PRODUCTIVITY OF SOME SELECTED RICE CULTIVARS UNDER ELEVATED CO_2 AND HIGH TEMPERATURE CONDITION

J. AKTAR[1], M. M. HAQUE[2] and K. M. S. HAQUE[1]

[1]MS Student, Department of Agronomy, [2]Professor, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur-1706, Bangladesh.

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ABSTRACT

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A field experiment was conducted to evaluate the effect of elevated CO_2 and high temperature on physiology, growth and productivity of some popular rice cultivars. Nine rice cultivars viz. moti, binni, khaskani, bunsha, maloti, shakkorkhora, bashful chikon, jhumur and one unknown were grown in four conditions. The growing conditions were open top chamber (OTC) with elevated CO_2 (570 ±50 ppm), OTC with ambient CO_2 (~360 ppm), OTC with high temperature (2°C high) and field condition. Elevated CO_2 increased grain yield in all the rice cultivars due to increase in panicle number. However, there were varietal differences in response to elevated CO_2 and high temperature which indicated the potential good genetic materials that would be better to adapt in future high CO_2 warmer world.

Key words: High temperate, elevated CO_2, stacking and aromatic rice cultivation.

INTRODUCTION

It is evident that human activities are substantially increasing the emissions of green house gasses such as carbon dioxide, methane, chloroflurocarbon and nitrous oxide into the atmosphere. These increases in green house gasses will enhance the green house effect and will warmer the earth's atmosphere. Among the green house gasses, CO_2 concentration is currently around 365 ppm in the atmosphere which is predicted to reach 700 ppm by the end of this century (Houghton *et al*., 1996). Such an increase in CO_2 could have serious effects on agriculture, although it has some resiliency for adaptation to climate change.

Increasing concentration of CO_2 in the atmosphere may have a significant impact on crop productivity by increasing the air temperature. The effects of global climate change on rice yield have been studied using simulation models (Bachelet and Gay, 1993; Horie *et al*., 1996). In particular, Horie *et al*. (1996) showed that supraoptimal temperatures negate the positive effect of elevated CO_2 on the rice yield mainly through high temperature-induced floret sterility even in a temperate region. One hour induction of high temperature greater than 35°C caused a high percentage of spikelet sterility (Yoshida, 1981). Comparing grain filling responses with temperature, Yoshida and Hara (1977) found maximum grain weight within 19 to 25°C for Indica and 16 to 22°C for Japonica rice.

Hence, we have to know the plant responses to various environmental factors, and to know how plants interact with changes in more than one climatic factor in order to predict crop responses to high CO_2 and high temperature. The present study was therefore, undertaken to investigate the effect of elevated CO_2 and high temperature on productivity of some selected rice cultivars of Bangladesh.

MATERIALS AND METHODS

A field experiment was carried out at the experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the rainy season of 2002. The experimental site is located at the center of Madhupur tract (24°09′ N latitude and 90°26′ E longitude) having an elevation of 8.2 meter from the sea level. Average air temperature ranged from 30.18°C (maximum) to 19.86°C (minimum) and total rainfall recorded 744.6 mm during the study period (August to December 2002). The soil type of the experimental field belongs to the shallow red-brown terrace type of Salna series. The soil is characterized by poor fertility and impeded internal drainage.

Nine selected rice varieties viz. Moti, Binni, Khaskani, Bunsha, Maloti, Shakkorkhora, Bashful chikon, Jhumur and Unknown were grown in four conditions. The growing conditions were: Open top chamber (OTC) with elevated CO_2 (570 ±50 ppm), OTC with ambient CO_2 (~360 ppm), OTC with ambient CO_2 + 2°C temperature and Open field (~360 ppm CO_2).

Construction procedure of OTC was followed according Uprety (1998). The OTC (area 9 meter^2) was made of an iron frame that installed on the ground which was covered with transparent polyvinyl chloride sheet with a frustum at the top to deflect air and prevent the reduction of desired CO_2 within the chamber. The CO_2 gas was supplied to the chambers from the CO_2 gas cylinder. The air blowers with 12 inch in diameter were fitted at the base of the chamber, which thoroughly mixed the supplied CO_2 gas with atmospheric air and blew the gas mixture towards the chamber tunnel.

One of the chambers had an electrical device for increasing inside air temperature up to 2^{o}C than more from the atmospheric air temperature. For making this, an electrical heater was placed adjacent to the chamber and continuous increment of chamber temperature was made by regulating the device kept outside of the chamber. Every OTC had a door for entrance into the chamber to manage the crop properly.

The land was prepared very well by disc plough followed by harrowing and laddering. The weeds and stubble were removed; drains were made around each OTC and field. Triple super phosphates, muriate of potash, gypsum and zinc sulphate were applied as the sources of P_2O_5, K_2O, S and Zn at the rate of 100, 115, 110, and 10 kg ha^{-1} respectively. Urea was applied at three installations first at 8 Days after transplanting, second at 20 days after transplanting and third at 45 Days after transplanting.

30-days old seedlings of all the varieties were transplanted on 31 July 2002. One seedling per hill was used by maintaining 25 cm row to row and 10 cm plant to plant distance in the well prepared land. There are 20 hills for each variety within each treatment. Gape filling was done with the even aged seedling within one week of transplanting. Several cultural operations such as weeding, irrigation and application of pesticide were done whenever necessary. Standing water of 2 to 4 cm was maintained in the field until the crops attained hard dough stage.

The total number of panicle at maturity stage was counted. Both fertile and sterile spikelets per panicle were separately counted manually from all of the panicles of sample plant. From the filled grain of a plant 1000 grains were randomly counted by Multi-auto counter and the weight of these grains was measured. Grain yield was measured from 10 hills and adjusted with 14% moisture content.

The findings were analyzed by partitioning the total variance with the help of computer by using MSTAT-C program. The treatment means were computed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Panicles per hill

Elevated CO_2 strongly increased the number of panicles per plant of rice crop (Table 1). The increase of number of panicles per hill was 50.6% over ambient, 66.6% over high temperature and 44.7% over field grown rice. Our results compare well with the findings of Apel (1985) where increase in panicle number was the resultant of greater growth stimulation at elevated CO_2 concentration. The decrease in panicle number per hill under high temperature was arisen from production of lower number of tillers at vegetative stage. Among the cultivars, unknown one adopted best in all the growing environments and produced the highest number of panicles per plant. The highest number (12.6) of panicles per plant was observed in unknown cultivar at elevated CO_2.

Table 1. Effect of elevated CO_2 and high temperature on the number of panicle per hill of different rice varieties

Variety	No. of panicle per hill			
	Elevated CO_2	Ambient CO_2	High temperature	Field
Moti	9.10bA	5.50bB	4.90Cb	5.80cB
Binni	9.00bA	7.30aB	6.10bC	6.90bB
Khaskani	8.79bA	5.90bB	6.00bB	6.00bB
Bunsha	9.33bA	5.80bB	4.60cC	5.90bcB
Maloti	8.76bA	5.90bB	5.60bcB	6.15bB
Shakkorkhora	7.36cA	4.70cC	4.20cC	5.25cB
Bashful chikon	8.53bA	5.00cB	5.10bcC	6.35bB
Jhumur	9.60bA	7.30aB	5.30bcC	6.50bB
Unknown	12.60aA	7.80aB	8.10aB	8.55aB

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

The number of panicles per plant of this cultivar was 7.80, 8.10 and 8.55 at ambient, high temperature and field condition respectively. Besides this cultivar, moti, binni, bunsha and jhumur also performed better under elevated CO_2. Under high temperature condition shakkorkhora was affected severely in producing number of panicles per plant. Contrary, binni and khaskani were more or less tolerant in production of panicles per plant under high temperature condition.

Spikelet per panicle

Enriched CO_2 increased significantly spikelets per panicle of all the rice cultivars (Table 2). It is interesting to note that all the rice cultivars responded almost equally in producing number of spikelets that ranged from 143.20 to 179.37 per panicle. Among the cultivars, however, moti produced the highest number of spikelets per panicle under elevated CO_2 concentration. Pattern of spikelet production under high temperature that was somewhat different to that of panicle production. Under high temperature condition, number of spikelets per panicle was similar to that other growing condition like ambient and field. Number of spikelets per plant under high temperature was 125.1 which was identical to spikelet number of ambient (122.5) and field (129.1) grown rice. Considering stability in producing spikelets per panicle over a wide range of growing conditions, the cultivar unknown showed the best performance. Other cultivars like khaskani (139.3) and maloti (139.7) were found better adopted in producing higher number of spikelets under high temperature condition. Whereas, bunsha was identified as susceptible to high temperature which produced only 89.80 spikelets per panicle.

Table 2. Effect of elevated CO_2 and high temperature on the spikelet of rice cultivars

Variety	Spikelet per panicle			
	Elevated CO_2	Ambient CO_2	High temperature	Field
Moti	179.37aA	142.93aB	144.17aB	133.12aB
Binni	178.30aA	127.30aB	97.10bB	110.00bB
Khaskani	143.20aA	138.10aA	139.30aA	113.60aA
Bunsha	159.58aA	123.20aB	89.80bC	113.20aB
Maloti	146.57aA	119.10aA	139.70aA	120.10aA
Shakkorkhora	174.70aA	98.60bC	132.00aB	179.20aA
Bashful chikon	165.20aA	91.50bB	111.10bB	122.30aB
Jhumur	172.20aA	115.40aB	122.70aB	120.20aB
Unknown	175.86aA	146.29aA	149.92aA	149.99aA

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

Filled grains per panicle

CO_2 enrichment also increased filled spikelets per panicle of rice cultivars compared to ambient, high temperature and field grown rice (Table 3). Filled spikelets per panicle under elevated CO_2 varied from 156.27 in moti to 123.40 in maloti which indicated the degree of responsiveness of different rice cultivars under high CO_2 condition. Such variability in degree of responsiveness of different wheat cultivars in producing filled grain per spike under CO_2 enrichment was also reported by Manderschied and Weigel (1997). High temperature however, decreased filled grain per panicle in all the rice cultivars. Averaged over the cultivars, reduction in filled grain per panicle was 36.30%, 9.54%, and 23.30% over elevated CO_2, ambient and field grown rice respectively. Such reduction in filled grain per panicle under high temperature was the resultant of flower abortion which ultimately increased the unfilled grain (Mackill *et al*., 1982). Some cultivars such as moti and maloti found stable to reduce sufficient filled grain per panicle under high temperature condition. Contrary binni and bunsha produced lower number of filled grain panicle under high temperature environment.

Grain sterility

Grain sterility of rice was common in all the cultivars but the percentage of sterility varied significantly among the varieties and the growing environments (Table 4). Sterility percentage of rice was the highest under high temperature which reached even upto 40.53% in binni. Other susceptible varieties were bunsha, moti and khaskani which showed higher grain sterility under high temperature. Satake and Yoshida (1978) also observed the high temperature induced sterility in indica rice. However, the cultivars unknown and maloti showed resistance to sterility under high temperature which produced lower percentage of sterile grains. Under elevated

CO_2 concentration bashful chikon showed the lowest percentage (11.34%) of sterility which was followed by unknown (12.58%), moti (13.04%) and shakkorkhora (13.91%). The highest percentage of sterility under elevated CO_2 was observed in khaskani (19.60%) and jhumur (19.04%) which confirmed its susceptibility to higher temperature as open top chamber with elevated CO_2 itself increases 2 to 3^{o}C temperature (Uprety , 1998).

Table 3. Effect of elevated CO_2 and high temperature on the number of filled grain per panicle of rice cultivars

Variety	Filled grain per panicle			
	Elevated CO_2	Ambient CO_2	High temperature	Field
Moti	156.27aA	120.07aB	108.77aB	122.19bB
Binni	152.30aA	102.90aB	57.90bC	109.26bB
Khaskani	126.73bA	101.90aA	84.70aB	97.00bB
Bunsha	136.73aA	86.93bB	65.80bC	99.40bB
Maloti	123.40bA	108.50aA	103.80aA	120.90bA
Shakkorkhora	150.60aA	105.20aB	108.50aB	164.00aA
Bashful chikon	147.00aA	73.50bC	88.30aB	109.40bB
Jhumur	141.20aA	104.50aB	98.40aB	107.10bB
Unknown	154.10aA	103.90aB	104.60aB	137.20aA

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

Table 4. Effect of elevated CO_2 and high temperature on the sterility of rice cultivars

Variety	Grain sterility (%)			
	Elevated CO_2	Ambient CO_2	High temp.	Field
Moti	13.04bB	14.07bB	24.45bA	9.91aB
Binni	15.25aB	18.70aB	40.53aA	10.03aC
Khaskani	19.60aA	15.03aB	23.23bA	14.51aB
Bunsha	14.47bB	17.75aB	27.25bA	12.11aB
Maloti	16.09aA	14.93aA	15.23cA	10.13aB
Shakkorkhora	13.91bA	14.12bA	17.71cA	8.51aB
Bashful chikon	11.34bB	20.60aA	20.48cA	10.72aB
Jhumur	19.04aA	9.49bC	19.48cA	11.02aB
Unknown	12.58bA	9.89bA	14.76cA	8.72aB

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

Seed weight and size

Either elevated CO_2 or high temperature influenced seed weight and size a little (Table 5) which is expected as the grain size in rice is fairly stable over a wide range of environment within a genotype (Yoshida, 1981). Weigel *et al.* (1994) reported that seed size remained unaffected in barley but decreased in wheat due to CO_2 enrichment. Further, it was observed that effect of high temperature in reducing seed size was not as pronounced as it influenced in decreasing other growth parameters of rice.

Grain yield

Elevated CO_2 and high temperature influenced inversely on the yield of rice cultivars (Table 6). Elevated CO_2 increased grain yield of rice by 38.83% over ambient, 64.85% over high temperature and 31.31% over field grown rice. The higher yields of rice cultivars under CO_2 enrichment was attributed mainly because of production of more tillers (Baker *et al*., 1990) or increase in ear number (Weigel *et al*., 1994). Among the cultivars moti (24.21 g plant^{-1}) and unknown (23.46 g plant^{-1}) responded more favorably under elevated CO_2 and produced higher grain yield. This yield was followed by the yield obtained from bunsha grown under elevated CO_2. Under elevated CO_2, the lowest yield (11.15 g plant^{-1}) was recorded from khaskani and than shakkorkhora (13.10 g plant^{-1}). The decrease in grain yield at high temperature was 15.79 % and 16.71 % as compared to ambient and field grown rice respectably. The decrease in grain yield of rice at high temperature was associated with increase in sterility percentage. However, the cultivars unknown, binni, bunsha and moti showed better performance under high temperature condition.

Table 5. Effect of elevated CO_2 and high temperature on the 1000-grain weight of rice cultivars

Variety	1000-grain weight (g)			
	Elevated CO_2	Ambient CO_2	High temperature	Field
Moti	17.44dA	17.08dA	16.99dA	17.20dA
Binni	22.14bcA	20.21bcAB	19.08cB	23.88bA
Khaskani	13.53dA	11.80fAB	11.24fB	11.33fB
Bunsha	25.21bA	25.16bA	23.19bB	24.74dA
Maloti	19.39cA	18.22cdAB	17.41dB	20.57cA
Shakkorkhora	14.46eA	14.66eA	13.70eA	14.69eA
Bashful chikon	23.50bA	20.99bcB	20.58bcB	21.66cA
Jhumur	18.79cdA	17.34dAB	15.60deB	18.54dA
Unknown	30.10aA	29.67aA	26.18aB	27.61aB

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

Table 6 . Effect of elevated CO_2 and high temperature on the yield of different rice cultivars

Variety	Grain yield (g plant^{-1})			
	Elevated CO_2	Ambient CO_2	High temperature	Field
Moti	24.21aA	18.13aB	12.62aC	17.33aB
Binni	19.62bA	14.32bB	14.10aB	14.70aB
Khaskani	11.15eA	8.39dB	8.38bB	8.65cB
Bunsha	18.97bA	12.68cB	12.85aB	12.16bB
Maloti	14.70dA	12.92cA	9.70bB	10.90cB
Shakkorkhora	13.10dA	9.28dB	7.45bC	10.08cB
Bashful chikon	16.68cA	9.43dC	8.45bC	12.30bB
Jhumur	16.42cA	14.09bA	8.45bC	12.37bB
Unknown	23.46aA	14.78bB	14.30aB	16.81aB

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

Conclusion can be drawn that elevated CO_2 increased the number of panicles per hill by 50.6% over ambient, 66.6% over high temperature and 44.7% over field grown rice. Enriched CO_2 increased significantly spikelets per panicle and filled spikelets per panicle of all the rice cultivars. Sterility percentage of rice was the highest under high temperature, which reached even upto 40.53% in binni. The highest percentage of sterility under elevated CO_2 was observed in khaskani (19.60%). Seed size slightly influenced by elevated CO_2 or high temperature. Elevated CO_2 increased grain yield of rice by 38.83% over ambient, 64.85% over high temperature and 31.31% over field grown rice. Both elevated CO_2 and high temperature brought about a reduction in the nitrogen content of leaf, straw and grain.

The results revealed the stimulatory effects of CO_2 enrichment on productivity of nine rice cultivars. Contrary, high temperatures negate the stimulatory effect of elevated CO_2. However, varietal differences indicated the potential of rice cultivars to better adapt at warmer condition. Further study with more number of rice germplasm may be undertaken to evaluate the interactive effect of elevated CO_2 and high temperature for wider adaptation under warmer and higher CO_2 world.

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