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EFFECTS OF NITROGEN FERTILIZER AND ELEVATED CO_2 ON DRY MATTER PRODUCTION AND YIELD OF RICE CULTI VARS

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Abstract

A pot experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the year 2003 to find out the dry matter production and yield of rice cultivars under different nitrogen levels and growing conditions. Thirty-day old single seedlings were transplanted in pot and were placed in 3 growing conditions, such as i) Open top chamber (OTC) with elevated CO_2 (570 ± 50 ppm), ii) OTC with ambient CO_2 (360 ± 50 ppm), and iii) open field condition. The three nitrogen levels used were, i) control, ii) optimum dose, and iii) supra optimum dose. Three rice cultivars used in the experiment were, i) BRRI dhan 39, ii) Khashkani, and iii) Shakkarkhora. Rice yield and dry matter production respond significantly to different environments. Increasing atmospheric CO_2 increased grain yield. Stem dry weight, leaf dry weight, leaf sheath dry weight and root dry weight were increased in elevated CO_2 than ambient CO_2 and field condition. BRRI dhan 39 gave highest yield (50.82 g/plant) at supra optimum N level in elevated CO_2. Local variety gave similar result under elevated CO_2 in optimum and supra optimum N levels. The lowest yield (15.09 g/plant) was produced by Shakkorkhora in field condition with no nitrogen application.

Key Words: Nitrogen, elevated CO_2, yield and dry matter.

Introduction

In Bangladesh, average yield of rice is only 1.96/ha (BBS, 2001). Higher yield may be achieved by using efficient management practice and environmental condition. Crop yield depends on photosynthesis. Plants dry matters are derived from photosynthetically fixed CO_2. The total dry matter of onion at bulbing stage increased by 32-44 % due to elevated CO_2 (Daymond *et al.*, 1997). Srivastava *et al.* (1999) reported that mungbean plants grown under elevated CO_2 (600 ppm) produced greater amount of photosynthates, which were partitioned to starch in the source of leaf and also to growing sink, such as shoot and roots. Increase in total dry mass of root crop radish may be upto 111% (Usund and Shimogawara, 1998). Elevated CO_2 increased the biomass of wheat organs serving as long-term

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carbohydrate (Fangmeier *et al.,* 1999). This result was also supported by Mjwara *et al.* (1996) *in Phaseolus vulgaries.*

Elevated CO_2 significantly increased in dry weight of leaves, culm, and roots in rice cultivars (Uprety *et al.,* 2000). The leaf area and biomass of spring wheat increased when exposed to higher concentration of CO_2 (Mulholland *et al.,* 1997). So, the experiment was undertaken to determine the effect of higher nitrogen fertilizer under elevated $C0_2$, which increases dry weight of rice plant as a result, increased yield of rice cultivars.

Materials and Method

A pot experiment was conducted at Bangbandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during the rainy season from July to December 2003. The experiment was laid out in a complete randomized block design with three replications. Three rice varieties were grown with three levels of nitrogen fertilizer under three CO_2 conditions. The rice varieties were BRRI dhan39 (modern), Khaskani (local), and Shakkorkhora (local). Three levels of nitrogen fertilizer were optimum dose, supra optimum dose, and control (without N application). Optimum dose for modern variety was 90 kg N/ha and for local 60 kg N/ha (BARC, 1997). Supra optimum dose for modern and local variety was 135 kg N/ha and 90 kg N/ha, respectively, which was 1.5 times higher than their optimum dose. Crop growing conditions with CO_2 were elevated CO_2, ambient CO_2, and open field. Crop under the 'elevated CO_2' was grown in open top chamber (OTC) at a CO_2 concentration of 570 ± 50 ppm, while the 'ambient CO_2' treatment was maintained at the ambient CO_2 concentration of ~360 ppm in OTC. The 'open' treatment consisted of crops grown under open field condition at ambient CO_2 concentration. Construction procedure of OTC was followed according to Uprety (1998) (Photo graph enclosed). The rice plants were grown in plastic pots containing approximately 12 kg clayed soil. The treatments were replicated thrice and each pot had one seedling. Thirty-day old seedlings of each variety were planted on 2 August 2003. Modem variety was harvested on 14 November 2003 and local variety Khaskani harvested on 4 December and Shakkorkhora was harvested on 10 December. A blanket dose of 20 kg P, 60 kg K, 20 kg S, and 3.5 kg Zn were applied prior to transplanting, while nitrogen was applied in three installments at 4, 21, and 52 days after transplanting. Cultural practices, such as weeding, irrigation, and application of pesticide were done as and when necessary. Standing water of 2 cm above the soil was maintained until the crops attained hard dough stage. After harvesting, the plants were segmented into leaf blade, leaf sheath, stem, and panicle. The components were kept in brown paper envelope and dried in oven at 70 °C for 72 hours and dry weight were recorded. Roots were washed on net very carefully so that no rootlets are lost during washing. The roots were sun dried and these were kept in brown

paper envelope and dried at 70^0C for 72 hours for constant weight. The data were analyzed by partitioning the total variance with the help of computer using MSTAT-C programme. The treatment means were computed by using Duncan Multiple Range Test (DMRT).

Results and Discussion

Leaf dry weight

Leaf dry weight of rice increased with CO_2 doubling and applied nitrogen (Table 1). Elevated CO_2 and applied nitrogen increased leaf dry mass by 15.67% over ambient and 20.00% over field condition. Leaf dry weight varied from 6.36 g to 20.05 g/plant which indicated that both elevated CO_2 and nitrogen are equally important in increasing dry weight of rice leaf. Higher dry matter accumulation in leaf under high CO_2 was supposed to be due to increase in photosynthesis (Pal *et al.*, 1997). Other authors (Allen *et al.*, 1988.; Weeerakoon *et al.*, 1999) also reported that leaf dry weight of rice, carrot, radish, and sweet potato increased under elevated CO_2. Application of supra optimum nitrogen increased leaf dry weight of rice almost double compared to control treatment. The interaction effect of elevated CO_2 and nitrogen level showed that Shakkorkhora with high CO_2 and supra optimum nitrogen produced the highest leaf dry weight and lowest in modern variety at ambient and no nitrogen condition.

Table 1. Leaf weight (g/plant) of rice plant as affected by enrichment CO_2 and nitrogen levels.

CO_2	Nitrogen level	BRRIdhan 39	Khaskani	Shakkorkhora
Elevated	Control	6.36dC	9.68cddB	10.78dA
	Optimum	9.95bc	12.33bB	15.61bcA
	Supra optimum	11.48aC	13.51aB	20.05aA
Ambient	Control	5.29eC	7.58dB	9.04eA
	Optimum	7.44cdC	10.69cB	13.97cdA
	Supra optimum	9.98bc	11.97bcB	16.59bA
Field	Control	5.38eC	6.70dB	9.2dA
	Optimum	7.38cC	8.60dB	14.00cA
	Supra optimum	9.40bcC	11.40cB	15.73bcA

Means followed by same small letter (column) and capital letter (row) did not differ significantly.

Leaf sheath dry weight

Plants under elevated CO_2 had the maximum leaf sheath dry weight compared to ambient and field condition (Table 2). Leaf sheath dry weight of rice also

increased elsewhere when CO_2 concentration increased from 373 to 545 ppm (Weerakoon *et al.,* 1999). Local variety of rice produced the highest leaf sheath dry weight than modem variety. Leaf sheath acted as a primary storehouse as well as channel for assimilates translocation towards the reproductive organs. It is assumed that modern variety of rice translocates more assimilates from leaf sheath towards the grain at the time of grain filling. This might be one of the causes for lower dry matter weight of leaf sheath of modern rice variety. Adequate nitrogen supply also increased leaf sheath dry weight. Thus the local variety Shakkorkhora gave the highest leaf sheath dry weight (25.96 g/plant) in supra optimum nitrogen level and at elevated CO_2 concentration. Uprety and Mahalaxmi (2000) reported that leaf dry weight increased with the increase of nitrogen supply at elevated CO_2 compared to ambient and field condition.

Table 2. Leaf sheath weight (g/plant) of rice as affected by elevated CO_2 and nitrogen levels.

CO_2	Nitrogen level	BRRIdhan 39	Khaskani	Shakkorkhora
Elevated	Control	10.20cC	15.66cB	18.51cA
	Optimum	14.91aC	18.31bB	23.62bA
	Supra optimum	15.00aC	21.16aB	25.96aA
Ambient	Control	7.98dC	12.87cdB	14.54dA
	Optimum	12.56bC	15.96cB	23.19bA
	Supra optimum	12.60bC	17.11bB	23.25bA
Field	Control	9.55dC	11.32dB	17.13cdA
	Optimum	11.42cC	14.54cdB	21.38cA
	Supra optimum	13.55abC	17.78bB	23.33bA

Means followed by same small letter (column) and capital letter (row) did not differ significantly.

Stem dry weight

Stem dry weight of rice plant increased at elevated CO_2 compared to ambient CO_2 and field condition. Elevated CO_2 increased dry weight by 23.76% and 33.69%, respectively, over ambient CO_2 and field condition. At elevated CO_2, the highest stem dry weight (42.37 g/plant) was recorded in Shakkorkhora and lowest (11.20 g/plant) in BRRIdhan 39 (Table 3). Varietal difference indicated that Shakkorkhora produced 54.49 % higher stem dry weight than BRRIdhan 39 and 37% higher than Khaskani. Nitrogen level also increased stem dry weight of rice. Optimum and supra optimum nitrogen levels increased dry weight of stem compared to control.

Khaskani showed non-significant effect on stem dry weight with optimum and supra optimum nitrogen level under elevated CO_2, but differed significantly in ambient and field condition. Interaction effect of CO_2 enrichment and nitrogen level indicated that stem dry weight was the highest in Shakkorkhora (42.37 g/plant) in supra optimum N levels and the lowest (8.27 g/plant) in modern variety at field condition with no nitrogen application. Sionit *et al.* (1981) also reported a significant increase in stem weight of wheat and Baker *et al.* (1990) reported so in rice when plants were exposed to elevated CO_2 concentration

Table 3. Stem dry weight (g plant') of rice plant as affected by elevated CO_2 and nitrogen levels.

CO_2	Nitrogen level	BRRIdhan 39	Khaskani	Shakkorkhora
Elevated	Control	11.20cC	23.07bcB	2 .05dA
	Optimum	19.3OaC	24.99bB	32.48cA
	Supra optimum	19.3OaC	26.2laB	42.37aA
Ambient	Control	9.O2dC	13.69dB	18.63eA
	Optimum	14.OObcC	18.3lcB	32.O2cA
	Supra optimum	15.23bC	18.29cB	38.95bA
Field	Control	8.27dC	l1.88eB	18.54eA
	Optimum	12.55cC	15.53dB	30.38dA
	Supra optimum	14.7IbC	19.42cB	33.63cA

Means followed by same small letter (column) and capital letter (row) did not differ significantly.

Root dry weight

Elevated CO_2 increased root dry weight by 41.95% and 43.18% compared to ambient and field condition, respectively (Table 4). The highest root dry weight was obtained in variety Shakkorkhora (8.82 g/plant) and the lowest (4.82 g/plant) in BRRIdhan 39 under elevated CO_2. Nitrogen also produced more root dry weight than plant grown with no applied nitrogen. Elevated CO_2 and supra optimum nitrogen produced the highest root dry weight (8.82 g/plant) in Shakkorkhora and lowest at (3.17 g/plant) in Khaskani with no nitrogen at field growing condition. As both shoot and root increased proportionately under elevated CO_2 and supra optimum nitrogen, it might have led to shoot: root ratio unchanged. Retuerto and Woodward (1993) also found no difference in root: shoot ratio of mustard plants grown in different CO_2 concentrations. Thus increase in root dry weight under elevated CO_2 and high nitrogen level had great impact on nutrient acquisition, growth and productivity of rice plants.

Table 4. Root dry weight (g/plant) of rice plant as affected by elevated CO_2 and nitrogen levels.

CO_2	Nitrogen level	BRRIdhan 39	Khaskani	Shakkorkhora
Elevated	Control	4.82bC	5.64bB	5.79bA
	Optimum	5.46bC	6.O2abB	6.3ObA
	Supra optimum	6.84aC	6.48aB	8.82aA
Ambient	Control	3.41cC	3.88cB	4,73cA
	Optimum	3.87cC	4.24bcB	5.74bA
	Supra optimum	3.77cC	4.42bc3	5.5lbcA
Field	Control	3.56cC	3.17dB	4.7OcA
	Optimum	4.33cC	3.63dB	5.OOcA
	Supra optimum	5.OlbC	4.18dB	5.65bcA

Means followed by same small letter (column) and capital letter (row) did not differ significantly.

Biomass accumulation

Enriched CO_2 and higher dose of nitrogen interacted positively on the accumulation of plant biomass (Table 5*)*. Plants grown at elevated CO_2 and high nitrogen increased biomass by 12.0% and 16.4% compared with ambient and field grown rice, respectively. An increase in dry mattert in different rice cultivars was also reported by Mitchell *et al.* (19997) and Weigel *et al.* (1994). Varietal difference indicated that local cultivars produced the highest dry mass than modern one. The highest dry mass (134.72 g/plant) was observed in Shakkorkhora and the lowest (48.17 g/plant) in BRRIdhan 39, which revealed that local cultivars are more responsive in producing more biomass under elevated CO_2 and high nitrogen level.

Table 5. Total biomass (g/plant) of rice cultivars as affected by elevated CO_2 and different nitrogen levels.

CO_2	Nitrogen level	BRRIdhan 39	Khaskani	Shakkorkhora
Elevated	Control	61.l3dC	77.73cdB	78.25dA
	Optimum	93.54bC	97.87bB	114.l2bA
	Supra optimum	103.44aC	107.9a5B	134.72aA
Ambient	Control	49.37eC	57.45eB	62.99eA
	Optimum	76.94dC	74.76dB	99.88cA
	Supra optimum	82.85cC	82.l7cB	113.37bA
Field	Control	48.l7eC	56.3OeB	66.53 cA
	Optimum	67.8ldC	72.57dB	93.54dA
	Supra optimum	80.43cC	84.O7cB	110.08bcA

Means followed by same small letter (column) and capital letter (row) did not differ significantly.

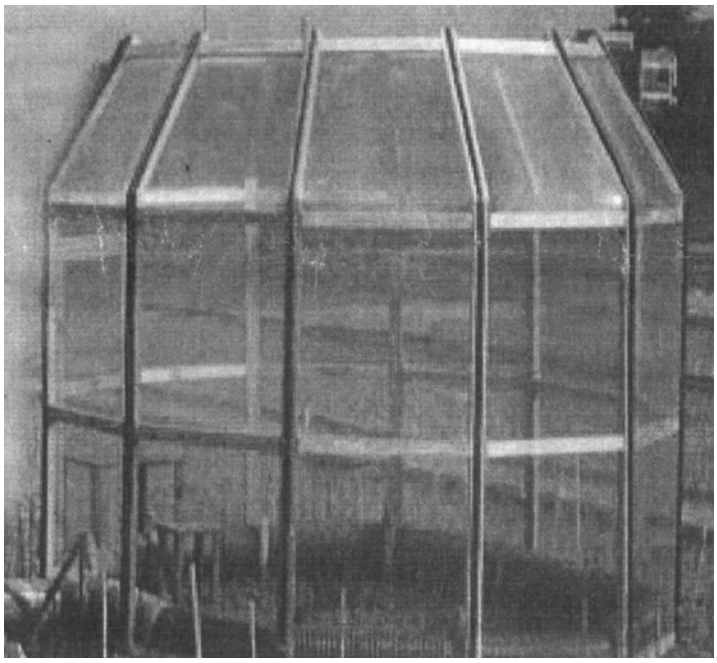
Grain yield

Elevated CO_2 and high nitrogen level increased yield of rice cultivars (Table 6). Elevated CO_2 increased grain yield of rice by 27.38% over ambient CO_2 and by 31.04% over field condition. Increase in grain yield under elevated CO_2 and applied nitrogen was due to higher production of total biomass. This result is in agreement with the findings of Siddique *et al.* (1989) and Tuba *et al.* (1994). Elevated CO_2 increased more grain yield in modern variety than local variety. CO_2 enrichment and high nitrogen level showed high response among the rice varieties. Interaction effect was positive which exhibited the highest yield (50.82 g/plant) in BRRIdhan 39 in supra optimum nitrogen level under elevated CO_2 and the lowest yield (15.09 g/plant) in Shakkorkhora with no nitrogen application under ambient CO_2 condition.

Table 6. Interactive effect of elevated CO_2 and nitrogen on grain yield (g/plant) of rice cultivars.

CO_2	Nitrogen level	BRRIdhan 39	Khaskani	Shakkorkhora
Elevated	Control	26.04dA	22.01dB	22,l2cdB
	Optimum	43.37bA	*32.55bC*	34.76aB
	Supra optimum	50.82aA	35.57aB	35.OOaB
Ambient	Control	23.70dA	18,l2eC	20.50dB
	Optimum	39.06bcA	22.72dC	24.37cB
	Supra optimum	41.27bA	24.9IcB	25.l0cB
Field	Control	21.67eA	20.50dA	16.94dB
	Optimum	32.22cA	2437cB	22.79cdC
	Supra optimum	37.50cA	25.10cC	29.54bB

Means followed by same small letter (column) and capital letter (row) did not differ significantly.



Construction of OTC

Conclusion

From the experiment, it can be concluded that the rising CO_2 and higher nitrogen both were the increase dry matter production which also translocates dry matter from plants to grain and also increased grain yield of rice cultivars. Modern variety (BRRIdhan 39) highly responded under higher CO_2 and higher nitrogen level.

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