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SOIL APPLIED CALCIUM CARBIDE-MEDIATED CHANGES IN MORPHO-PHYSIOLOGY, FEMALENESS AND FRUIT YIELD OF CUCUMBER PLANTS AND THEIR RELATIONSHIP WITH ENDOGENOUS PLANT ETHYLENE

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ABSTRACT

The potential of paint coated calcium carbide (PCC) as a potent source of soil-applied ethylene was examined in improving different morpho-phenological, physiological and yield attributes in cucumber (*Cucumis sativus* L.). Ethylene emission was monitored in soil under controlled conditions by the application of 100, 200, 300 and 400 mg pot^{-1} of PCC over 56 days of incubation which stimulated ethylene production in soil by 8-, 15-, 23- and 31-times, respectively over an unamended control soil. A pot experiment was conducted to evaluate the influence of various rates of PCC on growth and yield of Desi (local) and Bolan-F1 (hybrid) cultivar of cucumber. Application of lower to medium rates (100 to 300 mg pot^{-1}) of PCC strongly increased plant growth, femaleness, photosynthesis and fruit yield compared to control while higher (400 mg pot^{-1}) rate showed inhibitory response on growth and yield components of both cultivars. PCC rate of 300 mg pot^{-1} was found most effective in both cultivars in increasing female flower count, photosynthesis, fruit setting, and number of fruits, early fruit yield and total yield. Similarly, plant height and days to female flowering and fruit maturity was decreased at this rate in both cultivars. In both cultivars endogenous ethylene production increased linearly and reached maximum by the application of 400 mg pot^{-1} PCC but maximum effects regarding early and total fruit yield of cucumber were observed at 300 mg pot^{-1} PCC. However, plant femaleness, photosynthetic rate and fruit yield in Desi cultivar was more responsive to modulated plant ethylene level than Bolan-F1 cultivar. These data strongly suggested that the positive impact of PCC in low to medium concentrations at plant (transplanting stage), improved morpho-phenological, physiological and yield attributes by increasing the plant ethylene level.

Key words: Acetylene, Ethylene, Calcium carbide; Femaleness; Cucumber, Photosynthesis.

INTRODUCTION

Cucumber (*cucumis sativus* L.) locally known as "Kheera" is summer vegetable of *Cucurbitacae* family and is grown as one of the major salad crops in Pakistan. It is very highly esteemed for its freshness and vitamin contents. It was grown on 3.50 thousand hectares with total production of 50.5 thousand tons with an average yield of 14.4 tons per hectare in Pakistan during 2012-13 (FAO, 2013). Cucumber is being widely adopted vegetable especially among small land holding farmers owing to its higher yield potential and profit.

Besides using conventional cultural practices, the yield of cucumber in field is quite low compared to the yields obtained at experimental conditions indicating almost 45 % yield gap due to the suboptimal use of inputs. So, the conventional approaches, focusing mostly on intensive fertilization, could not only fulfill the demands of ever increasing population but also causing greater damage to environment. Therefore, along with traditional practices the use of novel approaches is highly desirable which can overcome the yield gap with reduced environmental damage. The use of plant growth regulators integrated with conventional approaches is one approach which can reduce heavy use of fertilizers by enhancing nutrient use efficiency. Ethylene is one of potent phytohormone which is produced endogenously as a result of plant metabolism. Involvement of ethylene has been observed in regulating growth and development of all plant organsincluding roots, stem, leaves, tuber, and flowers and also acts as signal molecule in different stress responses (Abeles *et al*., 1992; Lieberman *et al*., 1996). Like other plant hormones, the physiological effects of ethylene depends on numerous variables such as the type of tissue, stage of development, physiological age of species and prevailing environmental conditions (Dittey, 1969; Pratt and Goeschi, 1969). Moreover, modification of sex expression in cucurbits has remained a great interest for plant scientists because there is a correlation between fruit yield and the number of pistillate flowers per plant. Any treatment that would increase the formation of pistillate flowers would therefore, be beneficial in producing high yield. Exogenous application of foliar-applied ethylene-releasing chemicals (ethephon/ ethrel) (2-chloroethanephosphonic acid) has been shown to increase fruit yield by inducing femaleness and morphology of cucumber (Hong-yan, 2007; Bin-bin *et al*., 2009; Li *et al*., 2011; Thappa *et al*., 2011) without imposing any deleterious effect on the environment and human health.

The results of several studies have proved that an exogenous source of ethylene could be used for enhancing agricultural production. So far, most of studies have elucidated the role of non-enzymatically produced ethylene (ethephone/ethrel) on different morpho-physiological characteristics in plants which is usually restricted to foliar application. Recently, use of solid coated calcium carbide (CaC_2) has emerged as aneffective soil amendment which upon its reaction with soil moisture produces acetylene (C_2H_2) gas which can prolong the availability of NH_4^+ and NO_3^- in soil which is otherwise very low due to various losses of these ions (Walter *et al.*, 1979; Freney *et al*., 1993, 2000; Thompson, 1996; Bolman and Conrad, 1997; Hayden and Ross, 2005). Acetylene in addition to its role as controlling agent of NH_4^+ and NO_3^-ions in soil, it is also reducible to ethylene in rhizosphere by soil indigenous microbes (Muromstev *et al.*, 1995; Yaseen *et al.*,2005, 2006; Kashif *et al*., 2008) whose importance as a plant hormone involved in various developmental processes is well established.

Effect of coated CaC_2 in improving growth and yield of okra (Kashif *et al*., 2012), tomato (Siddiq *et al*., 2012) and sweet pepper (Ahmed *et al*., 2014) has been investigated. However, no work related to effect of calcium carbide as a soil–applied source of ethylene on endogenous plant ethylene level and its subsequent impact on morho-phenological, physiological and fruit yield attributes of cucumber has been reported. This work, therefore, was designed and undertaken, based on the hypothesis that soil-applied CaC_2 induced ethylene production in plant bodyhas significant correlation with plant femaleness and fruit yield.Due to rapid reaction of $CaC_2$with water it isdesired to apply in some coated form so that a sustained supply of acetylene and ethylene gases may be maintained in soil rhizosphere during critical growth stages of plant.

MATERIALS AND METHODS

Experiment 1: Ethylene biosynthesis in soil under controlled conditions: Before initiating the pot study, ethylene production in soil amended with different rates of paint coated CaC_2 (PCC) was monitored over a period of 56 days of incubation under controlled conditions in an incubator (24 ±1 °C).For this purpose, 50 g sandy clay loam soil (Typic Haplocambids) was taken in 125 mlErlenmeyer flasks fitted with rubber supa-seal. The content of the flask were maintained at 60% water holding capacity (WHC). PCC was added at the rate of 10, 20, 30 and 40 mg kg^{-1} soil. Equivalent amount of calcium present in PCC was also added in control flasks by using calcium sulphate ($CaSO_4$). This experiment was carried out according to completely randomized design and each treatment was repeated four times. C_2H_4 gas was collected by withdrawing 1 cm^3 gas samples from the head space of the flask above the soil with a gas tight glass hypodermic syringe. Concentrations of C_2H_4 were determined by gas chromatography (Shimadzu-4600) as described by Khalid *et al.* (2006b); fitted with a flame ionization detector (FID), and a capillary column (Porapak Q 80-100) operating isothermally under the following conditions: sample volume, 1mL; column temperature, 70ºC; detector temperature, 200ºC; carrier gas used, N_2 (13 mL min^{-1}); flow rate of H_2, 33 mL min^{-1}; flow rate of air, 330 mL min-1. The C_2H_4 concentrations were calculated by comparing with reference standards which were made by diluting 99.5% C_2H_4 obtained from Matheson (Secancus, NJ, USA).

Experiment 2: Wire house Experiment: Pot experiment was conducted in the wire house at the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad under natural conditions during the period 2010-2011. The wire house has a glass roof with no control over temperature, humidity and light as the sides are open having only a wire net to control birds. Cucumber nursery plantsof each cucumber cultivar (Bolan-F1 (Hybrid) and Desi (local) were grown in thermo pore cups containing media of compost and sand in 1:1 ratio in controlled temperature room. Fifteen days old cucumber seedlings of each cultivar were then used to transplant in earthen glazed pots during1st week of February 2011. The pots were filled with 10 kg sieved soil (same as used in previous experiment 1) having pH of 8.0 and contains total 0.04 % total N, 5.06 ppm available P and 0.98% total organic matter. The potswere randomly placed in the wire house. To stabilize the indigenous microbial population, the soil was preconditioned 10 d prior to transplanting with one application of Hoagland mineral nutrient solution (one liter, full-strength).Nitrogen, phosphorus and potassium were applied at recommended rate of 100-75-60 kg ha^{-1} in the form of urea, single super phosphate and murate of potash, respectively. All P and K were applied at sowing time by mixing in soil before pot filling whereas urea was applied in two splits i.e. half at seedling transplantation time by mixing in soil and other half dose at the time of flowering.Two seedlings of each cucumber cultivar from fifteen days old nursery were transplanted into pots and finally one plant was maintained in each pot.Calcium carbide was coated with paint by adopting same method as described by Mahmood (2010). Different rates of PCC (0, 100, 200, 300, 400 mg kg^{-1}) were placed 6 cm deep in soil in the center of pots afterthe seedlings were allowed to establish themselves.In control treatments $CaSO_4$was added to adjust the amount of calcium added from CaC_2. Canal water treated with Topsin-M @ 0.25% was used for irrigation of plants throughout the growth period. Recommended insecticide was sprayed two times during the growing period to protect plants from red bugs and leaf miner.

Ethylene production from leaves: After 50 days of seed sowing ethylene was analyzed by following procedure as adopted by Atta-Aly (1998).The second developing leaf from the top of the plant was excised 2 mm above the stem surface from each selected plant at 10 a.m. using stainless steel blade. It was placed immediately in 150 mL glass tubes, each containing 5 mL of H_2O for immersing the leaf base in water to prevent drought stress. Glass tubes were then sealed using rubber supa-seal and kept under a 1,000-lux fluorescent light for 8 h. One-mL gas samples were then withdrawn from the glass tube head space and concentrations of C_2H_4 were determined by gas chromatography (Shimadzu-4600).

Morpho-phenological, physiological and yield measurements: The measurement of photosynthetic rate (P_N) was done after 50 days of sowing with an Infrared Gas Analyser (IRGA, model ADC, Bioscientific Ltd., England) at 1100-1200 h when above the plant canopy photosynthetic active radiations (PAR) ≥ 1060 µmol m^{-2} s^{-1} were present. Care was taken to use leaves of the same age for the measurement of photosynthesis in control and treated plants. After measuring photosynthesis leaf area was measured with a leaf area meter (Licor Model 3100).

The number of days to the appearance of the first female flower after sowing was recorded on each plant.The total number of female flowers per vine was calculated. The number of days taken for the conversion of the female flower bud to initial fruit with at least 3 buds was recorded to calculate days to fruit setting. Days to fruit maturity was calculated by recording days taken by initial fruit to reach a marketable fruit size (≥ 100 g) with at least 3 fruits was counted from each plant. Fruit setting percentage per plant was calculated by calculating percentage of total number of fruits out of total number of female flowers. Total fruit yield was calculated by weighing fruits at each picking separately and thenfinally cumulative yield was measured while early yieldwas calculated by taking cumulative fruit yield of first five pickings.

Statistical Analysis: Data was analyzed by using the Statistix 8® computer program for computing analysis of variance while means were compared by Least Significant Difference test at 5% level of probability (Steel *et al.,* 1997).

RESULTS

Results of the laboratory experiment indicated that C_2H_4 emission was directly proportional to the rate of PCCapplied in soil. Increase in rate of C_2H_4production was observed with incremental increase in the application of PCC (Figure 1). Initially, no C_2H_4 was detected in the control and very low ethylene emission in the PCC amended incubations and then significant amount of C_2-H_4 emission was detected in PCC treated soils with the passage of time. This substrate-dependent C_2H_4 release in the amended soil continued even after 56 days of incubation (data is not shown) that allowed sufficient time to the plant roots for exposure to slowly released ethylene. In un-amended control, the release of C_2H_4 was considered as a reference for native C_2H_4 production in the soil, although its concentration was too low.

The vine length of two cucumber cultivar was significantly ($P < 0.01$) reduced by the application of all rates of PCC (Table 1). Both cultivars produced the shortest vine at 400 mgPCC pot^{-1}, which was significantly different from the other rates. The reduction in vine length was about 17.4 and 19.6% in Bolan-F1 and Desi cultivar, respectively, compared to control treatment (Table 1). Overall, maximum vine length (160.2 cm) was recorded in Desi (local) cultivar in the control treatment where no PCC was applied. Results revealed significant interaction effect between cultivar and CaC_2 on vine length. Maximum vine length (160.2 cm) was recorded in Desi (local) cultivar in the control treatment where no CaC_2 was applied. Similarly, vine length of Bolan-F1 cultivar was also found maximum in the control. Minimum vine length (112.7 and 128.9 cm) in Bolan-F1 and Desi cultivar respectively was observed in the treatment of 400 mg CaC_2 pot^{-1}. Similarly, Cultivar differences were found significant regarding all floral characteristics studied in the present study. A significant earliness regarding first female flowering (26.6%), fruit setting (11.0 %), fruit maturity (13.9 %) and an increase in female flower count (15.9%) and fruit setting % (11.3%) was observed in Bolan-F1 compared to Desi cultivar. Application of PCC had a significant effect on all floral characters (Table 1). It was also clear that the soil application of PCC had a significant role in promoting earliness in both cultivars compared with the control. However, when averaged over cultivars, the application of 300 and 400 mg PCC pot^{-1} produced the minimum days to first female flower (36.6), days to fruit setting (13.5) and days to fruit maturity (13.5). Moreover, maximum fruit setting% (78.0) and female flower count (24.7) was obtained at 300 and 400 mg PCC pot^{-1}, respectively**.** Interaction between cultivar and CaC_2 regarding all floral characteristics was found significant ($P < 0.01$). This interaction revealed that minimum days to first female flower (32.2), fruit setting (12.45) and maximum female flower count (31.0) was recorded at 400 mg PCC pot^{-1} in Bolan-F1 cultivar while minimum days to fruit maturity and maximum fruit setting percentage (82.0 %) was observed in Bolan-F1 cultivar in 300 mg PCC pot^{-1} treatment.

Main effect of PCC, cultivars and their interaction was found significant ($P < 0.01$) regarding leaf area and photosynthetic rate (Table 2). Application of PCC at 300 mg pot^{-1} increased the leaf area and photosynthetic rate (P_N) maximally, increasing P_N by 26.7 and 31.5% and leaf area by 15.1 and 24.6% in Bolan-F1 and Desi, respectively compared to control treatment. However, higher rate of PCC (400 mg pot^{-1}) decreased the leaf area and photosynthetic rate in both cultivars. We found that effects of different rates of PCC, cultivars and their interaction effect on yield attributes were all significant (Table 2). The application of different rates of PCC significantly enhanced number of fruits, early and total fruit yield compared to the control plants in both cultivars. However, application of 300 mg PCC pot^{-1} increased the fruit yield attributes maximally, increasing fruit number by 51.3 and 38.8%, early fruit yield by 122.0 and 86.6% and total fruit yield by 79.0 and 56.4% in Desi and Bolan-F1, respectively compared to control. Higher rate of PCC (400 mg pot^{-1}) decreased the fruit yield attributes in both the cultivars.

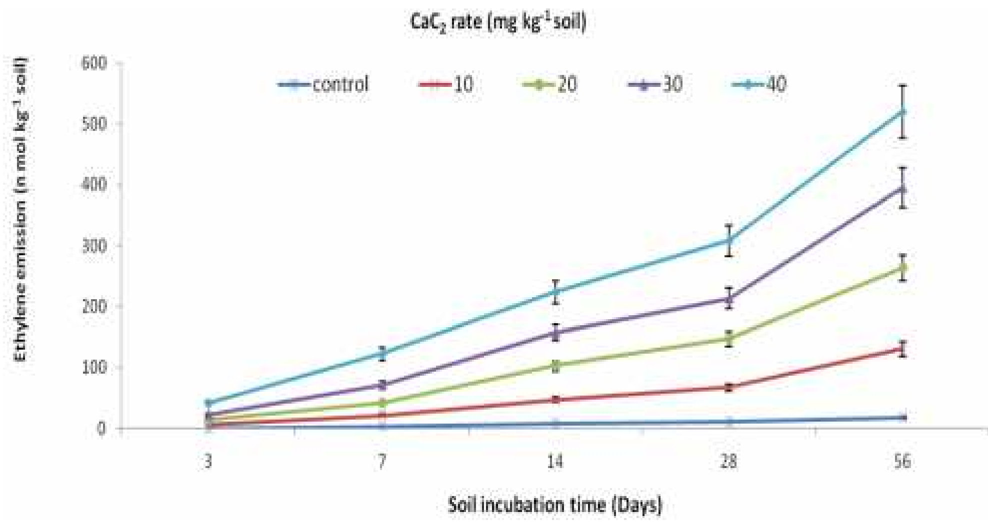

Figure 1. Ethylene release in the soil amended with paint coated CaC_2 at different intervals of incubation [Values are means of 4 replications while bars represent ± SE]

Table 1 Effect of different rates of paint coated calcium carbide and their interaction with cultivars on vine length, days to 1st female flower initiation, female flower count, fruit setting (%)and days to fruit setting and fruit maturity of cucumber (Each value is mean of 4 replications ± S.E)

Treatments	PCC (m(mg pot^{-1})	Vine length (cm)	Days to 1st female flower initiation	Female flower count	Fruit setting (%)	Days to fruit setting	Days to fruit maturity
Cultivar							
Desi	**0**	160.2 ± 9.11	50.5 ±2.88	12.6 ± 0.57	61.9±0.78	18.75±1.07	14.65±0.83
	100	153.7 ± 8.73	46 ± 2.62	15.0 ± 0.68	64.9 ± 0.83	17.5 ± 0.99	13.5 ± 0.77
	200	147.3 ± 8.37	45 ± 2.57	16.1 ± 0.73	67.7 ± 0.84	15.8 ± 0.90	11.8 ± 0.67
	300	144.8 ± 8.23	44.5 ± 2.54	17.3 ± 0.78	74.1 ± 0.86	14.45±0.82	10.5 ± 0.59
	400	128.9 ± 7.32	43 ± 2.46	18.5 ± 0.84	45.9 ± 0.58	14.5 ± 0.82	9.5 ± 0.54
Bolan-F1	**0**	136.5 ± 7.76	41 ± 2.34	22.1 ±1.0	68.9 ± 0.92	16.5 ± 0.94	12.6 ± 0.71
	100	126.5 ± 7.19	39.5 ± 2.25	24.5 ± 1.11	69.0 ± 0.92	16.1 ± 0.91	11.1 ± 0.63
	200	124.1 ± 7.05	34.25±1.95	25.1 ± 1.13	74.9 ± 1.04	14.62±0.83	10.6 ± 0.61
	300	122.6 ± 6.97	34.19±1.95	27.4±1.24	82.0 ± 1.03	12.45±0.71	8.4 ± 0.48
	400	112.7 ± 6.40	32.25±1.84	30.9 ± 1.40	55.5 ± 0.70	12.4 ± 0.70	8.8 ± 0.50
Significance							
PCC		**	**	**	**	**	**
Cultivar		**	**	**	**	**	**
PCC × Cultivar		**	**	**	**	**	**

Values sharing same letter(s) in each column do not differ at $p < 0.05$ according to LSD test, *Significant at $p < 0.05$, **Highly significant at $p < 0.01$, PCC = Paint coated calcium carbide.

PCC application significantly affected ethylene evolution, and was the highest with 400 mg pot^{-1} PCC (Table 2). Local cultivar, Desi was more responsive to exogenously applied PCC than the hybrid cultivar, Bolan-F1. Application of 300 mg PCC pot^{-1} increased ethylene by 88.3% in Bolan-F1 and 119.0% in Desi compared to control. Increase in ethylene by the application of soil applied PCC was significantly correlated with the increase in P_N(R= $0.58^{p< 0.01}$), leaf area (R= $0.64^{p< 0.01}$), femaleness ($0.88^{p< 0.01}$) early yield (R= $0.61^{p<0.01}$) and total fruit yield (R= $0.63^{p< 0.01}$). However, ethylene evolution with 400 mg pot^{-1}PCC proved inhibitory for photosynthetic rate, leaf area, fruit setting and fruit yield characteristics.

Table 2. Effect of different rates of paint coated calcium carbide and their interaction with cultivars on leaf area, photosynthetic rate, number of fruits per plant, early yield per plant, total yield per plant and ethylene production by young cucumber leaves (Each value is mean of 4 replications ± S.E)

Treatments	PCC (mg pot^{-1})	Leaf area (dm^2)	Photosynthetic Rate (μmole m^{-2} s^{-1})	Number of fruits	Early yield (g $plant^{-1}$)	Total yield (g $plant^{-1}$)	Ethylene production (nL $g^{-1}h^{-1}$)
Cultivar							
Desi	**0**	48.51±2.77	12.34±0.70	7.8±0.44	290.5±16.59	698.3±80.40	0.21±0.02
	100	51.31±2.93	13.26±0.75	10.0±0.57	395.0±22.55	927.3±106.76	0.31±0.02
	200	54.76±3.12	14.87±0.84	10.7±0.61	493.2±28.16	1106.4±127.39	0.35±0.03
	300	60.45±3.45	16.23±0.92	11.8±0.67	644.1±36.79	1250.5±143.99	0.46±0.03
	400	51.34±2.93	13.12±0.74	8.5±0.48	385.3±22.0	894.2±102.95	0.72±0.05
Bolan-F1	**0**	66.56±3.80	15.87±0.90	16.2±0.92	1295.5±74.0	2515.1±289.58	0.43±0.03
	100	70.76±4.04	17.78±1.01	17.9±1.02	1555.2±88.82	2907.5±334.75	0.62±0.04
	200	73.23±4.18	18.45±1.05	20.8±1.18	1987.9±113.54	3520.9±405.38	0.72±0.05
	300	76.65±4.37	20.12±1.14	22.5±1.28	2416.6±138.0	3934.9±453.05	0.81±0.06
	400	71.19±4.06	17.25±0.98	17.2±0.97	1545.0±88.25	2888.4±332.56	1.28±0.09
Significance							
PCC		**	**	**	**	**	**
Cultivar		**	**	**	**	**	**
PCC × Cultivar		*	*	**	**	*	**

Values sharing same letter(s) in each column do not differ at p < 0.05 according to LSD test, *Significant at p < 0.05, **Highly significant at p < 0.01, PCC = Paint coated calcium carbide.

DISCUSSION

Results indicated that PCC acted as a potent source of ethylene. To exploit CaC_2 potential it was coated with paint material to make its release slow and persistent; hence roots may be exposed to this hormone during critical periods of development. Initially, no significant amount of ethylene was detected during the first 72 h of incubationand then gradual increase in ethylene synthesis was observed afterwards in dose-dependent manner (Figure 1). The lag period observed regarding ethylene synthesis might be due to decomposition of calcium carbide (after reacting with water) into acetylene and subsequently biotransformation (enzymatically) of acetylene into ethylene gas which caused a gradual buildup of ethylene in soil. This observation is in good agreement with the findings of some other research workers (Yaseen *et al.*, 2006; Kashif *et al.*, 2008).

Ethylene performs various physiological functions in plants. It has stimulatory as well as inhibitory effect depending upon its concentration and sensitivity to plants.The results regarding morphological attributes revealed that PCC was effective in reducing the length of the main stem in a dose dependent manner. The inhibition of apical growth may have been due to ethylene released from CaC_2 which inhibits elongation and promotes radial expansion because of its more impact on cell enlargement instead of division of cells (Kieber *et al*., 1993) and plant polar auxin transport (Arora *et al*., 1982). At higher concentrations, vine length was reduced more severely by the application PCC CaC_2which might be due to anti-gibberellin activity of ethylenehormone that causes cessation of mitotic cell division in the apical meristematic zone of root and shoot (Hayashi *et al*., 2001). Similar reduction in plant height by application of CaC_2 has been reported in various vegetable crops (Kashif *et al*., 2008; Siddiq *et al*., 2009, 2012; Ahmed *et al*., 2014).

Flowering has been hastened or delayed by plant hormones depending on species (Latimer, 1991). Ethylene is a critical plant hormone for vegetative as well as reproductive growth and developmental processes. The results of the present study indicated that PCC as a potent source of ethylene reduced days to flowering, days to fruit setting and maturity and increased female flowers, total yield and early yield in both cultivars differing in yield potential. Such effects could be attributed to the fact that the application of PPC slightly repressed vegetative growth, enhanced carbohydrate contents via reduced respiration and caused earliness in female flowering and fruit setting. Moreover, synergism of aforementioned effects not only increased fruit setting but also accelerated fruit maturity process (Abdel-Rahman and Thompson, 1969). Earliness in fruit maturity from CaC_2 treated plants was might be due to acceleration of physiological maturity by ethylene hormone accompanied with loss of chlorophyll and breakdown of carbohydrate, protein and RNA with increasing activity of chlorophylase, protease, ribonuclease etc. (Hossain, 2004).

Results of this experiment also showed that hybrid cultivar produced more ethylene than local cultivar. Higher ethylene production in Bolan-F1cultivar (Hybrid) might be due to more female flowers because female buds of cucurbitaceous plants produced greater amounts of ethylene than those produced by male buds (Robinson *et al*., 1968; Rudich *et al*., 1972; Arora *et al.*, 1982). Exogenous application of PCC was correlated with the amount of ethylene production from the leaves of cucumber. PCC changed the direction of sexual differentiation in potentially male buds to female buds. Ultimately the total number of female flower was increased in both cultivars of cucumber plant under the present study.

The present work suggests that PCC application in both cultivars increases ethylene and influences leaf area and photosynthetic response. The higher leaf area and photosynthetic rate is correlated with calcium carbide-mediated increase in ethylene biosynthesis. Ethylene-induced increase in leaf area was supported by other findings that low concentration of ethylene is involved in inducing cell enlargement (Rodriguez-Pousada *et al*., 1993) and leaf growth (Lee and Reid, 1997; Khan *et al*., 2008; Iqbal *et al*, 2011). Moreover, due to higher leaf area, Bolan-F1 was expected to have higher photon interception and thus photosynthesis than Desi cultivar. Ethylene-induced increase in photosynthesis might be due to higher diffusion rate of CO_2 from atmosphere to intercellular cavities via affecting stomatal opening (Pierik *et al*., 2006; Wilkinson and Davies, 2010; Iqbal *et al*., 2011) or indirectly by enhancing nitrogen assimilation (Iqbal *et al.*, 2012). Similarly, increase in photosynthesis and nitrogen uptake by the application of coated calcium carbide as a source of soil-applied ethylenewas reported in tomato (Siddiq *et al*., 2012) and sweet pepper (Ahmed *et al*., 2014).

It is also of interest to note that the stimulated growth of both cultivars of cucumber coincided with the plant ethylene level, since plants treated with 300 mg pot^{-1} PCC which produced the highest parameters of plant growth and yield are attributed to physiological active concentration of endogenous ethylene involved in cell expansion (Ku *et al*. 1970; Riad, 1996) and cell division (Ilker *et al.* 1977; Metzer 1984; Riad, 1996) of various higher plant species. Results of the present experiment can also be explained by the suggestions of Ries (1985), in which increased endogenous production of ethylene by the exogenous application of growth retardantscan triggercertain physiological and biochemical changes (C:N ratio), causingan increase inflowering, female sex expression and ultimately fruit yield of plant.

Conclusion: This study shows that application of PCC at 300 mg pot^{-1}lead to the highest increase in number of female flowers, fruit setting percentageand photosynthetic rate resulting in maximum fruit yield per plant in both local and hybrid cultivars, Desi and Bolan-F1. In both cultivars, these morpho-phenological and physiological changes might be attributed to its effect on endogenous ethylene level. The hybrid cultivar, Bolan-F1 responded less to PCC than the local cultivar, Desi. The low femaleness and fruit yield of Desi cultivar was due to low level of ethylene. Overall, there was a positive significant correlation between endogenous ethylene level and female flowers. Similarly Leaf area, photosynthetic rate and all fruit yield characteristics had a positive significant correlation with endogenous ethylene level.

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