BRIEF COMMUNICATION

Effect of nitrogen on carbonic anhydrase activity, stomatal conductance, net photosynthetic rate and yield of mustard

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Abstract

Mustard (*Brassica juncea* L.) cv. Rohini was grown under three levels of urea nitrogen fertilization [0, 2, and 4 g(N) pot^{-1}]. Carbonic anhydrase activity and net photosynthetic rate in leaves of 50 d-old plants as well as yield attributes at harvest increased with increasing levels of nitrogen. Stomatal conductance was not affected, and oil content decreased.

Additional key words: *Brassica juncea*; oil content of seeds; seed mass and number; urea; yield attributes.

Carbonic anhydrase (CA; E.C. 4.2.1.1) catalyzes the reversible hydration of carbon dioxide and is essential for optimal photosynthetic activity (Everson 1970). Keeping this in view, the present experiment was performed to study the effect of graded levels of fertilizer nitrogen on CA activity, stomatal conductance (g_s) and net photosynthetic rate (P_N) as well as yield attributes of mustard.

Mustard (*Brassica juncea* L.) cv. Rohini was grown in earthen pots in the garden of the Department of Botany, Aligarh Muslim University, Aligarh (27°53' N, 78°4' E, and 187.45 m altitude), India. Each pot (diameter 25 cm; height 25 cm) was filled with 4 kg of an autoclaved homogeneous mixture (3:1) of soil and farmyard manure, texture - sandy loam; pH 7.4; conductivity 0.65 dS m^{-1}; available mineral elements: 0.39 g(N) pot^{-1} [22.1 g(N) m^{-2}], 0.04 g(P) pot^{-1} [2.4 g(P) m^{-2}], and 0.64 g(K) pot^{-1} [35.6 kg(K) m^{-2}]. Five pots were earmarked for each treatment, consisting of three levels of urea nitrogen, viz. 0, 2, and 4 g(N) pot^{-1}. Nitrogen was applied in two equal splits, *i.e.*, half at sowing (25 October), and the remaining half 30 d after sowing (DAS). Three vigorously growing plants were maintained in each pot. The pots were irrigated initially on alternate days. Later, as air temperature increased, watering was done as frequently as required. CA activity, P_N, and g_s were studied at 50 DAS. P_N and g_s were determined by the *LICOR 6200* Portable Photosynthesis System in comparable leaves at 10:00-11:00 h. CA activity was measured according to Dwivedi

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and Randhava (1974). At harvest (14 March), pods per plant, seeds per pod, 100 seed mass, seed yield per plant, oil content of air-dried seeds, and oil yield per plant were determined. Oil was extracted in the Soxhlet apparatus using petroleum ether as solvent. Values were analyzed statistically to assess their significance, using the F test. Correlation coefficient values for different pairs of parameters were also determined (Gomez and Gomez 1984).

The effect of added nitrogen was significant on CA activity, P_N, and most yield parameters, which were enhanced linearly (Table 1). However, the effect on g_s was non-significant. On the other hand, oil content of seeds was reduced significantly. Application of 4 g(N) pot^{-1}, that proved the most effective treatment, increased CA activity by 34.4 %, P_N by 65.4 %, pods per plant by 60.5 %, seeds per pod by 9.1 %, 100 seed mass by 4.6 %, seed yield per plant by 57.4 %, and oil yield per plant by 50.4 %, whereas oil content was decreased by 4.5 %, when compared with the no-nitrogen control.

Table 1. Effect of nitrogen on carbonic anhydrase activity, stomatal conductance (g_s), net photosynthetic rate (P_N) and yield characteristics of mustard. N.S. = non-significant.

Characteristic	Nitrogen concentration [g(N) pot^{-1}]			C.D. at 5 %
	0	2	4	
CA activity [μmol(CO_2) kg^{-1}(leaf f.m.) s^{-1}]	441.66	535.41	593.75	34.86
g_s [mol m^{-2} s^{-1}]	0.64	0.73	0.79	N.S.
P_N [μmol(CO_2) m^{-2} s^{-1}]	9.13	12.50	15.10	2.06
Pod number per plant	180.66	241.66	290.00	13.80
Seed number per pod	12.28	13.19	13.40	0.43
100 seed mass [mg]	333.00	340.00	348.33	3.25
Seed yield per plant [g]	6.80	8.70	10.70	1.187
Oil content of air-dried seeds [%, m/m]	39.90	39.10	38.10	0.42
Oil yield per plant [g]	2.72	3.43	4.09	0.87

Similar results have been published on the effect of applied nitrogen on other enzymes, including nitrate reductase (Afridi and Hewitt 1964, Hunter 1983, Srivastava and Douglas 1989).

The ameliorating effect of applied nitrogen on P_N noted in the present study could be expected on two counts. First, the enhanced CA activity would make considerable quantity of additional carbon dioxide available for the process. Secondly, a number of compounds involved in photosynthesis, such as chlorophylls, enzymes and co-enzymes, being themselves nitrogenous in nature, not only depend upon this essential nutrient element for their production (Marschner 1986) but also show a linear relationship to increasing quantities of added nitrogen, within limits (Salisbury and Ross 1992).

The beneficial effect of nitrogen on yield characteristics could be attributed to its role as a constituent of numerous metabolic compounds which take part in the growth and development of the plant (Salisbury and Ross 1992). The present effects

on yield attributes confirm our earlier findings (Mohammad *et al.* 1985) as well as those of Rana *et al.* (1991) on mustard.

The oil content of seeds decreased with increasing levels of nitrogen (Table 1). The apparent explanation for this adverse effect of nitrogen is the preferential utilization of carbon skeletons, at the time of seed filling, towards protein synthesis rather than oil formation (cf. the findings of Mazur *et al.* 1977, Kalra and Tripathi 1980, Chourasia *et al.* 1992 on rape, sunflower, and linseed, respectively). However, the positive effect of applied nitrogen on seed yield was so spectacular that it out-balanced the lowered oil content value of seeds in providing considerably enhanced oil yield per plant (Table 1), an obvious commercial advantage.

Seed yield at 4 g(N) pot^{-1} was strongly and positively correlated (Table 2) with number of pods per plant ($r = 0.994$), seeds per pod ($r = 0.971$), and 100 seed mass ($r = 0.987$). Therefore the highest seed yield was gained at this level of applied N (Table 1).

Table 2. Correlation coefficients (r) for selected pairs of characteristics of mustard. For abbreviations see Table 1.

Characteristic	P_N	Pods per plant	Seeds per pot	100 seed mass	Seed yield	Oil content
CA activity	0.959	0.997	0.977	0.983	0.999	N.S.
P_N	-	0.999	0.963	0.992	0.997	N.S.
Pods per plant	-	-	0.961	0.993	0.994	N.S.
Seeds per pot	-	-	-	0.922	0.971	-0.916
100 seed mass	-	-	-	-	0.987	-0.999
Seed yield	-	-	-	-	-	-0.985

The additional requirement for carbon skeletons needed for the enhanced accumulation of metabolites in the seed was met through efficient photosynthesis due to increased CA activity which was strongly and positively correlated with P_N ($r = 0.959$). This finding corroborates the results of Edwards and Mohamed (1973) on *Phaseolus vulgaris* and of Ohki (1978) on *Glycine max*.

Thus, we may conclude that higher yield of seed and oil in mustard was the result of the stimulatory effect of applied nitrogen on CA activity and P_N. These biochemical and physiological parameters stimulate plant growth and ameliorate yield attributes which contribute cumulatively to the final yield of a crop, as has been confirmed in the present study.

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