BRIEF COMMUNICATION

Effect of elevated CO_2 and moisture stress on the carbon and nitrogen contents in *Brassica juncea*

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Abstract

The responses of *Brassica juncea* cv. Pusa Bold to elevated CO_2 was studied under water stress. Carbon accumulation in leaves, stem and roots was significantly higher at elevated CO_2 concentration. The water stress decreased the carbon content in these plant parts and this adverse effect was reduced by CO_2 enrichment. On the contrary nitrogen content of leaves, stem and roots was significantly reduced at elevated CO_2. Water stress caused reduction in nitrogen content in these plant parts, similar at ambient as well as elevated CO_2 concentration.

Additional key words: carbon/nitrogen ratio, Indian mustard, open top chamber, saccharides.

Carbon dioxide concentration in the atmosphere is exponentially rising and is anticipated to be doubled by the end of next century. The continuous increase in the atmospheric CO_2 concentration will possibly lead to significant effect on carbon and nitrogen dynamics in plants so that carbohydrate becomes abundant and nitrogen becomes relatively scarce (Luo *et al.* 1994). In association with photosynthetic and growth responses, accumulation of storage carbohydrates and shifts in carbon/nitrogen balance may be an early indication of plant responses to increased carbon availability (Curtis *et al.* 1989, Fajer *et al.* 1992). Therefore, it is important to characterize the changes in nitrogen and carbon distribution in plants under elevated CO_2. This study will help in understanding the efficiency of utilization or remobilization of nitrogen and carbon at elevated CO_2 and would influence fertilizer management in agro-ecosystem. The crop of present study was *Brassica juncea*, which responds significantly to elevated CO_2 (Uprety *et al.* 1995, 1998) and it is an

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important oilseed crop in India. As large part of its growing area experiences drought, the CO_2 effect in plants was studied both under irrigation and water stress.

Brassica juncea (L.) Czern. & Coss cv. Pusa Bold is an amphidiploid (genome ab, n = 18) derivative of diploid species *B. campestris* (genome a, n = 10) and *B. nigra* (genome b, n = 8). Plants were raised in open top chambers in an ambient CO_2 concentration of 350 ± 20 μmol mol^{-1} and at elevated CO_2 concentration of 600 ± 15 μmol mol^{-1}. The CO_2 enrichment was done between 08:00 and 18:00. For details see Uprety *et al.* 1995.

Another set of plants were grown in open field. Nitrogen, phosphorus and potassium fertilizers were given at the rate of 30 + 30 : 60 : 40 kg ha^{-1}, respectively. Plants grew under irrigation and water stress was applied at pre-flowering (25 days after sowing), first flower appearance (35 DAS), 50 % flowering (45 DAS) and post-flowering (70 DAS) stages (withholding irrigation for a period of 7 - 10 d depending on the stage of growth).

Sampling of water stressed plants was done when plants showed wilting symptoms and leaf water potential measured by pressure chamber *3005* model (*Soil Moisture Equipment Corporation*, Santa Barbara, USA) was -1.8 MPa. Parallel samples of irrigated plants were taken. Response of plants at different stages was similar (with different absolute values). Thus observations at flowering stage are described here to avoid repetition. The carbon content in leaves, stems and roots was estimated by wet digestion following the modified Walkley-Black method (1934). The nitrogen was determined in the dried samples using a *Technicon Autoanalyser No. 1* (Tarrytown, USA). The sugars were extracted from the topmost fully expanded leaf of the main stem. Leaves were dried at 80 °C to constant mass and reducing and non-reducing sugars were determined with Somogyi reagent using *Cecil* scanning spectrophotometer (*Cecil Instruments*, Cambridge, UK). Starch was determined on dry residue left after sugar extraction by anthrone method (McCready *et al.* 1950). Three replicates of each treatment was taken for every observation and data were analysed statistically following the method of analysis of variance (Snedecor and Cochran 1980).

The elevated CO_2 significantly increased the carbon content in leaves (38 to 40 %), stems (29 %), and roots (29 %), compared to plants grown at ambient CO_2 concentration in open top chamber and field grown plants. Water stress treatment reduced the carbon content of leaves, stems and roots, up to 25, 15, and 18 %, respectively, under ambient CO_2 concentration, whereas up to 20, 10, and 17 %, respectively, under elevated CO_2 concentration (Table 1).

The increased CO_2 concentration brought about a significant reduction in the nitrogen content of leaves, stem and roots, the reduction was 29 to 30% compared to ambient CO_2 concentration. Water stress caused reduction in the nitrogen content of leaves (25 %), stems (20 %), and roots (17 %), similarly both under elevated as well as ambient CO_2 concentration (Table 1).

In consequence the C/N ratio of leaves, stems and roots was significantly increased due to CO_2 enrichment. The increase was as high as 95 % in leaves, 89 % in stems and 50 % in roots. Moisture stress brought about only a marginal increase in C/N ratio (Table 2).

Table 1. Effect of CO_2 concentration [µmol mol^{-1}] and water stress on carbon and nitrogen content [% d.m.] in leaf, stem and root of *Brassica juncea* cv. Pusa Bold.

CO_2		Carbon leaf	stem	root	Nitrogen leaf	stem	root
350 (field)	irrigated	22.75	15.69	25.65	3.82	2.82	2.26
	stress	17.71	13.64	21.25	2.85	2.24	1.92
350 (chamber)	irrigated	23.40	15.77	25.79	3.88	2.86	2.22
	stress	17.55	13.69	21.30	2.86	2.35	1.93
600 (chamber)	irrigated	31.46	20.06	33.08	2.77	2.02	1.52
	stress	25.15	17.98	27.59	2.00	1.54	1.25
C.D. at 5 %	CO_2	2.14	1.14	1.57	0.14	0.06	0.31
	stress	1.75	0.93	1.28	0.12	0.05	0.26

Table 2. Effect of CO_2 concentration [µmol mol^{-1}] and water stress on carbon/nitrogen ratio in leaf, stem and root and saccharide content [mg g^{-1}(d.m.)] in leaves of *Brassica juncea* cv. Pusa Bold.

CO_2		C/N ratio leaf	stem	root	Saccharides non-reducing	reducing	starch
350 (field)	irrigated	5.96	5.56	11.35	27.40	20.59	160.67
	stress	6.21	5.83	11.07	12.74	12.87	89.94
350 (chamber)	irrigated	6.03	5.51	11.62	25.51	20.44	158.83
	stress	6.14	5.83	11.04	13.13	13.51	91.50
600 (chamber)	irrigated	11.36	9.93	21.76	33.71	30.76	251.68
	stress	12.58	11.68	22.07	21.96	24.24	157.72
C.D. at 5 %	CO_2	0.88	0.39	1.10	0.66	2.12	5.89
	stress	n.s.	0.32	n.s.	0.54	1.73	4.81
	interaction	n.s.	0.55	n.s.	0.93	n.s.	8.93

There was significant increase in non-reducing and reducing sugars in leaves of *B. juncea* with increased CO_2 concentration. The enhancement was 44 and 39 % compared to ambient CO_2 concentration in chamber and open field, respectively. The moisture stress induced a significant decrease in non-reducing and reducing sugars in leaves of *Brassica*. The reduction of non-reducing sugar was however, 48 and 53 % under ambient CO_2 concentration compared to 30 % under elevated CO_2. The reduction of reducing sugar content was 22 to 33 % both under elevated as well as ambient CO_2 concentration. The higher concentration of CO_2 significantly increased the starch content (64 %) in leaves. Moisture stress markedly reduced leaf starch content. The reduction under elevated CO_2 ranged up to 37 % compared to 43 and 44 % under ambient CO_2 (Table 2).

A greater photosynthetic efficiency at elevated CO_2 may result in a reduced nitrogen allocation to Rubisco (Sage *et al.* 1989). Conroy *et al.* (1992) suggested that suppression of photorespiration at high CO_2 would reduce the flux of nitrogen through glycolate pathway, which would lower the leaf nitrogen requirement with a subsequent change in the amino acid balance of leaf tissue. In consequence of the increased CO_2 assimilation per nitrogen unit in photosynthetically active leaves more nitrogen may be allocated to the production of new organs (Sage and Pearcy 1987). Thus low nitrogen supply does not necessarily prevent a growth response to increasing CO_2 concentration. The performance of *B. juncea* plants grown under elevated CO_2 concentration was not inhibited by the nitrogen status. The ameliorating effect of CO_2 to water stress induced changes can be attributed to the accumulation of sugars in the cell sap. This may possibly help in the osmoregulation. It is in good agreement with previous suggestions (Uprety *et al.* 1995, 1996) that the alteration in water potential components and increased root growth under CO_2 enrichment attributes to amelioration of the adverse effect of water stress.

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