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DD Sharma

Department of Fruit Science, Dr.
Y. S. P. University of
Horticulture and Forestry
Nauni, Solan, Himachal
Pradesh, India

Bindu Bala

Department of Fruit Science, Dr.
Y. S. P. University of
Horticulture and Forestry
Nauni, Solan, Himachal
Pradesh, India

Niranjan Singh

Department of Fruit Science, Dr.
Y. S. P. University of
Horticulture and Forestry
Nauni, Solan, Himachal
Pradesh, India

DP Sharma

Department of Fruit Science, Dr.
Y. S. P. University of
Horticulture and Forestry
Nauni, Solan, Himachal
Pradesh, India

Correspondence**Niranjan Singh**

Department of Fruit Science, Dr.
Y. S. P. University of
Horticulture and Forestry
Nauni, Solan, Himachal
Pradesh, India

Effect of pruning levels and Benzyl adenine (BA) on bud-wood production in apple (*Malus × domestica* Borkh.)

DD Sharma, Bindu Bala, Niranjan Singh and DP Sharma

Abstract

The apple cultivars produce few lateral shoots because of apical dominance. At present, progeny trees are pruned severely which stimulate strong thick lateral branches with limited graftable bud wood. So, there is a need to produce maximum budwood of commercially important cultivars to meet the demand of growers. In order to stimulate regular succession of new growth over the entire tree canopy, some workers have attempted heading back of a part of the previous season's growth. In this experiment different treatments of pruning and benzyl adenine (BA) were given to four different cultivars namely, Vance Delicious, Early Red One, Gale Gala and Red Chief were applied viz., heading back to 10 cm, heading back to 15 cm, heading back to 20 cm, heading back to 10 cm + Pinching, heading back to 15 cm + Pinching, heading back to 20 cm + Pinching, heading back to 10 cm + BA 500 ppm, heading back to 15 cm + BA 500 ppm, heading back to 20 cm + BA 500 ppm and Control. In all there were nine combinations of pruning levels and BA treatments and were compared with control. The results revealed that maximum graftable scion wood (64.83 %), total number of shoots (124.33), number of lateral shoots (111.50), spread (2.40 m) and volume (12.47 m³) were recorded in the trees treated with heading back to 20 cm + BA at 500 ppm. However, average shoot length (136.00 cm), diameter of thin, standard and thick shoots (3.85, 7.92 and 13.44 mm, respectively), internodal length (2.95 cm), pruning wood weight (5.62 kg per tree) and leaf area (34.50 cm²) was found to be maximum in Heading back to 10 cm in combination with BA application at 500ppm concentration in different apple cultivars under study.

Keywords: apple, benzyl adenine (BA), bud-wood, graftable scion wood, plant growth, pruning

Introduction

The cultivated apple (*Malus × domestica* Borkh.) which is a member of family Rosaceae and sub family Pomoideae is native to South West Asia. In India, it was introduced only in the middle of the nineteenth century, yet it has already attained the status of being the most important temperate fruit with high economic returns (Singh *et al.*, 2016) ^[1]. In India, apple is produced predominantly in the North Western Himalayan region comprising of states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand which occupy a major share of apple production (Singh *et al.*, 2017) ^[2]. However, its cultivation has also been extended to a certain extent to the North Eastern states where mild temperate climatic conditions prevail (Singh and Sharma 2017) ^[3]. Apple is the most dominating fruit crop of Himachal Pradesh where it is cultivated commercially in an area of 110, 679 hectares with a production of 777, 126 MT (Anonymous, 2016) ^[4]. Most of the apple orchards in the state are of Delicious cultivars though of late, there is a trend towards the cultivation of spur type apples under high density planting. The ultimate success of apple orcharding however, largely depends on the quality of planting material. Keeping in view the attractive colour, dwarfness and high productivity of new cultivars, the demand for nursery plants of spur type and colour strains of apple is increasing day by day. For successful apple orcharding it is also important to procure scions from the plants which have been correctly identified and to multiply them on mass scale so that it can be made easily available to every common orchardist.

Lee *et al.*, 2005 ^[5] and Sharma and Singh, 2018 ^[6] reported that removal of the shoot tip by heading-back pruning stimulated longer shoot growth with the emergence of lateral shoots in the remained parts. They also found that the pruning severity has a direct correlation with the growth and the emergence of new shoots. Benzyladenine (BA) is known for increasing the number of laterals in shoot, cell division and also cell elongation. Greene and Autio, (1989) ^[7] found that benzyl adenine induced lateral branching in four years old 'Macspur McIntosh' at concentration up to 500 mg per litre, but the crop load was reduced. Zamanipour *et al.*, (2012) ^[8] also reported that benzyladenine (BA) treatments had significant effect on the number and length of lateral shoots than heading treatments. They also found that the repeated BA

treatments induced more lateral shoots than a single treatment. Production of more number of lateral shoots is one of the most important factors for increasing the number of graftable budwood in apple. The lateral shoot formation of budwood producing trees is an important feature for inducing maximum budwood production. Therefore, the present studies were conducted to investigate the effect of pruning levels and benzyladenine treatments on increasing lateral shoot formation for maximum budwood production.

Method and Material

Location and climate

The experimental apple orchard is situated at an elevation of 1250 m above mean sea level at 30° 51'N latitude and 76°11'E longitude in the Bhajon block of the Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The experimental orchard lies under the sub-temperate, sub-humid mid-hill agro climatic zone II of Himachal Pradesh where, summer is moderately hot during May-June while winter is quite severe during December-January. The annual rainfall ranges from 110-120 cm, the large amount of which is received during June to September.

Plant materials and experimental design

The present study was carried out on four cultivars of apple namely Early Red One, Gale Gala, Red Chief and Vance Delicious. The trees selected for the present study were of uniform size belonging to the age group of 7-8 years. In total 120 trees consisting of 30 trees per cultivar were selected. All the trees were given uniform cultural practices and recommended nutritional doses during the course of studies. The soil is mountainous alluvial loamy soil and having pH 6.62, organic carbon 1.58%, available N, P and K were 318.64, 16.62 and 172 kg ha⁻¹, respectively. The apple trees were spaced 2m apart in the row, with the rows again 2m apart and trained to Modified central leader system. The experimental trees received uniform cultural practices during investigation, except for different pruning and Benzyl adenine treatments, which varied according to the treatments. The experiment was performed on the sample size comprising of 30 trees; the trees being randomly selected. The homogeneity of the experimental area was checked by measuring tree trunk circumferences before giving different treatments.

Experimental treatments

The experimental plants were subjected to different heading back of new shoots to 10, 15 and 20 cm intensities in the month of mid-December along with pinching of newly growing shoots at 5-10 cm length and benzyladenine (BA) application at 500 ppm repeated 4 times at 10-15 days interval. In all, there were ten treatment combinations replicated thrice and the experiment was laid out in randomized block design

T₁ = Heading Back to 10 cm

T₂ = Heading Back to 15 cm

T₃ = Heading Back to 20 cm

T₄ = Heading Back to 10 cm + Pinching

T₅ = Heading Back to 15 cm + Pinching

T₆ = Heading Back to 20 cm + Pinching

T₇ = Heading Back to 10 cm + BA 500 ppm

T₈ = Heading Back to 15 cm + BA 500 ppm

T₉ = Heading Back to 20 cm + BA 500 ppm

T₁₀ = Control (Standard Pruning)

Measurements

The data on Trunk girth (cm), Tree height (m), Tree spread (m), Annual shoot growth (cm), tree volume (m³), Foliage Characters (Time of leaf emergence (bud burst) Average leaf area (cm²), Time of leaf fall, Flower Characters (Time and duration of flowering, Date of opening of first flower, Date of full bloom, Date of opening of last flower (end of flowering), Duration of flowering to study the effect of different pruning intensities and benzyladenine were recorded. Observations regarding growth parameters, viz. tree height, tree spread, tree volume, leaf area and chlorophyll content were recorded as per standard procedures during the course of study. Chlorophyll content was estimated with DMSO (Dimethyl Sulphoxide) method as suggested by Hiscox and Israeistam (1979) [9]. Procedure suggested by Westwood, (1978) [10] was adopted for fruit set estimation. For taking fruit yield the crop load removed from the trees at the time of harvest was recorded as kg tree⁻¹.

Statistical analysis

Data on growth characteristics of apple to determine the significance of differences were analyzed by using Randomized Block Design (RBD) as suggested by Gomez and Gomez, (1984) [11]. In addition to show the interrelationships between pruning intensities in combination with benzyladenine and mean values of each studied plant growth parameters statistical analysis program (SPSS) was used. The level of significance was tested for different variables at 5 per cent level of significance.

Results

It is evident from the perusal of data presented in Table 1 that the pruning levels and benzyladenine (BA) treatments exerted a significant effect on tree height. Maximum tree height (4.14 m) was recorded in T₃ treatment which was statistically at par with treatments T₁, T₆ and T₂ with the tree height of 3.98, 3.98 and 4.04 m, respectively. While the minimum tree height (3.53 m) was observed in T₁₀ which was statistically at par with the treatments T₇, T₈ and T₉, respectively. The highest tree spread (2.48 m) was recorded in treatment T₉, which was statistically at par with treatments T₆ and T₈ which exhibited 2.22 and 2.35 m tree spread, respectively. Minimum tree spread (1.72 m) was found in treatment T₁₀, which was statistically at par with treatment T₁. Significantly higher tree volume (12.47 m³) was obtained with treatment T₉, which was statistically at par with treatments (T₆ 10.71) and T₈ (11.21 m³) respectively. Minimum tree volume (5.69 m³) was recorded in control (T₁₀) which was statistically at par with treatments T₁ and T₂. Trunk girth was found maximum (23.30 cm) in the trees subjected to treatment T₂, which was statistically at par with all the treatments except T₉ and minimum trunk girth (18.52 cm) was however found in T₁₀. The maximum diameter of thin shoots [<4mm (3.85 mm)] was recorded in treatment T₇, which was statistically at par with T₄, T₅, T₉ and T₈. However, the minimum diameter of thin shoots [< 4mm (2.65 mm)] was found in T₁₀. Maximum standard shoot diameter [4-8mm (7.92 mm)] was recorded in T₇ which was statistically at par with T₅, T₉ and T₈ with 7.48, 7.71 and 7.85 mm of diameter, respectively. Whereas, the minimum shoot diameter [4-8 mm (5.86 mm)] was obtained in T₁₀. Diameter of thick shoots (> 8 mm) was highest [> 8mm (13.44 mm)] in the trees subjected to the T₇, and was statistically at par with treatments T₅, T₄, T₉ and T₈ with the thick shoots (> 8 mm) of 12.44, 12.66, 12.88 and 13.18 mm,

respectively. The minimum diameter of thick shoots [> 8 mm (9.45 mm)] was found in the control (T_{10}). The maximum percentage of graftable scion wood of 64.83 % was recorded in the treatment T_9 . Whereas, the minimum was observed in control with graftable scion wood of 49.01 %.

The effect of different pruning and BA treatments on the total number of shoots per tree was found to be statistically significant as shown in the Table 2. The highest total number of shoots per tree was observed in T_9 with a mean value of 124.33, whereas, the minimum total number of shoots per tree was obtained in treatment T_{10} with mean value 64.25. Maximum number of lateral shoots (111.50) was recorded in treatment T_9 which was significantly higher in comparison to the other treatments, whereas the minimum number (57.17) was recorded in control. The highest average shoot length (136.00 cm) was recorded in T_7 , which was significantly superior to all other treatments. Whereas, least average shoot length was observed in control with a value of 93.85 cm. Maximum number of buds per shoot (52.67) was recorded in treatment T_9 which was statistically at par with treatments T_6 and T_8 with average number of buds per shoot as 49.75 and 50.00 respectively, while minimum (39.50) number of buds was found in control. The highest internodal length (2.95 cm) was observed in the T_7 , which was significantly higher than all other treatments. The least internodal length (2.07 cm) was recorded in T_3 and was statistically at par with treatment T_6 . Results on pruning weight revealed that maximum pruning wood weight (5.62 kg) was recorded in T_7 which was statistically at par with treatments T_9 , T_6 , T_8 and T_4 which had pruning weight of 4.78, 4.82, 5.03 and 5.14 kg, respectively. The minimum pruned wood weight was observed in T_{10} with a value of 2.37 kg. Leaf area was largest (34.50 cm^2) in the trees subjected to the T_7 and was statistically at par with T_8 and T_1 with leaf area of 32.51 and 32.82 cm^2 , respectively. The minimum leaf area (26.62 cm^2) was found in the control. The accumulation of total chlorophyll content ranged between 1.91 to 2.63 mg/100g. The treatment T_8 had the maximum chlorophyll content (2.63 mg/100g) whereas, the lowest leaf chlorophyll content (1.91 mg/100g) was recorded in control. Data pertaining to the influence of cultivars showed significant effect on plant growth parameters. Among the four cultivars, Vance Delicious had significantly highest tree height (4.11 m), spread (2.55 m), volume (14.36 m^3), thin shoots [< 4 mm (3.48)], total number of shoots per tree (104.87), number of lateral shoots per tree (92.77), average shoot length (124.33 cm), internodal length (2.62 cm) and pruning weight (5.98 kg/tree) was recorded in cultivar Vance Delicious which was significantly higher than other cultivars. The minimum tree height (3.56 m), volume (6.32 m^3), average shoot length (109.19 cm) and internodal length (2.29 cm), total number of shoots per tree (80.00), number of lateral shoots per tree (78.87), pruning weight (3.82 kg/tree) was

observed in cultivar Red Chief and tree spread (1.99 m) in Early Red One. The highest trunk girth (26.01 cm), standard shoots [4-8 mm (7.76)], thick shoots [> 8 mm (12.36)] and total chlorophyll content (2.51 mg/g fresh wt.) was recorded in Red chief. However, lowest trunk girth (18.53), standard shoots [4-8 mm (6.90)], thick shoots [> 8 mm (11.67)] in Early Red One cultivar and total chlorophyll content (2.12 mg/g fresh wt.) in Gale Gala. The maximum graftable scion wood 57.86 %, number of buds per shoot (50.00) were recorded in Early Red One and leaf area (31.66 cm^2) in Gale Gala. Minimum graftable scion wood 55.10 and leaf area (29.61 cm^2) were recorded in Red chief and number of buds per shoot (42.97) in Gale Gala (Table 3).

The interaction between the treatments and the cultivars was also found to have a significant effect on the standard shoot diameter. The maximum diameter of 4-8 mm shoots [8.00 mm (Fig.1)] was recorded in the treatment T_7 with the cultivar Gale Gala, whereas the lowest [4.73 mm (Fig.1)] was recorded in the treatment T_{10} with the cultivar Vance Delicious. The maximum percentage of graftable scion wood of [67.17 % (Fig. 2)] was found in the treatment T_9 with Vance Delicious cultivar and the minimum graftable scion wood [46.87 % (Fig. 2)] was recorded in control with Red Chief. Maximum total number of shoots per tree [142.67 (Fig.7)] was recorded in T_9 with Vance Delicious cultivar whereas, the minimum number of shoots per tree [58.00 (Fig.7)] was obtained in T_{10} with cultivar Red Chief. Vance Delicious had the highest number of lateral shoots [134.67 (Fig.3)] with treatment T_9 whereas, the lowest number was obtained in the interaction of cultivar Red Chief (51.00) with T_{10} . Maximum average length of shoots [161.43 cm (Fig.4)] was recorded in T_7 with Vance Delicious cultivar whereas, the minimum shoot length [87.50 cm (Fig.4)] was obtained in the combination of Gale Gala with the treatment T_{10} . The maximum internodal length [3.26 cm (Fig.7)] was recorded in the treatment T_8 with Vance Delicious cultivar, which was statistically at par with combinations of treatment T_7 with cultivar Gale Gala (2.92 cm) and treatment T_7 with cultivar Early Red One (3.13 cm) whereas, the minimum internodal length [1.95 cm (Fig.7)] was recorded in treatment T_3 with Early Red One. The highest pruning weight [8.94 kg (Fig.5)] was observed in treatment T_7 with cultivar Vance Delicious, which was significantly higher than all other interactions. The lowest pruning weight [1.99 kg (Fig.5)] was recorded in T_{10} with cultivar Gale Gala. Red Chief cultivar was observed to contain highest chlorophyll content [2.99 mg/100g (Fig.6)] with treatment T_7 whereas, cultivar Gale Gala had least chlorophyll content [1.65 mg/100g (Fig.6)] with the treatment T_{10} . All the other interactions study between the treatments and cultivars were found to have non-significant effect on the tree height, tree spread, tree volume, trunk girth, number of buds per shoot and leaf area.

Table 1: Effect of pruning levels and benzyladenine (BA) on plant growth parameter

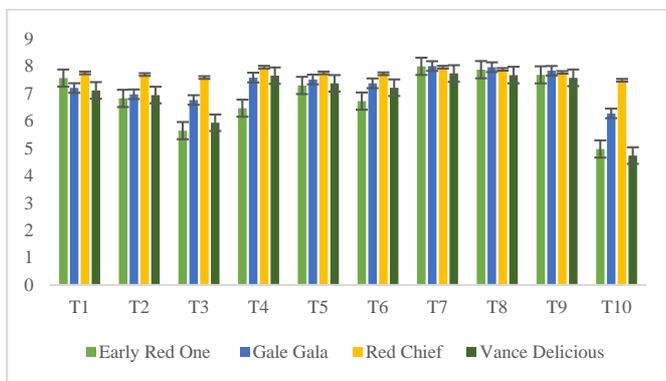
Treatment	Tree Height (m)	Tree Spread (m)	Tree volume (m^3)	Trunk girth (cm)	Thin shoots (< 4 mm)	Standard shoots (4-8 mm)	Thick shoots (> 8 mm)	Graftable Scion wood (%)
T_1	3.98 ^{ab}	1.80 ^c	7.02 ^c	21.41 ^{ab}	3.27 ^b	7.41 ^b	11.94 ^b	51.01 (45.56) ⁱ
T_2	4.04 ^{ab}	1.86 ^{bc}	7.93 ^{bc}	23.30 ^a	3.23 ^b	7.11 ^b	11.32 ^b	52.89 (46.64) ^h
T_3	4.14 ^a	2.03 ^{bc}	9.47 ^{bc}	22.81 ^{ab}	3.07 ^b	6.48 ^c	10.97 ^b	54.52 (47.58) ^g
T_4	3.75 ^{bc}	2.02 ^{bc}	8.60 ^{bc}	22.92 ^{ab}	3.48 ^a	7.41 ^{ab}	12.66 ^{ab}	55.07 (47.89) ^f
T_5	3.89 ^b	2.11 ^b	9.60 ^{bc}	22.58 ^{ab}	3.50 ^a	7.48 ^{ab}	12.44 ^{ab}	57.47 (49.28) ^e
T_6	3.98 ^{ab}	2.22 ^{ab}	10.71 ^{ab}	22.29 ^{ab}	3.25 ^b	7.26 ^b	12.07 ^b	59.30 (50.35) ^d
T_7	3.61 ^c	2.07 ^{bc}	8.38 ^{bc}	22.35 ^{ab}	3.85 ^{ab}	7.92 ^a	13.44 ^a	61.23 (51.47) ^c
T_8	3.68 ^{bc}	2.35 ^{ab}	11.21 ^{ab}	22.94 ^{ab}	3.73 ^{ab}	7.85 ^{ab}	13.18 ^a	62.69 (52.34) ^b
T_9	3.74 ^{bc}	2.48 ^a	12.47 ^a	21.32 ^b	3.57 ^a	7.71 ^{ab}	12.88 ^{ab}	64.83 (53.61) ^a
T_{10}	3.53 ^c	1.72 ^c	5.69 ^c	18.52 ^c	2.65 ^c	5.86 ^d	9.45 ^c	49.01 (44.41) ^j

Table 2: Effect of pruning levels and benzyladenine (BA) on plant growth parameter

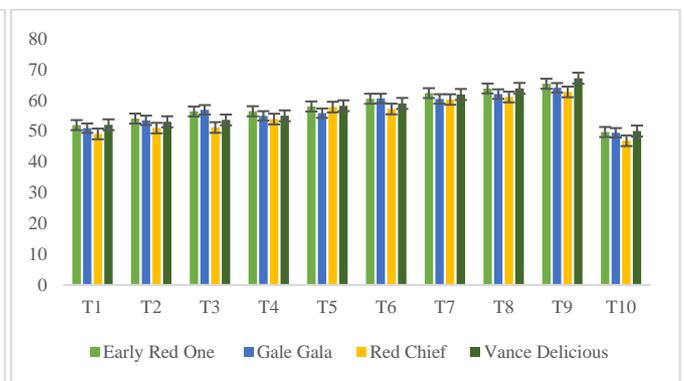
Treatment	Total number of shoots per tree	Number of lateral shoots per tree	Average shoot length (cm)	Number of buds per shoot	Internodal length (cm)	Pruning weight (kg/tree)	Leaf area (cm ²)	Total chlorophyll content (mg/g fresh wt.)
T ₁	72.58 ⁱ	65.25 ⁱ	104.45 ^d	44.67 ^c	2.35 ^c	3.47 ^c	32.82 ^{ab}	2.09 ^g
T ₂	79.83 ^h	71.50 ^h	105.80 ^d	46.00 ^{bc}	2.30 ^c	3.98 ^{bc}	30.83 ^{bc}	2.16 ^f
T ₃	87.50 ^g	78.17 ^g	100.00 ^e	48.75 ^b	2.07 ^d	4.74 ^b	29.71 ^{bc}	2.38 ^c
T ₄	90.92 ^f	84.08 ^e	117.51 ^c	46.00 ^{bc}	2.58 ^b	5.14 ^{ab}	31.80 ^b	2.25 ^e
T ₅	98.00 ^e	81.50 ^f	114.10 ^c	48.17 ^b	2.38 ^c	4.52 ^b	29.83 ^{bc}	2.34 ^{cd}
T ₆	103.00 ^d	91.25 ^d	103.03 ^{de}	49.75 ^{ab}	2.09 ^d	4.82 ^{ab}	29.21 ^c	2.33 ^d
T ₇	112.83 ^c	98.33 ^c	136.00 ^a	46.33 ^{bc}	2.95 ^a	5.62 ^a	34.50 ^a	2.52 ^b
T ₈	120.08 ^b	106.83 ^b	131.44 ^b	50.00 ^{ab}	2.66 ^{ab}	5.03 ^{ab}	32.51 ^{ab}	2.63 ^a
T ₉	124.33 ^a	111.50 ^a	120.19 ^c	52.67 ^a	2.29 ^c	4.78 ^{ab}	30.75 ^{bc}	2.28 ^e
T ₁₀	64.25 ^j	57.17 ^j	93.85	39.50 ^d	2.39 ^c	2.37 ^d	26.62 ^d	1.91 ^h

Table 3: Effect of cultivars on plant growth parameter

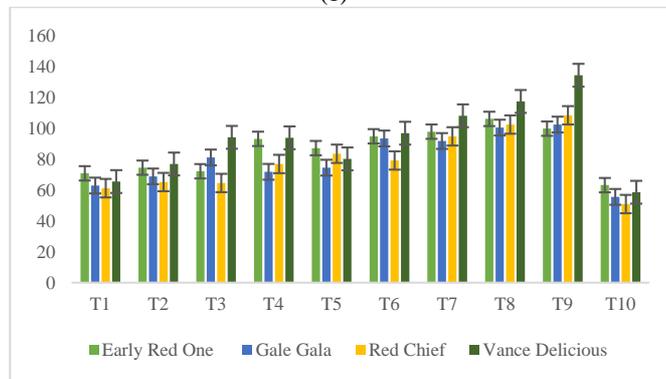
Treatment	Tree Height (m)	Tree Spread (m)	Tree volume (m ³)	Trunk girth (cm)	Thin shoots (< 4 mm)	Standard shoots (4-8 mm)	Thick shoots (> 8 mm)	Graftable Scion wood (%)
Early Red One	3.86 ^b	1.99 ^b	8.20 ^b	18.53 ^c	3.17	6.90 ^c	11.67	57.86 (49.52) ^a
Gale Gala	3.81 ^b	1.91 ^b	7.55 ^{bc}	19.61 ^c	3.40	7.35 ^b	12.13	56.86 (48.94) ^c
Red Chief	3.56 ^c	1.81 ^b	6.32 ^c	26.01 ^a	3.38	7.76 ^a	12.36 ^a	55.10 (47.92) ^d
Vance Delicious	4.11 ^a	2.55 ^a	14.36 ^a	24.02 ^b	3.48 ^a	6.99 ^c	11.97	57.39 (49.26) ^b



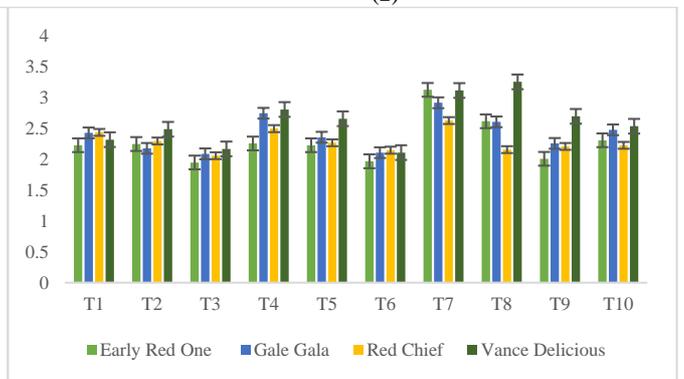
(1)



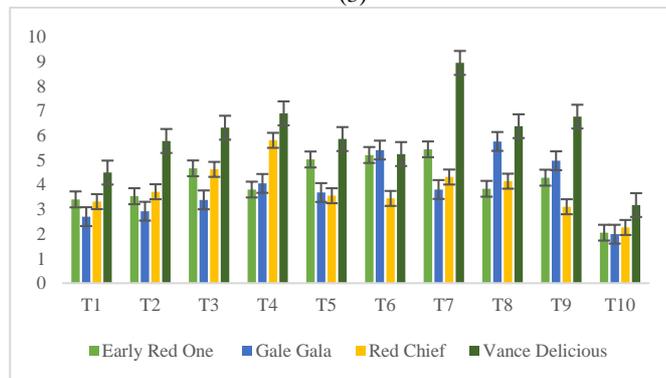
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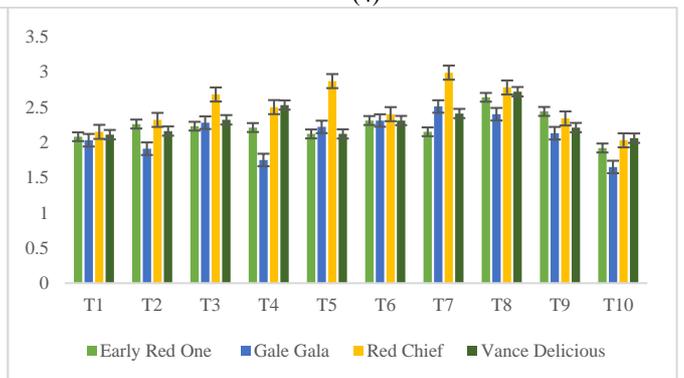
(3)



(4)

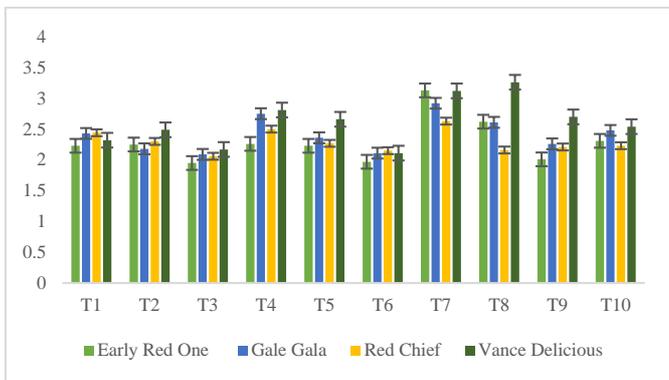


(5)

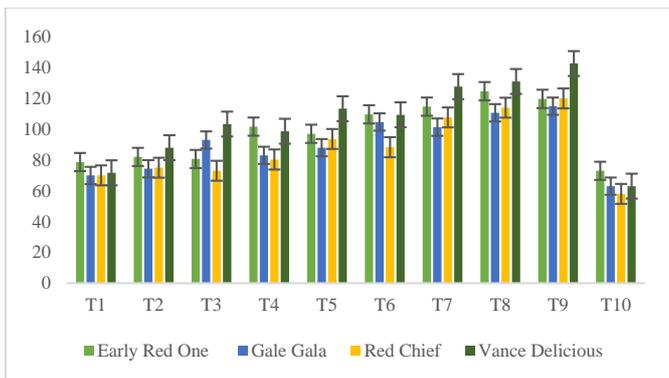


(6)

Fig 1: Effect of pruning levels and benzyladenine (BA) on Standard shoots (4-8 mm) (1), Graftable Scion wood (%) (2), Number of lateral shoots per tree (3), Average shoot length (cm) (4), Pruning weight (kg/tree) (5) and Chlorophyll content (mg/g fresh wt.) (6) bud-wood production in apple. Vertical bar represent mean of three replication \pm SE m and LSD ($p \leq 0.05$)



(7)



(8)

Fig 2: Effect of pruning levels and benzyladenine (BA) on internodal (7) and Total number of shoots per tree Graftable Scion wood (%) (8). Vertical bar represent mean of three replication \pm SE m and LSD ($p \leq 0.05$)

Discussion

Alternately, the effect of different levels of pruning and benzyladenine (BA) on tree height, spread, volume, trunk girth, shoot diameter, graftable scion wood, total number of shoots per tree, number of lateral shoots, average shoot length, number of buds per shoot, internodal length, pruning weight, leaf area and total chlorophyll content are in conformity with the results obtained by Khan *et al.*, (1992) [12] who also observed that height of severely pruned ber trees were lower than the medium and lightly pruned ones. Tree height increased with decrease in level of heading back treatment in sweet cherry Moghadam and Zamanipour, (2012) [13] in Red Delicious and Golden Delicious cultivars of apple Zamanipour *et al.*, (2012) [8]. Similar data has also been presented by Gudarowska *et al.*, (2006) [14] who also observed that pruning at the height of 80 cm improved the height in Ligol apple trees. Caglar and Ilgin, (2009) [15] found that the height and stem diameter of BA treated apple trees were slightly lower. Hrotko *et al.*, (1996) [16] in sweet cherry reported that trees treated with BA were significantly smaller. Pinching and BA treatments showed no significant effect on tree height. This is well supported by the data of lateral growth where lateral growth might have decreased the terminal growth in I dared apple tree Hrotko *et al.*, (1997) [17] which is in conformity with the results of the current investigation. Unarh, (1989) [18] reported that BA treatments resulted in spreading of moderately vigorous trees in apple. Sharma *et al.*, (1995) [19] reported that with increased pruning intensity, canopy volume decreased in Santa Rosa plum. Increase in tree volume could be attributed to less removal of pruning wood from the lightly pruned New Castle apricot trees Thakur, (2012) [20]. Ballinger *et al.*, (1963) [21] did not observe any measurable effect of pruning severity on trunk

circumference in cultivars Redhaven and Elberta peach cultivars. Similar results have also been reported in peach by Schneider and Mc Clung (1957) [22] and Schneider *et al.*, (1958) [23]. In sweet cherry also light pruned trees (heading in 80 cm) improved the shoot diameter Moghadam and Zamanipour, (2012) [13]. Increase in diameter of shoots with increase in severity of pruning in ber was observed than in unpruned trees was observed by Khan *et al.*, (1992) [12] which is in line with the results obtained in the present study. The shoot diameter was significantly increased by BA application as compared to than in control in Golden Delicious apple Cin *et al.*, (2007) [24]. Repeated sprays at the higher BA concentration decreased the shoot diameter in sweet cherry Magyar and Hrotko, (2005) [25].

Increased pruning weight was observed in heavily pruned plum trees Suklabaidya, (2012) [26]. Rana (2001) also showed that application of BA at 25, 50 and 100 ppm increased plant height and leaf area of strawberry. According to Hrotko *et al.*, (1996) [16] BA treatments reduced the length of internodes in comparison to the untreated 'Idared' apple trees but the number of internodes did not change significantly. Kalabekova, (1974) [27] also reported that heavy pruning severity reduced the number of vegetative buds which are likely to develop into new shoots in peach. Higher pruning levels enhanced shoot growth Siham *et al.*, (2005) [28] in 'Alexandra' peach. Heading back pruning led to an increase in the length of new shoots as reported by Mika *et al.*, (1992) [29] in young apple trees; Imuro *et al.*, (1982) [30] and Aoki *et al.*, (1985) [31] in persimmon trees. Similar results have been obtained by Sharma and Chauhan (2003) [32] Singh (1992) [33] and Sharma (1995) [34] in July Elberta peach in which leaf chlorophyll content increased with increase in pruning severity. Similarly, total chlorophyll content of leaves increased with increase in heading back levels Abo-El-Ez, (2009) [35] in persimmon. The increase in chlorophyll content with increased pruning severity might be due to the role of severe heading back pruning in nutrients absorption by roots, because removing more number of shoots will modify shoot/root ratio of the pruned tree.

This might possibly have resulted from the heading back of dormant shoots that had the most stimulating effect on shoot growth due to increased levels of cytokinins, auxins and gibberellins in the heavily pruned trees. Cytokinins promote shoot development through increased cell division and maintain a proper balance between long and short shoots in fruit trees Buban, (2000) [36]. Benzyladenine (BA) alone or in combination with gibberellins overcomes apical dominance which stimulates the development of lateral shoots Jaumien *et al.*, (2002) [37]. Benzyladenine (BA) increased endogenous cytokinin concentrations and also promoted the number of shoots from lateral buds in apple Hrotko *et al.*, (1997) [17] and Wertheim and Estabrooks, (1994) [38]. Pruning resulted in interruption of apical dominance by altering hormonal movement to the buds, hence lead to increase in number of lateral shoots Jacyna and Puchała, (2004) [39] and Robinson *et al.*, (2005) [40] and heading back also improved the feathering characteristic in sweet cherry Moghadam and Zamanipour, (2012) [41]. More severe heading back increased the shoot number as well as shoot growth in 'Empire' apple trees Elfving, (1990) [41].

Leaf pinching resulted in reduction of auxin content in the stem thereby encouraging lateral buds to develop into lateral shoots and it also helped in rapid stem elongation Sazo1 and Robinson, (2011) [42]. The pinching treatment in 'Idared' significantly resulted in more lateral shoots per tree Hrotko *et*

al., (1997) [17]. The increase in graftable scion wood can be explained on the basis of increase in total number of shoots per tree and lateral shoots. It might be due to the ability of BA and pruning to interrupt the apical dominance which stimulated the development of lateral shoots.

Conclusion

On the basis of the results obtained during the present investigation it can be concluded that different pruning levels and benzyladenine (BA) were significantly effective in improving budwood production of apple cultivars Early Red One, Gale Gala, Red Chief and Vance Delicious. Among different treatments, heading back to 20 cm + BA (500 ppm) was found to be the best treatment for increasing the graftable scion wood, total number of shoots and number of lateral shoots, tree spread and tree volume. Heading back to 10 cm in combination with BA (500 ppm) application significantly increased average shoot length, shoot diameter, internodal length, pruning wood weight and leaf area in different apple cultivars under study.

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