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A Comprehensive Study on the Efficacy of Crop Load Management Practices in Apple under the North-Western Himalayan Region

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Abstract

Crop load management is becoming increasingly important as a factor related to continued yields, better quality, higher shelf life, and return bloom in apples, particularly under intensive planting systems. In recent years, apple orchardists across J&K (UT) have shifted to high-density apple orcharding predominated by Super Chief and Redlum Gala cultivars. However, these cultivars bear heavily as a result consistent yield and quality become prime issues in addition to orchard longevity. To standardize the crop management practice in the cultivars as mentioned above, an experiment was laid at the farmer's field comprising both chemical and non-chemical methods from 2021-22 and 2022-23. Trees were trained as tall spindle treated with uniform cultural practices as recommended in packages and practices of SKUAST-K. Results revealed that average yield/tree (kg) varied significantly in both Redlum Gala and Super Chief. In Redlum Gala, the highest yield was obtained in T_3 (31.40 kg/plant) followed by 30.50 kg/tree in T_8, and the lowest yield/tree (24.433) was obtained in T_9. However, in Super Chief, the highest average yield/tree (30.50kg) was obtained by employing hand thinning @ 6 fruits/cm^2 TCSA at 25-30 mm fruitlet stage (T_7) while the lowest yield/tree (21.933kg) was obtained under no-thinning treatment (T_9). Similarly, crop load management practices had a significant effect on the quality of both Redlum Gala and Super Chief. The highest quantity of Fancy Grade (3.53kg/tree), and A-grade (24.53 kg/tree) in Redlum Gala resulted in T_3 and T_8 respectively whereas, the least quantity of B-grade (1.57kg/tree), and C-grade (0.70 kg/tree) were obtained in T_8 and T_7 respectively. In Super Chief, yield/tree of Fancy grade and C-grade apples varied non-significantly among various treatments although better results in terms of fancy grade yields were obtained under T_7 (3.73 kg/tree). Yields of A-grade apples varied significantly with maximum yield under T_7 (24.133 kg/tree). Hand thinning @ 6 fruit/cm^2 TCSA resulted in the least quantity of C-grade apples (1.0 kg/tree) in Super Chief cultivar. Pygmy fruit quantity varied non-significantly between T_4, T_5, and T_7. In case of Redlum Gala, T_7 was found most economical intervention in terms of BC ratio (2.21) followed by T_1(2.20). Similarly, in the case of Super Chief cultivar, T_7 was found as the best intervention in terms of B:C ratio (2.52). Significantly at par increase in the percentage of return bloom in Redlum Gala was observed under T_8 (6.40%), T_7 (6.13%), T_1 (5.567%), and T_5 (3.50%). The maximum decrease in return bloom in case of Redlum Gala cultivar was observed under T_9 (-9.70%) followed by T_6 (-5.23%). Different treatments resulted in significantly varied responses in terms of return bloom percentage in Super Chief. T_7 resulted in the highest increase in return bloom (11.63%) however, no treatment resulted in a decrease in the percentage of return bloom except control (-15.30%).

***Key words*:** Yield, Return bloom, Hand thinning, Crop load management, B:C ratio

Apple (*Malus* x *domestica* Borkh.) is widely grown in temperate regions across the globe and is known as the King of temperate fruits [1]. In India, apples are mainly grown in North-Western Himalayan regions, including Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. Jammu and Kashmir account for more than 70% of apple produce [2]. In recent years, some intensive systems of apple plantation are coming up growing recent selections of Red Delicious and Gala cultivars. These selections are well-known for their colour, size, quality, earliness, higher yields, and manageable canopies. However, due to overbearing, these cultivars become highly prone to alternate bearing, inferior grade yield, and become highly susceptible to biotic and abiotic vagaries [3]. Crop load management particularly under intensive planting systems is one of the most important horticultural practices for determining higher productivity, better quality, continued production, orchard longevity, and balanced canopy management [4] and is used in modern apple production to ensure consistent bearing and good fruit quality [5]. However, this practice is rarely followed by apple orchardists either in negligence or in fear of yield loss. Apples grown in high-density are characterized by heavy bloom and fruit set, which has several negative consequences such as small, poorly coloured, and low-quality fruits, as well as reduced return bloom the following year, which affects overall profitability [6-7].

Regulation of crop load is an effective method in apples to improve quality and to prevent biennial bearing [8]. Management of crop load is a balancing act between reducing

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crop load (yield) sufficiently to achieve optimum fruit size and adequate return bloom without reducing yield excessively [9]. The optimal crop load is one that produces a consistent annual crop and fruit of marketable quality [10]. The difference between the optimum crop load and under thinning or over thinning can sometimes be a difference of thousands of dollars per acre [11]. More precisely managing crop load will help growers achieve the optimum crop load and maximize crop value [12]. The consistent production of fruit of optimum color and size can only be accomplished when proper balance between vegetative growth and fruiting is maintained [13].

Crop load management is a multistep process that includes various management practices: pruning, chemical thinning, and hand thinning [14], mechanical thinning, which has been increasingly important in recent years [15] and artificial spur extinction [16].

Reducing the crop load by thinning to a certain number of fruits is also important for next year's crop [17]. Apple tree fruit thinning can increase fruit size, increase return bloom, reduce alternate bearing and reduces limb breakage and cost of handling [18]. Fruit trees start making flower buds for the next season's crop in the current growing season, therefore the crop load decisions that orchardists make will affect the current year's production, as well as the next year's crop [19]. If a crop is not thinned properly, and too many fruits are left on the tree, the fruit will be small due to too much competition, the resources that would go towards next year's buds will be diminished, and producing too few return bloom the following year [20]. If too many fruits are removed from the tree, the fruit will grow too large, which increases fruit quality and storage problems [21]. Apple fruit size and color has always been a critical factor in determining market value [22]. Early removal of fruit results in larger fruit size at harvest as reported by Jones *et al.* [23] and Racsko [24]. The practice of post-bloom thinning, which generally occurs at the 3-18 mm fruit size stage, is used to promote return bloom, as well as to regulate crop load. Fruit removal which occurs after the period of flower initiation (30 to 40 days after full bloom) will affect crop load only [25].

MATERIALS AND METHODS

A five-year apple orchard located at farmer's field situated in Manzgam area of district Kulgam at an altitude of 6250ft above mean sea level was selected for the study. Five plants were selected for each treatment and replicated 3 times comprising of 54 plants in total with 27 plants each of Redlum Gala and Super Chief. Uniform cultural practices as per guidelines of Krishi Vigyan Kendra, Kulgam in accordance with Package and Practices of TSS apple, SKUAST-K were given to plants under study. The experiment consists of 9 treatments as T_1: Naphthalene acetic acid (NAA) @ 10 ppm sprayed at 10 mm fruitlet stage in both cultivars; T_2: Naphthalene acetamide (NAD) @ 50 ppm at petal fall stage; T_3: Benzyl Adenine (BA) @ 100 ppm at 10 mm fruitlet stage; T_4: Ethephon @ 500 ppm at 15 mm fruitlet stage; T_5: Aminocyclopropane-1-carboxylic Acid (ACC) @ 150 ppm at 20 mm fruitlet stage; T_6: Ammonium thiosulphate (ATS) @ 2.5% at pink bud stage; T_7: Hand thinning @ 6 fruits/cm2 TCSA at 25-30 mm fruitlet stage; T_8: Artificial Spur Extinction (ASE) done few days before bud break with 3 plants of each cultivar for T_9 as control (no thinning). Fruits were harvested at optimum harvesting maturity which was from 19th to 24th August for Redlum Gala and 06th-9th September for Super Chief under Manzgam conditions. Data in terms of yield was estimated by taking the yield of all treated plants of individual cultivars, dividing it by the number of plants under the same treatment. Grades were assigned manually as per the standard procedure keeping size, colour, shape, blemish, scar, and disease or pest symptom on fruit in consideration. After assigning grades as Fancy, A, B, and C-grade, fruits under different grades were weighed using digital balance. The average grade was estimated by adding individual grades under a particular treatment and dividing it by the total number of plants under the same treatment. Economics was calculated based on prevailing market rates of the inputs and produce and depicted in terms of B:C ratio. In addition to this, return bloom was estimated and presented in terms of percentage increase or decrease of previous year bloom. Data was analyzed in Opstat software using one-factor analysis and means of treatments were compared based on the critical difference (C.D) test at $p \leq 0.05$.

RESULTS AND DISCUSSION

A: *Fruit yield*

The data presented in (Table 1) clearly shows average yield/plant (kg) in Redlum Gala varied significantly among various treatments with the highest yield in T_3 (31.40 kg/plant) followed by 30.50 kg/tree in T_8 and the lowest yield/tree (24.433) was obtained in T_9 (control). Yields/tree in Redlum Gala varied non-significantly between T_3, T_4, T_5, T_7, and T_8 as clear from (Table 1).

Table 1 Efficacy of various crop load management practices on average yield/tree (Kg) of apple

Crop management techniques	Redlum Gala	Super Chief
T_1: NAA @ 10 ppm at 10 mm fruitlet stage	28.600	26.533
T_2: NAD @ 50 ppm at Petal fall stage	27.933	28.433
T_3: BA @ 100 ppm at 10 mm fruitlet stage	31.400	29.833
T_4: Ethephon @ 500 ppm at 15 mm stage	29.833	25.500
T_5: ACC @ 150 ppm at 20 mm fruitlet stage	29.200	29.600
T_6: ATS@ 2.5% at pink bud stage	26.433	24.300
T_7: Hand thinning @ 6 fruit/cm^2 TCSA at 25-30mm fruitlet stage	29.300	30.500
T_8: Artificial Spur Extinction a few days before bud break	30.500	28.067
T_9: Control (No Thinning)	24.433	21.933
C.D (0.05)	2.860	2.723

In case of Super Chief cultivar, the highest average yield/tree (30.50kg) was obtained by employing hand thinning @ 6 fruits/cm^2 TCSA at 25-30 mm fruitlet stage (T_7) while the lowest yield/tree (21.933kg) was obtained under no-thinning treatment (T_9) as shown in (Table 1). However, yields obtained under T_7 varied non-significantly from T_2, T_3, T_5, and T_8 in case of Super Chief apple cultivar as shown in (Table 1). Varied effects of various treatments as observed during the current study may be attributed to the differential response by Redlum Gala and Super Chief cultivar to chemical thinners under prevailing weather conditions as reported by Ouma and Matta [26], Kosina [27], Autio *et al.* [28] and Bucchi and Bregoli [29].

The chemical thinner concentration, the environment particularly temperature and humidity at the time of application, method of application and coverage, drying conditions, leaf epicuticular wax, and above all plant developmental stage have been reported to contribute to update variability and henceforth differential response as pointed in earlier reports by Greene [30], Zhu *et al.* [31], Wertheim [32], Dennis [33].

B: *Fruit quality*

Data depicted in (Table 2) clearly shows that crop load management strategies have a significant effect on quality presented in the type of grades of Redlum Gala. The highest quantity of Fancy Grade Redlum Gala resulted in T_3 (3.53kg/tree) although results varied non-significantly from T_1 (3.067kg/tree) and T_2 (3.10 kg/tree). However, the highest quantity of A-grade apples resulted in the case of T_8 (24.53 kg) although this value was found significantly at par with T_7 (24.067kg) and T_5 (22.767). Similarly, the least quantity of B-grade apple resulted in T_8 (1.567 kg) while the highest quantity in T_6 (5.067 kg) as shown in (Table 2). The quantity of C-grade and pygmy apples in Redlum Gala varied significantly among various treatments as depicted in (Table 2).

Table 2 Effect of various crop load management practices on the quality of Redlum Gala apple (kg/tree)

Crop management techniques	Fancy-grade	A-grade	B-grade	C-grade	Pygmy
T_1: NAA @ 10 ppm at 10 mm fruitlet stage	3.067	21.633	2.467	1.167	0.267
T_2: NAD @ 50 ppm at Petal fall stage	3.100	17.633	2.767	4.200	0.300
T_3: BA @ 100 ppm at 10 mm fruitlet stage	3.533	21.933	2.867	2.967	0.100
T_4: Ethephon @ 500 ppm at 15 mm stage	1.967	18.767	2.533	6.500	0.067
T_5: ACC @ 150 ppm at 20 mm fruitlet stage	1.633	22.767	1.800	2.967	0.067
T_6: ATS@ 2.5% at pink bud stage	2.600	15.267	5.067	3.467	0.033
T_7: Hand thinning @ 6 fruit/cm^2 TCSA at 25-30mm fruitlet stage	2.067	24.067	2.467	0.700	0.000
T_8: Artificial Spur Extinction a few days before bud break	1.567	24.533	1.567	2.733	0.100
T_9: Control (No Thinning)	1.567	13.300	7.567	1.933	0.067
C.D (0.05)	0.897	2.498	1.194	3.087	0.170

However, Super Chief responded differently to the various crop management techniques as observed from the data presented in (Table 3). Yield/tree of Fancy grade and C-grade apples varied non-significantly among various treatments although better results in terms of fancy grade yields were obtained under T_7 (3.73 kg/tree). Yields of A-grade apples varied significantly with maximum yield under T_7 followed by T_3 (22.767 kg/tree). From (Table 3), it shows clearly that yields of C-grade and pygmy apples varied significantly among different treatments in Super Chief apple cultivar. Variation in the quality among Redlum Gala and Super Chief in terms of various studied grades may be attributed to differences in genotype, bearing habit, canopy growth, growth habit, etc. as reported by Afshari *et al.* [34], Sharma *et al.* [35], Koser [36]. Different crop load management practices affected yields of various types of grades in studied apple cultivars may be attributed to cultivar response as reported earlier by Costa *et al.* [37], Botton and Costa [38], Sharma *et al.* [39], Koser [40].

Table 3 Effect of various crop load management practices on the quality of Super Chief apple

Crop management techniques	Fancy-grade	A-grade	B-grade	C-grade	Pygmy
T_1: NAA @ 10 ppm at 10 mm fruitlet stage	3.667	17.267	0.767	4.533	0.300
T_2: NAD @ 50 ppm at Petal fall stage	3.367	20.300	1.867	2.533	0.367
T_3: BA @ 100 ppm at 10 mm fruitlet stage	2.700	22.767	2.333	1.933	0.100
T_4: Ethephon @ 500 ppm at 15 mm stage	2.100	19.400	2.400	1.567	0.033
T_5: ACC @ 150 ppm at 20 mm fruitlet stage	3.400	22.300	1.700	2.167	0.033
T_6: ATS@ 2.5% at pink bud stage	2.733	16.700	2.600	2.200	0.067
T_7: Hand thinning @ 6 fruit/cm^2 TCSA at 25-30mm fruitlet stage	3.733	24.133	1.600	1.000	0.033
T_8: Artificial Spur Extinction a few days before bud break	1.600	21.067	3.600	1.633	0.167
T_9: Control (No Thinning)	2.667	15.767	1.667	1.633	0.133
C.D (0.05)	NS	2.595	1.480	NS	0.152

Table 4 Benefit-cost ratio of crop load management strategies in apple

Crop management techniques	B:C ratio	
	Redlum Gala	Super Chief
T_1: NAA @ 10 ppm at 10 mm fruitlet stage	2.20	2.28
T_2: NAD @ 50 ppm at Petal fall stage	1.99	2.40
T_3: BA @ 100 ppm at 10 mm fruitlet stage	2.10	2.43
T_4: Ethephon @ 500 ppm at 15 mm stage	1.89	2.43
T_5: ACC @ 150 ppm at 20 mm fruitlet stage	2.10	2.43
T_6: ATS@ 2.5% at pink bud stage	1.94	2.34
T_7: Hand thinning @ 6 fruit/cm^2 TCSA at 25-30mm fruitlet stage	2.21	2.52
T_8: Artificial Spur Extinction a few days before bud break	2.14	2.39
T_9: Control (No Thinning)	1.91	2.44

C: *Economical analysis*

Due to the differential response of Redlum Gala and Super Chief to various crop management strategies, BC ratio was calculated and presented in the tabular form as shown in (Table 4). In case of Redlum Gala, T_7 was found most economical intervention in terms of B:C ratio (2.21) followed by T_1 (2.20). Similarly, in case of Super Chief cultivar, T_7 was found as the best intervention in terms of B:C ratio (2.52). From the (Table 4), it clearly shows that T_9 (no thinning) proved better in terms of BC ratio (2.44) as compared to other

treatments except T_7. Variation in terms of BC ratio between Redlum Gala and Super Chief under different crop load management treatments may be attributed to differences in consumer acceptance [41], harvesting date [42], productivity [1], quality [2], production cost [43], shelf life [44] and are in concordance to the earlier finding of Hassan *et al.* [45], Samriti *et al.* [46], Wani *et al.* [47], Radivojevic *et al.* [48].

D: *Return bloom*

Important information regarding the percentage increase/decrease in return bloom was observed during the study as shown in (Table 5). Significantly at par increase in the percentage of return bloom in Redlum Gala was observed under T_8 (6.40%), T_7 (6.13%), T_1 (5.567%), and T_5 (3.50%) as shown in (Table 5). The maximum decrease in return bloom in case of Redlum Gala cultivar was observed under T_9 (-9.70%) followed by T_6 (-5.23%) as evident from (Table 5). Similarly, in case of Super Chief cultivar, various treatments resulted in significantly varied responses in terms of return bloom percentage. T_7 resulted in the highest increase in return bloom (11.63%) followed by T_1 (8.23%) as evident from (Table 5). However, in super Chief cultivar, no treatment resulted in a decrease in the percentage of return bloom except control (-15.30%) [49-53].

Table 5 Effect of crop load management methods of return bloom in apple cv. Redlum Gala and Super Chief

Crop management techniques	Percent increase/decrease in return bloom	
	Redlum Gala	Super Chief
T_1: NAA @ 10 ppm at 10 mm fruitlet stage	5.567	8.233
T_2: NAD @ 50 ppm at Petal fall stage	3.033	3.600
T_3: BA @ 100 ppm at 10 mm fruitlet stage	-3.500	3.533
T_4: Ethephon @ 500 ppm at 15 mm stage	2.500	3.633
T_5: ACC @ 150 ppm at 20 mm fruitlet stage	3.500	6.967
T_6: ATS@ 2.5% at pink bud stage	-5.233	1.267
T_7: Hand thinning @ 6 fruit/cm^2 TCSA at 25-30mm fruitlet stage	6.133	11.633
T_8: Artificial Spur Extinction a few days before bud break	6.400	4.833
T_9: Control (No Thinning)	-9.700	-15.300
C.D (0.05)	3.413	4.279

CONCLUSION

Crop load management is one of the most important cultural practices affecting both yield and quality and henceforth economic feasibility of apple cultivation particularly in intensive systems. Standardization of crop management practices based on cultivar, location, and planting system is the need of the hour. Economic viability and return bloom in apples varied significantly during the study and this yardstick can be effectively used by orchardists of the North-Western Himalayan region. In high-yielding and vigorous apple cultivars, crop load management is critical to obtain yearly yields and better quality. By adopting crop load management as a "yardstick," orchardists can achieve sustainable production with yearly yields and superior fruit quality. This practice is not only essential for meeting market demands but also for ensuring the long-term health and productivity of apple orchards in this region.

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