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Use of Plant Growth Regulators (PGRs) in Enhancing Crop Productivity I: Effect of CaC_2 as a Source of Ethylene on Some Agronomic Parameters of Wheat (*Triticum aestivum* L.)

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Abstract: A pot experiment was conducted in the greenhouse to evaluate the effect of calcium carbide (as a source of ethylene) on some agronomic parameters of wheat (*Triticum aestivum* L., var. Inqalab-91) that was grown without or with two levels of N, P and K fertilizers (120-90-60 kg ha^{-1} and 60-45-30 kg ha^{-1}). Half dose of N and full dose of P and K was applied at sowing while remaining half after one week of germination. Calcium carbide as a source of ethylene was applied at 60 kg ha^{-1} after 2 and 8 weeks of germination. A factorial completely randomized design was followed with nine treatments each with three replicates. Data regarding plant height, number of tillers, length of spike, number of spikelets $spike^{-1}$ and grain yield was recorded. Plant height, number of tillers and spike length were significantly affected when CaC_2 was applied after one week of germination while number of spikelets and grain yield was maximum when CaC_2 was applied after 8 weeks of germination.

Key words: Calcium carbide, ethylene, PGR, wheat

INTRODUCTION

Wheat is the main food crop of Pakistan and is being grown on an area of *ca* 8 million ha with a total production of 18.2 ma t per annum. Only for a short time period in the recent years the production of wheat was sufficient to meet the national demands while some quantities were exported as well. In general, wheat yields remain low and significant amounts of foreign exchange have to be spent on imports. It is needed therefore to look for measures that will lead to enhanced wheat yields.

Like any other living organism, the growth of wheat is under the control of different hormones or plant growth regulators (PGRs) optimum quantities of which may or may not be produced. The use of exogenous hormones has therefore found utility in increasing crop production particularly in developed countries. These substances do not become part of the living cell but have an amazing effect on the plant growth[1]. Among different PGRs, ethylene is produced in all plant organs including roots, stems, leaves, buds, tubers, flowers and seeds[2]. In soil, microorganisms can produce C_2H_4 from various substances including amino acids, carbohydrates, alcohols and proteins[3]. However, the level of ethylene can be enhanced by applying certain precursors like calcium carbide (CaC_2) which provide a new opportunity for increasing crop production[4]. Calcium carbide is now well established as a precursor of ethylene[5] and its application to the soil results in increase levels of the latter[6]. Upon introduction into the soil and following exposure to moisture, calcium carbide is decomposed into calcium hydroxide and acetylene; the latter is reduced by soil microorganisms to ethylene that enters the plants through roots. Nitrogenase enzyme that is characteristic of N_2-fixing microorganisms may be responsible for a significant conversion of acetylene into ethylene.

Application of calcium carbide is reported to significantly increase the yields of different crops. Bibik *et al*.[7] reported increase in tuber formation, potato yield, tuber preservation and also disease resistance. Sharma and Yadav[8] showed an increase in the growth and yield of rice and wheat following application of CaC_2. Similar effects have been reported by other workers[9,10]. In cotton, the benefits of applying CaC_2 have been demonstrated by Ahmad *et al*.[11]. Our objective was to further evaluate CaC_2 for its role in enhancing crop yields as a prelude to developing formulations for commercial exploitation using wheat as a test crop.

MATERIALS AND METHODS

Soil used in this study was collected from the experimental fields (0-15 cm soil layer) at the University of Agriculture, Faisalabad, Pakistan. Before use, the soil was

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dried, ground, sieved (<2 mm) and analyzed for the physico-chemical characteristics (Table 1). Methods described in Handbook 60[12] were followed for analyses other than soil texture[13] and total nitrogen[14].

Twelve and half kg portions of the soil were placed in 27 glazed pots and sown to wheat (*Triticum aestivum* L.; var Inqlab-91) using 6 seeds pot^{-1}; the stand was thinned to 3 seedlings pot^{-1} after seed germination. The plants were fertilized with NPK at 0, and in the ratio of 120:90:60 kg ha^{-1} or 60:45:30 kg ha^{-1}. Urea, SSP and SOP were using as source of N, P and K, respectively. Half dose of N and full dose of P and K were applied at sowing while remaining half dose of N with first irrigation. Calcium carbide used after filling into medical capsules and applied at 60 kg ha^{-1} at two growth stages i.e. after 1 and 8 weeks of seed germination. Triplicate pots were used for each treatment and factorial completely randomized design was followed.

The plants were grown to maturity and data recorded on plant height, tillers plant^{-1}, spike length, spikelets spike^{-1} and grain yield pot^{-1}. The data was analyzed statistically for determining the significance of treatment means using Duncan's Multiple Range Test at 5% level of probability[15].

Table 1: Physical and chemical characteristics of soil

Characteristic	Value	Unit
Sand	73.50	%
Silt	12.59	%
Clay	13.91	%
Textural class	Sandy Clay loam	
Total nitrogen	0.05	%
Available phosphorous	8.35	ppm
Extractable K^+	125	ppm
pHs	7.7	-
EC_e	1.61	dS m^{-1}
Soluble Ca^{++}+ Mg^{++}	8.91	me L^{-1}
CEC	4.75	(C mole kg^{-1})

Table 2: Effect of time of application of CaC_2 with and without NPK fertilizers on plant height of wheat (cm)

Treatments ($N-P_2O_5-K_2O$) kg ha^{-1}	Time of CaC_2 Application (60 kg ha^{-1})			
	Control	After one week	After eight weeks	Mean
0-0-0	57.7	69.3	70.3	65.8
60-45-30	83.3	82.7	63.0	75.6
120-90-60	73.0	82.6	69.6	75.1
Mean	71.4	77.3	67.7	

Table 3: Effect of time of application of CaC_2 with and without NPK fertilizers on number of tillers pot^{-1} of wheat

Treatments ($N-P_2O_5-K_2O$) kg ha^{-1}	Time of CaC_2 application (60 kg ha^{-1})			
	Control	After one week	After eight weeks	Mean
0-0-0	8.0c	16.6c	6.7c	10.2C
60-45-30	9.0b	18.0b	13.0b	13.3B
120-90-60	16.0a	20.6a	18.3a	18.3A
Mean	11.0B	18.4A	11.2B	

RESULTS AND DISCUSSION

Plant height: Maximum plant height was observed where CaC_2 was applied after one week of germination (Table 2). It was followed by control and the treatment where CaC_2 was applied after eight weeks of germination. Results indicate that plant height increased with the application of CaC_2 at 60 kg ha^{-1}. Fertilizer application also affected the plant height. Maximum plant height was observed where NPK fertilizers were applied at 60-45-30 kg ha^{-1} while, it was minimum in control where no fertilizer was applied. It is also obvious from the data (Table 1) that full dose of fertilizer at 120-90-60 kg ha^{-1} reduced plant height. It might be due to CaC_2 application that stimulates the initial root growth and thus carbohydrates translocated towards roots and resulting in reduced height. Ahmad *et al.*[11] reported similar results in cotton crop. Interaction between time of application of CaC_2 at different growth stages and different rates of NPK fertilizers application elucidated the influence of CaC_2 and fertilizers when compared with control. However, this influence was inconsistent.

Number of tillers pot^{-1}: The maximum average number of tillers pot^{-1} was observed where CaC_2 was applied after one week of germination (Table 3). It was followed by the treatment where CaC_2 was applied after eight weeks of germination. Average number of tillers pot^{-1} was statistically similar in treatments where no CaC_2 was applied and CaC_2 was applied after eight weeks of germination. Results clearly show a significant increase in the number of tillers in wheat due to the application of CaC_2. Number of tillers of wheat was also affected by the application of different levels of NPK fertilizers; maximum tillers being at the higher rate of application i.e., 120-90-60 kg ha^{-1}. Increase in number of tillers of wheat would be induced by the application of fertilizer, however further increase in number of tillers over fertilizer was due to the production of ethylene in rihzosphere which stimulates the tillering[8,9,16].

Interaction exhibited between time of application of CaC_2 and different rates of NPK fertilizers revealed significant effect on number of tillers pot^{-1} compared to control. It is evident from the results (Table 2) that number of tillers increased with the application of CaC_2 with NPK fertilizers. Maximum numbers of tillers of wheat were observed in the treatment where NPK fertilizers at 120-90-60 kg ha^{-1} and CaC_2 at 60 kg ha^{-1} were applied. These results are in line with the findings of Sharma and Yadav[8] who reported that application of CaC_2 at 80 ppm with 60 ppm of nitrogen had an effect comparable to 120 ppm of nitrogen alone.

Table 4: Effect of time of application of CaC_2 with and without NPK fertilizers on spike length (cm) of wheat

Treatments ($N-P_2O_5-K_2O$) kg ha^{-1}	Time of CaC_2 Application (60 kg ha^{-1}) Control	After one week	After eight weeks	Mean
0-0-0	12.3b	16.6b	11.6b	13.5C
60-45-30	17.3a	17.3a	18.0a	17.5A
120-90-60	11.6b	17.3a	18.0a	15.3B
Mean	13.7C	17.1A	15.9B	

Table 5: Effect of time of application of CaC_2 with and without NPK fertilizers on number of spikelets $plant^{-1}$ of wheat

Treatments ($N-P_2O_5-K_2O$) kg ha^{-1}	Time of CaC_2 Application (60 kg ha^{-1}) Control	After one week	After eight weeks	Mean
0-0-0	10.3b	11.3c	17.7a	13.11B
60-45-30	16.3a	16.0a	18.7b	17.0A
120-90-60	16.0a	18.0b	17.0a	17.0A
Mean	14.22B	15.11B	17.8A	

Table 6: Effect of time of application of CaC_2 with and without NPK fertilizers on dry matter yield (g pot^{-1}) of wheat

Treatments ($N-P_2O_5-K_2O$) kg ha^{-1}	Time of CaC_2 Application (60 kg ha^{-1}) Control	After one week	After eight weeks	Mean
0-0-0	23.6	48.5	40.6	37.6C
60-45-30	49.1	71.5	68.0	62.9B
120-90-60	78.0	95.3	86.3	86.5A
Mean	50.2C	71.8A	65.0B	

Spike length and number of spikelets $spike^{-1}$: Maximum average spike length was observed where CaC_2 was applied after one week of germination (Table 4). Fertilizer application had also significantly positive effect on spike length; maximum average spike length being observed at 120-90-60 kg ha^{-1}. Interaction between time of application of CaC_2 at different growth stages and different rates of NPK fertilizers application resulted in significant increase in length of spikes over control. However, this influence was inconsistent.

Maximum number of spikelets was observed in the treatment where CaC_2 was applied after 8 weeks of germination followed by the treatment where CaC_2 was applied after one week of germination and control (Table 5). Application of fertilizer also had a pronounced effect on number of spikelets $spike^{-1}$; maximum being at 120-90-60 kg ha^{-1} and minimum in control. Interaction between time of application of CaC_2 and different rates of NPK fertilizers revealed the increase in number of spikelets with increase in rate of fertilizer application and CaC_2. Maximum numbers of spikelets were observed where CaC_2 was applied with 120-90-60 kg ha^{-1} fertilizer.

Dry matter yield: Maximum dry matter yield (root+straw+grain) was observed where CaC_2 was applied after eight weeks of seed germination followed by the treatment where it was applied after one week of germination and the treatment where no CaC_2 was applied. Tables of mean and analysis of variance clearly indicated a significant increase with the application of CaC_2 at 60 kg ha^{-1}. Dry matter yield of wheat was also affected by the application of fertilizers as usually observed. Maximum yield was observed where NPK fertilizers were applied at 120-90-60 kg ha^{-1} while, it was minimum in control where no fertilizer was applied. Interaction between time of application of CaC_2 at different growth stages and different rates of NPK fertilizers application elucidated a positive influence of CaC_2 and fertilizers when compared with control (Table 6).

Increased yield of wheat with the application of CaC_2 is attributed to enhanced uptake of nutrients by wheat due to production of ethylene from CaC_2 which induced increase in root primordia and increase in the soil volume being explored for nutrient acquisition. A close relationship between uptake of essential nutrient elements like N and the crop productivity is well-documented[17]. In addition to increased availability of nutrients, CaC_2 may also lead to changes in the form of available nutrients like N. It is quite well-known now that presence of both NH_4 and NO_3 is more beneficial as a source of plant N rather than the either available alone[18]; CaC_2 may help create this situation. One of the products of CaC_2 decomposition i.e., acetylene, is inhibitory to nitrification[19]. Therefore, a part of the fertilizer N will remain in NH_4-form over extended periods of time resulting in the plant availability of both NO_3 and NH_4. Nitrification inhibitors have indeed been reported to improve crop yields not only by maintaining higher levels of NH_4 but by decreasing the losses of N through denitrification and NO_3 leaching as well[20-23]. In addition, CaC_2 may also serve as a supplemental source of Ca which is useful for plant growth[8]. Enhanced availability of Ca is also reported to improve the uptake and assimilation of NO_3^-[24] thereby suggesting additional utility of CaC_2.

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