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Manipulation of Flowering Time to Mitigate High Temperature Stress in Rice (*Oryza sativa* L.)

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ABSTRACT

Background: High temperature is an important abiotic stress affecting the productivity of rice. Early morning flowering trait is an escape mechanism from heat. This trait is present in wild rice cultivars. Here we tried to induce early morning flowering trait by the application of methyl jasmonate.

Methods: A pot culture experiment was conducted during Rabi, 2017 and 2018 to study the effect of foliar application of methyl jasmonate on high temperature stress (more than 35°C) mitigation in rice was conducted in the Department of Plant Physiology, College of Agriculture, Vellayani during 2017-2019. The variety used was Uma (MO 16). Methyl jasmonate was applied as foliar spray to the spikelet in varying concentration with different time. Physiological observations were taken at 50% flowering stage and yield parameters were taken at harvest stage.

Conclusion: There was significant variation for physiological and yield components among treatments. 4mM L^{-1} methyl jasmonate at 7am treatment exhibited increase in pollen viability, spikelet fertility percentage, yield per plant and 1000 grain weight. Hence, it is found that methyl jasmonate can advance anthesis time and thereby plants can escape from the severity of temperature experiencing at the normal flowering time in rice.

Key words: Early morning flowering, High temperature stress, Methyl jasmonate.

INTRODUCTION

Rice production also got intensified in upland and rainfed-lowland cropping systems, many of which were prone to high temperature and drought condition (Jagadish *et al.,* 2007). In these environmental conditions, day temperature periodically exceeded critical temperature of about 33°C for seed set which resulted in reduction in the fertility of spikelets and lead to reduced in yield (Nakagawa *et al.,* 2003). Impact of high temperature on physiological and yield traits were studied in rice (Beena *et al*., 2018a; Beena *et al*., 2018b). Pravallika *et al*., 2020 evaluated the nutritional and seed filling traits in heat tolerant and susceptible rice genotypes. Imaki *et al.* (1982) reported that the time of flowering in rice differed among various cultivars and some cultivars flowered early in the morning. Such cultivars might be helpful to avoid the damage by high temperatures during flowering time (Imaki, 1983). High temperature stress during or after anthesis induces the sterility of spikelet (Satake and Yoshida, 1978).

Hence, keeping in view of all the above facts, this study was conducted to test the effectiveness of Methyl jasmonate (MeJA) to advance the flowering time to escape from the severity of temperature experiencing at the normal flowering time.

MATERIALS AND METHODS

The study was conducted in the polyhouse maintained by Instructional farm, College of Agriculture, Vellayani, Trivandrum during the years from 2017-2018 (two years). Design of the experiment was CRD with three replications. The variety used for this study was Uma (MO-16) is a high yielding variety (average yield- 6t/ha) susceptible to high temperature stress (Beena *et al*., 2018a). Seedlings were raised in pot trays and transplanted to mud pots on 18th days after sowing. The pots were kept under high temperature condition (36-40°C) in a temperature controlled polyhouse from seedling to maturity stage. Maximum and minimum temperatures were measured daily using a thermo-hygrometer. Foliar application of methyl jasmonate was sprayed (50 mL per pot) to the spikelet in varying concentration (2 mM L^{-1} to 4 mM L^{-1}) with different time (7am, 8 am and 9 am). Physiological observations were taken at 50% flowering stage and yield parameters were taken at harvest stage.

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Anthesis time

Time of anthesis was observed from 07.00 am to 12.00 pm.

Pollen viability

Pollen viability was measured by using 1% iodo- potassium iodide (IKI) solution which was prepared by dissolving 2.5 g of KI with 250 mg of iodine and made up to 125 ml. Just before anthesis spikelets were collected from each treatment. Then it was crushed and stained by using IKI solution in a glass slides. Fully stained grains were denote the fertile pollen and unstained, shriveled, empty grains which indicate sterile grains. Fertile pollen grains were visually counted under compound microscope, Leica. The pollen viability was calculated by using the formula:

Pollen viability (%) =

$$\frac{\text{Number of pollen grains stained}}{\text{Total number of pollen grains}} \times 100$$

Spikelet fertility (%)

The total numbers of filled and unfilled spikelets of three randomly selected primary tillers of the target plants in each treatment were counted. Then, spikelet fertility (%) was calculated by using the formula:

$$\text{Spikelet fertility (\%)} = \frac{\text{Number of fertile spikelets}}{\text{Total number of spikelets}} \times 100$$

Grain yield (g)

The each treatment plant was harvested separately, cleaned, dried and weighed and it was expressed in grams.

1000 grain (g)

One thousand seeds were taken randomly from each replication, weighed and expressed in grams.

RESULTS AND DISCUSSION

Minimum and maximum temperature (°C)

Minimum and maximum temperatures were recorded inside the polyhouse and ambient condition by using thermo-hygrometer from 18th DAS to maturity stage. It was observed that the mean minimum temperature (°C) recorded inside the polyhouse condition was 25.1°C and ambient condition was 24.1°C. Difference of mean minimum temperature was 1.0°C. The mean maximum temperature (°C) recorded inside the polyhouse condition was 40.8°C and ambient condition was 31.5°C. Difference of mean maximum temperature was 9.3°C. There are two extremes for this temperature, lower developmental threshold (base temperature) and upper developmental threshold. Below base temperature and above upper developmental threshold growth of the plant will stop (Wahid *et al*., 2007). The optimum temperature for the normal development of rice ranges from 27 to 32°C (Satake and Yoshida., 1978).

Anthesis time (am)

In the present study, anthesis time was early in plants sprayed with 4mM L^{-1} methyl jasmonate at 7am was 08:1 am whereas, for control anthesis time was 11:54 am (Table 1). These findings are in line up with the findings of Zeng *et al*. (1999). They reported that methyl jasmonate induced rice florets opening within about 30 minutes of different rice cultivars.

Pollen viability (%)

In the present study, pollen viability was drastically reduced in control plants (37.52%) whereas, the considerable increase in plants sprayed with 4mM L^{-1} methyl jasmonate at 7 am (61.93 %) and 2mM L^{-1} methyl jasmonate at 7 am (58.64 %) (Table 1). These findings are supported by Fahad *et al*. (2016). They reported that methyl jasmonate improves the pollen viability compared to the plants which were not treated under high temperature stress condition in rice. Early morning flowering character can be effectively used for the escape from the heat stress which induced the sterility of the spikelet during anthesis by shedding of the viable pollen while in the cooler hours in the morning on to the receptive stigma (Satake and Yoshida, 1978).

Spikelet fertility percentage (%)

In the present study, the spikelet fertility percentage was increased in 4mM L^{-1} methyl jasmonate at 7 am (56.07%) whereas, there was considerable reduction in spikelet fertility percentage in control (33.09%) (Table 1). Fahad *et al*. (2016) reported that methyl jasmonate improved the spikelet fertility under high temperature stress condition in rice. MeJA (Methy Jasmonate) was a crucial cellular regulator involved in developmental process in several plants (Norastehnia *et al.,* 2007; Kim *et al*., 2009). Foliar application of MeJA brings alteration in various physiological processes and hence stimulates plant defense responses against abiotic and biotic stresses (Walia *et al.,* 2007). Clarke *et al.* (2009) reported that exogenous application of MeJA in *Arabidopsis thaliana* improved basal thermo-tolerance and protected from the heat shock damage.

Grain yield per plant (g)

In the present study, grain yield per plant in 4mM L^{-1} methyl jasmonate at 7 am was 8.55 g (Table 1). There was considerable reduction in grain yield per plant in control was 4.22 g. These findings are in line up with the findings of Fahad *et al*. (2016) reported that methyl jasmonate improved the grain yield per plant under high temperature stress condition in rice. A significant impact of high temperature stress is mainly observed in tomatoes (*Lycopersicum esculentum*) as it affects meiosis, fertilization and growth of fertilized embryos eventually leading to a significant decrease in yield and fruit quality (Camejo *et al.,* 2005; Amrutha and Beena, 2020; Vijayakumar *et al*., 2021) and lentil (Baidya *et al*., 2020). Early morning flowering trait can be effectively used for the escape from the high temperature stress which helps to reduce the sterility of the spikelet during anthesis by shedding of the viable pollen while in the cooler hours in the morning on to the receptive stigma and which leads to significant increase in grain yield (Satake and Yoshida, 1978).

1000 grain weight (g)

Application of 4mM L^{-1} methyl jasmonate at 7 am recorded 1000 grain as 21.32 g. This treatment was at par with 2mM

Table 1: Effect of foliar application of Methyl jasmonate (MeJA) and water spray on anthesis time, pollen viability, spikelet fertility percentage, grain yield per plant and 1000 grain weight.

Treatments	Anthesis time (am)	Pollen viability (%)	Spikelet fertility percentage (%)	Grain yield per plant (g)	1000 grain weight (g)
T1: 2mM L-1 MeJA at 7 am	08:26	58.63^{b}	52.10^{b}	8.06^{b}	21.02^{ab}
T2: 2mM L-1 MeJA at 8 am	09:18	55.05^{c}	49.77^{c}	7.50^{cd}	20.85^{bc}
T3: 2mM L-1 MeJA at 9 am	10:30	51.54^{e}	47.59^{e}	7.16^{d}	20.50^{c}
T4: 4mM L-1 MeJA at 7 am	08:11	61.93^{a}	56.07^{a}	8.55^{a}	21.32^{a}
T5: 4mM L-1 MeJA at 8 am	09:04	58.32^{b}	49.38^{c}	7.89^{bc}	20.83^{abc}
T6: 4mM L-1 MeJA at 9 am	10:18	52.87^{d}	48.65^{d}	7.57^{cd}	20.50^{c}
T7: Water spray at 7 am	11:29	45.89^{f}	44.01^{f}	6.00^{e}	18.26^{d}
T8: Water spray at 8 am	11:30	45.38^{f}	39.78^{g}	5.42^{f}	18.20^{d}
T9: Water spray at 9 am	11:40	42.10^{g}	36.87^{h}	5.01^{f}	18.19^{d}
T10: Absolute control (stress)	11:54	37.52^{h}	33.09^{i}	4.22^{g}	17.85^{d}
C.D.(0.05)		0.88	0.86	0.42	0.50
C.V		1.02	1.12	3.62	1.47

L^{-1} methyl jasmonate at 7 am (21.02 g) and 4mM L^{-1} methyl jasmonate at 8am (20.83g). There was reduction in 1000 grain weight in control as compared to treatments (Table 1). This result was supported by Anjum *et al.* (2016). Early morning flowering trait leads to significant increase in grain yield and grain weight (Satake and Yoshida, 1978).

CONCLUSION

There were significant variation for physiological and yield components among treatments. 4mM L^{-1} methyl jasmonate at 7am showed better performance for all the parameters such as anthesis time, pollen viability, spikelet fertility percentage, yield per plant and 1000 grain weight compared to all the treatments under high temperature stress condition. Hence, it is found that methyl jasmonate can advance anthesis time and thereby plants can escape from the severity of temperature experiencing at the normal flowering time.

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