BRIEF COMMUNICATION

Effect of K application on leaf carbonic anhydrase and nitrate reductase activities, photosynthetic characteristics, NPK and NO_3 contents, growth, and yield of mustard

F. MOHAMMAD* and U. NASEEM

Department of Botany, Aligarh Muslim University, Aligarh 202002, India

Abstract

In a sand culture experiment on mustard (*Brassica juncea* L. Czern. & Coss) cv. Varuna, all tested characteristics at 60 d stage and yield characteristics at harvest were enhanced by K application as its levels increased from 5 to 10, 15, 20, 25, and 30 mM K, with 20 mM K proving best.

Additional key words: *Brassica juncea*; leaf area; oil content; pod; seed yield; stomatal conductance.

Potassium (K) is characterized by high mobility in plants at all levels. It activates at least 60 enzymes involved in growth. Its distribution is comparatively high in the cytosol and chloroplast wherein it neutralizes the soluble and insoluble anions and stabilizes and maintains the pH between 7 and 8, the optimum for most enzyme reactions (Marschner 2002). Thus, by changing their pH levels, K may affect to a great extent the activities of several enzymes in these compartments. It changes the physical shape of the enzyme molecule, exposing the appropriate chemically active sites for reaction. Carbonic anhydrase (CA; EC 4.2.1.1, a cytoplasmic as well as chloroplastic enzyme) catalyses hydration of CO_2 required for photosynthesis. Nitrate reductase [NR; EC 1.6.6.1, a key enzyme of nitrogen (N) metabolism] is another cytoplasmic enzyme, which catalyzes reduction of nitrate (NO_3) to nitrite (NO_2). These two processes (photosynthesis and N metabolism) in turn greatly affect plant growth and development. We tested the effect of K application on these enzymes and some metabolic and growth processes.

A sand culture experiment was conducted on mustard (*Brassica juncea* L. Czern. & Coss) cv. Varuna during 'rabi' (winter) season in a net house at the Department of Botany, Aligarh Muslim University, Aligarh, India. Coarse sand (size 0.2–2.0 mm) was purified according to Hewitt (1966). 2 kg of this was used to each of 30 earthen pots (25 cm height×25 cm diameter). The inner wall of the pot was lined with polythene sleeves, with their lower end passing through the hole of the bottom of the pot to ensure drainage and aeration. The field capacity of pots filled with the sand was maintained with the help of de-ionized water. Sterilized seeds were sown at a depth of 2 cm. Modified Hoagland nutrient solution with variation in K (KCl) levels (5, 10, 15, 20, 25, and 30 mM K), as also de-ionized water in required quantity, was supplied at alternate days after germination. There were five replicates for each treatment. The design of the experiment was simple randomized. CA and NR activities, stomatal conductance (g_s), net photosynthetic rate (P_N), leaf N, phosphorus (P), K, and NO_3 contents, and growth parameters (area of leaf and fresh and dry masses per plant) were studied at 60 d stage. Yield characteristics, namely pods per plant, seeds per pod, 100-seed mass, seed yield per plant, oil content, and oil yield per plant, were studied at harvest. CA and NR activities were measured according to Dwivedi and Randhawa (1974) and Jaworski (1971), respectively. g_s and P_N were measured using a *Licor-6200* portable photosynthesis system in comparable leaves at 10:00–11:00. Leaf N and P contents were estimated by adopting the method of Lindner (1944) and Fiske and Subba Row (1925), respectively. Leaf NO_3 content was estimated by the method of Johnson and Ulrich (1950). Soxhlet apparatus

Received 21 November 2005, *accepted* 24 February 2006.
*Author for correspondence; fax: + 91-571 -2702016, e-mail: firoz_59@rediffmail.com
Acknowledgements: The authors are grateful to the Chairman of the Department of Botany for providing the experimental facilities and to Prof. M.M.R.K. Afridi for advice.

Table 1. Effect of K on activities of leaf carbonic anhydrase (CA) and nitrate reductase (NR), stomatal conductance (g_s), net photosynthetic rate (P_N), NPK and NO_3 contents, growth, and yield of mustard.

Characteristics	Potassium [mM K]						
	5	10	15	20	25	30	CD at 5 %
CA activity [μmol(CO_2) kg^{-1}(leaf f.m.) s^{-1}]	205.7	231.3	249.1	285.4	262.6	255.8	16.15
NR activity [pmol(NO_2) kg^{-1}(leaf f.m.) s^{-1}]	29.6	33.7	34.7	35.9	32.3	31.6	2.3
g_s [mol m^{-2} s^{-1}]	0.56	0.59	0.63	0.76	0.72	0.70	0.12
P_N [μmol(CO_2) m^{-2} s^{-1}]	9.3	10.8	12.4	13.9	13.3	13.5	1.01
NO_3 content [mg kg^{-1}]	339.8	342.7	361.3	372.4	346.3	329.7	6.7
N content [%]	2.57	2.60	2.64	2.78	2.97	2.99	0.16
P content [%]	0.51	0.52	0.53	0.59	0.61	0.63	0.06
K content [%]	3.69	3.71	3.91	4.31	4.61	5.10	0.50
Leaf area [cm^2]	9.4	14.6	21.4	23.4	22.2	19.0	1.50
Fresh mass $plant^{-1}$ [g]	4.75	6.70	6.80	7.63	7.52	7.55	0.53
Dry mass $plant^{-1}$ [g]	1.76	2.62	2.75	3.14	3.02	3.12	0.22
Pods $plant^{-1}$	14.0	23.0	27.2	33.4	31.6	25.8	3.12
Seeds pod^{-1}	10.6	11.0	11.3	11.6	11.6	11.0	0.59
100-seed mass [mg]	294.3	296.0	296.0	300.2	301.2	302.1	3.00
Seed yield $plant^{-1}$ [g]	0.40	0.73	0.91	1.20	1.10	0.90	0.14
Oil content [%]	35.0	35.6	36.2	37.9	37.2	37.4	0.31
Oil yield $plant^{-1}$ [g]	0.14	0.26	0.33	0.46	0.41	0.34	0.05

was employed to extract oil, using petroleum ether as solvent. The data were analyzed statistically using analysis of variance at 5 % probability level (Gomez and Gomez 1984).

Increasing levels of K up to 20 mM K enhanced linearly all parameters studied. Application of 20 mM K increased CA activity by 38.7 %, NR activity by 21.5 %, g_s by 35.7 %, P_N by 49.5 %, NO_3 content by 9.6 %, contents of leaf N by 8.2 %, P by 15.7 %, K by 16.8 %, area of leaf by 148.9 %, fresh mass per plant by 60.6 %, dry mass per plant by 78.4 %, pod number per plant by 138.6 %, seed number per pod by 9.4 %, 100-seed mass by 2.0 %, seed yield per plant by 200.0 %, oil content by 8.3 %, and oil yield per plant by 228.6 % over the minimum level of K, *i.e.* 5 mM K (Table 1).

The enhancing effect of applied K on P_N could be ascribed to its role in (*1*) stomatal activity responsible for exchange of CO_2, water vapour, and O_2, (*2*) direct or indirect activation of enzymes and thus the enhancement in CA activity resulting in the production of additional quantity of CO_2 to be utilized in photosynthesis and in enhanced NR activity leading to the efficient formation of N-containing molecules responsible for the formation of proteins and enzymes, including those required in photosynthesis, (*3*) production of ATP regulating the rate of photosynthesis, and (*4*) transport of sugars through phloem to other parts of the plant for utilization and storage utilizing ATP among other processes. K application increases also water use efficiency (Pervez *et al.* 2004)

The enhanced CA and NR activities resulted in efficient photosynthesis and protein synthesis, which coupled with larger leaf area could furnish additional skeletons for the enhanced synthesis of metabolites, confirming the findings of Mohammad *et al.* (1997) and Mohammad (2004).

The enhanced content of nutrients in plants treated with 20 mM K was expected as K improves the absorption of N which also stimulates the uptake of P and K (Krauss 2001, Patnaik 2003).

The beneficial effect of K on growth and yield characteristics was also expected as its role in various processes (see above) responsible for growth and development of plants is well established (Marschner 2002). Seed yield culminated as shown by characteristics that responded positively to increasing levels of K up to 20 mM K.

In conclusion, enhancing effect of applied K on CA and NR activities, P_N, and leaf area improved the growth and yield attributes leading to the observed increase in yield of mustard.

References

Dwivedi, R.S., Randhava, N.S.: Evaluation of rapid test for hidden hunger of zinc in plants. – Plant Soil **40**: 445-451, 1974.

Fiske, C.H., Subba Row, Y.: The colorimetric determination of phosphorus. – J. biol. Chem. **66**: 375-400, 1925.

Gomez, K.A., Gomez, A.A.: Statistical Procedures for Agricultural Research. 2nd Ed. – J. Wiley and Sons, New York 1984.

Hewitt, E.J.: Sand and Water Culture Methods Used in the Study of Plant Nutrition. – Commonwealth Agricultural Bureaux, Farnham Royal 1966.

Jaworski, E.G.: Nitrate reductase assay in intact plant tissues. – Biochem. biophys. Res. Commun. **43**: 1274-1279, 1971.

Johnson, C.M., Ulrich, A.: Determination of nitrate in plant material. – Anal. Chem. **22**: 1526-1529, 1950.

Krauss, A.: Balanced fertilization, an integral part in quality management of crop production. – Proceedings of the 50th Anniversary Conference on Crop Science on the Verge of the 21st Century. Opportunities and Challenges. Research Institute of Crop Production, Prague 2001.

Lindner, R.C.: Rapid analytical methods for some of the more common inorganic constituents of plant tissue. – Plant Physiol. **19**: 76-89, 1944.

Marschner, H.: Mineral Nutrition of Higher Plants. 2nd Ed. – Academic Press, London 2002.

Mohammad, F.:. Phosphorus application improves physiological parameters, growth and yield of mustard (*Brassica juncea* L.).– J. indian bot. Soc. **83**: 42-45, 2004.

Mohammad, F., Khan, T., Afridi, R.M., Fatma, A.: Effect of nitrogen on carbonic anhydrase activity, stomatal conductance, net photosynthetic rate and yield of mustard. – Photosynthetica **34**: 595-598, 1997.

Patnaik, N.: Soil fertility and fertilizer use. – In: Viswanath, C.S. (ed.): Handbook of Agriculture. Pp. 203-247. Indian Council of Agricultural Research, New Delhi 2003.

Pervez, H., Ashraf, M., Makhdum, M.I.: Influence of potassium nutrition on gas exchange characteristics and water relations in cotton (*Gossypium hirsutum* L.) – Photosynthetica **42**: 251-255, 2004.