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RESPONSE OF WHEAT TO SOIL APPLIED CALCIUM CARBIDE FOR GROWTH, YIELD AND NITROGEN USE EFFICIENCY

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Abstract

A field experiment was carried out to investigate the effect of soil applied calcium carbide (CaC_2) on growth, yield and nitrogen use efficiency in wheat (*Triticum aestivum* L.). Treatments applied were: T_1 (control), T_2 (CaC_2 @ 60 kg ha^{-1}), T_3 (CaC_2 @ 90 kg ha^{-1}), T_4 (nitrogen @ 60 kg ha^{-1}), T_5 (nitrogen @ 120 kg ha^{-1}) , T_6 (CaC_2 @ 60 kg ha^{-1} + nitrogen @ 60 kg ha^{-1}), T_7 (CaC_2 @ 90 kg ha^{-1} + nitrogen @ 60 kg ha^{-1}), T_8 (CaC_2 @ 60 kg ha^{-1} + nitrogen @ 120 kg ha^{-1}) and T_9 (CaC_2 @ 90 kg ha^{-1} + nitrogen @ 120 kg ha^{-1}). Total number of tillers increased with T_8 and T_9 compared to other treatments while T_9 produced 30% more fertile tillers compared to T_5. Straw yield was significantly increased with application of T_8. Treatment T_9 significantly increased grain yield by 26% over T_5 while T_3 also produced more grain weight than control. Nitrogen uptake by grain and straw were also increased significantly with T_7, T_8 and T_9 over T_1, T_4 and T_5. These results provide information that wheat showed positive response to the application of CaC_2 in combination with nitrogen fertilizer for increase in grain yield as well as nitrogen use efficiency.

Introduction

Nitrogen deficiency in soils of Pakistan is wide spread and it is difficult to maintain nitrogen level as the nitrogen applied in the form of chemical fertilizers undergoes various transformations in the soil e.g., denitrification, volatilization and leaching. Loss of nitrogen through leaching is exclusively due to movement of NO_3 – N with water which is the outcome of nitrification process. Soil exchange complex has abundant negative charge and do not adsorb nitrate ions. This problem can be minimized by decrease in nitrification. Moreover the pressing need of more food from the scarce arable land necessitates the use of high doses of fertilizers, which have already polluted the air and water resources (Aulakh & Bijay-Singh, 1997; Moiser, 1998). Recent research has demonstrated that acetylene is a potent inhibitor of nitrification and growth regulator (Walter *et al*., 1979; Yaseen *et al*., 2006). Soil microbes convert acetylene into ethylene that is involved in regulation of many physiological responses (Abeles *et al*., 1992; Reid, 1995; Arshad & Frankenberger, 2002). Ethylene is involved in almost all developmental processes ranging from germination of seed to senescence of various organs (Lurssen, 1991). Ethylene production occurs naturally in all plant organs including roots, stems, leaves, buds, tubers, bulbs, flowers and seeds (Lieberman *et al*., 1965; Chadwick *et al*., 1986) through its magnitude of production vary. Thus, in some cases ethylene has stimulatory influences while in others it is inhibitory (Arshad & Frankenberger, 2002).

Calcium carbide is a rich source of acetylene when it reacts with water. Acetylene is converted into ethylene either in the soil by soil microorganisms or after absorption in the plant body. It plays non-primary roles by inducing dormancy, flower senescence, leaf expansion and elongation, adventitious root growth, antifreeze activity and wound signaling. The use of encapsulated calcium carbide (slow-release form of ethylene) to inhibit nitrification has shown promising and surprising results especially for wheat varieties (Chen *et al*., 1996; Rashid *et al*., 2007). When water is penetrated by the wax coating, encapsulated calcium carbide (ECC) releases acetylene that inhibits nitrification strongly (Banerjee *et al*., 1990). However the previous studies have shown that ECC creates a low level of acetylene which is adequate to inhibit nitrification (Bronson *et al*., 1992; Yaseen *et al*., 2005). Experimental results showed that growth and yield of wheat were enhanced by the application of calcium carbide and calcium mono hydroxide with the increase in nitrogen use efficiency (Sharma & Yadav, 1996). Keeping this aspect under consideration, the use of CaC_2 can be an innovative approach to improve the growth and yield of wheat. The present study was planned to evaluate the effects of CaC_2 with and without nitrogen on growth and yield of wheat under field conditions.

Materials and Methods

A field experiment was conducted to evaluate the effect of calcium carbide with and without N fertilizer on growth, yield and N use efficiency of wheat. The experiment was conducted at the Research area of Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. Before sowing of the crop, a composite soil sample was taken from 0-15 cm depth and analyzed for physical and chemical soil characteristics. The soil was alkaline, calcareous, poor in organic matter, deficient in available nitrogen and phosphorus and sandy clay loam in texture. The experiment was designed according to completely randomized block design with plot size of 5m x 5m i.e.25 m^2. Each treatment was replicated four times and the set of treatments was T_1 (control), T_2 (Calcium carbide alone @ 60 kg ha^{-1}), T_3 (Calcium carbide alone @ 90 kg ha^{-1}), T_4 (Nitrogen @ 60 kg ha^{-1}), T_5 (Nitrogen @ 120 kg ha^{-1}) , T_6 (CaC_2 @ 60 kg ha^{-1} + Nitrogen @ 60 kg ha^{-1}), T_7 (CaC_2 @ 90 kg ha^{-1} + Nitrogen @ 60 kg ha^{-1}), T_8 (CaC_2 @ 60 kg ha^{-1} + Nitrogen @ 120 kg ha^{-1}) and T_9 (CaC_2 @ 90 kg ha^{-1} + Nitrogen @ 120 kg ha^{-1}).

Wheat cv. Inqlab 91 was sown by broadcast method on 11th of November, 2003. Nitrogen as urea, phosphorous as single super phosphate and potassium as KCl were applied by broadcast method. Half N and full P and K were applied at the time of sowing and half N was applied at tillering stage. Powdered calcium carbide @ 60 and 90 kg ha^{-1} was encapsulated (using medical capsule) and placed in the root zone 4 cm deep in 30cm x 30 cm grid, followed by immediate irrigation with canal water. Calcium carbide was applied after two weeks of germination of wheat seeds.

Wheat crop was harvested on 28th April 2004 and separated into grain and straw. Dried samples of grain and straw were ground and analyzed for nitrogen concentration by following the method of Hu & Barker (1999).

Results and Discussion

Plant height: Maximum plant height was noted where full recommended dose of nitrogen @ 120 kg ha^{-1} (T_5) was applied (Fig. 1). There was 5% decrease in plant height with the application of CaC_2 @ 90 kg ha^{-1} + nitrogen @ 120 kg ha^{-1} (T_9) compared to application of alone full recommended dose of nitrogen (T_5) alone. However it was significantly higher than control. Data also indicate that the highest plant height was observed where recommended dose of N fertilizer was applied (@120 kg ha^{-1}, while it was lowest in control. Encapsulated calcium carbide (ECC) alone or in combination with N fertilizer affected plant height. Decrease in plant height might be due to the reason that CaC_2 stimulated the root growth due to which carbohydrates were translocated towards the roots, which resulted in the reduction of plant height. Sharma & Yadav (1996), Yaseen *et al*., (2005, 2006) reported similar results in different crops. Interaction between applications of CaC_2 and N fertilizer elucidates the consistent influence of CaC_2 on plant growth when compared with control.

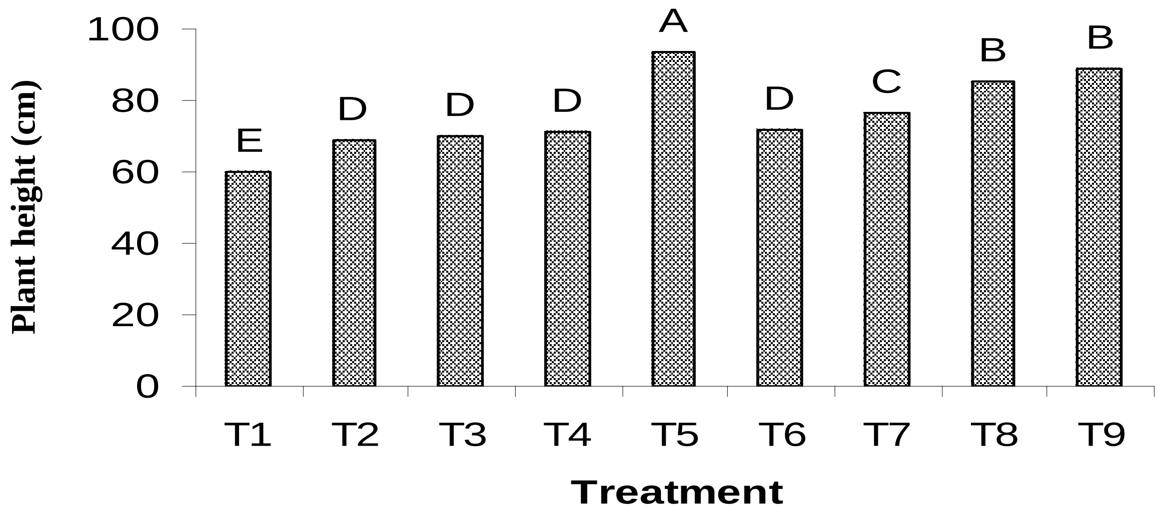

Fig. 1. Effect of differen doses of CaC_2 with and without nitrogen application on plant height of wheat.
T_1 = Control, **T_2** = CaC_2 alone @ 60 kg ha^{-1}, **T_3** = CaC_2 alone @ 90 kg ha^{-1}, **T_4** = N @ of 60 kg ha^{-1}, **T_5** = N @ of 120 kg ha^{-1}, **T_6** = $T_4 + T_2$, **T_7** = $T_4 + T_3$, **T_8** = $T_5 + T_2$, **T_9** = $T_5 + T_3$

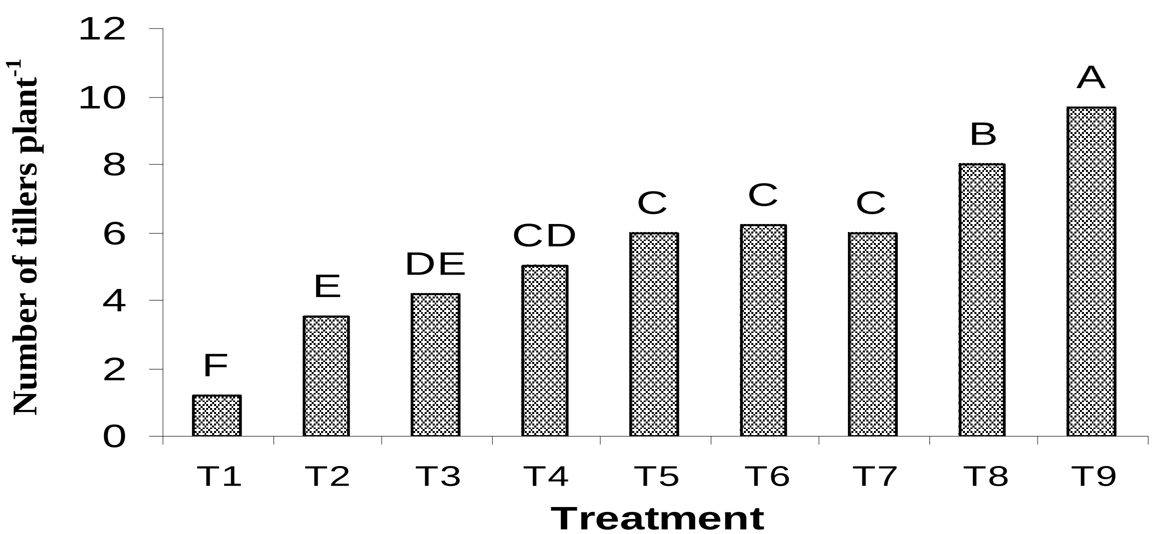

Fig. 2. Effect of different doses of CaC_2 with and without nitrogen application on number of tillers of wheat.
T_1 = Control, **T_2** = CaC_2 alone @ 60 kg ha^{-1}, **T_3** = CaC_2 alone @ 90 kg ha^{-1}, **T_4** = N @ of 60 kg ha^{-1}, **T_5** = N @ of 120 kg ha^{-1}, **T_6** = $T_4 + T_2$, **T_7** = $T_4 + T_3$, **T_8** = $T_5 + T_2$, **T_9** = $T_5 + T_3$

Number of tillers: Application of nitrogen as urea @120 kg ha^{-1} significantly increased the number of tillers per plant over control (Fig. 2). This increase in number of tillers was due to increased nutrition of crop by the application of urea. CaC_2 @ 90 kg ha^{-1} + nitrogen @ 120 kg ha^{-1} produced more significant results compared to full dose of nitrogen alone. There were 19 % more tillers in case of T_6 (CaC_2 @ 60 kg ha^{-1} + nitrogen @ 60 kg ha^{-1}) as compared to T_4 (nitrogen @ 60 kg ha^{-1}) while T_8 (CaC_2 @ 60 kg ha^{-1} + nitrogen @ 120 kg ha^{-1}) yielded 25 % more tillers than T_5 (nitrogen @ 120 kg ha^{-1}). Application of different doses of CaC_2 alone and in combination with nitrogen fertilizer significantly increased the number of tillers $plant^{-1}$. It may be on account of physiological role of CaC_2 as calcium carbide acts as nitrification inhibitor. It may also be due to stimulation of root mass by the conversion of acetylene into ethylene. Walter *et al.*, (1979), Foster *et al.*, (1992), Bronson *et al.*, (1993) and Yaseen *et al.*, (2006) reported similar results.

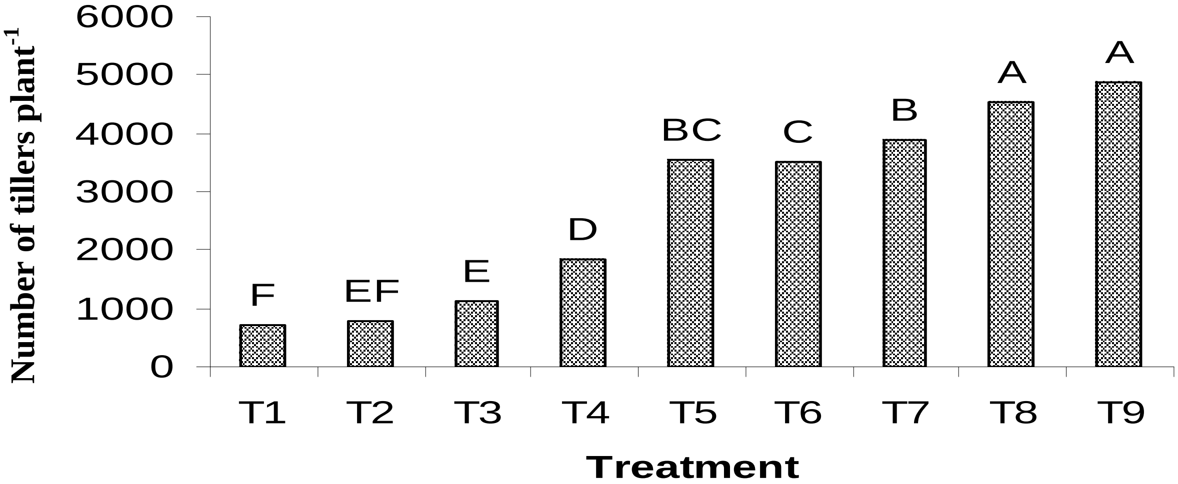

Fig. 3. Effect of different doses of CaC_2 with and without nitrogen application on grain yield of wheat.
$\mathbf{T_1}$ = Control, $\mathbf{T_2}$ = CaC_2 alone @ 60 kg ha^{-1}, $\mathbf{T_3}$ = CaC_2 alone @ 90 kg ha^{-1}, $\mathbf{T_4}$ = N @ of 60 kg ha^{-1}, $\mathbf{T_5}$ = N @ of 120 kg ha^{-1}, $\mathbf{T_6}$ = $T_4 + T_2$, $\mathbf{T_7}$ = $T_4 + T_3$, $\mathbf{T_8}$ = $T_5 + T_2$, $\mathbf{T_9}$ = $T_5 + T_3$

Grain yield: Wheat grain yield was significantly affected by the application of different doses of CaC_2, N fertilizer and the combination of both (Fig. 3). Maximum grain weight (4870 kg ha^{-1}) was recorded in T_9 (ECC @ 90 kg ha^{-1} + nitrogen @ 120 kg ha^{-1}) while control yielded minimum grains (720 kg ha^{-1}). The results indicate that nitrogen @ 120 kg ha^{-1} (T_5) increased grain yield compared to application of nitrogen @ 60 kg ha^{-1} (T_4). It reflects the increase of grain yield with the increase in application of nitrogen fertilizer (Yaseen *et al*., 2004). It means the application of nitrogen fertilizer (urea) significantly influenced grain yield. Analysis of variance indicates that CaC_2 @ 60 and @ 90 kg ha^{-1} interacted with N fertilizer @ 120 kg ha^{-1} and increased grain yield compared to alone N application (T_4 and T_5). Significant increase in grain yield (4550 kg ha^{-1} to 4870 kg ha^{-1}) with T_8 (CaC_2 @ 60 kg ha^{-1} plus N @ 120 kg ha^{-1}) and T_9 (ECC @ 90 kg ha^{-1} + nitrogen @ 120 kg ha^{-1}) clearly showed the influence of CaC_2 on grain yield. The consistent increase in grain yield from T_6 to T_9 proves the vital role of calcium carbide. The increased grain yield by the application of CaC_2 may be attributed to more uptakes of nutrients by wheat plants on account of three reasons: 1) Calcium carbide to inhibits and slows down the process of nitrification which results in reduction of nitrogen losses and ensures N availability to plants for a prolonged period of time to meet the needs and liabilities of the plants to form more proteins. 2) It releases ethylene which is responsible for root elongation, better and rapid uptake of nutrients to increase the total number of grains. 3) Calcium carbide enhances the number of fertile tillers and grain yield. These results are also in line with the findings of Chen *et al*., (1996), Sharma & Yadav (1996), Freney *et al*., (2000), Mahmood *et al*., (2002) and Yaseen *et al*., (2004, 2005) in different crops.

Straw yield: Straw yield was affected significantly by the application of CaC_2 and N fertilizer alone as well as the combination of both. Maximum straw weight (5330 kg ha^{-1}) was recorded with T_8 (CaC_2 @ 60 kg ha^{-1} plus N @ 120 kg ha^{-1}) while the minimum straw weight (1030 kg ha^{-1}) was recorded in control (Fig. 4). Nitrogen fertilizer and calcium carbide interaction increased the straw weight due to stimulatory effect of CaC_2 on number of tillers to enhance plant biomass in the presence of available form of N i.e. NH_4^+ for longer period. Results show that application of calcium carbide was involved in the increase of growth processes of wheat. These results are in agreement with the findings of Sharma & Yadav (1996), Freney *et al*., (2000) and Yaseen *et al*., (2005, 2006). They reported increase in plant biomass in rice, wheat and cotton as a result of application of CaC_2 plus N fertilizer.

Nitrogen uptake by grain: Maximum nitrogen uptake by grains was observed in T_9 (CaC_2 @ 90 kg ha^{-1} + Nitrogen @ 120 kg ha^{-1}) and minimum in control (Fig. 5). This increase in N uptake may be due to greater ability of plant to develop root system and presence of nitrogen in available forms in the growth medium. Graphical presentation of data shows that interaction between CaC_2 and nitrogen fertilizer significantly affected nitrogen uptake by grain (119.5 kg ha^{-1}) over fertilizer application alone. Data elucidates that CaC_2 application @ 90 kg ha^{-1} in combination with full dose of nitrogen fertilizer (T_9) increased nitrogen uptake compared to fertilizer application alone. Similar trend was noted with T_7 (CaC_2 @ 90 kg ha^{-1}+Nitrogen @ 60 kg ha^{-1}). Nitrogen @ 120 kg ha^{-1} (T_5) had dominant effect over control in increasing the nitrogen uptake by grains. CaC_2 @ 60 kg ha^{-1}+Nitrogen @ 60 kg ha^{-1}(T_6) exhibits 48 % more N uptake by grains as compared to T_4 (Nitrogen @ 60 kg ha^{-1}). There is also 55 % increase in N uptake by grains in T_7 (CaC_2 @ 90 kg ha^{-1} + Nitrogen @ 60 kg ha^{-1}) compared to T_5 (Nitrogen @ 120 kg ha^{-1}). Similarly T_8 (CaC_2 @ 60 kg ha^{-1}+Nitrogen @ 120 kg ha^{-1}) and T_9 (CaC_2 @ 90 kg ha^{-1}+Nitrogen @ 120 kg ha^{-1}) also exhibited 23 % and 33 % increase in N uptake by grains compared to T_5 (Nitrogen @ 120 kg ha^{-1}). This increase of N uptake by grains showed positive role of calcium carbide application on the growth of wheat crop. Freney *et al*., (2000), Rajala *et al*., (2002), Mahmood *et al*., (2002) and Yaseen *et al*., (2006) reported significant increase in N uptake by grain with the application of CaC_2 with fertilizer to different crops.

Nitrogen uptake by straw: Nitrogen uptake by wheat straw was significantly affected by the application of CaC_2 alone, nitrogen fertilizer alone and the combination of both (Fig. 6). Maximum nitrogen uptake was observed in T_9 (CaC_2 @ 90 kg ha^{-1} + Nitrogen @ 120 kg ha^{-1}) and minimum in the control. All the treatments show higher uptake of N compared to control. This increase in N uptake may be due to the availability of nitrogen from soil for a longer time. Graphical illustration of data shows that application of CaC_2 plus nitrogen fertilizer had significant effect on nitrogen uptake by straw compared to application of CaC_2 or fertilizer alone. Indeed, application of N fertilizer @ 120 kg ha^{-1} significantly increased nitrogen uptake by wheat straw (31.8 kg ha^{-1}). Although T_9 (CaC_2 @ 90 kg ha^{-1}+Nitrogen @ 120 kg ha^{-1}) enhanced nitrogen uptake yet it was statistically at par with T_5 (Nitrogen @ 120 kg ha^{-1}). These results clearly demonstrate that CaC_2 application significantly enhanced N use efficiency by minimizing N losses. Sharma & Yadav (1996), Keerthisinghe *et al*., (1996), Freney *et al*., (2000), Mahmood *et al*., (2002) and Yaseen *et al*., (2006) reported increase in availability of nitrogen in the growth medium that in turn resulted in high N uptake.

Nitrogen use efficiency: Addition of different doses of CaC_2 with half and recommended dose of N fertilizer for wheat showed very prominent influence of CaC_2 on the use of nitrogen in the grain. The values for nitrogen use efficiency are calculated from N uptake values. Application of N @ 60 and 120 kg ha^{-1} alone increased N use in grain by 34.2 and 59.7 %, respectively. However, addition of CaC_2 @ 60 and 90 kg ha^{-1} with 60 kg ha^{-1} N improved N use in grain to 98.3 and 115.0 %, respectively. Similarly, N use was improved to 80.2 and 93.2 %, respectively, with 120 kg ha^{-1} N. These results showed tremendous effect of CaC_2 on N economy of soil as well as its use in plant particularly in grain. Yaseen *et al*., (2006) and Rashid *et al*., (2007) reported increase in N use efficiency in wheat under similar conditions.

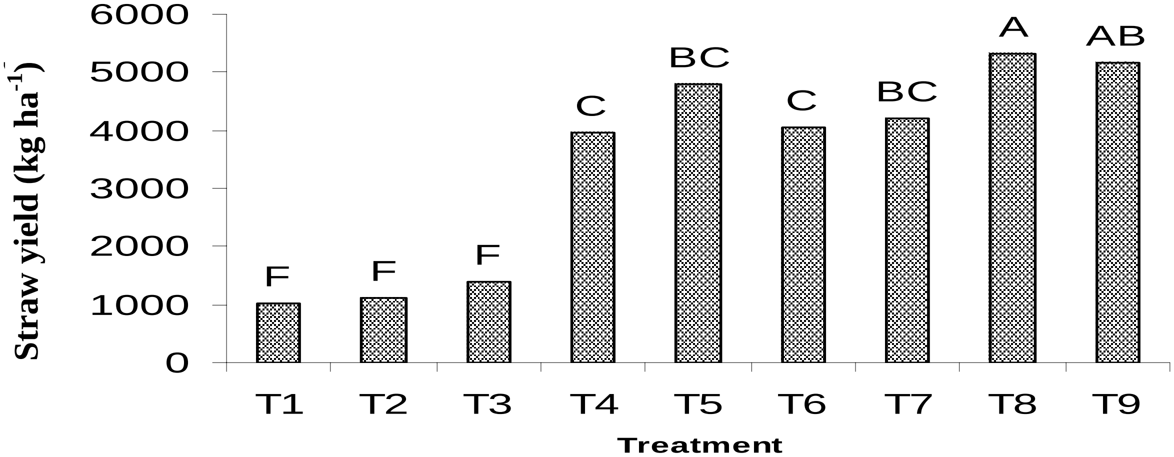

Fig. 4. Effect of different doses of CaC_2 with and without nitrogen application on straw weight of wheat.
T_1 = Control, **T_2** = CaC_2 alone @ 60 kg ha^{-1}, **T_3** = CaC_2 alone @ 90 kg ha^{-1}, **T_4** = N @ of 60 kg ha^{-1}, **T_5** = N @ of 120 kg ha^{-1}, **T_6** = T_4 + T_2, **T_7** = T_4 +T_3, **T_8** = T_5 + T_2, **T_9** = T_5 + T_3

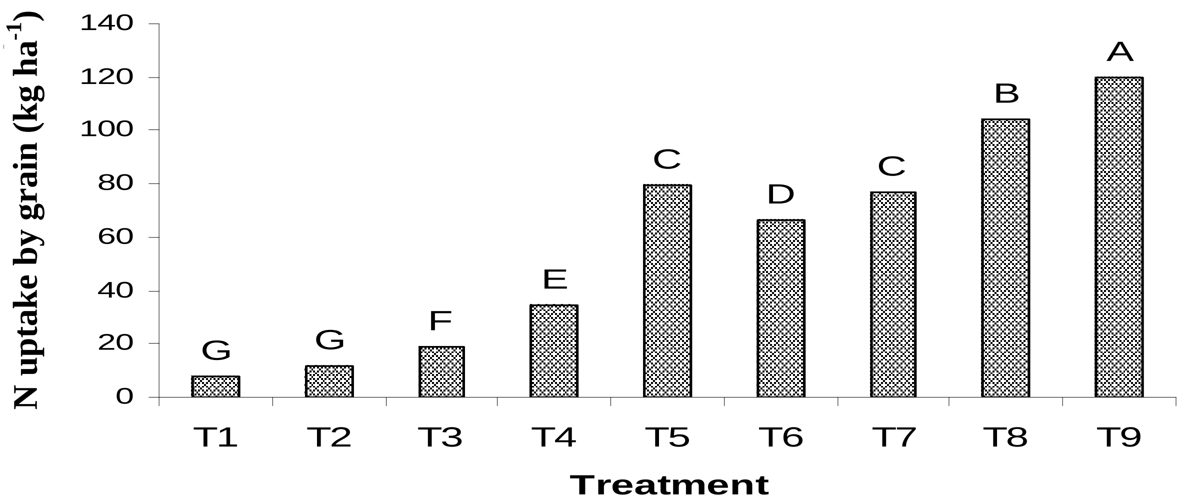

Fig. 5. Effect of different doses of CaC_2 with and without nitrogen application on nitrogen uptake by wheat grain.
T_1 = Control, **T_2** = CaC_2 alone @ 60 kg ha^{-1}, **T_3** = CaC_2 alone @ 90 kg ha^{-1}, **T_4** = N @ of 60 kg ha^{-1}, **T_5** = N @ of 120 kg ha^{-1}, **T_6** = T_4 + T_2, **T_7** = T_4 +T_3, **T_8** = T_5 + T_2, **T_9** = T_5 + T_3

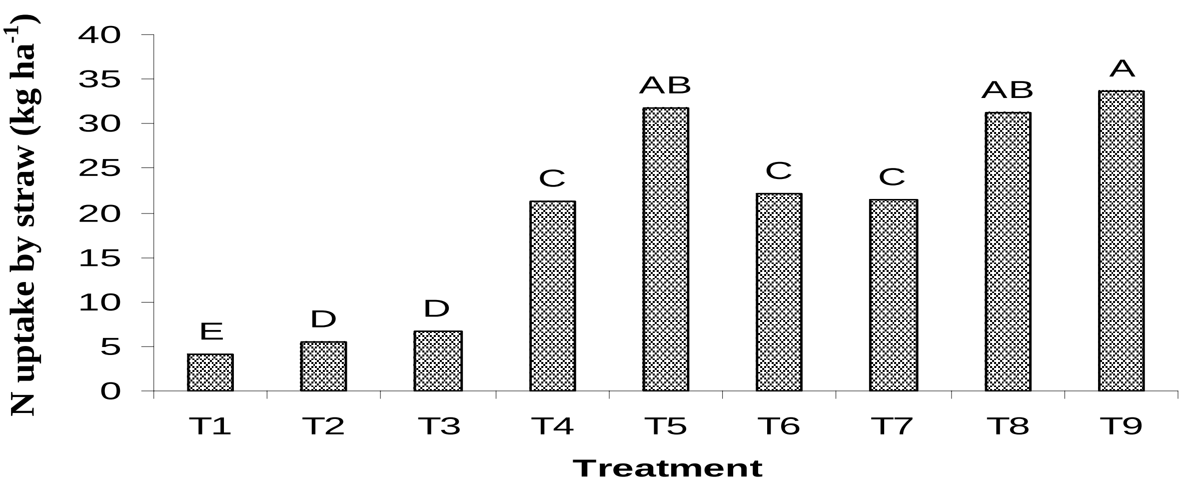

Fig. 6. Effect of different doses of CaC_2 with and without nitrogen application on nitrogen uptake by wheat straw.
T_1 = Control, **T_2** = CaC_2 alone @ 60 kg ha^{-1}, **T_3** = CaC_2 alone @ 90 kg ha^{-1}, **T_4** = N @ of 60 kg ha^{-1}, **T_5** = N @ of 120 kg ha^{-1}, **T_6** = T_4 + T_2, **T_7** = T_4 +T_3, **T_8** = T_5 + T_2, **T_9** = T_5 + T_3

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