Soil & Environ. 29(1): 33 - 37, 2010
www.se.org.pk
Online ISSN: 2075-1141
Print ISSN: 2074-9546

Comparative effect of different calcium carbide based formulations on growth and yield of wheat

***R. Mahmood*[*1], *M. Yaseen*[1], *M. Arshad*[1] *and A. Tanvir*[2]**
[1]Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan
[2]Department of Agronomy, University of Agriculture Faisalabad, Pakistan

Abstract

Soil applied calcium carbide (CaC_2) reacts with water to produce acetylene (C_2H_2) - a nitrification inhibitor gas. The soil microbes can reduce a part of acetylene to ethylene (C_2H_4), a potent plant growth regulator. To make it a slow release source of C_2H_2/C_2H_4, calcium carbide was coated with bee wax, paraffin wax and black enamel paint and matrices of polyethylene. Calcium carbide based formulations were compared in pot studies regarding their effect on growth and yield parameters of wheat. It was noted that calcium carbide application significantly reduced plant height, increased number of tillers and ultimately enhanced grain yield of wheat compared to that of alone NPK fertilizer treatment. Calcium carbide based formulations improved wheat crop growth and yield in the order of matrix-I (containing 21 % CaC_2) > matrix-II > paint coated > bee wax coated > paraffin wax coated > matrix-III = encapsulated calcium carbide > NPK alone treatment.

Key words: Calcium carbide formulations, coating, matrix-I, wheat yield, nitrification inhibitor

Introduction

Calcium carbide (CaC_2) as a nitrification inhibitor has been studied by a number of workers (Aulakh *et al*., 2001; Yaseen *et al*., 2006; Kashif *et al*., 2008; Ahmad *et al*., 2009). Due to its rapid reaction with water it is mostly applied to soil in some encapsulated form so that a sustained supply of acetylene gas may be produced to inhibit the activity of ammonium oxidizing enzyme for a longer period. Mostly waxes are used for the encapsulation of calcium carbide (Freney *et al*., 2000). Although they served the purpose well but under high temperature conditions like in Pakistan and large scale soil application made this type of formulation ineffective or impractical. Freney *et al*. (2000) suggested a new way to encapsulate calcium carbide. They blended calcium carbide with molten polyethylene and calcium carbonate mixture with different ratios and named the materials as matrices. They noted that matrices performed much well than wax coated CaC_2 in producing persistent supply of acetylene gas to inhibit nitrification.

Soil microbes having nitrogenase activity have the ability to reduce acetylene released from calcium carbide to ethylene. Ethylene is a plant hormone and plays roles in physiological processes throughout the life cycle of the plant (Mattoo and Suttle, 1991; Kashif *et al*., 2007). Ethylene plays a vital role in developmental processes such as the formation of apical hook in dark-grown seedlings, regulation of cell expansion and flower development. In case of cereals, ethylene has been reported to reduce lodging and enhance grain yield (Boutaraa, 1991).

In the present study, grains of calcium carbide were coated and formulated with different types of coating materials and response of wheat to these CaC_2 formulations was tested in a pot trial with the objective to select a better formulation with respect to growth, yield and N uptake of wheat.

Materials and Methods

Calcium carbide formulations

Encapsulation of calcium carbide was done by weighing and filling powdered CaC_2 into gelatin medical capsules. To coat calcium carbide with bee wax, paraffin wax or black enamel paint, CaC_2 particles of 2-4 mm diameter were mixed thoroughly with molten waxes or paint mechanically in a drum shape container. Wax and paint coated calcium carbide was then mixed with plaster of Paris by gentle manual rubbing to keep particles separated from each other. Final composition of wax coated CaC_2 was recorded as 38% calcium carbide, 49% bee-wax or paraffin wax and 13% plaster of paris. Whereas, in case of paint coating final composition was recorded as 35 % calcium carbide, 44 % black enamel paint and 21 % plaster of paris.

Matrix-I (21 % calcium carbide, 58 % polyethylene and 21 % plaster of paris), matrix-II (42 % calcium carbide, 48 % polyethylene and 10 % plaster of paris) and matrix-III (61 % calcium carbide, 34 % polyethylene and 5 % paraffin oil) were prepared by mixing powdered calcium carbide (about < 200 µm particle diameter) and plaster of paris or paraffin oil with molten polyethylene in a rotator mixer.

*Email: rasmassuaf@yahoo.com

After complete mixing, matrices were poured out on a paper sheet and allowed to cool down. The clumps were then cut into 4 mm diameter particles and dipped into paraffin oil to block the cut ends.

The experiment was conducted in pots to select the best calcium carbide formulation out of seven, with respect to growth and yield parameters of wheat. In this experiment earthen pots (25 cm long and 15 cm diameter) were lined with polyethylene sheet and filled with soil @ 12.5 kg pot^{-1} with gentle packing. 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. Nitrogen (N), phosphorus (P) and potassium (K) were applied at recommended rate of 60-45-30 mg kg^{-1} soil in the form of fertilizer urea, diammonium phosphate (DAP) and sulphate of potash (SOP), respectively. All P and K were added to the soil at sowing time. Nitrogen was applied in two splits i.e. half at sowing time and remaining half dose after two weeks of germination. Pots were arranged according to completely randomized design with 3 replications. Calcium carbide @ 22.5 mg kg^{-1} soil was applied two weeks after sowing, in the centre of pot at 4 cm depth according to the following treatment plan: T1 = Recommended dose of P&K alone; T2 = Recommended dose of NPK alone; T3 = NPK + Encapsulated calcium carbide; T4 = NPK + Bee wax coated calcium carbide; T5 = NPK + Paraffin wax coated calcium carbide; T6 = NPK + Enamel paint coated calcium carbide; T7 = NPK + Matrix-I; T8 = NPK + Matrix-II; T9 = NPK + Matrix-III.

Plant height, number of tillers per pot, root weight, biological yield and grain yield were determined during crop growth or after final harvest. Nitrogen concentration in wheat grains and straw was determined by procedures described by Jackson (1962). Nitrogen uptake by straw or grain was calculated by multiplying straw or grain yield with nitrogen concentration (%) in straw or grain, respectively.

After 8 weeks of calcium carbide application pot soil was sampled with a core sampler of 10 mm diameter for nitrate-N and ammonium-N determination according to the procedure described by Keeney and Nelson (1982).

Data of the experiment were subjected to ANOVA using MSTAT-C (1991) software package. Least Significant Difference (LSD) test was used to determine the differences among the treatment means ($P = 0.05$).

Results

Plant height

Data regarding the effect of calcium carbide based formulations on plant height (cm) of wheat is presented in Table 1. Plant height was reduced where calcium carbide was applied in either formulation along with NPK fertilizer compared to that of NPK fertilizer alone. A significant reduction in plant height was noted with matrix-I (T7) and matrix-II (T8) CaC_2 based formulations compared to that of NPK fertilizers alone.

Number of tillers

Different calcium carbide based formulations increased total as well as fertile number of tillers pot^{-1} of wheat (Table 1). Minimum number of total (16) and fertile (10) tillers pot^{-1} were noted in control (T1) whereas tillering were maximum (total = 32 and fertile = 27) when calcium carbide was applied in matrix-I formulation with recommended NPK fertilizers (T7). Treatments with paint coated calcium carbide (T6), matrix-I (T7) and matrix-II (T8) were statistically at par in producing fertile tillers. Statistically similar number of spike bearing tillers was observed with calcium carbide application in matrix-III (T9), bee wax (T4) or paraffin wax (T5) coated formulations.

Root weight

Root weight of wheat was significantly increased in the treatments of calcium carbide plus NPK fertilizers compared to the treatment without calcium carbide (Table 1). Maximum root weight (11.62 g pot^{-1}) was noted in T7 (matrix-I) and minimum (6.68 g pot^{-1}) in T1 (control, no N fertilizer). Root weight in treatment T8 (matrix-II) was statistically similar to that of T6 (paint coated CaC_2). Encapsulated, bee wax or paraffin wax coated calcium carbide treatments had statistically similar effect on root growth.

Biological yield

Data regarding effect of calcium carbide formulations on biological yield of wheat is presented in Table 1. Maximum biological yield of wheat (70.9 g pot^{-1}) was observed in T7 (matrix-I) and it was followed by T8 (matrix-II) and T6 (paint coated). Statistically similar biological yield was observed with the application of gelatin encapsulated, bee wax and paraffin wax coated calcium carbide formulations. Biological yield in the treatment T9 (matrix-III) was statistically at par with that produced in the treatment T3 (encapsulated CaC_2).

Grain yield

Data regarding effect of calcium carbide based formulations on grain yield (g pot^{-1}) of wheat is presented in Table 1. Calcium carbide application in different formulations significantly enhanced grain yield of wheat over fertilizer alone. Maximum grain yield (31.9 g pot^{-1})

Table 1. Effect of different calcium carbide based formulations on growth and yield parameters of wheat crop

Treat. No.	Treatment	Plant height (cm)	Total tillers pot^{-1}	Fertile tillers pot^{-1}	Root Weight (g pot^{-1})	Biological yield (g pot^{-1})	Grain yield (g pot^{-1})
1	P&K, alone	69.30 d	16 g	10 e	03.68 f	31.50 g	14.74 g
2	NPK, alone	81.83 a	24 f	17 d	08.22 e	48.50 f	21.39 f
3	NPK+Encapsulated CaC_2	78.87 b	26 ef	22 c	09.71 c	57.66 de	25.11 e
4	NPK+Bee wax coated CaC_2	76.00 bc	28 de	23 bc	09.56 cd	60.10 d	27.24 cd
5	NPK+Para. wax coated CaC_2	76.50 bc	29 cd	23 bc	09.79 c	60.03 d	27.55 c
6	NPK+Paint coated CaC_2	76.67 bc	30 bc	25 ab	10.72 b	63.88 c	29.50 b
7	NPK+Matrix-I	75.33 c	32 a	27 a	11.62 a	70.91 a	31.87 a
8	NPK+Matrix-II	75.00 c	32 ab	26 a	10.84 b	66.73 b	29.54 b
9	NPK+Matrix-III	77.00 bc	28 de	23 bc	08.85 de	56.66 e	25.52 de
	LSD ($p<0.05$)	2.65	1.86	2.01	0.71	2.66	1.86

was observed where matrix-I (T7) calcium carbide based formulation was applied with recommended dose of NPK fertilizers compared to that of NPK fertilizers alone. Grain yield in the treatment T7 was followed by treatments where matrix-II (T8) and paint coated calcium carbide (T6) were applied. Grain yield was statistically similar in the treatments of bee wax and paraffin wax coated calcium carbide based formulations.

Nitrogen concentration in different plant parts of wheat

Effect of calcium carbide based formulations on nitrogen (N) concentration (%) in wheat roots, straw and grain are presented in Table 2. Nitrogen concentration in all three plant parts increased with nitrogen fertilizer application and it was further enhanced where calcium carbide was applied with NPK fertilizers. Maximum N concentration in wheat root, straw and grain were observed where matrix-I formulated calcium carbide was applied in combination with NPK fertilizers. Encapsulated, bee wax coated, paraffin wax coated and matrix-III calcium carbide based formulations had statistically similar influence on N concentration in wheat root. Matrix-I, matrix-II and paint coated calcium carbide formulations significantly improved root N concentration whereas other formulations were at par compared to NPK fertilizer alone treatment regarding N concentration in root. Concentration of N in straw was maximum (0.60 %) with matrix-I, which was statistically at par with matrix-II and paint coated calcium carbide treatments. Bee wax and paraffin wax coated CaC_2 based formulations were statistically similar in their influence on straw N concentration. Encapsulated and matrix-III treatments did not differ significantly from that of NPK alone treatment regarding N concentration in wheat straw. Maximum N concentration in wheat grain was observed in treatments where matrix-I, matrix-II, paint coated or paraffin wax coated calcium carbide was applied. Encapsulated and matrix-III calcium carbide based formulations did not differ significantly from that of alone fertilizers treatment.

Nitrogen uptake by different plant parts of wheat

The effect of calcium carbide based formulations on nitrogen uptake (mg kg^{-1}) by wheat root; straw and grain are presented in Table 2. All three plant parts accumulated more N in the treatments where calcium carbide was applied in either formulation compared to that with N fertilizer alone. Wheat root, straw and grain took up minimum N in control (no N fertilizer) and maximum where calcium carbide was applied as matrix-I, followed by matrix-II and in paint coating with recommended dose of N fertilizer.

Statistically similar N uptake was observed in wheat root and straw where encapsulated, bee wax and paraffin wax coated calcium carbide were applied with recommended dose of N fertilizer. In treatments of bee wax coated calcium carbide, wheat grains took up statistically similar N compared to that with paraffin wax coated CaC_2 application. Moreover, matrix-III and encapsulated calcium carbide had almost similar effect on N uptake by grain.

Soil mineral nitrogen content

Data in Table 3 present the effect of calcium carbide based formulations on soil mineral nitrogen (nitrate-N and ammonium-N) content determined 8 weeks after CaC_2 application. Total mineral nitrogen content was significantly increased with N fertilizer application. More ammonium-N and less nitrate-N concentrations were observed in the calcium carbide treatments however, reverse response was observed in pots treated with NPK fertilizers alone. Maximum NH_4^+-N and minimum NO_3^--N concentrations were observed in the order of matrix-I fallowed by matrix-II, paint coated, paraffin wax coated, bee wax coated, matrix-III and gelatin encapsulated calcium carbide based formulations.

Table 2. Effect of different calcium carbide based formulations on N concentration and uptake by different plant parts of wheat

Treat. No.	Treatment	N concentration (%)			N uptake (mg pot^{-1})		
		Root	Straw	Grain	Root	Straw	Grain
1	P&K, alone	0.287 e	0.36 e	1.58 d	10.60 f	60.27 e	232.9 g
2	NPK, alone	0.453 d	0.56 d	2.13 c	37.30 e	152.5 d	455.8 f
3	NPK + Encapsulated CaC_2	0.463 cd	0.57 cd	2.16 c	44.97 c	186.5 bc	541.8 e
4	NPK + Bee wax coated CaC_2	0.466 cd	0.58 bc	2.21 b	44.63 cd	191.7 bc	601.8 d
5	NPK + Paraffin Wax coated CaC_2	0.466 cd	0.58 bc	2.25 a	45.70 c	189.5 bc	619.9 cd
6	NPK + Enamel paint coated CaC_2	0.477 bc	0.59 ab	2.24 ab	51.10 b	203.0 b	659.8 bc
7	NPK + Matrix-I	0.487 ab	0.60 a	2.27 a	56.57 a	224.5 a	722.5 a
8	NPK + Matrix-II	0.493 a	0.59 ab	2.26 a	53.50 ab	231.6 a	668.5 b
9	NPK + Matrix-III	0.467 cd	0.57 cd	2.15 c	41.33 d	178.5 c	549.7 e
	LSD (p<0.05)	0.013	0.013	0.03	3.37	6.99	43.59

Table 3. Effect of calcium carbide based formulations on soil mineral nitrogen after 8 weeks of calcium carbide application to wheat crop

Treatment No.	Treatment	Nitrate-N (ppm)	Ammonium-N (ppm)
1	P&K, alone	04.47 f	03.36 g
2	NPK, alone	36.23 a	17.93 f
3	NPK + Encapsulated CaC_2	23.26 b	30.10 e
4	NPK + Bee wax coated CaC_2	18.49 c	36.99 c
5	NPK + Paraffin Wax coated CaC_2	17.39 c	38.93 b
6	NPK + Enamel paint coated CaC_2	17.21 c	39.93 b
7	NPK + Matrix-I	12.22 e	48.21 a
8	NPK + Matrix-II	13.72 d	46.76 a
9	NPK + Matrix-III	22.87 b	32.59 d
	LSD (p<0.05)	01.36	01.78

Discussion

Varying response of wheat in terms of growth and yield parameters to different calcium carbide based formulations applied at the same rate is owing to the specific acetylene flux and ethylene production from each formulation. Matrix-I and matrix-II formulations performed better as these seemed to produce prolonged and sustained supply of acetylene and ethylene gases in the soil environment. Ethylene released from calcium carbide reduced plant height of wheat and improved number of spike bearing tillers and ultimately resulted in increase in grain yield. Inrease in grain yield with ethephon (an ethylene releasing compound) application in the absence of lodging has been attributed to increased spikes per area (Hill *et al*., 1982, Bahary, 1988) or spikes per plant (Ramos *et al*., 1989). Increase in root weight with calcium carbide application is a typical response of plant to ethylene (Sharma and Yadav, 1996; Freney *et al*., 2000; and Mahmood *et al*., 2002). This enhanced root growth could help fetch more nutrients from the soil and thus contribute to yield increase.

Grain yield of wheat depends upon the parameters which directly or indirectly contribute to it. Increase in grain yield may be due to the increase in number of spikes per plant, better root growth which in turn uptake more nutrients for healthy grain formation, prolong nitrogen supply due to nitrification inhibition and mixed nitrogen nutrition instead of nitrate alone. This all happened most probably due to addition of calcium carbide in the soil environment.

Presence of more ammonium and less nitrate in calcium carbide treated soil than that of NPK alone treatment indicates that acetylene released from calcium carbide significantly inhibited nitrification process. Other researchers (Freney *et al*., 2000; Aulakh *et al*., 2001; Patra *et al*., 2006) also reported that slow release of acetylene (C_2H_2) from encapsulated calcium carbide (ECC) reduced ammonia mono-oxygenase by reducing the population of ammonia oxidizing bacteria and has the potential to retard the enzyme activities in favor of C and N conservations in a semi-arid agro-ecosystem. Similarly Freney *et al*. (1992) reported that addition of ECC with the nitrogen fertilizer blocked nitrification in irrigated wheat for more than 10 weeks, thus preventing denitrification loss of nitrogen. In addition, loss of applied nitrogen from flooded rice in the Murrumbidgee Irrigation Area was reduced from 56% to 13% and methane production was also markedly reduced (Keerthisinghe *et al*., 1993).

All this discussion suggests the positive effect of calcium carbide application on growth and yield of wheat because of yield increase due to efficient use of nutrients. These results suggest recommending use of calcium carbide in combination with N fertilizer to improve wheat and other cereals yield per unit area.

Acknowledgments

This research work was conducted by the financial support of Higher Education Commission of Pakistan under Indigenous Fellowship Award Program.

References

Ahmad, Z., M. Abid and M. Azam. 2009. Enhancement of salinity tolerance in wheat through soil applied calcium carbide. *Soil and Environment* 28: 75-80.

Aulakh, M.S., K. Singh and J. Doran. 2001. Effects of 4-amino 1,2,4-triazole, dicyandiamide and encapsulated calcium carbide on nitrification inhibition in a subtropical soil under upland and flooded conditions. *Biology and Fertility of Soils* 33: 258-263.

Bahary, V.M. 1988. Fusicoccin activity and building in *Arabidopsis thaliana*. *Plant Physiology* 88: 999-1001.

Boutaraa, T. 1991. Effect of drought and ethrel on ultra structure and some yield components of wheat varieties cultivated in Algeria. M.Sc. Thesis, E.N.S., V. Kouba, Algiers, Algeria.

Freney, J.R., P.J. Randall1, J.W.B. Smith, J. Hodgkin, K.J. Harrington and T.C. Morton. 2000. Slow release sources of acetylene to inhibit nitrification in soil. *Nutrient Cycling in Agroecosystems* 56: 241-251.

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

Hill, D.M., R. Joice and N.R.W. Squires. 1982. Cerone: Its use and effect on development of winter barley. p. 391-397. *In:* Chemical Manipulation of Crop Growth and Development, J.S. Mclaren (ed.), Butterworths Scientific, London.

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

Kashif, S.R., M. Yaseen, M. Arshad and M. Ayub. 2008. Response of okra (*Hibiscus esculentus* L.) to soil given encapsulated calcium carbide. *Pakistan journal of Botany* 40: 175-181.

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 and Environment* 26: 69-74.

Keeney, D.R. and D.W. Nelson. 1982. Nitrogen-inorganic forms. p. 643-698. *In:* Methods of Soil Analysis Part 2: Chemical and Microbiological Properties, A.C. Page, R.H. Miller and D.R. Keeney, (eds.), American Society of Agronomy, Madison.

Keerthisinghe, D.G., J.R. Freney and A.R. Mosier. 1993. Effect of wax coated calcium carbide and nitrapyrin on nitrogen loss and methane emission from dry seed flooded rice. *Biology and Fertility of Soils*. 16:71-75.

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.

Mattoo, A.K. and J.C. Suttle. 1991. The Plant Hormone Ethylene. CRC Press, Boca Raton, Ann Arbor, Boston, London.

Patra, A.K., P.K. Chhonkar and M.A. Khan. 2006. Effect of green manure *Sesbania sesban* and nitrification inhibitor encapsulated calcium carbide (ECC) on soil mineral-N, enzyme activity and nitrifying organisms in a rice-wheat cropping system. European *Journal of Soil Biology* 42: 173-180.

Ramos, J.M., L.F. Garcia-del-Moral, J.L. Molina-Gano, P. Salamanca and F. Roca de Tagores. 1989. Effect of an early application of sulphur or ethephon as foliar spray on the growth and yield of spring barley in a Mediterranean environment. *Journal of Agronomy and Crop Science* 163: 129-137.

Sharma, F. and S. Yadav. 1996. Controlling ammonia volatilization from urea surface applied to sugar beet on a calcareous soil. *Communications in Soil Science and Plant Analysis* 17: 9-10.

Yaseen, M., M. Arshad and A. Khalid. 2006. Effect of acetylene and ethylene gases released from encapsulated CaC_2 on growth and yield of wheat and cotton. *Pedobiologia* 50: 405-411.