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Research paper

Effect of Zeba (Super absorbent polymer) to combat the impacts of increased temperature and irrigation interval on growth and yield attributes of Chilli (*Capsicum annum*)

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A B S T R A C T

It is very important to use adaptation technologies in crop fields to mitigate the adverse effect of increasing temperature and limited amount of water on crop growth and yield. Application of Super Absorbent Polymers is one of the technologies which can be used to overcome the impacts. This study was conducted at the Open University of Sri Lanka, during the period of 2019 to 2021. Experimental design consisted with three factors, i.e. temperature conditions (32-33 ^{0}C and 35-36^{0}C), irrigation intervals (3days, 5days and 8days) and application of Zeba (Super Absorbent Polymers) (2g of Zeba and without Zeba). Treatments were arranged in Complete Randomized Design with three replicates. In this study it was hypothesized that SAPs could reduce the magnitude of yield penalty of chilli due to increased temperature and longer irrigation interval. Growth and yield parameters of chilli were collected and statistical analysis of the data (ANOVA) was performed using Three-Factor Factorial Design and compared for the significance by using a Revised Least Significant Difference test at p=0.05. According to the results of this study, interaction effect of temperature, irrigation interval and application of Zeba has significantly ($p<0.05$) influenced on the measured parameters of chilli and Zeba positively influenced to mitigate the adverse effect of increased temperature and water stress condition. When irrigation interval was increased, it resulted a decrease in growth and yield of chilli due to limited availability of water to plants. Further, growth and yield of chilli were reduced under increased temperature than ambient temperature. All the treatments with zeba have resulted higher yield than treatments without zeba under both temperature conditions. At ambient temperature, treatments with Zeba, under all irrigation intervals showed high yield of chilli. Therefore, at ambient temperature, irrigation interval can be extended up to eight days with application of Zeba. At increased temperature, treatment with Zeba, three day irrigation interval and treatment with Zeba, five day irrigation interval showed high yield. Therefore, under increased temperature, irrigation interval can be extended up to five day when plants were treated with Zeba.

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1. INTRODUCTION

The human population is growing exponentially day by day. Meeting the needs of this growing population has become a challenge. Among those needs, meeting the demand for food is paramount. Crop cultivation is one of the main ways to meet the demand for food. But at present, due to various reasons, the crop cultivation is adversely affected. Among these reasons, adverse changes in climatic factors are the main ones. Today, the environmental conditions are unpredictable due to various reasons. Drought and temperature stress are the most limiting factors for crop production. Atmospheric temperature is gradually rising almost everywhere in the country and in recent years; the warming trend has become faster (Eriyagama *et al.,* 2010; Nissanka *et al.,* 2011; Sathischandra *et al.,* 2014). Notable increases in T_{min} and T_{max} were observed at many locations of Sri Lanka, and the increase in T_{min} indicates likely warming of nighttime temperatures in Sri Lanka (Naveendrakumar *et al.,* 2018). Further, monthly averages in T_{min}, 80% of locations of Sri Lanka showed significant increases during June and July (Naveendrakumar *et al.,* 2018). Extreme weather disasters, including prolonged droughts, occur more frequently with greater intensity in Sri Lanka than in other nations (IMF, 2018). Significant changes in rainfall, rain patterns, droughts, and temperature have been occurring in Sri Lanka, which results difficulties for agricultural output, livelihoods, and food security. (Coslet *et al.,* 2017; Eckstein *et al.,* 2019; Marambe *et al.,* 2015). The detrimental effects of climate change on agriculture will put the food security of the whole population and the livelihoods of the vast majority of people at risk. (Climate Change Secretariat, 2016).

Major abiotic factors that lower agricultural production and reduce global food security are drought and heat (Lamaoui *et al.,* 2018). Long-term drought and extreme temperatures escalate the damage to yield of plants and it will pose serious challenges on food security (Qi *et al.,* 2022). At temperatures above the optimum, photosynthesis is significantly inhibited, resulting in a significant loss of potential productivity of vegetable crops (Rashid *et al.,* 2020). Zhao *et al.* (2020) reported that the crop yield mainly affected by water stress and photosynthesis was mainly limited by stomatal conductance, because the stomatal conductance decreased under water stress. Also, Sadras *et al.* (2016) reported that the water deficit affects many functions in the crop, although most of the effects are related to the lower rate in growth, the most sensitive process, and stomatal closure. Chilli is considered as a high value crop, and it plays a major role in Asian diet. Lee *et al., (*2018) reported that the temperature stress and water stress are major factor influencing the productivity and resulted to decrease yield characteristics of pepper. Compared to treatments with longer irrigation intervals, chilli plants consumed more water when they were well-watered and further proved that supplemental irrigation has a substantial impact on growth and that chilli plants develop less when irrigation intervals are longer than seven days (Sahana *et al.,* 2021). Gunawardhana *et al.* 2014, reported that the temperature stress has especially affected the plant height, branches, canopy diameter and fruit weight at 0.01 probability level and furthermore, temperature stress showed significant effect at 0.05 probability level on transplant success, fruit diameter and number of fruits per plant. Irrigation can play a crucial role in enhancing crop productivity and building resilience to climate change and application of Water-saving and soil moisture conservation techniques are important to reduce yield reduction of chilli due to climatic variations (Adekaldu *et al.,* 2021). Application of Super Absorbent Polymers (SAPs) is one of the modern technologies that can be used to overcome the negative influence of increased temperature and limited amount of water to plant. This technology is popular in many countries, especially in Middle East countries, India and Pakistan etc.,

However, this technology is new to Sri Lanka. Therefore, one of the purposes of conducting this research is to introduce and disseminate this technology to Sri Lanka through research papers on the use of Super Absorbent Polymer. Sayyari and Ghanbari (2012) reported that SAPs showed a positive effect on increasing growth parameters and yield of pepper. SAPs application has the potential for the soil to retain more water from irrigation or rainfall and reduce the frequency of irrigation (Zheng *et al.,* 2023). Therefore, this study is designed to investigate the possibility to achieve a good yield by harvesting chilli without significant yield reduction under various irrigation intervals and temperature stress by applying organic-based super absorbent polymers (Zeba) and in this study it will be hypothesized that SAPs could reduce the magnitude of yield penalty of chilli imposed by high temperature and water stress condition.

2. METHOD

This study was conducted at the Open University of Sri Lanka, Nawala, Nugegoda. The cultivar MI-2 of chilli was used as chilli as the variety; this cultivar is currently recommended by the Department of Agriculture for production in Sri Lanka. Seedlings were maintained under a propagator and after one-month; plants were planted in the pots. Reddish brown earth soil was used as the growth medium. Experiment was designed with three factors. They were two temperature conditions, three irrigation intervals (I) and Zeba level (Z). Two temperature

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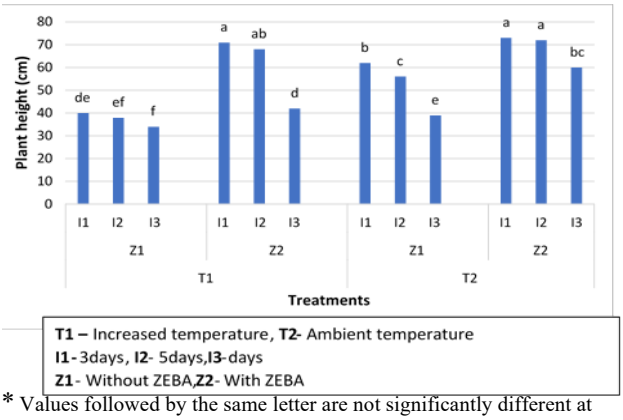
conditions were applied as ambient temperature (32-33 ^{0}C) and increased temperature (35-36 ^{0}C). Irrigation intervals applied were 3days (I1), 5days (I2) and 8days (I3). Zeba factor with two levels, one applied as without Zeba (Z1) and other as 2g of Zeba (Z2) per pot according to the recommendation. Treatments arranged in Complete Randomized Design (CRD) with three replicates. Based on positive properties of SAPs, the objectives of this study is to evaluate the effect of applying SAPs (Zeba) on chilli under temperature and water stress conditions. Growth parameters measured in two-week intervals; yield parameters measured after harvest. Data were tabulated and analysed by using Analysis of Variance (ANOVA) with Three-factor Factorial Design. The differences between the different treatment combinations were compared for significance by using a Revised Least Significant Difference (LSD) test at 0.05 level as described by Snedecor and Cochran (1989).

3. RESULTS AND DISCUSSION

3.1. Growth parameters of Chilli

Height of plant

According to the analysed data, all the factors and their interaction effects have significantly influenced (P<0.05) on the variation of plant height. According to figure 1, treatments with Zeba have shown higher plant height than treatments without Zeba. At ambient temperature conditions treatments with Zeba, followed by all three irrigation interval (3 days, 5days and 8days) (T2Z2I1,T1Z2I2,T1Z2I3) have shown higher plant height. At increased temperature condition, application of Zeba with irrigated to 3days and 5days (T1Z2I1, T1Z2I2) have resulted higher yield. Zeba has positively influenced on the plant height of plants at the increased temperature condition due to the ability of Zeba to mitigate the temperature and water stress. When irrigation interval has extended, it resulted to decrease plant height due to water stress conditions to plants. However, according to the results of this study application of Zeba has extended the irrigation interval up to 5 days at increased temperature and 8 days at ambient temperature condition. Zeba has a possibility to extend the irrigation interval because of water absorption and water retention properties of the polymer (Yang *et al.,* 2020). Treatment without Zeba, 8 days irrigation interval at the increased temperature condition (T1Z1I3) has significantly (p<0.05) shown the lowest plant height due to increased temperature and longer irrigation interval condition. Asl *et al.* (2011) reported that stress conditions resulted in reducing the cell turgidity, cell growth, the number of stem cells and the cell volume of plants, causing reduction in plant height.

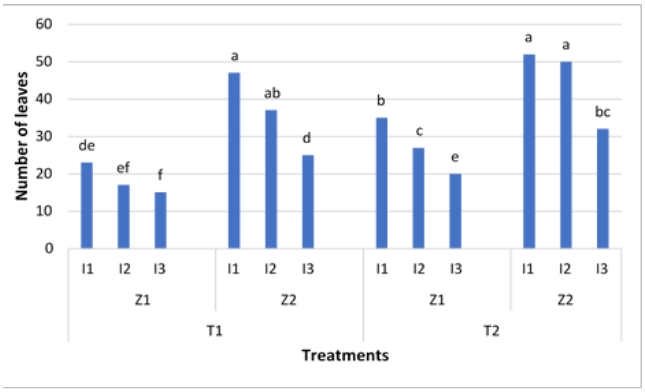


* Values followed by the same letter are not significantly different at p =0.05 level.

Figure 1: Effect of different treatments on plant height of Chilli (*Capsicum annum*)

Number of leaves

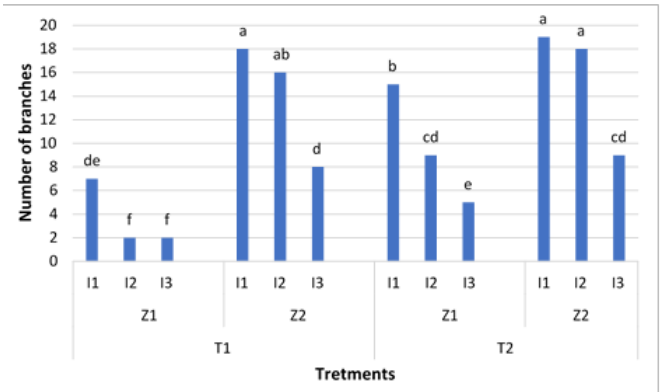
Treatments at ambient temperature have shown higher number of leaves than treatments at increased temperature (Figure 2). However, treatments at increased temperature with Zeba and short irrigation interval have shown higher number of leaves due to mitigation of water stress and temperature stress condition by Zeba. According to the analysed data, all the factors such as irrigation interval, Zeba and temperature condition and their interaction effects have significantly influenced (P<0.05) on variation of number of leaves. Treatment at ambient temperature, 3 days irrigation interval with Zeba (T2Z2I1) has shown the highest number of leaves (52). As similar to the T2Z2I1, treatments with Zeba, 5days and 8days irrigation interval under ambient temperature condition (T2Z2I2, T2Z2I3) and treatment with Zeba, irrigated once per 3 days and 5 days irrigation interval at increased temperature condition (T1Z2I1, T1Z2I2) have resulted higher number of leaves. Therefore, according to the obtained results from the study irrigation interval can be extended than three day at both temperature conditions with application of Zeba. Treatment at increased temperature, without Zeba and 8 days irrigation interval (T1Z1I3) has resulted the significantly (P<0.05) lowest number of leaves due to water stress condition and temperature stress condition.



T1 – Increased temperature, **T2-** Ambient temperature
I1- 3days, **I2** - 5days, **I3**-days
Z1- Without ZEBA, **Z2**- With ZEBA

* Values followed by the same letter are not significantly different at p =0.05 level.

Figure 2: Effect of different treatments on number of leaves of Chilli *(Capsicum annum)*



T1 – Increased temperature, **T2-** Ambient temperature
I1- 3days, **I2** - 5days, **I3**-days
Z1- Without ZEBA, **Z2**- With ZEBA

* Values followed by the same letter are not significantly different at p =0.05 level.

Figure 3: Effect of different treatments on number of branches of Chilli (*Capsicum annum*)

Number of branches

All the factors, Zeba, temperature condition and irrigation interval have significantly influenced ($P<0.05$) on the variation of the number of branches of the chilli plants. Treatments at increased temperature, without application of Zeba have shown lower number of branches than the treatment at ambient temperature. Also, treatments with Zeba, and short irrigation interval under increased temperature condition have resulted higher number of branches than treatments at increased temperature with longer irrigation interval and without application of Zeba. Treatments at increased temperature, without Zeba irrigated to 5 days and 8 days (T1Z1I2, T1Z1I3) have shown ($P<0.05$) lower number of branches. Treatments with Zeba at ambient temperature, 3days irrigation interval (T2Z2I1) and 5 days irrigation interval (T2Z2I2) has shown higher number of branches. When irrigation interval was extended without application of Zeba under both temperature conditions have produced low number of branches. Shana *et al.* 2021 reported that the number of branches of chilli may reduce under longer irrigation interval due to the insufficient water availability for proper vegetative growth. However, according to this study higher number of branches can be observed under 5 days irrigation interval with application of Zeba under both temperature conditions. It might be due to ability of Zeba to act as a water reservoir that releases water to plants once the soil at the root level starts to dry (AbdAllah *et al.,* 2021)
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3.2. Yield parameters of chilli

Number of pods per plant

Statistical analysis revealed that all three factors of irrigation interval, temperature condition and Zeba have significantly influenced the number of pods per plant. And also, the interaction effect of these three factors has significantly affected the number of pods per plant. Treatments with Zeba irrigated to 3 days, 5days , 8days under ambient temperature condition (T2Z2I1, T2Z2I2, T2Z2I3) and treatments applied with Zeba irrigated once per 3 day and 5 day under increased temperature condition (T1Z2I1, T1Z2I2) have shown higher number of pods per plant. The lowest number of pod production was shown in the treatment without Zeba, 8 days irrigation interval under increased temperature condition (T1I3Z1). Application of Zeba positively influenced the number of pods of chilli by creating a positive interaction effect with temperature and irrigation. These results can be justified with the findings of Pacuta *et al.* (2021). They have reported that, in drought and heat stress conditions, the application of super absorbents may increase the production of biomass or photosynthesis and further positive effect of SAP in increasing the yield and after applying SAP, humidity fluctuation was reduced, when irrigation intervals were increased and plant growth was increased. It is obvious that by continuing plant growth and reducing drought stress effects on the plant, its yield is increased.

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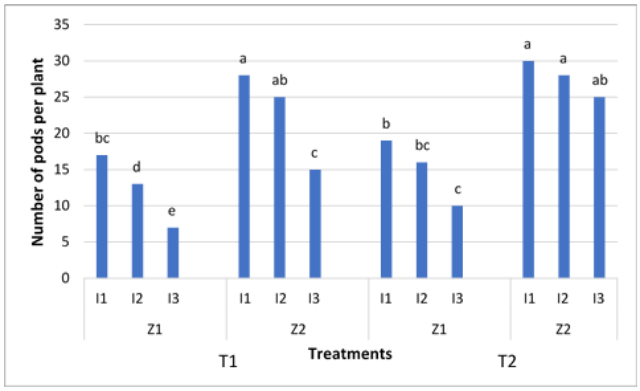


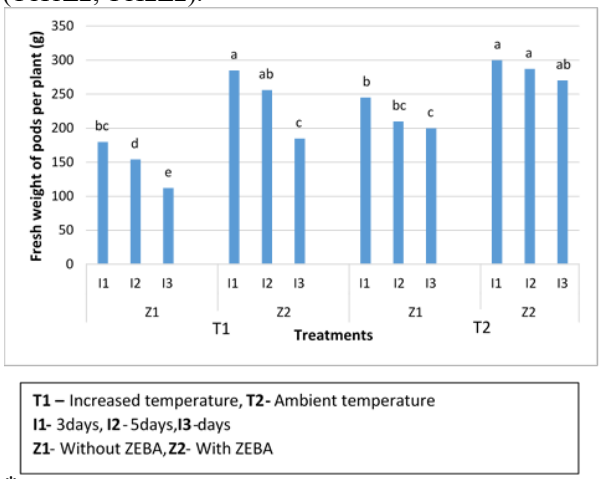
* Values followed by the same letter are not significantly different at p =0.05 level.

Figure 4: Effect of different treatments on the number of pods of chilli (*Capsicum annum*)

Fresh weight of pods

Statistical analysis revealed that all factors, irrigation interval, temperature condition and Zeba have significantly influenced the fresh weight of pods. Also, the interaction effect of these factors has significantly affected the fresh weight of pods.

Figure 5 describes that treatments with Zeba , irrigated once per 3days, 5days and 8days under ambient temperature condition (T2I1Z2, T2I2Z2, T2I3Z2) have given higher yield while treatments with Zeba, irrigated once per 3days and 5days have given higher yield when plant are exposed to increased temperature conditions (T1I1Z2, T1I2Z2).



* Values followed by the same letter are not significantly different at p =0.05 level.

Figure 5: Effect of different treatments on fresh weight of pods of chilli (*Capsicum annum*)

Treatment without Zeba, with 8 days irrigation interval under increased temperature condition (T1I3Z1) has shown the lowest fresh weight of pods and it might be due to impact of high temperature conditions on plants due to elevated temperature conditions and longer irrigation interval.

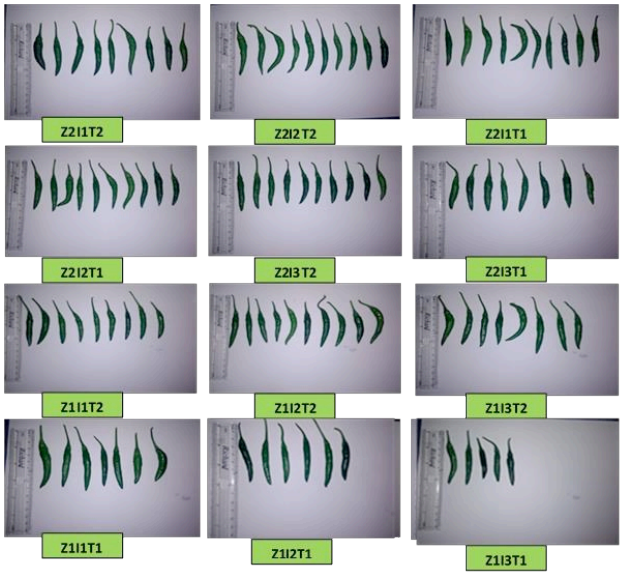


Figure 6: Effect of different treatments on chilli pods (*Capsicum annum*)

CONCLUSION

In this study, we focused on evaluating the effect of Zeba on growth and yield parameters of the chilli. Results of this study revealed that the interaction effect of temperature, irrigation interval and application of Zeba has significantly ($p<0.05$) influenced the growth and yield parameters of chilli. When the irrigation interval was increased without application of Zeba, it has resulted in reducing growth and yield parameters of chilli either at the increased temperature or ambient temperature due to limited amount of water available to plants. And also, the growth and yield of chilli were low under increased temperature condition than ambient temperature condition due to heat stress condition on crops. All the treatments with Zeba have resulted higher yield than treatments without Zeba either at the ambient temperature or increased temperature condition. Under ambient temperature condition, irrigation interval can be extended up to eight days without significant yield loss. Under increased temperature condition when plants are treated with Zeba, irrigation interval can be extended up to 5 days without significant reduction in yield. It might be due to positive effect of Zeba to reduce the effect of heat stress and limited water availability for plants

Finally, our results supported our hypothesis that the SAPs could reduce the magnitude of yield penalty of chilli imposed by high temperature and water stress condition. However, final conclusion can be made after conducting more studies in different locations of the country.

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