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Yield and quality performance of apples under varied summer pruning intensities in the North-Western Himalayan region

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Abstract— *This study aimed to evaluate the influence of varied intensities of summer pruning on five predominant apple cultivars in ultra-high-density planting systems on yield and quality performance at harvest. The experiment was carried out during 2021-22 and 2022-23 growing seasons under the Kulgam district of J&K (UT) in the North-Western Himalayan region of India. Experimental plants were evaluated at harvest for yield and quality performance. The economic value of various treatments was calculated by estimating total costs (Rs/tree), gross income (Rs/tree), and Net income (Rs/tree) by framing questionnaires and collecting requisite information. Results revealed that summer pruning showed varied results in terms of various observations due to different genetic makeup, growing habits, bearing patterns, market price, and fruit quality. Significantly at par highest average yields/tree was obtained in Red Fuji (49.741kg) and Jeromine (49.268 kg) while the lowest value was obtained in Red Chief (27.919kg). However, Redlum Gala excelled over other cultivars in terms of Fancy (4.148kg), A-grade (27.517kg), and B-grade (4.158kg) although its yield was 42.313kg/tree which was lower as compared to Red Fuji and Jeromine. Maximum C-grade apples were obtained in the case of Red Fuji (23.998 kg/tree) and minimum in Red Chief cultivar (2.267 kg/tree). Mild summer pruning resulted in significantly the highest yield (47.076kg/tree) as compared to other summer pruning intensities. Summer pruning significantly affected the quantity of various apple grades. The maximum quantity of Fancy-grade apples (3.451kg/tree) was obtained in medium summer pruning whereas, mild summer pruning resulted in the highest A-grade (25.465kg/tree). Results revealed that the highest average yield was obtained in the mediumly pruned Red Fuji cultivar (57.53kg/tree) which was significantly at par with mildly pruned Jeromine (56.48 kg/tree). Better results in terms of Fancy-grade apples were obtained in mediumly pruned Redlum Gala (5.69 kg/tree) as compared to other treatment combinations. Similarly, mildly pruned Jeromine excelled in other treatment combinations in terms of A-grade apple yield (36.78 kg/tree). Similarly, various treatment combinations varied in terms of B-grade and C-grade apple yield. A negative correlation was observed between the crop yield (t/ha) and pruning severity in almost all cultivars excluding Red Fuji. A strong linear negative correlation (-0.99) between summer pruning and crop yield was observed in the Red Chief variety. A slight positive correlation was observed in the case of Red Fuji. The economic viability of various treatment combinations varied and was found better in terms of BC ratio in mediumly pruned and severely pruned Jeromine cultivar (3.67) followed by mediumly pruned Red Chief cultivar (3.57) and the lowest in unpruned Red Fuji (0.80).*

Keywords— ***Summer pruning, cultivar, yield, quality.***

I. INTRODUCTION

Apple (*Malus* X *domestica* Borkh.) is the most important temperate fruit worldwide with a total production of almost 90 mT (FOA, 2023). India occupies 5th rank globally in terms of production after China, USA, Poland, and Turkey, with Jammu & Kashmir accounting for more than 75% of the country's production (Rehman and Mubarak, 2023). Although Red Delicious strains occupy a major area under apple cultivation, recently Gala strains, Fuji, and other delicious clones/selections have also covered a good percentage of acreage (Rehman *et al*, 2023). These cultivars have gained popularity only after the adoption of some intensive planting systems like ultra-high density, semi-high density, and medium density orcharding. Under these systems, it has been found essential to strike a balance between vegetative and reproductive growth to maximize the production and quality traits and summer pruning is one of the techniques to do so. Summer pruning under intensive systems of planting contains growth, maintains a balance between vegetative and reproductive growth, improves fruit size and fruit production to obtain high yield and quality fruit (Hussein Moatamed, 2012). This technique is also used for breaking apical dominance and increasing twigs and spurs formation of apples (George *et al*, 2002), increasing fruit set (Fathi and Mokhtar, 1998), and increased the percentage of retained fruit to perfect flowers (Ebied, 2005). Summer pruning can also effectively reduce the measured plant growth during the current year (Dejong *et al*, 2004). Time of summer pruning is also an effective factor for improving the quality of the apple and increase in resistance to bruising and storage decay (Ibrahim *et al*, 2007). This technique is required to obtain good fruit colour for tree types such as slender spindle trees whose canopy has gaps that become filled with shoot growth soon after full bloom (Robinson *et al*, 1991).

Similarly, a positive correlation between summer pruning and colour development has been reported by Belter and Thomas (1980); Ogata *et al*1(986); Ystass (1992). Ogata *et al*, 1986 and Platon and Zagrai, 1997 reported that in apple summer pruning significantly improved the yield during the current and succeeding years. Several hypotheses mainly related to endogenous growth control, hormone regulation, and shoot-to-root ratio (Ferree *et al*, 1984; Saure, 1992) have been proposed to partially or fully interpret the effects of summer pruning. Given the above, the present experiment was conducted to not only evaluate the performance of cultivars but also to understand their response to summer pruning under high-density planting system.

II. MATERIAL AND METHODS

Red chief (V1), Redlum Gala (V2), Red Velox (V3), Red Fuji (V4), and Jeromine (V5) on M.9 rootstock in Tall Spindle System after 4th and 5th year of planting were evaluated along with the impact of summer pruning. Plants were trained to the central leader system with uniform cultural practices as per the package of practices of SKUAST-Kashmir. Summer pruning treatments varied in terms of severity as S_1 (no pruning), S_2 (10% removed), S_3 (20% removed), and S_4 (30 % removed). Summer pruning was confined during the 1st week of August in both the years (2022 & 2023) across cultivars without keeping growth habit in consideration. It was a two-year study replicated at 3 different locations on 5 plants of each cultivar. The design of the experiment was two factorial Randomised Block Design (RBD). 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, and finally converted to yield/ ha. 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 and finally converted to tonnes per hectare. Economics was calculated based on prevailing market rates of the inputs and produce. The data were subjected to statistical analysis of variance using Web Agri Stat Package, an online software developed by Central Coastal Agricultural Research Institute of Indian Council of Agricultural Science (ICAR) and means of treatments were compared based on the critical difference (C.D) test at $p \leq 0.05$.

III. RESULTS AND DISCUSSION

Crop yield:

Table 1 shows a lot of variability in crop yield among different varieties and pruning intensities. Among the varieties, Jeromine and Red Fuji being at par registered significantly higher yields than the rest, with a numerically high value (49.74 t/ ha) recorded in Red Fuji. The performance of varieties is a function of genetic makeup and environment. Since the performance of varieties varies depending on the location, these two varieties under discussion seem to be better suited to the microclimate and other factors of the study location. The results are consistent with the findings of Kumar *et al* (2013) and Kumar (2020). The variation could also be the result of phenotypic characteristics of the varieties, management

practices, and the site of the plantation as reported by Bhat *et al*, 2006 and Hampson *et al*, 2009.

Summer pruning also impacted crop yield and it could be observed from the data that severe pruning at 30% removal of growth (S4) reduced yield drastically. A significantly higher yield was recorded in 10% removal (47.07 t/ha) followed by 20% removal of growth. These figures indicate that optimizing pruning has a severity that substantially impacts yield, and severe and no summer pruning causes yield penalty. From the interaction (Table 2 & Fig1) it is clear that severe summer pruning had a negative impact on crop yield in all varieties. A negative correlation was observed between the two (Fig 3-7) in almost all cultivars excluding Red Fuji (Fig 6). A strong linear negative correlation (-0.99) between summer pruning and crop yield was observed in the Red Chief variety (V_1). With the increase in pruning severity, there was a corresponding decrease in yield in this variety. A slight positive correlation was observed in case of Red Fuji (Fig 6). Data in Table 2 shows that the maximum yield (57.53 t ha^{-1}) was obtained in case of Red Fuji (V_4) with 10% summer pruning. From Fig 1, it can be observed that various apple cultivars responded differently to different levels of summer pruning as far as yield is concerned. Yields improved upto moderate pruning but heavy summer pruning had a negative effect on yield across the different cultivars. However, the effect was more prominent in less vigorous cultivars like Red Chief and Jeromine. This varied response of different apple cultivars to different severity levels of summer pruning may be attributed to the different growth habits of studied cultivars (Cooley and Autio, 2011).

Table 1: Average yield and yield of different grades of apple as influenced by variety and summer pruning.

Varieties	Average yield (t/ha)	Fancy	A grade	B Grade	C grade
V_1	27.92	2.24	19.31	4.13	2.27
V_2	42.31	4.15	27.52	4.16	6.51
V_3	39.83	2.60	26.45	4.44	6.11
V_4	49.74	2.02	8.44	15.35	23.99
V_5	49.27	2.55	33.27	5.14	8.45
CD(p≤0.5)	2.24	0.31	3.99	1.70	2.07
Pruning Severity					
S_1	41.93	1.77	21.01	7.09	12.30
S_2	47.08	2.87	25.47	7.03	11.57
S_3	43.70	3.45	24.79	6.91	8.41
S_4	34.56	2.76	20.72	5.55	5.58
CD(p≤0.5)	2.00	0.28	3.56	NS	1.85

Table 2: Variety x pruning severity interaction effect on yield and different grades of apple.

Treatment combination	Average yield	Fancy	A grade	B grade	C grade
V_1S_1	34.57	1.14	22.11	6.93	4.32
V_1S_2	29.53	2.30	21.92	4.14	1.34
V_1S_3	25.48	3.29	18.17	2.86	1.11
V_1S_4	22.10	2.23	15.02	2.60	2.29
V_2S_1	43.48	2.07	25.77	5.72	10.06
V_2S_2	46.61	3.78	29.14	4.91	8.71
V_2S_3	44.48	5.69	30.07	3.66	4.29
V_2S_4	34.67	5.06	24.53	2.34	2.98

V_3S_1	39.62	2.52	22.78	5.11	9.05
V_3S_2	48.67	3.57	31.66	4.99	7.86
V_3S_3	39.85	2.48	27.94	4.81	4.27
V_3S_4	31.19	1.84	23.42	2.83	3.24
V_4S_1	43.62	1.25	4.77	12.00	26.85
V_4S_2	54.09	1.17	7.82	16.09	29.15
V_4S_3	57.53	2.80	10.38	18.46	25.44
V_4S_4	43.72	2.87	10.84	14.85	14.54
V_5S_1	48.33	1.86	29.66	5.66	11.22
V_5S_2	56.48	3.55	36.78	5.01	10.77
V_5S_3	51.14	3.00	36.75	4.75	6.94
V_5S_4	41.12	1.81	29.87	5.14	4.84
SE	34.57	1.14	22.11	6.93	4.32
CD(p≤0.5)	**4.48**	**0.62**	**NS**	**3.43**	**4.14**

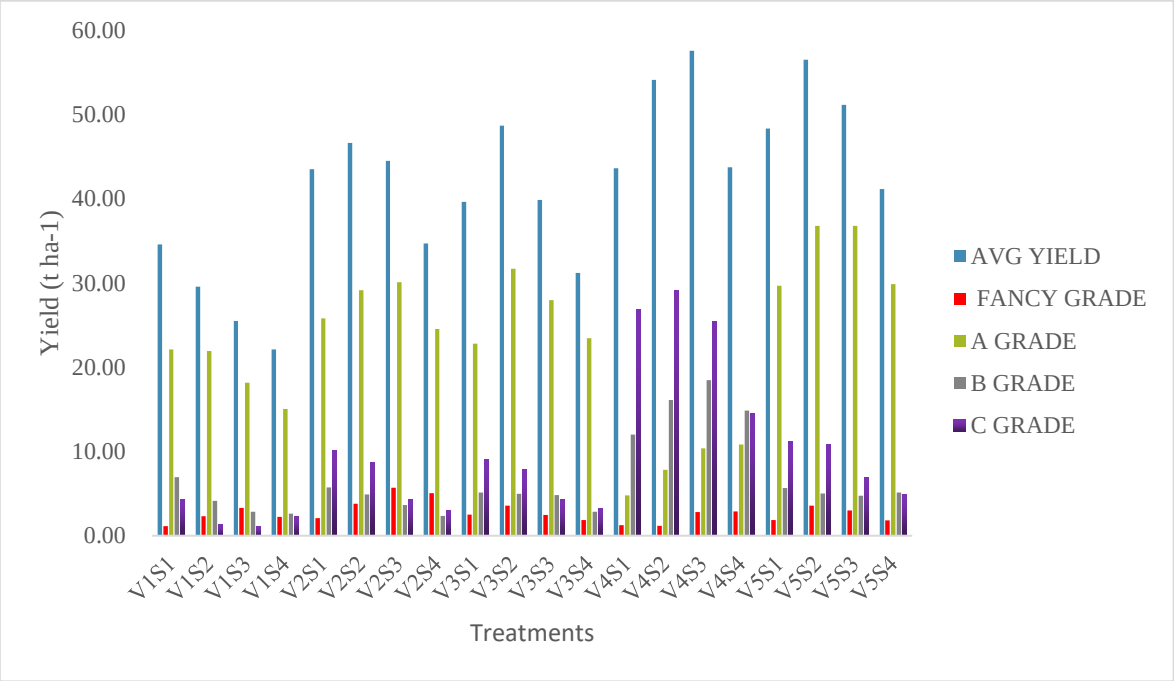


Fig 1: Effect of interaction between variety and summer pruning intensity on crop yield fruit quality.

Apple quality (grades): Apple fruit quality is instrumental in improving the economic value of produce. In Kashmir valley lack of quality apple has been considered a major reason for lower returns. So, any technological intervention impacting fruit quality may prove reasonably beneficial for apple growers. Quality in terms of fruit grading based on standard values was influenced both by the type of cultivar and severity of summer pruning. 'A' grade apple dominated the other grades with higher numerical values irrespective of the cultivar and pruning severity, except for Red Fuji. Since grading is based on size and colour of the fruit, Red Fuji with a lack of round colour under Kulgam conditions was the reason for low fancy and A-grade apple in this variety.

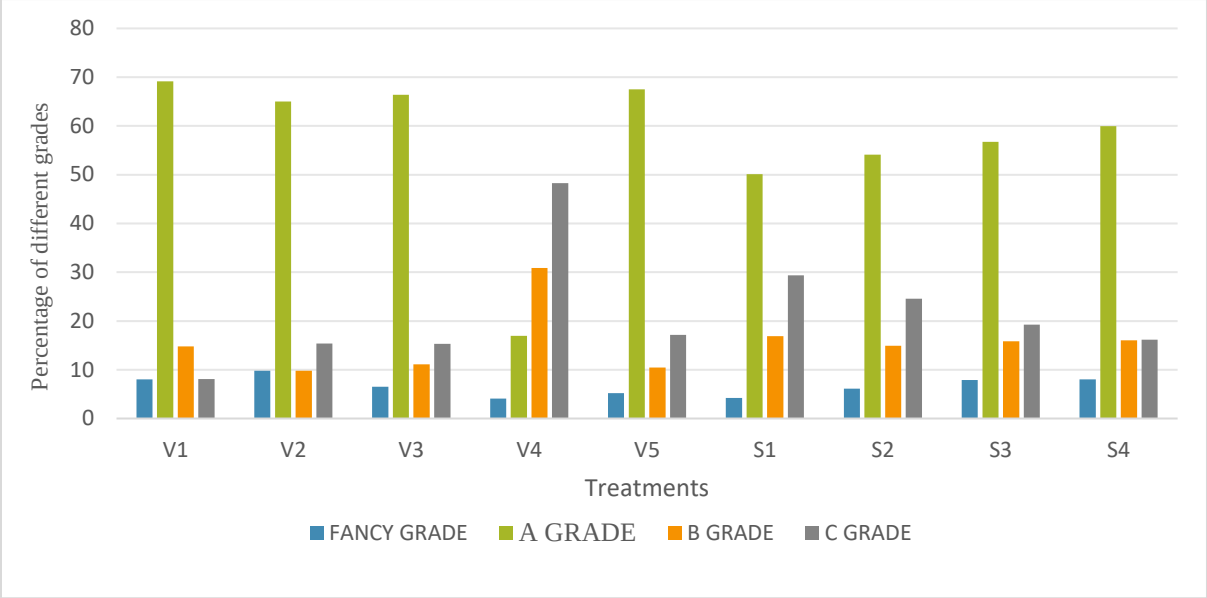
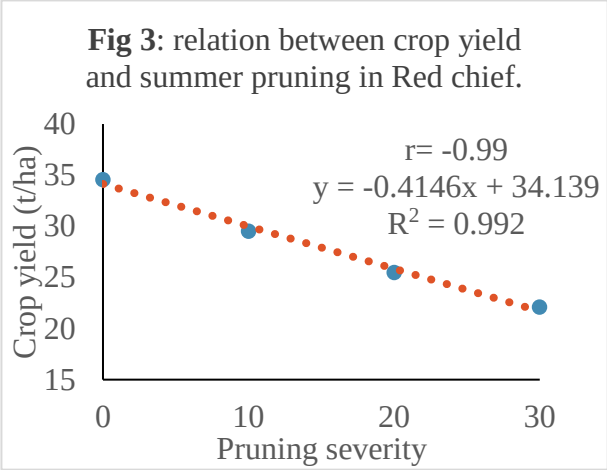
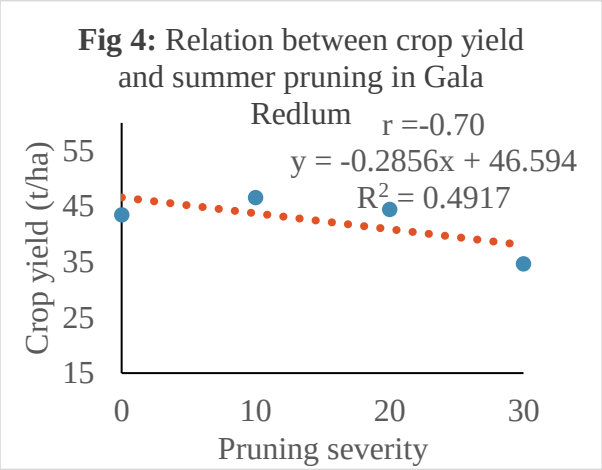
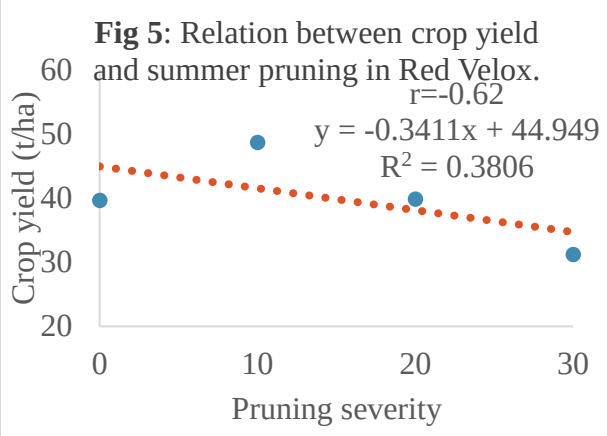


Fig 2: Percentage of different grades of apple as influenced by variety and summer pruning.







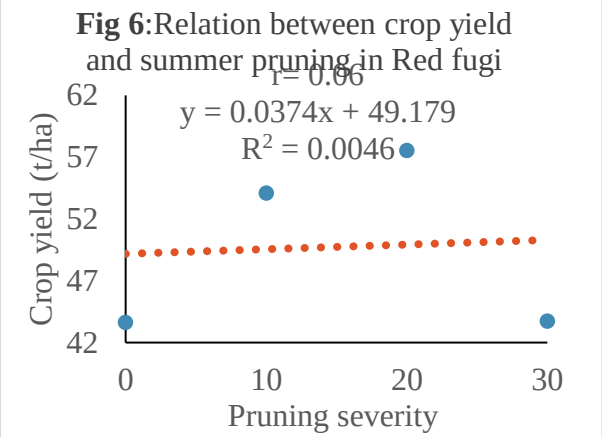


Fig 2 gives an idea about the percentage of different apple grades influenced by variety. It is quite clear that high percentage of 'A' grade was obtained from all varieties excluding Red Fuji where high percentage of apple was of C grade. Fancy grade is considered the top grade of apple and Redlum Gala(V_2) registered significantly higher values for fancy grade apple (4.14 t /ha) in comparison to all other cultivars. Jeromine recorded significantly higher yield of A grade apple (33.27/ ha) in comparison to all varieties, followed by Redlum gala (27.5/ha). Red Fuji registered

significantly higher yields of both 'B' and 'C' grade apple. With regard to the pruning severity prominent impact on 'A' grade apple was recorded with 10% and 20% summer pruning, both being statistically at par but significantly superior than rest of the treatments. 20% summer pruning however registered significantly higher yield of fancy-grade apple compared to other treatments. In the interaction it is evident from Table 2 and Fig that the fancy grade apples yield was highest in case of Redlum gala (V_2) with 10% summer pruning. Whereas, the least fancy grade apple was obtained in Red Fuji under no summer pruning treatment (Control). Irrespective of cultivar summer pruning to the extent of 10% and 20% recorded significant improvement in fancy grade apple and both severe pruning and no pruning had negative interaction effect on all varieties.

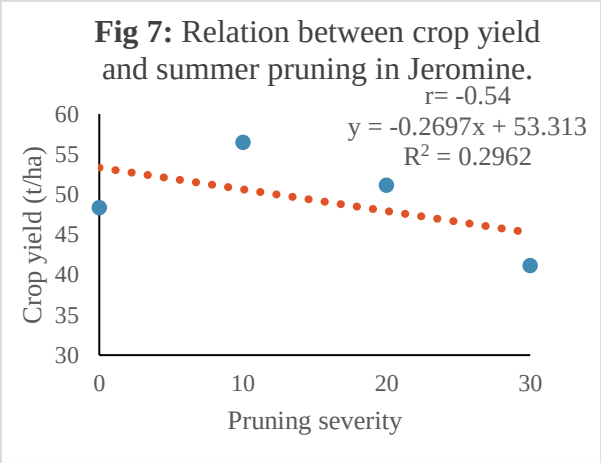


Fig 7: Relation between crop yield and summer pruning in Jeromine.

Varied responses in terms of fancy grade fruit of various cultivars to different severity of summer pruning may be attributed to various factors like genetic makeup of cultivars (Kumar, 2020), prevailing climatic conditions (Singh and Chauhan, 2002), growth pattern (Cooley and Autio, 2011), fruit drop (Sharma *et al*, 2011) and light interception (Wagenmakers and Callesen, 1989; Barritt *et al*, 1991).

From Table 2 and Figure 2, it can be understood that the highest average A-grade apple (36.78 t /ha) were obtained in mild summer pruned (10% summer pruning) Jeromine cultivar which was at par with moderately pruned (20%) Jeromine cultivar. Red Fuji cultivar yielded more quantity of A-grade apple under severe pruning (30%) as compared to other pruning treatments which was in contrast to results obtained on other studied cultivars at sameseverity of summer pruning. Better results in terms of average A-grade apples were obtained in light summer pruning (10%) across cultivars except Red Fuji. This may be attributed to the vigorous growing habit of Red Fuji as compared to other studied cultivars (Lugaresi *et al*, 2022). Better light penetration during the 1st week of August in highly vigorous cultivars like Red Fuji by summer pruning may contribute to more A-grade apples as reported by Ashraf and Ashraf, 2014; Lugaresi *et al*, 2022; Uselis *et al*, 2020 and Fenili *et al*, 2019.

As evident from table -1, Red Fuji yielded highest quantity of B-grade apples in the current system of planting. Severe summer pruning (S_4) in highly vigorous Red Fuji cultivar decreased average B-grade apple from 18.46 t/ha under-recorded under moderate (20%) summer pruning to 14.8 t/ha (Table-2). However, in other cultivars, severe summer pruning decreased B-grade apples more or less in a similar pattern due to their similar growth pattern. The lower yield of B-grade in Red Fuji apples under severe pruning may be attributed to better light penetration.

In general, a higher percentage of C-grade apples was recorded in Red Fuji among the cultivars and under no summer pruning treatment (S1) among the pruning treatments (Fig 2). C-grade apple was comparatively less in all cultivars, excluding Red Fuji. This may be due to better light penetration under the system of planting these varieties and also due to their genetic ability to develop fruit colour and size under optimum conditions (Uselis *et al*, 2020; Fenili *et al*, 2019; Ashraf and Ashraf, 2014).

Economics

Ultimately it is the economics that defines the feasibility of technology for the farming community. Despite the high yields of certain cultivars, they don't need to fetch good returns under specific situations. Red Fuji for instance attained the highest yield in the present study but failed to compete with other cultivars in terms of returns because of high percentage of low-grade apples in this variety. Data regarding the economic viability of various treatment combinations is shown in Table 3. From the data it can be inferred that various varieties responded differently to the summer pruning. Red Chief (V_1) for instance was economically less feasible when intense pruning was done.

Highest net returns (Rs.2136858/ha) in Redlum Gala (V_2) resulted in S_3 (20%). However, Red Velox (V_3) responded better (Rs. 2123825/ha) under mild summer pruning(S_2). Summer pruning proved economically important for Red Fuji which generated net returns of Rs. 1016356 /ha under S3 (Medium pruning) as compared to just Rs.524693/ha in case of no summer pruning (S1). Medium summer pruning may have sufficiently open canopy for better penetration of light in Red Fuji, therefore improving the quality and income from this treatment. Mild summer pruning (S2) proved most profitable practice (2937527 /ha) in Jeromine variety and also in comaprison to all other treatment combinations in the experiment. Variation in terms of economic feasibility of varied summer pruning intensities in different apple cultivars may be due to additional costs of cultivation and market price of produce (Nicholas and Anthony, 2003), consumer preference (Guanxin et al, 2015), Demand (Dong and Li, 2008), Supply (Xiang, 2015), yield (Bhat et al, 2006), type of harvested grade (Uselis *et al*, 2020) and storability/shelf life (Naqash *et al*, 2017).

IV. CONCLUSION

This study revealed that summer pruning is highly beneficial for apple grown particularly under intensive systems of planting. Vigorous growing apple cultivars responded very well in terms of yield and quality improvement and overall economic feasibility to more severe levels of summer pruning when compared to less and moderate growing types. To harness the real value of tall spindle system of apple, needs summer pruning to be followed by apple orchardists. Maintaining the right balance between vegetative and reproductive growth in high-density systems is a tedious job, particularly when the scion cultivar is vigorous and the soils are more fertile. Summer pruning curtailed the growth of more vigorous apple cultivars effectively in tall spindle system thereby increasing light interception and ultimately leading to improved yield, quality, and income.

Table 3: Economics of apple crop as influenced by variety and summer pruning.

Treatments	Costs /ha (Rs)	Gross returns Rs/ha	Net returns Rs/ha	BC ratio
V_1S_1	838550	2155784	1317234	1.57
V_1S_2	765950	2032296	1266347	1.65
V_1S_3	388200	1774711	1386511	3.57
V_1S_4	340450	1475185	1134736	3.33
V_2S_1	652200	2406981	1754782	2.69
V_2S_2	702200	2713673	2011473	2.86
V_2S_3	673250	2810107	2136858	3.17
V_2S_4	529100	2243608	1714509	3.24
V_3S_1	594350	2191169	1596820	2.69
V_3S_2	733000	2856825	2123825	2.90
V_3S_3	603800	2412036	1808237	2.99
V_3S_4	476850	1948749	1471900	3.09
V_4S_1	654300	1178993	524693	0.80
V_4S_2	814400	1608061	793661	0.97
V_4S_3	868900	1885255	1016356	1.17
V_4S_4	664850	1587841	922991	1.39
V_5S_1	724950	3115799	2390850	3.30
V_5S_2	850150	3787677	2937527	3.46
V_5S_3	773100	3606917	2833817	3.67
V_5S_4	625850	2919764	2293914	3.67

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