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Effect of Foliar Application of Salicylic Acid and Calcium Chloride on Growth, Yield and Quality of Pear (*Pyrus communis* L.) cv. Carmen

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ABSTRACT

An experiment was designed to evaluate the effect of repeated foliar application of salicylic acid (0, 100, 150 and 200 ppm) and calcium chloride (0.20, 0.25 and 0.30 %) on the vegetative growth, fruiting and fruit quality of pear cv. Carmen/Quince-C at the Experimental Farm, Division of Fruit Science, SKUAST-Kashmir, Srinagar (J&K), India. The treatments were applied as foliar spray at 3, 6 and 9 weeks after petal fall. The experiment was laid out in Randomized Complete Block Design with factorial arrangements with three replications. Results showed that salicylic acid treatment significantly improved vegetative growth, fruit yield and physico-chemical character of fruit. Salicylic acid @ 200 ppm resulted maximum shoot extension growth (27.47 cm), leaf area (21.20 cm^2) and fruit yield (6.92 kg per $plant^{-1}$), fruit weight (168.44g, firmness (10.16 kg cm^{-2}), total soluble solids (14.01 ^oBrix), acidity (0.54 %), total sugars (12.97 %) and ascorbic acid (9.41 mg per 100 g). Calcium chloride ($CaCl^2$) sprays were not effective in improving vegetative growth while size of fruit, fruit weight, fruit yield and fruit firmness was increased. $Cacl_2$ @ 0.30 % resulted fruit weight (165 g), yield (6.87 kg $tree^{-1}$) and fruit firmness (10.18 kg cm^{-2}) while total soluble solids (12.87 ^0Brix), acidity (0.52%), ascorbic acid (9.7 mg kg^{-1}) and total sugars (11.81 %) were maximum without $CaCl_2$ sprays (control). The interactions effects of repeated salicylic acid and $CaCl_2$ sprays on growth, fruit yield and physico-chemical parameters of fruits were non-significant.

1. Introduction

Pears (*Pyrus* spp.) belong to family Rosaceae are considered only next to apple in importance, acreage and production among temperate fruits in the world. The most important commercial pear cultivars grown worldwide are belongs to *P. communis* and *P. pyrifolia*, although there are significant acreages of several other species. According to FAO (2018), total pears production in the world is 23733772 ton from an area of 13.81923 ha with China as leading producer. India's share was 318000 tonnes from an area of 44000 ha. Due to wide range of agro-climatic adaptability of pear, the scattered plantations of this crop are found right from subtropical plains to cold dry temperate hilly regions of India (Kumar and Sengupta, 2009). In India, pears are cultivated in more than eleven states and predominantly grown in temperate zones of Jammu and Kashmir, Himachal Pradesh and Uttarakhand, subtropical areas of Punjab, Haryana, Jharkhand, North Eastern region (Manipur, Mizoram, Nagaland) and Tamil Nadu. Area, production and productivity of pears in Jammu and Kashmir during 2018-19 was reported 13.94 thousand ha, 86.03 thousand tonnes and 6.17 t/ha, respectively (Anonymous, 2019). Due to its nutritive properties, good taste and low caloric content, the European pear is a fruit that is appreciated by consumers. It has low protein and lipid contents and good source of carbohydrates such as fructose, sorbitol, and sucrose and contains a low amount of glucose and dietary fibre (Blattny, 2003).

Plant growth in the natural environment is often adversely affected by a number of factors. These include environmental factors such as low temperature, heat, drought, wind, ultraviolet light, anoxia, and high salinity and

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Biological factors such as pathogens (Reddy and Reddy, 2001). Under stressful conditions, growth hormones are considered vital for several processes in the life cycle of plants; where endogenous levels of growth substances change throughout the growing season with corresponding variations in growth and development. Salicylic acid is one of the naturally occurring phyto-chemicals considered to be a potent plant hormone because of its diverse regulatory role in plant metabolism (Raskin, 1992a, 1992b). It plays an important role in the regulation of plant growth, development, ripening, flowering, and responses to abiotic stresses (Vicente and Plasencia, 2011). Salicylic acid and its derivatives are also useful in enhancing the postharvest quality of several fruits (Hayat *et al.*, 2010; Kazemi *et al.*, 2011). Among nutrient management, calcium plays an important role in fruit production and quality and is considered to be deficit in highest rainfall areas and is less mobile in soils (Zatylnyl and Pierre, 2006). Amiri *et al.* (2008) claimed that foliar application of nutrients is more efficient to improve quality of pear, as foliar sprays can supply essential elements directly to the foliage and fruits; however it is very difficult to achieve the goal because of the restricted uptake and penetration of calcium into the fruit and its movement within fruit tissue (Schlegel and Schonherr, 2002). To explore the role of salicylic acid and calcium chloride, the present investigation was carried out on newly introduced pear cv. Carmen due to its red/blush colour, juicy and early harvesting as it has great potential in Kashmir valley.

2. Materials and Methods

The study was conducted at experimental farm of Division of Fruit Science, SKUAST-Kashmir, Shalimar campus, Srinagar (J & K) on Carmen cv. Pear grafted on Quince C planted at a spacing of 3 x 3 m. The experimental site is located at an elevation of 1685 m amsl and is characterized by very cold temperature (upto -7^{o}C occurs) during December to March and hot temperatures (35^{o}C) commenced from July-September. April and May are cold and mild, June to August comparatively warm and September is mild. October and November are cold and generally dry. The treatments comprised of (a) salicylic acid (S_0: control, S_1: 100 ppm, S_2: 150 ppm and S_3: 200 ppm) and (b) calcium chloride (C_0: control, C_1: 0.20 %, C_2: 0.25 % and C_3: 0.30 %) each with four levels. The salicylic acid and calcium chloride as per the treatment detailed above were sprayed on the trees at 3, 6 and 9 weeks after petal fall. The spraying was carried out through Knapsack Sprayer till slight run off of the spray liquid from the leaves. The experimental design was laid out on forty eight uniform trees with factorial randomized complete block design replicated thrice with one tree per replication.

Observations were recorded on growth, yield and physico-chemical characters of fruit. Ten randomly shoots of current season growth were selected and measured with the help of measuring tape at the cessation of growth and average was worked out and expressed in cm. On the same branches total numbers of leaves was counted and mean value was expressed as number of leaves per shoot. Leaf area of twenty leaves was measured with the help of automatic Leaf Area Meter (Systronics, Model: 221) and average leaf area was expressed in cm^2. Trunk girth was measured at 45 cm above ground level and trunk cross sectional area was worked out as per procedure suggested by Westwood (1993). Number of fruits per plant harvested and fruit yield per plant (kg) were also recorded under each treatments. Ten fruits were randomly taken for all the physio-chemical characters. Fruit weight (g) was determined with the help of digital weighing machine; and fruit length and diameter were determined using a digital Vernier caliper and expressed in cm. Fruit volume was measured by water displacement method and expressed in cm^3. 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. Titrable acidity (in terms of malic acid), reducing sugar and total sugar and ascorbic acid were determined as per the standard procedures (AOAC, 2000). Data generated from present investigations were appropriately computed, tabulated and statistically analyzed at 5% level of significance as per the procedure given by Snedecor and Cochran (1994).

3. Results and Discussion

Data reveals that vegetative growth under study was significantly affected by foliar application of salicylic acid (Table 1). Maximum shoot extension growth (27.47 cm) was noted with the application of salicylic acid @ 200 ppm; although, it was statistically at par 150 ppm (26.86 cm) and 100 ppm (26.70 cm) whereas minimum shoot extension growth (25.89 cm) was recorded in control. Maximum increase in trunk cross sectional area was recorded with the application of salicylic acid @ 200 ppm (6.54 cm^2) however, results were non-significant. Minimum increase in trunk cross sectional area was recorded under control. Maximum leaf area (21.20 cm^2) was recorded with 200 ppm salicylic acid and was statistically at par with 150 ppm (20.93 cm^2) and 100 ppm (20.72 cm^2) sprays of salicylic acid. Minimum leaf area (19.94 cm^2) was recorded in control. Calcium chloride treatments showed non-significant effect on shoot extension growth, tree cross section area as well as leaf area. Increase in shoot extension growth and leaf area might be attributed to the promotive bio-regulatory effects of salicylic acid on physiological and biochemical processes in plants such as ion uptake, cell elongation, cell division, cell differentiation, sink/source regulation, enzymatic activities, protein synthesis and photosynthetic activity as well as increase in the

antioxidant capacity of plants (Hayat *et al.* 2010). Also, salicylic acid has anti-senescence influence on plant organs (Morris *et al.*, 2000); thus the vegetative growth might be prolonged due to salicylic acid treatments leading to increase in vegetative growth. Shaaban *et al.* (2011) in apple and Baba *et al.* (2017) in strawberry also observed increased growth and foliage parameters due to the salicylic acid application.

Salicylic acid and calcium chloride had non-significant on number of fruits per plant when different doses of were sprayed (Fig. 1). Maximum number of fruits per plant (41.42 and 41.92) was counted with salicylic acid @ 200 ppm and $CaCl_2$ @ 0.30 %, respectively whereas minimum was registered in control. Yield per plant was significantly affected by the foliar application of salicylic acid and calcium chloride (Table 2). Highest fruit yield (6.92 kg plant^{-1}) was recorded with 200 ppm salicylic acid which was statistically at par with the 150 ppm (6.72 kg plant^{-1}) salicylic acid. In case of calcium chloride treatments highest fruit yield (6.87 kg plant) was recorded with the application of 0.30 per cent $CaCl_2$ which was statistically at par with 0.25 per cent $CaCl_2$ (6.67 kg plant^{-1}). Lowest fruit yield was recorded under control. In present investigation, salicylic acid and calcium chloride were sprayed after fruit set, thus there was no role of chemicals on the number of fruits per plant. The increased fruit yield with salicylic acid and calcium chloride application on plants might be obviously due to its beneficial effects on weight of fruits. Baba *et al.* (2017) also reported enhancement in the fruit yield of strawberry with the application of salicylic acid.

Observations on physical parameters of fruit reveal that the physical parameters of fruit were significantly influenced by the foliar application of salicylic acid and calcium chloride (Table 2). Maximum fruit length (10.03 cm), fruit breadth (6.70 cm) and fruit weight (168.44 g) were recorded with the application of salicylic acid @ 200 ppm which was statistically at par with 150 ppm in case of fruit length (9.97 cm) and fruit breadth (6.58 cm) however in fruit weight 200 ppm salicylic acid was superior among all treatments. Minimum fruit length (9.42 cm), fruit breadth (6.09 cm) and fruit weight (154.12 g) was recorded in control. Foliar application of calcium chloride was effective in improving the physical characters of fruits. Application of 0.30 per cent calcium chloride registered maximum fruit length (10.00 cm), fruit breadth (6.67 cm) and fruit weight (165.00 g) which was statistically at par with 0.25 per cent in case of fruit length (9.95 cm) and fruit breadth (6.56 cm) whereas 0.30 per cent $CaCl_2$ showed superior results for fruit weight among all other treatments of calcium chloride. Minimum fruit length, fruit breadth and fruit weight was recorded in control. Beneficial response of salicylic acid on physio-chemical parameters of fruit is might attributed to its role in cell division, cell elongation, photosynthesis, water relations and metabolic aspects of plants. Salicylic acid is known to affect leaf and chloroplast structure (Uzunova and Popova, 2000), chlorophyll and carotenoids contents (Fariduddin *et al.*, 2003) and the activity of enzymes such as Rubisco (ribulose-1,5-bisphosphate carboxylase oxygenase) and carbonic anhydrase (Hayat *et al.*, 2010) thereby improving the photosynthetic efficiency of plant, due to that more assimilates might available and translocated towards the fruits. Encouraging results of salicylic acid application on physical characters of fruits have also been reported in sweet cherry (Gholami *et al.*, 2010) and pear (Khalaj *et al.*, 2017). Asgharzade *et al.* (2012) advocated that fruit size, weight and appearance of apple fruits was improvement with foliar sprays of calcium chloride and further conveyed that the increase in fruit weight and size was ascribed to a linear increase in calcium concentrations of fruits and leaves due to calcium applications.

Fruit volume and fruit firmness were significantly affected by salicylic acid and calcium chloride treatments (Table 2). Maximum fruit volume (145.42 cm^3 and 146.00 cm^3) and fruit firmness (10.18 kg/cm and 10.16 kg/cm) were observed in 200 ppm salicylic acid and 0.30 per cent calcium chloride, respectively which was statistically at par 150 ppm (10.06 kg/cm) salicylic acid and 0.25 per cent (10.06 kg/cm^2) calcium chloride in case of fruit firmness, however in case of fruit volume both salicylic acid (200 ppm) and calcium chloride (0.30 %) were statistically higher among all the treatments. Minimum fruit firmness and fruit volume was observed under control. Higher fruit firmness as a result of salicylic acid application is attributed to the fact that ethylene production is inhibited by salicylic acid that in turn inhibits the activity of cell wall and membrane degrading enzymes such as polygalacturonase, pectic methyl esterase (PME) and cellulase and thus resulting in firmer fruits. Kazemi *et al.* (2011) also observed significant improvement in fruit firmness in apple with the application of salicylic acid. Siddiqui and Bangerath (1995) revealed that the effect of $CaCl_2$ on fruit firmness is likely to be associated with the calcium content of the covalently-bound pectin fractions in the fruits. Xuan *et al.* (2003) also reported that foliar application of calcium chloride increased the firmness of pear fruits.

Salicylic acid treatments significantly improved all the chemical parameters (TSS, acidity, total sugars and ascorbic acid) (Table 3 and Fig. 2). Maximum total soluble solids (14.01^{o}B), acidity (0.54 %), total sugars (12.97 %) and ascorbic acid (9.41 mg/100 g) were recorded with the foliar application of salicylic acid @ 200 ppm, though it was at par with 150 ppm salicylic acid in case of total soluble solids (13.76^{o}B), total sugar (12.76 %) and ascorbic acid (9.31 mg/100 g), whereas statistically higher than other treatments in case of acidity. Minimum TSS (12.43^{o}B), acidity (0.44 %),

total sugars (11.33 %) and ascorbic acid (8.51 mg/100 g) was observed in control. Higher content of total soluble solids and sugars might be attributed to the fact that salicylic acid regulates sugar metabolism (Dong *et al.,* 2011) and increases the photosynthetic efficiency of plant (Hayat *et al.,* 2010) due to which more assimilates are available and translocated to the fruits. Earlier Ali *et al.* (2015) also reported that application of salicylic acid increases total soluble solids and total sugars in peach. The highest titrable acidity as a result of salicylic acid may be attributed to the fact that salicylic acid inhibit ethylene biosynthesis (Leslie and Romani, 1988) and thus prevent the conversion of acids into sugars. Ramirez *et al.* (2010) also observed that application of salicylic acid increased titrable acidity in apple. The biosynthesis and action of ethylene is affected by salicylic acid (Srivastava and Dwivedi, 2000), prevents destruction of vitamin C and acts as an anti-stress power (Elwana and El-Hamahmy, 2009).

Calcium chloride sprays caused significant influence on total soluble solids, acidity, total sugars and ascorbic acid of fruits (Table 3 and Fig. 2). Control treatment resulted in maximum amount of TSS (13.66^{o}B) and total sugars (12.73 %) which was statistically at par with 0.20 per cent calcium chloride whereas maximum acidity (0.52 %) and ascorbic acid (9.42 mg/100 g) was recorded in 0.30 per cent $CaCl_2$ and was statistically at par with 0.25 per cent calcium chloride with a value of 0.50 per cent and 9.24 mg/100 g for acidity and ascorbic acid, respectively. $CaCl_2$ inhibits the ethylene biosynthesis (Wojcik *et al.*, 2014) which in turn inhibits the conversion of starch into sugars and total soluble solid concentration in fruits. Bhat *et al.* (2012) also reported that calcium applications reduced the total soluble solids and sugar content at harvest in pear fruit. Increase in acidity as a result of calcium chloride treatment might be attributed to the fact that $CaCl_2$ reduces the respiration rate which results in maintained acidity over a long period thus reducing the possibility of utilization of some of the acids in the process of respiration and conversion of some of these acids to sugars (Raese and Drake, 1993) with Anjou pears, (Farooq and Khajwal, 1999) with Bartlett. Higher amount of ascorbic acid under calcium chloride treatments might be attributed to the inhibitory action of calcium on the activity of oxidizing enzymes. Increased ascorbic acid concentration in pomegranate was also reported by Ramezanian *et al.* (2009) with pre-harvest $CaCl_2$ foliar sprays.

4. Conclusion

Application of salicylic acid @ 200 ppm improved shoot extension growth and leaf area of Carmen pear while the effect of calcium chloride sprays were not significant on these parameters. Foliar application of salicylic acid @ 200 ppm as well as calcium chloride @ 0.30 % was effective in improving the fruit yield and fruit quality by beneficial effect on physico-chemical characteristics of fruits.

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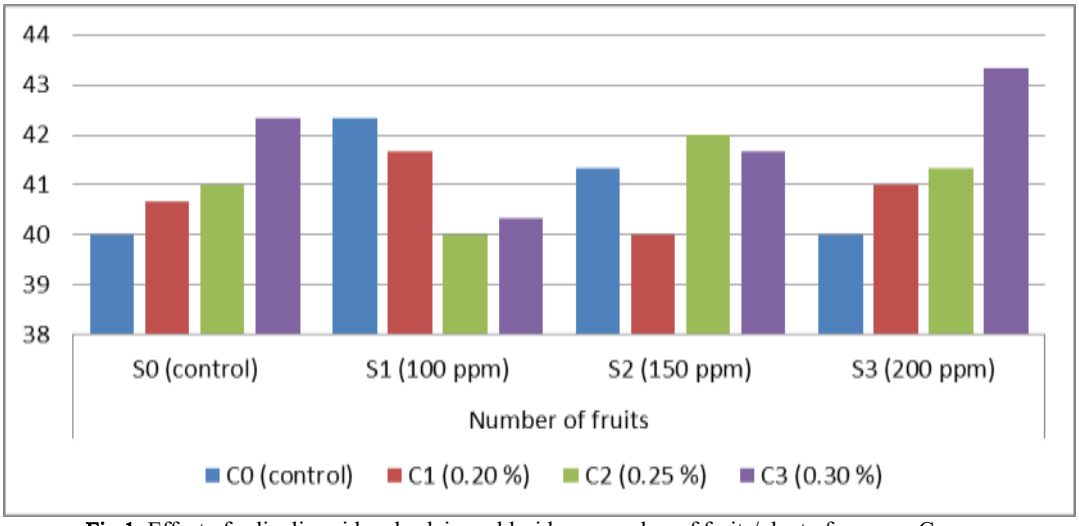

Fig 1. Effect of salicylic acid and calcium chloride on number of fruits/plant of pear cv. Carmen

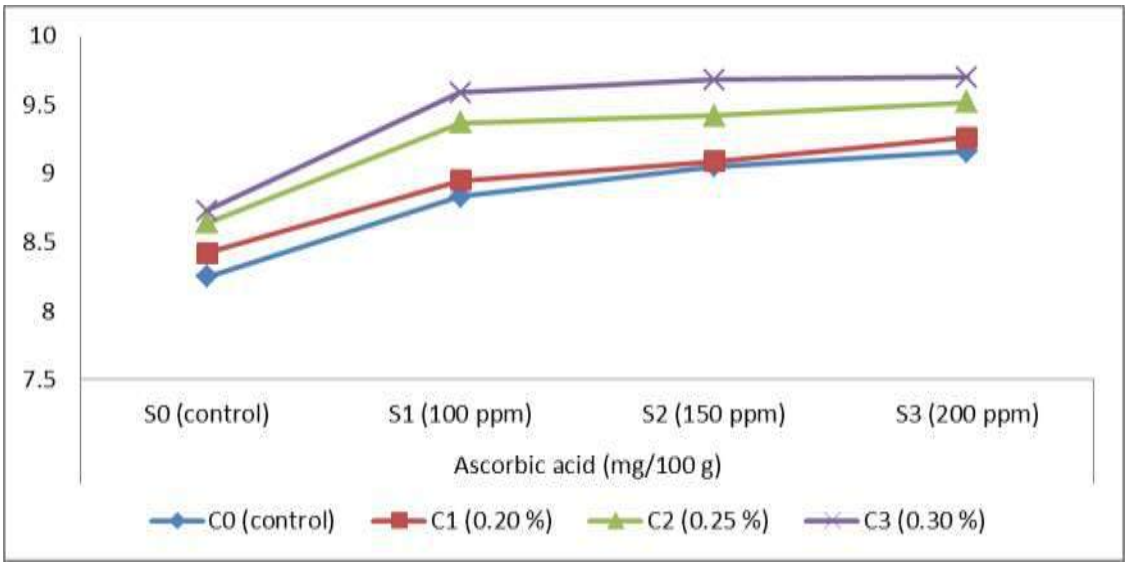

Fig 2. Effect of salicylic acid and calcium chloride on ascorbic acid of pear cv. Carmen

Table 1. Effect of salicylic acid and calcium chloride on growth and fruit yield of pear

Treatments	Shoot extension growth (cm)	Trunk cross sectional area (cm^2)	Leaf area (cm^2)	Fruit yield (kg $plant^{-1}$)
Salicylic acid				
S_0: Control	25.89	5.45	19.94	6.29
S_1: 100 ppm	26.70	5.79	20.72	6.46
S_2: 150 ppm	26.86	6.13	20.93	6.72
S_3: 200 ppm	27.47	6.54	21.20	6.92
$CD_{0.05}$	0.99	NS	0.74	0.22
Calcium chloride				
C_0: Control	26.02	5.37	20.36	6.40
C_1: 0.20 %	26.65	5.93	20.62	6.46
C_2: 0.25 %	26.89	6.19	20.81	6.67
C_3: 0.30 %	27.36	6.42	20.99	6.87
$CD_{0.05}$	NS	NS	NS	0.22

Table 2. Effect of salicylic acid and calcium chloride on physico-chemical parameters of pear

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Fruit volume (cm^3)	Fruit firmness (kg/cm^2)
Salicylic Acid					
S_0: Control	154.12	9.42	6.09	133.35	9.47
S_1: 100 ppm	158.02	9.65	6.34	138.15	9.75
S_2: 150 ppm	163.58	9.97	6.58	142.92	10.06
S_3: 200 ppm	168.44	10.03	6.70	146.00	10.16
$CD_{0.05}$	2.11	0.20	0.22	2.67	0.20
Calcium chloride					
C_0: Control	157.56	9.46	6.18	136.04	9.47
C_1: 0.20 %	158.94	9.67	6.31	138.46	9.74
C_2: 0.25 %	162.67	9.95	6.56	141.48	10.06
C_3: 0.30 %	165.00	10.00	6.67	145.42	10.18
$CD_{0.05}$	2.11	0.20	0.22	2.67	0.20

Table 3. Effect of salicylic acid and calcium chloride on chemical parameters of pear

Treatments	TSS (^oBrix)	Titrable acidity (%)	Total sugar (%)
Salicylic acid			
S_0: Control	12.43	0.44	11.33
S_1: 100 ppm	13.10	0.48	12.01
S_2: 150 ppm	13.76	0.51	12.76
S_3: 200 ppm	14.01	0.54	12.97
$CD_{0.05}$	0.26	0.02	0.47
Calcium chloride			
C_0: Control	13.66	0.46	12.73
C_1: 0.20 %	13.55	0.48	12.53
C_2: 0.25 %	13.24	0.50	12.05
C_3: 0.30 %	12.87	0.52	11.81
$CD_{0.05}$	0.26	0.02	0.47