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IMPACTS OF HEAT STRESS ON MINERAL NUTRITION OF BORO RICE CULTIVAR (BR 19) AS INFLUENCED BY THE INDIGENOUS ORGANIC FERTILIZERS

MOHAMMED SADID HOSSAIN*, MD HARUNOR RASHID KHAN[1] AND MD SHIFUL ISLAM[1]

Department of Environmental Science and Technology, Jashore University of Science and Technology, Jashore-7408, Bangladesh

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Global climate change has resulted in a wide range of impacts across every region of the country. The accumulation of greenhouse gases in the atmosphere has warmed the planet and caused changes in the global climate. According to Intergovernmental Panel on Climate Change, between 1880 and 2019, average global surface temperatures rose by 1.7°C(1). Bangladesh covers an area of 147,570 square kilometer, is predominantly an agro-based developing country in the world(2). The agro-climatic conditions of the country are suitable for growing rice round the year. However, the country's average rice yield is much lower (2.97 t/ha)(2) than those of China and Japan (6 - 6.5 t/ha)(3). The BBS reported that rice is the staple food for about 160 million people of the country(2). Due to ground water irrigation systems and modern high-yielding varieties, dry-season boro rice gained popularity.

Although large amounts of chemical fertilizers are used in Bangladesh, farmers mostly prefer to apply more urea fertilizer than others. The imbalanced and continuous chemical fertilization is considered to be the main cause of declining rice productivity in Bangladesh(4). So indigenous organic fertilizers are getting popular among farmers. As an amendment, rice straw is available in significant quantities at the farmers' level. Approximately 40% of N, 30 to 35% of P, and 80-85% of K taken up by rice remain in the straw at crop maturity(4). The tricho-compost significantly increases soil fertility and fetches higher crop yield. It also acts as bio-pesticides. It is well documented that the interaction of Trichoderma strains of tricho-compost with the plant may promote increase of growth nutrient availability and enhances power of disease resistance.

Plant growth is affected by climatic factors such as temperature and precipitation. Heat stress often decreases the concentration of nutrients in plant tissues or decreases the total content of nutrients in the plants, though effects can vary among nutrients and

*Author for correspondence: <sadid.est@just.edu.bd>. [1]Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh.

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species[5]. Heat stress can also disrupt enzymes involved in nutrient metabolism [11] and nutrient uptake is affected by soil temperature[5]. Soil temperature may influence the physico-chemical and biological processes which affect nutrient availability in soils, and in turn affect plant nutrient uptake[5]. Against this background, the present research study was undertaken to evaluate the effects of heat stress in combination with different doses of organic amendments on mineral nutrition of Boro rice.

The field experiment was conducted with a Boro rice variety (BR 19) at Chandipur (23°40´N, 90°18´E), Keraniganj in Dhaka, Bangladesh during February to May (Boro season), 2018. About 42 days old seedlings of this variety were collected from the seedling division of Bangladesh Rice Research Institute (BRRI), Gazipur. The maturation period of this variety was 165-170 days. Three different indigenous organic amendments viz. Rice Straw Compost (RSC), Mustard Meal (MM) and Tricho-compost (TC) were applied at the rates of 0, 4, 8; 0, 3, 6 and 0, 2.5, 5 t ha^{-1}, respectively. The treatments were T_1 = Control, T_2 = RSC_4, T_3 = RSC_8, T_4 = MM_3, T_5 = MM_6, T_6 = $TC_{2.5}$, T_7 = TC_5. Tricho-compost was spore suspension of a Trichoderma harzianum + processed raw material (cow dung + poultry refuse + water hyacinth + vegetable waste + saw dust + maize bran + molasses).

The experiment was laid out in a split plot design with three replications, where the main plots were assigned by daily usual field temperature (22-25°C) and elevated soil temperature (26-28°C) as well as the subplots by the different rates of RSC, MM, and TC. Seven subplots (2m × 2m) were assigned in each main plot (Fig. 1). A drain (25 cm) was placed between the main plots to apply hot water. A standard spacing (10 cm) among the plots and a thick boundary (15 cm) was also set up around each subplot to prevent any kind of contamination with adjacent subplots. Each subplot (experimental unit) consisted of 8 rows of plants. The seedlings were transplanted at the rate of two seedlings per hill. The hill to hill and row to row distance were 20 cm and 25 cm, respectively. The soil temperature was raised by 3°C i.e. 26-28°C from the daily usual soil temperature of 22-25°C in the experimental plot by applying hot water on the furrow between the hills of rice plants 30 days after transplantation of seedlings and the heating practice was continued for 7 days separately. Temperature increment was maintained for about 6 to 7 hours in a day. The soil thermometers were inserted into the ground in each experimental plot to examine and record the temperature rise. After treatment with 1 M CH_3COONH_4 (pH 5.0) and with 30% H_2O_2 to remove free salts and organic matter, respectively, particle size distribution of the initial soil was determined by the Hydrometer method[6]. Soil pH was measured by the soil-water ratio of 1:2.5[7] using a Corning pH meter model-7. The electrical conductivity of soil solution was measured at the ratio of 1:5[8]. Organic matter content was determined by wet combustion with $K_2Cr_2O_7$[9]. The CEC was determined by Micro-Kjeldahl method[7]. Available N was determined by 1.3 M KCl extraction, micro-steam distillation method using Devarda's

alloy[7], available P by 0.5 M $NaHCO_3$, pH 8.5 extraction[10], available S by $BaCl_2$ turbidity[11]. Available cations viz. Na^+, K^+, Ca^{2+} and Mg^{2+} extracted with 1 M CH_3COONH_4 (pH 7.0) and the extracts were analyzed for Na^+ and K^+ by flame photometer and for Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer. The properties of the soil are presented in Table 1. Plant samples were collected after harvesting the crop at maturity. The plants per plot were cut at the 1 cm above ground

Table 1. Physico-chemical properties of initial soil (1-15 cm).

Properties	Values	Properties	Values
Textural class	Clay loam	Available NO_3^- (mg/kg)	51.98
Gravimetric water content (%)	2.87	Available P (mg/kg)	82.10
Soil reaction (pH)	5.55	Available S (mg/kg)	22.28
Electrical conductivity (µS/cm)	56.9	Available Na (cmol/kg)	1.14
Organic carbon (%)	0.58	Available K (cmol/kg)	8.40
Cation exchange capacity (cmol/kg)	24.0	Available Ca (cmol/kg)	9.28
Total N (mg/kg)	237.31	Available Mg (cmol/kg)	1.32
Available NH_4^+ (mg/kg)	11.02		

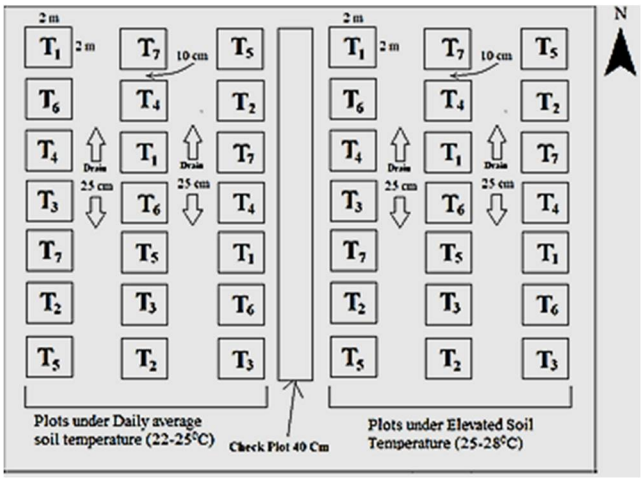

Fig. 1. Layout of the field experiment.

level. The N contents in the plant shoots were analyzed by the H_2SO_4 digestion through the micro-Kjeldhal method[7] and P contents by spectrophotometry[7]; K contents by Gallenkamp flame photometry[7]. Total S by $BaCl_2$ turbidity method[11]. Ca, Mg determined by atomic absorption spectrometry. The analysis of variance (ANOVA) of the

data and the test of significance of the different treatment means were assessed by Tukey's Range Test at 5% ($p \leq 0.05$) level.

N content: Nitrogen (N) contents in the analyzed tissues at maturity stage of Boro rice variety (BR 19) were found to have significant positive ($p \leq 0.05$) influence by the individual application of rice straw compost, mustard meal and tricho-compost under both soil temperatures. At daily average soil temperature (22 - 25°C), the highest content of N in the rice shoots (10.33 g/kg) was attained by the application of the treatment T_7 (TC_5) which received highest dose of tricho-compost (5 t/ha, Fig. 2a). The lowest N content (5.5 t/ha) was observed due to control where no amendment was applied. At elevated temperature (26-28°C), the highest response (11.58 g kg^{-1}) was found by the treatment T_2 (RSC_4) and lowest effect (5.78 g/kg) was found in the control plot. It was also observed that this cultivar also shows slightly better enhancement in nitrogen content in the analyzed tissue at the elevated soil temperature (26 - 28°C) than that of daily average field temperature (22 - 25°C). This is might me due to increase in soil temperature increases the soil nitrogen mineralization rates through the increase in microbial activity and increase in the decomposition of organic matter in the soil. Thus availability of nitrogen might be increased in the elevated soil temperature (26 - 28°C) for the plant uptake. Another study reported that lower N concentrations in the shoots were found at lower root-zone temperature (10°C) and higher concentrations were observed at higher root-zone temperature (20°C) which has an agreement with the current findings [13].

P contents: The analyses of results concluded that the effects of the treatments with their higher doses have a positive significant ($p \leq 0.05$) influence on the P contents of the cultivar (BR 19). At average (22 - 25°C) and elevated (26 - 28°C) soil temperatures, the highest P contents (1.57 and 2.73 g/kg, respectively) were found to be observed by the application of the treatment T_6 ($TC_{2.5}$) which received the tricho-compost at a rate of 2.5 t/ha (Fig. 2b). In both soil temperatures, lowest responses (0.17 and 0.15 g/kg) were caused in the control plot. Slightly higher responses were found in P contents in plant shoot in case of elevated soil temperatures than that of daily average soil temperatures. This might be due to rise in soil temperature increases metabolic activities of micro-organisms which further stimulates the availability of nutrients for plants.

K contents: The content of potassium in the rice shoots at maturity was found to be increased significantly ($p \leq 0.05$) with the increased level of treatments both under daily usual soil temperature (22 - 25°C) and elevated soil temperatures (26 - 28°C). At daily usual soil temperature (22 - 25°C), the highest K contents (7.83 g/kg) was found to be observed by the application of the treatment T_4 (MM_3) which received the mustard meal at a rate of 3 t/ha (Fig. 2c). In case of elevated soil temperature (26 - 28°C), best response (6.20 g/kg) was obtained by the treatment T_6 ($TC_{2.5}$) which received tricho-compost at a rate 2.5 t/ha. Another study demonstrated that K content in rice plants was increased with the increased rates of organic amendments[14].

Ca, Mg, S contents: Calcium, magnesium, and sulfur contents in the rice shoot at maturity was found to have increased significantly ($p < 0.05$) with the increased doses of amendments both under daily usual soil temperature (22-25°C) and elevated soil temperatures (26 - 28°C). In case of sulfur content in rice shoot, best responses (1.43 and 1.34 g/kg) were found by the treatment T_7 (TC_5) under both soil temperatures (Fig. 2d). No significant temperature variation was observed in case of S contents in rice shoots. At daily usual soil temperature (22 - 25°C), the highest Ca content (4.75 g/kg) was recorded by the treatment T_6 ($TC_{2.5}$) and lowest (0.98 g kg^{-1}) content was observed by the control treatment (Fig. 2e). There was slightly better response was found in the elevated temperature (26 - 28°C). Almost similar trend was found to be observed in case of Mg contents (Fig. 2f) in rice shoot both under regular (22 - 25°C) and elevated (26 - 28°C) soil temperatures. Ashrafi *et al*.[15] explained that N, P, K and S concentration in grain, husk, straw and root of rice plant had been increased with higher doses of organic manure application compared to control treatment which were in agreement with the current findings[15].

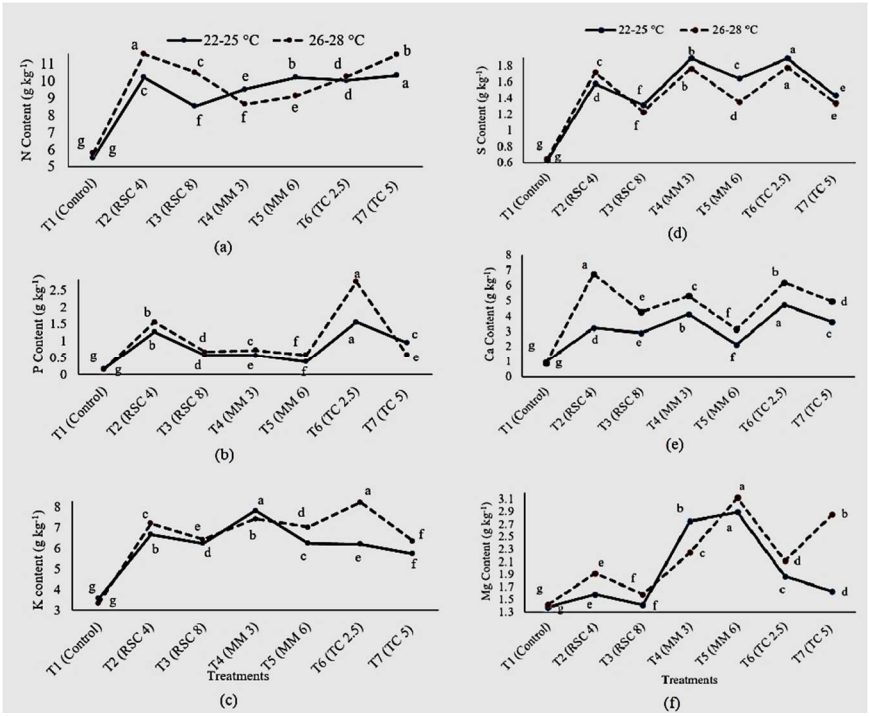

Fig. 2. The nutrient contents in rice plant (BR 19) tissue at maturity under 2 different soil temperatures as influenced by the different doses of rice straw compost, mustard meal and tricho-compost. The nutrient contents are Nitrogen (a), Phosphorus (b), Potassium (c), Sulfur (d), Calcium (e), Magnesium (f). Tukey's range tests were done at 5% significance level and values followed by the letters are significantly different at 5% level by Tukey's range test.

The field experiment explicitly determined the effects of heat stress on the mineral nutrition rice cultivar (BR 19) grown in association with the different rates of indigenous organic fertilizers. The analyses of results suggested that the higher doses of the amendments exerted better responses in case of nutrient contents of this rice variety. The results also conclude that this cultivar shows better nourishment for the N, P, K, S, Ca, and Mg contents in plant tissues under the elevated soil temperature (26 - 28°C) than those of their daily usual average field temperature (22-25°C). This might be due to increase in soil temperature, which enhances the rates of mineralization through the stimulated microbial activities, i.e. the decomposition of organic matter in the soil resulting the availability of these plant nutrients. At the daily usual (22 - 25°C) and elevated (26 - 28°C) soil temperatures, the highest P contents in rice shoots were determined by the application of the T_6 ($TC_{2.5}$) treatment, which received the tricho-compost at the rate of 2.5 t/ha. Almost similar trends were obtained for K, S, Ca and Mg contents in rice shoots under both the daily usual (22 - 25°C) and elevated (26 - 28°C) soil temperatures. Therefore, further investigation is needed to ensure the effects of variation in soil temperatures on mineral nutrition of rice as well as rice production.

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