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Effect of Calcium Carbide-Derived Ethylene on Growth and Yield of Rice

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Abstract

Calcium carbide (CaC_2) is an established precursor of ethylene (a plant hormone), which influences plant growth and development. A field study was conducted to assess the potential of CaC_2-derived C_2H_4 for improving growth and yield of rice. Forty-day-old seedlings of rice (cv. Basmati-385) were transplanted in the puddled field. Encapsulated CaC_2 was applied @ 60 kg ha^{-1} alone or in combination with full dose of recommended NPK fertilizers. Control contained basal dose of PK without CaC_2 and N fertilizer. This study revealed that CaC_2 being a source of C_2H_4 in soil along with recommended dose of NPK fertilizers had significant influence on the growth and yield of rice plants. The CaC_2 plus recommended NPK fertilizers significantly increased plant height (32.3%), number of tillers (169%), straw (83%) and paddy yield (110%), N concentration in straw (19.1%) and paddy (39.7%) compared to control. Spike initiation was also enhanced (~ 6-fold more than control) in response to CaC_2 application. Application of CaC_2 in the absence of N fertilizer also gave promising results.

Key words: Soil amendments, Ethylene, Rice, Growth, Yield

Introduction

Ethylene (C_2H_4) is a plant hormone, which is involved in regulation of many physiological responses (Abeles *et al.*, 1992; Reid, 1995; Arshad and Frankenberger, 1998). Ethylene is involved in almost all the growth and development processes of plant, ranging from germination of seed to senescence of various organs and in many responses to environmental stress (Lurssen, 1991). Ethylene production occurs naturally in all plant organs including roots, stems, leaves, buds, tubers, bulbs, flowers and seeds but the magnitude of ethylene production varies from organ to organ and is dependent upon growth and developmental processes. This is the reason that ethylene has stimulatory influence in some cases while in others it is inhibitory (Arshad and Frankenberger, 2002).

Being a gas, ethylene is difficult to use for agricultural production. In the late 1960's, a breakthrough came when ethylene was applied in the liquid from under the trade name of 'ethephon' (Cooke and Randall, 1968; Sterry, 1969). At present different ethylene releasing sources are available in market such as methionine, ethephon, ethrel and calcium carbide (CaC_2).

Calcium carbide in the presence of soil moisture decomposes with the formation of calcium ion and acetylene. In the presence of an enzyme (nitrogenase), acetylene is then reduced by soil microorganisms to ethylene, which enters the plant through the roots. Calcium carbide as an ethylene precursor is now well established with calcium ion and acetylene as intermediates (Muromtsev *et al.*, 1988; Muromtsev *et al.*, 1993, Bibik *et al.*, 1995). Physiological effects of CaC_2-derived, microbially produced ethylene in plant growth have been reported by few scientists (Muromtsev *et al.*, 1988, 1993; Bibik *et al.*, 1995). It is highly likely that the CaC_2 based formulation could be effective to improve the growth and yield of rice. So effects of CaC_2 as an ethylene source were assessed in the field in the presence or absence of nitrogen fertilizers.

Materials and Methods

The research work reported in this manuscript was conducted in the research area of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad. Before the transplanting of rice seedlings in the field, composite soil sample was taken from a depth of 0-15 cm surface layer of soil. This sample was air dried, ground, homogenized and then it was analyzed for various physiochemical properties. The soil was sandy clay loam having pH, 7.9; ECe, 2.5 dS m-1; organic matter, 0.63%; available phosphors 6.58, mg kg^{-1}; and extractable potassium, 176 mg kg-1 soil.

Encapsulated calcium carbide was applied @ 60 kg ha^{-1} alone or in combination with recommended N fertilizer (@ 100 kg ha^{-1}) for rice. However, basal recommended doses of PK fertilizers (@ 75 and 60 kg ha^{-1}, respectively) were same in all the treatments. Control was consisted of PK fertilizers lacking CaC_2 and N fertilizer.

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The experiment was conducted in a randomized complete block design (RCBD) with 4 replications with a net plot size of 25 m2 (5 m × 5 m). For growing nursery, rice cv. Basmati-385 was sown in a separate field in the month of June and was transplanted with a row to row and hill to hill distance of 20 cm × 20 cm in the field after 40 days of germination under flooded conditions. Half of nitrogen, full dose of phosphorus and potassium as urea, SSP and SOP, respectively were broad cast into the respective plots before rice transplanting. The remaining half of recommended dose of N was applied at the stage of panicle initiation. Encapsulated CaC_2 @ 60 kg ha^{-1} was incorporated at a depth of 2 cm soil, two weeks after rice transplanting following immediate irrigation. Pesticides were sprayed to control the attack of pests. The data regarding plant height, number of tillers m-2, spike initiation, straw and paddy yields, and nitrogen concentration in straw and paddy were recorded at maturity and after harvesting. The data were subjected to statistical analysis (Steel and Torrie, 1980).

Results

Plant height

The data regarding the effect of encapsulated CaC_2 as an C_2H_4 source on plant height is given in Table 1. CaC2 @ 60 kg ha-1 significantly influenced the plant height (32.3 % greater than control) of rice when used in combination with recommended NPK fertilizer. Statistically this plant height was at par where only recommended NPK fertilizers were applied. Application of CaC_2 without N fertilizer also significantly increased the plant height, which was 17.8% more than control.

Number of tillers m^{-2}

Calcium carbide significantly affected tillering of rice either applied alone or in combination with recommended NPK fertilizers compared to control (no CaC_2 + no N fertilizer) (Table 1). However, maximum number of tillers (169% higher than control) were recorded where encapsulated CaC_2 (@ 60 kg ha-1) was applied along with full dose of recommended NPK fertilizers. The application of encapsulated CaC_2 alone @ 60 kg ha-1 resulted in 66.5 % more tillers over control. Full dose of recommended NPK fertilizers alone also significantly increased number of tillers, which were 104 % greater than control.

Spike initiation

Like number of tillers, application of CaC_2 also significantly enhanced the initiation of spikes (Table 1). Maximum early spikes were observed where encapsulated CaC_2 plus recommended NPK fertilizers were applied. This maximum increase in spike initiation was ~6-fold higher than control. Alone applications of encapsulated CaC_2 @ 60 kg ha^{-1} and recommended NPK fertilizers also enhanced the spike initiation (up to 131%) over control but they were statistically at par with each other.

Straw yield (kg ha-1)

It is evident from Table 2 that the combined application of CaC2 and recommended NPK fertilizers had a significant influence on straw yield and caused an increase of 83% over control (PK fertilizers only). Whereas the encapsulated CaC_2 alone @ 60 kg ha^{-1} produced 13.4% more straw yield than control. The straw yield (7409 kg ha^{-1}) with full dose of recommended NPK fertilizers was 69.6% higher than control, which differed significantly from control.

Paddy yield (kg ha^{-1})

The data pertaining to the effect of encapsulated CaC_2, as a C2H4 source on paddy yield is summarized in Table 2. Maximum increase (110%) in paddy yield was observed in response to the application of CaC_2 @ 60 kg ha^{-1} plus full dose of recommended NPK fertilizers, followed by NPK fertilizer application only (76% greater than control), however both the treatments differed significantly from control. Application of encapsulated CaC_2 alone statistically produced same paddy yield like control but the response was still positive (5 % increase over control).

Table 1: Effect of encapsulated CaC_2 on plant height, number of tillers and spike initiation of rice (average of four replications).

Treatment	Plant height (cm)	No. of tiller m^{-2}	Spike initiation
Control (PK only)	71.9 c	185 d	8.80 c
Recommended NPK	94.6 a	378 b	20.4 b
CaC_2 alone (No Nitrogen Fertilizer)	84.7 b	309 c	16.5 b
CaC_2 + Recommended NPK	95.1 a	499 a	50.6 a

Values sharing similar letters do not differ significantly at $P \leq 0.05$.

Table 2: Effect of encapsulated CaC_2 on straw and paddy yield, and nitrogen concentrations in rice straw and paddy (average of four replications).

Treatment	Straw yield (kg ha^{-1})	Paddy yield (kg ha^{-1})	N conc. in straw	N conc. in paddy
Control (PK only)	4586 d	1356 c	0.42 b	1.91 c
Recommended NPK	7409 b	2387 b	0.49 a	2.27 b
CaC_2 alone (No N Fertilizer)	5202 c	1420 c	0.45 ab	2.08 bc
CaC_2 + Recommended NPK	8288 a	2844 a	0.50 a	2.67 a

Values sharing similar letters do not differ significantly at $P \leq 0.05$.

Nitrogen concentration in straw

Table 2 revealed that all the treatments had a significant increasing effect on N concentration in straw over control. Maximum N concentration in straw (19.1% higher than control) was noted where encapsulated CaC_2 @ 60 kg ha^{-1} was applied in combination with recommended NPK fertilizers. Statistically it had non significant difference with N concentration of straw where CaC_2 alone was applied which increased N concentration upto 15% over control.

Nitrogen concentration in paddy

Significantly more N concentrations were observed in response to application of full dose of NPK fertilizer alone and/or in combination with encapsulated CaC_2 @ 60 kg ha^{-1} over control (Table 2). Maximum N concentration in paddy was recorded where full dose of recommended N fertilizer was applied in combination with encapsulated CaC_2 and this increase was 39.7 % over control. It was followed in descending order by full dose of NPK fertilizers (12.9%) and CaC_2 applications alone (8.9%). Statistically both the treatments were at par with each other. The effect of application of encapsulated CaC_2 @ 60 kg ha^{-1} alone was also non-significant with control.

Discussion

This study demonstrated the role of calcium carbide as an ethylene source in improving the growth and yield of rice. It was found that CaC_2 had significant influence on various growth parameters. Plant height and numbers of tillers were significantly increased upon the application of CaC_2 either alone or in combination with recommended dose of NPK fertilizers. Ethylene might have stimulatory or inhibitory effects on the growth of plant depending upon the concentration. In general, lower concentrations are stimulatory while higher concentrations of ethylene are inhibitory (Arshad and Frankenbeger, 1998, 2002). The CaC_2 on reacting with water forms acetylene in soil, which has inhibitory effects on nitrification process (Keerthsinghe *et al.*, 1996; Freney *et al.*, 2000). Reduction in nitrification may result in reduced losses of nitrogen, which ultimately lead to increase the growth of rice plants. Arshad *et al.* (1994) reported increase in plant height of soybean plants on exposure to L-MET applied to soil. Suge (1985) reported that combined application of ethylene and gibberellins stimulated internal elongation in excised stem sections of four floating rice cultivars; however the effect was cultivar-dependent. Langan and Oplinger (1987) also reported a significant effect of ethephon, C_2H_4 releasing compound, on plant height of hybrid maize. However several authors have reported that C_2H_4 had inhibitory effects on plant height (Arshad and Frankenberger, 1988; Sagaral and Foy, 1989; Sagaral and Parish, 1989). Foster *et al.* (1992) reported that injection of ethephon into the plant base promoted tillering in barley plant and reduced elongation of upper stem. Similarly foliar application of ethephon reduced plant height and increased tillering (Foster *et al.*, 1992).

Results also revealed that spike initiation of rice was enhanced by the application of CaC_2. Ethylene released by the microorganisms in soil from CaC_2 affected the spike initiation. This fact is supported by many authors that ethylene acts as a ripening hormone and causes early maturity (Ferguson, *et al.*, 1990, Prohens *et al.*, 1999).

Calcium carbide application significantly increased straw and paddy yield along with NPK fertilizers. Our results are confirming the previous reports that C_2H_4 releasing source could have positive effects on the yield of various crops. Chaiwanakupt *et al.* (1996) studied that addition of wax coated CaC_2 effectively inhibited nitrification and increased the grain yield of rice up to 31 %. Similarly Bibik *et al.* (1995) studied the effect of soil applied Retprol a CaC_2 based formulation on potato and found increases in number of tubers (up to 80 %) and potato yield (121 %). Hazzrika and Sarkar (1996) found that coating of urea with CaC_2 reduced the N losses and increased the fertilizer N recovery by rice and hence yield of rice. This study supported the premise that C_2H_4 can influence the plant growth and development.

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