RESPONSE OF GROWTH, FLOWERING, SEED YIELD AND SEED GERMINABILITY OF SWEET PEPPER TO PACLOBUTRAZOL FOLIAR SPRAY

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ABSTRACT

A field trial was conducted during the two successive seasons 2003 and 2004 in the Experimental Farm, Faculty of Agriculture, Fayoum, Cairo University to investigate the influence of paclobutrazol (PP_{333}) foliar spray at the rates 5, 10, 15 and 20 mg l^{-1} on growth, flowering, seed yield, seed germinability as well as some chemical constituents of sweet pepper (*Capsicum annuum* L.) plants. Convincing influences of PP_{333} treatments, especially at the rate 15 mg l^{-1} were observed on all studied parameters during the two growing seasons. Vegetative growth characters, floral traits, seed yield and its components, seed germinability, leaf pigments concentrations, and some nutrients concentrations in leaves were positively affected in PP_{333}-treated plants. Spraying plants foliage with PP_{333} at all studied rates significantly reduced plant height, leaf area $leaf^{-1}$, and leaf area $plant^{-1}$ at the same time in which No. of main shoots $plant^{-1}$, No. of lateral shoots on main stem $plant^{-1}$, No. of leaves $plant^{-1}$, fresh and dry weights of leaves and canopy $plant^{-1}$, stem thickness upon the soil surface, flowering time, No. of flowers $plant^{-1}$, pollen viability, fruit set% (only in the second season), No. of fruits $plant^{-1}$, No. of seeds $fruit^{-1}$, seed yield $fruit^{-1}$, $plant^{-1}$ and $feddan^{-1}$, seed germination%, germination rate, chlorophylls (a, b and total) and carotenoids concentrations in fresh leaves, and nutrients (N, P, K, Fe, Mn, and Zn) concentrations in dry matter of leaves were significantly increased. On the other hand, fruit set% (only in the first season) and seed weight index nonsignificantly affected under the same treatments

In view of these results, growth, flowering, seed production, and germinability of the developing seeds of sweet pepper could be improved by the foliar application of PP_{333} at the rate 15 mg l^{-1}.

Key words: Sweet pepper, *Capsicum annuum* L., paclobutrazol (PP_{333}), growth, flowering, seed yield, seed germinability.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is widely cultivated in tropical and subtropical regions, and considers as one of the principal vegetable crops grown in Egypt, due to its multifarious use and enormous nutritional values. Recently, beside green fruits production, an increasing attention was directed towards local production of improved seeds where the prevailing weather conditions could help our country to be one of the main producers of vegetable seeds. Seed production generally needs certain growth factors in order to be successful. Many of these factors influence both quality and quantity of the

harvested seeds. Selection of cultivar, suitable soil type, appropriate cultivation methods, adequate supplementation of plant nutrients, and probably the application of a growth retardant, are among the important factors that greatly affect variant phases of growth and development (**Osman, 2000**).

Paclobutrazol (PP_{333}); a growth retardant has been known as one of these factors. Its mode of action appears as an antigibberellin, since its effect can be reversed by gibberellin application. Moreover, it might alter the level of other endogenous plant hormones (**Robert and Culver, 1983**). The effectiveness of PP_{333} on pollen viability and number of seeds per fruit (**Mercado *et al.*, 1997a**) leads us to include it as an activating agent for seed yield and quality of sweet pepper.

In this respect, **Menesy *et al.* (1989)** on *Senecio hybridus*, **Salem *et al.* (1991)** on *Gomphrena globosal* L., **Osman (2000)** and **Nassar *et al.* (2001a and b)** on sweet pepper, **El-Sallami (2001)** on poinsettia and **Matter (2003)** on *Althaea rosea* L., reported that PP_{333} as a growth retardant had a positive effect on growth characters, floral traits, seed yield and chemical constituents of plants.

Accordingly, the present work aimed to study the effect of PP_{333} foliar application at different rates on growth, flowering, seed yield, germinability of harvested seeds and some chemical constituents of sweet pepper grown during the two seasons 2003 and 2004.

MATERIAL AND METHODS

A field trial was carried out during the two successive summer seasons 2003 and 2004 in the Experimental Farm, Faculty of Agriculture, Fayoum, Cairo University, Egypt. This experiment aimed to study the influence of paclobutrazol (PP_{333}) foliar spray on growth, flowering, seed yield, germinability of yielded seeds and some chemical constituents of sweet pepper plants. Before sowing, soil samples to 25 cm depth from the experimental site were collected and analyzed by the standard procedures of **Jackson (1967).** Results of analysis of the soil samples are shown in Table 1.

Imported seeds of sweet pepper cv. California Wonder produced by Sun Seed company, USA, were sown in the nursery on January 15, 2003 and 2004. Sixty days after seed sowing, each season, seedlings were transplanted into the field. A seasonal total of 300, 200 and 300 kg feddan^{-1}, calcium superphosphate (15.5% P_2O_5), ammonium nitrate (33.5% N) and potassium sulphate (48% K_2O), respectively were applied. Recommended cultural practices for growing sweet pepper were followed. Treatments comprised 4 PP_{333} rates; 5, 10, 15, and 20 mg l^{-1} in addition to the control treatment in which plants sprayed only with distilled water. For PP_{333} treatments, suspended paclobutrazol ±-(R^*, R^*)-β-[(4-chlorophenyl)methyl]-α-(1, 1-dimethyl)-1 H-(1, 2, 4-triazol)-1-ethanol (**Kamoutsis *et al.*, 1999**) was diluted with distilled water to the rates 5, 10, 15, and 20 mg l^{-1} and sprayed on the plants foliage to run off, two times; 25 and 35 days after transplanting. Few drops of tween-20 were added to the spraying solution as a wetting agent. The experimental design used was a randomized complete blocks with 4 replications. Each experimental unit consisted of 5 rows 3 m long and 70 cm width, within row spacing averaged 45 cm apart.

Table (1): Physical and chemical properties of the experimental site before sowing of both 2003 and 2004 seasons.

Properties	2003	2004
Physical:		
Clay %	46.11	48.01
Silt %	26.83	25.04
Sand %	27.06	26.95
Soil texture	Clay	Clay
Chemical:		
pH (1: 2.5)	7.51	7.43
EC_e (dSm^{-1})	1.72	1.55
Organic matter %	1.79	1.73
$CaCO_3$ %	5.55	5.42
Total N %	0.07	0.06
Available nutrients (mg kg^{-1} soil):		
K	70.00	63.20
P	20.00	21.60
Fe	05.50	06.00
Mn	08.01	07.81
Zn	00.82	00.78

Vegetative growth characters:

Seventy days after transplanting, 4 plants were randomly chosen from each experimental unit and cut off at ground level and submitted to the following determinations: plant height (cm), No. of main shoots $plant^{-1}$, No. of lateral shoots on main stem $plant^{-1}$, No. of leaves $plant^{-1}$, leaf area $leaf^{-1}$ (cm^2), leaf area $plant^{-1}$ (dm^2), fresh and dry weights of leaves and canopy $plant^{-1}$ (g), and thickness of stem upon the soil surface (cm).

1. Floral traits:

Four plants randomly chosen in each experimental unit then labeled to record flowering time; a number of days from transplanting till 25% full bloom, and No. of flowers $plant^{-1}$; till the end of the experiment. Pollen viability was tested 80 days after transplanting by staining with acetocarmen dye. Number of viable and nonviable pollen grains were counted using microscopic examination (**Singh, 1961**). Fruit set % was calculated according to the following formula:

Fruit set% = (A ÷ B) × 100, where A means a number of setted fruits $plant^{-1}$ throughout the entire season, and B denotes a number of flowers $plant^{-1}$ throughout the complete flowering period.

2. Seed yield and its components:

At red ripe stage, fruits were picked from 4 randomly selected plants in each experimental unit and counted then, seeds were manually extracted and air-dried. Number of seeds $fruit^{-1}$ were counted and weighed, as well as seed yield $plant^{-1}$ and $feddan^{-1}$ was determined.

3. Seed germinability:

Two experiments were conducted in 2003 and 2004 to examine the ability of the extracted mature seeds to germinate. A random sample of 100 seeds from each replicate of every experimental unit was placed on a water

wetted-filter paper in a petri dish and placed in an incubator at a temperature of 25ºC, and were counted daily starting 5 days after beginning the experiment which terminated 3 weeks later. Seed germination % and germination rate were calculated according to the formula described by **Cleland (1957)**.

4. Chemical constituents:

Ten weeks after transplanting, leaves of 4 randomly selected plants were collected from each experimental unit for chemical determinations. Leaf pigments; chlorophylls (a, b, and total) and carotenoids were extracted by acetone (80%) then, their concentrations were determined (mg g^{-1} fresh weight) using colorimetric method as described by **Arnon (1949)**. Nitrogen concentration (mg g^{-1} dry matter) was colorimetrically determined by using the Orange G dye according to the method of **Hafez and Mikkelsen (1981)**. For P, K, Fe, Mn and Zn determinations, the wet digestion of 0.1 g of fine dry material of leaves of each treatment was done with sulphuric and perchloric acids as outlined by **Piper (1947)**. Phosphorus concentration (mg g^{-1} dry matter) was colorimetrically estimated using chlorostannus molybdo-phosphoric blue color method in sulphuric acid system as described by **Jackson (1967)**. Potassium concentration (mg g^{-1} dry matter) was determined using a Perkin-Elmer, Flame Photometer (**Page *et al.*, 1982**). Iron, manganese, and zinc concentrations (mg g^{-1} dry matter) were determined using a Perkin-Elmer, Model 3300, Atomic Absorption Spectrophotometer according to the method outlined by **Chapman and Pratt (1961)**.

5. Statistical analysis:

The obtained data were statistically analyzed, and comparisons among means of different treatments were performed using the Least Significant Differences procedure (LSD) at p=0.05 level as illustrated by **Snedecor and Cochran (1980)**.

RESULTS AND DISCUSSION

1. Vegetative growth characters:

Data presented in Tables (2a and 2b) indicate that, at the same time in which plant height, leaf area $leaf^{-1}$ and leaf area $plant^{-1}$ were significantly decreased, number of main shoots $plant^{-1}$, number of lateral shoots on main stem $plant^{-1}$, number of leaves $plant^{-1}$, fresh and dry weights of leaves and canopy $plant^{-1}$ and thickness of stem upon the soil surface significantly increased as the rate of paclobutrazol (PP_{333}) increased till 15 mg l^{-1} then, these results nonsignificantly reversed. The trend was similar in both seasons.

Table (2a): Response of vegetative growth characters of sweet pepper plants to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character / Treatment	Plant height (cm)	No. of main shoots plant^{-1}	No. of lateral shoots on main stem plant^{-1}	No. of leaves plant^{-1}	Leaf area leaf^{-1} (cm^2)	Leaf area plant^{-1} (dm^2)
2003 season						
Control	14.22	3.13	1.05	44.15	8.34	3.68
PP_{333} (mg l^{-1}):						
5	13.68	3.57	1.69	47.18	7.35	3.47
10	12.70	3.82	2.48	50.98	6.30	3.21
15	12.11	4.06	3.06	53.84	5.46	2.94
20	12.17	4.00	2.94	53.62	5.81	3.12
LSD $_{0.05}$	0.52	0.18	0.16	2.64	0.43	0.19
2004 season						
Control	14.49	3.30	0.98	46.63	8.28	3.86
PP_{333} (mg l^{-1}):						
5	13.81	3.61	1.64	49.56	7.41	3.67
10	13.00	3.80	2.24	52.60	6.46	3.40
15	12.24	4.11	3.00	56.28	5.38	3.03
20	12.38	3.98	3.00	55.21	5.74	3.17
LSD $_{0.05}$	0.60	0.14	0.18	2.50	0.45	0.18

Table (2b): Response of vegetative growth characters of sweet pepper plants to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character / Treatment	Fresh weight of leaves plant^{-1} (g)	Dry weight of leaves plant^{-1} (g)	Fresh weight of canopy plant^{-1} (g)	Dry weight of canopy plant^{-1} (g)	Stem thickness upon the soil surface (cm)
2003 season					
Control	10.76	1.61	20.75	2.66	0.58
PP_{333} (mg l^{-1}):					
5	13.66	2.12	24.00	3.20	0.63
10	16.17	2.59	27.39	3.79	0.68
15	18.11	2.98	29.59	4.27	0.74
20	17.41	2.86	28.60	4.10	0.71
LSD $_{0.05}$	0.76	0.13	1.02	0.20	0.04
2004 season					
Control	10.91	1.64	21.04	2.71	0.60
PP_{333} (mg l^{-1}):					
5	12.98	2.01	23.86	3.18	0.64
10	15.84	2.53	26.78	3.81	0.69
15	18.06	2.98	30.12	4.35	0.74
20	17.32	2.84	29.15	4.20	0.74
LSD $_{0.05}$	0.81	0.16	1.11	0.18	0.04

Foliar spray with PP_{333} at all rates (5, 10, 15 and 20 mg l^{-1}) significantly decreased plant height and leaf area per leaf as well as per plant, and the opposite was observed with all other aforementioned vegetative growth characters as compared to the control in both seasons. Data also show that, the best applied treatment was PP_{333} foliar spray at the rate 15 mg l^{-1} which produced results exceeded those of the control by -15.19%, 27.06%, 198.52%, 21.32%, -34.78%, -20.81%, 66.93%, 83.40%, 42.88%, 60.53%, and 25.42% as means of both seasons for plant height, No. of main shoots plant^{-1}, No. of lateral shoots on main stem plant^{-1}, No. of leaves plant^{-1}, leaf area leaf^{-1}, leaf area plant^{-1}, fresh weight of leaves plant^{-1}, dry weight of leaves plant^{-1}, fresh weight of canopy plant^{-1}, dry weight of canopy plant^{-1}, and stem thickness upon the soil surface, respectively. The histological effect of PP_{333} was studied by **Zhaoliang *et al.* (1995)**, who indicated that the reduction in plant height and leaf area of potato was due to the decrease in cell length rather than reducing number of cells. They also reported that, increasing thickness of leaves, stems, and roots was a result of increasing cell division to produce more cell layers. Changes in GA/ABA balance in PP_{333}-treated plants were probably responsible for the reduction in plant height (**Wan *et al.*, 1989**). The reduction in leaf area in PP_{333}-foliar sprayed plants may be due to the reduction in cell division (**Nassar *et al.*, 2001b**). The increase in No. of leaves per plant in plants treated with PP_{333} might be attributed to the increase in No. of main and lateral shoot per plant (Table 2a) which, in turn, may be resulted from breaking the apical dominance induced by PP_{333}. The depressive effect of PP_{333} on leaf area plant^{-1} show that, the enhancing effect of PP_{333} on No. of leaves plant^{-1} was not able to surmount its depressive effect on leaf area leaf^{-1} (**Osman, 2000**). The stimulation effect of low PP_{333} concentrations on dry matter production might be due to that PP_{333}-treated plants consume less energy for respiration and consequently have higher content of dry matter than the untreated plants (**Steffens and Wang, 1984**). On the other hand, the depressive effect at high rates of PP_{333} could be due to the drastic internal shading within the compacted canopy (**Pombo *et al.*, 1985**). The reduction in leaf area associated with the increase in its fresh and dry weights (Tables 2a and 2b) might be due to the increase in leaf thickness. Many investigators reported similar findings on different crops; **Robert and Culver (1983), Street *et al.* (1986), McArthur and Eaton (1987), El-Masry and Barakat (1991), Latimer (1992), Helal (1993), Nassar *et al.* (2001b),** and **Matter (2003),** on sunflower, rice, strawberry, potato, tomato, *Euphorbia pulcherrima* L., sweet pepper, and hollyhock, respectively.

2. Floral traits:

As shown in Table (3), data exhibit a positive effect of PP_{333} on floral traits (flowering time, No. of flowers plant^{-1}, pollen viability, and fruit set %) of sweet pepper plant in both seasons of 2003 and 2004.

In spite of the rate 20 mg l^{-1} PP_{333} nonsignificantly decreased or stabilized flowering time as compared to the rate 15 mg l^{-1} in 2003 and 2004 seasons, respectively, the same trait nonsignificantly increased with increasing PP_{333} rate from 5 to 15 mg l^{-1}. Results of the control treatment significantly remained behind the findings yielded from all PP_{333} treatments in both seasons, and the trend was stable. The retarding effect of PP_{333} on flowering time could be related to the role of PP_{333} on delaying senescence of the

vegetative organs preceding flowering (**McArthur and Eaton, 1987**), which probably attained due to the increment in nutrients acquisition (**Osman, 2000**). The present results are in harmony with those of **Nassar *et al.* (2001a)** on sweet pepper, as well as **Adham (2001)** and **Matter (2003)** on hollyhock.

Data in Table (3) also reveal that, the gradual increase in PP_{333} rate from 5 to 15 mg l^{-1} associated with a significant gradual increase in number of flowers $plant^{-1}$. On the other side, the rate 20 mg l^{-1} PP_{333} represented nonsignificant reduction as compared to its previous rate (15 mg l^{-1}) in both seasons, and the trend was consistent. All applied treatments (5, 10, 15, and 20 mg l^{-1}) significantly increased over the control in both years of study. The treament of 15 mg l^{-1} PP_{333} yielded the highest number of flowers $plant^{-1}$ surpassed the control by 22.90% and 20.84% in 2003 and 2004 seasons, respectively. The positive effect of PP_{333} on mentioned trait might be resulted from diversion of the assimilates into flower development, possibly due to the reduced demand by the roots (**Wilkinson and Richards, 1987**). The possible alternation of the endogenous hormonal balance induced by PP_{333} cannot be overlooked in this concern. Paclobutrazol has been reported to increase number of flowers per plant in some plant species (**Tukey, 1985; Nishizawa, 1993; Nassar *et al.*, 2001a;** and **Matter, 2003,** on apple, strawberry, sweet pepper, and hollyhock, respectively).

Table (3): Response of floral traits of sweet pepper plants to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character / Treatment	Flowering time (day)	No. of flowers $plant^{-1}$	Pollen viability (%)	Fruit set (%)
		2003 season		
Control	62.5	221.4	72.08	8.56
PP_{333} (mg l^{-1}):				
5	65.8	236.3	72.25	8.45
10	66.9	250.6	76.30	8.78
15	68.3	272.1	78.41	8.80
20	67.8	266.4	78.22	8.77
LSD $_{0.05}$	3.2	9.4	3.07	N.S.
		2004 season		
Control	63.8	217.4	70.14	8.35
PP_{333} (mg l^{-1}):				
5	66.9	229.6	72.34	8.51
10	68.5	244.3	78.74	9.05
15	70.0	262.7	80.78	9.18
20	69.0	260.0	80.06	8.87
LSD $_{0.05}$	2.7	11.0	3.18	0.44

Pollen viability as in Table (3), illustrated to be increased gradually with increasing the concentration of PP_{333}. The increment was nonsignificant between every two treatments, except between 5 and 10 mg l^{-1} PP_{333} which showed to be significant. The trend was similar in both 2003 and 2004 seasons. Each one of all treatments significantly exceeded the control, except

the lowest PP_{333} rate; 5 mg l^{-1} in both seasons. The applied rate 15 mg l^{-1} PP_{333} was the best treatment which yielded results excelled those of the control by 11.93% as an average of both seasons. The promoting effect of PP_{333} on pollen viability could be attributed to that PP_{333} might caused changes in the hormonal balance due to inhibition of gibberellin biosynthesis (**Dalziel and Lawrence, 1984**). **Polowick and Sawhney (1985)** showed that gibberellin biosynthesis might be involved in pollen sterility, and hence PP_{333} might improve pollen viability. Other beneficial effects induced by PP_{333} during the early stages of pollen formation, especially during meiosis of pollen mother cells or closer phases, might also be considered (**Mercado *et al.*, 1997a**).

Data in Table (3) also show that, PP_{333} concentration expressed a nonsignificant influence on fruit set % in the first season. On the other hand, in the second one it imposed a significant effect on the same character. The differences among all treatments in addition to the control were nonsignificant in the first season. While, in the second one they were significant, except between the control and the treatment of the lowest rate of PP_{333} (5 mg l^{-1}). The highest values were obtained from the treatment of the rate 15 mg l^{-1} PP_{333} which increased over the control values by 2.80% and 9.94% in the first and the second seasons, respectively. The pronounced effect of PP_{333} on fruit set percent, especially in the second season could be due to its stimulatory effect on germination and growth of pollen tubes (**Mercado *et al.*, 1997b**), which ensured good setting. Similar findings on fruit set % of tomato and sweet pepper were proved by **Baruah *et al.* (1995)** and **Nassar *et al*. (2001a),** respectively.

3. Seed yield and its components:

Regardless seed weight index, seed yield and its components positively affected when plants foliage were sprayed with PP_{333} at different rates, in both seasons as illustrated in Table (4).

Except seed weight index which nonsignificantly affected, number of fruits per plant, number of seeds per fruit, as well as seed yield per fruit, plant, and feddan significantly increased with increasing PP_{333} rate till 15 mg l^{-1} then, nonsignificantly reduced with stable trend in both seasons. All applied treatments exhibited significant increments as compared to the control treatment. The rate 15 mg l^{-1} PP_{333} showed to be the favorable treatment in which the results increased over the control ones by about 35%, 19%, 19%, 60% and 60% as means of the two studied seasons for No. of fruits $plant^{-1}$, No. of seeds $fruit^{-1}$, seed yield $fruit^{-1}$, $plant^{-1}$ and $feddan^{-1}$, respectively. These results clearly indicated a synergistic effect of PP_{333} with other factors, i.e. mineral nutrients, especially K on seed production. The increment in seed yield per feddan is related to the increase in seed yield per fruit and plant as well as in number of fruits per plant (Table 4), which are connected with the increase in number of flowers per plant (Table 3). The positive effect of PP_{333} on seed yield potential complemented the results of **Mercado *et al.* (1997a)** and **Osman (2000)**. **Setia *et al.* (1997)** and **Nassar *et al.* (2001a)** reported similar increases in seed yield of *Brassica juncea* and sweet pepper, respectively with PP_{333} foliar spray at low rates.

Table (4): Response of seed yield and its components of sweet pepper plants to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character / Treatment	No. of fruits plant^{-1}	No. of seeds fruit^{-1}	Seed weight index (g 100seeds^{-1})	Seed yield g fruit^{-1}	Seed yield g plant^{-1}	Seed yield kg fed^{-1}
2003 season						
Control	17.35	162.3	0.557	0.904	15.68	196.06
PP_{333} (mg l^{-1}):						
5	18.63	170.5	0.556	0.948	17.66	220.76
10	20.70	181.2	0.561	1.017	21.05	263.03
15	23.04	190.8	0.558	1.065	24.54	306.62
20	22.36	190.0	0.560	1.064	23.79	297.39
LSD $_{0.05}$	0.94	7.1	N.S.	0.042	1.21	14.33
2004 season						
Control	16.78	171.5	0.551	0.945	15.86	198.21
PP_{333} (mg l^{-1}):						
5	18.21	180.8	0.554	1.002	18.24	228.00
10	20.84	193.4	0.547	1.058	22.05	275.58
15	22.92	207.2	0.549	1.138	26.08	325.90
20	21.94	207.1	0.550	1.139	24.99	312.38
LSD $_{0.05}$	1.03	9.2	N.S.	0.048	1.15	14.69

4. Seed germinability:

The effect of PP_{333} rate on germinability of yielded seeds expressed as seed germination% and germination rate in 2003 and 2004 seasons is given in Table (5).

Foliar spray with PP_{333} on sweet pepper plants had a significant effect on germinability of produced seeds. In general, seed germination% and germination rate significantly increased and accelerated, respectively as PP_{333} rate increased till 15 mg l^{-1} then, nonsignificantly contrasted in both seasons. Foliar spray with PP_{333} at all rates (5, 10, 15, and 20 mg l^{-1}) significantly increased seed germination% and significantly accelerated germination rate as compared to the control, and the trend was similar in both seasons. The best treatment was in favor of the rate 15 mg l^{-1} PP_{333} in which the results surpassed those of the control by 17.17% and -14.91% for seed germination % and germination rate, respectively in the first season. In addition to, 16.88% and -18.64% in the second one. The increase in seed germinability of PP_{333}-treated plants might be attributed to that PP_{333} stimulate the endogenous cytokinins synthesis. Cytokinins activate a number of enzymes which may be participating in reactions of conversion of complex compounds to simlpe ones for accelerating germination rate and consequently increasing seed germination %. These results are not in agreement with those of **Globerson *et al.* (1989)** and **Barakat *et al.* (1995)**, who indicated that application of PP_{333} did not cause any significant improvement of seed germination % and/or germination rate of the extracted seeds. On the other hand, the present results are in agreement with those obtained by **Osman (2000)** and **Nassar *et al.* (2001a)**, who mentioned that the application of PP_{333} at low concentrations was significantly effective in this concern.

Table (5): Response of germinability of produced sweet pepper seeds to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character	Seed germination	Germination rate	Seed germination	Germination rate
Treatment	(%)		(%)	
	2003 season		2004 season	
Control	62.3	11.4	64.0	11.8
PP_{333} (mg l^{-1}):				
5	65.1	10.8	67.4	11.1
10	68.2	10.3	70.6	10.5
15	73.0	09.7	74.8	09.6
20	70.9	09.9	74.6	10.0
$LSD_{0.05}$	2.7	0.4	3.1	0.5

5. Chemical constituents:

a. Leaf pigments concentrations:

Data presented in Table (6) indicate that, leaf pigments (chlorophylls a, b, and total as well as carotenoids) concentrations significantly increased as PP_{333} rate increased till 15 mg l^{-1} then, nonsignificantly reduced with similar trend in both two studied seasons. Data also reveal that, all applied treatments of PP_{333} significantly increased leaf pigments concentrations as compared to the control in both seasons. These results represent that the application of PP_{333} at the rate 15 mg l^{-1} produced preferable results exceeded the control ones by about 13.7%, 14.1%, 14.7% and 17% as averages of the two studied seasons for chlorophyll a, chlorophyll b, total chlorophylls and carotenoids, respectively. The increment in leaf pigments caused by PP_{333} foliar spray might be attributed to the influence of PP_{333} on depressing leaf area characteristically (Table 2a), which lead to intensification of pigments in the leaf. Furthermore, PP_{333} stimulate the endogenous cytokinins synthesis. Cytokinins proved to be retard chlorophyll degradation, preserve it and increase its synthesis. Besides, cytokinins activate a number of enzymes participating in a wide range of metabolic reactions in leaves. These reactions included the maturation of proplastids into chloroplasts (**Kulaeva, 1979**). Similar findings were reported by **Robert and Culver (1983)** on sunflower, **Helal (1993)** on poinsettie, **Lee and Kwack (1995)** on *Hibiscus syriacus*, **Osman (2000)** and **Nassar *et al.* (2001b)** on sweet pepper and **Matter (2003)** on hollyhock.

Table (6): Response of leaf pigments concentrations of sweet pepper plants to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character	Chlorophyll (µg g^{-1} fresh weight)			Carotenoids (µg g^{-1}
Treatment	a	b	total	fresh weight)
		2003 season		
Control	595.6	353.4	0968.2	235.3
PP_{333} (mg l^{-1}):				
5	617.5	367.9	1008.5	249.5
10	644.7	386.5	1058.5	266.2
15	674.9	407.2	1112.3	279.7
20	666.8	400.8	1097.6	276.8
LSD $_{0.05}$	21.7	13.9	38.8	10.6
		2004 season		
Control	617.3	397.1	1031.7	249.7
PP_{333} (mg l^{-1}):				
5	644.3	413.5	1078.7	260.1
10	676.5	429.3	1130.6	276.8
15	704.0	449.1	1181.1	287.6
20	701.6	445.1	1176.7	286.9
LSD $_{0.05}$	24.8	15.7	43.7	9.5

b. Nutrients concentrations:

The effect of PP_{333} concentration on nutrients (N, P, K, Fe, Mn and Zn) concentrations of sweet pepper plants is shown in Table (7).

All PP_{333} concentrations under study had significant effects on nutrients concentrations in both seasons. All tested nutrients concentrations significantly increased as PP_{333} rate increased till 15 mg l^{-1} then, nonsignificantly decreased in both seasons. All applied treatments of PP_{333} significantly excelled the control in both 2003 and 2004 seasons, and the trend was stable. The applied treatment in which plants foliage sprayed with PP_{333} at the rate 15 mg l^{-1} exhibited to be the best. The findings obtained from this treatment hiccupped the control results by 18.12%, 27.36%, 22.86%, 20.04%, 21.93%, and 24.79% as means of both seasons for N, P, K, Fe, Mn and Zn, respectively. The increase in mentioned nutrients concentrations in leaves of plants sprayed with PP_{333} might be related to the sensitivity of the root system, even though PP_{333} was applied to the leaves. It worth mentioning that with PP_{333} foliar applications, run off from the leaves onto the soil media was not prevented, so roots were exposed directly to small but notable concentration of PP_{333}. Generally, PP_{333} at low concentrations increases root growth slightly (**Wieland and Wample, 1985** and **Bausher and Yelenosky, 1986**), which may cause eventual increase in acquisition of nutrients from the soil. Similar findings were obtained on sweet pepper by **Osman (2000)** and **Nassar *et al.* (2001b)**.

Table (7): Response of some nutrients concentrations of sweet pepper leaves to PP_{333} foliar spray in the two studied seasons of 2003 and 2004.

Character / Treatment	N	P	K	Fe	Mn	Zn
			(mg g^{-1} dry matter)			
2003 season						
Control	21.03	2.38	41.36	2.04	0.83	0.62
PP_{333} (mg l^{-1}):						
5	22.14	2.61	44.27	2.17	0.88	0.66
10	22.98	2.80	47.17	2.36	0.96	0.72
15	24.46	2.98	50.15	2.52	1.03	0.76
20	23.89	2.94	50.01	2.48	1.01	0.76
$LSD_{0.05}$	0.89	0.14	2.84	0.11	0.05	0.03
2004 season						
Control	23.12	2.70	40.56	2.10	0.86	0.59
PP_{333} (mg l^{-1}):						
5	24.38	2.94	43.58	2.20	0.91	0.62
10	26.07	3.21	47.09	2.36	0.97	0.68
15	27.69	3.49	50.48	2.45	1.03	0.75
20	27.19	3.48	50.10	2.45	1.02	0.73
$LSD_{0.05}$	1.09	0.23	2.95	0.09	0.04	0.03

In view of the aforementioned results, growth, flowering, seed yield production and germinability of the yielded seeds of sweet pepper plants could be improved by the foliar spray of PP_{333} at the rate 15 mg l^{-1}.

REFERENCES

Adham, H. E. I. (2001). Effect of some growth retardants, pinching, and planting date on growth, flowering, and chemical composition of *Althaea rosea* L. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

Arnon, D. I. (1949). Copper enzymes in isolated chloroplast. Polyphenol-oxidase in *Beta vulgaris* L. Plant Physiol., 24: 1-5.

Barakat, M. A. S.; Ragheb, W. S. and El-Shamaa, H. A. (1995). Yield, chemical constituents and seed germinability of pea (*Pisum sativum* L.) as affected by paclobutrazol (PP_{333}). Commun. Sci. and Dev. Res., 50: 53-65.

Baruah, G. K. S.; Arora, S. K. and Pandita, M. L. (1995). Effect of paclobutrazol (PP_{333}) and nitrogen levels on growth, flowering and yield of tomato (*Lycopersicon esculentum* Mill.). Ann. Agric. Res., 16: 490-492.

Bausher, M. G. and Yelenosky, J. G. (1986). Sensitivity of potted citrus plants to top sprays and soil application of paclobutrazol. HortScience, 21: 141-143.

Chapman, H. D. and Pratt, P. F. (1961). "Methods of Analysis for Soil". Plants and Water, Univ. Calif., D.V., Agric. Sci., USA.

Cleland, K. W. (1957). Permeability of isolated rate of wheat sarcosomes. Nature, 176: 497-499.

Dalziel, J. and Lawrence, D. K. (1984). Biochemical and biological effects of kaurene oxidase inhibitors, such as paclobutrazol. pp. 43-57. In: Menhenett, R. and Lawrence, D. K. (eds.). Biochemical aspects of synthetic and naturally occurring plant growth regulators. Mangor. 11, British Plant Growth Regulators, London.

El-Masry, T. A. and Barakat, M. A. (1991). Effect of paclobutrazol (PP_{333}) on growth, yield, and quality of some potato cultivars. Alex. J. Agric. Res., 36: 143-155.

El-Sallami, I. H. (2001). Controlling growth habit of potted poinsettia under two light intensity conditions. Assiut J. Agric. Sci., 32 (4): 109-139.

Globerson, D.; Mills, M.; Luner, R.; Windler, J.; Ben-Yehuda, R.; Levy, M. and Eliassay, R. (1989). Effects of paclobutrazol (PP_{333}) on flowering and seed production of onion, cucumber and carrot. Acta Hort., 253: 63-66.

Hafez, A. R. and Mikkelsen, D. S. (1981). Colorimetric determination of nitrogen for evaluating the nutritional status of rice. Commun. Soil Sci. and Plant Analysis, 12 (1): 61-69.

Helal, A. A. (1993). Physiological studies on controlling the growth and flowering of *Euphorbia pulcherrima*. Ph.D. Thesis, Fac. Agric., Zagazig Univ., Egypt.

Jackson, M. L. (1967). "Soil Chemical Analysis". New Delhi, Prentice Hall of India Private Limited, New Delhi, pp. 144-197 and 326-338.

Kamoutsis, A. P.; Chronopoulou-Sereli, A. G. and Paspatis, E. A. (1999). Paclobutrazol affect growth and flower bud production in Gardenia under different light regimes. HortScience, 34 (4): 675-679.

Kulaeva, O. N. (1979). Plant Growth Substances (Ed.). F. Skoog, Springer-Verlag, New York.

Latimer, J. G. (1992). Drought, paclobutrazol, abscisic acid, and gibberellic acid as alternatives daminozide in tomato transplant production. J. Amer. Soc. Hort. Sci., 117: 243-247.

Lee, H. S. and Kwack, B. H. (1995). Effect of uniconazole and GA_3 on growth and flowering of *Hibiscus syriacus* L. showing different growing habits. J. Korean Soc., 36 (1): 121-131.

Matter, F. M. A. (2003). Effect of paclobutrazol and pinching on growth, flowering, and chemical constituents of hollyhock (*Althaea rosea* L.) plants. Fayoum J. Agric., Res. & Dev., 17 (1): 20-31.

McArthur, D. A. J. and Eaton, G. W. (1987). Effect of fertilizer, paclobutrazol, and chloromequat on strawberry. J. Amer. Soc. Hort. Sci., 112: 241-246.

Menesy, F. A.; El-Tantawy, M. A. and Eissa, S. H. (1989). Effect of cycocel and pinching on growth, flowering and leaf pigments content of cineraria (*Senecio hybridus* Regel.) plants. J. Agric. Res., Tanta Univ., 15 (1): 84-95.

Mercado, J. A.; Trigo, M. M.; Reid, M. S.; Valpuesta, V. and Quesada, M. A. (1997a). Effect of low temperature on pepper pollen morphology and fertility: Evidences of cold induced exine alternations. J. Hort. Sci., 72: 317-326.

Mercado, J. A.; Vinegla, B. and Quesada, M. A. (1997b). Effects of hand-pollination, paclobutrazol treatments, root temperature, and genotype on pollen viability and seed fruit content of winter-grown pepper. J. Hort. Sci., 72: 893-900.

Nassar, H. H.; Barakat, M. A.; El-Masry, T. A. and Osman, A. S. (2001a). Effect of potassium fertilization and paclobutrazol foliar application on seed production and seed germinability of sweet pepper. Egypt. J. Hort., 28 (1): 101-111.

Nassar, H. H.; Barakat, M. A.; El-Masry, T. A. and Osman, A. S. (2001b). Effect of potassium fertilization and paclobutrazol foliar application on vegetative growth and chemical composition of sweet pepper. Egypt. J. Hort., 28 (1): 113-129.

Nishizawa, T. (1993). The effect of paclobutrazol on growth and yield during first year greenhouse strawberry production. Scientia Hort., 54: 267-274.

Osman, A. S. (2000). Effect of potassium fertilization and paclobutrazol foliar application on seed production and quality of sweet pepper. M.Sc. Thesis, Fac. Agric., Fayoum, Cairo Univ., Egypt.

Page, A. I.; Miller, R. H. and Keeny, D. R. (1982). "Methods of Soil Analysis". Part II. Chemical and Microbiological Methods. 2nd Ed. Amer. Soc. Agron., Madison, Wisconsin, USA.

Piper, C. S. (1947). "Soil and Plant Analysis". The University of Adelaide, Adelaide, UK.

Polowick, P. L. and Sawhney, V. K. (1985). Temperature effects on male fertility and flower and fruit development in *Capsicum annuum* L. Scientia Hort., 25: 117-127.

Pombo, G.; Orzolek, M. D.; Tukey, L. D. and Pyzik, T. P. (1985). The effect of paclobutrazol, daminozide, glyphosate, and 2,4-D in gel on the emergence and growth of germinated tomato seeds. J. Hort. Sci., 60: 353-357.

Robert, L. W. and Culver, E. B. (1983). The influence of paclobutrazol, a new growth regulator, on sunflowers. J. Amer. Soc. Hort. Sci., 108: 122-125.

Salem, M. A.; El-Leity, A. S. and El-Maaddawy, E. E. (1991). Effect of uniconazole and paclobutrazol foliar application on growth, flowering and sugars contents of globe amaranth (*Gomphrena globosal* L.). J. Agric. Res., Tanta Univ., 17 (2): 492-500.

Setia, N.; Setia, R. C. and Parminder, K. (1997). Morphological development and anatomical features of *Brassica juncea* L. as influenced by paclobutrazol. Phytomorphology, 47: 427-436.

Singh, S. N. (1961). Studies on the morphology and viability of pollen grains of mango. Hort. Advance, 5: 121-144. (c.f. Hort. Abst., 33: 1803, 1963).

Snedecor, W. C. and Cochran, W. G. (1980). Statistical Methods. 7th ed. The Iowa State Univ. Press, Ames, Iowa, USA.

Steffens, G. L. and Wang, S. Y. (1984). Physiological changes induced by paclobutrazol (PP_{333}) in apple. Acta Hort., 146: 135-142.

Street, J. E.; Jordan, J. H.; Ebelhar, M. W. and Boykin, D. L. (1986). Plant hieght and yield responses of rice to paclobutrazol. Agron. J., 78: 288-291.

Tukey, L. D. (1985). Cropping characteristics of bearing apple trees sprayed annually with PP_{333} (paclobutrazol). Proc. 5th Int. Symp. Growth Regulat. in Fruit Prod. ISHS. p. 95 (Abst.).

Wan, Y. S.; Wu, S. R. and Li, S. J. (1989). Effect of regulation of plant form of seedlings of *Capsicum frutescens* L. raised by soilless culture. Plant Physiol. Comm., 2: 52-54.

Wieland, W. F. and Wample, R. L. (1985). Root growth, water relations and mineral uptake of young Delicious apple trees treated with soil and stem-applied paclobutrazol. Scientia Hort., 26: 129-137.

Wilkinson, R. I. and Richards, R. (1987). Effect of paclobutrazol on growth and flowering of *Bouvardia humboldtii*. HortScience, 22: 444-445.

Zhaoliang, L.; Yueqing, S.; Mingzhi, S.; Yahong, S.; Zi, L.; Yg, S.; Mz, S. and Yh, S. (1995). The effect of paclobutrazol on plant physiology of some crops. Acta Agric. Shanghai, 11: 43-47. (c.f. Field Crop Abst., 49: 5957, 1996).

استجابة النمو والإزهار ومحصول البذور والقدرة الإنباتية لبذور الفلفل الحلو للرش الورقي بالباكلوبيوترازول

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اجرى هذا البحث بمزرعة كلية الزراعة بالفيوم، جامعة القاهرة خلال الموسمين الصيفيين ٢٠٠٣ و٢٠٠٤، وذلك بهدف دراسة استجابة النمو، الإزهار، محصول البذور، القدرة الإنباتية لبذور الفلفل الحلو صنف كاليفورنيا وندر، وكذلك بعض المكونات الكيماوية للرش الورقي بالباكلوبيوترازول بمعدلات ٥، ١٠، ١٥، و٢٠ ملليجرام/ لتر.

تم الحصول على نتائج معنوية نتيجة رش المجموع الخضري لنباتات الفلفل الحلو بالباكلوبيوترازول مرتين خلال موسم النمو؛ بعد ٢٥ و٣٥ يوم من الشتل، خاصةً النتائج المتحصل عليها من الرش بالمعدل ١٥ ملليجرام/ لتر.

تأثرت صفات النمو الخضري، الخصائص الزهرية، محصول البذور ومكوناته، القدرة الإنباتية للبذور، تركيزات صبغات الأوراق، وتركيزات بعض العناصر المعدنية في المادة الجافة للأوراق إيجابياً في النباتات المعاملة بالباكلوبيوترازول.

أدى رش المجموع الخضري للنباتات بالباكلوبيوترازول بجميع المعدلات المستخدمة إلى نقص معنوي في ارتفاع النبات ومساحة الأوراق في الوقت الذي أدى فيه إلى زيادة معنوية في عدد الأفرع الرئيسية/ نبات، عدد الأفرع الجانبية على الساق الرئيسي/ نبات، عدد الأوراق/ نبات، الأوزان الطازجة والجافة للأوراق والمجموع الخضري (جزء النبات فوق سطح التربة)/ نبات، سمك الساق عند مستوى سطح التربة، ميعاد الإزهار، عدد الأزهار/ نبات، حيوية حبوب اللقاح، نسبة عقد الثمار (في الموسم الثاني فقط)، عدد الثمار/ نبات، عدد البذور/ ثمرة، محصول البذور لكل من الثمرة والنبات والفدان، نسبة إنبات البذور المنتجة، الإسراع من معدل الإنبات، تركيزات الكلوروفيللات (أ، ب، والكلية) والكاروتنويدات في الأوراق الطازجة للنبات، وتركيزات جميع العناصر محل الدراسة (النيتروجين، الفوسفور، البوتاسيوم، الحديد، المنجنيز، والزنك) في المادة الجافة لأوراق النبات. على الجانب الآخر، لم يحدث تأثير معنوي على نسبة عقد الثمار (في الموسم الأول فقط) ودليل وزن البذور نتيجة تطبيق نفس المعاملات. **في ضوء تلك النتائج**، يمكن استنتاج أن النمو، الإزهار، إنتاج البذور، والقدرة الإنباتية للبذور المنتجة يمكن تحسينها معنوياً برش المجموع الخضري لنباتات الفلفل الحلو بالباكلوبيوترازول بتركيز ١٥ ملليجرام/ لتر.