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BIOMASS PARTITIONING, N UPTAKE AND FERTILIZER N RECOVERY IN RICE IN RESPONSE TO ELEVATED TEMPERATURE

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ABSTRACT

Temperature is a primary climatic factor adversely affecting the global foodproduction in the present climate change scenario. Rice is also beingaffected with rise in temperature both in terms of quality as well as quantity.A pot experiment was conductedinkharif season (2013) inside Temperature Gradient Tunnel (TGT) Facility to study the impact of elevated temperature on biomass partitioning and Nchemistry of rice crop. Five different temperature gradients were maintained inside the TGT and three nitrogen (N) doses i.e., N0: no N (control), N1: 0.8 g N pot^{-1} and N2: 1.0 g N pot^{-1} were applied in each of them. Results showed a significant decrease in above and below ground biomassleading to loss of grain yield with elevation in temperature. The partitioning of biomass towards root and grain decreases significantly whereas partitioning towards shoot got enhanced.Uptake of nitrogen reduced significantly with increase in temperature. Agronomic efficiency decreased significantly from19.04 g grain per g N to 13.89 g grain per g N applied and recovery efficiency from 55.7% to 44% with 3.9ºC temperature elevation. Proper plant nutrition is one of the reliable strategies among the various approaches to alleviate the temperature stress in crop plants.

Key Words: Biomass Partitioning, Elevated Temperature, Nutrient Uptake, Recovery Efficiency, Rice

I INTRODUCTION

Rice is one the staple food crop for more than half of the world population. It is grown mostly in irrigated cropping systems of South and Southeast Asia, with maximum day temperatures close to or higher than the critical threshold ranging between 33ºC [1] and 35ºC [2]. Global climate models predict an increase in the mean temperature by 2-4.5ºC and the rice area affected by water stress to double by the end of this century [3]. Several researchers reported that warmer temperature hastens the crop development and shortens the crop growth period thereby reducing yield of crop [4, 5]. High temperature stress induces morphological and [6], anatomical [7] as well as physiological and biochemical changes in plants. It induces the changes in water relations [8], accumulation of compatible osmolytes [9], decrease in photosynthesis [10], hormonal changes [11] and cell membrane thermo stability [12]. Significant reductions has been reported by different rice varieties in per plant total dry weight, root dry weight, total root length, leaf area and specific leaf area in response to increased daily mean temperature from 28ºC to 32ºC [13]. Nitrogen fertilization has been reported to mitigate the adverse effects of abiotic stresses and results showed that N-adequate plants are able to tolerate excess light by maintaining photosynthesis at high rates and developing protective mechanisms [14]. There are already many challenges to achieve higher productivity of rice. In the future, the new challenges will include climate change and its consequences which can alter the contents of nitrogen (N), phosphorus (P), iron (Fe), zinc (Zn) and other essential nutrients by regulating their uptake in plants [15].

However, very little research has inspected the influence of projected increase in temperature and varying N doses on biomass partitioning, N uptake and fertilizer N recovery of rice crop. Our objective was to study the impacts of elevated temperature on N chemistry of rice crop and determine whether these effects are mediated by source of N.

II Materials and methods

2.1. Site

The study was conducted in the Temperature Gradient Tunnel (TGT) Facility 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) during the kharif season of year 2013. The study site has a subtropical, semiarid climate with an annual precipitation of 750 mm and the mean annual maximum temperature is 35°C while the mean annual minimum temperature is 18°C.

2.2. Experimental Design and Treatments

The experiment was conducted inside the TGT by growing rice crop (variety Pusa 44) in pots. The soil type used for the experimental setup was alluvial with sandy loam texture and pH 7.6, fairly suitable for paddy cultivation. Transplanting of 30 days old seedlings (two in each pot) was done in the last week of July, 2013.

The whole area inside the TGT was divided into 5 equal parts having 5 different elevated temperature levels. Temperature levels with +0ºC, +0.8ºC, +2ºC, +3.1ºC and +3.9ºC elevation in the ambient temperature were named as S1, S2, S3, S4 and S5 temperature sensors respectively. Pots with 3 different N doses (N0: Control; N1: 100% recommended dose of N and N2: 125% recommended dose of N) were kept in each part. In total there were 15 treatments inside TGT with 3 replications each.Above nitrogen doses correspond to N0: No nitrogen; N1: 0.8 g N pot-1 and N2: 1.0 g N pot-1 were applied in three splits (recommended dose of fertilizer for rice was taken as $N:P_2O_5:K_2O$:: 120:60:60 kg ha-^{1}).

2.3. Plant sampling and analysis

Stem, leaf and grain were segregated after harvest of the rice crop and then weighed for biomass partitioning. Root biomass weight and root length were also taken for assessing the effects on root system. Plant samples were then collected and analysis was done for N content in rice leaf, stem and grains. The samples (0.5 g) were taken in a conical flask of 150 mL capacity. About 15 mL of di-acid mixture (HNO3:HClO4 :: 10:4) was added to each sample and digested on a hot plate at 180-200 °C till the solution becomes clear but not completely dry. These samples were then washed with double distilled water and filtered through Whatman No. 1 filter paper and final volume was made to 50 mL. Nitrogen content in plant parts was determined following the micro-Kjeldahl method as described by Jackson [16].

2.4. Calculations and statistical analysis

2.4.1.Plant N use efficiencies

Fertilizer use efficiency parameters were calculated as follows.

Agronomic efficiency (AE) was calculated as Nova and Loomis [17]

$$\text{AE (g grain g}^{-1}\text{ N applied)} = \frac{\text{Grain in N pot (g pot}^{-1}\text{) - grain in no N pot (g pot}^{-1}\text{)}}{\text{N dose (g pot}^{-1}\text{)}} \quad \text{(Eq.1)}$$

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Recovery efficiency (RE) was calculated as Ditz [18]

$$\text{RE (\%)} = \frac{\text{Plant N in N pot (g pot}^{-1}\text{) - plant N in no N pot (g pot}^{-1}\text{) x 100}}{\text{N dose (g pot}^{-1}\text{)}} \quad \text{(Eq.2)}$$

2.4.2. Data analysis

Statistical analysis of the data was done using analysis of variance technique recommended for the design [19]. Analysis of variance was done to test whether the differences were statistically significant. The least significant difference (LSD) test at the 0.05 probability level was used to compare significant differences among treatment means. Unless indicated otherwise, differences were considered significant at $P<0.05$.

III RESULT AND DISCUSSION

3.1. Impact of elevated temperature on biomass partitioning

Both elevated temperature and N doses affected the aboveground and belowground biomass significantlyin a specific manner (Fig. 1). Results showed that under elevated temperature condition there was lesser dry matter (DM) partitioning towards root and grain whereas more partitioning towards shoot has been reported. Similar result has been reported by Kim [20] that showed a significant increase in shoot DM with elevated temperature by 20.8%. Partitioning coefficients with recommended N dose (N1) were found to be 0.21, 0.43 and 0.36 for root, shoot and grain respectively under + 2° C elevation in temperature which got rearranged to 0.16, 0.52 and 0.32 respectively under + 3.9 ° C elevation in temperature(Table 1). With additional 25% N dose over recommended (N2) found to be effective in more partitioning of DM towards root and grain in each sensors. Results reflected that under elevated temperature condition, high temperature induced floral sterility, translocationincapability of photosynthates and nitrogen from shoot to grain directed to a lower grain biomassand N contentand in turn a higher shoot DM but additional N dose can compensate it to some extent (Fig. 1 and Table 1).

3.2. Impact of elevated temperature on nitrogen uptake in rice

Nitrogen uptake in rice grain as well as total N uptake in rice significantly decreased with rise in temperature (Fig. 3 and 4). Grain N uptake was 0.9 g pot^{-1} with 0ºC and 0.8ºC temperature elevation. Temperature rise beyond 0.8ºC reduced N uptake in rice grains and at 3.9ºC rise in temperature grain N uptake was 0.6 g pot^{-1}. Total N uptake reduced from 1.5 g pot^{-1} to 1.1 g pot^{-1} with 3.9ºC rise in temperature.Although grain N uptake and total N uptake decreased significantly in all the elevated temperature treatments but the impact was reduced to some extent with N treatments. In each case maximum uptake was found to be with N2 dose (Fig. 3 and 4). Reduced root biomass, root length and above ground biomass at higher temperature has resulted in lower N uptake of the crop.

3.3. Impact of elevated temperature on nitrogen use efficiency in rice

Agronomic efficiency (AE) of rice crop decreased with increase in temperature (Fig. 4). AE (pooled data over N doses) of rice was found to be maximum (19.04 g grain per g N applied) at no temperature elevation while it reduced to 13.89 g grain per g N applied with temperature rise by 3.9ºC. Recovery efficiency of rice crop also decreased from 55.7% to 44% with rise in temperature by 3.9ºC (Fig. 4).

IV CONCLUSION

In conclusion, our study showed that elevated temperature alone alters not only grain, shoot, root, and total dry biomass but also the source (shoot)-sink (grain) balance of the rice plant.Total as well as grain uptake of Nitrogen decreased significantly with rise in temperature. Both agronomic and recovery efficiency of rice decreased with increase in temperature.Therefore, it is barely to assume to get higher grain yield under the projected global warming compared to that under the ambient climatic conditions but the effect can be minimized to some extent with additional management options which are needed to be reassessed. Proper plant nutrition is one of the reliable strategies among the various approaches to alleviate the temperature stress in crop plant.

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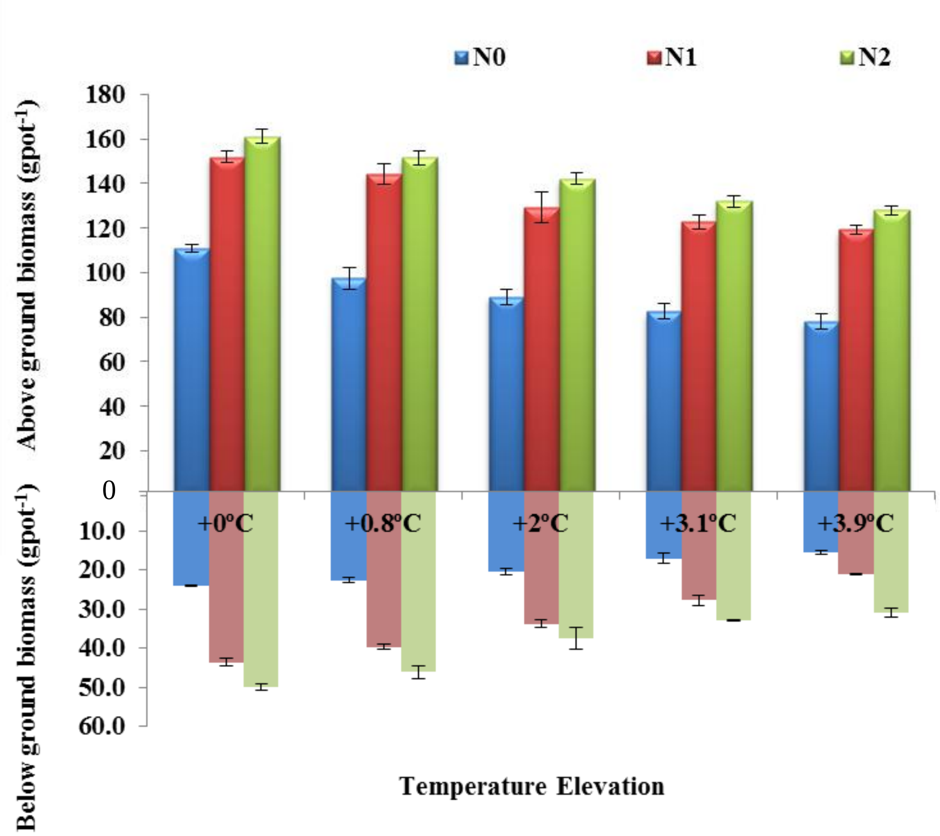

Fig. 1. Impact of elevated temperature and N doses on above ground and below ground biomass of rice crop

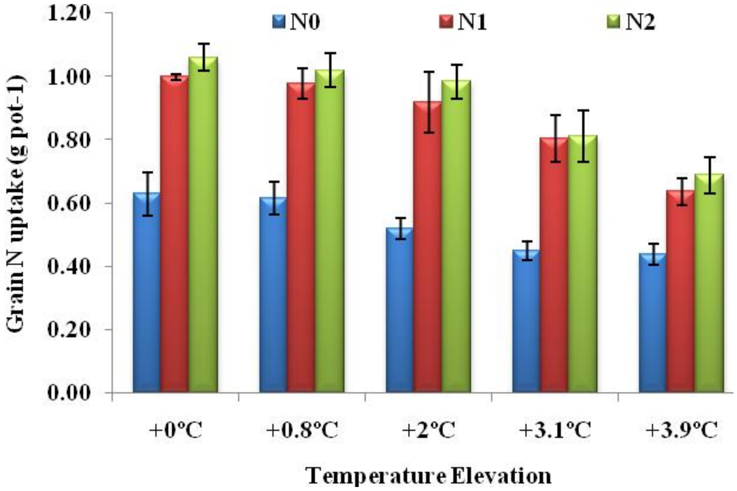

Fig. 2.Impact of elevated temperature and N doses on grain N uptakeof rice crop

Note : N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose) and

N2- 1.0 g N pot^{-1} (125% of recommended dose)

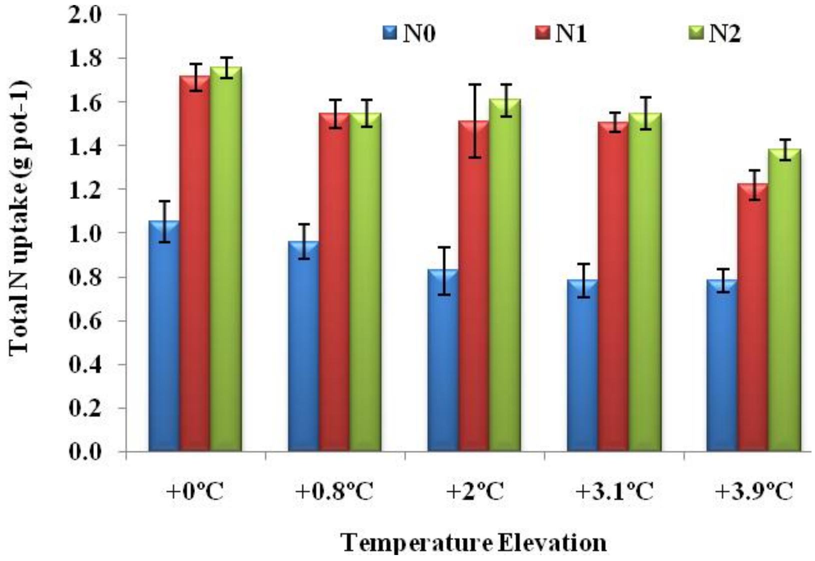

Fig. 3. Impact of elevated temperature and N doses on total N uptake of rice crop

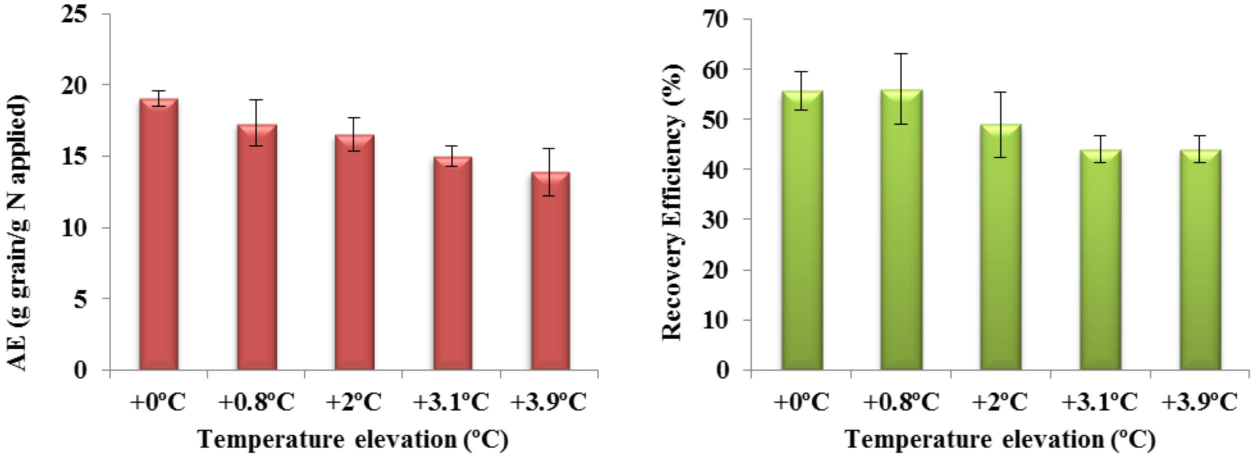

Fig. 4.Impact of elevated temperature on agronomic efficiency and recovery efficiency of rice crop

Note : N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose) and

N2- 1.0 g N pot^{-1} (125% of recommended dose)

Table 1.Impact of elevated temperature and N dose on biomass partitioning coefficient of rice crop

		Partitioning coefficient		
Temperature Sensors	**N Levels**	**Root**	**Shoot**	**Grain**
S1 (+0ºC)	N0	0.193	0.436	0.372
	N1	0.223	0.403	0.374
	N2	0.236	0.391	0.382
S2 (+0.8ºC)	N0	0.186	0.445	0.368
	N1	0.215	0.423	0.362
	N2	0.233	0.402	0.365
S3 (+2ºC)	N0	0.181	0.461	0.357
	N1	0.207	0.432	0.361
	N2	0.208	0.429	0.363
S4 (+3.1ºC)	N0	0.178	0.490	0.332
	N1	0.185	0.453	0.362
	N2	0.199	0.442	0.359
S5 (+3.9ºC)	N0	0.160	0.523	0.316
	N1	0.162	0.520	0.319
	N2	0.174	0.488	0.338
ANOVA (P = 0.05)	N	0.014	0.03	0.003
	Temp.	0.009	0.021	0.015
	N x Temp.	NS	NS	NS

Note : N0 - Control (no N), N1 - 0.8 g N pot^{-1} (100% of recommended dose) and

N2- 1.0 g N pot^{-1} (125% of recommended dose)