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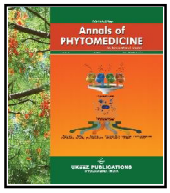

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Pruning effects on growth, yield and fruit quality of apple (*Malus* × *domestica* Borkh.) cv. Gale Gala

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Abstract

The present investigation was carried out on 12-year old trees of apple cv. Gale Gala raised on MM 106 rootstocks at 2.5 m × 2.5 m spacing in the experimental farm of Regional Horticultural Research and Training Station (RHR&TS), Mashobra, Dr. YSP UHF, Nauni, Solan, Himachal Pradesh, during the year 2019-20. Pruning is one of the important cultural practices which influence the tree growth, yield and it also facilitates the light penetration into the canopy for excellent fruit quality and colour development. Under this experiment, seven treatments were given to plants of cv. Gale Gala. The results revealed that trees headed back to 50% of one-year old growth significantly increased shoot growth and trunk girth. Trees subjected to 25% of Spur removal + Heading back of 25% of one-year old growth recorded maximum leaf area (59.43 cm^2), fruit retention (70.89%), fruit yield (41.26 kg/tree), length and width (57.17 mm and 65.65 mm) fruit weight (121.45 g), and TSS (12.20°B).

1. Introduction

Apple (*Malus* × *domestica* Borkh.), belongs to family Rosaceae and sub-family Pomoideae, having its origin in Asia Minor, Caucasus and Central Asia. It is the most leading fruit crop grown under temperate climate and in recent years, the geographically the distribution of apple has gone wider and it is successfully grown even in many tropical and sub-tropical countries. Apple is one of the commonly consumed fruits which is a rich source of sugars and dietary fibres and constitutes an important part of the human diet. Fruits including apple have abundance of various bioactive or functional compounds like polyphenolics, folic acid, vitamins C, dietary fibres and minerals (Sharma *et al*., 2019). The presence of these compounds helps in prevention and controls various infections and diseases in human body (Bhatt *et al*., 2021; Hamid *et al*., 2021). Apple is a good source of polyphenols which are referred to as potent antioxidants and protects body against various associated diseases of oxidative stress like hyper-inflammation, coronary heart disease and cancer (Kashyap *et al*., 2017; Thakur *et al*., 2020; Kaushal *et al*., 2022). In HP (Himachal Pradesh), apple is one of the most predominant fruit crop. It occupies an area of 112.63 thousand hectare with an annual production of 446.57 thousand metric tons (Horticultural Statistics at a Glance, 2018). Area of apple fruit cultivation is continuously growing in the state of Himachal Pradesh with the average growth of 1.5 per cent every year (Wani and Songara, 2017).

Gala is one of the most widely grown apple cultivar in the world. It can be grown in both temperate and warm apple growing regions with good quality which is one of the unique features of Gala and it is generally regarded as a low-chill variety. Gala is genetically small fruited and is characterized by heavy bloom and set of fruits during the whole growing seasons with small sized fruits (Raffo *et al*., 2011). Pruning is one of the important cultural practice which affects tree growth, yield and quality of fruit crops. It facilitates the light penetration into the canopy for excellent fruit quality and colour development. Pruning is also responsible for the reduction of competition with vegetative growth and could also lead to more assimilates being available for fruit growth which results in larger fruit size (Smith *et al*., 2007). However, the variation in severity of pruning depends upon the vigour of the shoot. Fruit thinning have other beneficial effects like increased return bloom, improved fruit size and reduced alternate bearing habit of apple trees. During the post bloom period, thinning of the apple crop is one of essential steps to ensure large superior fruit quality, fruit size and reliable annual cropping. Thinning of flowers or fruitlets of apple trees also improves fruit appearance and returns bloom which has become a standard practice in the growing of many fruit crops (Shukla *et al*., 2007). The present studies were carried out to investigate the pruning effects on growth, yield and fruit quality of apple cv. Gale Gala.

2. Materials and Methods

2.1 Location and climate

The experiment was carried out at RHR & TS (Regional Horticultural Research and Training Station), Mashobra, District-Shimla, HP

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located at an altitude of 2146 m above mean sea level and lies between 31°12" N latitude and 77°22" E longitude. The area experiences 135-150 cm of annual rainfall and the climate is temperate. Based on temperature, pleasant weather prevails during April that follows three months of mild summer in May-June.

2.2 Plant material

The study was carried out on 12-year-old trees of apple cultivar Gale Gala where twenty one trees were selected with uniform vigour. During the entire course of investigation, experimental trees were kept under uniform cultural practices.

2.3 Time and method of application

Pruning was carried out in dormant season after complete leaf shedding of the trees. During pruning, there was heading back of the scaffold branches and thinning out of fruiting shoots. 25 per cent and 50 per cent part of old wood was removed under severe pruning and spur growth was removed under other treatments, while no pruning was employed under control. The dried and diseased branches were also removed completely. The details of treatments followed during the study have been presented below in Table 1.

Table 1: Treatment details

Treatment		Treatment details
T1	:	¼th Heading back (25% removal of one year old growth)
T2	:	½ Heading back (50% removal of one year old growth)
T3	:	Removal of secondary branches (<½ of the size of primary branches) + No heading back
T4	:	Removal of secondary branches (<½ of the size of primary branches) + Heading back (25% removal of one year old shoot)
T5	:	25% Spur removal + No heading back
T6	:	25% Spur removal + Heading back (25% removal of one year old growth)
T7	:	Control

2.4 Vegetative measurements

Annual shoot growth was measured by randomly selecting the ten shoots and the length was measured at the end of growing season and expressed as centimetres (cm). The shoots were selected from the current season's growth from all over the periphery of the tree. Leaf area was calculated by selecting five fully developed and matured leaves which were detached during the 3rd week of July. Their area was measured with the help of Automatic Leaf Area Meter (Licor Model 3100). Trunk girth was calculated before the start of the growth and again after the completion of the growth. It was calculated by taking 30 cm above the ground level with the help of measuring tape once. The fruit set was determined by counting the number of fruit set in the tagged branches by dividing it with the number of flower cluster in that particular branch and the ratio was then multiplied by 100. The formula for the fruit set (Westwood, 1993) is as under:

$$\text{Fruit set (\%)} = \frac{\text{Number of fruits set on fruiting branch}}{\text{Number of flower on fruiting branch}} \times 100$$

Fruit retention was calculated by selecting the total number of fruits retained on the marked branches and counted at the time of harvest and the percentage of fruit retention was calculated:

$$\text{Fruit retention (\%)} = \frac{\text{Total number of fruit retained on fruiting branch}}{\text{Total number of fruit set on fruiting branch}} \times 100$$

Under different, treatments the yield of fruits was recorded at the time of harvest by weighing the total fruits by using top pan balance. The yield of fruits was expressed in kilograms per tree (kg/plant).The size of fruit in terms of length and breadth of ten randomly selected fruits in each replication was recorded with a digital vernier calliper. Fruit weight was calculated by selecting the ten fruits which were weighed on electronic top pan balance and the average fruit weight was expressed in gram per fruit (g/fruit).

2.5 Physicochemical measurements

The total soluble solids content of the fruits was determined by Erma hand refractometer ranging from 0-32° Brix). Titratable acidity was estimated as per method of Ranganna (1995) in which a known aliquot of the sample was titrated against N/10 NaOH solution using phenolphthalein as an indicator. Statistical analysis was carried out according to the procedure for analysis of randomized block design (RBD) as given by Gomez and Gomez (1984).

3. Results

3.1 Effect on annual shoot growth, leaf area and trunk girth

Maximum shoot growth (22.90 cm) was recorded in T_2, which was at par with treatment T_4 and T_6, but significantly higher than all other treatments (Table 2). Whereas, minimum shoot growth (18.02 cm) was recorded in T_5, which was significantly at par with T_3, but significantly lower than all other treatments. Maximum leaf area (59.43 cm^2) was recorded in T_6, which was at par with treatment T2, T_4 and T_3, but significantly higher than all other treatments. Whereas, minimum leaf area (47.80 cm^2) was recorded in T_5 which was significantly at par with T_7, but significantly lower than all other treatments. With respect to the trunk girth, maximum increase in trunk girth (1.94 cm) was recorded in T_2, which was at par with treatment T_6, but significantly higher than all other treatments. Whereas, minimum increase in trunk girth (1.07 cm) was recorded in T_5 and significantly lower than all other treatments.

3.2 Effect on fruit set, fruit retention and fruit yield

It is evident from the data presented in Table 3 that maximum fruit set (55.80%) was recorded in T_3, which was at par with treatment T_4, but significantly higher than all other treatments. Whereas, minimum fruit set (40.07%) was recorded in T_7, which was significantly at par with T_2, but significantly lower than all other treatments. Whereas, maximum fruit retention (70.89%) was recorded in T_6 and was at par with treatment T_4 and T_3, but significantly higher than all other treatments and minimum fruit retention (59.30%)

was recorded in T_7 which was closely followed by T_2 and T_1 and these treatments were statistically at par with each other. Maximum fruit yield (41.26 kg/tree) was recorded in T_6 which was at par with treatment T_4, T_3 and T_5. Whereas, minimum fruit yield (30 kg/tree) was recorded in T_7 which was significantly lower than all other treatments.

Table 2: Effect of pruning on leaf area and fruit set of apple cv. Gale Gala

Treatment details		Annual shoot growth (cm)	Increase in trunk girth (cm)	Leaf area (cm^2)
T_1	¼th Heading back (25 % removal of one-year old growth)	20.45	1.43	51.20
T_2	½ Heading back (50 % removal of one-year old growth)	22.90	1.94	58.69
T_3	Removal of secondary branches (< ½ of the size of primary branches) + No heading back	20.02	1.57	56.89
T_4	Removal of secondary branches + (< ½ of the size of primary branches) + Heading back (25% removal of one-year old shoot)	21.25	1.63	57.03
T_5	25% Spur removal + No heading back	18.02	1.07	47.80
T_6	25% Spur removal + Heading back (25% removal of one-year old growth)	20.85	1.90	59.43
T_7	Control (recommended pruning)	20.50	1.14	48.80
CD $_{(0.05)}$		**2.07**	**0.01**	**2.55**

Table 3: Effect of pruning on fruit set and fruit retention of apple cv. Gale Gala

Treatment details		Fruit set (%)	Fruit retention (%)	Fruit yield (kg/tree)
T_1	¼th Heading back (25% removal of one-year old growth)	53.30	62.25	34.73
T_2	½ Heading back (50% removal of one-year old growth)	40.27	61.44	33.70
T_3	Removal of secondary branches (< ½ of the size of primary branches) + No heading back	55.80	66.47	38.68
T_4	Removal of secondary branches + (< ½ of the size of primary branches) + Heading back (25 % removal of one-year old shoot)	54.78	67.26	38.86
T_5	25% Spur removal + No heading back	43.93	64.21	35.83
T_6	25% Spur removal + Heading back (25% removal of one-year old growth)	46.37	70.89	41.26
T_7	Control (recommended pruning)	40.07	59.30	30.00
CD $_{(0.05)}$		**2.42**	**4.74**	**5.62**

3.3 Effect on fruit size and fruit weight

The maximum fruit length (57.17 mm) was recorded in T_6 (Table 4) which was significantly at par with treatment T_3 and T_4. Whereas, minimum fruit length (52.48 mm) was recorded in T_7 which was at par with T_1, T_2 and T_5, but significantly lower than all other treatments. Maximum fruit width (65.65 mm) was recorded in T_6 which was followed by T_3 and T_4. Whereas, minimum fruit width (59.17 mm) was recorded in T_7. Maximum fruit weight (121.45 g) was recorded in T_6 which was at par with T_3, but significantly higher than all other treatments. Whereas, minimum fruit weight (98.08 g) was recorded in T_7 which was closely followed by T_1, but significantly lower than all other treatments.

Table 4: Effect of pruning on fruit size and weight of apple cv. Gale Gala

Treatment details		Fruit size (mm)		Fruit weight (g)
		Length (mm)	Width (mm)	
T_1	¼th Heading back (25 % removal of one-year old growth)	54.13	59.27	104.75
T_2	½ Heading back (50 % removal of one-year old growth)	54.36	62.70	109.94
T_3	Removal of secondary branches (< ½ of the size of primary branches) + No heading back	56.38	65.12	116.60
T_4	Removal of secondary branches + (< ½ of the size of primary branches) + Heading back (25% removal of one-year old shoot)	56.07	63.11	111.34
T_5	25% Spur removal + No heading back	54.49	62.09	109.90
T_6	25% Spur removal + Heading back (25% removal of one-year old growth)	57.17	65.65	121.45
T_7	Control (recommended pruning)	52.48	59.17	98.08
CD $_{(0.05)}$		**2.17**	**2.72**	**5.25**

3.4 Effect on TSS, acidity and firmness

Maximum total soluble solids (12.20° Brix) was recorded in T_6 (Table 5) and significantly higher than all other treatments. Whereas, minimum total soluble solids (11.50°Brix) was recorded in T_7 which was statistically lower than all other treatments. Maximum titratable acidity (0.45 %) was recorded in T_7 which was closely followed with T_3 and T_4, but higher than all other treatments. Whereas, minimum acidity (0.35%) was recorded in T_6. Fruit firmness was non-significantly influenced by different pruning treatments. Maximum firmness (9.22 kg/cm^2) was recorded in T_3 which was closely followed with treatment T_7 and T_4. Whereas, minimum firmness (9.10 kg/cm^2) was recorded under treatments T_6 which was closely followed by T_2 and T_1.

Table 5: Effect of pruning on TSS, acidity and fruit firmness of apple cv. Gale Gala

Treatment details		Fruit firmness (kg/cm^2)	TSS (°Brix)	Acidity (%)
T_1	¼th Heading back (25 % removal of one-year old growth)	9.12	11.70	0.41
T_2	½ Heading back (50 % removal of one-year old growth)	9.11	12.17	0.38
T_3	Removal of secondary branches (< ½ of the size of primary branches) + No heading back	9.22	11.87	0.44
T_4	Removal of secondary branches + (< ½ of the size of primary branches) + Heading back (25% removal of one-year old shoot)	9.20	12.00	0.42
T_5	25% Spur removal + No heading back	9.17	11.57	0.41
T_6	25% Spur removal + Heading back (25% removal of one-year old growth)	9.10	12.20	0.35
T_7	Control (recommended pruning)	9.21	11.50	0.45
CD $_{(0.05)}$		**N/S**	**0.10**	**N/S**

4. Discussion

Heavy pruning severity reduces the number of vegetative buds that are likely to develop into new shoots; thereby, reducing the competition for carbohydrates and other metabolites and consequently might favour the shoot growth and leaf growth (Hassani and Rezaee, 2007). Fruit set and fruit retention were decreased by different pruning treatments which might be due to more vegetative and fruiting growth in lower level of pruning and less fruiting growth in higher level of pruning intensities (Kaith *et al.*, 2011a). Return bloom and fruit yield were increased by different pruning treatments and might be due to training and pruning of apple trees which results from the reduction in fruiting lateral density and the extinction procedure enhanced light interception by the spur canopy which is well correlated to tree productivity and led to improvement of fruiting

and return bloom characteristics (Wunsche and Lakso, 2000; Robinson *et al*., 2014). Bussi *et al.* (2005) found that the increase in the severity of pruning in peach cultivar Alexandra increased the average fruit size, weight and volume. Pruning decreases the number of flower buds and consequently the number of fruits as a result; however, it usually increases fruit size (Smith *et al*., 2007). Fruit TSS and acidity always have a correlated phenomenon as fruits acids participated in sugar accumulation in advance stages of ripening. The enhanced fruit TSS in the fruits from heavily pruned trees could possibly be associated with the increase in leaf fruit ratio that augmented the availability of more photosynthates and uptake of nutrients from the soil which sequentially improved fruit quality. These findings are in agreement with those of Kaith *et al.* (2011b) and Samira *et al.* (2014) that heavy pruning improved fruit quality in 'Starking Delicious' apple.

5. Conclusion

On the basis of results obtained in the present investigation, it can inferred that heading back of trees to 50% of one-year old growth significantly increased shoot growth and trunk girth. Pruning of trees with 25% of spur removal and 25% heading back of one-year old shoot growth enhanced leaf area, fruit retention and fruit yield. Better fruit quality in terms of fruit size, fruit weight, fruit TSS and fruit sugars was observed with 25% removal of spur + 25% heading back of one-year old growth.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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