PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 11 (2): 154-159, 2012
ISSN 1680-5194

Nutritional and Physiological Response of Wheat to Soil Applied Matrix-I Formulated Calcium Carbide with and Without Nitrogen Fertilizer

Rashid Mahmood[1], Muhammad Yaseen[1], Anser Ali[2],
Javaid Iqbal[2], Safdar Hussain[2] and M. Ahmad Alias Haji A. Bukhsh[3]
[1]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan
[2]Sub-Campus D.G. Khan, University of Agriculture, Faisalabad, Pakistan-38040
[3]Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan

Abstract: Calcium carbide is well known as a nitrification inhibitor and its role as a source of ethylene (C_2H_4), a potent plant growth regulator, is not thoroughly investigated. A pot trial was conducted to evaluate the effectiveness of formulated calcium carbide with different doses of nitrogen fertilizer on nitrogen use efficiency, growth and yield of wheat. At the 1st step calcium carbide was formulated with polyethylene and plaster of paris and named as Matrix-I (21% calcium carbide, 58% polyethylene and 21% plaster of paris). Wheat cv. Inqulab-91 seeds were sown in pots and 5 plants were maintained. Calcium carbide was applied @ 0, 7.5, 15 and 22.5 mg/kg pot soil with 0, 30 and 60 mg N/kg soil. It was noted that nitrogen fertilizer application significantly enhanced almost all growth and yield parameters of wheat. It was also observed that matrix-I not only improved growth and yield parameters of wheat except plant height, which was reduced by CaC_2 application, but also enhanced N uptake by different plant parts of wheat, when applied @ 15 mg CaC_2 kg^{-1} soil at 8 cm soil depth. It was further noted that matrix-I better improved N use efficiency when applied with half recommended dose of N fertilizer than that of with full recommended N fertilizer rate.

Key words: Calcium carbide, wheat, nitrification inhibitor, nitrogenous fertilizer application, yield and its attributes

INTRODUCTION

Nitrogen (N) fertilizer, when applied through broadcast over the soil surface, most of it is lost due to ammonia volatilization (Freney *et al.*, 1992a; 1992b). These losses can be checked by applying N fertilizer through incorporation or deep placement methods. However, close contact of drilled fertilizer with soil increases the processes of nitrification/denitrification and N loss in the form of N_2O emissions and/or nitrate leaching (Freney *et al.*, 1993). It is thus crucial to incorporate or deep place N fertilizer with some nitrification inhibitor to enhance nitrogen use efficiency and yield of crop (Mahmood, 2009).

Previous studies have shown that Encapsulated Calcium Carbide (ECC) when applied to soil creates a low level of acetylene, which is adequate to inhibit nitrification (Berg *et al.*, 1982; Bronson *et al.*, 1992). Keerthisinghe *et al.* (1996) reported that addition of ECC to soil significantly reduced the emission of N_2 + N_2O from incorporated and deep placed urea and resulted in increased exchangeable ammonium concentration and thus a prolonged stay of fertilizer N in the soil may benefit more crop production.

Calcium carbide is also a famous precursor of ethylene. Acetylene released from ECC is reduced to ethylene by soil microorganisms, which enters the plant through roots (Muromtsev *et al.*, 1988; Bibik *et al.*, 1995). Ethylene is a plant hormone which is involved in almost all developmental processes ranging from germination of seed to senescence of various organs and in many responses to environmental stress (Lurssen, 1991; Kashif *et al.*, 2007). There is a cross talk between the ethylene signaling pathway and other hormone signaling pathways, particularly with auxin, whose effects are often mediated by ethylene (Mahmood, 2009). The wide range effects of ethylene have made it a topic of intense research for decades and a lot of work has been done on different crops regarding ethylene effects (Kashif *et al.*, 2008).

In some previous studies Matrix-I calcium carbide based formulation performed as the most sustainable source of acetylene/ethylene and the best nitrification inhibitor than other formulations tested. This study was planned to check the response of growth and yield parameters and nitrogen use efficiency of wheat plants at different rates of matrix-I formulated calcium carbide in the presence of different levels of nitrogen.

MATERIALS AND METHODS

A pot experiment was conducted at wire house of Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan, under natural

Corresponding Author: M. Ahmad Alias Haji A. Bukhsh, Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan

environmental conditions, to evaluate the effect of rate of calcium carbide as Matrix-I with different doses of nitrogen fertilizer on wheat growth and yield parameters and nitrogen uptake by plant.

Formulation of calcium carbide: Matrix-I (21% calcium carbide, 58% polyethylene and 21% plaster of paris) was prepared by mixing powdered calcium carbide (about <200 µm diameter) and plaster of paris with molten polyethylene in a rotator mixer. After complete mixing matrices were poured out on a paper sheet and allowed to cool down. The clumps then cut into 4 mm diameter particles and dipped into paraffin oil to block the cut ends.

Soil preparation and pot filling: The surface soil from 0-30 cm depth was collected from the research area of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. The soil was air-dried, ground and passed through 2 mm sieve and analyzed for physical and chemical properties. The soil was sandy clay loam in texture. Some other properties of this soil were as follows: pH 7.85; ECe 2.53dS/m; organic matter contents 0.62% and total N contents 0.032%. Earthen pots (25 cm long and 15 cm diameter) were lined with polyethylene sheet and filled with soil @ 12.5 kg/pot with gentle packing. The pots were arranged according to Completely Randomized Design (CRD) 2 factor factorial with 4 replications. The data were analyzed statistically by using Fischer's analysis of variance technique and difference among treatment means was compared by using least significance test (LSD) at 5% level of probability (Steel and Torrie, 1984). Ten seeds of wheat cv. Inqulab-91 per pot were sown at 1 cm depth and only five seedlings were maintained after germination at two-leaf stage. Uprooted plants were incorporated in the same pot. Phosphorus (P) and potassium (K) were applied at recommended rate of 45-30 mg/kg soil in the form of fertilizer Single Super Phosphate (SSP) and Sulphate of Potash (SOP), respectively. All P and K were added to the soil at sowing time.

Nitrogen fertilizer application: Nitrogen fertilizer was applied at zero (control), half (30 mg/kg soil) and full recommended rate (60 mg/kg soil). In every case nitrogen was applied in two splits i.e. half at sowing time and remaining half dose after two weeks of germination.

Calcium carbide application: Calcium carbide in the form of matrix-I was applied two weeks after sowing at 8 cm depth @ 0, 7.5, 15 and 22.5 mg/kg soil.
Pots were irrigated with canal water to keep the moisture level of soil approximately near to field capacity. Weeds were uprooted manually, chopped and mixed within the same pot soil. Necessary plant protection measures were adopted for all the pots during the crop growth period.

Parameter studied: Following parameters were studied during growth period or at final harvest.

Plant height: Heights of all plants from each pot were measured in cm with meter rod and means were taken.

Number of total and fertile tillers/pot: Total and fertile tillers were counted from each pot at the completion of tillering and booting stage, respectively.

Biological yield: Each pot was harvested and tied into bundle. Biological yield was recorded by weighing the bundle of each pot with digital electrical balance.

Grain yield: The bundles were first sun-dried and then threshed manually. The grain weight was recorded in grams with the help of digital electrical balance.

Straw yield: Straw yield was calculated by the difference of biological yield and grain yield.

Nitrogen concentration in different plant parts: Dried and powdered straw, grain and root material (1.0 g) was digested using 20 ml of H_2SO_4 (conc.) and 8 g of digestion mixture (K_2SO_4: $FeSO_4$: $CuSO_4$ = 10: 1: 0.5) for each sample. Nitrogen was determined by distillation and with micro Kjeldahl's apparatus and titration with standard H_2SO_4 (Jackson, 1962).

Nitrogen uptake by straw or grain: Nitrogen uptake by straw or grain was calculated by multiplying straw or grain yield with nitrogen concentration (%) in straw or grain, respectively.

Spike length: Spike length (cm) was measured with the help of ruler and mean was calculated from each pot.

Number of spikelets/spike: Number of spikelets/ spike was counted and mean was calculated from each pot.

Number of grains/spike: Spikes from each pot were threshed manually, grains were counted and mean was calculated.

RESULTS AND DISCUSSION

Plant height: Effect of rate of calcium carbide (matrix-I) with and without different doses of N fertilizer on plant height (cm) of wheat is shown in Table 1. Plant height was significantly increased with increasing rate of N fertilizer whereas calcium carbide application reduced plant height compared to that in the treatment of N fertilizer alone. Minimum plant height (73.9 cm) was

Table 1: Effect of different rates of matrix-I formulated calcium carbide with and without nitrogen fertilizer on growth and yield parameters of wheat

N-CaC_2 (mg kg^{-1} soil)	Plant height (cm)	Total number of tillers	Number of fertile tillers	Spike length (cm)	Number of spikelets per spike	Number of grains per spike	1000-grains weight (g)	Biological yield (g)	Grain yield (g)
0-0	75.29g	14.25h	10.00e	8.29e	11.57e	44.32g	41.12f	31.99i	14.39h
0-7.5	75.17gh	14.75gh	10.50e	8.55e	11.61e	45.31fg	42.56e	32.44i	14.53h
0-15	74.54gh	15.50fgh	11.00e	9.18d	11.96e	47.68def	43.94e	36.33h	16.73g
0-22.5	73.93h	16.25fg	10.25e	9.15d	12.01e	48.42cde	43.56e	36.57h	16.00gh
30-0	85.18d	17.25f	14.00d	9.03d	14.14d	47.21ef	45.75d	41.96g	18.76f
30-7.5	83.36e	20.50e	16.67c	9.79c	15.02d	49.41cde	47.50c	46.55f	20.73e
30-15	82.26ef	23.00d	19.91b	9.78c	15.23d	53.37a	49.06ab	59.95d	25.64c
30-22.5	81.74f	22.75d	17.75c	9.76c	14.94c	50.62bc	46.92cd	54.69e	23.62d
60-0	94.27a	20.75e	17.50c	10.26b	16.70b	50.02cd	48.36bc	55.44e	24.06cd
60-7.5	91.92b	24.75c	20.00b	10.48ab	17.42ab	52.65ab	49.45ab	66.09b	28.32b
60-15	90.73b	26.75b	23.75a	10.80a	17.77a	54.54a	50.50a	70.57a	31.21a
60-22.5	89.52c	29.25a	22.50a	10.39ab	16.91b	53.06ab	47.56c	62.75c	25.61c
LSD p<0.05)	1.19	1.67	1.72	0.42	0.79	2.45	1.38	2.44	1.58

Figures in the same column with different letter(s) differ significantly at $p<0.05$ by LSD test

noted where calcium carbide was applied @ 22.5 mg/kg soil with no N fertilizer while it was maximum (94.3 cm) in treatment where full recommended dose of N fertilizer was applied without calcium carbide. Comparison of all the three N fertilizer levels indicates that CaC_2 application @ 7.5 and 15 mg/kg soil had statistically similar effect on plant height in the presence of N fertilizer while higher dose of CaC_2 (22.5 mg/kg soil) showed significant effect on plant height.

Number of tillers: Data on the effect of rate of calcium carbide (matrix-I) with and without N fertilizer on total and fertile number of tillers/pot of wheat is presented in Table 1. Number of tillers as well as number of spikes bearing tillers (fertile tillers) per pot was increased with increasing rate of nitrogen fertilizer. These were further increased with the addition of calcium carbide to the N fertilized pots. It is quite obvious from the data that calcium carbide application significantly increased total number of tillers/pot compared to that in the respective treatment of nitrogen fertilizer alone. Maximum number of total tillers/pot (29.2) was observed in the treatment where calcium carbide was applied @ 22.5 mg/kg along with full recommended dose of nitrogen (60 mg/kg soil) while minimum in the control.

Calcium carbide, when applied without N fertilizer, did not affect number of spikes/pot (number of spike bearing tillers). Treatment having calcium carbide application @ 7.5 mg/kg soil with half of recommended dose of nitrogen (30 mg/kg soil), produced spikes even more than that of the treatment with full recommended dose of nitrogen fertilizer but without calcium carbide. Maximum number of spikes/pot was recorded in the treatments where calcium carbide was applied @ 15 or 22.5 mg/kg soil in the presence of full recommended dose of N fertilizer as compared to treatment of recommended N fertilizer alone. According to an estimate, pots treated with 22.5 mg CaC_2/kg soil produced 35% more number of spike bearing tillers in the presence of full dose of nitrogen fertilizer than that of alone full dose of N fertilizer.

Spike length: Spike length was significantly increased with increasing rate of N fertilizer (Table 1). However, calcium carbide application with either dose of nitrogen fertilizer further increased the spike length compared with the respective alone N fertilizer treatment. Maximum spike length (10.8 cm) was noted where N-CaC_2 was applied @ 60-15 mg/kg soil (full recommended dose of nitrogen fertilizer-rate of CaC_2). Data also revealed that different rates of calcium carbide did not differ from each other in increasing spike length.

Number of spikelets: A gradual increase in number of spikelets/spike was noted with increasing rate of nitrogen fertilizer and it was further increased with the addition of calcium carbide as shown in Table 1. Maximum number of spikelets/spike (17.8) was observed where calcium carbide was applied @ 15 mg/kg soil along with full recommended does of nitrogen fertilizer (60 mg/kg soil). In case of half and full recommended dose of N fertilizer, almost similar number of spikelets per spike were observed with the addition of calcium carbide. Calcium carbide without nitrogen fertilizer did not affect number of spikelets/spike of wheat.

Number of grains: Combined effect of calcium carbide and nitrogen fertilizer application on number of grains/spike is obvious from Table 1. Number of grains/spike was significantly increased with increasing rate of nitrogen fertilizer however addition of calcium carbide further improved production of grains. Maximum number of grains/spike (54.5) was noted where calcium carbide was applied @ 15 mg/kg soil with full recommended dose of nitrogen and it was minimum (44.3) in control where no calcium carbide and N fertilizer were applied. Treatments with calcium carbide @ 15 or 22.5 mg/kg soil plus half recommended N fertilizer produced grains comparable to that where full recommended N was applied without CaC_2. These results suggest that calcium carbide has definite role in the production of more wheat grains either by improving N use efficiency or stimulating growth promoting hormones.

Thousand grains weight: Effect of calcium carbide with and without nitrogen fertilizer on thousand grains weight (g) of wheat is shown in Table 1. 1000-grains weight was increased with increasing rate of nitrogen fertilizer. Calcium carbide (matrix-I) application significantly enhanced 1000-grains weight compared with respective fertilizer alone treatment. Maximum and statistically similar weight was noted in treatments with CaC_2 @ 15 mg/kg + 30 mg/kg N or 15 or 22.5 mg/kg CaC_2+60 mg/kg nitrogen. Irrespective to the rate of N fertilizer applied, a reduction in 1000-grains weight was noted with the application of calcium carbide @ 22.5 mg/kg soil compared with the treatment where it was applied @ 15 mg/kg soil.

Biological yield: It is evident from the data (Table 1) that increase in nitrogen fertilizer application significantly increased the biological yield of wheat and addition of calcium carbide further improved it. It was noted that maximum biological yield was produced by the application of calcium carbide @ 15 mg/kg soil, followed by 7.5 mg/kg soil in the presence of full recommended dose of nitrogen fertilizer. Treatment with half of recommended nitrogen fertilizer plus 15 mg/kg CaC_2 produced 8% more biological yield than that where full recommended N fertilizer was applied without CaC_2. Compared with 15 mg/kg soil CaC_2, similar or less biological yield was observed with its higher rate (22.5 mg/kg soil) when applied with either dose of nitrogen fertilizer.

Grain yield: Grain yield of wheat was also affected by rate of calcium carbide with and without N fertilizer as is clear from the data summarized in Table 1. It is clear from data that grain yield was significantly increased with increasing rate of N fertilizer and addition of calcium carbide. Maximum grain yield (31.2 g) was noted where calcium carbide was applied @ 15 mg/kg soil, followed by 7.5 mg/kg soil in the presence of full recommended dose of nitrogen fertilizer. Irrespective to the dose of nitrogen fertilizer applied, a reduction trend in grain yield was observed with the application of high dose of calcium carbide (22.5 mg/kg) compared to the treatments where it was applied @ 15 mg/kg soil. Treatment where half of recommended nitrogen fertilizer was applied with 15 mg/kg CaC_2 produced grain yield statistically similar to that where full recommended N fertilizer was applied without CaC_2.

Table 2: Effect of different rates of matrix-I formulated calcium carbide with and without nitrogen fertilizer on nitrogen concentration and uptake by wheat straw and grain

N-CaC_2 (mg kg^{-1} soil)	%N in straw	%N in grain	N uptake by straw (g pot^{-1})	N uptake by grain (g pot^{-1})
0-0	0.37f	1.55i	0.06g	0.22g
0-7.5	0.38f	1.57i	0.07fg	0.23g
0-15	0.39e	1.63h	0.08fg	0.27g
0-22.5	0.40e	1.64h	0.08f	0.26g
30-0	0.45d	1.98g	0.11e	0.37f
30-7.5	0.47d	2.03f	0.12d	0.42e
30-15	0.49c	2.07e	0.17b	0.53cd
30-22.5	0.50c	2.09d	0.15c	0.49d
60-0	0.57b	2.14c	0.18b	0.52d
60-7.5	0.58ab	2.18b	0.22a	0.62b
60-15	0.59a	2.24a	0.23a	0.70a
60-22.5	0.60a	2.22a	0.22a	0.57c
LSD ($p<0.05$)	0.014	0.023	0.014	0.045

Figures in the same column with different letter(s) differ significantly at $p<0.05$ by LSD test

Nitrogen concentration in wheat straw and grain: Nitrogen concentration in both plant parts i.e. straw and grains was increased significantly with increasing rate of nitrogen fertilizer (Table 2). Irrespective to the dose of nitrogen fertilizer applied, addition of calcium carbide in the N fertilized pots significantly increased N concentration in straw and grain however, straw N concentration in treatments where CaC_2 was applied @ 7.5 mg kg^{-1} soil did not differ significantly from respective alone fertilizer treatment. Maximum N concentration in grains as well as in straw was noted in the treatment where calcium carbide was applied @ 15 mg kg^{-1} soil with full recommended dose of nitrogen fertilizer and it was comparable with the treatment having 22.5 mg CaC_2 kg^{-1} soil plus full recommended dose of N fertilizer.

Nitrogen uptake by wheat straw and grain: Nitrogen application significantly increased N uptake of wheat straw and grains (Table 2). Application of calcium carbide with half or full recommended dose of nitrogen fertilizer further enhanced N uptake by both plant parts. Maximum N uptake was noted where calcium carbide @ 15 mg/kg soil was applied with full dose of nitrogen fertilizer. Compared with 15 mg CaC_2/kg soil, a reduction in N uptake was observed where CaC_2 was applied @ 22.5 mg/kg soil. Wheat straw and grain accumulated more nitrogen in the treatment with half dose of nitrogen fertilizer plus CaC_2 @ 15 mg/kg soil than the treatment where recommended dose of N fertilizer was applied without CaC_2.

Relative percent increase in parameters: Relative percent increase in plant growth and yield and analytical parameters of wheat due to calcium carbide application at zero (control), half and full recommended dose of nitrogen fertilizer is presented in Table 3. It is revealed from the data that calcium carbide application increased

Table 3: Relative percent increase/decrease in growth and yield parameters and nitrogen status of wheat plant due to calcium carbide application compared to respective treatment of fertilizer alone

	Maximum increase due to addition of CaC_2 (%)		
Parameter	No N fert.	½ N fert.	Full N fert.
Total tillers	14.04	33.33	40.96
Fertile tillers	10.00	42.29	35.71
Plant height	-1.38	-4.03	-5.04
Spike length	10.74	8.42	5.26
No. of spikelets/spike	3.71	7.63	6.41
No. of grains/spike	9.23	13.05	9.04
1000-grains weight	6.83	7.26	4.43
Total yield	14.35	42.90	27.29
Grain yield	16.18	36.67	29.72
Straw yield	16.93	47.95	25.43
N%age in grain	5.87	5.56	4.67
N%age in straw	8.11	11.11	5.26
N uptake by grain	22.73	43.24	5.77
N uptake by straw	33.33	54.55	27.78

Table 4: Effect of rate of matrix-I formulated calcium carbide with half and full recommended dose of N fertilizer on different efficiency parameters of wheat

	Types of efficiency		
N-CaC_2 (mg kg^{-1} soil)	Agronomic efficiency (g g^{-1} N)	Physiological efficiency (g g^{-1} N)	Apparent N recovery (%)
30-0	11.6d	29.5d	39.2d
30-7.5	16.5bc	31.7bcd	51.7c
30-15	23.8a	34.5ab	68.9a
30-22.5	20.3ab	32.6abcd	61.9ab
60-0	12.9cd	32.8abc	38.9d
60-7.5	18.4b	35.4a	51.9c
60-15	19.3b	33.9abc	56.9bc
60-22.5	12.8cd	31.2cd	40.9d
LSD ($p<0.05$)	3.9	3.3	7.9

Figures in the same column with different letter(s) differ significantly at $p<0.05$ by LSD test

grain yield by 16.2%, 36.7% and 29.7% over respective no calcium carbide treatment, when applied with zero, half and full recommended dose of nitrogen fertilizer, respectively. Similarly in case of other parameters calcium carbide comparatively gave more benefit where applied with half of recommended nitrogen fertilizer than zero or full dose of it.

Nitrogen use efficiency: Application of calcium carbide in the form of matrix-I formulation significantly improved agronomic efficiency, physiological efficiency and apparent nitrogen recovery (Table 4). All of these efficiencies had maximum values in the treatments where calcium carbide plus half of the recommended N dose was applied. The extents of these efficiencies were increased from 11.6, 29.5 and 39.2 to 23.8, 34.5 and 68.9, respectively due to application of calcium carbide along with half of recommended dose of nitrogen fertilizer. In case of full recommended dose of nitrogen fertilizer though calcium carbide application improved nitrogen use efficiency but up to less extent than that with half of recommended dose of nitrogen fertilizer.

Improvement in wheat growth and yield parameters and N uptake by different plant parts with increasing rate of N fertilizer up to an optimum level is a well known fact and has already been reported by Bakhsh *et al.* (1999); Mahmood *et al.* (2010) and Khan *et al.* (2000).

Cereal grain yield is the contribution of several components: spikes per unit area, grains per spike and grain mass. The net effect of ethylene on grain yield depends on the balance of positive, null and negative responses of individual yield components to ethylene. Decrease in plant height with calcium carbide is a typical response of ethylene produced in the soil due to CaC_2 application (Dahnous *et al.*, 1982; Wiersma *et al.*, 1986; Rajala *et al.*, 2002 and Mahmood *et al.*, 2002). Increase in number of tillers and spikes per unit area with calcium carbide application are owing to ethylene production and better N supply due to nitrification inhibition. Cartwright and Waddington (1982); Sharma and Yadav (1996), Mahmood *et al.* (2002) and Yaseen *et al.* (2004) also reported similar results of ethylene on tillering in cereals.

Increase in number of grains/spike and grain weight with the addition of calcium carbide might be due to effective action of calcium carbide on oxidation of NH_4^+ i.e. nitrification inhibition for certain period of time that leads to prolonged stay of nitrogen in the soil and thus enhances the N economy of the soil or stimulatory effect on certain other growth promoting hormones. However, it can also be speculated that mixed nitrogen supply (ammonium-N and nitrate-N both, instead of nitrate-N alone) also made the nitrogen nutrition of wheat plants better and they took up more N compared to that where no CaC_2 was applied. This improved N economy of soil might help to produce more and bold grains. Benefits of mixed nitrogen nutrition on plant growth and development are also reported by Chen *et al.* (1998) and Ali *et al.* (2001).

It is revealed from the results that calcium carbide application with lower dose of nitrogen fertilizer (30 mg/kg soil) improved most of the wheat growth and yield parameters as well as N uptake almost to the same level as with full recommended dose of nitrogen fertilizer applied without calcium carbide. This is clear indication that calcium carbide application improved the N use by the wheat plant. This also indicates existence of a lot of N losses due to nitrification and denitrification under field conditions. That is why N use efficiency seldom exceeds 40%. Moreover, results of this experiment also suggest that nitrification inhibition and ethylene supply benefited the wheat crop most probably by enhancing the N economy in the growth medium i.e. soil by minimizing N losses.

REFERENCES

Ali, A., T.C. Tucker, T.L. Thompson and M. Salim, 2001. Effects of salinity and mixed ammonium and nitrate nutrition on the growth and nitrogen utilization of barley. J. Agron. Crop Sci., 186: 223-228.

Bakhsh, A., A.H. Gurmani, A.U. Bhatti and H. Rehman, 1999. Effect of balanced application of N, P and K on the grain yield of wheat. Sarhad J. Agric., 15: 453-457.

Berg, S.P., L.N. Levis, A.J. Trewaves and P. Kelley, 1982. Ethylene and abscission. In: Ethylene and Plant Development, Roberts J.A. and G.A. Trucker (Eds.), Butterworths, London, pp: 173.

Bibik, N.D., S.V. Letunova, E.V. Druchek and G.S. Muromtsev, 1995. Effectiveness of soil-acting ethylene producer in obtaining sanitized seed potatoes. Russian J. Agric. Sci., 9: 19-21.

Bronson, K.F., A.R. Mosier and S.R. Bishnoi, 1992. Nitrous oxide emissions in irrigated corn as affected by nitrification inhibitors. Soil Sci. Soc. Am. J., 56: 161-165.

Cartwright, P.M. and S.R. Waddington, 1982. Growth regulators and grain yield in spring cereals. In: Opportunities for Manipulation of Cereal Productivity, Hawkins, A.F. and B. Jeffcoat (Eds.), Monograph 7. British Plant Growth Regulator Group, Wantage, pp: 61-70.

Chen, J.G., S.H. Cheng, W.X. Cao and X. Zhou, 1998. Involvement of endogenous plant hormones in the effect of mixed nitrogen source on growth and tillering in wheat. J. Pl. Nutr., 21: 87-97.

Dahnous, K., G.F. Vigue, A.G. Law, C.F. Ronzak and D.G. Miller, 1982. Hight and yield responses of selected wheat, barley and triticale cultivars to ethephon. Agron. J., 54: 580-582.

Freney, J.R., C.J. Smith and A.R. Mosier, 1992a. Effect of a new nitrification inhibitor (wax coated calcium carbide) on transformations and recovery of fertilizer nitrogen by irrigated wheat. Fertilizer Res., 32: 1-12.

Freney, J.R., D.L. Chen, A.R. Mosier, I.J. Rochester, G.A. Constable and P.M. Chalk, 1993. Use of nitrification inhibitors to increase fertilizer nitrogen recovery and lint yield in irrigated cotton. Fertilizer Res., 34: 37-44.

Freney, J.R., O.T. Denmead, A.W. Wood, P.G. Saffigna, L.S. Chapman, G.J. Ham, A.P. Hurney and R.L. Stewart, 1992b. Factors controlling ammonia loss from trash covered sugarcane fields fertilized with urea. Fertilizer Res., 31: 341-349.

Jackson, M.L., 1962. Chemical composition of soil. In: Chemistry of Soil, Bean, F.E. (Ed.), Van Nostrand Co., New York, pp: 71-144.

Kashif, S.R., M. Yaseen, M. Arshad and M. Abas, 2007. Evaluation of calcium carbide as a soil amendment to improve nitrogen economy and yield of okra. Soil Environ., 26: 69-74.

Kashif, S.R., M. Yaseen, M. Arshad and M. Ayub, 2008. Response of Okra (*Hibiscus esculentus* L.) to soil given encapsulated calcium carbide. Pak. J. Bot., 40: 175-181.

Keerthisinghe, D.G., L.X. Jian, L.Q. Xiang and A.R. Mosier, 1996. Effect of encapsulated calcium carbide and urea application methods on denitrification and N loss from flooded rice. Fertilizer Res., 45: 31-36.

Khan, M.A., I. Hussain and M.S. Baloch, 2000. Wheat yield potential current status and future strategies. Pak. J. Biol. Sci., 3: 82-86.

Lurssen, K., 1991. Ethylene and agriculture. In: The Plant Hormone Ethylene, Mattoo, A.K. and J.C. Suttle (Eds.), CRC Press, Boca Raton, Ann Arbor, Boston, London, pp: 315-326.

Mahmood, R., 2009. Effectiveness of Calcium carbide for improving nutrient use efficiency and yield of wheat crop, Ph.D. Dissertation, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad.

Mahmood, R., M. Yaseen, M. Arshad and A. Tanvir, 2010. Comparative effect of different calcium carbide based formulations on growth and yield of wheat. Soil Environ., 29: 33-37.

Mahmood, T., M. Yaseen, M. Arshad, M.J. Akhtar, M. Saleem and M. Yousaf, 2002. Effect of time of application of CaC_2 on growth and yield of wheat. Abstracts: 33rd all Pakistan Science Conference. Pakistan Association for the Advancement of Science. December 25-28, University of Agriculture, Faisalabad, Pakistan.

Muromtsev, G.S., V.N. KarnenKo and I.I. Chernyaeva, 1988. Ethylene producing regulators of growth in plants. Inventor's certificate No. 1372649555 R. Byull. Izobret. No. 5.

Rajala, A., P. Peltonen-Sainio, M. Onnela and M. Jackson, 2002. Effects of applying stem-shortening plant growth regulators to leaves on root elongation by seedlings of wheat, oat and barley: Mediation by ethylene. J. Pl. Growth Regulation, 38: 51-59.

Sharma, F. and S. Yadav, 1996. Controlling ammonia volatilization from urea surface applied to sugar beet on a calcareous soil. Comm. Soil Sci. Plant Anal., 17: 9-10.

Steel, R.G.D. and J.H. Torrie, 1984. Principles and Procedures of Statistics-A biometrical Approach, Mc Graw Hill Book Co., Tokyo, Japan, pp: 172-177.

Wiersma, D.W., E.S. Oplinger and S.O. Guy, 1986. Environment and cultivar effects on winter wheat response to ethephon plant growth regulator. Agron. J., 78: 761-764.

Yaseen, M., M. Arshad, S.R. Kashif and A. Rahim, 2004. Response of different crops to soil applied encapsulated calcium carbide. Abstracts: 10th International Congress of Soil Science, March 16-19, Tandojam, Sind.