang, S.J. and Chen, Y.Y. (2014). Exogenous 24-epibrassinolide ameliorates high temperature-induced inhibition of growth and photosynthesis in *Cucumis melo*. *Biologia Plantarum*, 58(2): 311–318.
- Zhang, Y.P.; Zhu, X.H.; Ding, H.D.; Yang, S.J. and Chen, Y.Y. (2013). Foliar application of 24-epibrassinolide alleviates high-temperature-induced inhibition of photosynthesis in seedlings of two melon cultivars. *Photosynthetica*, 51(3): 341–349.
- Zhao, X.; Nishimura, Y.; Fukumoto, Y. and Li, J. (2011). Effect of high temperature on active oxygen species, senescence and photosynthetic properties in cucumber leaves. *Environmental and Experimental Botany*, 70(2–3): 212–216.