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EFFECT OF SOIL APPLIED ENCAPSULATED CALCIUM CARBIDE ON GROWTH AND YIELD OF RICE (*ORYZA SATIVA* L.)

MUHAMMAD YASEEN, MUHAMMAD ARSHAD AND ABDUL RAHIM

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

Abstract

Poor N fertilizer use efficiency by rice is caused by losses of N through volatilization as its oxides. Use of nitrification inhibitor like calcium carbide (CaC_2) may reduce N losses. Calcium carbide releases acetylene gas which acts as a inhibitor of nitrification. A fraction of acetylene is microbially reduced to ethylene which is a potent plant hormone. A field experiment was conducted to evaluate the effect of encapsulated CaC_2 on growth and chemical composition of rice (*Oryza sativa* L.). The results revealed that encapsulated CaC_2 applied alone or along with chemical fertilizer significantly increased early emergence of panicle, number of tillers and paddy yield. Soil amended with encapsulated CaC_2 resulted in 20% increase in paddy yield over NPK fertilizer alone. Plant analysis also indicated that encapsulated CaC_2 promoted N concentration and uptake by plant which is supported by the reduced oxidation of applied fertilizer NH_4^+ to NO_3^- in the presence of encapsulated CaC_2. It is plausible likely that CaC_2 might have affected growth and chemical composition of rice by acting as nitrification inhibitor and/ or as a source of plant hormone ethylene.

Introduction

Ethylene (C_2H_4) is a phytohormone which plays an important role in regulation of many physiological responses. Ethylene is involved in almost all growth and developmental processes ranging from germination of seed to senescence of various organs (Lurssen, 1991; Abeles *et al.*, 1992; Reid, 1995; Arshad & Frankenberger, 2002). Being a gas, ethylene is difficult to use on commercial scale for agriculture production. In the late 1960's, a breakthrough came when an ethylene releasing liquid was introduced under the trade name of 'ethephon' (Cooke & Randall, 1968; Sterry, 1969). Later, researchers at All-Russian Scientific Research Institute of Agriculture Biotechnology (ARSRIAB) and St. Petersburg Institute of Basic Chemical Industry jointly developed an ethylene releasing soil amendment 'Retprol' from calcium carbide. In soil, Retprol decomposes into calcium ion and acetylene gas. Acetylene is then reduced by soil microorganisms to ethylene, which may affect plant growth after having been taken up by plant roots. Being a rich source of acetylene, calcium carbide is also considered a powerful inhibitor of nitrification (Banerjee *et al.*, 1990) and thus reduces N losses substantially.

Poor recovery of fertilizer N by flooded rice is a major problem in the management of N for this crop (De Datta *et al.*, 1989; Freney *et al.*, 1990). Field studies with flooded rice have shown that about 70% of the applied N could be lost due to volatilization and denitrification processes (Frenney *et al.*, 1990; Buresh *et al.*, 1993). Volatilization losses following urea application can be reduced by decreasing the concentration of ammonical N in the flood water by incorporating or deep placing the fertilizer into soil instead of broadcasting it. However, these losses could further be minimized effectively by application of nitrification inhibitor such as encapsulated CaC_2 (Keerthisinghe *et al.,* 1996). In this study effect of soil applied encapsulated CaC_2 fertilizer on growth, yield and N recovery by rice under field conditions was investigated.

Materials and Methods

An experiment was conducted at the Research Area of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad. Soil was normal, sandy clay in texture, low in organic matter and available nitrogen. The experiment was laid out according to randomized complete block design with a plot size of 5 X 5 m^2 area. Each treatment was replicated four times. The set of four treatments included control, recommended rate of NPK fertilizer (100-75-60 kg ha^{-1}), CaC_2 @ 60 kg ha^{-1} and recommended rate of NPK fertilizer + CaC_2 @ 60 kg ha^{-1}

Rice cv. Basmati-385 was used as test crop. Nursery was sown on 27th of June, 2004 and transplanted on 2nd August, 2004. Plant to plant and row to row distance of 22 x 22 cm was kept. Nitrogen as urea, phosphorus as SSP and potassium as KCI were applied by broadcast method. Half N and full P and K were applied at transplanting time and remaining half nitrogen was applied at panicle initiation stage. Calcium carbide was applied after 2 weeks of transplanting. Powdered CaC_2 was encapsulated according to the 60 kg ha^{-1} rate and placed in the root zone 4 cm deep with a capsule to capsule distance of 30 cm followed by immediate irrigation. Canal water was used throughout the growth period. After 2 weeks of calcium carbide application a composite soil sample was taken from 0–15 cm soil depth for NH_4^+ and NO_3^--N from each replication. Moist soil, equivalent to 10 g dry weight, was extracted for one hour with 100 ml of 2M KCl solution, containing 15 µM phenylmercuric acetate. The soil suspensions were filtered through Whatman No.42 filter papers and analyzed for NH_4^+ by the Indophenol blue method and NO_3^- by a modified Griss-Ilosvay method (Keeney & Nelson 1982).

Data on emergence of panicles was noted 2 months after transplanting while data on plant height and number of tillers at panicle growth stage. Paddy and straw yields were recorded at maturity. The crop was harvested on 3rd November, 2004. Paddy and straw samples were dried and ground. Total nitrogen in plant material was determined by Hu & Barker (1999) method of Sulphuric acid digestion and distillation on micro Kjeldahl's apparatus (Jackson, 1962). Nitrogen uptake was calculated by multiplying nitrogen concentration in straw or paddy with straw or paddy yield.

The data collected for various characteristics were analyzed statistically using Fisher's analysis of variance technique (Steel & Torrie, 1980). The treatments' means were compared by Duncan's Multiple Range test at 5% probability level (Duncan, 1955).

Results

Effects of calcium carbide (CaC_2) on growth, yield and nitrogen (N) recovery efficiency of rice revealed that all the growth parameters except plant height, increased significantly by application of CaC_2 @ 60 kg ha^{-1} alone and in combination with NPK fertilizer (Tables 1&2). Maximum number of tillers (454 m^{-2}) was recorded in the treatment where CaC_2 was applied with NPK fertilizer, which was 32% higher than that recorded in NPK alone treated plants. Moreover, CaC_2 application also stimulated the early onset of panicles. Panicle emergence was 2.4 folds higher in CaC_2 plus NPK treated

Table 2. Effect of Calcium carbide on nitrogen concentration, uptake and recovery by rice.

Treatment	N Concentration (%)		N Uptake (kg ha^{-1})		N Recovery (%)	
	Straw	Paddy	Straw	Paddy	Straw	Paddy
Control	0.38b	1.74a	16.52b	22.30c	-	-
NPK fertilizer (100-75-60 kg ha^{-1})	0.44a	2.06b	32.95a	46.97b	16.4	27.7
CaC_2 (@ 60 kg ha^{-1})	0.41ab	1.89bc	20.52b	23.28c	-	-
CaC_2+ NPK fertilizer	0.45a	2.43a	35.57a	65.98	19.1	43.7

Means sharing different alphabet(s) within columns differ significantly at $p < 0.05$

Table 3. Effect of encapsulated calcium carbide on exchangeable ammonium and nitrate concentration in soil at 2 weeks past treatment.

Treatments	NH_4-N	No_3-N
	ug Ng^{-1} soil	
Control	2.10c	8.41b
NPK fertilizer	36.50b	14.16a
CaC_2 (@ 60 kg ha^{-1})	3.21c	7.40bc
CaC_2+ NPK fertilizer	46.84a	5.26c

Means sharing different alphabet(s) within columns differ significantly at $p < 0.05$

plants compared to NPK alone treated plants. Although effect of CaC_2 on total biomass was not so pronounced, its influence on paddy yield was significant ($p< 0.05$). Rice straw yield (7393 kg ha^{-1}) by application of CaC_2 plus NPK fertilizer was statistically similar to that of by NPK fertilizer alone (7409 kg ha^{-1}). Significant differences among treatments for paddy yield were recorded (Table 1). Paddy yield of 3334 kg ha^{-1} was obtained by application of CaC_2 in combination with fertilizer and it was 20% more than that of alone fertilizer application. Application of CaC_2 showed a little effect on N concentration in rice straw. Similar trend was observed for N uptake by straw. However, N concentration in paddy increased significantly which also resulted in more N uptake by paddy. The highest N concentration (2.43%) and uptake (65.98 kg ha^{-1}) in paddy were observed in the treatment of CaC_2 plus fertilizers. It means that N uptake was enhanced from 46.97 to 65.98 kg ha^{-1} with the application of CaC_2. These results were also reflected in N recovery efficiency where N recovery was enhanced from 25 to 44% (Table 2). So almost 76% more nitrogen was recovered by application of CaC_2. Data demonstrate inhibitory role of CaC_2 on oxidation of NH_4^+ to NO_3^- (Table 3). Significantly highest concentration of NH_4^+-N was observed in the treatment where CaC_2 was applied with fertilizer. However, the presence of high concentration of NO_3^--N (14.16 µg N g^{-1}soil) in the fertilizer treatment indicated normal activity of nitrification process in this treatment while least concentration of NO_3^--N (5.2 µg N g^{-1} soil in CaC_2 plus fertilizer treatment showed nitrification inhibitory effect of CaC_2.

Discussion

Calcium carbide is a source of acetylene (C_2H_2) gas in soil (Keerthisinghe *et al.*, 1996; Randall *et al.*, 2001; Aulakh *et al.*, 2001), which is reduced to ethylene (C_2H_4) by soil microorganisms (Muromtsev *et al.*, 1988). Both acetylene and ethylene are potent nitrification inhibitor (Benerjee *et al.*, 1990; Bronson *et al*., 1992; Freney *et al.*, 1992; Arshad & Frankenberger, 2002) that limits oxidation of NH^{+}_{4} to NO^{-}_{3}. Furthermore, ethylene stimulates the initiation of early root growth, tillering and panicle (Hazarika & Sarkar, 1996). Data revealed stimulatory effect of CaC_2 on number of tillers and panicle emergence (Table 1). Addition of encapsulated CaC_2, with or without fertilizer, significantly ($p< 0.05$) increased the number of tillers, early panicle emergence, paddy yield, N uptake and recovery. It is evident from the results that addition of encapsulated CaC_2 with fertilizer further increased the growth parameters compared to fertilizer application alone. Chaiwanakupt *et al.*, (1996) reported that addition of encapsulated CaC_2 effectively inhibited nitrification. Retention of nitrogen in soil for longer period might have stimulated tillering. Increase in number of tillers and paddy yield in response to encapsulated CaC_2 was also observed in this study. This might be attributed to the ethylene released from CaC_2 as this phytohormone has such effects (Arshad & Frankenberger, 2002). Tillering is an important yield contributing parameter. Highly positive correlation between number of tillers and paddy yield ($r = 0.851$, $p< 0.01$) also indicated the contribution of tillering in enhancing the paddy yield (Hazarika & Sarkar, 1996).

Results also showed that the recovery efficiency of urea applied to rice can be significantly improved by using CaC_2 along with urea which is supported by the data regarding N uptake and recovery (Table 2). Freney *et al.*, (1990) showed that incorporation of urea into the soil could reduce ammonia volatilization but this may not necessarily result in reduced N loss because the N conserved could be nitrified and then denitrified. The efficiency of urea fertilizer N would be improved only when both of the potential N-loss processes are controlled simultaneously throughout the early growth period. Hazarika & Sarkar (1996) found that coating of urea with Calcium carbide reduced the N-losses and increased the fertilizer N recovery by rice and hence grain yield of rice. In agreement with the findings of Keerthisinghe *et al.*, (1996) for flooded rice, CaC_2 is an effective additive to enhance N recovery in paddy fields.

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