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Growth, yield components and grain yield response of rice to temperature and nitrogen levels

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ABSTRACT

An experiment was carried out during the *kharif* season of year 2013 inside Temperature Gradient Tunnel (TGT) of Centre for Environment Science and Climate Resilient Agriculture (CESCRA), at IARI farm to study impact of elevated temperature on the growth and yield responses of rice crop under four N levels. Results showed that grain and biomass yield of rice had decreased significantly with rise in temperature inside the TGT. With recommended N dose, yield reduction of rice was 37 per cent with rise in temperature to 3.9ºC over ambient air condition but application of 125 per cent N can prevent the yield loss by 6per cent as compared to 100 per cent recommended N treatment. Yield parameters Spikelet sterility of rice did increase with increase in temperature.

Key words: Elevated temperature, nitrogen dose, rice, yield

Rice (*Oryza sativa L.*) is one of the most important cereal crops of the world.It forms the backbone for National food grain supply and contributes to 46 per cent to total cereal production and 43 per cent to total food grain production. Among the rice growing countries in the world, India has the largest area under rice crop (about 45 million ha) and ranks second in production, next to China.

In the 5th Assessment Report (AR5), the Inter-Governmental Panel on Climate Change (IPCC) did caution for terrible consequences of climate change on natural resources, crop growth and production, agricultural sustainability and human health (IPCC 2014). Global simulation studies indicated that between 2080 and 2100, temperature increase may lead to 10-40 per cent loss in crop production in India (IPCC, 2007); whereas, studies conducted in India showed though similar trend of decline in agricultural production with climate change but at varying magnitudes. Rising level of CO_2 and subsequently temperature, is likely to affect all aspects of plant growth, development and function differentially according to the plant species and geographical location (Centritto and Loreto, 2005).

Climate change and its impact would emerge as a new challenge in near future, in addition to many challenges that are already present to achieve higher productivity in rice crop (Krishnan *et al*., 2011). A study conducted at International Rice Research Institute (IRRI), showed that grain yield of rice found decreased by 10 per cent for each 1°C increase in growing-season minimum temperature (IRRI, 2004).

According to Zacharias *et al*. (2010), high temperature stress caused reduction in total dry matter, tiller mortality, reduced the number of panicles, grain per panicle, floret sterility and grain weight thus reducing the grain yield of rice. According to Waraich *et al.* (2012) proper plant nutrition is one of the good strategies to alleviate the temperature stress in crop plants. It is therefore important to determine how growth and yield response of rice crop are influenced by elevated temperature as it would have crucial implications on future food security of this highly-populated region of the world. Hence the study was undertaken to study the impact of increased temperature on the growth and yield responses of rice crop under different N levels.

MATERIALS AND METHODS

Site

The experiment was carried out during the *kharif* season of 2013 in the Temperature Gradient Tunnel (TGT) of Centre for Environment Science and Climate Resilient Agriculture (CESCRA), at IARI farm, New Delhi, India (28°35'N and 77°12'E). The climate of Delhi is, semi-arid. The mean annual maximum temperature is 35°C while the mean annual minimum temperature is 18°C.

Experimental design and treatments

The experiment was conducted by growing rice crop (variety Pusa 44) in pots inside the TGT. Statistical design of the experiment is completely randomised design (CRD). Two rice seedlings (30 days old) were transplanted in each pot on July 23, 2013. Area inside the tunnel was divided into five parts having five different temperature levels. Temperature gradient was created inside the temperature gradient tunnel during the *kharif* season of 2013. S1, S2, S3, S4 and S5 were the five temperature sensors installed inside the tunnel. S5 sensor was installed near the outlet of the tunnel, and it recorded the maximum temperature during the whole crop growth period while S1 sensor was installed near the inlet point having lowest temperature. Temperature elevation was prevalent throughout the cropping period.

According to the fifth assessment report of IPCC, temperature increase by the end of this century would vary in different representative concentration pathways (RCPs). In the intermediate scenarios (RCP 4.5 & RCP 6.0) temperature rise will be 1.1° to 2.6°C and 1.4° to 3.1°C. In the following study temperature treatments were fixed quite close to the projected temperature scenarios of IPCC. Five temperature sensors namely S1, S2, S3, S4 and S5 were installed inside the tunnel for temperature levels of 0°C, 0.8°C, 2°C, 3.1°C and 3.9°C respectively.

Pots with four different N doses were kept in each part. Four N levels were N0: No nitrogen; N1: 0.6 g N pot^{-1}; N2: 0.8 g N pot^{-1} and N3: 1.0 g N pot^{-1}. Above doses of nitrogen corresponded to N0: Control; N1: 75 per cent recommended dose of N; N2: 100 per cent recommended dose of N and N3: 125 per cent recommended dose of N. The recommended dose of fertilizer for ricewas 120:60:60 kg NPK ha^{-1}. In total there were 20 treatments inside TGT and replicated thrice. Half of the nitrogen dose was applied as basal and remaining half applied in two equal splits at 37 and 61 days after transplanting (DAT). Phosphorous and potassium were applied completely as basal dose.

Plant sampling and analysis

In the experiment, after harvest shoot biomass and yield parameters (number of tillers, total no of panicles, no of grains/panicle, no. of filled and unfilled grains/panicle, grain yield / weight, test weight of grains etc.) were recorded for rice crop. The grains were separated from the straw, dried, and weighed. Grain moisture was determined after weighing and subsamples were dried in an oven at 65°C for 48 h. At the time of harvest the moisture content was found to be 14 per cent.

Data analysis

Statistical analysis of the data was done by using the analysis of variance technique recommended for the design (Gomez and Gomez, 1984) and the differences between means were tested to find out whether they are statistically significant or not. Unless indicated otherwise, differences were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Temperature gradient inside the TGT

Five sensors were recorded by the data logger. This data were downloaded and mean temperature elevation of the five sensors over the ambient temperature was calculated for the whole cropping season. Temperatures recorded by the five sensors were in the order of S1<S2<S3<S4<S5 and during the whole rice crop growing season, the mean temperature elevation created inside the TGT was in the order of +0°C, +0.8°C, +2°C, +3.1°C and +3.9°C respectively.

Phenological response of rice to elevated temperature

Crop growth duration got reduced with the elevated temperature in rice crop. Days to 50 per cent flowering and flag leaf initiation in rice got decreased with elevation in temperature. The rise in temperature by 3.9°C diddecrease days to 50 per cent flowering and flag leaf initiation by 8 and 7 days respectively (Table 1). At the same time with application of N, days to 50 per cent flowering and flag leaf initiation got enhanced over control (no N dose) and the increase was observed with increase in N levels. With 2.0–3.9°C rise in temperature, days to flag leaf initiation found reduced by 3–9 days and 50 per cent flowering by 3–7 days under recommended dose of N(N2). With the application of 125 per cent of recommended N dose (N3), days to 50 per cent flowering and flag leaf initiation found increased by 4 and 3-9days respectively over control (no N dose) for the temperature treatment 3.9°C.

Earlier studies also reported that high temperature shortened the period of crop growth and accelerated the crop development (Tao *et al.,* 2006; Challinor and Wheeler, 2008).Similar reports were reported by Rani and Maragatham (2013) and they found that rise in temperature by 4°C did reduce crop duration by 12 days over ambient temperature, whereas temperature rise by 2°C had reduced the crop duration by 6 days than ambient temperature. As a result grain yield got declined under elevated tempera-ture significantly than the ambient temperature condition.

Table 1: Effect of elevated temperature on phenology of rice crop (days)

N dose ($g\ pot^{-1}$)	+0ºC	+0.8ºC	+2ºC	+3.1ºC	+3.9ºC	LSD (P = 0.05)
			Days to flag leaf initiation			
0	75	75	72	70	68	N:1.43
0.6	76	75	73	71	67	Temp.:2
0.8	78	77	75	74	69	N X Temp.: 1.24
1.0	79	79	76	75	71	
			Days to 50 per cent flowering			
0	95	95	92	90	87	N: 1.31
0.6	95	96	94	91	87	Temp. : 2.1
0.8	97	97	94	92	90	N X Temp.: 1.66
1.0	99	99	95	93	91	

LSD: Least Significant Difference

Table 2 : Effect of elevated temperature on plant height, number of tillers and number of panicles of rice crop.

N dose ($g\ pot^{-1}$)	+0ºC	+0.8ºC	+2ºC	+3.1ºC	+3.9ºC	Thermal effect (% loss per ºC)	LSD (P = 0.05)
				Plant Height (cm)			
0	82.8	83.7	81.8	83.1	82.1	0.1	N: 2.14
0.6	83.5	84.7	81.9	85.4	84.5	-0.3	Temp.: NS
0.8	85.1	85.5	82.4	87.3	84.7	0.1	N X Temp.: NS
1.0	87.8	86.7	88.3	89.3	86.5	0.05	
				No. of tillers pot^{-1}			
0	56	54	49	41	38	7.7	N: 8.3
0.6	60	59	55	54	50	3.7	Temp. : 9.3
0.8	76	68	64	63	61	6.4	N X Temp.: NS
1.0	75	75	72	71	67	2.0	
				No. of panicles pot^{-1}			
0	49	43	38	34	33	10.0	N: 4
0.6	56	50	42	40	39	9.7	Temp. : 5
0.8	67	62	55	50	43	8.8	N X Temp.: 9
1.0	69	65	63	51	43	8.0	

LSD: Least Significant Difference

Effect of elevated temperature on yield parameters and rice grain yield

Grain and biomass yield of rice crop significantly had decreased with rise in temperature inside the TGT (Fig. 1 and Fig. 2). Grain yield of rice crop did reduce by 42.6per cent with rise in temperature to 3.9ºC, while biomass yield had reduced by 29.6 per cent. Application of nitrogen significantly increased the rice yield over control in all the temperature treatments. In N2 treatment i.e. with 100 per cent recommended N dose, yield reduction of rice was 37 per cent with rise in temperature by 3.9ºC but application of 125 per cent of recommended dose of N could prevent the yield loss by 6 per cent as compared to 100 per cent recommended N treatment with rise in temperature by 3.9ºC.

Loss in grain yield was found to be 11.9 per cent and biomass yield to be 8.9 per cent per degree Celsius rise in temperature and this loss was reduced to 8.7 and 5.7 per cent

Table 3 : Effect of elevated temperature on panicle length, number of grains per panicle and harvest index of rice crop

N dose	Temperature elevation					Thermal effect	LSD
(g pot^{-1})	+0ºC	+0.8ºC	+2ºC	+3.1ºC	+3.9ºC	(% loss per ºC)	(P = 0.05)
			Panicle length (cm)				
0	24.9	24.8	24.5	23.9	23.8	1.1	N: 0.5
0.6	25	24.9	24.8	24.0	23.9	1.0	Temp.: 0.6
0.8	25.1	25.0	24.9	24.5	24.1	0.8	N X Temp.: 1.1
1.0	25.5	25.4	25.0	24.1	24.6	1.2	
			No. of grains panicle^{-1}				
0	106	101	98	95	91	3.8	N: 8
0.6	111	106	103	99	98	3.5	Temp. : 9
0.8	117	114	109	108	98	3.4	N X Temp.: NS
1.0	119	118	110	109	100	3.3	
			Harvest index				
0	0.47	0.45	0.44	0.40	0.38	4.1	N: 2.1
0.6	0.47	0.46	0.45	0.42	0.38	4.1	Temp. : 3.8
0.8	0.48	0.46	0.45	0.44	0.39	3.9	N X Temp.: NS
1.0	0.49	0.48	0.46	0.45	0.40	3.6	

LSD: Least Significant Difference

Table 4 : Effect of elevated temperature on spikelet sterility and thousand grain weight of rice crop.

N dose	Temperature elevation					Thermal effect	LSD
(g pot^{-1})	+0ºC	+0.8ºC	+2ºC	+3.1ºC	+3.9ºC		(P = 0.05)
		Spikelet sterility (%)				(% gain per ºC)	
0	17.9	22.1	26.5	31.0	33.9	23.9	N: 3.4
0.6	16.4	20.1	24.2	29.2	30.0	23.6	Temp.: 3.8
0.8	16.2	19.1	23.8	28.1	30.5	23.1	N X Temp.: 7.6
1.0	15.1	18.7	21.2	26.3	28.3	23.0	
		1000 grain wt. (g)				(% loss per ºC)	
0	16.4	16.5	16.2	16.5	16.3	0.1	N: NS
0.6	16.1	16.4	16.2	15.9	15.9	0.0	Temp. : NS
0.8	16.3	16.5	16.7	16.3	15.8	0.1	N X Temp.: NS
1.0	16.1	16.2	16.3	16	15.9	0.0	

LSD: Least Significant Difference

respectively with the application of 125 per cent of recommended dose of N. Rani and Maragatham, (2013) also reported yield reduction in rice due to elevated temperature by 13.3and 23 per cent under 2°C and 4°C temperature rise treatments respectively.

Yield parameters like number of tillers, number of panicles per pot, panicle length, number of grains per panicle, harvest index and spikelet sterility of rice had decreased significantly with rise in temperature. Application of nitrogen significantly did increase the plant height, number of panicles per pot, panicle length and number of grains per panicle in rice plant. The recorded plant height was found ranged from 81.8 to 89.3 cm under different treatments. Number of tillers per pot was found to be maximum (76) in N2 treatment at 0ºC temperature. Rise in temperature by 3.9ºC did decrease the number of tillers to 61 from 76 under N2 treatment. In no nitrogen treatment (control) tiller number was least (56)

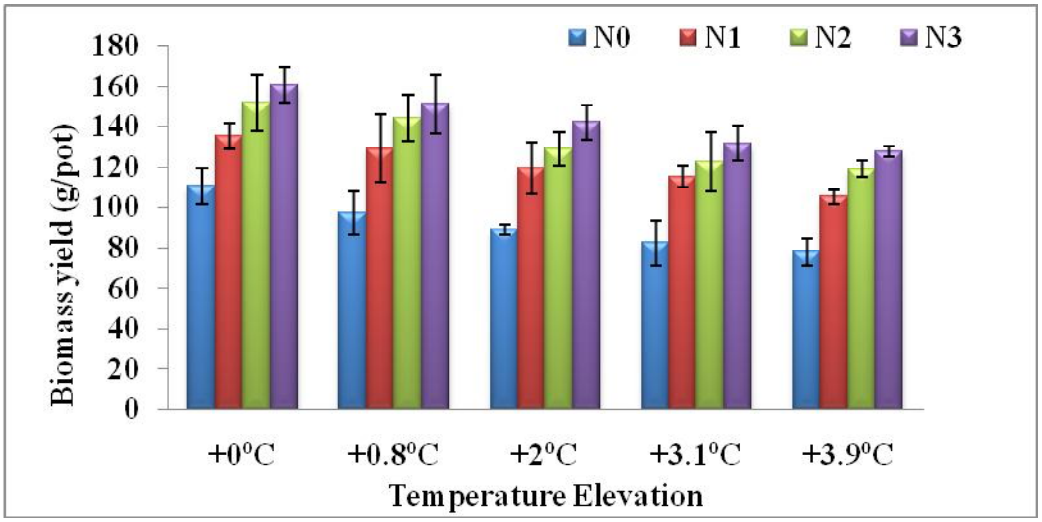

Fig. 1 : Effect of elevated temperature on grain yield of rice crop

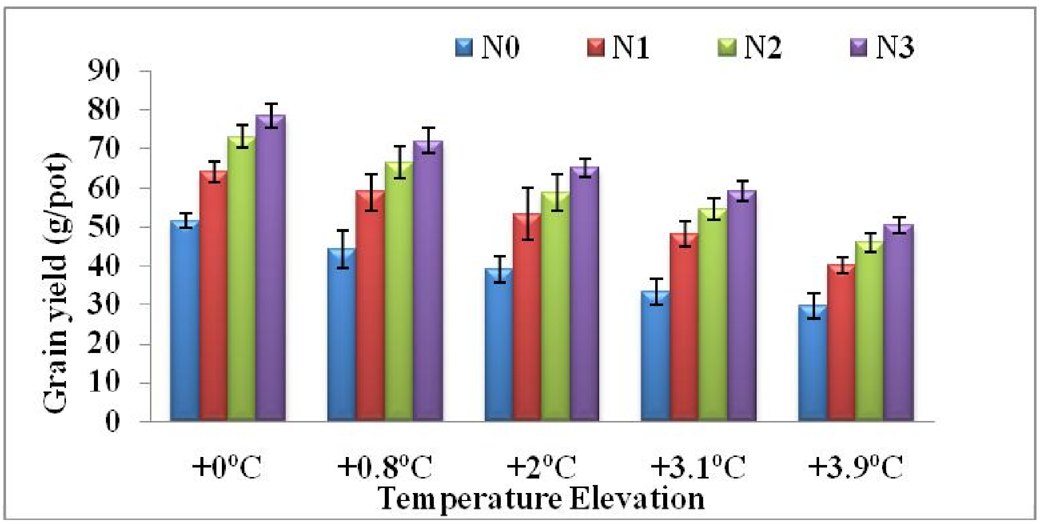

Fig. 2 : Effect of elevated temperature on biomass yield of rice crop

N0 Control (no N); N1 0.6 g N pot^{-1} (75% of recommended dose); N2 0.8 g N pot^{-1} (100% of recommended dose); N3 1.0 g N pot^{-1} (125% of recommended dose)

which further got reduced to 38 under3.9ºC temperature rise treatment (Table 2). At maximum temperature elevation (+3.9ºC) number of tillers per pot was found to be highest (67) when N3 treatment was enforced. With the rise in temperature, loss in no. of tillers was reported to be 7.7 per cent per degree Celsius.

Maximum number of panicles per pot (69) was observed in N3 treatment under ambient temperature condition. Number of panicles per pot had reduced to 43 in both N2 and N3 treatment under 3.9ºC temperature treatment. Loss of 10 per cent per degree celsius rise in temperature (N0 treatment) was reported for number of panicles per pot and this got reduced to 8.8 and 8 per cent under N2 and N3 treatment respectively (Table 2). The treatment N3 t recorded higher number of grains per panicle (119) under ambient air condition. Rise in temperature to 3.9ºC did cause reduction in number of grains per panicle under all the nitrogen treatments and this was minimum under N3 treatment (Table3).

Significant decrease in harvest index was recorded with increase in temperature. With the application of increased level of N, harvest index got increased and found to be maximum (0.40) under N3 treatment when 3.9ºC increase in temperature was enforced (Table 3). Similar result was reported by Zacharias *et al*. (2010), who found that high temperature stress caused reduction in total dry matter, tiller numbers / plant, number of panicles / plant, grains per panicle, and grain weight. Lin *et al*., (1997) also showed significant reduction in seed set per cent and panicle weight in rice plants when grown at elevated temperature. Maximum spikelet sterility (33.9%) was recorded in N treatment under 3.9ºC temperature treatment over ambient temperature condition. Spikelet sterility of rice also significantly increased with increase in temperature at other N levels. Application of nitrogen significantly reduced spikelet sterility of rice to a little extent. Thousand grain weight of rice crop was not affected much by increase in temperature or N levels (Table4).

CONCLUSION

High temperature stress of 3.9ºC significantly had reduced both grain and biomass yields of rice crop. Application of additional (25%) dose of N over recommended level, however, was able to prevent rice yield loss by 6per cent. Crop growth duration days to 50 per cent flowering and flag leaf initiation in rice got decreased with elevated temperature. Plant growth parameters like number of tillers, number of panicles, panicle length, number of grains per panicle and harvest index had decreased, while spikelet sterility did increase with increase in temperature. Application of additional dose of nitrogen over the current recommended dose could help in reducing yield loss under global warming scenario. Hence there is a scope for N management under changing climate.

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