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EFFECT OF RATE AND TIME OF APPLICATION OF ENCAPSULATED CALCIUM CARBIDE ON GROWTH AND N UPTAKE OF WHEAT

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A pot experiment was conducted in the wire-house to determine appropriate rate and time of application of calcium carbide (CaC_2) for wheat (*Triticum aestivum* L., var. inqlab 91). CaC_2 was applied @ 30, 60, 90 and 120 kg ha^{-1} with and without NPK fertilizers @ 120-90-60 kg ha^{-1} at three times i.e. sowing, 2 and 4 weeks after sowing. Number of tillers, root dry weight, 1000-grain weight, grain yield, straw yield and N uptake were significantly increased by the application of CaC_2 plus NPK compared to NPK fertilizer alone and control. Results indicated that application of CaC_2 @ 60 kg ha^{-1} seemed appropriate rate as maximum number of tillers, root weight, grain yield and N uptake were obtained by this rate while application of CaC_2 two weeks after sowing appeared as best time of application. Results also indicated that CaC_2 increased the grain yield by influencing the yield contributing parameters through changing the growth pattern and better acquisition of nutrients, which is a typical characteristic of acetylene/ ethylene released from CaC_2.
Key words: Wheat, Calcium carbide, Ethylene, Rate and time of application, N uptake.

INTRODUCTION

Soil applied nitrogen undergoes various transformations such as volatilization, nitrification, denitrification and leaching etc. These transformations result in poor N recovery that seldom exceeds 40% under flooded and un-flooded conditions (Sharma and Yadav, 1996). Generally nitrogen applied as broadcast on the soil surface is volatilized. The extent of various N losses is up to 70% in alkaline and calcareous soils (Buresh et al., 1993; Hazarik and Sarkar, 1996). The same is case of Pakistani soils. Incorporating N fertilizer deep into soil instead of broadcast minimizes ammonia volatilization (Keerthisinghe et al., 1996). However, incorporation of nitrogen fertilizer into the soil converts NH_4-N into NO_3-N by nitrification process. Nitrate being anion either leaches down or denitrifies into N_2O or N_2. Thus these all conversions reduce the time of N stay in soil that leads to more N losses and thus results in poor nitrogen recovery efficiency (Keerthisinghe et al., 1996; Sharma and Yadav, 1996). Being a source of acetylene (C_2H_2), CaC_2 is considered a powerful nitrification inhibitor because it inhibits the *Nitrosomonas* activity that converts NH_4^+ into NO_3^- (Banerjee et al., 1990; Freney et al., 1990; Randall et al., 2001). Many studies indicate that CaC_2 can effectively inhibitor oxidation of NH^+_4 into NO^-_3 under both flood and non-flood soil conditions (Banerjee et al., 1990; Freney et al., 1990; Keerthisinghe et al., 1996; Sharma and Yadav, 1996; Randall et al., 2001; Ahmad et al., 2004). Moreover acetylene released from CaC_2 is converted into plant hormone ethylene (C_2H_4) by soil microorganisms (Muromtsev et al., 1988; Lurssen 1991; Arshad and Frankenberger, 2002). C_2H_4 plays major role in growth and development processes of plants by stimulating germination shoot and root growth and early crop maturity (Arshad and Frankenberger, 2002). So both C_2H_2 and C_2H_4 may be regarded as potent nitrification inhibitor and growth stimulator (Freney et al., 1990; Arshad and Frankenberger 2002). However, question may arise, how much CaC_2 should be used and what should be appropriate time of application when C_2H_2/C_2H_4 released from CaC_2 has optimal influence on nitrification/plant growth. In this study difference doses of CaC_2 were applied at different times to study influence of CaC_2 on growth and yield of wheat.

MATERIALS AND METHODS

A pot experiment was conducted to evaluate the effect of rate and time of application of encapsulated calcium carbide (CaC_2) on growth and N uptake by wheat. The experiment was conducted in wire house, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. The soil used was collected from surface soil layer of 15cm. The soil was sandy clay loam in texture. Some other properties of this soil was as follows: pH 7.7; EC_e 1.16dS m^{-1}; organic matter contents 0.88% and total N contents 0.05%. Soil was mixed thoroughly, ground, passed through 2mm sieve and added in polythene lined earthen pots @ 12 kg per pot. Pots were placed according to completely randomized design in four replicates. The set of treatments were as follows: control; NPK fertilizers @ 120-90-60 kg ha^{-1}; NPK + CaC_2 @ 30 kg ha^{-1}; NPK + CaC_2 @ 60 kg ha^{-1}; NPK + CaC_2 @ 90 kg ha^{-1} and NPK + CaC_2 @ 120 kg ha^{-1} Times of application of CaC_2 were at sowing time, and two and four weeks after sowing of wheat.

Encapsulation of CaC_2

Stones of CaC_2 were ground in pestle and mortal. The required weight of CaC_2 was filled in protein covering (Capsules). Each capsule contained approximately 0.375g ground CaC_2. The objective of encapsulation was just to place CaC_2 safely in soil at required soil depth.

Application of treatment

Wheat cv. Inqlab 91 was sown on 15th of November. Five plants were maintained in each pot. Nitrogen as urea, P_2O_5 as SSP and K_2O as KCl were applied. Half N and full P_2O_5 and K_2O were applied at sowing time while other half N at tillering stage. Encapsulated CaC_2 were placed at 4cm depth in the centre of pot followed by irrigation with canal water. Moisture was maintained approximately at 60% throughout the experiment till grain formation stage. At booting, plant height, number of fertile tiller and leaf area of 3rd fully matured leaf from the top, were measured. At maturity crop was harvested on 20th April. Weights of grain and straw samples were recorded. The whole earthen boll of each pot was taken out and washed under tap water gently to separate roots.

Plant analysis

Grain and straw samples were dried and ground to determine total nitrogen in these samples by Hu and 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 grain or straw with grain or straw yield.

Data analysis

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

RESULTS AND DISCUSSION

Results

Effect of CaC_2 regarding rate and time of application was determined on plant height, leaf area, number of tillers, root dry weight, total biomass, straw and grain yields, and nitrogen (N) concentration and uptake in straw and grains of wheat. Plant height (cm) was compared 90 days after sowing in pots treated with and without CaC_2 applied at sowing, 2 weeks and 4 weeks after sowing. Significant effect of rate and time of application of CaC_2 on plant height was noted (Fig. 1). Maximum plant height (76.40 cm) was observed where fertilizers were applied. It was followed by the treatment where CaC_2 was applied @ 30 kg ha^{-1} with fertilizer at sowing time. Minimum plant height (70.15 cm) was observed in the control. Results indicated that plant height increased with the application of NPK fertilizer however, it reduced significantly when higher doses of CaC_2 were applied in NPK fertilized pots. Among time of application treatments, minimum plant height was observed where CaC_2 was applied 2 weeks after sowing.

Maximum average number of tillers pot^{-1} was observed where CaC_2 was applied @ 60 kg ha^{-1} 2 weeks after sowing (Fig.2) and increase in tillers was more than 23 % compared to alone NPK fertilizer. Results indicated that application of CaC_2 2 weeks after sowing gave relatively better results compared to other two times of application perhaps roots were emerged out and fully respond to CaC_2 at this growth stage.

Leaf area increased with application of NPK fertilizer compared to control. Maximum leaf area was noted in pots treated with CaC_2 @ 90 kg ha^{-1} and where CaC_2 was applied 2 weeks after sowing (Fig. 3). This might be due rapid cell division and elongation in leaf.

Data (Table 1) revealed stimulatory effect of CaC_2 on root weight. All the CaC_2 application rates increased the root dry weight compared to fertilizer and control treatments. Maximum root dry weight was observed where CaC_2 was applied @ 60 kg ha^{-1} with NPK fertilizer 2 weeks after sowing. Among the time of application of CaC_2 treatments, CaC_2 application at sowing and 2 weeks after sowing produced almost similar root dry matter.

Maximum average total yield (Straw + grain) was observed where CaC_2 was applied @ 60 kg ha^{-1} 2 weeks after sowing of wheat. It was followed by 90, 120 and 30 kg ha^{-1} CaC_2, respectively (Fig. 4). Maximum straw yield was observed where CaC_2 was applied @ 90 kg ha^{-1}along with NPK fertilizer. However, all the CaC_2 rates and time of application of CaC_2 did not show any significant effect on straw yield (Fig. 5). Increase in grain yield was noted by the application of fertilizer compared to control however, fertilizer influence became more pronounced with the addition of CaC_2. Data in Table 2 clearly showed the increase in grain yield pot^{-1} due to CaC_2 application. All the CaC_2 application rates increased grain yield significantly compared to fertilizer alone. Maximum grain yield was observed where CaC_2 was applied @ 60 kg ha^{-1}. Increase in grain yield due to addition of different rates of CaC_2 varied from 13 to 36 % over alone NPK fertilizers application. Results revealed that 60 kg ha^{-1} CaC_2 is the best rate and 2 weeks after sowing is the best time of application.

Thousand grains weight was highest in the treatment where CaC_2 was applied @ 120 kg $ha^{-1}$with fertilizers 2 weeks after sowing. It was statistically followed by 60 kg ha^{-1} CaC_2 application rate at sowing time (Fig. 6). It is evident from the results that CaC_2 application with fertilizer increased grain number and weight compared to fertilizer alone and control.

Nitrogen concentration in wheat straw was not much affected by CaC_2 (Table 3), however CaC_2 application showed significant contribution to increase the N concentration in grains compared to fertilizer. All the CaC_2 application rates showed statistically similar N concentration in grain (Table 5). No effect was visualized by time of application of CaC_2. However, CaC_2 @ 60, 90 and 120 kg ha^{-1} significantly increased the N uptake by straw than 30 kg ha^{-1} CaC_2 application at sowing time and fertilizer alone (Table 4). Maximum N uptake by grain was observed by application of 60 and 90 kg ha^{-1} CaC_2 2 weeks after sowing. Results also indicate that CaC_2 application 2 weeks after sowing increased the N uptake by grain which decreased with increase in CaC_2 application after 60 kg ha^{-1}(Table 6).

Discussion

Calcium carbide releases nitrification inhibitor acetylene that is converted into plant hormone ethylene (Muromtsev et al. 1988; Arshad and Frankenberger, 2002), both gases had pronounced influence on pant 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). Results of this study indicate that application of CaC_2 at appropriate rate and optimum time with recommended doses of NPK fertilizers significantly increased grain yield of wheat. It reduced the plant height due to stimulatory effect of ethylene on early root growth. Healthy root growth actively absorbed more nutrients from the soil to enhance tillering. Many workers have already reported that production of acetylene/ethylene in rihzosphere stimulates the tillering (Freney et al. 1990; Sharma and Yadav, 1996; Randall et al. 2001; Ahmad et al. 2004). Application of CaC_2 @ 60 kg ha^{-1} with fertilizer increased 23 % tillers over fertilizer is evident of role of ethylene on tillering. Sharma and Yadav (1996) also reported increased tillering in wheat with CaC_2 application.

Increased yield of wheat grain with the application of CaC_2 is attributed to enhanced uptake of nutrients by wheat due to production of ethylene from CaC_2. It may be due to increase in root primordia to explore more volume of soil to acquire nutrients (Ahmad et al., 2004). The influence of nutrients on crop growth is well documented. Enhanced N uptake by grain due to CaC_2 application in this study is evident as application of CaC_2 @ 60 kg ha^{-1}increased the grain yield by 36% than that of fertilizer. This may be due to nitrification inhibitory effect of acetylene released from CaC_2 that might maintain fertilizer N in plant available form of N as NH_4 over extended periods of time.

Interaction between rate and time of CaC_2 applications revealed that application of CaC_2 2 weeks after sowing provided better results compared to two other times of application. These results elucidate that acetylene/ ethylene could stimulate root growth better at this time as roots have already emerged out from seed and could be better stimulated by CaC_2 itself or gases released from it. Moreover CaC_2 also releases Ca which is useful for root growth. Therefore enhanced availability of Ca is also reported to improve the uptake and assimilation of NO_3, thereby suggesting another benefit of the use of CaC_2.

Table 1. Effect of rate and time of application of encapsulated CaC_2 on root dry weight (g)

Treatment	Time of application of CaC_2			Mean
	Sowing time	Two weeks after sowing	Four weeks after sowing	
Control	2.67 e	2.67 d	2.67 a	2.67 E
Fertilizer alone	4.32 d	4.32 c	4.32 a	4.32 D
Fertilizer + CaC_2 @ 30 kg ha^{-1}	5.52 c	5.24 b	4.33 a	5.03 C
Fertilizer + CaC_2 @ 60 kg ha^{-1}	6.75 ab	6.65 a	5.08 a	6.13 A
Fertilizer + CaC_2 @ 90 kg ha^{-1}	5.91 bc	5.78 ab	5.05 a	5.58 B
Fertilizer + CaC_2 @ 120 kg ha^{-1}	7.07 a	5.76 ab	4.81 a	5.88 AB
Mean	5.73 A	5.05 A	4.38 B	

Figure in the same column with different letter(s) differ significantly ($P <= 0.05$) by DMRT
* Fertilizer (N-P-K) = 120-90-60 kg ha^{-1}

Table 2. Effect of rate and time of application of encapsulated CaC_2 on grain yield pot^{-1}

Treatment	Time of application of CaC_2			Mean	% increase in grain yield over fertilizer
	Sowing time	Two weeks after sowing	Four weeks after sowing		
Control	14.67 c	14.67 d	14.67 d	14.67 E	-
Fertilizer alone	21.00 b	21.00 c	21.00 bc	21.00 D	-
Fertilizer + CaC_2 @ 30 kg ha^{-1}	23.40 ab	27.03 b	20.47 c	23.63 C	12.52
Fertilizer + CaC_2 @ 60 kg ha^{-1}	26.35 a	34.26 a	24.97 a	28.53 A	35.85
Fertilizer + CaC_2 @ 90 kg ha^{-1}	24.24 ab	30.39	24.56 ab	26.40 B	25.71
Fertilizer + CaC_2 @ 120 kg ha^{-1}	22.03 b	26.93 b	23.03 abc	24.00 C	14.28
Mean	21.95 B	25.71 A	21.45 B		

Figure in the same column with different letter(s) differ significantly (P <= 0.05) by DMRT
* Fertilizer (N-P-K) = 120-90-60 kg ha^{-1}

Table 3. Effect of rate and time of application of encapsulated CaC_2 on nitrogen concentration in straw (%)

Treatment	Time of application of CaC_2			Mean
	Sowing time	Two weeks after sowing	Four weeks after sowing	
Control	0.46 c	0.46 b	0.46 c	0.46 C
Fertilizer alone	0.70 b	0.70 a	0.70 b	0.70 B
Fertilizer + CaC_2 @ 30 kg ha^{-1}	0.70 b	0.40 a	0.70 b	0.70 B
Fertilizer + CaC_2 @ 60 kg ha^{-1}	0.70 b	0.70 a	0.74 b	0.71 B
Fertilizer + CaC_2 @ 90 kg ha^{-1}	0.81 a	0.70 a	0.70 b	0.74 B
Fertilizer + CaC_2 @ 120 kg ha^{-1}	0.84 a	0.70 a	0.71 a	0.78 A
Mean	0.70 A	0.66B	0.68 AB	

Figure in the same column with different letter(s) differ significantly (P <= 0.05) by DMRT
* Fertilizer (N-P-K) = 120-90-60 kg ha^{-1}

Table 4. Effect of rate and time of application of encapsulated CaC_2 on nitrogen uptake by straw (mg pot^{-1})

Treatment	Time of application of CaC_2			Mean
	Sowing time	Two weeks after sowing	Four weeks after sowing	
Control	85.58 c	85.58 c	85.58 c	85.58 C
Fertilizer alone	239.42 b	239.42 b	239.42 b	239.42 B
Fertilizer + CaC_2 @ 30 kg ha^{-1}	246.91 b	235.13 b	244.11 b	242.05 B
Fertilizer + CaC_2 @ 60 kg ha^{-1}	241.03 b	294.93 a	270.01 ab	268.66 A
Fertilizer + CaC_2 @ 90 kg ha^{-1}	317.87 a	272.40 ab	252.96 ab	281.08 A
Fertilizer + CaC_2 @ 120 kg ha^{-1}	310.34 a	249.15 ab	294.07 a	284.52 A
Mean	240.17	229.43	231.03	

Figure in the same column with different letter(s) differ significantly (P <= 0.05) by DMRT
* Fertilizer (N-P-K) = 120-90-60 kg ha^{-1}

Table 5. Effect of rate and time of application of encapsulated CaC_2 on nitrogen concentration in grains (%)

Treatment	Time of application of CaC_2			Mean
	Sowing time	Two weeks after sowing	Four weeks after sowing	
Control	1.71	1.71 ·	1.71	1.71 C
Fertilizer alone	2.76	2.76	2.76	2.76 B
Fertilizer + CaC_2 @ 30 kg ha^{-1}	2.97	2.83	3.08	2.96 A
Fertilizer + CaC_2 @ 60 kg ha^{-1}	2.87	2.94	2.97	2.93 A
Fertilizer + CaC_2 @ 90 kg ha^{-1}	2.90	2.97	3.01	2.96 A
Fertilizer + CaC_2 @ 120 kg ha^{-1}	2.94	3.01	3.08	3.01 A
Mean	2.69	2.70	2.77	

Figure in the same column with different letter(s) differ significantly ($P <= 0.05$) by DMRT
* Fertilizer (N-P-K) = 120-90-60 kg ha^{-1}

Table 6. Effect of rate and time of application of encapsulated CaC_2 on nitrogen uptake by grains (mg pot^{-1})

Treatment	Time of application of CaC_2			Mean
	Sowing time	Two weeks after sowing	Four weeks after sowing	
Control	294.98 c	249.98 e	249.98 c	249.98 D
Fertilizer alone	585.22 b	585.22 d	585.22 b	585.22 C
Fertilizer + CaC_2 @ 30 kg ha^{-1}	694.45 a	767.64 c	603.70 b	688.60 B
Fertilizer + CaC_2 @ 60 kg ha^{-1}	753.19 a	1007.32 a	741.67 a	834.06 A
Fertilizer + CaC_2 @ 90 kg ha^{-1}	702.79 a	907.92 ab	740.57 a	783.67 A
Fertilizer + CaC_2 @ 120 kg ha^{-1}	647.07 ab	808.13 ab	709.73 a	721.64 B
Mean	605.45 B	721.03 A	605.14 B	

Figure in the same column with different letter(s) differ significantly ($P <= 0.05$) by DMRT
* Fertilizer (N-P-K) = 120-90-60 kg ha^{-1}

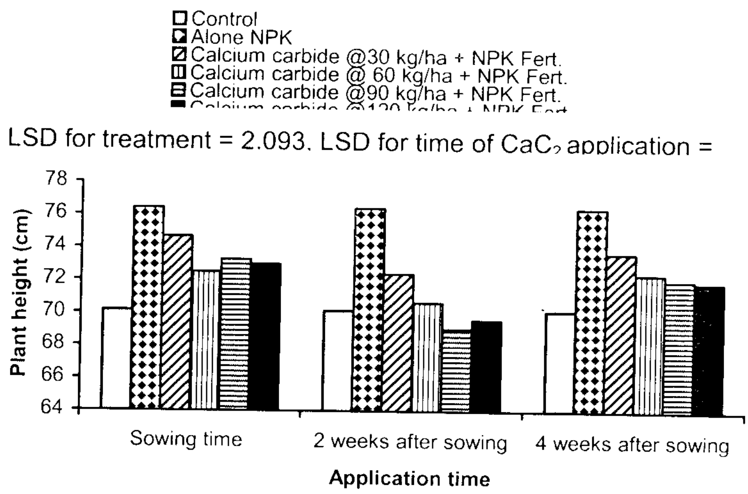

Fig. 1. Effect of rate and time of application of CaC_2 on plant

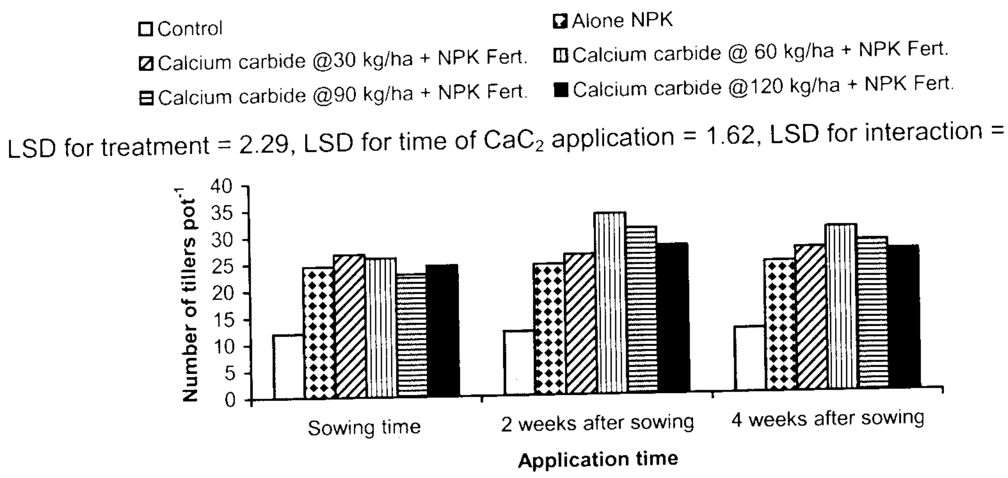

Fig.2. Effect of rate and time of application of CaC_2 on tillers

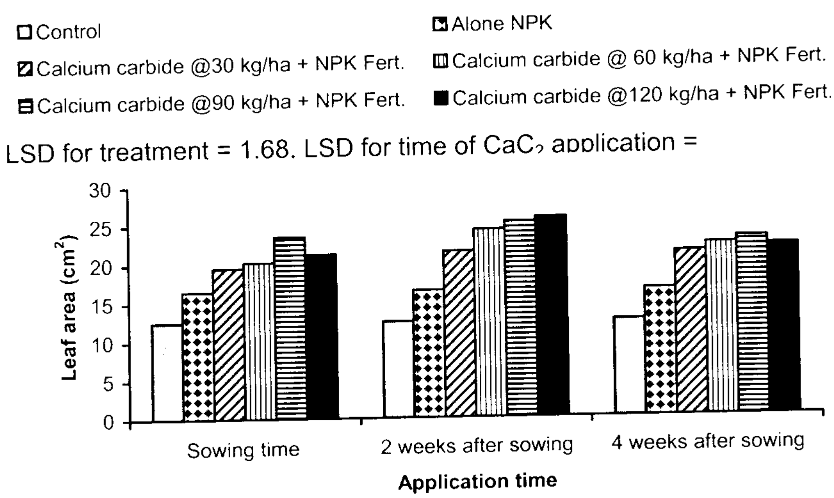

Fig.3. Effect of rate and time of application of CaC_2 on leaf area

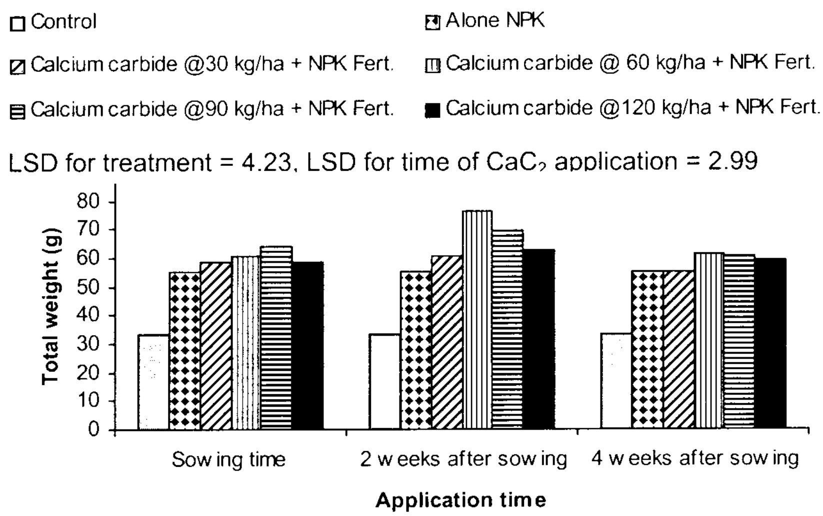

Fig. 4. Effect of rate and time of application of CaC_2 on total yield pot^{-1} (g)

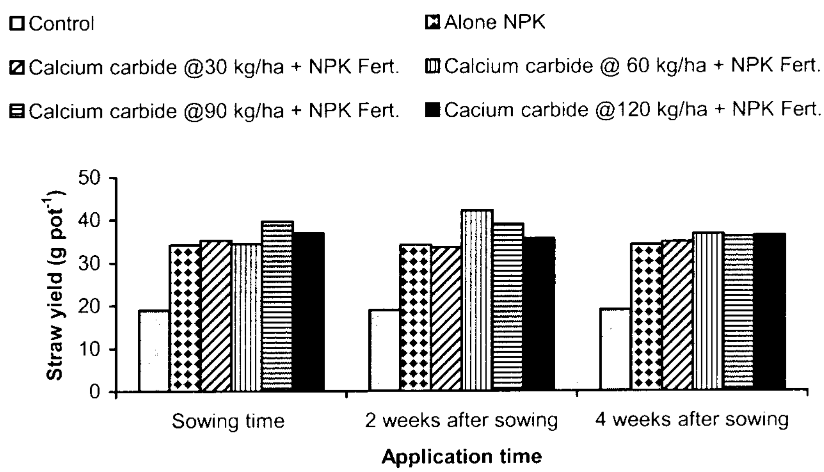

Fig. 5. Effect of rate and time of application of CaC_2 on straw yield pot^{-}

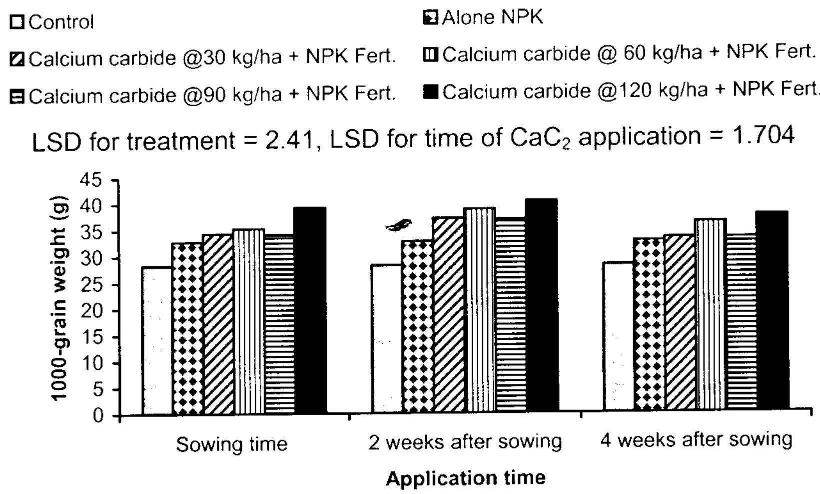

Fig.6. Effect of rate and time of application of CaC_2 on 1000-grain weight (g)

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