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Effect of Irrigation and Nitrogen Fertilization on Growth and Yield of Capsicum (*Capsicum Annum*) under Temperature Induced Water Stress

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Abstract – *Climate change represents abnormal climatic conditions that can effect agricultural production through their impact on temperature changes and water availability. In addition to that the climate change will intensify the existing hunger and food insecurity problems since it can greatly increase the risk of crop failure and the loss of livestock. Nutrients play a vital role in the production of certain crops and its application is one of the quickest and easiest way in increasing yield. Nitrogen fertilization has been reported to mitigate the adverse effects of temperature stress and water stress. Therefore, this study has done to identify the interaction effects of temperature, irrigation and nitrogen fertilization on growth and yield of Capsicum annum. Three factors have used: temperature with two levels (Temperature stress/ T1 and Ambient temperature/T2), Irrigation with three levels (Field capacity/ I1, 150% of field capacity/ I2 and 200% of field capacity/ I3) and nitrogen fertilizer (recommended level/ N1, 150% of recommended level of nitrogen and 200% of recommended level of nitrogen). Three replicates have used for every treatment and trials was replicated thrice. All the treatments were arranged in Completely Randomized Design (CRD) and Analysis of variance (ANOVA) tests were conducted on the measured variables using the PROC MIXED procedure of SAS Software for Windows (University Version).*
The Duncan Multiple Range Test was used to determine the differences in treatment means at P<0.05. According to the analyzed data, all the factors and their interaction effects were significantly (P<0.05) different and influenced on growth and yield parameters of Capsicum annum. The study findings clearly revealed that under ambient temperature condition, application of currently recommended level of nitrogen by Department of Agriculture Sri Lanka was enough to obtain higher yield. However, under temperature stress condition, plants treated with 150% of the DOA recommended nitrogen fertilizer have shown significantly higher yield. Plants with the application of 200% of Nitrogen have shown poor results on growth and yield either at the temperature stress or ambient temperature conditions.

Keywords: *Temperature, Irrigation, Nitrogen, Growth, Yield*

1 INTRODUCTION

Global warming and climatic changes are huge threats to the world. Climatic changes are occurred in rapidly and its adverse nature negatively influenced on agriculture sector. Agriculture in developing countries, has received considerable attention recently with regard to climate change because of the high dependence of agriculture on the climate. The climate change represents abnormal climatic situations that can effect agricultural production through their impact on temperature changes and water availability (Syaukat, 2011). World's population is increasing at an alarming rate and is expected to reach about nine to ten billion by the end of year 2050 (Waraich *et al.,* 2012). Therefore, it resulted in additional demand for food production. According to the Second National Communication (2011), in Sri Lanka temperature is expected to rise from 1.1– 2.4 °C by 2100, depending on the rate of emission. The analysis of long-term air temperature data shows that significant warming has taken place in all climatic zones in Sri Lanka, while most locations exceed the global average rate of warming (De costa 2008). Mean surface temperatures show an increasing trend by 2.6 °C /100 years and 1.7 °C /100 years on average in annual average maximum and minimum temperature respectively in Sri Lanka. This means that the warming trend for maximum temperature is twice that for minimum temperature (Zubair *et al.,* 2010). In general, high temperature may lead to significant losses in crop productivity in many species due to limited vegetative and reproductive growth. Temperature stress also resulted in scorching and sunburns on leaves, leaf senescence and abscission, inhibition of shoot and root growth and reduction of yield. In high temperature, plants adapted to decrease leaf area, number of leaves and induced the closure of stomata to decrease transpiration losses. Then it resulted to decrease photosynthesis rate due to reduction of area of the leave, number of leaves and CO_2 fixation.

Due the temperature increment water stress or scarcity is also induced. De Silva *et al.,* (2007) predicted using HadCM3 general circulation model that, by 2050, rainfall will decrease by 9% to 17% in the main *maha* cultivation season resulting lack of water to irrigate farmer fields. Therefore, significant reduction in growth and yield of agricultural crops may be resulted.

Thus, it is very important to mitigate such temperature and water stress condition to obtain higher yield with quality. Nitrogen is very important for temperature tolerance in plants (Waraich, 2012). High temperature resulted high light intensity and it affected on mineral nutrition uptake and negatively affected on plant. Nitrogen plays a major role in utilization of absorbed light energy and photosynthetic carbon metabolism (Kato *et al.,* 2003). Furthermore, plants which were grown under high light intensity with a high N supply had greater tolerance to photo-oxidative damage (Kato *et al.,* 2003). The regulatory function of N in water stress tolerance of plant depends upon the intensity of water stress and N level. The proper N level supports regular plant growth and helps plants to defence stress (Chang *et al.,* 2016). It has been proposed that crops supplied with relatively higher N had better growth and yield performance than that supplied with low N under drought stress (Haefele *et al.,* 2008; Tran *et al.,* 2014 and Wang *et al.,* 2016). According to the earlier statements, higher N reduces the adverse effects of temperature stress and water stress on crop growth and yield.

Therefore, this study was conducted to investigate the interaction effects of temperature, irrigation and nitrogen level on growth and yield parameters of Capsicum in order to find out the best level of nitrogen and irrigation level under temperature stress conditions as well as under ambient temperature condition.

2. METHODOLOGY

Experiment was designed with three factors namely temperature, irrigation and nitrogen levels. Two temperature levels were used as higher temperature (36-37 ^{0}C) and ambient temperature (32-33 ^{0}C). Three irrigation treatments used as Field capacity, 150% from field capacity and 200% from field capacity and volume basis method has used to find above volume. Three N level were used as 100%, 150% and 200% of the recommended nitrogen level by Department of Agriculture Sri Lanka. Urea was used to provide nitrogen. Twelve treatments arranged in Complete Randomized Block Design (CRD) with three replicates. Pots were arranged randomly at the poly tunnel as well as in a plant house. Experiment was repeated thrice to replicate the poly tunnel effects.

Factor 1: Temperature – Two Levels

Temperature stress – T1 (36-37 ^{0}C)

Ambient temperature – T2 (32-33 ^{0}C)

These temperatures were selected based on IPCC result on global climate (IPCC, 2007) and the HadCM3 predictions of Sri Lankan air temperature in 2050 for A2 scenario of IPCC (De Silva *et al.*, 2007 and De Silva, 2006).

Factor 2: Irrigation Capacity–Three Levels

Field capacity soil moisture – I1

150% of field capacity soil moisture – I2

200% of field capacity soil moisture – I3

Factor 3: Nitrogen (%) – Three levels

100% from recommended level – N1

150% from recommended level – N2

200% from recommended level –N3

Poly tunnel / Temperature stress (T)

R 01	T2N3I3	T2N2I1	T2N2I2	T2N1I2	T2N2I3	T2N3I2	T2N1I1	T2N1I3	T2N3I1
R 02	T2N2I2	T2N1I2	T2N2I3	T2N3I2	T2N1I1	T2N1I3	T2N3I1	T2N3I3	T2N2I1
R 03	T2N2I3	T2N3I2	T2N1I1	T2N1I3	T2N3I1	T2N3I3	T2N2I1	T2N2I2	T2N1I2

Ambient temperature / Without temperature stress (T2)

R 01	T2N3I3	T2N2I1	T2N2I2	T2N1I2	T2N2I3	T2N3I2	T2N1I1	T2N1I3	T2N3I1
R 02	T2N2I2	T2N1I2	T2N2I3	T2N3I2	T2N1I1	T2N1I3	T2N3I1	T2N3I3	T2N2I1
R 03	T2N2I3	T2N3I2	T2N1I1	T2N1I3	T2N3I1	T2N3I3	T2N2I1	T2N2I2	T2N1I2

Fig. 1. Field Layout of the Experiment

2.2 LOCATION

2.2.1 Temperature stress in poly Tunnel

The study carried out at the Open University of Sri Lanka. One set of plants kept in temperature stress condition at the poly tunnel and temperature range maintained at 36^{0}C - 37^{0}C through an automated regulatory system. Poly tunnel is consisted with top-vent roof. When the temperature inside the poly tunnel increases above the maximum temperature set in thermostat the ventilation fans start to operate automatically until the temperature is reduced to the maximum set temperature in the thermostat.

2.2.2 Ambient Temperature in Plant House

The other set of plant kept in ambient temperature condition (32^0C - 33^0C) at plant house. Type of net house frame is rigid wall and roof of the plant house was made with polyvinyl chloride (PVC) sheet of 120 micron gauge to have more than 90% transmittance of light. UV-stabilized polyethylene shade net which covered sun by 50% was used to cover the side parts of the plant house and fiberglass hoops to support the fabric and secure it with clothespins. Free movement of air and other climatic conditions are same as outside.

2.2.3 Temperature and relative humidity variation inside the plant house and poly tunnel

There were no significant differences in RH observed in the inside and outside environment although elevated day time air temperatures in the poly tunnel resulted in higher partial pressure of water (*Gunawardena et al.,* 2011). This condition was maintained with the opening of the top of the poly tunnel which helped to maintain the same water vapour concentration compared to the outside. According to the observed data for RH, there was no significant differences in RH at the inside and outside of the plant house. In addition to that light intensity in the poly tunnel and plant house was not significantly different. Therefore, apart from the temperature other conditions were approximately similar for poly tunnel and the plant house.

The variation of temperature inside the poly tunnel and the ambient temperature of plant house over a period of 24 hours was observed as shown below (Fig.2). The temperature within the poly tunnel was lower than the maximum temperature set for that particular poly tunnel during a day represents the diurnal variation. However, the temperature maintained inside the poly tunnels was always higher than the ambient temperature at plant house; therefore, temperature stress was forced on the plants during daytime while there was photosynthetic activity.

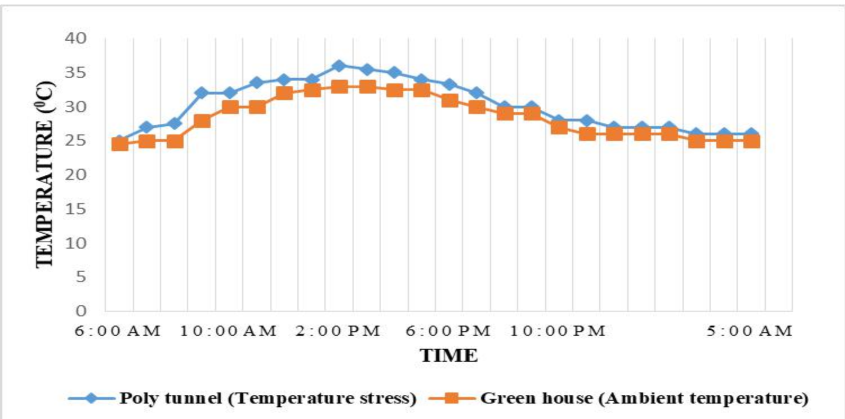

Fig. 2. Variation of temperature with time (day) inside of the poly tunnel and the plant house

2.3 EXPERIMENTAL DESIGN

The experiment was arranged with three factor factorial experiment with twelve treatments in pots. The pots (each 25cm high and 28.5 cm in bottom diameter) were filled with Reddish Brown Earth Soil collected from Anuradhapura. Before experiment started, soil was prepared by removing stones and crop residues air dried, crushed, and well mixed thoroughly to avoid water logging conditions. CA-8 variety of Capsicum (*Capsicum annum*) was used for the experiment and nursery was maintained for one month. Thereafter, one month old plants were planted in pots, fertilization was done according to the recommendation of Department of Agriculture (DOA), Sri Lanka. Application of nitrogen fertilizer at appropriate intervals was done as recommended by DOA. Field capacity of the soil measured using pressure plate apparatus by applying 1/3 bar pressure. As a control, additional ten pots were kept inside the poly tunnel and the plant house without adding fertilizer and plants to determine the weight losses in soil due to evaporation. Pots irrigated to field capacity. Before watering at each time, the pots were weighted and confirmed the constant weight in all pots. According to the weight losses in additional pots, amounts of water required for each pot to fulfill the field capacity, 150% from field capacity and 200% from field capacity were calculated and applied the calculated amount of water to treatments. Therefore, irrigation was done once per two days according to the treatments (Field capacity (I1) 150% from field capacity (I2), 200% field capacity (I3)) by compensating the loss in weight.

Growth parameters were measured once per two weeks till the end of the growing season and yield parameters were taken at harvest. Analysis of variance (ANOVA) tests were conducted on the measured variables using the PROC MIXED procedure of SAS software for Windows (University Version). Treatment effects due to N fertilizer, temperature stress, irrigation amount and their interactions on growth and yield parameters were tested. The Duncan Multiple Range Test was used to determine the differences in treatment means at $P < 0.05$. A probability level of 0.05 was considered to identify significantly different treatment means in this study.

3.0 RESULTS AND DISCUSSION

3.1 Growth parameters of *Capsicum annum*

3.1.1 Plant height (cm)

According to the analysed data, all the factors and their interaction effect have significantly ($P<0.05$) influenced on plant height. Under ambient temperature condition, significantly highest plant heights were shown in treatments with 100% DOA recommended Nitrogen fertilizer and field capacity level of irrigation (T2N1I1), 150% nitrogen fertilizer with field capacity (T2N2I1) and 150% of the field capacity (T2N2I2) level irrigation. Therefore, under ambient temperature conditions, increment of nitrogen fertilizer application or the irrigation above the field capacity level is not necessary as there is no significant difference ($p>0.05$) among these treatments. Under temperature stress condition, significantly highest plant heights were shown in treatments with 150%

of the DOA recommended levels of nitrogen fertilizer with field capacity (T1N2I1) and 150% of the field capacity (T1N2I2) level irrigation. Therefore, under temperature stress condition, application of nitrogen fertilizer higher than the recommended level is beneficial. Efficient nitrogen nutrition has the capability to assuage water stress and temperature stress in crops by sustaining metabolic activities (Saud *et al.,* 2017). However, too much of nitrogen fertilizer application cannot be recommended because treatments with 200% nitrogen of recommendation have resulted lower performances either at temperature stress condition or ambient temperature condition. It could be the excessive use of nitrate fertilizer to plants induce toxicity.

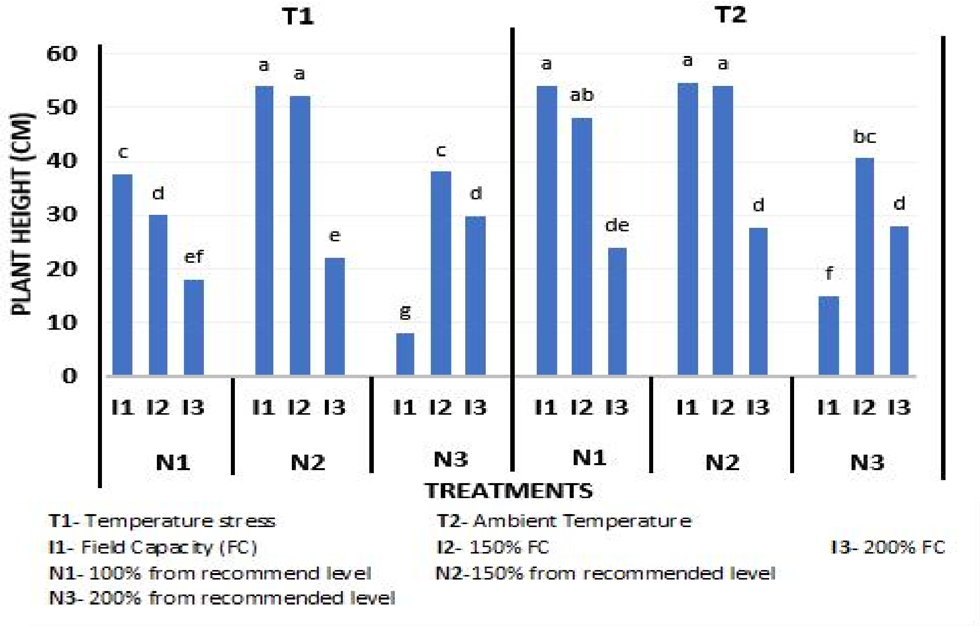

Fig.3. Effect of different treatments on plant height (cm) of *Capsicum annum* at 75days after planting

Note: Values followed by same letter are not significantly different at p =0.05 level

3.1.2 Number of leaves

Results of number of leaves also followed the same pattern as the results of plant height. Treatment of 200% nitrogen (DOA recommendation) with irrigated to field capacity has resulted the lowest number of leaves at both temperature stress and ambient temperature conditions (T1N3I1, T2N3I1). Treatments of 150% nitrogen of DOA recommendation with irrigation at field capacity and 150% of field capacity levels either at the temperature stress or ambient temperature condition (T1N2I1, T1N2I2, T2N2I1, T2N2I2) have resulted higher number of leaves. However, these treatments have not significantly differed (P>0.05) from the treatment with recommended level of nitrogen and irrigated to field capacity (T2N1I1). Therefore, under ambient temperature condition recommended level of nitrogen has enough to obtain higher number of leaves and it is contrast to the results under temperature stress condition. Because, under temperature stress condition, recommended level of nitrogen is not sufficient to obtain higher number of leaves.

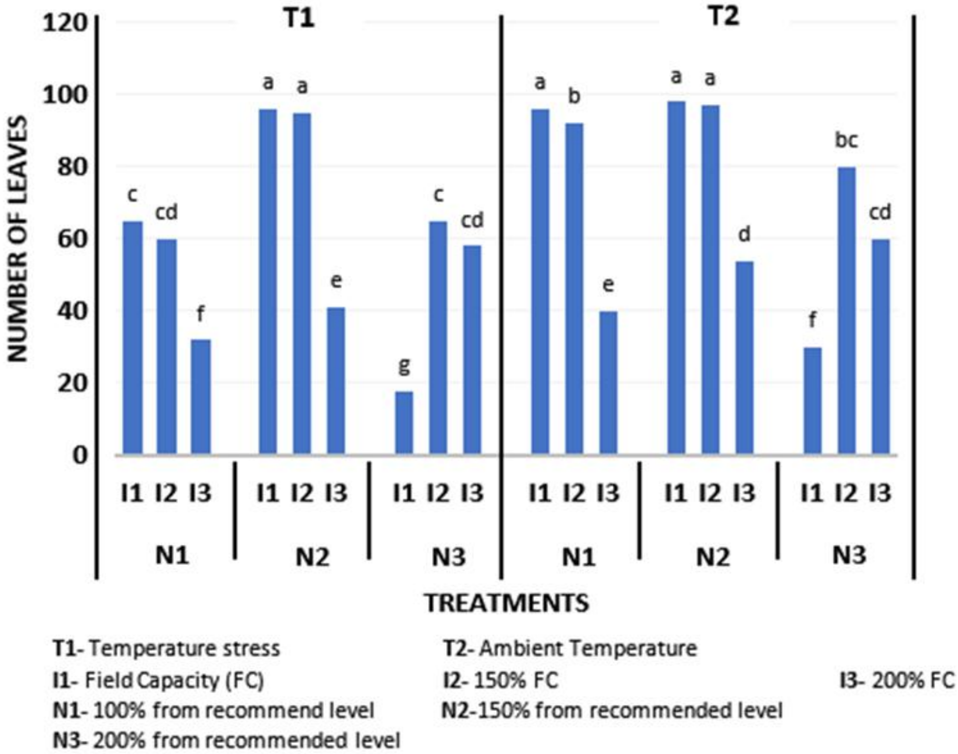

Fig.4. Effect of different treatments on number of leaves of *Capsicum annum* at 75days after planting (*Values followed by same letter are not significantly different at p =0.05 level)*

3.1.3 Leaf area (cm^2)

Leaf area is one of the very important parameters because it has influence on photosynthesis. According to the analysed data all the parameters and their interaction effects (Temperature* Nitrogen* Irrigation) have significantly ($P<0.05$) influenced on leaf area. Leaf area of treatments with 150% nitrogen of DOA recommendation and irrigated to field capacity has shown the highest leaf area under the temperature stress condition (T1N2I1) and it was not significantly different ($P>0.05$) from the treatment with that in 150% nitrogen of DOA recommendation and irrigated to 150% of field capacity under temperature stress condition (T1N2I2). Under ambient temperature condition, treatments treated with 150% nitrogen (DOA recommendation) and irrigated to field capacity and 150% of field capacity (T2N2I1, T2N2I2) have shown higher leaf area. However, those treatments are not significantly different from the treatment applied with recommended level of nitrogen and irrigated to field capacity under ambient temperature condition (T2N1I1). According to this finding, it is not needed to increase the amount of nitrogen beyond the recommended level under ambient temperature condition. Barrs (1968) reported that favourable weather condition and management practices are important to increase leaf area.

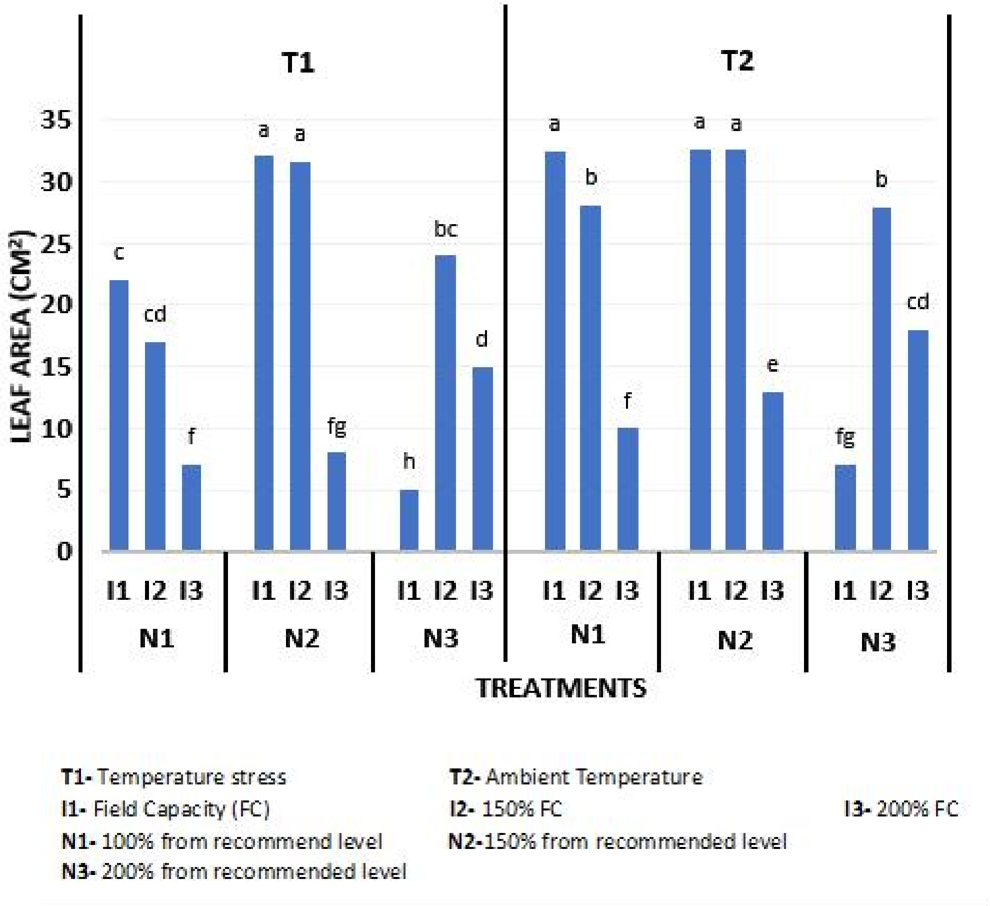

Fig.5. Effect of different treatments on leaf area (cm²) of *Capsicum annum* at reproductive stage

(*Values followed by same letter are not significantly different at p =0.05 level)*

3.1.4 Number of branches

According to analysed data effect of temperature, irrigation and nitrogen has significantly ($p<0.05$) influenced on number of branches. Treatments with 200% nitrogen of recommendation and irrigated to field capacity have resulted lowest number of branches at temperature stress (T1N3I1) and ambient temperature condition (T2N3I1), respectively. Vos *et al.*, (2005) reported that effective level of nitrogen application promoted branching. Treatments with recommended level of nitrogen application under every irrigation at temperature stress condition (T1N1I1, T1N1I2, T1N1I3) have shown lower number of branches. However, treatment with application of DOA recommended level of nitrogen and irrigated to field capacity under ambient temperature condition (T2N1I1) has shown positive influence on number of branches. Therefore, 150%of the DOA recommendation of nitrogen application has given the ability with stand the temperature stress as well as the highest number of branches.

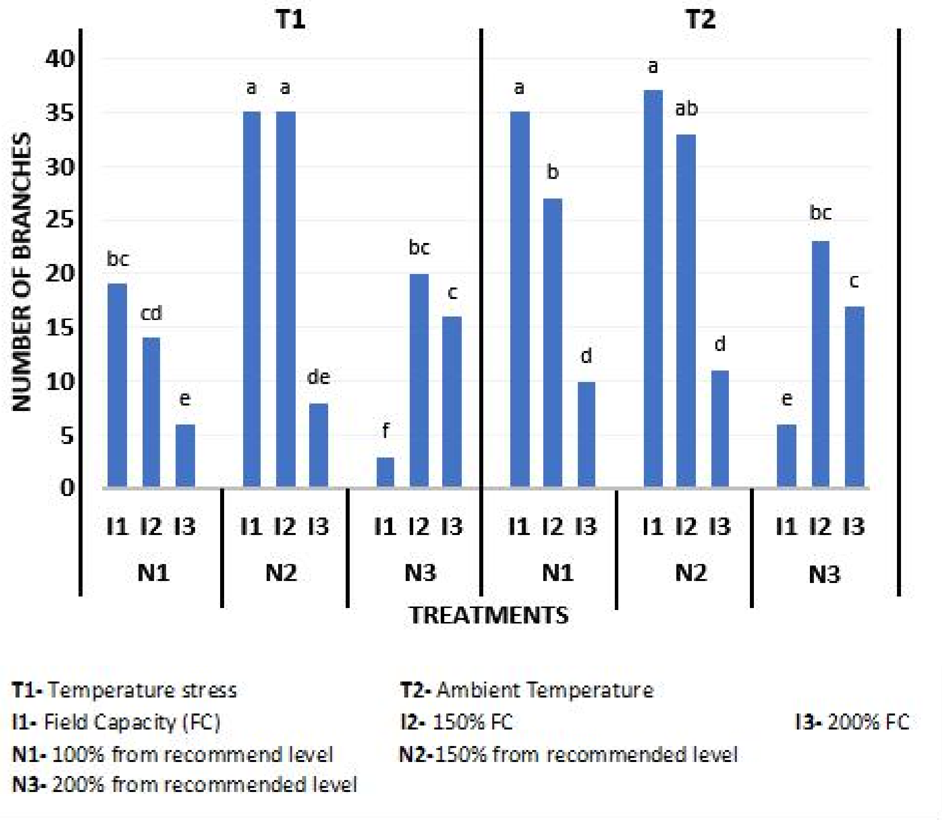

Fig. 6. Effect of different treatments on number of branches of *Capsicum annum* at 75 days after planting

(*Values followed by same letter are not significantly different at p =0.05 level)*

3.2 Yield parameters of *Capsicum annum*

3.2.1 Number of flowers

Number of flowers also significantly influenced ($p<0.05$) by all the factors and their interaction effects. Under temperature stress conditions, application of recommended level of nitrogen fertilizer has not produced higher number of flowers in all three irrigation treatments (T1N1I1, T1N1I2, T1N1I3). However, at the ambient temperature condition treatment with application of DOA recommended level of nitrogen and irrigated to field capacity (T2N1I1) has produced higher number of flowers. Under temperature stress condition, treatments which applied with 150% nitrogen of recommendation with irrigated to field capacity and 150% of field capacity have resulted higher number of flower production. This may be due to the fact that when nitrogen fertilizer applied above the recommended dosage (150%) it enhanced the plants in temperature stress to produce higher number of flowers. Treatments with 200% nitrogen of DOA recommendation have resulted lower number of flowers either at the temperature stress condition or ambient temperature condition under all three irrigation treatments (T1N3I1, T1N3I2, T1N3I3, T2N3I1, T2N3I2, T2N3I3). This may be due to the toxic effect of higher nitrogen dosage to the plants.

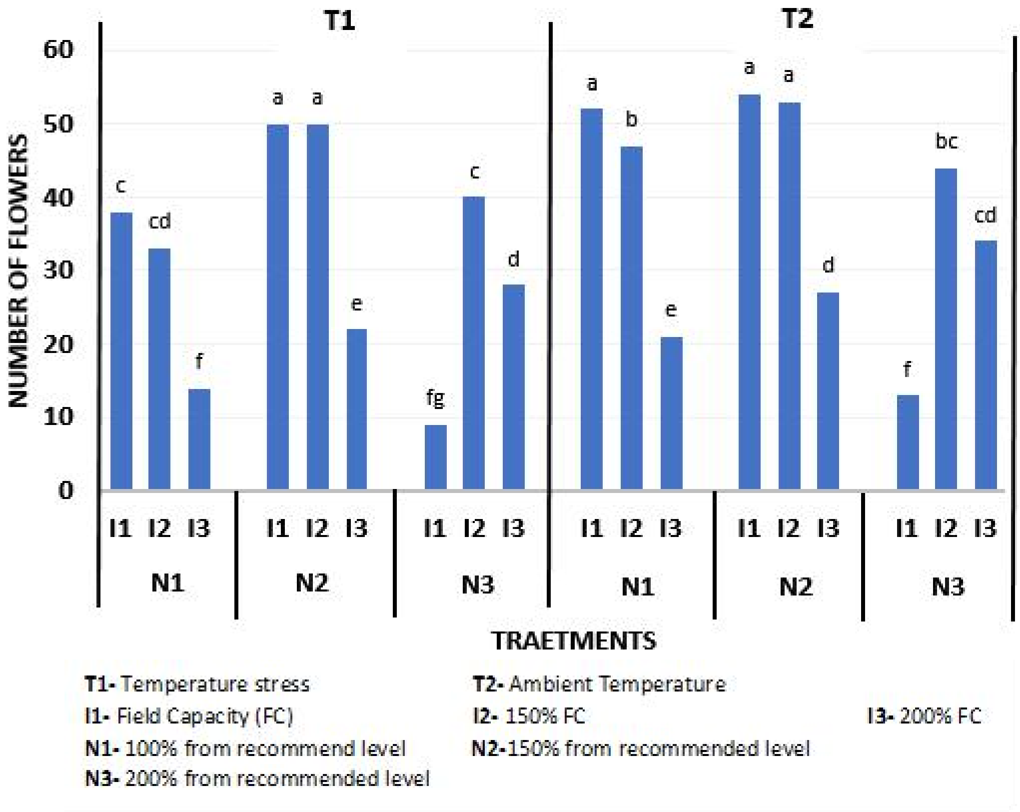

Fig. 7. Effect of different treatments on number of flowers of *Capsicum annum*

(Values followed by same letter are not significantly different at p =0.05 level)

3.2.2 Number of pods

All the treatment and their interaction effect have significant ($p<0.05$) influenced on number pods. Number of pods variation has directly proportional to the number of flowers. According to the analysed data treatments which incorporated with 200% nitrogen of recommendation have resulted lower number of pods similar to number of flowers either at the temperature stress condition or ambient temperature condition under all three irrigation treatments (T1N3I1, T1N3I2, T1N3I3, T2N3I1, T2N3I2, T2N3I3). Temperature stress conditions throughout the growing season significantly reduced yield and fruit size of capsicum (Molla Md *et al.,* 2003). Under temperature stress condition application of recommended level of nitrogen was not sufficient to obtain higher number pods in all three irrigation treatments (T1N1I1, T1N1I2, T1N1I3). Significantly highest number of pods were shown in treatment with 150% of Nitrogen fertilizer in field capacity and 150% of field capacity moisture level irrigations. Therefore, better to increase the amount of nitrogen application, when plants are under temperature stress. However, higher doses above 150% of recommended level of nitrogen application may become toxic to capsicum plants. According to the findings, application 150% nitrogen of DOA recommendation and irrigation at field capacity and 150% of field capacity soil moisture levels have shown better results on number of pod production under temperature stress condition (T1N2I1, T2N2I2). However, under ambient temperature condition, DOA recommended dosage of nitrogen fertilizer is sufficient to produce significant yield in

Capsicum plants.

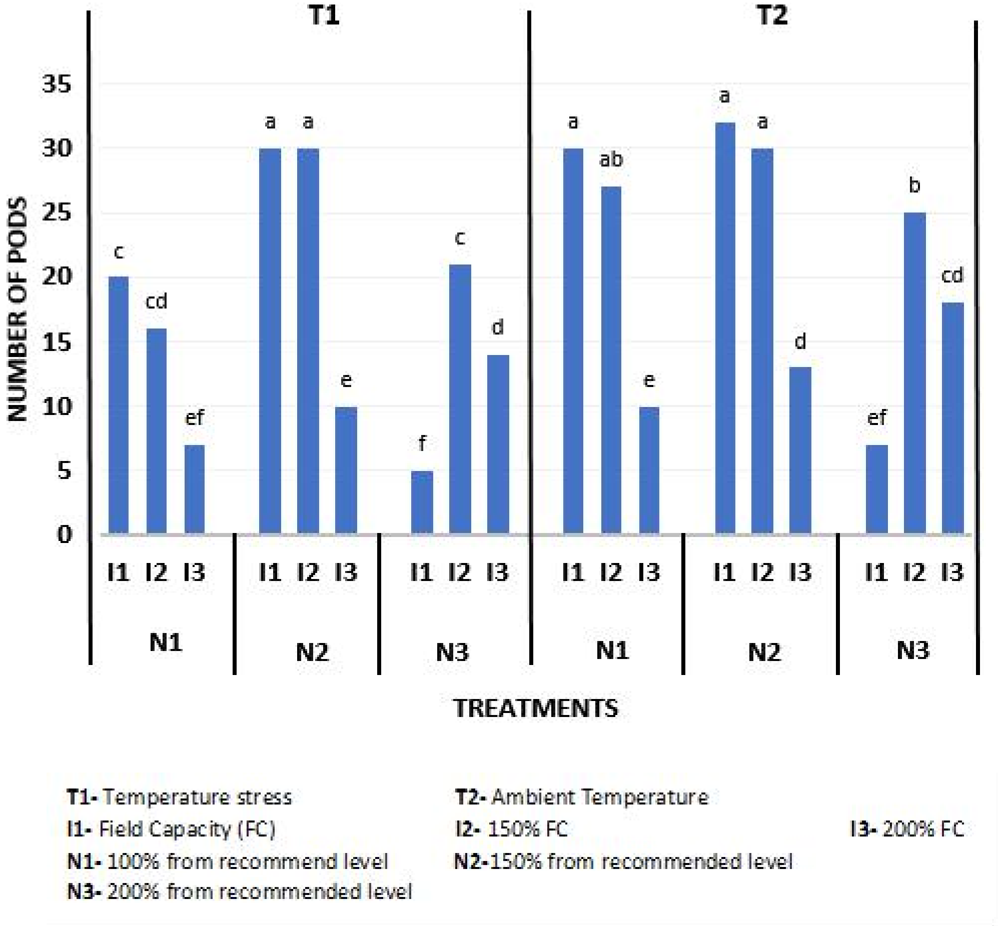

Fig. 8. Effect of different treatments on number of pods of *Capsicum annum* at the harvesting stage

(*Values followed by same letter are not significantly different at p =0.05 level)*

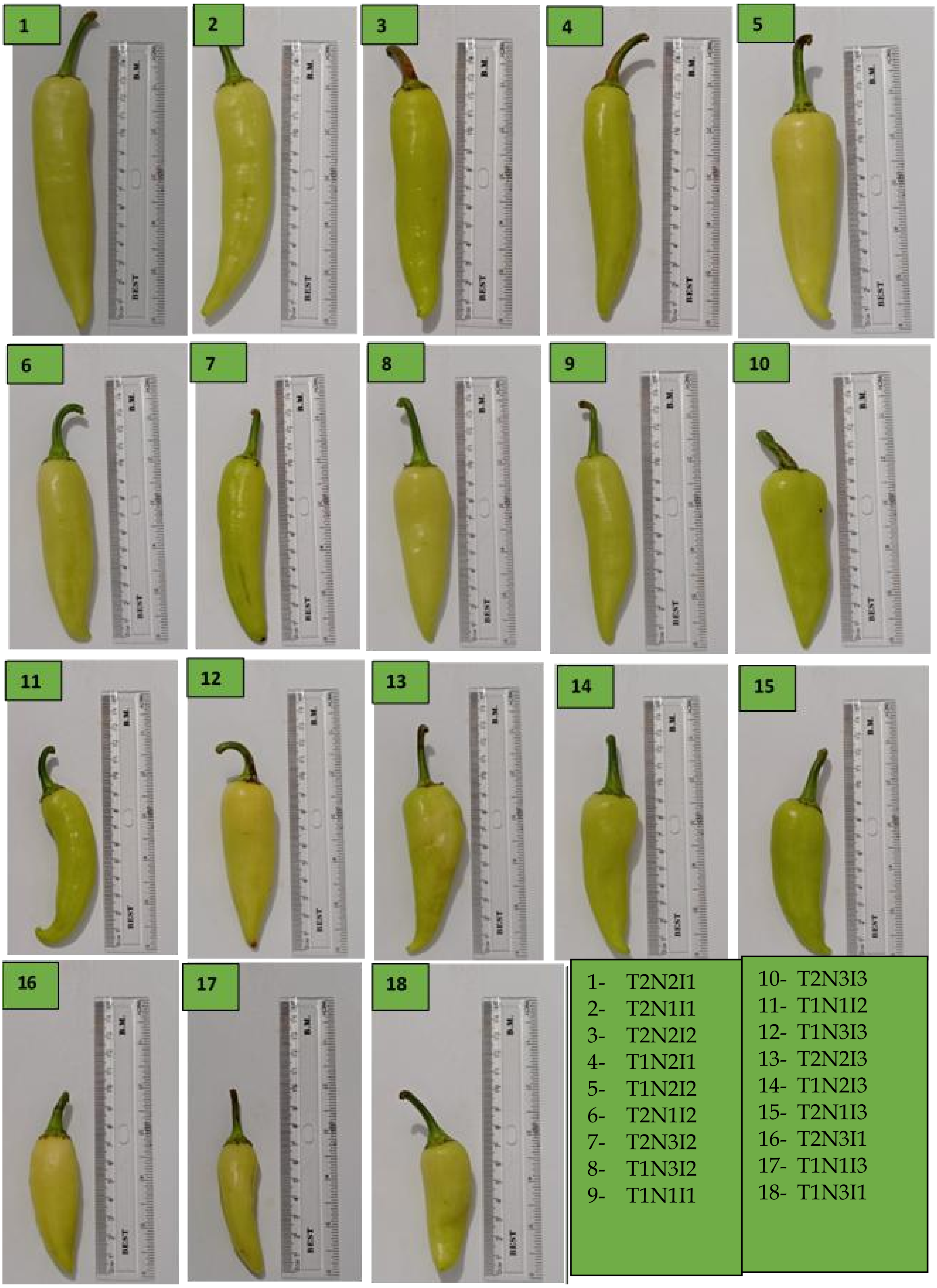

Fig. 9. Effects of different treatments on length of pods (cm) at harvest

4.0 CONCLUSION AND RECOMMENDATION

According to this study interaction effect of temperature, irrigation and nitrogen has significant contribution on growth and yield parameters of *Capsicum annum*. Application of higher level of nitrogen fertilizer is vital to improve growth and yield parameters of Capsicum under temperature stress condition. However, application of too much of nitrogen resulted negative impact on measured parameters of Capsicum either at the temperature stress or ambient temperature. According to the results of the study, application of recommended level of nitrogen fertilizer in all three irrigation treatments under temperature stress condition was not enough to obtain higher yield. Therefore, application of 150% nitrogen of DOA recommendation with irrigation at field capacity level of soil moisture will increase the yield of Capsicum under temperature stress conditions. However, under ambient temperature condition, it is better to follow the currently recommended level of nitrogen fertilizer application by the Department of Agriculture in Sri Lanka.

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