Research Article

Effect of Global Warming Induced Temperature and Water Stress on *Musa acuminata* (Cavendish Banana)

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Abstract

Anthropogenic activities have changed the global climate adversely. Plant growth and development depend on the atmospheric temperature and soil moisture level. When the temperature exceeds the optimum and when there is water stress also, plants respond negatively showing a sharp decline in growth and development affecting the yield. This study intends to investigate the impact of simulated temperature and water stress reflecting global warming on in vitro propagated banana plants. It is presumed that this research would help in planning the cultivation of said plants to obtain a substantial yield. Shoot initiation of banana was carried out using sword suckers on Murashige and Skoog medium with 2.5 mg/L Benzyl Adenine and shoot proliferation on MS medium with 4.0 mg/L BA. Rooting occurred on the shoot proliferation medium itself by maintaining for 4-5 weeks after the shoots have developed well. After acclimatizing the plants were transferred into two locations viz. temperature regulated polytunnel (maximum temperature 35 ℃) and plant house (ambient temperature). Plants in each location were further subjected to 100% and 50% moisture levels. All the experiments were repeated twice to justify the replication of temperature effect. The mean values of the vegetative parameters were taken for statistical analysis. The results revealed that the vegetative and hence the reproductive growth of in vitro propagated banana were not successful under stressful conditions, because all the plants exposed to temperature stress and water stress were dead at the 40th week of the study. Therefore, banana will not be a successful crop under the induced global warming conditions, because the plants under the stresses did not show either vegetative or reproductive growth successfully.

Keywords*: Banana, global warming, growth parameters, temperature stress, water stress*

1. Introduction

The temperature increment due to global warming is a major problem faced by the world today. According to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2001), the cause of this is mainly the anthropogenic emission of various greenhouse gasses such as carbon dioxide, methane, and nitrous oxide, which are emitted at an increasing rate with the economic and population growth of the world since the pre-industrial era.

Sri Lanka would also face the consequences of this temperature increment. As reported by Chandrapala and Fernando (1995), there was an increase in temperature in Colombo by 0.0164 ℃ during the period of 1961 to 1990.

It was predicted by General Circulation Model (HadCM3) that the annual average global temperature would increase. During May to September, the southwest monsoonal period, the annual air temperature across Sri Lanka is predicted to be increased by 1.6 ℃ (A2 scenario) and by 1.2 ℃ (B2 scenario). Further, it is predicted that northeast monsoons also would decrease in the coming years (De Silva *et al*., 2007).

Sri Lanka is experiencing these effects even now because temperature related extreme indices have risen over most parts of the country and the annual average rainfall has been decreasing at a rate of about 7 mm per year, for the last 57 years (Ranasinghe *et al*., 2014).

The increase in temperature and the decrease in rainfall would affect the growth and development of plants. Plants would be subjected to temperature as well as water stress due to an increase in evapotranspiration. The agricultural activities which involve plant growth and development would be heavily affected by climate change because the harvest is largely dependent on growth and development.

Chapin *et al*., (1987) reported that temperature and soil moisture are important factors that determine the growth and productivity of plants. De Silva (2006) has predicted that increase in temperature will lead to increase in soil moisture deficit and additional irrigation water would be needed to satisfy the evapotranspiration demand.

Hatfield and Prueger (2015) also reported that the rate of plant growth and development depends on the surrounding temperature of the plant and each plant species has a specific temperature range represented by minimum, maximum and optimum temperatures.

Dishani and De Silva (2013) reported that temperature plays a major role in the growth and development of plants. When the temperature exceeds the optimum level required for biological processes, the plants would respond negatively, especially showing a steep decline in growth and yield (Rozenweig and Hillel, 1995). According to Pastori and Foyer (2002), an increase of one degree above normal would lead to a significant reduction in the growth and yield of a plant.

Tissue culture is a field that is very popular in Sri Lanka as well as worldwide and there are many large-scale tissue culture laboratories established worldwide for mass-scale clonal propagation. Idowu *et al*., (2009), reported that tissue culture is a well-established technology, all over the world.

Sri Lanka also has many commercialized laboratories, which produce tissue cultured plants mainly for the export market and the country earns foreign exchange from this industry (Padukkage *et.al*.,(2023). In addition, some laboratories produce many different varieties of plants including mainly banana and pineapple for local farmers. They prefer the *in vitro* propagated plants to their counterparts obtained through traditional vegetative propagation methods, due to many beneficial characteristics such as high yield and early fruiting.

This research was carried out to study effect of climate change on *in vitro* propagated plants is very important, since only a limited number of research of this kind have been carried out in Sri Lanka or worldwide up to now. Furthermore, research on the impact of climate change on banana has not been conducted so far. Therefore, this study would be vital to those who are involved in the field of tissue culture as well as the cultivation of banana.

As reported by Mbaka *et. al*.,(2008), *in vitro* propagated plants are usually produced by obtaining explants from selected healthy mother plants, having desirable characteristics such as ability to withstand stress, producing high yield and disease resistance.

1.1 Justification for selecting banana (Musa spp.)

Banana is one of the most important crop plants in Sri Lanka, as a fruit, and is exported to other countries and Sri Lanka earns foreign exchange. Due to these reasons banana (variety Cavendish) was selected as a model plant for this study.

Banana (Musa spp.) is a member of the family Musaceae and is one of the oldest fruits in the world. According to Singh (1969) it is a basic important nutritious food source. Banana ranks as the fourth most important food crop in the world when the production is considered and has an economic significance to many developing countries (Nazriya *et al*., 2007)). Also, banana has many health benefits as it is a good source of minerals and vitamins (Singh *et al*., 2016). Banana is considered to be a good source of income locally and internationally and an important foreign exchange earner (Central Bank of Sri Lanka, 2021).

Annual banana production in Sri Lanka is around 780,000 metric tons. The average yield of banana comes to around 13 x 103 kg/ha. At present, 5% of the total production is exported mainly to Middle East countries (Central Bank of Sri Lanka, 2021).

The main aim of the research project was to study the impact of induced temperature and water stress on vegetative and reproductive characteristics of the banana (Musa spp.) plants, developed through tissue culture technology. The specific objectives are (i) to *in vitro* propagate banana plants up to field testing level and (ii) to study the effect of induced temperature and water stress reflecting global warming on growth and yield parameters of, *in vitro* propagated banana (var: Cavendish) plants.

Material and Methods

2.1 Sterilization of equipment

The glassware required for the preparation of media, sterilization, and inoculation of the explants were washed with the detergent liquid, Vim dish wash and running tap water and allowed to dry in a dryer. The glassware then was sterilized in hot air oven at 180 ℃ for two hours.

The metal equipment such as scalpels and pair of forceps were washed with detergent and running tap water. These were then wrapped in aluminum foil and sterilized in hot air oven at 180 ℃ for two hours. After each inoculation, the metal tools were dipped in 70% ethyl alcohol and flamed.

The bench and the inner walls of the laminar flow cabinet were cleaned with 70% ethyl alcohol before and after use.

2.2 Preparation of stock solutions and media

Modified Murashige and Skoog's medium, (MS medium; Murashige and Skoog, 1962) was used as the basal medium. Different growth regulator combinations were incorporated into this medium depending on the requirement.

Stock solutions of macro elements, microelements, vitamins, Ferrous Sodium EDTA required for MS medium, and hormones were prepared using distilled water and stored in the refrigerator, to use when necessary. Appropriate aliquots of each stock solution were used when each medium was prepared. In addition, Bacteriological agar and sucrose were also incorporated into each medium as a gelling agent and a carbon source respectively.

Different types of media necessary for shoot initiation, proliferation, sub culturing and rooting were prepared accordingly, and the pH of the media was adjusted to 5.8±0.1 with the use of 0.1 M NaOH or 0.1 M HCl.

2.3. Sterilization of media

25 mL of the media was dispensed into sterilized jam bottles, covered with previously autoclaved polypropylene, and secured with rubber bands. The bottles containing media were autoclaved at 121 ℃ temperature and 1.05 kg/cm2 for 15 min.

2.4. Selection of explants and surface sterilization

Explants were selected from healthy mother plants of Musa spp. variety Cavendish brought from CIC Agri Farm, Pelwehera, Dambulla and grown in the home garden. Four to six weeks old sword suckers were used as explants.

The outer leaves and the roots of the explant were removed and washed thoroughly with water to remove soil particles. Some of the outer whorls of leaves were further removed. The corm was then cut into a cube of 1.5 cm^3. The height of pseudo-stem was also reduced to 1.5 cm. Then these cubes were washed in running tap water by immersing in a beaker containing water and the detergent Teepol. The surface sterilization was carried out with 50% Clorox (Commercial bleach, 5.2% Sodium Hypochlorite) for 10 minutes and rinsing three times, one minute in each rinse, with sterilized distilled water under the laminar flow cabinet following the method explained by Nagahawatte *et al*. (2014).

2.5. Shoot initiation, proliferation and rooting in shoots

Shoot initiation of banana was carried out on MS basal medium, incorporated with 2.5 mg/L benzyl adenine (BA) under a laminar flow cabinet. The cultures were incubated under 16-h photoperiod at 25 ℃ with light intensity of 3000-4000 lux in a culture room (Nagahawatte *et al*., 2014).

The initiated shoots were transferred after separating into parts having two to three shoots, into a MS basal medium fortified with 4.0 mg/L BA and incubated under conditions similar to shoot initiation (Nagahawatte *et al*., 2014).

After two subcultures, the shoots were maintained, in the medium of shoot proliferation itself, for four to five weeks for rooting.

2.6. Acclimatization and maintenance of plants

Rooted plantlets were washed well with tap water to remove agar, and then planted in pots with potting medium of coir dust, compost and burnt rice hull in 2:2:1 ratio and maintained in a plant house at ambient temperature and watered daily.

The acclimatized, *in vitro* propagated plants of banana were potted, one plant each in pots having a diameter of 0.5 m, in a potting medium of topsoil, coir dust and compost in 1:1:1 ratio. All the pots were filled with this mixture in equal amounts.

2.7. Temperature regulated polytunnel and the climatic conditions

The polytunnel (Figure 1) was constructed in the agricultural fields of the Open University premises, Nawala, in which the maximum daily temperature was maintained at 35℃.

The polytunnel was constructed in the direction of North-South to prevent the effect of mutual shading. The floor area of the tunnel was approximately 6.7 x 3.3 m^2 and the top was semi-circular in shape. The basic structure was constructed with galvanized iron (GI) pipes and covered with UV treated polythene having the gauge of 120 microns. There was a manually operated door to access the tunnel.

The top of the tunnel has a semi-circular roof which has an opening enabling air circulation to maintain near natural conditions of relative humidity and CO^2 concentration.

Above conditions satisfied simulation of high temperature inside the tunnel. However, in order to prevent the temperature from rising above the set temperature of 35 ℃, there were two exhaust fans and a thermostat installed. When the internal temperature increased above the set temperature, the automation of fans would bring the temperature down to 35 ℃.

(a) **(b)**

Figure 1: The external (a) and internal (b) view of the polytunnel in which the plants were maintained at a maximum temperature of 35 ^{o}C

2.8. Temperature control in the polytunnel

The variation of the temperature inside the polytunnel and the ambient temperature outside over a period of 24 hours was measured (Figure 2). The temperature at night fell below the maximum temperature set for the polytunnel to represent the diurnal variation. However, the temperature maintained inside the polytunnel was always higher than the ambient temperature; therefore, temperature stress was enforced on the plants during the daytime while there was photosynthetic activity.

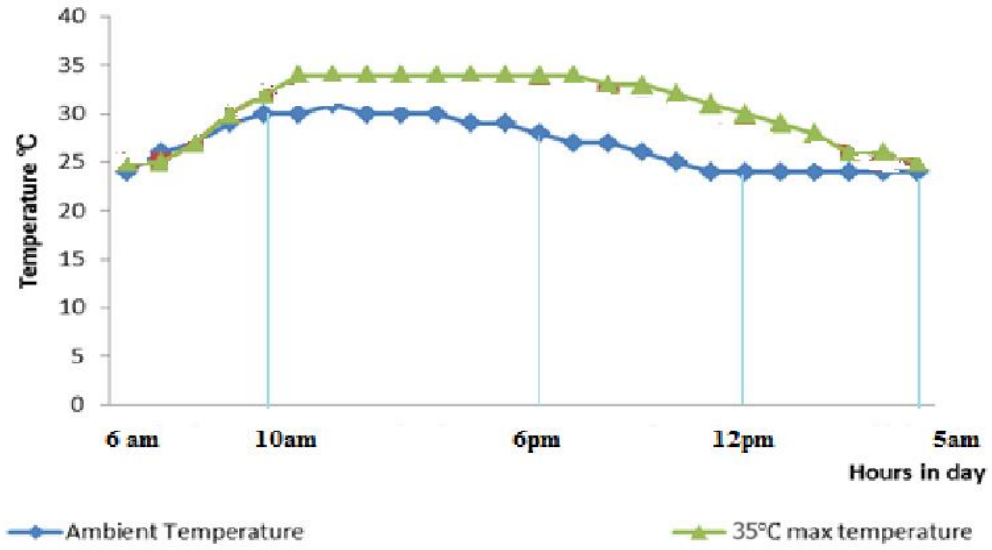

Figure 2: Temperature variation inside and outside the polytunnel

2.9. Experimental design

Pots containing banana plants were individually divided into two equal groups. Then one group of plants was kept inside a polytunnel (Plate 2) with a temperature control system at a maximum daily temperature of 35 ^{o}C while the other group was maintained at ambient temperature inside a plant house in the same arrangement. Then two water regimes i.e., 100% field capacity and 50% of the field capacity, were imposed on plants growing both at 35 ^{o}C and ambient temperature. The experiment was arranged with four treatments (Table 1) as factorial (two factor) completely randomized design with six replicates of banana plants for each treatment.

(a) **(b)**

Figure 3: Arrangement of banana plants in the polytunnel at 35 ^{o}C (a) with 50% water stress (b) without water stress

Table 1: Two different environmental conditions of the experiment

No	Environmental conditions
Condition 1 - Polytunnel	Polytunnel (35 ℃) at 50% and 100% of field capacity soil moisture
Condition 2 - Plant house	Ambient Temperature (28 ℃ -30 ℃) at 50% and 100% of field capacity soil moisture

2.10. Manuring and plant care

Except for water management, banana plants were manured and maintained according to the recommendation of the CIC Agri Farm. The water management of the plants was done as described in Table 1.

2.11. Measurement of growth parameters

Immediately after plants were transferred to each location, and at four-week time intervals, vegetative growth parameters such as mean height of plants, mean number of functional leaves, mean length and width of leaves were measured. The girth of pseudo-stem at the base was also recorded. These measurements were recorded in all four treatments of banana plants.

2.12. Measurement of physiological parameters

2.12.1. Leaf chlorophyll content of banana leaves

Soil-Plant-Analysis-Development (SPAD) 502 chlorophyll meter (Minolta Camera Co, Osaka, Japan) was used to estimate the total chlorophyll content of banana plants.

The measurements were taken on both sides of the mid rib of banana leaves selecting six locations altogether, three on the left and three on right side of the vein of banana leaf. The three locations selected on each side were at one third from the base of the leaf, at the mid- point of the leaf and at one third from the tip of the leaf. The measurements were recorded randomly selecting, three fully expanded healthy leaves from each plant. The mean value of six SPAD readings was taken as a single average reading for a leaf. SPAD measurements were recorded as soon as the four treatments were imposed and at four-week intervals.

2.13. Measurement of yield and quality parameters of banana

Any yield parameter could not be measured as the banana plants did not produce fruits. The probable reason could be the unavailability of sufficient space for rooting from the pots having a diameter of 0.5 m. The recommended size by CIC Agri Farm, Pelwehera for the pits was 0.31 m^3. As the plants were to impose water stress, they had to be planted in pots.

2.14. Data analysis

ANOVA was carried out to analyze the parameters related to growth using SAS University software package. All the analyses were carried out at least in duplicate and in randomized order with the mean values for each treatment using six replicates to deduce random error.

3. Results and Discussion

3.1. *In vitro* propagation of banana

3.1.1. Shoot initiation, proliferation and rooting in banana shoots

Shoot initiation of banana took place after 2 ½ months of culture inoculation on MS basal medium, incorporated with 2.5 mg/L Benzyl Adenine (Figure 4: (a). Browning was seen in some of the cultures due to production of poly phenolic compounds.

(a) **(b)**

Figure 4: Shoot initiation (a) and shoot proliferation (b) of banana

The proliferation of Banana took place after one (1) month of subculturing, when the initiated shoots were sub cultured into MS basal medium with 4.0 mg/L BA and maintained under conditions similar to shoot initiation (Figure 4 (b)).

When the proliferated shoots were maintained in the proliferating medium approximately for 1 ½ months, the shoots produced well-developed roots (Figure 5).

Figure 5: Rooting in banana shoots

3.1.2. Acclimatization of banana plantlets

The acclimatization was 100% successful on the potting medium of coir dust, compost and burnt rice hull in 2:2:1 ratio. The pots were maintained for about two months for the plants to be fully acclimatized.

3.2. Transfer of banana plants to the field

After four (4) months of acclimatization (Figure 6), the banana plants were transferred into the polytunnel and the plant house for the imposition of the treatments, after planting in pots having a diameter of 0.5 m.

Figure 6: Banana plants after acclimatization

3.2. Transfer of banana plants to the field

After 4 months of acclimatization (Plate 5), the banana plants were transferred into the polytunnel and the plant house for the imposition of the treatments, after planting in pots having a diameter of 0.5 m.

3.3. Growth parameters

3.3.1. Chlorophyll content of leaves

According to Figure 7, data have shown an increasing trend from week 0 to week 40. The highest chlorophyll content was observed in plants of the treatment with no temperature stress and no water stress. The lowest performances were shown in plants of the treatment with temperature stress and water stress. All the plants in the treatment with temperature stress and water stress died at the end of week 40.

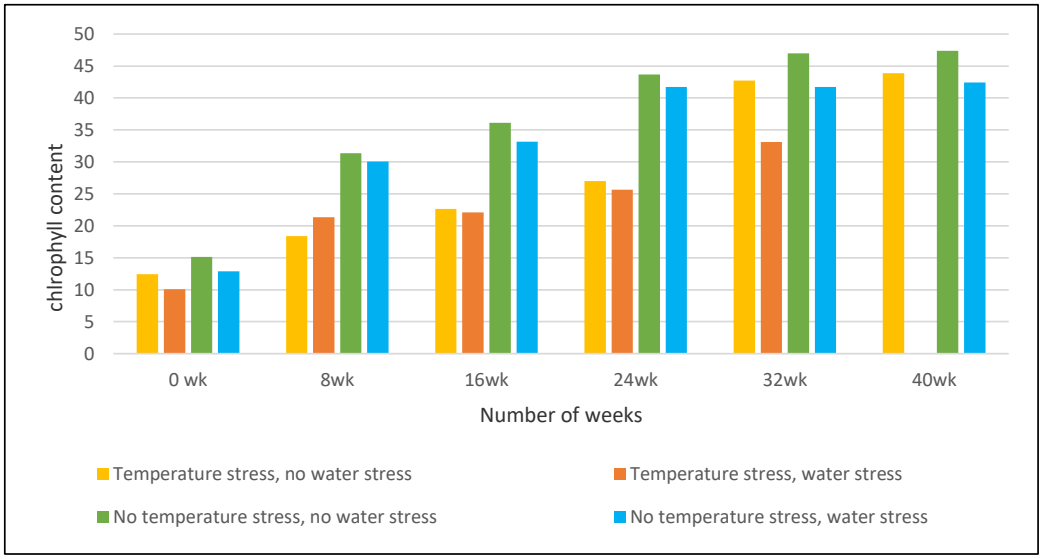

Figure 7: Chlorophyll content of leaves in each treatment during week 0 to week 40

According to Figure 8, significantly high chlorophyll content was shown in plants with the treatment with no temperature stress and no water stress treatment which was taken in the 40th week. However, it was not significantly different from the plants in the treatment with temperature stress and no water stress, but it was significantly different from the plants in the treatment with no temperature stress but with water stress. It has been reported by Isoda, (2010) that when there was water stress, peanut and cotton plants have shown a decrease in chlorophyll content.

Exposure to high temperatures usually results in a reduction in chlorophyll biosynthesis (Dutta *et al*., 2009). Reduced accumulation of the chlorophyll in the plants may be due to either decreased biosynthesis of the chlorophyll or due to its increased degradation or otherwise a combined effect of both under high temperature stress. The chlorophyll biosynthesis inhibition, under high temperature stress is attributed to the deactivation of various enzymes (Dutta *et al*., 2009).

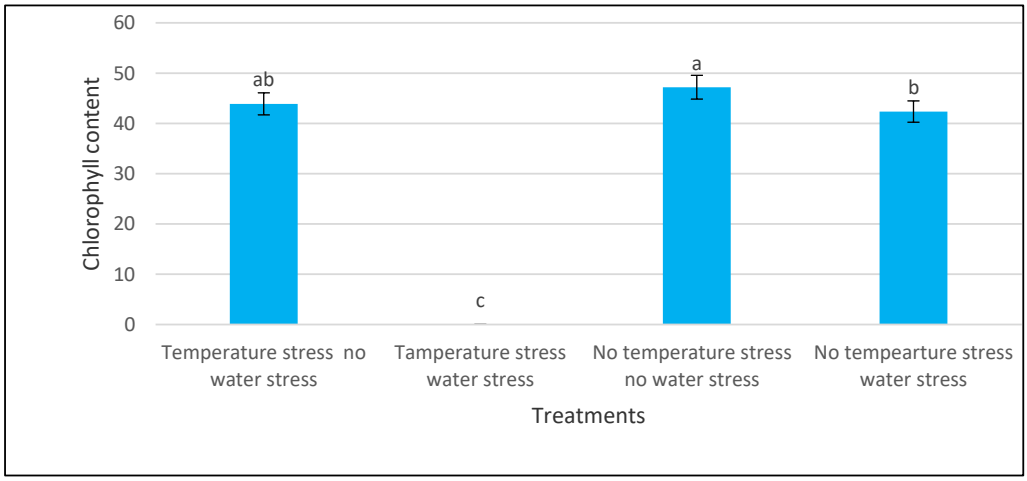

Figure 8: Chlorophyll content of leaves in the Week 40

According to the interaction plot for chlorophyll content (Figure 9), there is a significant interaction effect. Both factors such as temperature and water have significantly influenced on the variation of the chlorophyll content.

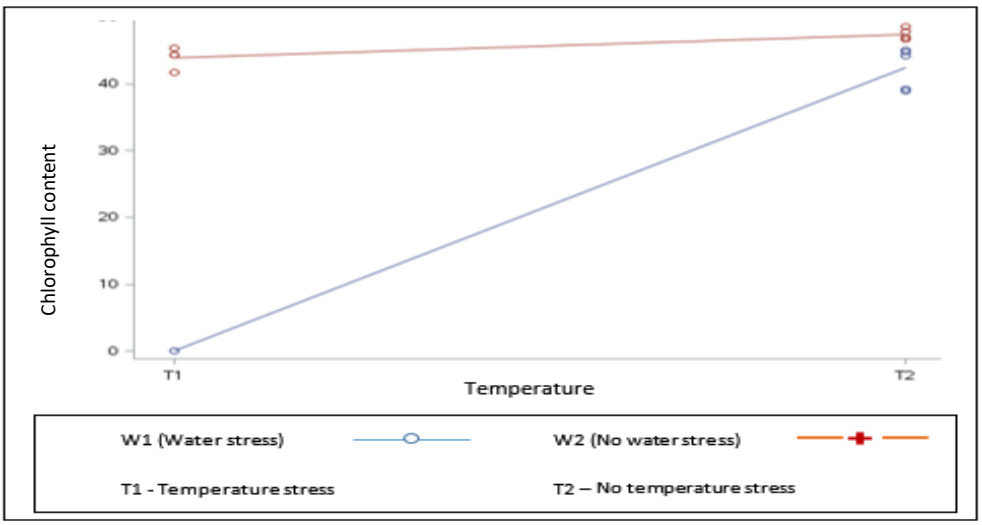

Figure 9: Interaction plot for chlorophyll content of leaves after 40 weeks

When the plants are under stress, the growth has retarded because the food that they produce is low due to the absence of sufficient chlorophyll.

3.3.2 Girth of plants

According to Figure 10, girth has shown an increasing trend during week 0 to week 40. The lowest girth was shown in plants of the treatment with temperature stress and water stress. The highest girth was observed in control treatment where the plants were having no temperature stress or water stress.

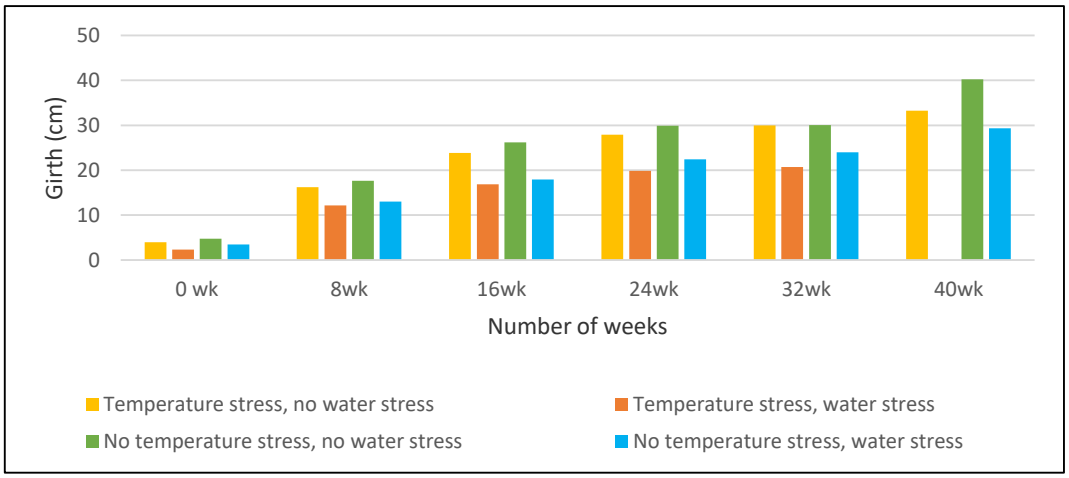

Figure 10: Girth of plants during week 0 to week 40

According to Figure 11, in the 40th week, the significantly highest girth was shown by the plants of the treatment with no temperature stress and no water stress. The girths of plants which were treated with temperature stress and water stress have not shown any value in 40th week because all the plants were dead in the 40th week. At the end of 32nd week, the highest girth was shown by plants which were under no water stress and no temperature stress and plants with temperature stress but no water stress. These results agree with those of Khan *et al.* (2001) and Shao *et al.* (2008) who stated that when the plants were under drought stress there was a reduction in diameter of the plant stem due to the cell enlargement being obstructed.

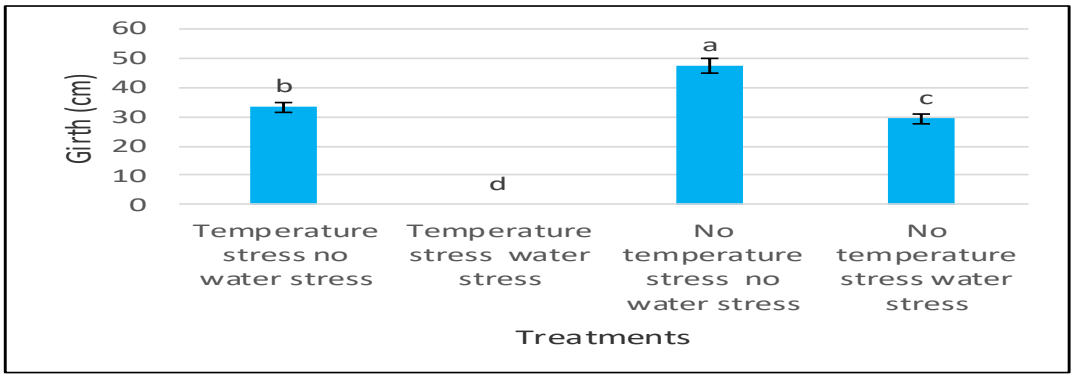

Figure 11: Girth of plants in the week 40

According to the interaction plot (Figure 12), both the factors the temperature stress and the water stress have significantly influenced on the variation of the girth and interaction effect was also significant. Therefore, there was an interaction effect also, of both temperature stress and water stress on the girth.

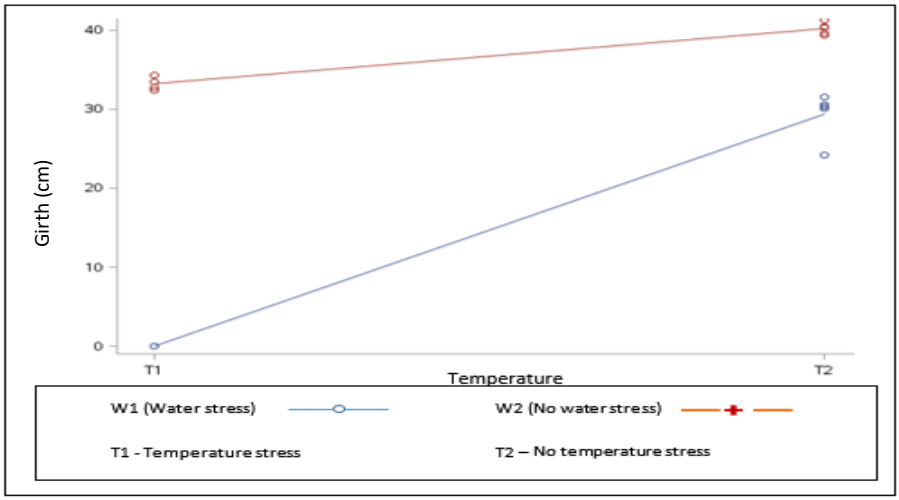

Figure 12: Interaction plot for girth after 40 weeks

3.3.3 Height of plants

According to Figure 13, the plant height has shown an increasing trend from week 0 to week 40. The highest plant height was shown by the plants which were under the treatment of no water and no temperature stress, and the lowest plant height was shown in plants of the treatment with both temperature and water stress. These results agree with those obtained for chilli *Capscicum annum* L. by Gunawardena and De Silva (2014). The plant height has been reported to have reduced significantly under water limiting conditions in maize also (Khan *et al*., 2001).

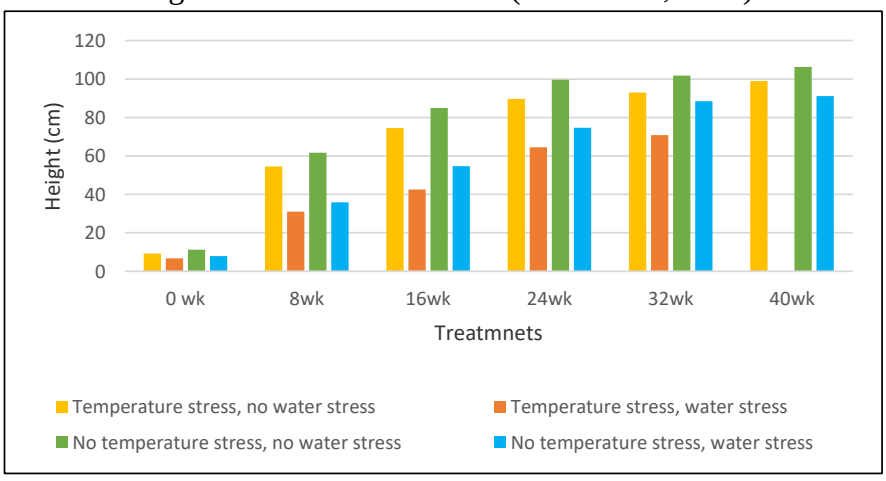

Figure 13: Plant height during week 0 to week 40

The Figure 14 illustrates the plant height under different treatments at the 40th week. The highest plant height was observed in plants having no temperature stress and no water stress (control treatment). Furthermore, there was a significant difference in plant height in all other treatments compared to the control. At the week 40, the plants under temperature stress and water stress died may be due to the toxic effect of fertilizer in combination with the stresses imposed.

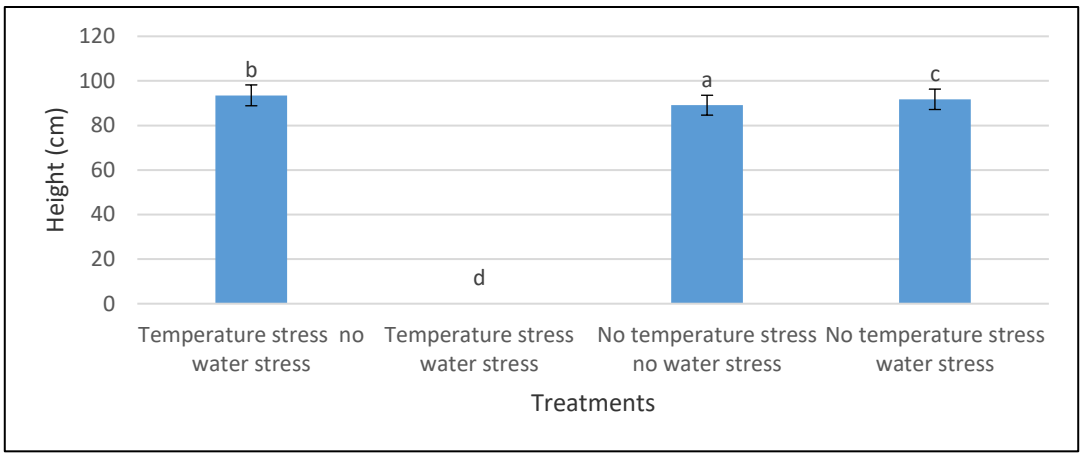

Figure 14: Plant height at week 40

According to the interaction plot for plant height (Figure 15), both the factors of temperature and water stresses have significantly influenced on plant height and the interaction effect was also significant. Therefore, there was an interaction effect of the stresses imposed on the plant height.

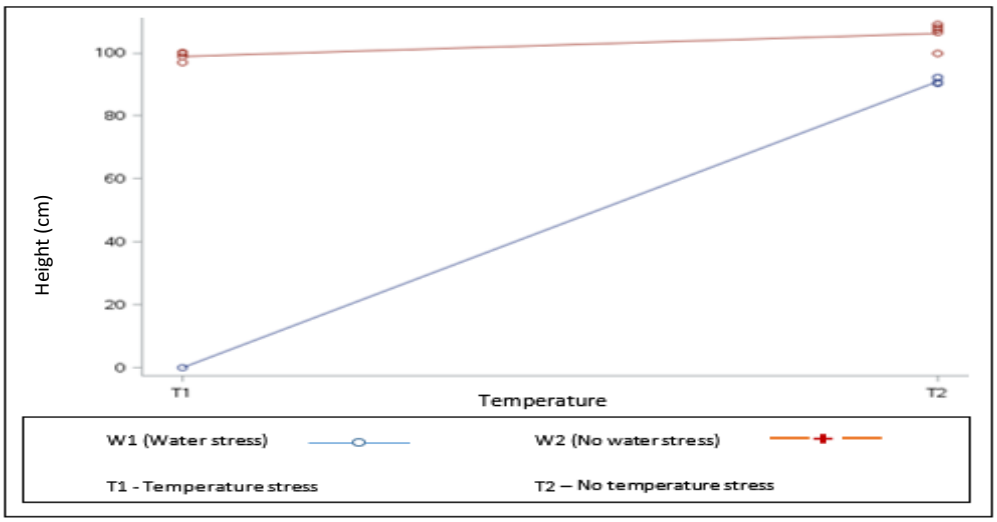

Figure 15: Plant height from week 0 to week 40

According to Figure 16, which shows the leaf length at the 40th week, the significantly highest leaf length was shown in the treatment with no temperature stress and no water stress. The treatment with water stress and temperature stress has not shown a value for leaf length due to death of the plants. The leaf size has been reported to have reduced significantly under the water limiting conditions in maize (Khan *et al*., 2001). It has been shown that drought impairs mitosis and cell elongation which results in poor growth (Hussain *et al*., 2008). It has been revealed by Taiz and Zeiger (2006) that drought limits the process of cell growth mainly due to the loss of turgour. Nonami, (1998) has reported that water limiting conditions results in impaired cell elongation mainly because of the poor water flow from xylem to the nearby cells. As reported by Rucker *et al*. (1995), number of leaves and the size of individual leaf are also reduced under the drought conditions, and the expansion of the leaf normally depends upon the turgor pressure and the supply of assimilates. Reduced turgor pressure and slow rate of photosynthesis under drought conditions mainly limit the leaf expansion.

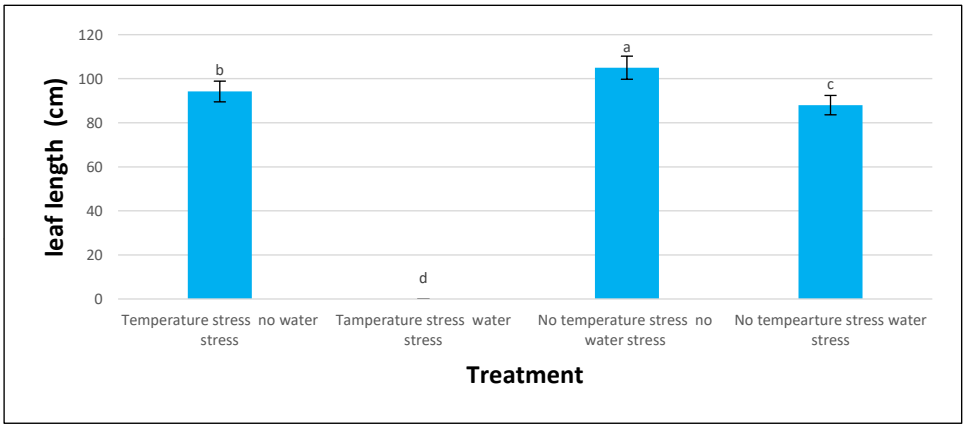

Figure 16: Leaf length at week 40

According to the interaction plot for leaf length after 40 weeks (Figure 17), both factors temperature stress and water stress have significantly influenced the leaf length and in addition, there was a significant interaction effect.

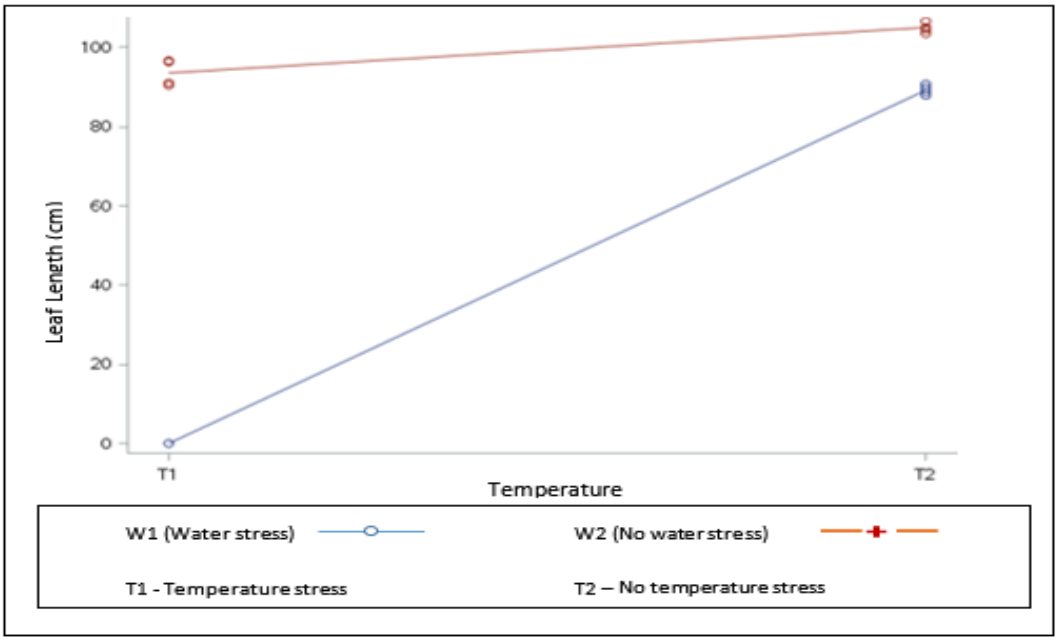

Figure 17: Interaction plot for leaf length, after 40 weeks

3.3.5. Leaf width

According to Figure 18, the leaf width has shown an increasing trend from week 0 to week 40 and the highest leaf width was shown in the plants of the treatment with no temperature stress and no water stress. The lowest leaf width was shown in the plants under the treatment of both temperature stress and water stress.

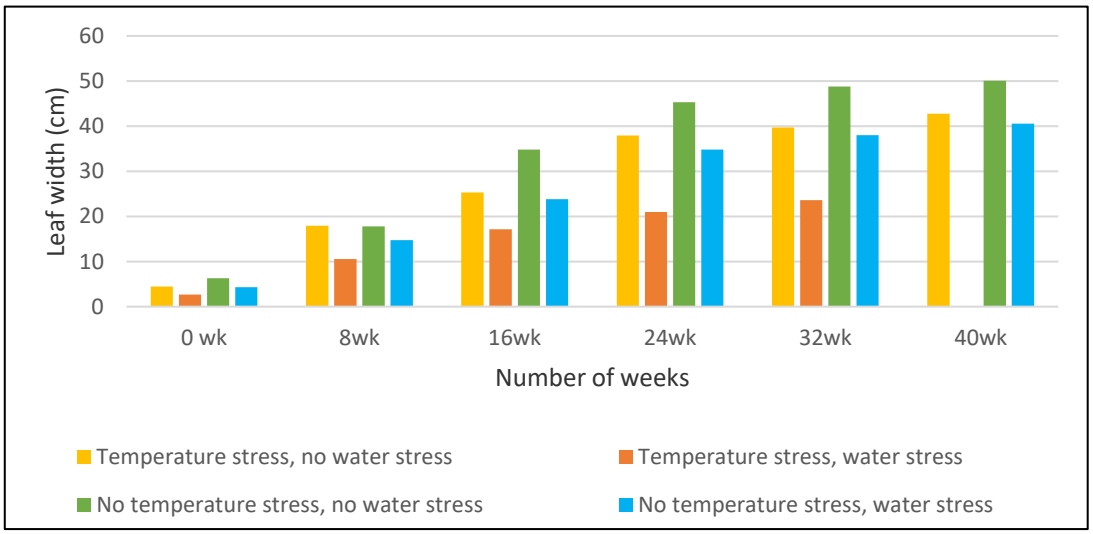

Figure 18: Leaf width from week 0 to week 40

According to Figure 19, at the 40th week, the significantly highest leaf width was shown in the plants of the treatment with no water and no temperature stress. The treatment with temperature stress and water stress has not given any value for leaf width due to the death of plants after 40 weeks. Rucker *et al*. (1995) have reported that reduced turgour pressure and slow rate of photosynthesis under drought conditions mainly limit the leaf expansion. These findings agree with the results of this study.

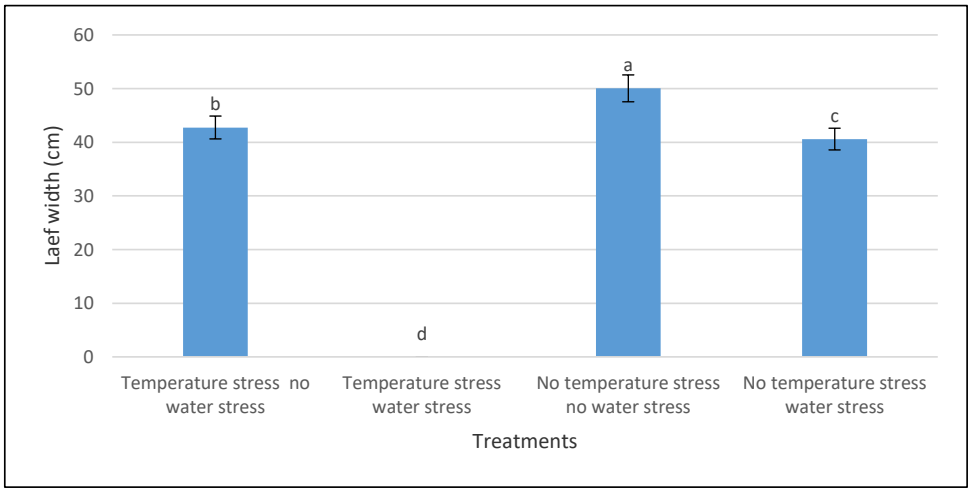

Figure 19: Leaf width at week 40

According to the interaction plot (Figure 20) for leaf width after 40 weeks, both the factors the temperature stress and water stress have significantly influenced on the leaf width and in addition, there was a significant interaction effect of the stresses imposed.

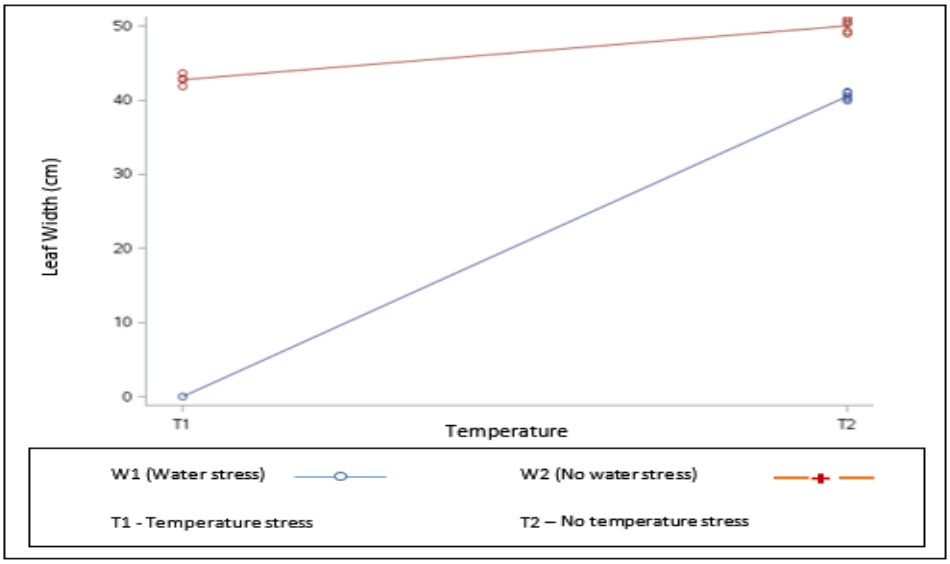

Figure 20: Interaction plot for leaf width, after 40 weeks

3.3.6 Number of leaves

According to Figure 21, from week 0 to week 40, number of leaves has shown a non-linear correlation. The highest number of leaves was shown in the treatment with no temperature and no water stress, and the lowest number of leaves was shown in plants of the treatment with temperature stress and water stress.

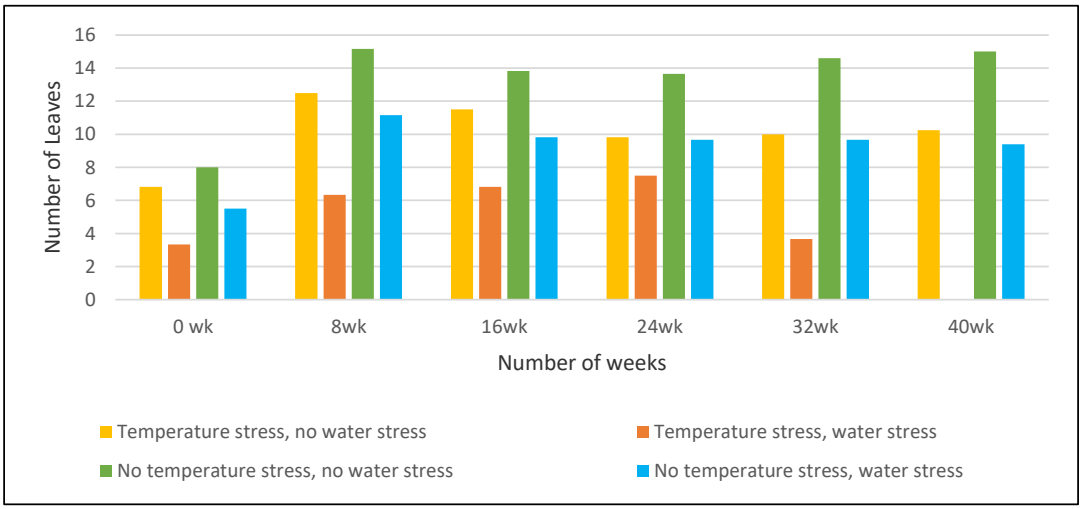

Figure 21: Number of leaves from week 0 to week 40

According to Figure 22, at the 40th week the significantly highest number of leaves was shown in plants of the treatment with no temperature stress and no water stress. There was no significant difference in the number of leaves in the plants of the other two treatments. However, they were significantly different from the treatment with no temperature stress and no water stress.

Akıncı and Losel (2009, 2010) reported that the water stress caused major reductions in height, leaf number, leaf area index, fresh and dry weights of cotton plants and some Cucurbitaceae members. According to Khan *et al.* (2001) and Shao *et al.* (2008), plant height, stem diameter, plant biomass and leaf area are reduced under drought stress. These agree with the results obtained for the parameters of the present study.

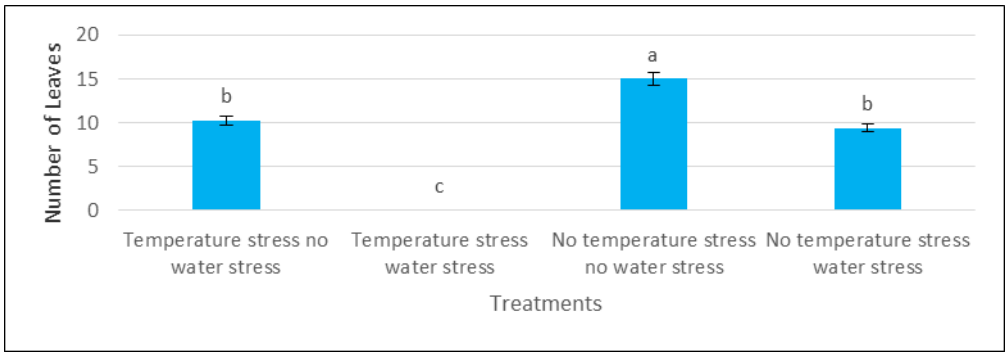

Figure 22: Number of leaves at week 40

According to the interaction plot for number of leaves (Figure 19), both temperature stress and water stress have significantly influenced the number of leaves. In addition, the interaction effect of the temperature stress and water stress was also significant.

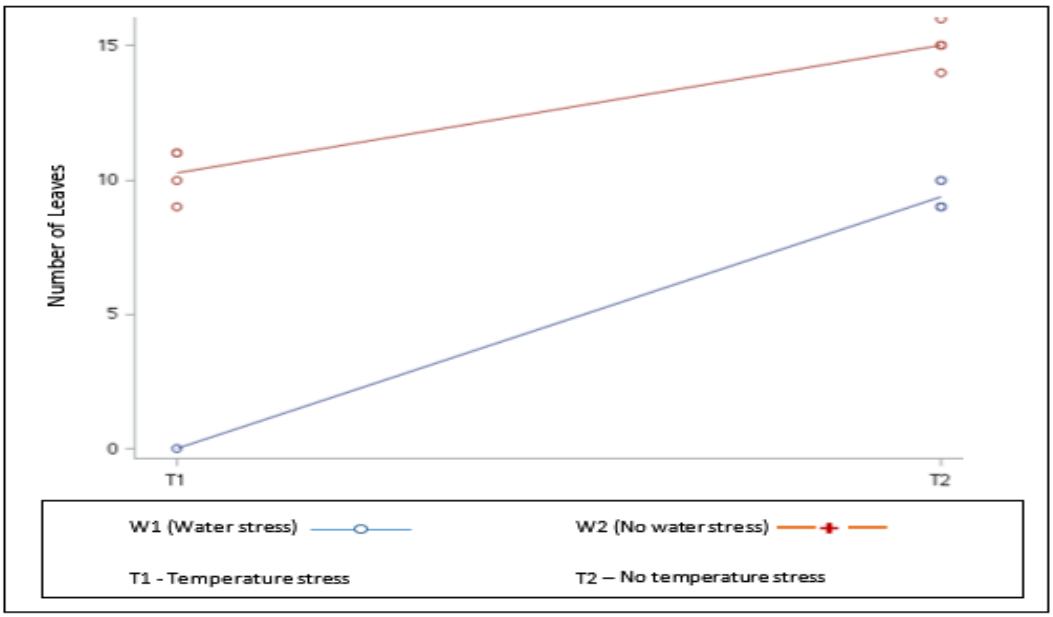

Figure 19: Interaction plot for number of leaves, at week 40

3.4. Yield parameters of banana

Although, according to CIC Agri Farm *Pelwehera, Dambulla*, the flower initiation should take place 4 ½ months after planting, flowering of banana did not take place even after 1 ½ years. The probable reason could be the insufficient space in the pots for rooting. All the plants which were not under stressful conditions had nearly

normal vegetative aerial growth. However, the plants were unsuccessful in reproductive growth mainly due to poor root growth. According to Blomme (2000), the variety Cavendish has a root system which is four times larger compared to other banana varieties. He further reported that improved root system would result in better anchorage, faster growth and higher yield and poor root growth would result in yield decline. As reported by Stover and Simmonds (1987) and Price (1995), root system is crucial for plant support, water and nutrient uptake and production of plant growth regulators which are important factors for the reproductive growth.

4. Conclusion

In vitro shoot initiation and proliferation of banana were successful on MS medium incorporated with 2.5 mg/L of BA and 4.0 mg/L BA respectively. Rooting in banana shoots was obtained on keeping the proliferated shoots in the proliferating medium for about 1 ½ months.

When the growth parameters of banana are considered, it is evident that all the growth parameters such as chlorophyll content of leaves, girth of stem and length and width of leaves have been affected by the temperature stress and water stress imposed ($P < 0.05$). This suggests that the above growth parameters would be negatively impacted by the predicted global warming. The number of leaves was affected individually by temperature and water stress ($P < 0.05$). However, the interaction effect of both the factors on the number of leaves was not significant.

From the results obtained, it can be inferred that the banana plants should be planted in soil not in pots in order to facilitate the required rooting space. Unavailability of fruits of banana could be due to not having sufficient rooting space in the pots to enable the plants to absorb water and nutrients and production of growth hormones too which would promote the reproductive growth.

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