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Kiran Thakur
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India

N Sharma
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India

DP Sharma
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India

Bunty Shylla
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India

Correspondence
Kiran Thakur
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, India

Effect of different growth regulators on tree growth and leaf area of apricot (*Prunus armeniaca* L.) CV. new castle

Kiran Thakur, N Sharma, DP Sharma and Bunty Shylla

Abstract
Apricot (*Prunus armeniaca* L.) is one of the most important stone fruit crop of temperate regions of India especially of Himachal Pradesh, Jammu and Kashmir and Uttarakhand. An study on "Effect of Different Growth Regulators on Tree Growth and Leaf Area of Apricot (*Prunus armeniaca* L.) cv. New Castle" was carried out in the experimental orchard of the Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan (*H.P.*). The prime objective of this study was to evaluate the effect of forchlorfenuron (CPPU), Prohexadione-calcium and Brassinolide on tree growth and quality of apricot cv. New Castle. From the results it was conferred that treatment with CPPU at 10 ppm caused higher increase in annual shoot growth (112.9 cm), trunk girth (7.8 %) and tree volume (33.7 %), whereas treatment with CPPU at 5 ppm gave higher leaf area (56.9 cm^2), however, Pro-Ca applied at 100 and 200 ppm significantly decreased these vegetative growth attributes as compare to control.

Keywords: Annual shoot growth, CPPU, Brassinolide, Prohexadione-calcium (Pro-Ca)

1. Introduction
Apricot (*Prunus armeniaca* L.) is a deciduous tree fruit species belonging to family Rosaceae. It is one of the important stone fruit crops and grown worldwide in mild temperate to extreme cold regions. In India, it is cultivated in hilly regions of Himachal Pradesh, Jammu and Kashmir, Uttarakhand (Parmar and Kaushal, 1982) [8] and to a limited extent in the hill region of north-eastern states of the country. The area under apricot cultivation in India is around 5358 ha with annual production of 15072 MT (Anonymous, 2016) [1]. Total area under apricot cultivation in Himachal Pradesh is 3650 ha with production of 11514 MT during 2016-2017 (Anonymous, 2017) [2]. Solan, Shimla, Kullu, Mandi and Kinnaur are the main districts in Himachal Pradesh where apricot is grown extensively. Some drying type apricots are being grown in the dry temperate areas of Kinnaur, Lahaul & Spiti in Himachal Pradesh and in Ladakh region of Jammu & Kashmir. The low-moderate chilling "New Castle" is the most commercial cultivar of apricot in the mid-hills of Himachal Pradesh.
The purpose of using plant growth substances as foliar applications is to improve quality vegetative growth for producing maximum yield. Sitofex (CPPU){(N-(2-chloro-1-pyridinyl)-N phenylurea)} at different concentrations enhanced cell division, increased cell size and ultimately leads to increased tree growth (Asaad, 2014). Pro-Ca is an inhibitor of GA synthesis with low toxicity and persistence (Smit *et al*. 2005) [8], which reduces the levels of GA1 (the highly active form) and increases GA20 (inactive form) causes a reduction in shoot elongation, reducing the excessive vegetative growth. Brassinolide was the first isolated brassinosteroid in 1979 when it was shown that pollen from Brassica napus could promote stem elongation and cell divisions, and the biologically active molecule was isolated. BRs have been shown to be involved in numerous plant processes like promotion of cell expansion and cell elongation synergism with auxin, play role in cell division and cell wall regeneration, promotion of vascular differentiation etc. The target of this study was achieving the possibility improving growth through spraying above mentioned growth regulators on "New Castle" apricots.

2. Material and Methods
The experimental trees were subjected to different treatments of forchlorfenuron, Prohexadione-calcium and Brassinolide as per details given in Table 1.

Table 1: Description of forchlorfenuron, Prohexadione-calcium and Brassinolide treatments

Treatments	Chemicals	Concentration (ppm)	Time of application
T_1	CPPU	2.5	Petal fall
T_2	CPPU	5	Petal fall
T_3	CPPU	10	Petal fall
T_4	Pro-Ca	50	Pit-hardening
T_5	Pro-Ca	100	Pit-hardening
T_6	Pro-Ca	200	Pit-hardening
T_7	Brassinolide	0.5	Petal fall
T_8	Brassinolide	1	Petal fall
T_9	Brassinolide	2	Petal fall
T_{10}	Control	-	-

The experiment was laid out in Completely Randomized Block Design (CRBD) with three replications.

2.1 Annual shoot growth
Ten shoots from the current season's growth were randomly selected from all over the periphery of each tree. The length of these shoots was measured with measuring tape at the end of growing period and the average shoot length was expressed in centimetre (cm).

2.2 Tree height
The height of the tree was measured in meter (m) with the help of graduated flag staff from the soil surface to the top of a tree, once before the start of the growing season and again after the termination of the growth in each year. The increase in height was expressed in percentage.

$$\text{Increase in tree height (\%)} = \frac{\text{Final tree height-Initial tree height}}{\text{Initial tree height}} \times 100$$

2.3 Tree spread
The spread of the tree was measured in meter (m) in two directions i.e. East-West and North-South once before the start of the growing season and again at the end of growing period in each year with the help of graduated flag staff at the height where the canopy spread was the maximum. The increase in spread was calculated and expressed in percentage.

$$\text{Increase in tree spread (\%)} = \frac{\text{Final tree spread -Initial tree spread}}{\text{Initial tree spread}} \times 100$$

2.4 Tree volume
The volume of the tree was worked out from tree height and spread measurements once before the start of the experiment and again after the completion of the experiment in each year as per formulae given by Westwood (1978).

Volume $= 4/3\pi a^2 b$ if $a<b$, or
$= 4/3\pi ab^2$ if $a>b$
a= 1/2 the length of major axis (height)
b= 1/2 the length of minor axis (spread)

$$\text{Increase in tree volume (\%)} = \frac{\text{Final tree volume -Initial tree volume}}{\text{Initial tree volume}} \times 100$$

The total tree volume was worked out and expressed in cubic meter (m^3) and the increase in volume over the each growing season was expressed in percentage.

2.5 Tree girth
Tree girth was recorded at 30 cm above the ground level with the help of measuring tape once before the start of the growth and again after the completion of the growth. The results of increase in the tree girth over the growing season were expressed in percentage.

$$\text{Increase in tree girth (\%)} = \frac{\text{Final tree girth -Initial tree girth}}{\text{Initial tree girth}} \times 100$$

2.6 Leaf area
From each experimental tree, 25 fully developed and matured leaves were randomly selected from all the four directions of the tree periphery and detached during the last week of June. These leaves are then pressed overnight between the herbarium sheets for full expansion. Their area was measured with the help of Automatic Leaf Area Meter (Licor Model 3100) in the laboratory and average values were expressed in square centimetre (cm^2).

3. Results and Discussion
3.1 Shoot growth
The data pertaining to the effect of forchlorfenuron, Prohexadione-calcium and Brassinolide on shoot growth of apricot cv. New Castle are presented in Table 2.

Table 2: Effect of forchlorfenuron, Prohexadione-calcium and Brassinolide on annual shoot growth of apricot

Treatment		Shoot growth (cm)
T_1	CPPU (2.5 ppm)	91.5
T_2	CPPU (5 ppm)	108.4
T_3	CPPU (10 ppm)	112.9
T_4	Pro-Ca (50 ppm)	94.3
T_5	Pro-Ca (100 ppm)	74.3
T_6	Pro-Ca (200 ppm)	69.7
T_7	Brassinolide (0.5 ppm)	95.7
T_8	Brassinolide(1 ppm)	98.9
T_9	Brassinolide (2 ppm)	102.5
T_{10}	Control	85.1
$CD_{0.05}$		11.9

It is evident from the data that pre harvest application of different plant growth regulators exerted a significant influence on annual shoot growth. The shoot growth values under various treatments ranged from 69.7 to 112.9 cm.
The maximum shoot growth (112.9 cm) was recorded in the trees under the treatment T_3 (10 ppm CPPU), which was however, statistically at par with the treatments T_2 (5ppm CPPU) and T_9 (2 ppm Brassinolide), but significantly higher than the remaining treatments. The minimum shoot growth (69.7 cm) was recorded in the trees under the treatment T_6 (200 ppm Pro-Ca), which was significantly lesser than all other treatments except, the treatment T_5 (100 ppm Pro-Ca).

3.2 Increase in tree height, tree spread, tree volume and trunk girth

Table 3: Effect of forchlorfenuron, Prohexadione-calcium and Brassinolide on increase in tree height, tree spread, tree volume and trunk girth of apricot

Treatment		Increase in tree height (%)	Increase in tree spread (%)	Increase in tree volume (%)	Increase in trunk girth (%)
T_1	CPPU (2.5 ppm)	16.0	22.3	23.9	5.6
T_2	CPPU (5 ppm)	23.9	26.1	32.0	7.0
T_3	CPPU (10 ppm)	25.2	27.6	33.7	7.8
T_4	Pro-Ca (50 ppm)	13.6	16.0	10.5	5.1
T_5	Pro-Ca (100 ppm)	12.7	15.7	14.7	5.1
T_6	Pro-Ca (200 ppm)	12.1	14.8	11.9	4.9
T_7	Brassinolide (0.5 ppm)	16.0	21.5	19.8	5.2
T_8	Brassinolide(1 ppm)	17.8	22.4	24.6	6.5
T_9	Brassinolide (2 ppm)	22.3	23.6	29.1	6.5
T_{10}	Control	14.8	18.0	19.5	5.1
$CD_{0.05}$		0.9	1.5	1.6	0.6

The increase in tree height over the growing season ranged from 12.1 to 25.2 per cent under different treatments (Table 3). Significantly higher increase in tree height (25.2 %) was recorded under the treatment T_3 (10 ppm CPPU), in comparison to all other treatments. However, the minimum increase in tree height (12.1%) was registered in the T_6 (200 ppm Pro-Ca), which was significantly lesser than all other treatments except, the treatments T_5 (100 ppm Pro-Ca).

The data (Table 3) on per cent increase in tree spread over the growing season revealed that there was a significant influence of different treatments on this aspect. The maximum increase in tree spread (27.6 %) was recorded in the treatment T_3 (10 ppm CPPU), which was however, statistically at par with the treatment T_2 (5 ppm CPPU) but significantly higher than the remaining treatments. The minimum increase in tree spread (14.8 %) was observed in the treatment T_6 (200 ppm Pro-Ca), which was significantly lower than all other treatments except, T_4 (50 ppm Pro-Ca) and T_5 (100 ppm Pro-Ca).

The increase in tree volume over the growing season varied from 11.9 to 33.7 per cent. The maximum increase (33.7 %) in tree volume was observed in the treatment T_3 (10 ppm CPPU) and this treatment in this respect was significantly superior to all other treatments. The increase in tree volume was registered significantly lowest (11.9 %) in T_6 (200 ppm Pro-Ca).

The increase in trunk girth ranged from 4.9 to 7.8 per cent under different treatments. The maximum increase in trunk girth (7.8 %) was recorded in the treatment T_3 (10 ppm CPPU), which was significantly superior to all the remaining treatments. The minimum increase in trunk girth (4.9 %) was recorded in trees under the treatment T_6 (200 ppm Pro-Ca), which was significantly lesser than all other treatments except, T_4 (50 ppm Pro-Ca), T_5 (100 ppm Pro-Ca), T_7 (0.5 ppm Brassinolide) and T_{10} (control).

3.3 Leaf area

The perusal of data depicted in Table 4 indicates that the average leaf area was significantly affected by different treatments. In the year 2013, the average leaf area varied from 44.5 to 57.0 cm^2. It was found to be the largest (57.0 cm^2) in the trees given foliar application of CPPU at 5 ppm (T_2), which was statistically superior to all the other treatments. The minimum leaf area (44.5 cm^2) was recorded in trees under the treatment T_6 (200 ppm Pro-Ca), which was significantly lesser than all other treatments except, T_5 (100 ppm Pro-Ca).

Table 4: Effect of forchlorfenuron, Prohexadione-calcium and brassinolide on average leaf area of apricot

Treatment		Leaf area (cm^2)		
		2013	2014	Pooled
T_1	CPPU (2.5 ppm)	49.8	51.2	50.5
T_2	CPPU (5 ppm)	57.0	56.8	56.9
T_3	CPPU (10 ppm)	55.1	54.7	54.9
T_4	Pro-Ca (50 ppm)	46.4	45.9	46.2
T_5	Pro-Ca (100 ppm)	45.8	44.2	45.0
T_6	Pro-Ca (200 ppm)	44.5	43.3	43.9
T_7	Brassinolide (0.5 ppm)	49.3	50.6	49.9
T_8	Brassinolide(1 ppm)	51.2	52.2	51.7
T_9	Brassinolide (2 ppm)	53.7	53.6	53.7
T_{10}	Control	48.7	49.8	49.2
$CD_{0.05}$		1.5	3.7	1.9

In the year 2014, the largest leaves (56.8 cm^2) were noticed on the trees given foliar spray of CPPU at 5 ppm (T_2), which in this respect were however, statistically at par with the treatments T_3 (10 ppm CPPU) and T_9 (2 ppm Brassinolide). The leaf area was reduced significantly following the application of Prohexadione-calcium at different concentration. The most pronounced reduction in leaf area was observed when it was applied higher dose (T_6); however, it was statistically at par with the treatments $T_4$and T_5.

The pooled data further revealed that the average leaf area was recorded significantly largest (56.9 cm^2) in T_2 (CPPU 5 ppm) compared to the remaining treatments. It was observed smallest (43.9 cm^2) in T_6, which was however, statistically at par with T_5.

In this investigation, the increase in different tree growth attributes with CPPU treatment might be due to its cytokinin like action which leads to rapid cell division and cell elongation (Thomas and Katterman, 1986) [10]. Fathi *et al.* (2011) [5] observed similar increase in vegetative growth following the application of CPPU in "Costata" persimmon. Application of brassinolide at different concentrations also caused higher increase in shoot growth and tree height, spread and volume as compared to control, which might be a result of its involvement in the process of cell enlargement and elongation (Mussig and Altmann, 1999) [6]. The reduction in vegetative growth by Pro-Ca may be due to the GA biosynthesis inhibiting action of Pro-Ca (Bomben *et al*., 1998). The decrease in vegetative growth as observed with Pro-Ca application in the study is in line with the earlier findings in apples (Norelli and Miller, 2004) [5].

4. Conclusion
From the results it was concluded that plant growth regulators CPPU and Brassinolides had positively influenced the tree growth and leaf area. However Pro-Ca had significantly reduced the tree growth as well as the leaf area but reduction in shoot elongation by Pro-Ca causes a reduction in excessive vegetative growth, and this may lead to redirecting more photosynthates into fruits, thus increasing fruit mass.

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