Pak. J. Bot., 41(4): 1619-1625, 2009.

EFFECT OF ENCAPSULATED CALCIUM CARBIDE ON GROWTH, YIELD AND N USE EFFICIENCY OF RICE (*ORYZA SATIVA* L.)

MUHAMMAD YASEEN*, SYED AZHER HUSSAIN, SAIF UR REHMAN KASHIF AND MUHAMMAD ARSHAD

Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan.

Abstract

A field experiment was conducted to evaluate the potential of encapsulated CaC_2 on plant growth and yield of rice. Application of encapsulated CaC_2 in combination with recommended dose of N fertilizer significantly increased number of tillers, straw and paddy yield compared to N fertilizer application alone. Maximum number of tillers m^{-2} and paddy yield was observed where encapsulated CaC_2 @ 60 kg ha^{-1} was applied with N fertilizer @ 60 kg ha^{-1} applied two weeks after transplanting. Results revealed that half of the recommended dose of N produced maximum paddy yield just with addition of CaC_2 @ 60 kg ha^{-1} than that of full dose of N fertilizer. Moreover, application of encapsulated CaC_2 resulted in higher N-use efficiency by rice crop than that observed with N fertilizer alone. Maximum agronomic, apparent and physiological efficiencies were observed where CaC_2 plus N fertilizer (each applied @ 60 kg ha^{-1}) was applied. These findings indicated that CaC_2 affects plant growth by improving N-use efficiency in addition to a hormonal action

Introduction

Application of nitrogen (N) fertilizer by broadcast method on the surface of alkaline and calcareous soils undergoes either volatilization loss of N to the atmosphere or leaches down from rootzone due to nitrification. The extent of various N losses is up to 70 % on alkaline and calcareous soils (Buresh *et al.,* 1993). Even with the recommended fertilizer application practices, N recovery seldom exceeds 40% under flooded and un-flooded conditions (Sharma & Yadav, 1996).

Transformation of applied nitrogen fertilizers in the soil in the form of volatilization, nitrification, denitrification and leaching results in the poor nitrogen recovery. Incorporation into the soil or their deep placement particularly of ammonical nitrogen fertilizers may convert NH_4-N into NO_3-N by nitrification process, which is liable to either leach down or denitrify into N_2O or N_2 in rice fields. All of these conversions reduce the time of N stay in soil and thus result in poor nitrogen recovery efficiency (Keerthisinghe *et al*., 1996; Sharma & Yadav, 1996) and loss of costly input. Apart from economics, nitrogen loss has serious social and environmental implications. The fertilizer nitrogen which leaches down contributes to nitrate pollution of the groundwater, while part of fertilizer nitrogen which enters the atmosphere in gaseous forms pollutes the environment.

Calcium carbide (CaC_2) is a rich source of a nitrification inhibitor, acetylene (C_2H_2) and plant hormone ethylene (C_2H_4). Ethylene is formed from biotic reduction of C_2H_2 in the soil as well as in plant body (Porter, 1992; Aulakh *et al*., 2001; Yaseen *et al*., 2005, 2006). Banerjee *et al*., (1990) reported that CaC_2 inhibits the *Nitrosomonas* activity to prolong the stay of N in soil as NH_4^+ ion. The work of many researchers also supported the use of CaC_2 as an effective inhibitor of oxidation of NH^+_4 into NO^-_3 under flooded and non-flooded soil conditions (Freney *et al*., 2000; Keerthisinghe *et al*., 1996; Randall *et al*., 2001).

*E-mail: dryaseenuaf@yahoo.com

Keeping in view the role of CaC_2 in plant growth, an experiment was carried out with different doses of CaC_2 with appropriate dose of urea fertilizer for improving growth, yield and N use efficiency in rice.

Materials and Methods

A field experiment was conducted to evaluate the effect of encapsulated Calcium carbide on growth, yield and N use efficiency of rice. The experiment was laid out according to randomized complete block design with plot size 5m x 5m (25 m^2) area. Rice cv Super Basmati was grown in nursery according to recommended method. Thirty days old seedlings were transplanted by keeping plant to plant distance 22 cm and row to row 30 cm. Chemical fertilizers were applied by broadcast method. Two rates of nitrogen i.e., 60 and 120 kg ha^{-1} as urea were applied with phosphorus @ 90 kg P_2O_5 ha^{-1} as single super phosphate and potassium @ 60 kg K_2O as sulfate of potash. Half dose of nitrogen and full dose of phosphorus and potassium were applied at sowing time while the remaining half of nitrogen was applied two weeks after transplanting of rice seedlings. Powdered Calcium carbide was filled in medical capsules @ 60 and 90 kg ha^{-1} and applied two weeks after transplanting in the root zone (6 cm deep) in 30 x 30 cm^2 grid. At maturity, crops were harvested. Data regarding yield-contributing parameters were recorded.

Straw and paddy samples of rice were analyzed for total N content according to Hu & Barker (1999). Plant samples were oven-dried at 65˚C for 48 h, and ground to pass through a 40-mesh sieve. Total N uptake was determined by multiplying nitrogen concentration in straw or paddy with straw or paddy yield.

The data was analyzed statistically using randomized completely block design (Steel & Torrie, 1980). Means were compared by Duncan's multiple range test (Duncan, 1955).

Nitrogen use efficiency was calculated in terms of agronomic efficiency, apparent nitrogen recovery and physiological nitrogen efficiency by following formulae:

$$\text{Agronomic efficiency (kg kg}^{-1}) = \frac{\text{Paddy yield}_{\text{(fertilized)}} - \text{Paddy yield}_{\text{(control)}}}{\text{Nitrogen applied}}$$

$$\text{Apparent nitrogen recovery (\%)} = \frac{\text{N}_{\text{(fertilized)}} - \text{N uptake}_{\text{(control)}}}{\text{N applied}} \times 100$$

$$\text{Physiological nitrogen efficiency (kg kg}^{-1}) = \frac{\text{Paddy yield}_{\text{(fertilized)}} - \text{Paddy yield}_{\text{(control)}}}{\text{N uptake}_{\text{(fertilized)}} - \text{N uptake}_{\text{(control)}}}$$

Results

Number of tillers: Number of tillers m^{-2} was significantly affected by application of N and CaC_2 (Fig. 1). Maximum number of tillers was counted where full dose of N (120 kg ha^{-1}) was applied in combination with CaC_2 @ 60 kg ha^{-1} (N120 C60). Similar results were also observed with the application of full dose of N plus CaC_2 @ 90 kg ha^{-1} (N120 C90). Comparison between application of N alone and CaC_2 @ 90 kg ha^{-1} plus full dose of N (N120 C90) clearly showed that later treatments produced more tillers as compared to N alone. Comparison between half recommended dose of N plus CaC_2 @ 60 kg ha^{-1} (N60 C60) and half dose of N plus CaC_2 @ 90 kg ha^{-1} (N60 C90) elucidated influence of

CaC_2 on tillering. Difference in tillering in both treatments shows that CaC_2 application with N fertilizer produced more tillers. Statistical analysis indicates that full dose of N (120 kg ha^{-1}) had same effect on number of tillers m^{-2} compared with half N plus CaC_2 @ 60 kg ha^{-1} (N60 C60). Over all results indicate that application of different doses of CaC_2 with N fertilizer significantly increased number of tillers m^{-2}.

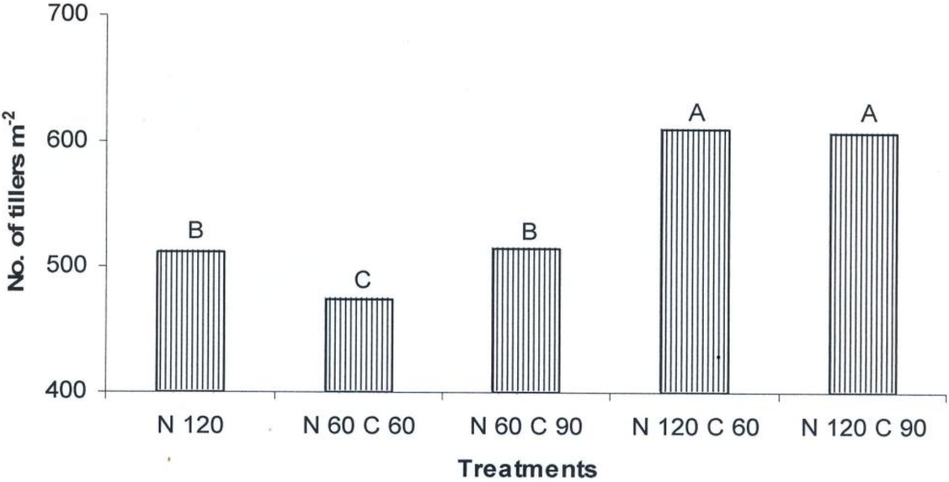

Fig. 1. Effect of nitrogen application alone and with CaC_2 on number of tillers of rice (average of four repeats).
*****Values sharing same letter (s) do not differ significantly at $p \leq 0.05$

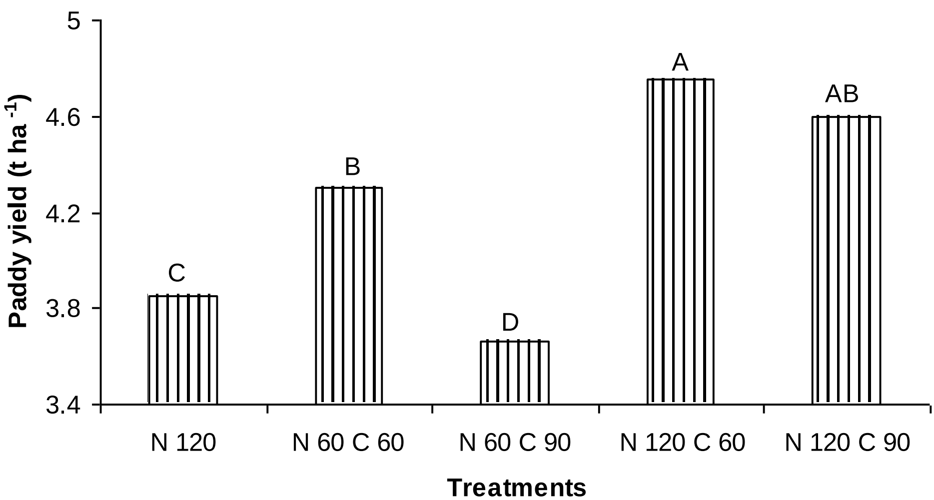

Fig. 2 Effect of nitrogen application alone and with CaC_2 on paddy yield of rice (average of four repeats).
*Values sharing same letter (s) do not differ significantly at $p \leq 0.05$

Paddy yield: Paddy yield was significantly affected by the application of N fertilizer and/ or with different doses of CaC_2 (Fig. 2). Maximum paddy yield was observed by the application of N fertilizer @ 120 kg ha^{-1} applied in combination with CaC_2 @ of 60 kg ha^{-1} (N120 C60) and minimum with half dose of N with CaC_2 @ 90 kg ha^{-1} (N60 C90). Statistical analysis indicated that half dose of N with CaC_2 @ 60 kg ha^{-1} (N60 C60) had better effect on paddy yield compared with full dose of N alone (120 kg ha^{-1}). Analysis of variance indicates that paddy yield was decreased by the application of CaC_2 @ 90 kg ha^{-1} than by 60 kg ha^{-1} with N fertilizer. Interaction of CaC_2 and fertilizer revealed that when CaC_2 @ 60 kg ha^{-1} was applied along with full dose of N (N120 C60), it resulted in increase in paddy yield over application of fertilizer alone (N @ 120 kg ha^{-1}). In general results indicated that paddy yield was significantly increased by the application of CaC_2 alone and it was further increased when applied in combination with different doses of N fertilizer.

Straw yield: Data pertaining to the effect of different doses of CaC_2 application in combination with N fertilizer on straw yield are presented in Fig. 3. Straw yield was significantly increased by the application of N fertilizer. Maximum straw yield was obtained with the application of N fertilizer @ 120 kg ha^{-1} in combination with CaC_2 @ 60 kg ha^{-1} (N120 C60) and minimum with half dose of N with CaC_2 (N60 C60). Slight decrease in straw yield was observed with the same rate of N but with higher dose of CaC_2 (comparison between N120 C60 and N120 C90). Better stand of crop was observed with half dose of N in combination with CaC_2 @ 90 kg ha^{-1} (N60 C90) than half recommended dose of N with CaC_2 @ 60 kg ha^{-1} (N60 C60). However application of full dose of N performed better compared with half dose of N plus CaC_2 @ 60 or 90 kg ha^{-1}.

Nitrogen use efficiency: Nitrogen use efficiency can be discussed in terms of agronomic efficiency, apparent nitrogen recovery and physiological nitrogen efficiency. Data regarding the effect of CaC_2 application on N use efficiencies is presented in Fig. 4. It is quite clear from the data that CaC_2 application alongwith N fertilizer significantly improved agronomic efficiency. The highest agronomic efficiency was observed in treatment where N fertilizer @ 60 kg ha^{-1} was applied along with CaC_2 @ 60 kg ha^{-1} (N60 C60) followed by N60 C90 (N @ 60 kg ha^{-1} + CaC_2 @ 90 kg ha^{-1}). The lowest agronomic efficiency was noted with the application of full dose of N alone. Application of CaC_2 @ 60 and 90 kg ha^{-1} in combination with full dose of N did not affect this efficiency. This may imply that CaC_2 application contributed in increasing paddy yield and hence improved agronomic efficiency. Calcium carbide application significantly improved apparent nitrogen recovery over application of fertilizer N alone. The highest apparent nitrogen recovery was observed with the application of half dose of N plus CaC_2 @ 60 kg ha^{-1} (N60 C60) which clearly indicates the role of CaC_2 in increasing uptake of nitrogen. Increase in nitrogen rate from half to full dose with CaC_2 @ 90 kg ha^{-1} did not affect apparent nitrogen recovery. Similar trend was also observed with application of full dose of N fertilizer alone (N120) and with CaC_2 @ 60 kg ha^{-1} (N120 C60).

Data indicated that application of half dose of N plus CaC_2 @ 60 kg ha^{-1} (N60 C60) showed maximum physiological nitrogen efficiency (PNE) followed by application of full dose of N plus CaC_2 @ 60 kg ha^{-1} (N120 C60). Application of full dose of N alone (N120) positively affected this parameter than application of full dose of N along with CaC_2 @ 120 kg ha^{-1} (N120 C90).

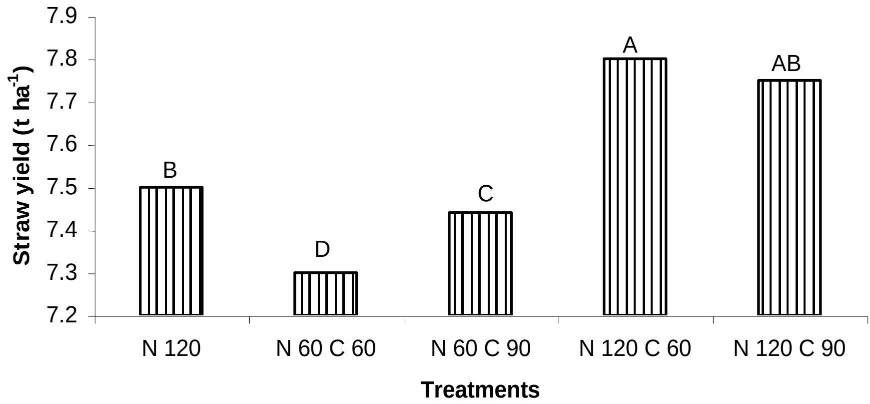

Fig. 3. Effect of nitrogen application alone and with CaC_2 on straw yield of rice (average of four repeats).
*Values sharing same letter (s) do not differ significantly at $p \leq 0.05$

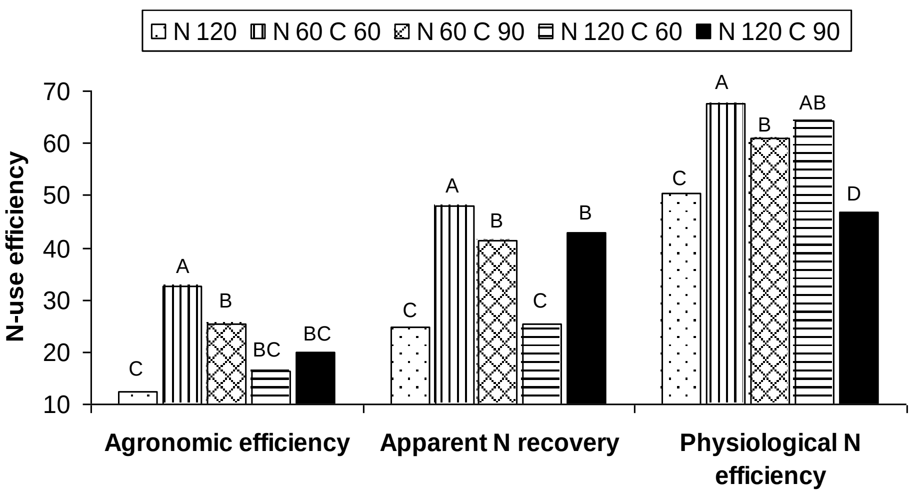

Fig. 4. Effect of nitrogen application alone and with CaC_2 on nitrogen use efficiency of rice (average of four repeats).
*Values sharing same letter (s) do not differ significantly at $p \leq 0.05$

Discussion

Nitrogen use efficiency and increased yield are the main thrust of today's agriculture in view of the increasing cost of nitrogen fertilizer and environmental pollution concerns. This study demonstrated the effectiveness of encapsulated CaC_2 under N fertilized conditions for improving the growth and yield of rice by acting as a source of C_2H_2 (nitrification inhibitor) and C_2H_4 (plant hormone). Some earlier studies revealed that CaC_2 acted as a potential source of C_2H_2 in soil, which was partially reduced to C_2H_4 over a period of time (Muromtsev *et al.*, 1991; Bibik *et al.*, 1995; Akhtar *et al.*, 2005; Yaseen *et al.*, 2006; Rashid *et al.*, 2007).

Results revealed that encapsulated CaC_2 @ 60 kg ha^{-1} plus N fertilizer had significant stimulatory effect on the growth and yield of rice crops. These positive effects of CaC_2 in the presence of N fertilizer could be attributed to the physiologically active concentration of plant hormone C_2H_4 as well as longer availability of N in the rhizosphere due to C_2H_2 (nitrification inhibitor). It is highly likely that a gradually formation of physiologically active concentration of C_2H_4 from the microbial reduction of C_2H_2 might have also contributed in root growth promotion, which subsequently resulted in better shoot growth and yield of treated plants. Researchers have reported C_2H_4 as a potent plant growth regulator (Abeles, 1992; Muromstev *et al*., 1991; Arshad & Frankenberger, 2002). It has been postulated that a very small amount of C_2H_4 in the rhizosphere could be physiologically active in influencing the growth and development of plants (Arshad & Frankenberger, 1998; Arshad *et al*., 2004). Additionally, reduced NH_4-oxidation due to C_2H_2 might also have resulted in a higher uptake of NH_4-N, saving energy required by the plant to assimilate NO_3^- into metabolic processes. This premise is supported by the fact that the recovery of applied N by plants was enhanced as a result of combined application of encapsulated CaC_2 and N fertilizer compared with the application of N fertilizer alone. Encapsulated CaC_2 application in urea fertilized soil significantly improved the N uptake that resulted into higher agronomic, physiological and N-use efficiency of applied N fertilizer. These results suggested the use of CaC_2 in combination with nitrogen fertilizers for improving the yield of rice.

References

Abeles, F.B., P. Morgan and M.S. Salveit Jr. 1992. *Ethylene in Plant Biology*. Academic Press, San Diego.

Akhtar, M.J., M. Arshad, A. Khalid and M.H. Mahmood. 2005. Substrate-dependent biosynthesis of ethylene by rhizosphere soil fungi and its influence on etiolated pea seedlings. *Pedobiologia*, 49: 211-219.

Arshad, M. and W.T. Frankenberger Jr. 1998. Plant growth regulating substances in rhizosphere: Microbial production and functions. *Adv. Agron.*, 62: 145-151.

Arshad, M. and W.T. Frankenberger Jr. 2002. *Ethylene: Agricultural Sources and Applications*. Kluwer Academic Publishers, New York.

Arshad, M., Z.H. Nazli, A. Khalid and Z.A. Zahir. 2004. Kinetics and effects of trace elements and electron complexes on 2-keto-4-methylthiobutyric acid-dependent biosynthesis of ethylene in soil. *Applied Microbiology*, 39: 306-309.

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.

Banerjee, N.K., A.R. Mosier and N.N. Goswami. 1990. Use of encapsulated calcium carbide to reduce denitrification losses from urea-fertilized flooded rice. *Mitt. Dtsch Bodenkd Ges*., 60: 211-216.

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 Agriculture Science*., 9: 19-21.

Buresh, R.J., M.I. Sampson and S.K. De Datta.1993. Quantification of denitrification in flooded soils as affected by rice establishment method. *Soil Biology and Biochemistry*, 25: 843-848.

Duncan, D.B. 1955. Multiple range and multiple F-test. *Biometrics*, 11: 1-42.

Freney, J.R., P.J Randall, J.W.B. Smith, J. Hodgkin, K.J. Harrington and T.C. Morton. 2000. Nutrient cycling. *Agro-ecosystems,* 56: 241-251.

Hu, Y. and A.V. Barker. 1999. A single plant tissue digestion for macronutrient analysis. Communications in Soil Science. *Plant Analls,* 30: 677-687.

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 Research*, 45: 31-36.

Muromstev, G.S., N.P. Krasinskaya, S.V. Letunova and I.G. Beresh. 1991. Use of ethylene producing soil-acting preparation on citrus crops. *Soviet Agricultural Science*, 2: 24-26.

Porter, L.K. 1992. Ethylene inhibition of ammonium oxidation in soil. *Soil Science Society America Journal*, 56: 102-105.

Randall, P.J., J.R. Freney, J. Hodgkin and T.C. Morton. 2001. Effect of Acetylene generated from Carbide on nitrification in soil, yield of irrigated maize and growth of maize seedlings. In: *Plant Nutrition-Food security and Sustainability of Agro-Ecosystems*. (Ed.): W.J. Horest Kluwer Academic Publishers, New York, pp. 774-775.

Rashid, M., M. Yaseen and M. Arshad. 2007. Effect of rate and time of Calcium carbide application on nitrogen use efficiency of applied urea and growth of wheat. *Pakistan Journal of Botany*., 39(2): 497-502.

Sharma, J.P. and B.R. Yadav.1996. Increasing urea efficiency in rice-wheat cropping sequence through addition of some calcium salts and potassic fertilizer. *Current Agriculture*, 20(1-2): 73-76.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics.* McGraw Hill Book Co Inc, New York.

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

Yaseen, M., M. Arshad and A. Rahim. 2005. Effect of soil applied encapsulated calcium carbide on growth and yield of rice (*Oryza sativa* L.). *Pakistan Journal of Botany*, 37(3): 629-634.

(Received for publication 20 February 2008)