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EFFECTS OF CO_2 AND NITROGEN LEVELS ON YIELD AND YIELD ATTRIBUTES OF RICE CULTIVARS

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Abstract

A pot experiment was conducted at Bangbandhu Sheikh Mujibur Rahman Agricultural University during July–December of 2003 to determine the effect of rice varieties under CO_2 enrichment and different levels of nitrogen supply. Plants were grown from seedling to maturity inside open top chamber under elevated CO_2 (570 ±50) ppm, ambient CO_2 (~360ppm) and open field condition. Cultivars responded considerably under different nitrogen levels. Increasing atmospheric CO_2 directly stimulated photoynthesis and plant growth resulting in increased grain yield. Among the cultivars, BRRIdhan 39 gave the highest yield (50.82 g/plant1) at supra optimum N level and elevated CO_2. Local varieties gave similar results under elevated CO_2 in optimum and supra optimum N level. The lowest yield was produced by the local variety Shakkorkhora (15.09 g) under ambient CO_2 with no nitrogen application.

Keywords: CO_2 enrichment, nitrogen level, rice cultivars

Introduction

The current trend of increasing atmospheric CO_2 indicates that the level might be doubled from the present level around 350 ppm by the middle of this century (Watson *et al.,* 1990; Hoghton *et al.,* 1996). The global mean temperature will also rise to 3-4 °C with doubling of the CO_2 concentration (Reddy *et al.,*1995). So, the change of the atmosphere will obviously bring a shift in overall agriculture globally. Different food crops increase productivity from 10 to 40% under enhanced level of CO_2 (Kimball, 1983; Michell *et al.,* 1999; Weigel *et al.,* 1994; Hamid *et al*., 2003). The variation in the range of productivity among the crop species is attributed to difference in photosynthetic performance and sink strength. C_3 species responds more to high level of CO_2 compared to C_4 species. Interaction effect of elevated CO_2 and different levels of nitrogen showed that high CO_2 can increase the rubisco efficiency and cause mobilization of nitrogen for growth and development (Pal *et al*., 2004). Thus the crops that show increased rubisco efficiency under elevated level of CO_2 may require less amount of nitrogen for optimum biomass production. Yielding ability, the most important quantitative characters in crops, depends on the development of other characters.

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Therefore, the present study was conducted to examine the effects of various doses of nitrogen fertilizer and different CO_2 levels on photosynthesis, growth, and productivity of rice cultivars.

Materials and Method

Pot experiment was conducted at Bangbandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during July to December of 2003. The experiment was conducted in complete randomized block design with three replications. Physical and chemical properties of soil are presented in Table 7. Three rice varieties were grown with three doses of nitrogen fertilizer under three CO_2 conditions. The rice varieties were BRRI dhan 39 (modern), Khaskani (local), and Shakkorkhora (local). Three doses of nitrogen fertilizer were optimum dose (recommended dose), supra optimum dose (1.5 times higher than optimum), and control (no nitrogen). Optimum dose for modern variety was 90 kg N/ha and for local 60 kg N/ha. Supra optimum doses for modern and local varieties ware 135 kg N/ha and 90 kg N/ha, respectively. Three 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 CO_2 concentration of ~360 ppm in OTC. The open treatment contained crop grown under open field condition at ambient CO_2 concentration. Chamber is made of an iron frame of 3m in diameter and 3m in height. It was installed on the ground and covered with transparent polyvinyl chloride sheet. The top of the chamber was open to ensure near natural conditions. The CO_2 gas was supplied to the chamber from gas cylinder using a manifold gas regulator, pressure gauge, and underground pipeline for using natural air with the help of a blower. The blower of 30cm diameter thoroughly mixed the supplied CO_2 gas with atmospheric air and blew it to the chamber. The rice plants were grown in plastic pots containing approximately 12kg 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. Except N, fertilizer doses of 20 kg P, 60 kg K, 20 kg S, and 3.5 kg Zn per ha in the form of triple super phosphate, muriate of potash, and gypsum fertilizers, respectively, were applied prior to transplanting, Nitrogen fertilizer was applied in the form of urea in three splits at 4, 21, and 52 days after transplanting. Several cultural practices, such as weeding 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. The concentration of CO_2 in the chamber was monitored using infrared gas analyzer (Model LI 6200, Licon, Lincoln, USA).

Results and Discussion

Plant height

Plant height was significantly increased by the interactive effect of elevated CO_2 and higher nitrogen levels in all the rice cultivars (Table 1). Highest plant was recorded in local variety Shakkorkhora (161.7 cm) grown under elevated CO_2 in optimum nitrogen level and lower plant (92.2 cm) was observed in modern variety BRRIdhan 39 in no nitrogen used in ambient CO_2. It is not a general phenomenon that plant height of all the species should increase under elevated CO_2. Overdick *et al*. (1988) did not find any increase in plant height in either okra, cowpea or radish at elevated CO_2 environment. Saebo and Mortesen (1996) observed shorter plants in barley and oats but not in wheat. They suggested that competitiveness for light between the species might be more important factor for plant height than the other growth stimuli. An increase in plant height under external stimuli further depends on growth characteristics of plant species. Generally short saturated plants elongate less under external stimuli. Thus in present study, modern variety BRRIdhan 39 responded less than tall local varieties under elevated CO_2 and increased nitrogen. The tallest plants was observed in local variety Shakkorkhora (161.7 cm) under elevated CO_2 and applied nitrogen (60 kg/ha). In contrast, modern variety BRRIdhan 39 responded a less in plant height and it was 114.0 cm under elevated CO_2 and supra optimum nitrogen (135 kg/ha) conditions.

Table 1. Interactive effect of elevated CO_2 and nitrogen on plant height (cm) of rice cultivars.

Variety	Nitrogen levels	Elevated CO_2	Ambient CO_2	Field
BRRIdhan 39	Control	102.7 eA	97.2 eB	97.4 dB
	Optimum	112.7 dA	109.7 deB	99.50 dC
	Supra optimum	114.0 dA	111.7 dB	104.0 dB
Khaskani	Control	144.7 cA	141.7 cA	126.2 cB
	Optimum	153.0 bA	152.0 aA	135.2 abB
	Supra optimum	147.0 bA	149.2 bA	130.0 bB
Shakkorkhora	Control	148.5 bA	145.7 bA	132.5 bB
	Optimum	161.7aA	157.7 aB	139.0 aC
	Supra optimum	149.5 bA	151.0 aA	140.7 aB

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

Panicles per plant

Elevated CO_2 and nitrogen supply increased the number of panicles per plant of different rice cultivars than those grown under ambient and field conditions (Table 2). As elevated CO_2 and nitrogen stimulated tillering rate of rice cultivars and thus the habitual subsequently increased the number of panicles per plant. Among the rice cultivars, modem variety responded more in producing higher number of panicles per plant under elevated CO_2 and high nitrogen level. Modern variety BRRIdhan 39 produced the highest number of panicles (17.3) per plant at high CO_2 concentration and supra optimum nitrogen level.

Table 2. Interactive effect of elevated CO_2 and nitrogen on number of panicles per plant of rice cultivars.

Variety	Nitrogen levels	Elevated CO_2	Ambient CO_2	Field
BRRIdhan 39	Control	11.0dA	10.0 cA	10.0cA
	Optimum	16.0 b A	13.5 aB	13.2 bB
	Supra optimum	17.3 aA	14.8 aB	14.2 aB
Khaskani	Control	11.5 dA	10.2 cB	10.5 cB
	Optimum	13.7 eA	12.0 bB	11.5 cC
	Supra optimum	14.7 cA	12.7 bB	12.7 bB
Shakkorkhora	Control	10.0dA	7.2 dC	8.5dB
	Optimum	13.5 cA	11.2 bcB	10.0 dC
	Supra optimum	14.5 cA	12.0 bC	13.2 bB

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

Number of spikelets per panicle

Elevated CO_2 and applied nitrogen enhanced the number of spikelets per panicle of both local and modem rice cultivars (Table 3). Other authors (Hamid *et al.,* 2003; Manderscheid *et al.,* 1995) also found similar result of increasing number of spikelets per panicle under elevated CO_2 conditions. Both CO_2 fumigation and nitrogen have growth stimulating effect on plants that favoured formation of more number of spikelets per plant of rice cultivars. Local variety Khaskani produced the highest (278.88) number of spikelets per plant under elevated CO_2 at supra optimum nitrogen, while lowest (109.31) was produced by BRRIdhan 39 in field condition in control treatment.

Table 3. Effect of elevated CO_2 and nitrogen levels on number of spikelets/panicle of rice cultivars.

Variety	Nitrogen levels	Elevated CO_2	Ambient CO_2	Field condition
	Control	124.56fB	128.63fA	109.3lfC
BRRIdhan39	Optimum	130.78 eA	126.69 eB	128.84 eB
	Supra optimum	135.l9eB	136.33 eA	135.56eB
	Control	209.58 cB	201.45 cdC	220.94 bA
Khaskani	Optimum	263.06 bA	234.32 bC	*255.29* aB
	Supra optimum	278.88aA	241.OaC	248.l6aB
	Control	182.77 dB	211.36 cA	183.76 dB
Shakkorkhora	Optimum	203.l6cB	195.71 dC	211.34bA
	Supra optimum	198.82 cB	197.37 dB	201.40 cA

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

Table 4. Effect of elevated CO_2 and nitrogen levels on the number of grains/panicle of rice cultivars.

Variety	Nitrogen levels	Elevated CO_2	Ambient CO_2	Field condition
	Control	112.50gA	112.64eA	95.67gB
BRRIdhan 39	Optimum	117.25gA	113.l0eB	108.l9gC
	Supra optimum	121.62 gA	116.54 eB	114.52 gB
	Control	186.21 cdA	169.04cdB	186.bcA
Khaskani	Optimum	223.45 abA	187.27 abC	212.11 aB
	Supra optimum	230.89 aA	190.33 aB	197.02 bcB
	Control	165.57 efA	160.69dB	150.87fC
Shakkorkhora	Optimum	191.00 cdA	168.65 cdC	176.20 cdB
	Supra optimum	184.74 dA	165.78 dB	167.45 eB

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

Number of grains per panicle

CO_2 enrichment increased the number of grains per panicle of rice cultivars compared to ambient and field conditions (Table 4). Under elevated CO_2 condition, grains per panicle varied from 95.67 to 230.89 which indicated a wide degree of responsiveness over the cultivars and nitrogen levels. Elevated CO_2 increased grains per panicle by 9.73% and 8.17% compared with ambient and field conditions. Manderschied *et al.* (1995) also reported that the variability in degree of responsiveness of different wheat cultivars in producing grains per spike under CO_2 enrichment. Increase in grain number per panicle, however, is not a common phenomenon under elevated CO_2 concentration. Manderschied *et al.* (1995) observed increase in grain number per ear only in two wheat cultivars, while other four cultivars did not respond at high CO_2. Local variety Shakkorkhora under elevated CO_2 and supra optimum nitrogen produced the highest (230.89) number of grains per panicle. There is positive relationship between nitrogen supply and leaf photosynthesis. Higher photosynthesis under elevated CO_2 and high nitrogen might have translocated more photosynthates to grains which increased the grain number per panicle of rice (Cock and Yoshida, 1973).

Table 5. Effect of elevated CO_2 and nitrogen levels on 1000- grain weight (g) of rice cultivars.

Variety	Nitrogen levels	Elevated CO_2	Ambient CO_2	Field condition
BRRIdhan 39	Control	20.44 bB	21.65 cA	20.75 cB
	Optimum	23.91 aA	23.09 aB	22.12 bB
	Supra optimum	24.44 aA	22.82 bC	23.54 aA
Khaskani	Control	10.51 fA	10.49 eA	10.45 eA
	Optimum	10.73 eA	10.14 fB	10.07 fB
	Supra optimum	10.63 eA	10.38 eB	10.56 eA
Shakkorkhora	Control	13.39 cA	13.00 dB	13.04 eB
	Optimum	13.61 cA	13.30 dB	13.31 dB
	Supra optimum	13.08 dA	13.00 dB	13.09 eA

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

Weight of 1000 -grains

Elevated CO_2 and nitrogen level had little impact on grain size of rice (Table 5). Individual grain weight is a fairly stable character in rice (Yoshida, 1981) and it is mostly determined genetically. The size of the husk is determined as early as 5 days before flowering, which is very difficult to change by management (Murata and Matsushima, 1978). Weigh *et al.* (1994) reported that seed size remained unaffected in barley but decreased in wheat due to CO_2 enrichment. In the present study, seed size increased slightly at elevated CO_2 condition when more nitrogen was applied. Imai *et al.* (1985) reported that there is negative correlation between number of spikelets per panicle and seed size. Therefore, increase in spikelets per panicle under elevated CO_2 and high nitrogen may be the cause of its little effect on seed size.

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 31.04% over field condition. Increase in grain yield under elevated CO_2 and applied nitrogen was due to production of higher number of tillers and higher number of filled spikelets per panicle. The present findings are in agreement with those of Siddique *et aL,* 1989. Tuba *et al.,* 1994 also reported that an increase in grain yield at CO_2 enrichment and higher nitrogen could be explained by increase in total biomass and panicle number. Photosynthetic rates increased at high CO_2 and high nitrogen which might have aided better grain filling and enhanced grain yield of rice (Reddy *et al.,* 1995; Sarma-Natu *et al*., 2004). 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 indicated that the highest yield (50.82 g/plant) was found in modern variety BRRIdhan 39 in supra optimum nitrogen level and elevated CO_2 and the lowest yield (15.09 g/plant) in the local variety Shakkorkhora at ambient CO_2 condition.

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

Variety	Nitrogen levels	Elevated CO_2	Ambient CO_2	Field condition
BRRIdhan 39	Control	26.04 eA	23.70 cdB	21.67 dC
	Optimum	43.37 bA	39.06 abB	32.22 bC
	Supra optimum	50.82aA	41.27aB	37.50aC
Khaskani	Control	22.01 fA	18.12 eC	20.50 dB
	Optimum	32.55 deA	22.72 dC	24.37 cB
	Supra optimum	35.57 cdA	24.91 cB	25.10 cB
Shakkorkhora	Control	22.l2fA	15.09fC	16.94 eB
	Optimum	34.76 cdA	25.63 cB	22.79 cdC
	Supra optimum	35.00 cA	26.77 cC	29.54 bcB

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

Table 7. Physical and chemical properties of soil.

Properties	Values
Textural class	Silty clay
Sand (%)	26
Silt (%)	39
Clay (%)	35
pH	6.5
Organic matter (%)	0.76
Exchangeable bases (%) Mg	0.54
Exchangeable bases (%) K	0.10
Available nutrient (μ/ml): NH4 + -N	25.00
Available nutrient (μ/ml): P	0.09
Available nutrient (μ/ml): S	7.00
Available nutrient (μ/ml) : Zn	1.00

Conclusion

From the above result, enrichment of CO_2 and nitrogen level increased grain yield of all the cultivars under study. Enrichment of CO_2 and nitrogen both enhanced growth and development of rice cultivars which resulted in increased yield. Modern variety (BRRIdhan 39) responded better compared to other cultivars.

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