Indian J. Plant Physiol., Vol. 17, No. 1, (N.S.) pp. 84-87 (Jan.-Mar., 2012)

SHORT COMMUNICATION

ELEVATED CO_2 ALTERS SEED COMPOSITION AND QUALITY IN *BRASSICA*

K. CHAKRABORTY*# AND D.C. UPRETY

Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi-110012

Received on 25th October, 2011, Revised and accepted on 25th February, 2012

The effect of elevated CO_2 (550 ± 50 µmol mol^{-1}) on seed composition and quality in two cultivars of *Brassica* viz. RH 30 (*B. juncea*) and Pusa Gold (*B. campestris*) was studied in open-top chambers. Elevated CO_2 enhanced yield attributes viz. seed yield, total number of pods per plant, number of seeds per pod, pod dry weight per plant, seed yield, thousand-seed weight and harvest index. Total and reducing sugar, starch and oil content increased significantly, however, total soluble protein decreased in both the cultivars under elevated CO_2. Fatty acid profile of seeds suggested alteration of saturated to unsaturated fatty acid ratio under elevated CO_2.

***Key words*: *Brassica*, elevated CO_2, fatty acid profile, protein content, seed quality**

Brassica is one of the most important oilseeds cultivated in tropical and subtropical region of the world and is the second most important oilseed in India, contributing about 30% of total edible oil production of the country. Mustard oil is a rich source of various essential fatty acids that contribute to its nutritional value. The vulnerability of *Brassica* crop to climate change has made the response studies to elevated CO_2 important in order to identify cultivars suitable under elevated CO_2. The cultivation and nutrient management practices can be suggested for these cultivars.

Open top-chambers (OTC) and free air CO_2 enrichment (FACE) technologies were first time established in India for crop response studies in South Asian regions (Uprety *et al* 1998)..

With the change in global climate in the form of change in land use cover, decline in biodiversity and composition of atmospheric gases, it has become important to analyse the effect of increasing level of CO_2 on cultivated *Brassica* species. The effect of elevated CO_2 on different physiological parameters (Uprety *et al*. 1995) and seed quality (Das and Uprety 2006a) has been reported but information is lacking on seed quality parameters, fatty acid and protein profile in *Brassica* species. The present study was undertaken to refine the responses studies by laying emphasis on these parameters in two *Brassica* species, *Brassica juncea* (RH 30) and *Brassica campestris* (Pusa Gold).

Two *Brassica* cultivars viz. *B. juncea* (RH 30) and *B. campestris* (Pusa Gold) were grown in the soil inside OTCs (diameter 2 m and height 3 m) covered with PVC sheets (125 µm) with 85% transmission of PAR. The CO_2 level in OTC was raised to 550 ± 50 µmol mol^{-1}. The crop grown in OTC without elevated CO_2 and in natural field condition served as control. The concentration of CO_2 under control sets was 370±10 µmol mol^{-1}. Standard package of practices was adopted for raising the crop under all treatments. The present experiment was a split-plot experiment taking CO_2 treatment as main effect and cultivars of *Brassica* as sub-effect.

*Corresponding author: koushik_iari@rediffmail.com, & present address: #Directorate of Groundnut Research, Junagadh

Seeds were harvested from each experimental treatment at physiological maturity. The yield attributing characters viz. total number of pods per plant, the number of seeds per pod, pod dry weight per plant, seed yield (g m^{-2}), thousand-seed weight and harvest index were recorded from each treatment followed by analysis of various biochemical parameters. Observations were recorded on seed composition in terms of reducing and total sugar, starch, oil and total soluble protein content from the seed. The composition of different fatty acids in extracted oil was analysed.

The oil content of the seed was estimated by cold percolation method (Kartha and Sethi 1957) using CCl_4 as solvent. The defatted seed was kept in hot air oven at 160ºC for drying and starch content estimated by anthrone method (McCready *et al*. 1950). Total and reducing sugar were estimated by Nelson's arsenomolybdate method (Nelson 1944). For seed protein % N is determined and multiplied by a factor and total soluble protein by Lowry's method (Lowry *et al*. 1951). Qualitative analysis of fatty acids was carried out by gas–liquid chromatography (GC model 3840) (Hewlett Packard (Palo Alto, CA) following the method of Morrison and Smith (1964). The fatty acids were converted into methyl esters using BF_3-methanol reagent and then estimated using diethylene glycol succinate (DEGS) column. The esters of fatty acids were identified by comparing with a set of standard fatty acid ester using flame ionization detector with nitrogen as carrier gas and flow rate of 40–50 ml/min. The column/oven temperature was 170–200ºC with detector and injector port temperature as 230ºC.

Elevated CO_2 resulted in better plant growth and also showed significant change in different yield attributing characters. Elevated CO_2 significantly increased the number of pods in both cultivars (37% in RH 30 and 38% in Pusa Gold) and seed yield (g/m^2) by 13% in RH 30 and 12% in Pusa Gold. With the increase in test weight (thousand-seed weight) of seeds harvested under elevated CO_2 by 15% in RH 30 and 13% in Pusa Gold, the harvest index for the plants increased by 11% in RH 30 and 9% in Pusa Gold (Table 1). Plants are directly affected by elevated CO_2, because it serves as substrate to photosynthetic carbon assimilation and adversely affects the photorespiratory activity and stomatal functions. C_3 plants like rice, wheat, mustard, pulses respond to elevated CO_2 since it reduces oxygenase activity of ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) enzyme in plants while C_4 plants (sorghum, maize and sugarcane) show little or no photosynthetic response to elevated CO_2 as C_4 pathway is not competitively inhibited by oxygen (Idso 1999).

Seed quality parameters were also affected significantly due to elevated CO_2 treatment. Due to enhanced rate of carbon fixation by elevated CO_2 grown plants there was significant accumulation of photosynthates in the sink which finally increased both structural and non-structural carbohydrates in the seeds. There was 31.4 and 29.1% increase in total sugar content in the seeds of RH 30 and Pusa Gold, respectively, while reducing sugar increased by 33 and 30% and non-reducing sugar by 29 and 28% in RH 30 and Pusa Gold, respectively under elevated CO_2 (Fig. 1). Similarly, seed starch content increased by 27 and 23% in RH 30 and Pusa Gold, respectively under elevated CO_2 grown plants compared to ambient CO_2 grown plants (Fig. 2). These

Table 1. Effect of elevated CO_2 on yield attributing characters in RH 30 and Pusa Gold

Treatment	RH 30			Pusa Gold			CD (P≤0.05)
	Elevated	Ambient	Field	Elevated	Ambient	Field	(Var x Treat)
Seed number pod^{-1}	19.85	17.23	17.18	43.20	38.10	36.90	1.30
1000 seed weight (g)	5.13	4.62	4.65	4.55	3.34	3.21	0.39
Seed yield (g m^{-2})	970.50	857.56	840.10	735.20	655.40	631.80	87.30
Pod weight (g $plant^{-1}$)	18.75	14.07	13.11	17.46	13.54	12.75	NS
Harvest index (%)	44.81	40.23	39.80	40.52	37.10	35.91	2.99

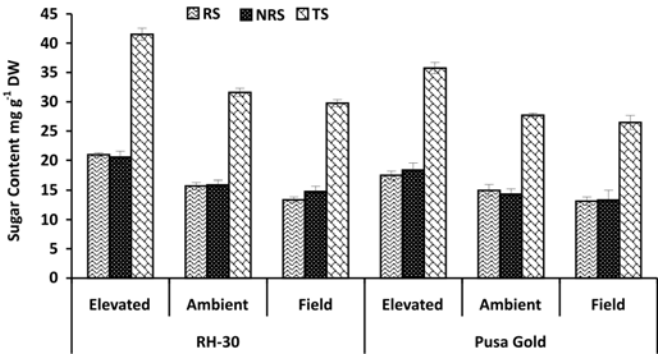

Fig. 1. Effect of elevated CO_2 on reducing (RS), non-reducing (NRS) and total sugar (TS) in *Brassica* seeds. Error bars represent ±SD, CD (P≤0.05) = 1.34 (RS), 2.55 (NRS) and 2.23 (TS).

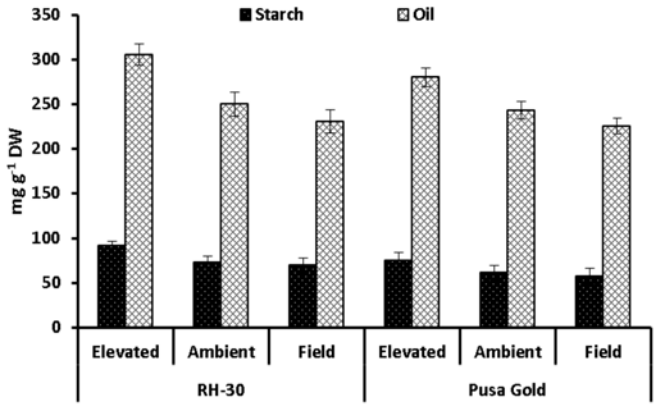

Fig. 2. Effect of elevated CO_2 on starch and oil content in *Brassica* seeds. Error bars represent ±SD, CD (P≤0.05) = 10.48 (starch) and 16.04 (oil).

results suggest the sustenance of the stimulatory effect of CO_2 till seed formation stage. Sequestration of carbon in leaf tissue leads to the accumulation of more carbohydrate probably in *Brassica* seeds and the higher proportion of carbohydrates in the seeds was probably due to redistribution of this carbon from the vegetative parts to the seeds.

Unlike carbohydrate, total soluble protein in the seeds was reduced by 13% in RH 30 and 15% in Pusa Gold due to elevated CO_2 (Fig. 3). This was due to accumulation of more carbohydrates which significantly increased the C:N ratio in the tissue, which in turn may be responsible for lesser availability of nitrogen for

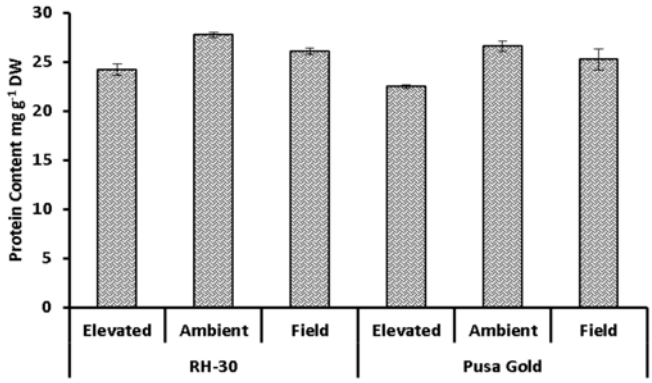

Fig. 3. Effect of elevated CO_2 on total soluble protein in *Brassica* seeds. Error bars represent ±SD, CD (P≤0.05) = 1.01.

protein synthesis on unit dry mass basis. Although the total protein content of the whole plant grown under elevated CO_2 may remain same but due to greater accumulation of carbohydrates in the tissue, unit protein content is reduced due to dilution effect.

Elevated CO_2 treatment significantly increased the oil content by 22 and 15% in RH 30 and Pusa Gold, respectively (Fig. 2). This increase in oil content of seeds is obviously at the expense of either carbohydrate or protein. In the present study, greater oil content appeared alongwith more accumulation of carbohydrates under elevated CO_2, however, the total soluble protein content was reduced. This meant that more oil content in the elevated CO_2 grown seeds was at the expense of protein. In the fatty acid profile study, it was observed that the saturated fatty acid content i.e., palmitic acid and stearic acid was altered in the seeds of elevated CO_2 grown plants of both RH 30 and Pusa Gold (Fig. 4). Excess production of carbon substrates in CO_2-enriched plants could lead to higher availability of substrate in the form of malonyl CoA required for the production of long carbon chain fatty acids than short-chain saturated fatty acids (Das and Uprety 2006b). Thus, elevated CO_2 alters the fatty acid composition in seeds which may be further investigated.

Thus, from the present study it can be concluded that elevated CO_2 helped to fix more carbon in plant parts leading to the accumulation of greater carbohydrate and oil content in *Brassica* with altered fatty acid composition of the seeds.

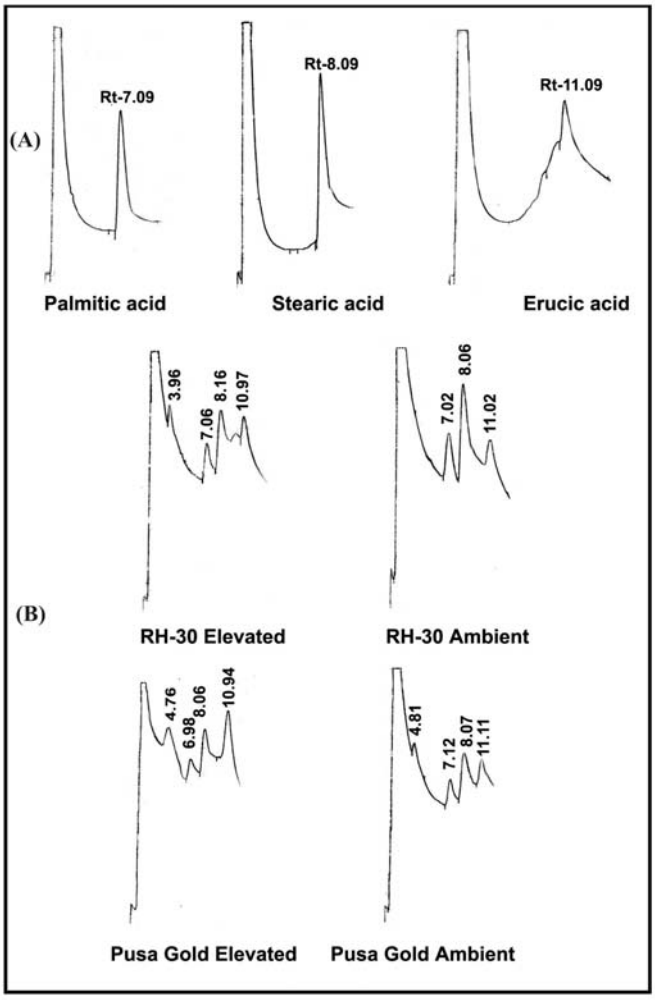

Fig. 4. Fatty acid profile of *Brassica* oil from seeds harvested under elevated and ambient CO_2 levels. Values in chromatograph indicate retention time (Rt) of standard fatty acid (A) and fatty acid from treatments (B).

ACKNOWLEDGEMENT

Authors are grateful to N. Diwedi and S. Jaiswal for help rendered in the lab and field work. The senior author is also thankful to Indian Council of Agricultural Research, New Delhi, India for providing the Junior Research Fellowship during the course of this study.

REFERENCES

Das, R. and Uprety, D.C. (2006a). Interactive effect of moisture stress and elevated CO_2 on the oxidative stress in *Brassica* species. *J. Food Agril. & Env.* **4:** 298-305.

Das, R. and Uprety, D.C. (2006b). Effect of elevated CO_2 on water relation components of *Brassica* species under moisture stress condition. *Ind. J. Plant Physiol.* **48:** 48-56.

Idso, S.B. (1999). The long term response of trees to atmospheric CO_2 enrichment. *Global Change Biol.* **5:** 493-495.

Kartha, A.R.S. and Sethi, A.S. (1957). A cold percolation method for rapid gravimetric estimation of oil in small quantities of oilseeds. *Ind. J. Agric. Sci.* **27:** 211–217.

Lowry, O.H., Rosenbrough, N.J. and Randall, R.J. (1951). Protein measurement with Folin Phenol reagent. *J. Biol. Chem.* **193:** 265-275.

McCready, R.M., Gugglog, J., Silviera, V. and Owens, H.S. (1950). Determination of starch and amylase in vegetables. *Anal. Chem.* **22:** 156-158.

Morrison, W.R. and Smith, L.M. (1964). Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride–methanol. *J. Lipids Res.* **5:** 600–608.

Nelson, N. (1994). A photometric adaptation of the Sumogyi method of determination of glucose. *J. Biol. Chem.* **243:** 6281-6283.

Uprety, D.C., Dwivedi, N. and Mohan, R. (1998). Characterization of CO_2 responsiveness in *Brassica oxycampestris* inter specific hybrid. *J. Agron. Crop. Sci.* **180:** 7-13.

Uprety, D.C., Mishra, S.M. and Abrol, Y.P. (1995). Effect of elevated CO_2 on the photosynthesis, growth and water relation of *Brassica* species under water stress. *J. Agron. Crop. Sci.* **175:** 231-237.