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Research Article

Simulation of increasing night temperature on vegetative and generative of paddy (*Oryza sativa* L.)

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Abstract : The rate of respiration increases with increasing temperature. It causes a problem to occur with photosynthesis result (photosynthate) generated during photosynthesis as a source of energy for metabolism of plants. The objective of this study was to evaluate of growth and the production result by affected an increasing night temperature on paddy. The simulation was performed in growth chamber with increased night temperature by 2^0 C (T1) and 4^0 C (T2) higher than normal night temperature (T0). Growth phase of rice plant treated an increase in night temperature among others on the vegetative phases continues on the generative phase (VG), was treated only on the vegetative phase (V) and treated only on the generative phase (G). The number of tillers, leaf area, number of leaf, the total dry weight of rice plant on the T2 had values that were lower than at T0 and T1. The decreased values in the parameter number of tillers, leaf area, number of leaf, and total dry weight at the end of the observation were observed on T2V and T2 VG. The T2 had longer panicle than T1 and T0, but the number of panicle, weight of seed per plant, harvest index (HI), the number of productive tillers, flowering time, harvesting time , nitrogen content in the leaves, the and percentage of open stomata values were lower than T1 and T0. T1G, T1VG, T2VG and T2G showed lower percentage of full grain than at T0. T1 and T2 treatments on VG and V resulted in the delay of flowering time. T1 and T2 on the VG phase resulted in the delay of harvesting time.

Keywords *: generative, night temperature, vegetative*

Introduction

In the current year and the next few years, due to global warming phenomenon, the increase in the greenhouse effect and air temperature become major factors affecting rice production. Projections of an increase in average air temperature globally at the end of the 21^{st} century (1980-1999) are about 2-4^{o}C (IPCC, 2007). Minimum temperature (night time) increases faster than the maximum temperature (day time) on the previous few years (Easterling et al., 1997). Research on the temperature of the night on rice plant into the area to take precedence. Especially at night, the rice plant undergoes respiration. Respiration is a plant's effort to sustain its life cycle if faced with increased air temperature. An increase in respiration requires carbon fixation to continue growth and survive. However, when respiration does not increase along with the increase in air temperature, it will result in the loss of rice yield. Temperature is decisive factor of plant development.

The rice crop is a C3 type of plant species and is very fond of increasing rates of CO_2 assimilation and end result of rice grain. However, some studies show that a high air temperature impact to the decline of the yield despite an enriched CO_2 (Horie et al., 2000). Farrel et al. (2006) suggested that the flowering phase is very development phase of the response to temperature. A key mechanism of the high temperatures result in pollination is decreasing of pollen ability to enlarge so that a declining ability to invade (Matsui, 2005). The optimum temperature on the charging phase japonica rice showed at range 21-22^{o}C for 40 days when it formed penicles, when the air temperature is above the optimum temperature then it can lose weight of full seed per plants (Kim, 2011).

High temperatures can affect the reproductive or vegetative phase, i.e. the burning of leaves, aging of leaves, disability of roots growth, and affect to the seed ripening. Some research that is often done in connection with heat will be stressing the antagonistic process in plants. Stomata will be open to cool the leaves through the process of transpiration. However, when stressed by heat and then followed with drought, a plant cannot open its stomata, causing the temperature of leaves to remain high (Rizksky et al., 2002). At high temperatures, inactivation of enzyme increases over the activity of activation enzyme to support metabolism (Craft-Brander and Salvucci, 2000).

Plant growth in high temperatures requires greater heat tolerance on thylakloid membrane and photosynthesis enzymes so it can increase photosynthesis in high temperatures (Yamori et al., 2013). The larger leaf photosynthesis decreased at night temperature of 23^o C compared temperatures on 14, 17 and 20^o C (Prasad, 2008). Therefore, although the process of photosynthesis occurs in the morning and afternoon, but with an increase in temperature at night also gave an impact on the process of photosynthesis. The objective of this study was to evaluate of growth and the production result by affected an increasing night temperature on paddy.

Materials and Methods

This study was carried out in farm laboratory, Jatikerto Village, Kecamatan Kromengan, Kabupaten Malang from October 2013 to January 2014. Jatikerto village has an altitude of 355 m above sea level. Pots were placed inside growth chamber for the plants treated with increased night temperature as their treatments. Tools used in this study were hoes, meter, scales, ovens, buckets, lamps 100 Watt, thermometer, leaf area meters, SPAD –502PLUS (Soil Plant Analysis Development), electron microscope. The materials used included rice seed of IR64 variety, urea fertilizer (200 kg/ha), SP-36 fertilizer (75 kg/ha) and KCl fertilizer (50 kg/ha). Urea was applied three times at 14 DAT (day after transplanting), 21 - 28 DAT and 30-40 DAT. SP-36 and KCl were applied the same time with application of urea at 14 DAT. Seven treatments, i.e. (1) without an increase in night temperature (T0). (2) 2^o C increase in night temperature treated at vegetative phase and generative phase (T1 VG), (3) 2^o C increase in night temperature treated at vegetative phase only (T1 V). (4) 2^o C increase in night temperature treated on generative phase only (T1 G), (5) 4^o C increase in night temperature treated at vegetative phase and generative phase (T2 VG), (6) 4^o C increase in night temperature treated at vegetative phase only (T2 V), and (7) 4^o C increase in night temperature treated on phase only (T2 G) were arranged in a randomized block design. For 2^o C and 4^o C increase in night temperatures, the entire population was placed in growth chamber. For increasing 2^o C, the treatment imposed was placed and assembled with 9 100-Watt-lamps. For increasing 4^o C, the treatment imposed was placed and assembled with 12 100-Watt-lamps. Every lamp was supplied with hood cover and wrapped in black cloth. The growth chamber was opened at 6 a.m. until 6 p.m. After 6 p.m., the growth chamber was closed and light was turned on. Watering time was on 14-15 DAT, 29-30 DAT and 44-45 DAT. The other day, the soil was watered intermittently until 80 DAT. After 80 DAT, the soil was allowed to dry until harvesting time came. Weeding mechanism was done manually if there was a weed inside of the pot. Data obtained ware subjected to analysis of variance followed by LSD test to show the difference in F test

Results and Discussion

Rice plant growth parameters showed that at the end of the day of the observation, the level of greenness of leaf did not differ significantly in spite of increased night time temperature by 2^o C and 4^o C. Increasing night temperature for 2^o C and 4^o C at various phases of growth (VG, V and G) did not either give an impact on changes in the greenness level of leaf rice plant's leaves (Figure 1). The greenness level of rice plant's leaves represent of the amount of chlorophyll as the leaf photosynthetic agent.

The number of tillers of rice plant caused by increasing night temperature by 2^o C was same as the treatment without increasing night temperature (Figure 2). However, with an increase in nighttime temperature of 4^o C that were treated on the VG and V phases have resulted in a declining number of tillers as compared to the rice plant treated at increase temperature of 2^o C and night time treatment without an increase in the temperature of the night. At the age of 50 and 60 DAT, the number of tillers per plant at T1 treatment did not significantly differ with T0 treatment. However, with increased temperature at night until it reached 4^{o}C, the plant could no longer adapt to the pressure of the environment.

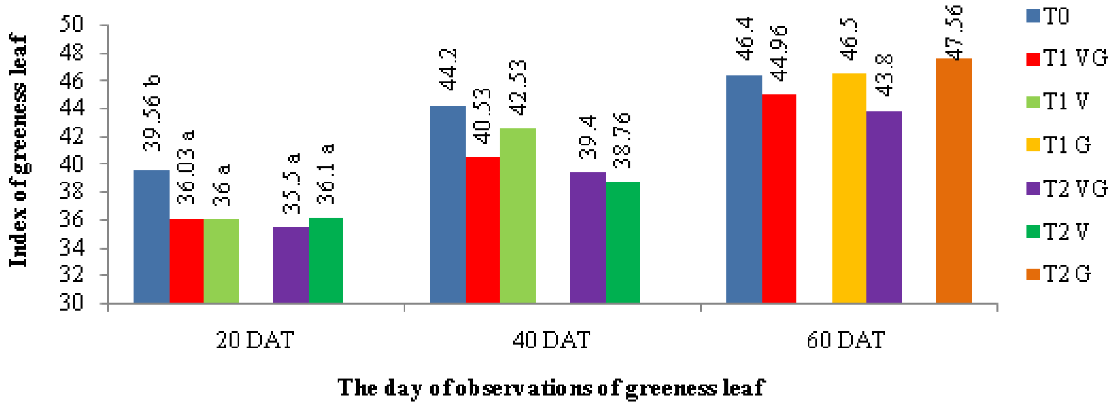

Figure 1. Greeness leaf of rice plant (index)

Heat stress occurs at the time due to environmental change, then there will be adjustments to plant parts like leaves to face the pressure of the environment. Actions to counteract the environmental pressure are done by performing metabolism and structural adjustment (Yamanouchi et al., 2002). Heat stock proteins (HSP) is a stabilization factor when subjected to environmental pressure (Shah et al., 2011). Rapid accumulation of HSP on the organ that is experiencing sensitive give the role to protect the cell metabolism so that it can adapt when subjected to temperature increase (Wahid et al., 2007). The existence of HSP can help to resolve the high temperature stress by mean of a fixing photosynthesis system, distributing assimilate efficient use of water and nutrients to the stability of the cell membrane (Wahid et al., 2007). When there is a stabilization factor and relief from the HSP to confront the pressure temperature, gradually, there will be an impact on the process of enzyme in plant metabolism. At high temperatures, enzyme in activation will increase over the activity of activation enzyme to support metabolism activities (Crafts-Brander and Salvucci, 2000). Decrease in the number of tillers of rice plant as a result of an increase in nighttime temperatures is caused by the distribution of photosynthate to elongation of stem cell is bigger than to increase the number of tillers of rice plant (Cheng et al., 2009).

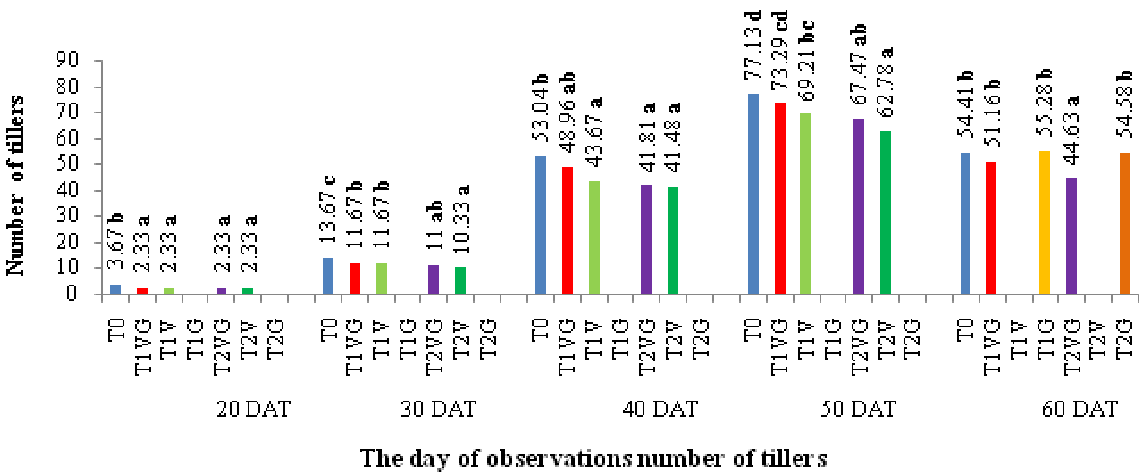

Figure 2. Number of tillers

The average number of leaf, leaf area, and total dry weight due to the increased temperature by 2°C and 4°C declined in line with increase in temperature of the night when compared to treatment T0 (Figures 3, 4 and 5). The average number of leaf, leaf area and total dry weight of rice plant caused by increased total temperature 2°C that was treated in phase V, VG and G did not differ significantly when compared to the T0 treatment. However, the increase in the night temperature by 4^o C that was treated on the VG and phase V resulted in the decrease of average number of leaves, leaf area and total dry weight of rice plant when compared at T0 and treatments of increased night temperature of 2^o C. Rice plant at the treatment of increased temperature of the night by 2^{o}C experienced acclimation. Acclimation is an adjustment to compensate for the respiration rate of temperature change (Aktin, 2003).

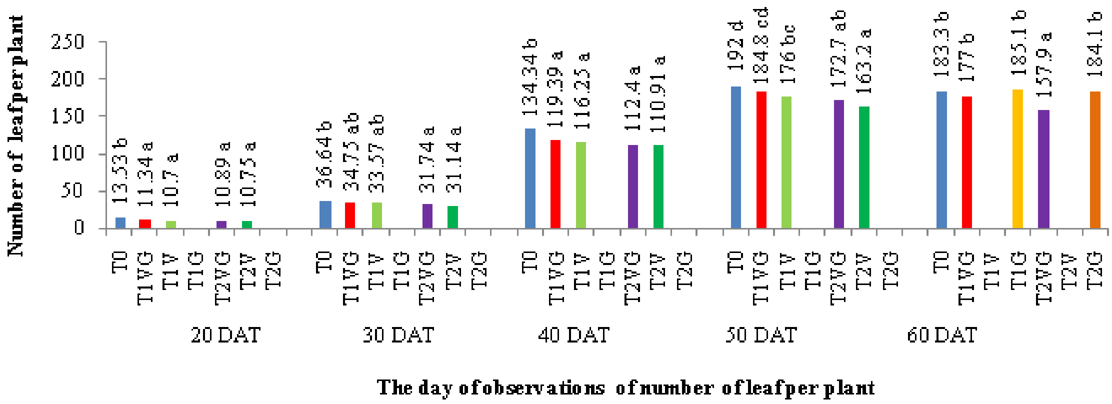

Figure 3. Number of leaf per plant

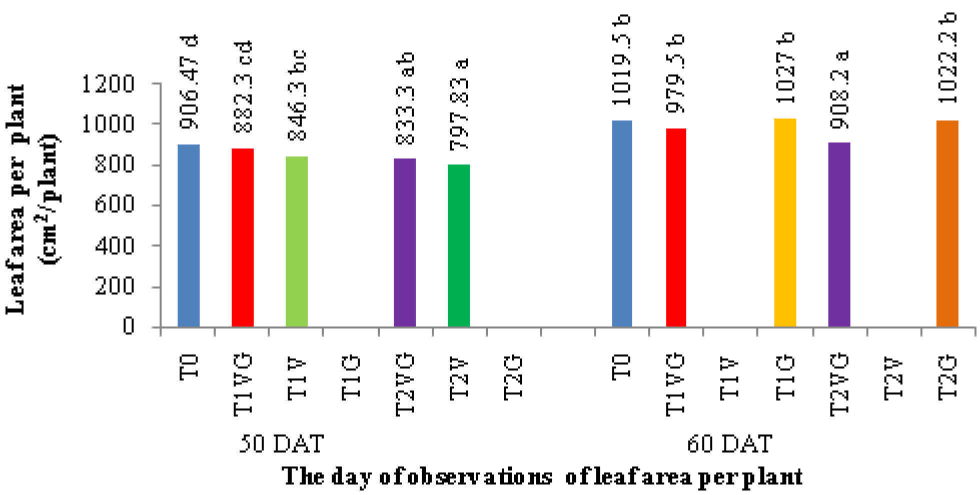

Figure 4. Leaf area per plant

The total dry weight significantly decreased when the increased night time temperature was 4^{o}C compared to the total dry weight on T0 and T1. The high temperatures can increase respiration but cause cell membrane to lose stability and potentially lower biomass (Peng et al., 2004). An increase in temperature of 27-32^{o}C will increase the number of injuries of membrane on the leaves rice plant by 60% (Muhammed and Tarpley, 2009). The functional system of cell membrane is as a center of plant productivity and plant acclimation to high temperature (Muhammed and Tarpley, 2009). Respiration has an impact on plant's growth rate as it forms energy for new complex molecules such as proteins, the cell membrane, and the cell wall that constitutional process as plant growth (Beevers, 1970). Observation on vegetative parameters such as number of leaf, leaf area, number of tillers of rice plant, nitrogen content, chlorophyll content and total dry weight indicated a positive correlation. So, if the number of leaf increases, it will impact on the total dry weight per plant to increase. The high temperatures result in the declione of pollination flowering rice plant which in turn decrease the ability of pollen to swell or dilate so it declines the ability to fertilize (Matsui, 2005).

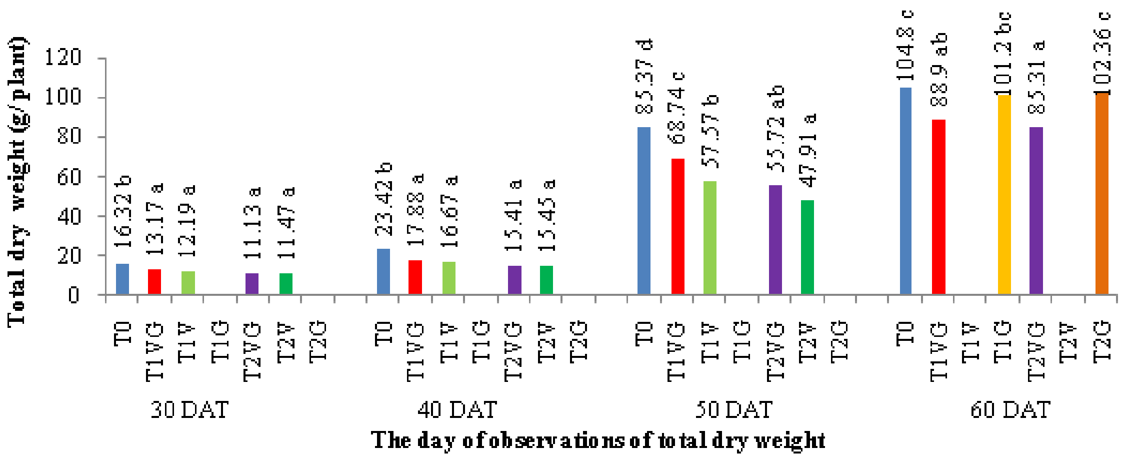

Figure 5. Total dry weight

The dectrease of pollination in high temperatures is also affected by hormonal balance during flowering, distribution of photosynthate, low ability of flower petals to mobilize carbohydrates as a result of heat stress, and the sift in activities of enzymes in the biosynthesis of starch and sugar (Keeling at al., 1994). The optimum temperature on the charging phase (seed repening) of japonica rice is between 21°-22°C for 40 days when it has formed penicles, when the air temperature is above optimum range then it can lose the weight of seed per plants (Kim, 2011)

The weight of seed per plant (Figure 6), number of panicle (Figure 7), harvest index (Figure 8), and number of productive tillers decreased along with increasing the night temperature by 2^{o} C and 4^{0} C which were treated at all treatment phase of growth.

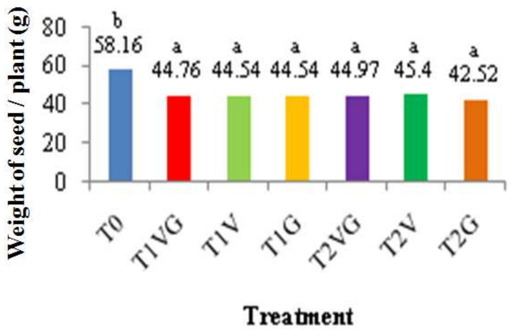

Figure 6. Weight of seed

Weight of seed per plant have positive correlation to the number of penicle per plant and harvest index. So with the increasing weight of seed per plant it is caused by the increasing number of panicle per plant and harvest index.

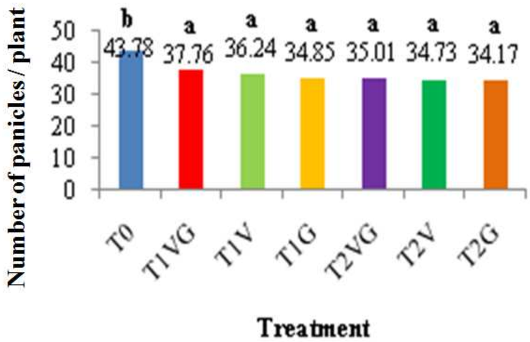

Figure 7. Number of panicle

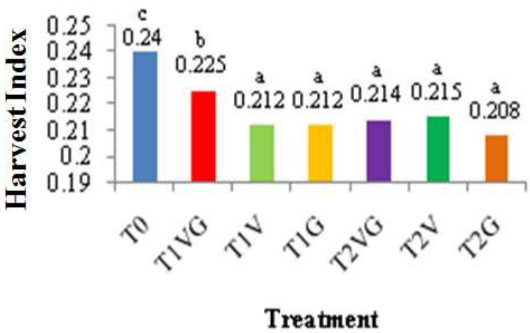

Figure 8. Harvest index

Length of panicle (Figure 9) shows a decline in treatment T1 VG, T1 V, T1 G,T2 VG, T2 V and T2 G. the length of panicle in general indicates a positive correlation with the vegetative observation parameters. So, length of panicle rice plant comes from the support of photosynthate generated during the vegetative phase. The precentage of full seed is very sensitive to an increase in nighttime temperature of 2^{0} C and 4^{0} C. thus treatments T1 Vg, T2 V, T2 Vg, and T2 V shows a lower percentage of full seed (Figure 10).

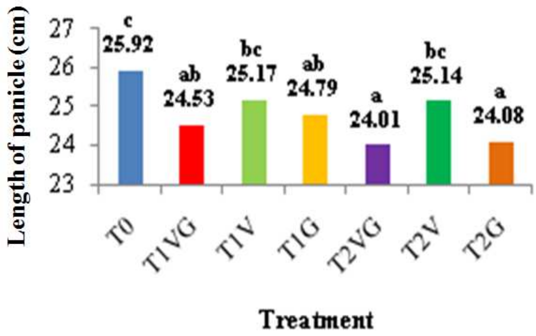

Figure 9. Length of panicle

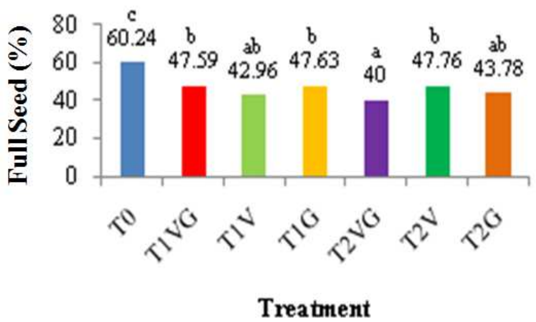

Figure 10. Precentage of full seed

The percentage of full seed has a positive correlation with leaf area during vegetative phase will have an impact on increasing the percentage of full seed. Increasing night temperature by 2^0 C and 4^0 C on Vg and V group caused delay in flowering time of the rice plants (Figure 11).

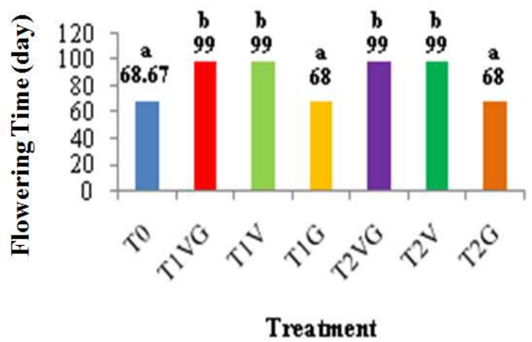

Figure 11. Flowering time

This is due to an extended vegetative phase as aresult of increased nighttime temperature. The longer the age of flowering rice plant then also have implications for the time of the harvest as well, as both have very real positive correlation with increasing night temperature. So, increasing nighttime temperature by 2^0 C and 4^0 C will also cause a delay in harvest time (Figure 12). The weight of seed per plant has areal negative correlation to harvesting time. So, earlier harvest time will result in a lower weight per plant as it will consequently lower the harvest index value. In this simulation, starch content in rice is higher in treated plants that T0.

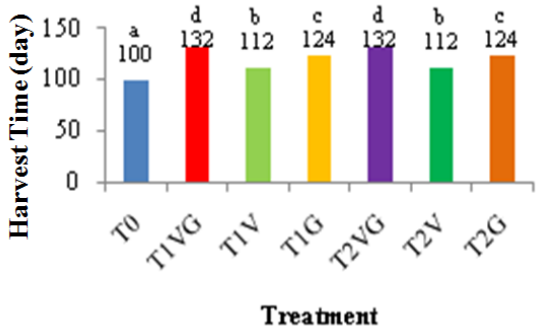

Figure 12. Harvest time

Conclusion

Increasing night temperature of 4^0 C treated on the vegetative and generative phases, and that treated only on vegetative resulted in 15% decreasein the mean number of leaf per plant, 12% decrease in leaf area, 22.5% decrease in ndthe number of panicle per plant, 70% decrease in the percentage of open stomata parameter, a 28% decrease in total dry weight per plant, Increasing night temperature of 4^0 C treated at the vegetative and generative phases, and that treated on the vegetative phase only and on the generative only showed 13,67% decrease in the number of panicle per plant, 5% decrease in length of panicle, 9% decrease in the harvest index parameter, and 16% decrease in weight of seed per plant than that the treatments without night temperature increase. The increase of night-time temperature by 2^0 C and 4^0 C resulted the delay of flowering time and harvest time.

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