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Research Article

Effect of High Temperature on Performance of Rice and its Management

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ABSTRACT

A split plot experiment was conducted during *kharif* 2012 and 2013 in pots using rice variety PR 118. The main plots consisted of five heat stress treatments (control, heat stress during tillering, panicle emergence, anthesis and grain development phase). The sub plots consisted of two treatments (control and spray of 50 ppm salicylic acid in rice nursery 5 days before transplanting). Heat stress was applied by placing the pots inside a polyhouse constructed for this purpose. Results suggested that the most susceptible stages to high temperature (heat stress) in rice were anthesis and grain development. Maximum reduction (37.0 and 31.5% during 2012 and 2013, respectively) in grain yield was recorded in pots subjected to heat stress during anthesis stage, and not sprayed with salicylic acid. Next adversely affected stage was grain development stage without application of salicylic acid, and yield reduction (17.1 and 17.3% during 2012 and 2013, respectively) due to heat stress during this stage was significant. Adverse effects of heat stress can be reduced by foliar application of 50 ppm salicylic acid to rice nursery 5 days before transplanting.

Key words: Heat stress, Growth stage, Salicyclic acid, Grain yield, Rice

Introduction

Rice (*Oryza sativa* L.) is one of the most important crops globally, and also in India and Punjab. It is grown over 162 million ha area and contributes to 34% of global food grain production (Raj *et al*., 2016), and is also a staple food for more than 50% of owrld's population. On an average, an Indian consumes 83 kg rice per year. According to Agricultural Policy Vision 2020 of ICAR, India will need 112.4 million tonnes of rice in the year 2020. Sustainability of food and nutritional security of India and many other countries depends upon rice.

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Plants grow better under a range of abiotic factors and any deviations from these optimum ranges leads to changes in physiological processes in the plant and they may experience stress. Under changing climatic scenario, extreme of temperatures and rainfall events are expected. Some of the significant changes observed in climate of Punjab were reported by Prabhjyot-Kaur *et al.* (2016). These changes may increase plant stresses. In rice, high temperature at all stages of development may affect rice productivity and particularly during flowering, when it causes spikelet sterility. High temperature also increases plant respiration, affects photosynthesis and shortens the grain-filling duration, combined effect of these leads to lower productivity (Peng *et al.,* 2004). Many studies

(Peng *et al*., 2004; Lobell, 2007; Sandhu *et al*., 2016) related to effect of change in temperature on crop productivity are available. Sandhu *et al*. (2012) reported that the daily maximum temperature during 2010 at anthesis (during and after heading) remained higher than the optimum (30–33°C) for anthesis (Yoshida, 1978) for 7 consecutive days might have resulted in increased spikelet sterility and thus reduced grain yield. Sandhu *et al*. (2013) highlighted that the maximum temperature during entire rice season and vegetative stage was significantly (p=0.10) and positively correlated with its grain yield. Samui (1999) observed that in India the rice productivity is more if rainfall ranged between 100-115 cm, sunshine hours between 250-350 h for photo-insensitive varieties, maximum and minimum temperature ranged between 29-32°C and 23-25 °C, respectively. These parameters vary annually and intra and inter-seasonal variations play a pivotal role in determining the final crop yields.

Studies related to management of rice crop under high temperature are rarely available in literature. Some of the studies have shown that salicylic acid can be helpful in protecting the crops from harmful effects of high temperature. Khan *et al*. (2003) reported that salicylic acid improved the photosynthetic efficiency, plant growth and yield. Another study by Iqbal *et al*. (2013) found that salicylic acid reduced the loss of chlorophyll, rubisco activity and showed maximum protection from heat stress by lowering ethylene formation through the decrease in ACS (1-aminocyclopropane carboxylic acid synthase) activity. Giraudat *et al*. (1994) reported that salicylic acid induces tolerance to abiotic stresses such as temperature, drought and salinity in crops. These studies highlighted the potential of salicylic acid to maintain crop productivity under elevated temperature conditions.

Keeping in mind the facts mentioned above, the present study was conducted to analyze the effects of elevated temperature on performance of rice and to evaluate the efficacy of salicylic acid in reducing the harmful effects of high temperature in rice.

Materials and Methods

The experiment on rice during *kharif* 2012 and 2013 was conducted in pots using PR 118 variety in a split plot design. The main plots consisted of five heat stress treatments (control, heat stress during tillering, panicle emergence, anthesis and grain development phase). The sub plots consisted of two treatments (control and spray of 50 ppm salicylic acid in rice nursery 5 days before transplanting). The experiment was replicated three times. The pots were filled with 10 kg of soil. Before filling the pots the soil was passed through a sieve and was mixed with hands to make in homogeneous. Thirty-day old six seedlings were transplanted on 13th and 12th July during 2012 and 2013, respectively, and finally only two seedlings were retained on 10 days after transplanting. Fertilizers were applied @ 0.75 g urea, 1.50 g single super phosphate, 0.40 g muriate of potash and 0.50 g zinc sulphate pot^{-1} at the time of transplanting. Two more doses of urea @ 0.75 g pot^{-1} were applied at 3 and 6 weeks after transplanting. Weeds were controlled manually and the pots were irrigated daily with equal quantity of water. The heat stress was applied by placing the pots inside (Table 1, for the period when pots were inside poly house). A poly house constructed for this purpose. To avoid excessively high temperature inside the poly house, its western side was kept open during the day time; however, during the night all sides were kept closed. Daily maximum and minimum temperatures (Table 1) were recorded from inside and outside polyhouse with maximum and minimum thermometers, placed on top of the pots.

Results and Discussion

Plant height

The plant height of rice at harvest was influenced by the heat stress as well as by salicylic acid (Table 2). Maximum plant height was observed in pots subjected to heat stress during tillering stage and plant height in these pots was higher than control. Similar to the results of the present study, Oh-e *et al*. (2007) also found increase in plant height of rice under high

Table 1. Details of heat stress imposed to rice during the crop seasons

Treatments	Time period for stress	Temperature (°C) inside polyhouse			Temperature (°C) outside polyhouse		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Heat stress				**2012**			
Control	13 July- 1 Nov	-	-	-	32.8	21.0	26.9
Tillering	28 July-17 Sept	39.4	25.7	32.6	33.0	24.1	28.6
Panicle initiation	17 Sept- 25 Sept	38.8	22.8	30.8	30.8	20.8	25.8
Anthesis	25 Sept-28 Sept	37.4	21.9	29.7	33.0	19.5	26.3
Grain development	28 Sept- 1 Nov	36.0	16.9	26.5	32.2	14.3	23.3
				2013			
Control	12 July- 8 Nov	-	-	-	31.7	21.0	26.4
Tillering	28 July-17 Sept	39.6	24.8	32.2	32.1	23.5	27.8
Panicle initiation	25 Sept- 28 Sept	37.5	22.8	30.2	31.9	21.9	26.9
Anthesis	28 Sept-7 Oct	38.9	24.2	31.6	31.5	22.0	26.8
Grain development	7 Oct - 11 Nov	34.9	17.7	26.3	29.5	15.8	22.7

Table 2. Growth and yield attributes of rice as influenced by heat stress and salicylic acid treatments

Treatments	Plant height at harvest (cm)		Panicle length (cm)		Number of panicles plant^{-1}		No of grains panicle^{-1}		Test wt (g)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Heat stress										
Control	42.4	43.9	22.1	22.2	14.0	14.5	74.6	70.8	24.1	25.9
Tillering	54.4	56.4	22.4	22.0	15.8	15.2	75.9	72.7	23.1	24.3
Panicle initiation	43.8	45.5	23.2	22.7	14.6	13.8	80.6	71.6	24.2	24.3
Anthesis	43.8	45.8	22.5	22.3	14.7	13.5	65.2	61.8	23.8	24.7
Grain development	47.1	49.7	22.7	22.0	14.6	13.1	76.7	70.1	23.2	23.3
CD	4.1	4.4	NS	NS	NS	NS	9.4	NS	NS	NS
Salicylic acid										
Control	44.4	45.2	21.8	21.9	14.2	13.8	70.0	65.7	23.5	24.4
50 ppm	48.2	51.3	23.3	22.6	15.3	14.3	79.2	73.1	23.9	24.6
CD	3.6	1.6	NS	NS	1.1	NS	6.2	4.1	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	9.1	NS	NS

temperature than under ambient temperature condition. Application of salicylic acid significantly increased plant height by 8.6 and 13.5% cent during 2012 and 2013, respectively, compared to control. The increase in plant height with application of salicylic acid might have been due to improvement in photosysthetic efficiency and plant growth as reported by Khan *et al.* (2003).

Panicle length

The application of heat stress and salicylic acid non significantly influenced the panicle length of rice. However, salicylic acid increased the panicle length by 6.9 and 3.2% during 2012 and 2013, respectively.

Number of panicles per plant

Heat stress at various stages failed to influence the number of panicles plant^{-1} of rice (Table 2). However during 2012, application of salicylic acid increased (7.8%) the number of panicles plant^{-1} of rice but failed to have any impact during 2013.

Number of grains per panicle

The number of grains panicle^{-1} of rice (Table 2) was influenced by the heat stress as well as by the salicylic acid. Heat stress during anthesis caused a reduction in number of grains panicle^{-1} only during 2012. Reduction in number of grain panicle^{-1} due to heat stress during anthesis was 12.6 and 12.7% during 2012 and 2013, respectively. Average maximum temperature in heat stressed pots during anthesis was 37.4 and 38.9 ^{o}C during 2012 and 2013, respectively (Table 1). These high temperatures might have adversely affected anthesis stage as these were higher than the optimum temperature (30-33^{o}C; Yoshida, 1978). Earlier studies (Tian *et al*., 2007; Xie *et al*., 2009) had reported that high temperatures at flowering and grain-filling phase caused spikelet sterility and shortened the grain-filling duration. It has also been reported that the young microspore stage shows sensitivity to high temperature (Satake and Yoshida, 1978).

Salicylic acid significantly increased number of grains panicle^{-1} of rice by 13.1 and 11.3% during 2012 and 2013, respectively. Supporting the present results, Baohua *et al*. (2018) reported that under heat stress, rice plants sprayed with salicylic acid had higher pollen viability and seed setting rate as compared to control.

Interaction among heat stress and salicylic acid treatments was found to be significant in case of number of grains panicle^{-1} of rice during the year 2013 (Table 3). Minimum number of grains panicle^{-1} (52.8) was observed in the pots subjected to heat stress during anthesis stage and not spread with salicylic acid, and it was significantly lower than those observed under control conditions.

Test weight and grain yield

Heat stress and salicylic acid failed to have any significant effect on the test weight of rice (Table 2). The grain yield of rice was impacted by heat stress only during 2012; however, salicylic acid has infleunce it in both the years (Table 3). Interaction among heat stress and salicylic acid treatments was found to be significant during both years. Maximum reduction in grain yield of 37.0 and 31.5% during 2012 and 2013, respectively, compared to control (not stressed and without salicylic acid) was observed in pots subjected to heat stress during anthesis stage and not sprayed with salicylic acid, and this reduction was statistically significant. Next adversely affected stage was grain development stage without application of salicylic acid and yield reduction (17.1 and 17.3% during 2012 and 2013, respectively) due to heat stress during this stage was significant. It has been reported that extremely high temperatures during the reproductive stages of rice significantly decreases the grain yield by more than 50 per cent (Zhang *et al*., 2018; Fu *et al*., 2012). Male sterility induced by heat stress is one of the main reasons that cause reduction in grain yield of rice (Satake and Yoshida, 1978).

During both years salicylic acid under stressed conditions helped in maintaining the grain yield statistically similar to that obtained under control (not stressed and without salicylic

Table 3. Interaction effect of heat stress and salicylic acid on number of grains/panicle and grain yield of rice (g pot^{-1})

Treatments	No of grains panicle^{-1} (2013)			Grain yield (g pot^{-1})					
				2012			2013		
	Control	Salicylic acid (50 ppm)	Mean	Control	Salicylic acid (50 ppm)	Mean	Control	Salicylic acid (50 ppm)	Mean
Heat stress									
Control	70.6	71.1	**70.8**	52.7	56.7	**54.7**	48.5	51.3	**49.9**
Tillering	71.3	74.1	**72.7**	57.3	56.5	**56.9**	51.1	52.8	**52.0**
Panicle initiation	64.5	78.7	**71.6**	53.5	59.1	**56.3**	48.4	54.6	**51.5**
Anthesis	52.8	70.8	**61.8**	33.2	54.8	**44.0**	33.2	49.1	**41.2**
Grain development	69.4	70.8	**70.1**	43.7	46.2	**44.9**	40.1	44.8	**42.5**
Mean	65.7	73.1		48.1	54.6		36.9	42.1	
CD									
Heat stress		NS			9.1			NS	
Salicylic acid		4.1			4.1			2.7	
Interaction		9.1			9.2			6.1	

acid) conditions. On an average, salicylic acid helped to increase the grain yield significantly by 13.5 and 11.7% during 2012 and 2013, respectively. Baohua *et al*. (2018) reported that salicylic acid conferred heat resistance in rice resulting in higher pollen viability and seed-setting rates under heat stress. This could be a reason for improvement in grain yield of rice with the application of salicylic acid.

Conclusions

The most susceptible stages of rice to high temperature (heat stress) are anthesis and grain development. The adverse effects of heat stress can be reduced by foliar application of 50 ppm salicylic acid to rice nursery 5 days before transplanting. However, these are the results of experiments conducted in pots and needs to be validated under field conditions.

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