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ENVIRONMENTAL SCIENCE

Impact of elevated temperature on iron and zinc uptake in rice crop

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Abstract

Climate change associated with rise in temperature has adverse impact on global food production. Rice crop is also affected by this rise in atmospheric temperature. An experiment was conducted during the *kharif* season of year 2013 inside Temperature Gradient Tunnel (TGT) in IARI farm, to study impact of elevated temperature on uptake of iron (Fe) and zinc (Zn) in rice crop. There were 5 different temperature treatments inside the TGT. Two nitrogen (N) doses were applied in all 5 temperature treatments. Results showed that high temperature stress significantly reduced both grain and biomass yields of rice crop. Grain and biomass yield of rice reduced by 26.6% and 23.5% respectively in treatment with 100% recommended dose of nitrogen. Uptake of Fe and Zn decreased significantly with rise in temperature. Uptake of Fe and Zn in rice grains reduced by 41.5% and 27.3% respectively with rise in temperature by 3.9°C. Reduced yield at higher temperature has resulted in lower micronutrient uptake of the crop. Application of N dose, reduced the harmful effect of temperature rise to certain extent.

Highlights

- High temperature stress significantly reduced yield and uptake of Fe and Zn in rice crop.
- N application can prevent the loss to certain extent.

Keywords: Elevated temperature, micronutrient uptake, rice, grain, biomass, yield

Rice (*Oryza sativa* L.) which is considered as a global food grain is widely cultivated throughout the world and feeds major share of world's population. Being the second most important staple food crops of the world, it is almost exclusively consumed by humans and is one of the most important crop plants on earth (Lucca *et al*. 2002). In south and south east Asia 90% of rice is grown and consumed, where the normal consumption per day per person varies from 300 to 800 g. Rice consumption is upto 990 g per day per person in some parts of the world (Virk and Barry, 2009). However, low levels of vital micronutrients especially Fe and Zn are observed in rice crops similar to other staple food crops (Virk and Barry 2009; Bouis and Welch, 2010). Micronutrient deficiency affects billions of lives, where 5 billion suffer from iron and 2.7 billion suffer from zinc deficiency across the world (Anonymous, 2004). Zn deficiency has affected 27% of total population in India leading to various disorders such as weak immune system, diarrhoea, slow mental and physical growth (World Health Organization, 2007). Child deaths due to Zn deficiency is about 4.4% of total child deaths in the world (Black, 2003). Rice is consumed in large proportion and is an indispensable staple food for half of the world's population providing 50–85% of daily energy source. Therefore, even a small increment in the nutritive value of rice can have high impacts on human nutrition (Zeng *et al*. 2010; Chandel *et al*. 2010).

Reduction in growth, stress tolerance and synthesis of chlorophyll takes place due to Zn deficiency in plants (Kawachi *et al.* 2009; Lee *et al*. 2010). Moreover, plant products quality is also affected adversely by Zn deficiency and susceptibility to injury in plants by high light intensity is increased along with temperature and infection of few fungal diseases (Cakmak, 2000).

At present time the most prominent environmental issue is climate change and global warming, Change in the global climate is causing melting of glaciers, rise in sea level and increasing the frequency of occurrence of extreme events. The Inter-Governmental Panel on Climate Change (IPCC), in its 5th Assessment Report (AR5) warned for dire consequences of climate change. This global warming is likely to affect crop production, soil health and agricultural sustainability (IPCC, 2014). Rising temperature can alter the contents of nitrogen, phosphorus, iron, zinc and other essential nutrients in plant by regulating the uptake of these nutrients (Kumar *et al*. 2011).

Among all the micronutrients deficiency, Zn deficiency is a wide spread nutritional disorder in wetland rice and is the most limiting micronutrient (Neue and Lantin, 1994). This is most common in soils of flooded rice and has gained importance during the past decades. Symptoms of Zn deficiency in rice are visible from beginning of seedling stage in nursery and 3 weeks af er transplanting in transplanted rice plots. Supply of fertilizer form of Zinc enhances rice yield (Sudhalakshmi *et al*. 2007; Jiang *et al*. 2008); but no movement of zinc to grains from plant parts under fertilizer application of Zn was observed (Jiang *et al*. 2008). The following study was undertaken with the objective to study the impact of increased temperature on yield and Fe and Zn uptake of rice crop.

Materials and Methods

Site

The experiment was carried out during the *kharif* season of year 2013 in the Temperature Gradient Tunnel (TGT) facility (as shown in figure 1.) developed by the Centre for Environment Science and Climate Resilient Agriculture (CESCRA), in IARI farm, New Delhi, India (28°35'N and 77°12'E).

Experimental Design and Treatments

Rice variety Pusa 44 was sown in pots with 2 nitrogen levels. N levels were N0: No nitrogen and N1: 0.8 g N pot^{-1}. The doses of nitrogen correspond to N0: Control and N1: 100% recommended dose of N. Recommended dose of N was taken as 120 kg N ha^{-1}. In total there were 10 treatments inside TGT with 3 replications each (Table 2). Irrigation was provided on every alternate day to maintain the saturation level throughout the cropping period.

The bulk soil was collected from the Genetics H field of IARI farm, New Delhi. The pots of 15 L capacity with 30 cm diameter were filled with 15 kg of soil. The soil was alluvial, sandy loam in texture with pH 7.6. The physico-chemical properties of the soil are given in Table 1. Two rice seedlings (30 days old) were transplanted in each pot on July 23, 2013.

Fig. 1. Temperature Gradient Tunnel Facility at IARI farm, New Delhi.

Soil sampling

Surface soil samples were collected from 3 spots in each pot before transplanting and just af er harvesting of the crop. The entire volume of soil was mixed thoroughly and subsamples were used for analysis. Soil was air-dried for 7 days, sieved through 0.2 mm screen, mixed and stored in sealed plastic jars for further analysis. Representative subsamples were drawn to determine various physico-chemical properties of the soil.

Table 1. Physico-chemical properties of the experimental soil.

Parameters	Values
Sand (%)	48%
Silt (%)	26%
Clay (%)	26%
Texture class	Sandy loam
pH (1:2::Soil:Water)	7.6
Electrical conductivity (d S m-1)	0.47
Available Fe (ppm)	9.5
Available Zn (ppm)	5.7

Table 2.Treatments in experiment 2 on assessing the impacts of elevated temperature and N levels on yield and nutrient uptake in rice

Sen-sors	Treat-ments	N source
S1	N0	Control (no N)
	N1	0.8 g N pot^{-1} (100% of recommended dose) †
S2	N0	Control (no N)
	N1	0.8 g N pot^{-1} (100% of recommended dose)
S3	N0	Control (no N)
	N1	0.8 g N pot^{-1} (100% of recommended dose)
S4	N0	Control (no N)
	N1	0.8 g N pot^{-1} (100% of recommended dose)
S5	N0	Control (no N)
	N1	0.8 g N pot^{-1} (100% of recommended dose)

†Recommended dose of N 120 kg ha^{-1}

S1, S2, S3, S4 and S5 refers to 5 different temperature sensors having different temperature regime (S5>S4>S3>S2>S1).

Data analysis

Microsof Excel statistical package was used for the statistical analysis of the data. Analysis of variance was done to test whether the differences were statistically significant. Unless indicated otherwise, differences were considered significant at $P<0.05$.

Results and Discussion

Temperature gradient was created inside the temperature gradient tunnel (TGT) during the *kharif* season of 2013. S5 sensor recorded the maximum temperature during the whole crop growth period while S1 sensor having lowest temperature. Temperature elevation was prevalent throughout the cropping period. Temperatures recorded by the five sensors are in the following order S1<S2<S3<S4<S5. Daily temperature data of the 5 sensors were recorded by the data logger. Mean temperature elevation of the 5 sensors over the ambient temperature was calculated for the whole cropping season. 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<3.9°C (Figure 2).

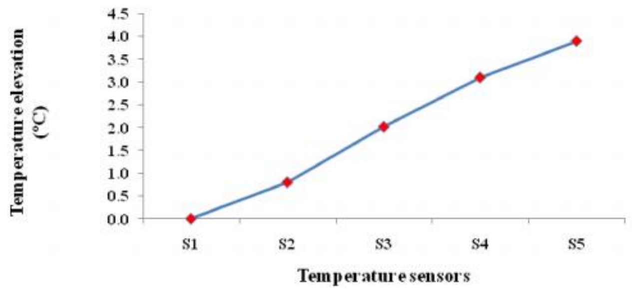

Fig. 2. Mean temperature data recorded inside TGT indicate temperature gradient during the rice growing season

S1, S2, S3, S4 and S5 refers to 5 different temperature sensors having different temperature regime (S5>S4>S3>S2>S1).

Elevated temperature caused reduction in grain and biomass yield of the crop. In N0 and N1 treatment grain yield reduced by 31.7% and 26.6%respectively with rise in temperature by 3.9°C (Figure 3). Biomass yield also significantly reduced by 26.8% and 23.5%

with risein temperature (Figure 4). Similar results are reported by earlier workers who found that rice yield reduced by 13.3% and 23% for 2°C and 4°C rise in temperature respectively (Rani and Maragatham, 2013).

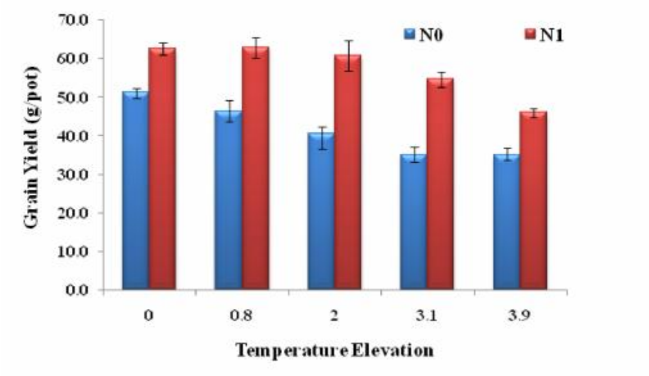

Fig. 3. Impact of elevated temperature on grain yield N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose)

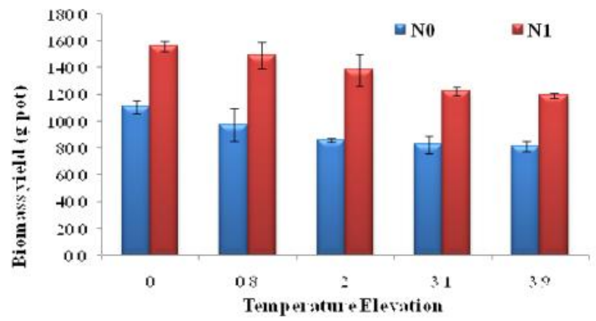

Fig. 4. Impact of elevated temperature on biomass yield of rice crop N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose)

Impact of elevated temperature on soil in rice

Available iron content of soil was neither affected by temperature nor by N levels in the experiment. The Fe content in soil was at par under both elevated temperature and N treatments. Similar result was observed with the Zn content in the soil. Fe in soil ranged from 9.5-9.8 ppm and 9.1-11.1 ppm for N0 and N1 doses respectively whereasfor Zn it ranged 5-5.3 ppm and 5.1-5.3 ppm for N0 and N1 treatments respectively (Table 3).

Table 3 Impact of elevated temperature on soil micro-nutrients in rice crop.

N dose (g pot^{-1})	Temperature elevation 0°C	0.8°C	2°C	3.1°C	3.9°C	
	Fe (ppm)					
0	9.5	9.8	9.5	9.6	9.6	LSD (P = 0.05)
0.8	9.1	11.1	9.8	10.2	9.1	N: NS Temp.: NS N X Temp.: NS
	Zn (ppm)					
0	5.1	5.0	5.3	5.0	5.2	LSD (P = 0.05)
0.8	5.2	5.1	5.2	5.2	5.3	N: NS Temp.:NS N X Temp.: NS

Impact of elevated temperature on Fe and Zn uptake in rice

Iron uptake in grain and total iron uptake decreased with increase in temperature. Uptake of Fe and Zn in rice grains reduced by 29.58% and 27.02% respectively with rise in temperature by 3.9°C. Total uptake of Fe and Zn found to be reduced by 33.2% and 23.7% respectively with temperature elevation of 3.9°C. Other temperatures result Grain Fe uptake decreased from 10.7 mg pot^{-1} to 7.8mg pot^{-1} in N1 and 7.7 mg pot^{-1} to 5.1 mg pot^{-1} in N0 treatments (Figure 5) while total Fe uptake reduced from 44.1 mg pot^{-1} to 35.9 mg pot^{-1} in N1 and 31.7 mg pot^{-1} to 21.1 mg pot^{-1} in N0 treatments with 3.9°C rise in temperature (Figure 6). Increase in temperature by 3.9ºC decreased zinc uptake in rice grain from 1.6 mg pot^{-1} to 1.1 mg pot^{-1} in N1 and 1.2 mg pot^{-1} to 0.9 mg pot^{-1} in N0 treatments (Figure 7). Total Zn uptake in rice decreased from 4.6 mg pot^{-1} to 3.6mg pot^{-1}and 3.4 mg pot^{-1} to 2.5 mg pot^{-1} with increased temperature in N1 and N0 treatments respectively (Figure 8). It has been found that with the application of N dose, the impact of temperature got reduced over controlfor grain Fe and Zn uptake as well as total Fe and Zn uptake. Available iron and zinc content of soil was neither affected by temperature nor by N levels in the experiment. Reduced grain and biomass yield at higher temperature has resulted in lower micronutrient uptake of the crop.

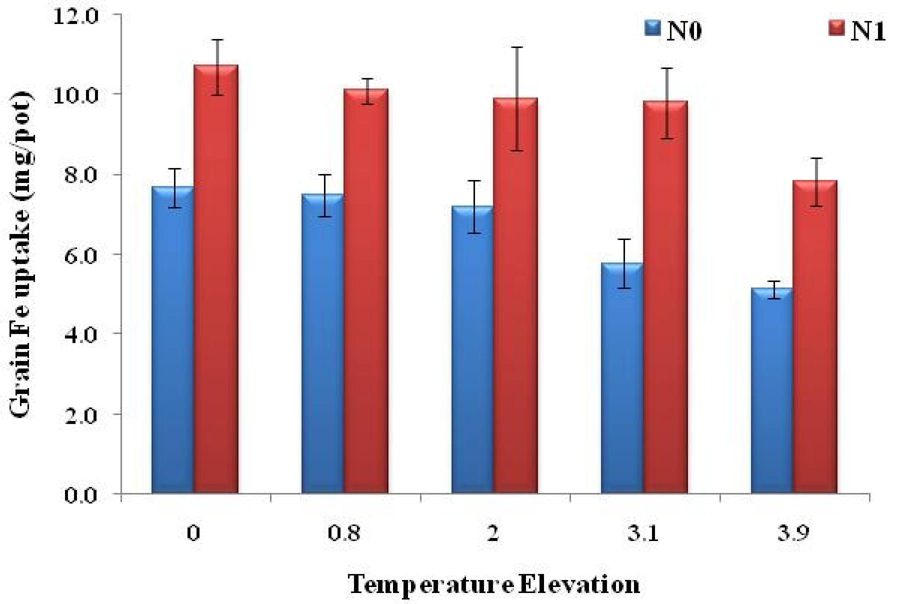

Fig. 5. Impact of elevated temperature on grain Fe uptake rice crop
N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose)

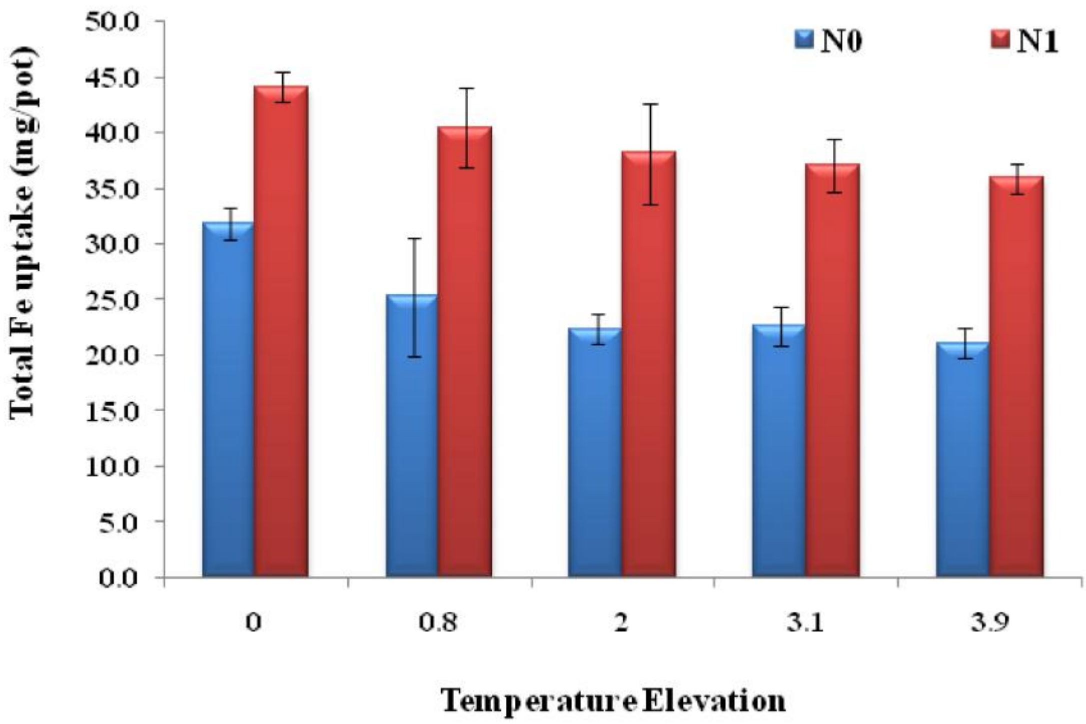

Fig. 6. Impact of elevated temperature on total Fe uptake of rice crop
N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose)

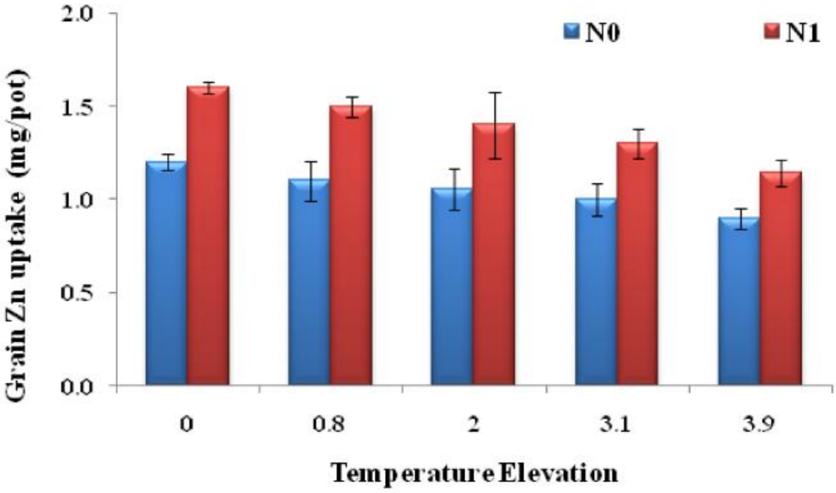

Fig. 7. Impact of elevated temperature on grain Zn uptake of rice crop
N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose)

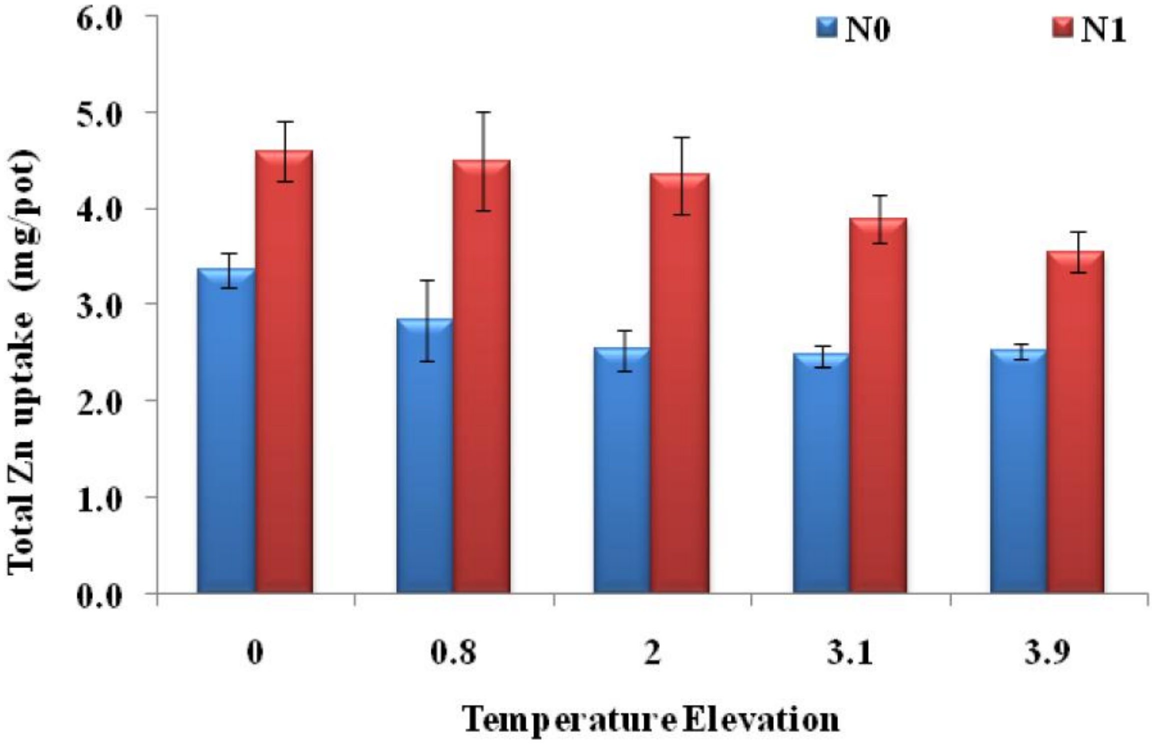

Fig. 8. Impact of elevated temperature on total Zn uptake of rice crop
N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose)

Conclusion

High temperature stress significantly reduced both grain and biomass yields of rice crop. Total as well as grain uptake of Fe and Zn decreased significantly with rise in temperature. Reduced yield at higher temperature has resulted in lower micronutrient uptake of the crop. It has been found that with the application of N dose, the impact of temperature got reduced over control for grain Fe and Zn uptake in rice crop. So, it is concluded that in future climate change scenario yield as well as uptake of nutrients will be adversely affected in rice crop.

Acknowledgements

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