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Response of prohexadione calcium and paclobutrazol on growth and physio-chemical characteristics of pear cv. Clapp's Favorite

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ABSTRACT

The present investigation was conducted to study the response of growth retardants on pear cv. Clapp's Favorite during the year 2015-2016. The experiment was laid out with thirteen treatments replicated thrice on 12 year-old-trees with uniform vigour and health under uniform cultural practices. The treatment comprises of single spray and double spray of growth retardants (prohexadione calcium @ 100, 200 and 300 ppm and paclobutrazol @ 100, 200 and 300 ppm). The first spray of growth retardants was applied at petal fall stage and second spray was four weeks after first spray. The plants sprayed twice with prohexadione calcium @ 200 ppm (T_9S_2) recorded minimum annual shoot extension growth (16.92 cm), internodal length (1.82 cm) and leaf area (22.20 cm^2) along with increase in fruit set (18.34 %) and minimum fruit drop (32.45 %). Increased fruit yield (51.24 kg), yield efficiency (4.08) and following year return bloom (24.04 %) was noticed in T_9S_2 treatment. Prohexadione calcium sprayed twice @ 200 ppm (T_9S_2) also increased fruit weight (82.85 g), TSS (13.21 %) and total sugars (10.23 %) closely followed by the double spray of prohexadione calcium @ 300 ppm sprayed twice which was also effective in enhancing the fruit firmness (6.15 kg/cm^2) followed by treatment $T_{12}S_2$ i.e. paclobutrazol @ 200 ppm double spray (6.07 kg/cm^2). Double spray of prohexadione calcium @ 200 ppm was effective in reducing the vegetative characters and increasing yield and fruit quality characters.

Keywords: *Pyrus communis*, growth retardants, quality, return bloom.

INTRODUCTION

Growth control is required for young fruit trees to hasten flowering and bearing trees prevent crowding and excessive shadings. Frequently, management mistakes or abnormal weather conditions disrupt this delicate balance, resulting in excessive vegetative growth. However, an appropriate balance between vegetative growth and crop load is essential. If not appropriately controlled, this excessive growth negatively influences flower bud formation and fruit set, by causing shading or the early competition for stored resources. Various non-chemical ways to control vegetative growth have been practiced, including use of dwarfing rootstocks, pruning and limb spreading. Although dwarfing rootstocks have been successfully used to control vegetative growth, however, rootstock cannot be a sole solution because unanticipated events such as lack of crop resulting from frost or excessive thinning and biennial bearing tendencies may tip the balance in favour of vegetative growth. These situations require additional forms of growth control.

Although many growth retardants are used in fruit crops for overcoming these problems like adenile benzyl amine is used to reduce the physiological loss in weight, GA_{12} aldehyde is used to reduce the acidity in fruits (Wani *et al.*, 16), chloroqemutat causes reduction in shoot length and ethephon that requires high dose for shoot reduction but sometimes it leads to substantial thinning. However, it has been reported that application of prohexadione calcium and paclobutrazol can significantly reduce these problems when applied at appropriate time and in proper quantity (Rademacher and Kober, 11). Prohexadione calcium (Rademacher *et al.*, 12) and paclobutrazol (Arzani and Roosta, 2) both are novel plant growth regulators that emerged as important management tools that an orchardist has available to manage tree canopy volume. One of the major advantages of these growth regulators is that these do not leave any harmful residues on plants because of their less biological activation life when applied on the plant. Now-a-days prohexadione calcium and paclobutrazol produces shortest shoot length and did not have any negative effect on return bloom and yield (Costa *et al.*, 6). To inhibits the shoots growth or to control the excessive vegetative growth which is the main character of the pear fruit plant and to enhance the fruit set, fruit size and ultimately yield, the present study was conducted with two growth retardants (prohexadione calcium and paclobutrazol) on the Clapp's Favourite pear to standardize the optimum dose for regulating the growth of the plant.

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MATERIALS AND METHODS

The experiment was carried out at farmer's field during 2015-2016 near SKUAST-Kashmir, Shalimar, Srinagar (J&K). The experimental orchard was situated at an altitude of 1685 m amsl which lying between 34º75'N latitude and 74º50'E longitude. The study was conducted on twelve year old pear trees cv. 'Clapp's Favourite' grown on seedling rootstock. The orchard was having proper drainage and soil was moderately deep, showing good fertility status. Most of the precipitation received from October to April and rest is erratically distributed. Winters are severe extending from December to March and the temperature often goes below freezing point during this period. The plants having similar vigour and size were selected, marked and maintained under uniform cultural practices and trained as modified leader system at a spacing of 5 × 5 metre.

The experiment was laid out in a randomized block design with three trees representing a treatment. Thirty nine healthy trees grouped into three replications and thirteen treatments including a control (water spray) were marked as per the treatments. Two growth retardants (prohexadione calcium and paclobutrazol) with three concentrations of each (100, 200, 300 ppm) were sprayed (details given in Table 1). The first spray of these growth retardants was given at petal fall stage and second at four weeks after first spray.

Observations were recorded on various vegetative characters. Four branches per plant were randomly selected in four directions and marked/tagged and annual shoot extension growth (cm) and internodal length (cm) was worked out with the help of measuring tape. Leaf area (cm^2) was calculated with help of automatic leaf area meter (221 Systronics). Yield per plant (kg) was calculated by weighing whole fruits from a single plant. Yield efficiency (kg/cm^2) was calculated as per standard method. On the selected branches total number of flowers was counted initially and number of fruitlets at pea stage and per cent fruit set was calculated. Fruit drop (%) was calculated with the help of formula:

$$\text{Fruit drop (\%)} = \frac{\text{No. of fruitlets at peanut stage – No. of fruits at harvest}}{\text{No. of fruitlets at peanut stage}} = 100$$

Fruit retention (%) was calculated by dividing number of fruits at harvest with number of fruitlets at peanut stage multiply by 100. Return bloom (%) was calculated in the following year by counting the number of flowers in the following season with respect to the previous season and expressed in per cent.

Ten fruits were randomly taken for all the physio-chemical characters. Fruit weight (g) was determined with the help of digital weighing balance, however fruit length and diameter were determined using a digital Vernier caliper. L/D ratio of fruit was calculated by dividing the fruit length with fruit diameter. Fruit flesh firmness was determined with the help of a digital Effegi pressure tester plunger and expressed in kg/cm^2. Total soluble solids were determined by using digital hand refractometer whereas acidity was measured in terms of malic acid. Total sugar was determined as per the standard procedures (AOAC, 1). The fruit juice was measured by pressing out juice from a known pulp weight with the help of laboratory model basket. Data collected on various parameters were statistically analyzed as per the procedure given by Snedecor and Cochran (14).

RESULTS AND DISCUSSION

The effect of growth retardants on the vegetative growth and yield parameters on the Clapp's Favourite pear are given in Table 2. Vegetative growth is the parameter most obviously affected by Prohexadione-Ca and paclobutrazol applications. The inhibitory effect of the Pro-Ca formation of growth active gibberellin leads to reduction of shoot growth. The effect of Prohexadione-Ca and paclobutrazol dosage on all the shoot extension growth, intermodal length, leaf area, fruit yield and yield efficiency were statistically

Table 1. Treatment details:

Treatments	Chemicals concentrations	Treatments	Chemicals concentrations
T_1 S_0		Water spray	
Single spray (S_1)		Double spray (S_2)	
T_2 S_1	Prohexadione Ca 100 ppm	T_8 S_2	Prohexadione Ca 100 ppm
T_3 S_1	Prohexadione Ca 200 ppm	T_9 S_2	Prohexadione Ca 200 ppm
T_4 S_1	Prohexadione Ca 300 ppm	T_{10} S_2	Prohexadione Ca 300 ppm
T_5 S_1	Paclobutrazol 100 ppm	T_{11} S_2	Paclobutrazol 100 ppm
T_6 S_1	Paclobutrazol 200 ppm	T_{12} S_2	Paclobutrazol 200 ppm
T_7 S_1	Paclobutrazol 300 ppm	T_{13} S_2	Paclobutrazol 300 ppm

Table 2. Effect of prohexadione calcium and paclobutrazol on vegetative and yield characters of Clapp's Favourite pear.

Treatments	Annual shoot extension (cm)	Internodal length (cm)	Leaf area (cm^2)	Fruit yield (kg/tree)	Yield efficiency (kg/cm^2)
T_1S_0	21.44	4.39	24.63	33.59	3.23
T_2S_1	18.43	2.42	23.44	35.30	3.32
T_3S_1	17.54	2.20	23.04	39.50	3.53
T_4S_1	17.63	2.25	23.10	38.50	3.51
T_5S_1	18.47	2.42	23.44	34.77	3.24
T_6S_1	17.64	2.21	23.08	38.93	3.52
T_7S_1	17.88	2.28	23.10	37.60	3.33
T_8S_2	17.89	2.10	23.00	42.73	3.71
T_9S_2	16.92	1.82	22.20	52.24	4.28
$T_{10}S_2$	17.01	1.85	22.40	50.57	3.73
$T_{11}S_2$	17.89	2.16	23.03	42.67	3.68
$T_{12}S_2$	17.09	1.84	22.75	51.12	4.05
$T_{13}S_2$	17.17	1.88	22.88	50.54	3.72
$CD_{0.05}$	0.17	0.26	0.80	0.66	0.18

significant ($P<0.05$). Minimum average annual shoot extension growth (16.92) was obtained in the treatment prohexadione calcium @ 200 ppm sprayed twice (T_9S_2) which was statistically at par with treatment $T_{10}S_2$ (17.01 cm) i.e. prohexadione calcium @ 300 ppm sprayed twice and treatment $T_{12}S_2$ (17.09 cm) i.e. paclobutrazol @ 200 ppm sprayed twice (17.09 cm) whereas maximum shoot extension growth (21.44 cm) was recorded under control (T_1S_0). Minimum internodal length (1.82 cm) was recorded in treatment T_9S_2 i.e. prohexadione calcium @ 200 ppm sprayed twice which was statistically at par with treatment of paclobutrazol @ 200 ppm sprayed twice ($T_{12}S_2$), prohexadione calcium @ 300 ppm sprayed twice ($T_{10}S_2$) and paclobutrazol @ 300 ppm sprayed twice ($T_{13}S_2$) and paclobutrazol @ 100 ppm sprayed twice recorded 1.84 cm, 1.85 cm and 1.88 cm, respectively. Reduction in vegetative growth is attributed to the reason that prohexadione calcium inhibits biosynthesis of active gibberellic acid isomers in plant tissues (Pasa *et al.*, 10). Prohexadione calcium reduces the shoot elongation in fruit trees due to inhibition in the biosynthesis of gibberellic acid as it stops the formation of GA_1 (active form) from GA_{20} (Basak and Rademacher, 3). Double spray of prohexadione calcium applied @ 200 ppm registered minimum leaf area (22.20 cm^2) closely followed and statistically at par with other double spray of Pro-Ca and Paclabutrazol concentrations except double spray of both the growth retardants @ 100 ppm whereas maximum leaf area (24.63 cm^2) was measured in control (T_1S_0). Cares *et al.*, (5) observed that prohexadione calcium is a plant bio regulator that inhibits gibberellic acid biosynthesis and hence causes reduction in annual extension growth and leaf area of sweet cherry cv. Lappins and Sweet heart.

Fruit yield and yield efficiency had also influenced by the prohexadione calcium and paclobutrazol application. Prohexadione calcium 200 ppm sprayed twice (T_9S_2) had scored highest values for fruit yield (52.24 kg) and yield efficiency (4.28 kg/cm^2) which were statistically superior among all the treatments, however, minimum values were registered under control for fruit yield (33.59 kg) and yield efficiency (3.23 kg/cm^2). The increase in yield may be attributed to the reason that prohexadione calcium inhibits gibberellic acid biosynthesis, which changes the source sink relationship by recollecting the carbohydrates source toward fruits, however yield efficiency is the ratio of fruit yield and trunk cross sectional area, decrease in cross sectional area with the use of prohexadione calcium resulted in increase in yield efficiency (Costa *et al.*, 6).

Data presented in Fig. 1 depicts that all the fruiting characters and return bloom was significantly affected by the application of Pro-Ca and paclobutrazol chemicals. Maximum fruit set (18.34 %) was recorded when prohexadione calcium was sprayed twice @ 200 ppm which was statistically higher among all the treatments however minimum fruit set was recorded under control (T_1S_0). The increase in fruit set was attributed to the fact that prohexadione calcium primarily inhibits the excessive vegetative growth in fruit trees and thus reduces abortion of fruitlets, thereby increases fruit set (Rademacher and Kober, 11).

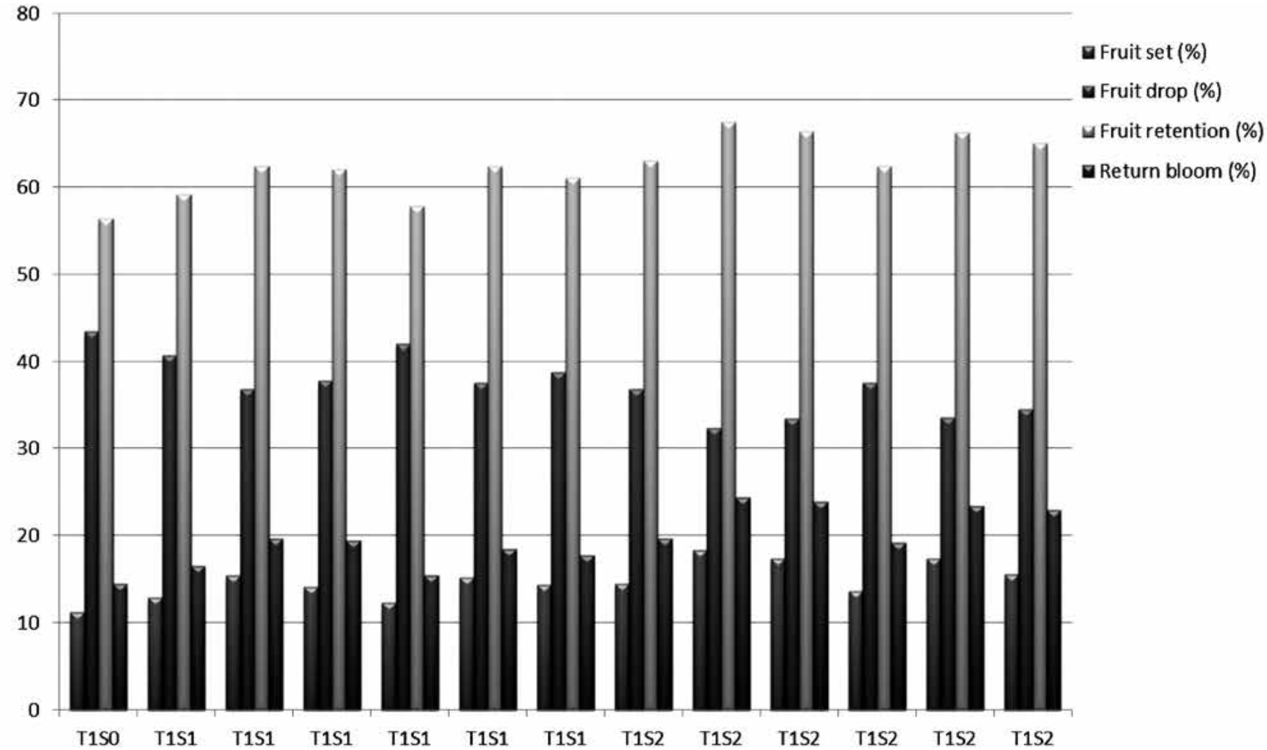

Fig. 1. Effect of prohexadione calcium and paclobutrazol on fruit set, drop, retention and return bloom of 'Clapp's Favourite' pear.

Minimum fruit drop (32.45 %) and maximum fruit retention (67.49 %) was noticed in the treatment T_9S_2 i.e. prohexadione calcium @ 200 ppm sprayed twice which were statistically and significantly superior over other treatments. Similar results with respect to fruit drop was earlier reported by Vercammen and Gomand, (15) in 'Conference' pear, however Shehaj *et al*. (13) reported conformity results for fruit retention in pear cv. 'Passe Crassane'. Pro-ca inhibits the vegetative growth in fruit plants and also inhibits the ethylene biosynthesis in fruits that also inhibits rapid fruit drop and thus it increases the fruit retention in fruits plants (Rademacher and Kober, 11).

Return bloom was observed in the following year on the marked branches and it was noticed that the double spray of Pro-Ca @ 200 ppm had maximum return bloom (24.04 %) which was statistically at par with the treatment $T_{12}S_2$ (23.92 %) i.e. twice spray of paclobutrazol @ 200 ppm and $T_{10}S_2$ (23.59 %) i.e. twice spray of Pro-Ca @ 300 ppm, however minimum return bloom (14.46 %) was recorded under control (T_1S_0). Reduction in vegetative growth due to spray of Pro-ca results in the conserve higher amounts of assimilates in the fruit plants and these assimilates increases return bloom in the following year as there is more reproductive bud formation takes place (Bill, 4).

All the physio-chemical characters were significantly influenced by the application of prohexadione calcium and paclobutrazol (Table 3) except acidity which showed non-significant results. Prohexadione calcium @ 200 ppm sprayed twice (T_9S_2) had recorded maximum fruit weight (82.85 g) which was significantly superior over other treatments, whereas, minimum fruit weight (68.96 g) was recorded in control (T_1S_0). Earlier Costa *et al*., (6) also reported higher fruit weight in 'Abbate Fetel' pear while applying the Pro-Ca four times @ 100 ppm. Maximum fruit length (6.81 cm) and fruit diameter (6.44 cm) was registered in the treatment $T_{12}S_2$ i.e. paclabutrazol @ 200 ppm sprayed twice which was statistically at par with the double spray of Pro-Ca @ 200 ppm (6.73 cm and 6.34 cm) and Pro-Ca @ 300 ppm (6.66 cm and 6.36 cm), however minimum values for fruit length (4.67 cm) and fruit diameter (4.47 cm) was registered in the treatment T_1S_0 (control). Meintejes *et al*., (8) in 'Rosemarie', 'Flamingo', 'Early Bon Chretien', 'Packham's Triumph' and 'Forelle' pear also reported similar results with respect to fruit size after application of Pro-Ca. Treatment T_9S_2 (Pro-Ca @ 200 ppm) and $T_{12}S_2$ (paclobutrazol @ 200 ppm) recorded maximum (1.06) value for L/D ratio whereas minimum (0.86) value was recorded in T_2S_1, T_8S_2 and $T_{11}S_2$. Maximum fruit firmness (6.15 kg/cm^2) was recorded

Table 3. Effect of prohexadione calcium and paclobutrazol on fruit physio-chemical characters of Clapp's Favourite pear.

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	L/D Ratio	Fruit firmness (kg/cm²)	Total soluble solids (%)	Total sugars (%)	Acidity (%)	TSS/ Acid ratio	Fruit juice (ml)
T_1S_0	68.96	4.67	4.47	1.04	4.73	9.72	8.35	0.52	18.96	31.35
T_2S_1	73.28	4.91	5.72	0.86	4.97	11.12	8.62	0.48	23.13	40.43
T_3S_1	77.66	5.83	5.90	0.98	5.63	12.14	8.98	0.47	25.84	44.92
T_4S_1	76.47	5.67	5.89	0.96	5.78	11.80	8.89	0.47	25.01	43.84
T_5S_1	72.60	4.89	5.25	0.93	4.59	11.01	8.52	0.51	22.37	39.55
T_6S_1	76.64	5.42	5.58	0.97	5.73	12.00	8.99	0.45	26.67	44.50
T_7S_1	75.08	5.38	5.37	1.01	5.55	11.71	8.99	0.47	24.92	43.51
T_8S_2	78.14	5.09	5.97	0.86	5.33	11.91	9.13	0.47	25.37	44.37
T_9S_2	82.85	6.73	6.34	1.06	5.93	13.21	10.23	0.43	30.17	50.69
$T_{10}S_2$	81.85	6.66	6.36	1.05	6.15	13.06	10.11	0.44	29.81	50.07
$T_{11}S_2$	77.58	5.05	5.85	0.86	5.33	11.73	9.01	0.49	23.98	42.73
$T_{12}S_2$	82.13	6.81	6.44	1.06	6.07	12.92	9.89	0.44	29.48	50.91
$T_{13}S_2$	80.79	6.42	6.26	1.03	5.96	12.74	9.67	0.46	27.73	49.55
$CD_{0.05}$	0.54	0.19	0.16	0.04	0.09	0.34	0.35	NS	1.65	1.32

in treatment $T_{10}S_2$ i.e. prohexadione calcium @ 300 ppm sprayed twice which was statistically at par with $T_{12}S_2$ i.e. paclobutrazol @ 200 ppm sprayed twice (6.07 kg/cm²), however, minimum fruit firmness (4.73 kg/cm²) was recorded in control (T_1S_0). The linear increase in fruit firmness was also reported Guak (7) in apple cv. 'Golden Delicious'. Prohexadione calcium reduces competition between shoot growth and fruit development and hence, increases the amount of mineral nutrition including calcium moves towards fruit and increases fruit firmness (Bill, 4).

Treatment T_9S_2 i.e. prohexadione calcium sprayed twice @ 200 ppm scored maximum TSS (13.21%) and total sugars (10.23%) which was statistically at par with treatment $T_{10}S_2$ i.e. Pro-Ca sprayed twice @ 300 ppm (13.06% and 10.11%) and treatment $T_{12}S_2$ i.e. paclobutrazol sprayed twice @ 200 ppm (12.92% and 9.89%) whereas minimum TSS (9.72%) and total sugars (8.35%) was recorded in control (T_1S_0). Minimum acidity (0.43%) was recorded in prohexadione calcium @ 200 ppm sprayed twice and maximum acidity (0.52%) was recorded in control, however the results for the acidity were non-significant. The reason attributed to this is that prohexadione calcium inhibits gibberellic acid biosynthesis that resulted in reduction of vegetative growth and consequently facilitates more assimilates towards fruit like carbohydrates, cellulose and sugars (Guak, 7). Prohexadione calcium @ 200 ppm sprayed twice (T_9S_2) recorded highest TSS/acid ratio value (30.17) which was statistically at par with treatment $T_{10}S_2$ i.e. prohexadione calcium @ 300 ppm sprayed twice (29.81) and treatment $T_{12}S_2$ i.e. paclobutrazol @ 200 ppm sprayed twice (29.48) whereas, minimum TSS/acid ratio (18.96) was recorded in control. Maximum fruit juice (50.91%) was recorded in treatment $T_{12}S_2$ (paclobutrazol @ 200 ppm sprayed twice) which was statistically at par with treatment T_9S_2 i.e. Pro-Ca @ 200 ppm sprayed twice (50.69%) and treatment $T_{10}S_2$ i.e. Pro-Ca @ 300 ppm sprayed twice (50.07 %), whereas minimum fruit juice (31.35 %) was recorded in control. Increase in TSS, total sugar, fruit juice and decrease in acidity content of pear fruit is that due to less competition between shoot growth and fruit development, more photosynthetic assimilates moves towards fruits as a result increases sucrose and cellulose levels in fruits that further resulted in increase of TSS/acid ratio in fruits (Ouzounidou *et al.*, 9).

Foliar application of prohexadione calcium 200 ppm sprayed twice at complete petal fall and second at four weeks after first spray resulted in minimum vegetative growth which increased fruit yield and quality and return bloom as the assimilates used in vegetative growth were translocated towards fruits as a result of which fruit yield, fruit quality and return bloom were improved.

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