# EFFECT OF ENRICHED $CO_2$ ON RICE UNDER OPEN TOP CHAMBER (OTC) CONDITION IN NEPAL

Kishore Sherchand and Alok Sharma
Nepal Agricultural Research Council, Khumaltar, Lalitpur
*P.O. Box 5459, Kathmandu, Nepal. Email: sherchan_k@yahoo.com*

## ABSTRACT

Rice is the most important crop for majority of farmers of Nepal both in terms of its contribution to the national economy and employment. The objective of this study was to evaluate the effect of the elevated $CO_2$ on rice crop under open top chamber (OTC) condition. Treatments were $CO_2$ enriched, Ambient (OTC without $CO_2$ enriched) and Field. The present study attempts to summarize the results obtained during 2001 to 2004. The effect of $CO_2$ enrichment was realized in raising the temperature by an average of 1.30 $^0$C (Tmax) and 0.56 $^0$C (Tmin). The elevated $CO_2$ with this level of temperature raised grain yield and yield components but varied greatly by year. Tiller number was the most contributing factor to cause yield difference. The $CO_2$ enriched plot had lesser N and organic carbon in grain, and straw but higher organic carbon in the root compared to the Ambient and the Field. The study indicated that the rise of temperature to this level due to the elevated $CO_2$ did not adversely affect the rice yield.

## INTRODUCTION

Rice is the most important food crop contributing about 20 percent of the Agriculture Gross Domestic Product of Nepal. Global warming is the major concern and question remains whether the green house gases, the major factor for the global warming, can affect the agriculture or not. Among the GHGs $CO_2$ is the main one, the effect of which should be related to the crop production. $CO_2$ serves as the primary substrate for photosynthesis and is the one to contribute to the yield formation in plants. However, the increase in the atmospheric temperature as a result of GHGs is the major concern.

Several studies showed that yield would tend to increase with a doubling of $CO_2$ concentration (Idso et al., 1987). Effects of free-air $CO_2$ enrichment (FACE) with different N level indicated that the rice in response to $CO_2$ were also associated with N uptake and reached the ceiling level of N supply (Kim, et al., 2003; Kim et al., 2003; and Huang et al. (2003) indicated that the biomass accumulation under FACE would increase from transplanting to 20 days after heading but would decline after that caused mainly by the decline of net assimilation rate (NAR). The predicted positive effect of elevated $CO_2$ on crop biomass production also suggested that more C would reach soil and increase soil C, an aspect of carbon sequestration, as well as N concentration (Prior, et al., 1997). Abrol et al. (1992) studied the effect of increased $CO_2$ on various phenology of wheat and found that 10C linear rise in global temperature will depress grain yield by 8-10 percent through decline in grain number by 5.5 percent and grain weight by 3 percent. Baker (2004) in response to the future speculation opinioned that the threat of global warming would be rescued by selecting and breeding rice cultivars with enhanced capability of global increases in $CO_2$. However, Ken Boote and Hartwell Allen from $CO_2$ and Climate Change Project, USA worry while the increased $CO_2$ tends to boost rice and other crop yields, elevated temperatures have the opposite effect and render rice plants totally impotent at higher temperatures in the tropical environments (Hoover, http:// rgp.ufl.edu/ publications/ explore/ v06n2/ rice.html). This study was conducted to determine the effect of elevated $CO_2$ on rice crop under the fabricated open top chamber (OTC) condition (Fig. 1).

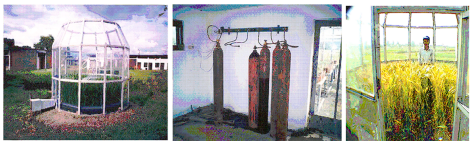

Fig. 1. Open Top Chamber and Rice at Khumaltar (1350 m)

## MATERIALS AND METHODS

The research for $CO_2$ enrichment technology was carried out at Khumaltar Agriculture Research Center (1350 m) in the identical OTCs designed by Indian Agriculture Research Institute (IARI), New Delhi, India (Uprety, 1998). Two OTCs were used for $CO_2$ enrichment treatment (about 580ppm $CO_2$), one OTC as an ambient (350ppm $CO_2$) and an open field of the same area. In the $CO_2$ enriched chambers, $CO_2$ gas passes through copper pipes connected to manifold. The gas circulates inside the chamber through a black polythene pipe of 6" diameter and mixed with air using a blower, which spreads it uniformly through small holes surrounding the chamber. In 2001 and 2002, the Ambient chamber was not fitted with the black polythene pipe but later it was corrected in 2003 and 2004 to nullify the effect of not having air circulation in the Ambient chamber.

## RESULTS AND DISCUSSION

### Soil and Plant Analysis

*Soil*

Soil samples were taken from each plot prior to the start of the experiment and during standing rice of 2001 and prior to 2002 planting. Table 1 indicates that there has been increase in the content of N, P and organic carbon (OC) in the soils irrespective of treatments. The soil results indicate that the pH has also increased. In 2001, farm yard manure (FYM) was added to the soil prior to the start of the experiment. The addition of FYM as well as the inorganic fertilizers should have contributed to this. The pH, N and OC were found slightly higher in the open field than in the $CO_2$ enriched plot and also in 2002 than in 2001. The P2O5 and K2O however were not consistent. The enriched $CO_2$ plot did not seem to have increased the soil carbon.

Table 1. Soil Analysis for pH, N, P, K and Organic Carbon (OC)

| Treatment | pH 2001 | N ^ % | $P_2O_5$ ^ (Kg/ha) | $K_2O$^ (Kg/ha) | OC ^ % |
|---|---|---|---|---|---|
| Benchmark Composite Sample | 4.2 | 0.05 | 432 | 343 | 1.24 |
| $CO_2$ Enriched | 4.5 | 0.13 | 471 | 282 | 1.33 |
| Ambient | 4.6 | 0.13 | 479 | 255 | 1.36 |
| Field | 5.7 | 0.17 | 414 | 285 | 1.44 |

* Those values of CO2 Enriched, Ambient and Field represent means of 2001 and 2002 samples.

*Plant*

Grain mean N and OC percents were lower from the Field than from the Ambient and $CO_2$ enriched plots (Table 2). The Ambient plot recorded higher than the $CO_2$ enriched plot, however year to year variation was noticed. On the other hand, N of the straw and root were found higher in the open Field as compared to the $CO_2$enriched plot. The C content was not consistent yet that of root was found to be higher both the years in the $CO_2$ enriched plot suggesting the carbon translocation to the root was a visible observation when the plant is enriched with $CO_2$ .

Table 2. N and Organic Carbon (OC) in Grain, Straw and Root

| Treatment | N % | | | OC % | | |
|---|---|---|---|---|---|---|
| | Grain^ | Straw^ | Root^^ | Grain^ | Straw^ | Root^^ |
| $CO_2$ Enriched | 1.29 | 0.83 | 0.95 | 6.61 | 18.14 | 20.17 |
| Ambient | 1.43 | 0.86 | 1.11 | 6.77 | 20.03 | 18.15 |
| Field | 1.23 | 1.06 | 1.43 | 6.01 | 18.21 | 19.01 |

* Mean of 2002, 2003 and 2004 ** Mean of 2002, 2003 and 2004

*Temperature*

Gradual fall in temperature were observed during the later stage of growth of rice, more in the second year. In 2001 and 2002, when Ambient chamber was not air blown through the polythene pipe, the maximum temperature (Tmax) remained lower by 0.70 $^0$C in the $CO_2$ enriched than the Ambient but higher than the Field plot (Fig. 2a1). The minimum temperature (Tmin) on the other hand was found slightly higher in the $CO_2$ enriched plot (Fig. 2a2). This can be explained by the fact that air circulation during night period was stopped in the OTC system which would have caused to raise the Tmin in the night. However, in 2003 and 2004 after replication of the 6" polythene pipe in the Ambient to blow air as in the $CO_2$ chamber, the average Tmax and Tmin of the $CO_2$ enriched chamber over the Ambient rose by 1.30 $^0$C and 0.56 $^0$C, respectively (Fig. 2b1 and Fig. 2b2). This observation was seen to be in agreeing with others' because $CO_2$ gas as well as air circulation was interrupted during night when the minimum temperature is recorded. The $CO_2$ however is presumed to be accumulated more in the enriched plot, which would raise the night temperature. Yet the temperature rise due to the $CO_2$ to this level observed in the controlled experiment would still raise the issues of how much it would affect the rice yield.

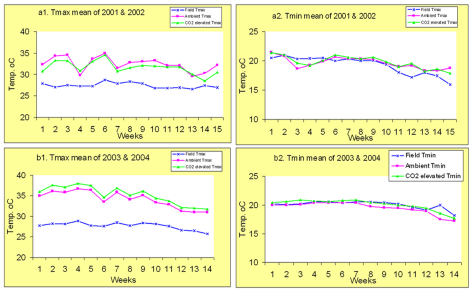


Fig. 2. Maximum (1) and Minimum (2) Temperature during Rice Growing

### Agronomic Parameters

*Phenology*

Different phenological events, heading days and physiological maturity after transplanting of rice are presented in Table 3. There was no significance between the treatments. However, it was found that both the heading days and the physiological maturity were found to be 2 to 3 days early in the $CO_2$ enriched plot than the field. While looking at the separately, the first two years (2001 and 2002) showed somewhat increased days whereas the second two years (2003 and 2004) showed decreased days due to increased $CO_2$ which agreed with the temperature effect to delay or hasten the phenological events.

Table 3. Phenology (Days after Transplanting)* and Yield Components*

| Treatment | Panicle Initiation | Heading | Physiological Maturity | Tillers/Sqm # | Seeds/Panicle # | Plant Ht. (cm) | 1000 Grain Wt. (gm) |
|---|---|---|---|---|---|---|---|
| $CO_2$ Enriched | 42 | 67 | 102 | 338 | 134 | 108 | 24.6 |
| Ambient | 44 | 66 | 102 | 284 | 124 | 109 | 25.5 |
| Field | 46 | 69 | 105 | 252 | 117 | 100 | 26.1 |

* Mean of 2001, 2002, 2003 and 2004

*Yield components*

Number of tillers per square meter was highest in $CO_2$ enriched plot followed by ambient and field plots in all the years (Table 3). The tiller numbers was the most influencing yield component to cause yield differences. However, number of seeds per panicle showed somewhat inconsistent results yet that of Field was lower than the other two (Table 3). Plant height and kernel weight were also seemed to be inconsistent which suggests that these may not be contributing to increased grain yield. Yet the plant height which contributes to the biomass production was found to be lower in the Field plot in all the years (Table 3). And the grain weight tended to be lower in the $CO_2$ enriched or was little influenced agreeing with others' observations (Table 3).

*Yield*

The grain yield in the $CO_2$ enriched chamber increased by 62.6 % in 2001 but in other years by 5.6 % to 11.5 % over the Ambient and by 15.8 % to 45.1 % over the Field (Table 4). The first year variation could have been due to bios management practice at the start. Because the chamber plots were filled up with new soils over a layer of about 10 to 15 cm. Also the plots were filled up with about 10 t/ha of FYM. This could have created uncontrolled variation in the top soils. However, this would have been corrected later due to the continuous cropping. Because, the yield level of the $CO_2$ enriched plot came down to an agreeable level the following years. Consistently, the yield of $CO_2$ enriched plot came higher and that of Field came lower.

Straw yield was also found to be significant (Table 5). The $CO_2$ enriched plot produced 30.4 % to 48.6 higher yield than the Field with an average of 31 % and was higher by 1.1 % to 37.3 % than the Ambient. In 2002, the straw yield of the Ambient was lower than the Field. This could have been possible, because, the moisture content in the straw under our situation may remain uncontrolled.

Table 4. Grain Yield (Gyld) and Percent Change

| Treatment | 2001 | | 2002 | | 2003 | | 2004 | |
|---|---|---|---|---|---|---|---|---|
| | Gyld Kg/ha | Change % | Gyld Kg/ha | Change % | Gyld Kg/ha | Change % | Gyld Kg/ha | Chang % |
| $CO_2$ Enriched | 10857 | 70 | 11966 | 15.8 | 9861 | 45.1 | 8917 | 26.9 |
| Ambient | 6860 | 7.4 | 11392 | 10.2 | 9395 | 38.3 | 8110 | 15.4 |
| Field | 6386 | 0 | 10334 | 0 | 6794 | 0 | 7028 | 0 |

Table 5. Straw Yield (Syld) and Percent Change

| Treatment | 2001 | | 2002 | | 2003 | | 2004 | |
|---|---|---|---|---|---|---|---|---|
| | Syld Kg/ha | Change % | Syld Kg/ha | Change % | Syld Kg/ha | Change % | Syld Kg/ha | Chang % |
| $CO_2$ Enriched | 10867 | 37 | 14465 | 30.4 | 12393 | 48.6 | 12770 | 31 |
| Ambient | 8253 | 4 | 10329 | -6.9 | 12296 | 47.5 | 11740 | 20.4 |
| Field | 7934 | 0 | 11096 | 0 | 8339 | 0 | 9750 | 0 |

## CONCLUSION

This study has offered varieties of scopes such as study on the effects of rising atmospheric $CO_2$ on rice productivity, biogenic emissions and generate database for crop and climatic model. The $CO_2$ enrichment contributed to increase grain and biomass production. Tiller number was the most contributing factor to cause yield differences. The pH, N and OC rose the following years than the benchmark irrespective of the treatments. The $CO_2$ enriched plot had lesser N, P and K content in grain, straw and root. However, OC content in root was higher. The temperature gain by an average of 1.30 $^0$C (Tmax) and 0.56 $^0$C (Tmin) due to the elevated $CO_2$ was not the factor that could adversely affect the rice yield, which seemed to be agreeing with the model prediction (Sherchand, 2003).

## REFERENCES

Abrol, Y. P., D.C. Uprety and A. Sharma (1992), First Agri. Sci. Congress (invited paper), pp. 63-70.

Baker. J.T. (2004), Yield response of southern US rice cultivars to CO2 and temperatire. Agriculture and Forest Meteorology, 122, 120-137.

Hoover, A. http:// rgp.ufl.edu/publications/explore/v06n2/rice.html.

Huang J., G. Dong, H. Yang , Y. Wang, J. Zhu, L. Yang, Y. Shan. (2003), Effect of free-air CO2 enrichment on biomass accumulation and distribution in rice 14(2), 253-257, Translated from Chinese by Y. Yong, S. Tai and X. Bao.

Idso, S.B., B.A. Kimball, M.G. Anderson and J.R. Mavney (1987), Effects of atmospheric CO2 enrichment on plant growth: the interactive role of air temperature, Agric. Ecosys. Environ., 20, 1-10.

Kim, H.Y., M. Lieffering, K. Kobayashi, M. Okada, M.W. Mitchell and M. Gumpertz (2003), Effects of free-air CO2 enrichment and nitrogen supply on the yield of temperate paddy rice crops. Field Crops Research 83, 261–270.

Kim, H.Y., M. Liefferingh, K. Kobayashic, M. Okadad and S. Miura (2003), Seasonal changes in the effects of elevated CO2 on rice at three levels of N supply: a free air CO2 enrichment (FACE) experiment. Global Change Biology, 9, 826-837.

Prior, S.A., H.A. Torbert, G.B. Runion, H.H. Rogers, C.W. Wood, B.A. Kimball, R.L. LaMorte, P.J. Pinter and G.W. Wall (1997), Free-air carbon dioxide enrichment of wheat: soil carbon and nitrogen dynamics, J. Environ. Qual., 26, 1161-1166.

Sherchand, K. (2003), Global change inpact assessment of agriculture in the Kali Gandaki watershed of Nepal, paper presented at the Regional Workshop on Global Change Impact Assessment for Himalayan Mountain Regions for Environmental Management and Sustainable Development, Kathmandu, Nepal, 18-20 December.

Uprety, D.C. (1998), Carbon dioxide enrichment technology: open top chamber : a new tool for global climate research, J. Scientific and Industrial Research, 57, 226-270.