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Full Length Research Paper

Effect of rate and application depth matrix-I calcium carbide based formulation on growth, yield and nitrogen uptake of wheat

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Calcium carbide (CaC_2) is a source of acetylene gas which is a well known nitrification inhibitor and converts into ethylene in the soil environment. Ethylene is a potent plant growth regulator and influences a number of biological processes from root growth to leaf senescence. A pot experiment was conducted to study the effect of a calcium carbide based formulation, Matrix-I (21% calcium carbide, 58% polyethylene and 21% plaster of paris), applied at 0, 7.5, 15 and 22.5 mg CaC_2 kg^{-1} soil at 0, 4, 8 and 12 cm soil depth, on growth, yield and nitrogen uptake of wheat. Increasing the rate and application depth of Matrix-I, decreased wheat plant height and increased the number of tillers, biological yield, grain yield, 1,000-grains weight and nitrogen uptake by wheat grain and straw. However, when calcium carbide at 22.5 mg kg^{-1} soil was applied at greater soil depths, it inversely affected the economical yield of wheat. Comparatively maximum increase in yield parameters of wheat was observed when formulated calcium carbide was buried at 15 mg kg^{-1} soil at 8 cm soil depth.

Key words: Wheat, calcium carbide, growth, nitrogen uptake.

INTRODUCTION

Calcium carbide is a potent source of nitrification inhibitor gas acetylene and plant hormone ethylene (Muromtsev et al., 1988). Both the gases directly or indirectly has pronounced influence on plant growth from germination to maturity and thus influence the yield and yield contributing parameters (Bronson et al., 1992; Freney et al., 1992; Ahmad et al., 2004; Yaseen et al., 2005, 2006; Kashif et al., 2008). Since acetylene inhibits the ammonium oxidizing enzyme in the soil and its conversion to ethylene also depends upon soil microbes therefore, variation in application depth of calcium carbide will change the volume of soil exposed to acetylene supply and may thus influence the nitrification inhibition and ethylene production from calcium carbide.
Secondly, root exposure to ethylene supply may also change with changing the application depth of CaC_2 and thus in turn its influence on plant growth and development may change.

Entrapment of gases in the soil due to increasing depth of calcium carbide is also a possible way that can change crop responses to calcium carbide application. Calcium carbide has a very vigorous reaction with water and acetylene releases in the soil environment too rapidly to be used as nitrification inhibitor and ethylene precursor. Therefore, to slow down its exposure to soil moisture, calcium carbide is mostly applied to soil in some water proof coating (Kashif et al., 2008) or as formulation with some insulator materials (Freney et al., 2000). Matrix-I is the calcium carbide based formulation which performed the best in preliminary experiments to improve seedling emergence, growth and yield of wheat crop (Mehmood et al., 2010). In this experiment, response of wheat to different doses of calcium carbide based formulation Matrix-I applied at different soil depths was evaluated to

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find out the best rate and depth of application of calcium carbide.

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 environmental conditions. Average temperatures in the wire house were 20±7°C during the day and 12±5°C at night time. The relative humidity was 50% (midday) to 85% (midnight). Light intensity was 350 to 1400 µmol photon m^{-2} s^{-1} depending upon the daily conditions. The methodology of the experiment can be discussed under the following headings.

Preparation of matrix-I

Matrix-I (21% calcium carbide, 58% polyethylene and 21% plaster of paris) was prepared by mixing powdered calcium carbide (about < 200 µm in diameter) and plaster of paris with molten polyethylene in a rotator mixer. After complete mixing matrix was 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. The amount of the oil absorbed by the matrix-I particles was determined by weighing the material before and after dipping into paraffin oil.

Soil preparation and pot filling

The surface soil from 0 to 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 the soil were as follows: pH 7.85; EC_e 2.53 dS m^{-1}; 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 at 12.5 kg pot^{-1} with gentle packing. The pots were arranged according to 4×4 factorials in completely randomized design (CRD) with 4 replications (n = 4).

Seed sowing and fertilizer application

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-leaves stage. Uprooted plants were incorporated in the same pot. Nitrogen (N) phosphorus (P) and potassium (K) were applied at recommended rate of 60-45-30 mg kg^{-1} soil in the form of fertilizers urea, diammonium phosphate (DAP) and sulphate of potash (SOP), respectively. All P, K and half N were added to the soil at sowing time and remaining half dose of N was applied two weeks after germination.

Treatment plan

Calcium carbide in the form of matrix-I was applied two weeks after sowing at 0, 4, 8 and 12 cm soil depth at 0, 7.5, 15 and 22.5 mg kg^{-1} soil with recommended dose of NPK fertilizers. Phosphorus (P) and potassium (K) were applied at a recommended rate of 45 to 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 was applied at 60 mg/kg soil in two splits that is half at sowing time and remaining half dose after two weeks of germination.

Agronomic practices

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.

Data collection

Plant height, total as well as fertile number of tillers, thousand grains weight, biological yield and grain yield were determined by using standard procedures. Nitrogen concentration in wheat straw and grain was determined by using the analytical procedure described by Jackson (1962). Nitrogen uptake was calculated by multiplying nitrogen concentration in wheat straw and grain with their respective yield (Yasin et al., 2006).

RESULTS

Growth and yield parameters

Data regarding effect of rate and application depth of calcium carbide in the form of Matrix-I formulation on plant height (cm) of wheat was presented (Figure 1). A significant reduction in plant height was noted with increasing rate and application depth of calcium carbide. Maximum plant height was observed in the treatments with no calcium carbide (control) or where it was applied at soil surface. Plant height was statistically similar and minimum in treatments where Matrix-I was applied at 15 and 22.5 mg CaC_2 kg^{-1} soil at 8 and 12 cm depth. Rate and application depth of calcium carbide (Matrix-I) affected the number of total (Figure 2) as well as fertile tillers (Figure 3) of wheat. Total number of tillers was significantly increased with increasing rate and application depth of calcium carbide. Statistically, similar and maximum number of tillers was observed in the treatments where calcium carbide was applied at 22.5 or 15 mg kg^{-1} soil at 8 or 12 cm soil depth with NPK fertilizers. Maximum number of fertile tillers was obtained in the treatment of matrix-I at 15 mg CaC_2 kg^{-1} soil applied at 8 cm depth. Compared to this treatment a statistical decrease in number of fertile tillers was observed in treatments where calcium carbide was applied at the same rate but at shallower or greater depths than 8 cm (Figure 3). An overall view of the data indicates that lower rates of calcium carbide applied at greater depths gave almost statistically similar number of fertile tillers to that of higher rates at shallower depths. Total as well as fertile number of tillers did not differ in treatments where CaC_2 was applied at soil surface compared to control having NPK fertilizers alone.

Calcium carbide (matrix-I) application significantly increased thousand grains weight (g) of wheat (Figure 4). Maximum 1,000-grains weight (48.8 g) was observed where calcium carbide was applied at 15 mg kg^{-1} soil at 8 cm depth. Whereas CaC_2 at 7.5 mg kg^{-1} soil at 12 cm depth and 15 or 22.5 mg kg^{-1} soil at 4 cm depth were

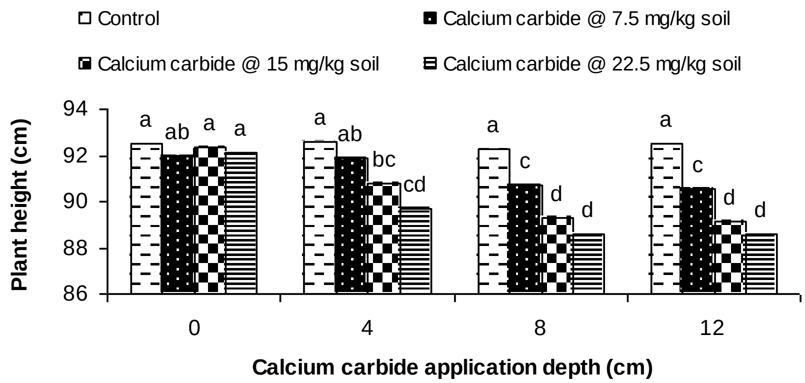

Figure 1. Effect of rate and application depth of calcium carbide (matrix-I) on plant height (cm) of wheat.

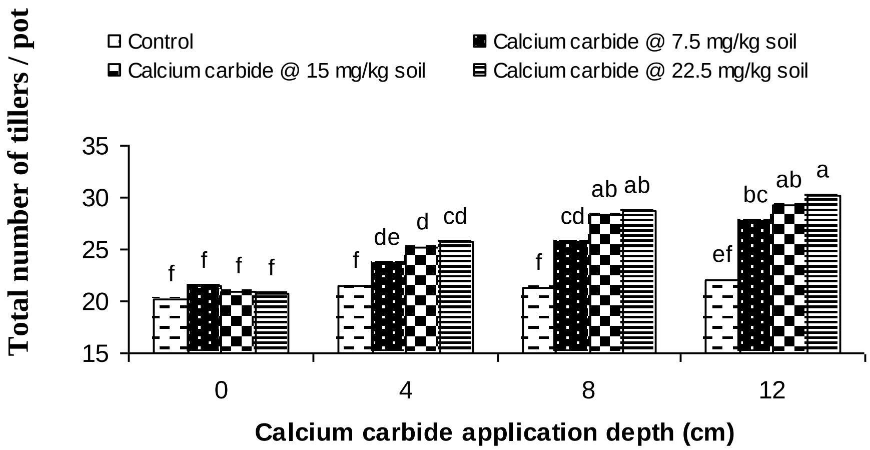

Figure 2. Effect of rate and application depth of calcium carbide (matrix-I) on total number of tillers pot^{-1} of wheat.

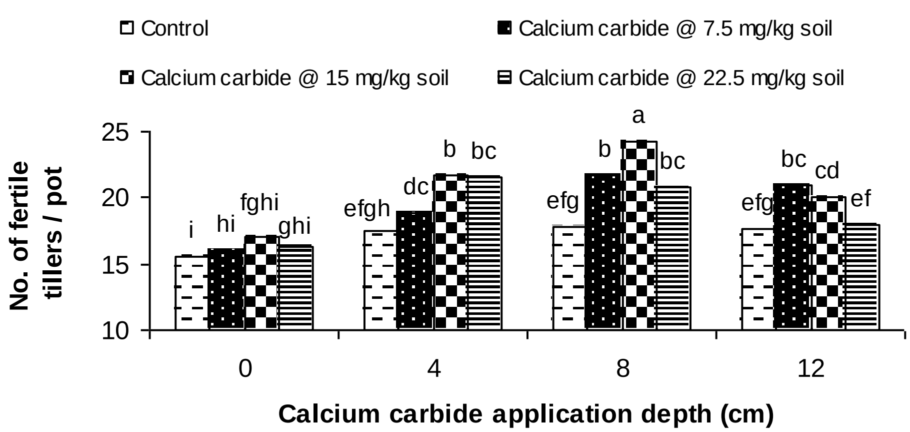

Figure 3. Effect of rate and application depth of calcium carbide (matrix-I) on number of fertile tillers pot^{-1} of wheat.

statistically at par with the treatment where maximum 1,000-grains weight was observed. Calcium carbide application at 22.5 mg kg^{-1} soil at 12 cm depth showed a reduction in 1,000-grains weight compared with its lower

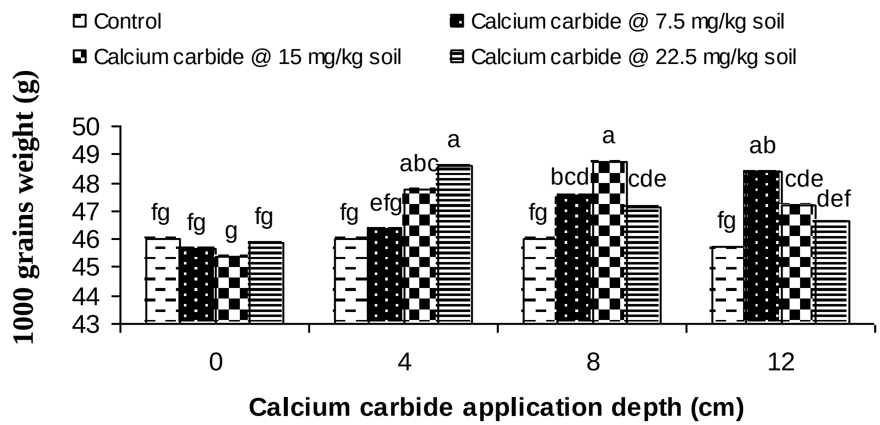

Figure 4. Effect of rate and application depth of calcium carbide (matrix-I) on 1000-grains weight (g) of wheat.

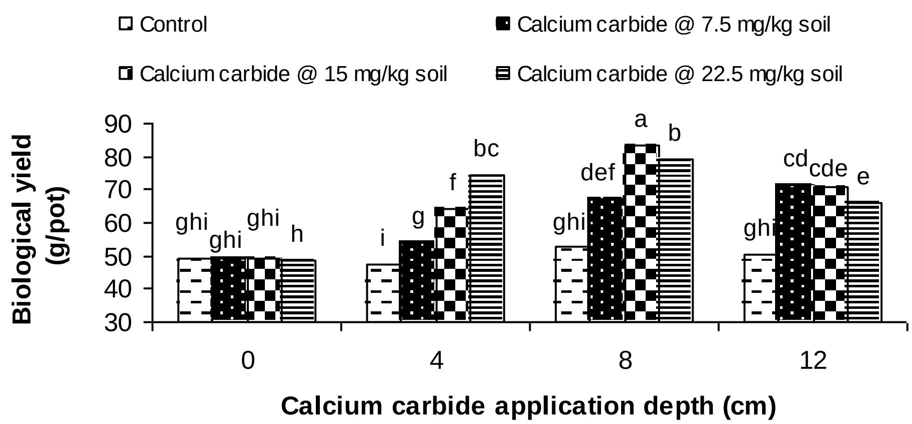

Figure 5. Effect of rate and application depth of calcium carbide (matrix-I) on biological yield (g pot^{-1}) of wheat.

rates at shallower depths. Treatments where calcium carbide was applied at soil surface did not influence 1,000-grains weight in comparison with fertilizer alone. Data regarding effect of rate and application depth of calcium carbide on biological yield (g pot^{-1}) of wheat was presented (Figure 5). It was noted that CaC_2 application significantly enhanced biological yield and maximum biological yield was observed where calcium carbide was applied at 15 mg kg^{-1} soil at 8 cm depth followed by 22.5 mg kg^{-1} soil at 4 or 8 cm depth. A comparative reduction in biological yield of wheat was observed where same rates of calcium carbide was applied at depth greater than 8 cm. Biological yield was not affected where calcium carbide was applied at the soil surface compared to that of control.

Effect of rate and application depth of calcium carbide (matrix-I) on grain yield (g pot^{-1}) of wheat was presented (Figure 6). It is revealed from the data that calcium carbide significantly improved grain yield of wheat when applied with NPK fertilizers. Grain yield was increased with increasing rate and application depth of calcium carbide up to 15 mg kg^{-1} soil and 8 cm depth whereas at higher rate and greater depth, a reduction trend in grain yield was noted. Maximum grain yield was observed in treatment where CaC_2 at 15 mg kg^{-1} soil was applied at 8 cm depth. It was followed by 22.5 mg kg^{-1} soil application at 8 or 4 cm and 7.5 mg kg^{-1} soil application at 12 cm depth. Grain yield in the treatment where calcium carbide was applied at soil surface did not differ from that of NPK alone.

Nitrogen uptake by wheat straw and grains

Data regarding the effect of rate and application depth of calcium carbide (Matrix-I) on nitrogen uptake (g pot^{-1}) of wheat straw and grains was summarized (Figures 7 and 8). Nitrogen uptake in straw and grain increased significantly in the treatments where NPK fertilizers were applied in combination with CaC_2 compared to NPK fertilizer alone. In both plant parts, maximum nitrogen uptake was observed where calcium carbide at 15 or

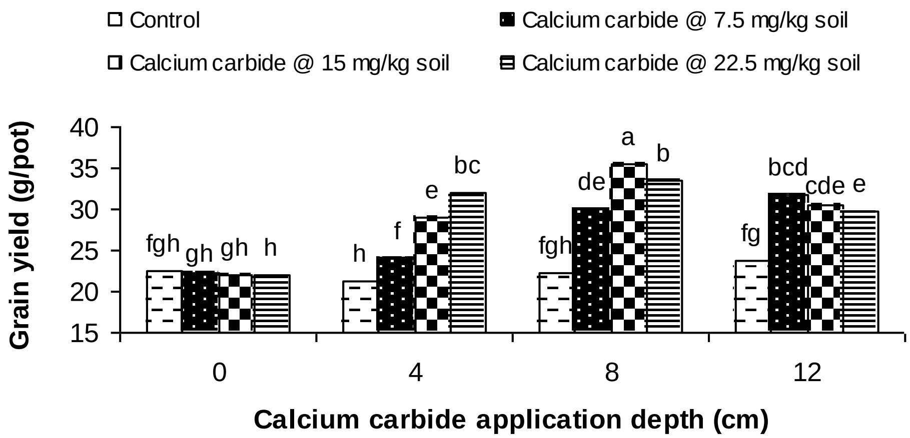

Figure 6. Effect of rate and application depth of calcium carbide (matrix-I) on grain yield (g pot^{-1}) of wheat.

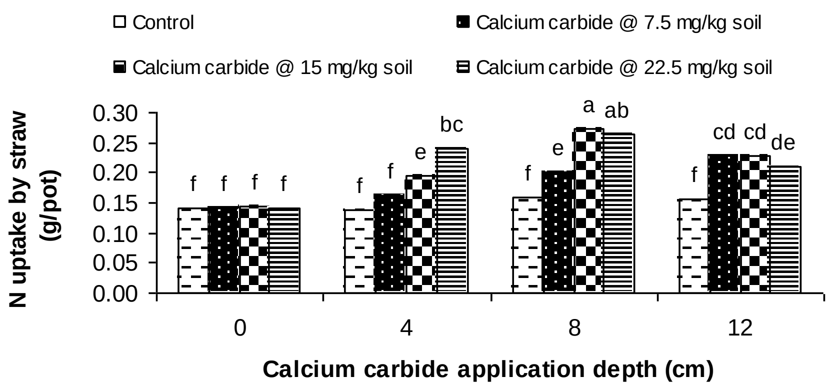

Figure 7. Effect of rate and application depth of calcium carbide (matrix-I) on nitrogen uptake (g pot^{-1}) by wheat straw.

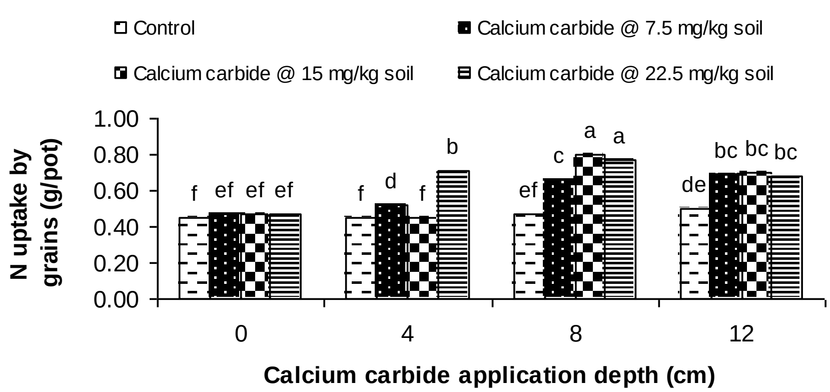

Figure 8. Effect of rate and application depth of calcium carbide (matrix-I) on nitrogen uptake (g pot^{-1}) by wheat grain.

22.5 mg kg^{-1} soil was applied 8 cm deep followed by the treatments where it was added at 22.5 mg kg^{-1} soil at 4 cm soil depth. A reduction in N uptake was noted where calcium carbide was added at 15 or 22.5 mg kg^{-1} soil at 12 cm depth compared with the treatments where it was applied at 8 cm depth. However, a gradual increase in nitrogen uptake by wheat straw and grain was noted with increasing depth of 7.5 mg kg^{-1} soil of calcium carbide.

Compared to NPK alone, surface application of calcium carbide did not show any significant influence on N uptake.

DISCUSSION

Results of this study indicate that application of CaC_2 at right rate and proper soil depth with recommended dose of NPK fertilizers significantly increased grain yield of wheat. It reduced the plant height due to stimulatory effect of ethylene on early root growth. Such responses of plant due to application of ethephon (ethylene releasing liquid compound) on plant root growth and development have already been reported by Cooke et al. (1983). Healthy root growth actively explores more volume of soil and absorbs more nutrients from the soil to enhance tillering. Many workers have reported that production of acetylene/ethylene in rhizosphere stimulates the tillering (Freney et al., 1990; Sharma and Yadav, 1996; Randall et al., 2001; Ahmad et al., 2004). Increase in grain yield of wheat with the application of CaC_2 is attributed to enhance uptake of nutrients by wheat roots. It may be due to increase in root primordia to explore more volume of soil to acquire nutrients (Ahmad et al., 2004). Enhanced N uptake by grains in response to CaC_2 application may be due to nitrification inhibitory effect of acetylene released from applied CaC_2. Inhibition of nitrification process for certain periods helps to maintain applied fertilizer N in plant available form over extended periods of time.

Interaction between rate and application depth of calcium carbide revealed that lower rates of calcium carbide at greater depths benefited the crop production in the similar way as higher rates applied at shallower depths. It is because of the fact that ethylene released from calcium carbide enters the plant body via roots. Increase in application depth of CaC_2 not only allows acetylene to penetrate into greater volume of soil to inhibit nitrification but also increase the root surface area by stimulating root growth for the absorption of nutrients. This activity can improve N economy of soil for greater period and side by side also improve N use efficiency by crop. Production of comparatively less number of fertile tillers with calcium carbide, applied at 22.5 mg kg^{-1} soil at 12 cm depth might be due to the production of excess ethylene in the rhizosphere. Decrease in number of spike bearing tillers per unit area due to excess ethylene accumulation in the soil was also reported by Klassen and Bugbee (2002).

The results obtained, therefore, suggest that application of calcium carbide at the right rate and proper depth could improve growth and yield contributing parameters for improving wheat grain yield. It can be concluded from the aforementioned results that application of CaC_2 at 15 mg kg^{-1} soil at 8 cm depth gave better results regarding all growth and yield parameters of wheat. Therefore, it can be tested further with changing nitrogen fertilizer application rate. This is necessary to improve nitrogen use efficiency by judicious use of N fertilizer.

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