Effect of fruitlet thinning on apple production and quality under high density plantation

Abstract:

The study entitled "Effect of fruitlet thinning on apple production and quality under high density plantation'' was carried out in the Experimental Block of Division of fruit science at SKUAST-K, Shalimar, on 5-year-old Fuji Zehn Aztecapple plants, trained on tall spindle system spaced at 1×3m during the years 2020 and 2021. The experiment was laid out in Randomized Complete Block Design with 11 treatments (T_0: Control, T_1: Hand thinning @ 2 fruitlets retained per cluster, T_2: Hand thinning @ 3 fruitlets retained per cluster, T_3: NAA @ 15 ppm, T_4: NAA @ 20 ppm, T_5: BA @ 120 ppm, T_6: BA @ 140 ppm, T_7: NAA+BA @ 15ppm+120ppm, T_8: NAA+BA @ 20ppm+120ppm, T_9: NAA+BA @ 15ppm+140ppm and T_{10}: NAA+BA @ 20ppm+140ppm) replicated thrice. Chemical and hand thinning were practised at 12 mm king fruitlet diameter stage. T_9 (NAA+BA@15+140ppm) resulted in maximum trunk girth increment (0.41 cm), annual shoot extension growth (65.46 cm) , leaf area (34.71 cm2), fruit drop (39.26%), minimum per cent reduction in return bloom (52.22%), maximum fruit length (79.98 mm), fruit diameter (89.00 mm), fruit weight (224.90 g), fruit volume (197.86 cm3), Soluble Solid concentration (15.87%), SSC : acidity (40.08), total sugar content (11.07%), anthocyanin content (7.14 mg/100g), ascorbic acid content (6.94 mg/100g), with a highest organoleptic rating score (4.87) whereas the maximum yield (21.97 kg/tree), yield efficiency (1.50 kg/cm2), fruit firmness (8.36 kg/cm2), hue angle (68.57°), acidity (0.59%) were recorded under control. Highest fruit retention (97.97%) and maximum leaf: fruit ratio (27.50) were obtained under T_1 (Hand thinning @ 2 fruitlets retained per cluster).

Key words: Apple, hand thinning, chemicals, yield, quality, return bloom.

Introduction:

Apple is considered the "King of Temperate Fruits," and the productivity in Jammu and Kashmir is estimated to be 11.43 MT/ha, which is the highest among other apple-producing states in the country. However, it is still far below the levels achieved by horticulturally advanced countries.The low productivity of apples in the region is attributed to various factors, including old and senile orchards, low-density plantings, lack of quality planting material, limited irrigation facilities, and a higher incidence of insect pests and diseases. Additionally, biennial bearing of commercial cultivars (bearing fruit every other year) contributes to economic losses.

Thinning in apple cultivation is a horticultural practice used to regulate fruit set and achieve optimal fruit quality and yield. The process involves removing some of the developing fruits from the apple tree to reduce competition for resources and improve the overall health of the tree and the remaining fruits.

The use of chemical thinners, specifically 1-Napthaleneacetic acid (NAA) and synthetic cytokinin 6-Benzyladenine has been found to be effective in reducing fruit set, increasing average fruit weight, and providing good yield potential for the following season.

NAA when applied as a thinner, stimulates the synthesis of ethylene in the fruitlet tissue(Dennis, 2000). The increase in ethylene production triggers the process of fruit abscission, leading to the detachment of some of the developing fruits from the tree. As a result, excess fruits are shed from the tree, reducing the overall fruit load. Also, NAA affects the hormonal balance within the fruit. It reduces the synthesis of the hormone auxin in the fruit. By limiting auxin synthesis, NAA restricts seed development in the fruit and the subsequent carbohydrate demand. This, in turn, leads to fruit abortion, where some of the developing fruits fail to develop fully and are eventually shed from the tree(Kolaric, 2010).

One of the key effects of 6-BA is the stimulation of shoot growth in the apple tree. As the shoots grow, they compete for resources, including carbohydrates, within the tree.The increased shoot growth leads to greater competition for carbohydrates between shoots and developing fruits. This competition for carbohydrates can limit the energy and nutrients available to support all the developing fruits on the tree. As a result of the increased competition for carbohydrates, some of the developing fruits are naturally shed from the tree through the process of fruit abscission(Allen *et al.*, 2019). This thinning process reduces the overall fruit load, allowing the remaining fruits to receive more resources and nutrients.

Achieving consistency in yield and regular bearing year after year by practising thinning is crucial for successful apple production. Fuji apple trees are known to exhibit a moderate to strong alternate bearing habit. Alternate bearing, also known as biennial bearing, is the tendency of certain fruit trees, including apple trees, to produce a heavy crop of fruits in one year (the "on" year) and a lighter crop or no crop at all in the following year (the "off" year). This cycle repeats, with alternating years of heavy and light fruit production.

Hence, the aim of the study was focussed at overcoming the effect of crop load on Fuji Zhen Aztec with the help of thinning to optimise the crop load, enhance the fruit quality and return bloom.

Materials and methodology:

The experimental farm of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar campus, Srinagar, Jammu & Kashmir was selected for conducting the study during the years 2020 and 2021.

In order to assess the effect of thinning on the qualitative and the quantitative traits of apple cultivar Fuji Zehn Aztec, plants of uniform girth were taken into consideration.The experiment was conducted in a Randomised Complete Block Design with three replications. The treatments included:T_0 -Control, T_1-Hand thinning @ 2 fruitlets/ cluster, T_2-Hand thinning @ 3 fruitlets/ cluster, T_3 -Napthalene acetic acid @ 15 ppm, T_4-Napthalene acetic acid @ 20 ppm, T_5-Benzyl adenine @ 120 ppm, T_6-Benzyl adenine @ 140 ppm, T_7-Naphthalene acetic acid + Benzyl adenine @ 15 + 120 ppm, T_8-Naphthalene acetic acid + Benzyl adenine @ 20 + 120 ppm, T_9-Naphthalene acetic acid + Benzyl adenine @ 15 + 140 ppm, T_{10}-Naphthalene acetic acid + Benzyl adenine @ 20 + 140 ppm. The plants were raised on M9-T337 and trained on Tall Spindle system with a spacing of 1 × 3m. The plants were thinned 20 Days after full bloom (at 10-12mm fruitlet diameter stage) on May 5, 2020.Four branches of uniform girth were selected from each tree for recording different observations.

Results and Discussion:

Thinning significantly affected the growth, phenology, yield and quality attributesin Fuji Zehn Aztec plants.

1. **Vegetative growth:**

The maximum increment in plant girth (0.41 cm),annual shoot extension growth (65.46 cm) and leaf area (34.71 cm^2) were observed under treatment T_9 (NAA+BA @ 15+140 ppm)while the minimum increment in plant girth (0.18 cm), annual shoot extension growth (57.19 cm) and leaf area (26.20 cm^2) were recorded under treatment T_0 (control).However, all the other treatments were significantly superior over control. The highest vegetative growth in such treatment may be credited to the increased supply of photosynthetic assimilates and nutrients which consecutively enhances the cell division and plasticity of cell wall. Similar results have also been reported by Cripps (1981) who observed reduction in the vegetative growth of apple with increment in crop load due to increased competition between reproductive and vegetative growth. Anthony *et al.* (2019) too found that apple trees with lowest crop load contained significantly higher vegetative growth as compared to trees with heavier crop loads.

Table 1:Effect of different thinning treatments on increment in plant girth (cm), annual shoot extension growth(cm) and leaf area (cm^2) ofFuji Zehn Aztec.

Treatment code	Treatment	Increment in plant girth (cm)	Annual shoot extension (cm)	Leaf area (cm^2)
T_0	Control	0.18	57.19	26.20
T_1	Hand thinning @ 2 fruitlets/cluster	0.29	62.25	30.34
T_2	Hand thinning @ 3 fruitlets/cluster	0.27	61.78	28.80
T_3	NAA @ 15 ppm	0.31	62.52	31.24
T_4	NAA @ 20 ppm	0.32	63.25	31.69
T_5	BA @ 120 ppm	0.23	59.14	27.24
T_6	BA @ 140 ppm	0.25	59.44	27.60
T_7	NAA + BA @ 15 + 120 ppm	0.38	64.28	33.68
T_8	NAA + BA @ 20 + 120 ppm	0.37	64.16	33.36
T_9	NAA + BA @ 15 + 140 ppm	0.41	65.46	34.71
T_{10}	NAA + BA @ 20 + 140 ppm	0.34	63.34	32.26
	C.D ($p \leq 0.05$)	**0.026**	**0.016**	**0.030**

2. **Phenology:**

The highest fruit retention (97.97%) was recorded under treatment T_1 (Hand thinning @ 2 fruitlets/cluster)while the least (60.74%) was observed in treatment T_9 (NAA+BA @ 15+140 ppm). The maximum fruit drop (39.26%) was recorded under treatment T_9 (NAA+BA @ 15+140 ppm) while the minimum fruit drop (2.03%) was observed in treatment T_1 (Hand thinning @ 2 fruitlets/cluster).This might be due to the fact that final fruit retention depends on the thinning frequency. Higher the thinning frequency lesser is the percentage of final fruit retention. Moreover, fruit drop has a negative interaction with final fruit retention. Similar results have been obtained by Bhatt (2017) in plum cv. “Kala Amritsari”. In hand thinning quite less number of fruits abscised. This might be due to reduced competition among the fruitlets at the earliest stage (Theron *et al.*, 2002).

Return bloom was significantly affected by the different thinning treatments such that the minimum per cent reduction in bloom density (52.22%) was observed under treatment T_9 (NAA+BA @ 15+140 ppm)and the maximumper cent reduction of bloom density (86.29%) was recorded under treatment T_0 (control). These results are in congruence with the results of

Embree *et al*. (2007) who reported that with the decrease in the crop load in “on” year, number of blossom clusters is promoted in the “off” year. It might be due to the reason that in control, heavy crop load acts as a drain for all the available nutrients which inhibits the flower bud formation. Also, Neilsen and Dennis (2000) reported inhibition in flower formation for the next season due to the production and translocation of high amount of Gibberlins from apple seeds.

Table 2:Effect of different thinning treatments on fruit retention(%), fruit drop (%) and return bloom (%)in Fuji Zehn Aztec.

Treatment code	Treatment	Fruit retention (%)	Fruit drop (%)	Return bloom (%)
T_0	Control	76.00 (8.777)	24.00 (4.997)	86.29
T_1	Hand thinning @ 2 fruitlets/cluster	97.97 (9.948)	2.03 (1.741)	72.78
T_2	Hand thinning @ 3 fruitlets/cluster	94.51 (9.773)	5.49 (2.548)	75.34
T_3	NAA @ 15 ppm	68.72 (8.350)	31.28 (5.682)	68.23
T_4	NAA @ 20 ppm	67.81 (8.295)	32.19 (5.761)	63.11
T_5	BA @ 120 ppm	71.46 (8.512)	28.54 (5.435)	81.54
T_6	BA @ 140 ppm	70.82 (8.475)	29.18 (5.494)	78.67
T_7	NAA + BA @ 15 + 120 ppm	62.51 (7.969)	37.49 (6.204)	55.29
T_8	NAA + BA @ 20 + 120 ppm	63.38 (8.024)	36.62 (6.134)	57.23
T_9	NAA + BA @ 15 + 140 ppm	60.74 (7.857)	39.26 (6.345)	52.22
T_{10}	NAA + BA @ 20 + 140 ppm	65.77 (8.171)	34.23 (5.935)	59.78
	C.D ($p \leq 0.05$)	**0.002**	**0.003**	**0.253**

*Values within parenthesis are square root transformed values and the C.D. values have been obtained by square root transformation.

3. Yield attributes:

Different thinning treatments had a significant reduction in fruit yield and yield efficiency as compared to control. The highest fruit yield(21.97 kg/tree) and highest yield efficiency (1.50 kg cm^{-2}) were observed under the treatment T_0 (control) while the lowest fruit yield (19.42 kg/tree) and yield efficiency (0.96 kg cm^{-2}) were recorded in treatment T_9 (NAA+BA @ 15+140 ppm). All the other treatments were significantly less than control.This might be attributed to the fruitlet abscission resulted from NAA and BA application and since yield is primarily a function of fruit number (Forshey and Elfving, 1977). Our results are in line with the findings of Clever (2007) who found a significant reduction in the yield of apple cv. "Elstar Elshof" with the spray of NAA 10 ppm + BA 100 ppm. Koike and Ono (1998) also reported a decrease in yield by thinning.

Table 3:Effect of different thinning treatments on fruit yield (kg/tree) and yield efficiency (kg/cm^2)in Fuji Zehn Aztec.

Treatment code	Treatment	Yield (kg/tree)	Yield efficiency (kg/cm^2)
T_0	Control	21.97	1.50
T_1	Hand thinning @ 2 fruitlets/cluster	20.35	1.29
T_2	Hand thinning @ 3 fruitlets/cluster	20.50	1.41
T_3	NAA @ 15 ppm	20.00	1.20
T_4	NAA @ 20 ppm	19.98	1.15
T_5	BA @ 120 ppm	21.14	1.45
T_6	BA @ 140 ppm	20.90	1.42
T_7	NAA + BA @ 15 + 120 ppm	19.51	1.07
T_8	NAA + BA @ 20 + 120 ppm	19.63	1.08
T_9	NAA + BA @ 15 + 140 ppm	19.42	0.96
T_{10}	NAA + BA @ 20 + 140 ppm	19.81	1.14
	C.D ($p \leq 0.05$)	**0.029**	**0.046**

4. Physico-chemical parameters:

The maximum fruit length (79.98 mm), fruit breadth (89.00 mm), length: breadth ratio (0.90), fruit weight (224.90 g),fruit volume (197.86 cm^3) and specific gravity (1.13 g/cm^3) were registered under treatment T_9 (NAA+BA @ 15+140 ppm) while the minimum fruit length (70.52 mm), fruit breadth (81.12 mm) and length: breadth ratio (0.87), fruit weight (188.35 g),fruit volume (187.50 cm^3) and specific gravity (1.00 g/cm^3) were observed under treatment T_0 (control).Such increase is due to the reduction in the fruitlet competition which is due to the earlier abscission caused by greater thinning action of NAA and BA. Thus, there is a significant increase in the nutrient supply during early fruit development stage due to increased rate of photosynthesis because of the reduction in crop load, greater leaf to fruit ratio, higher availability and supply of photosynthates to the remaining fruitets (Williams and Edgerton, 1981). The results are in accordance with the findings of Radivojevic*et al*. (2014) who found that fruit size was significantly affected by crop load in apple cv. "Braeburn".

Maximum leaf: fruit ratio (27.50) was documented under treatment T_1 (Hand thinning @ 2 fruitlets/cluster) and minimum leaf: fruit ratio (11.00) was recorded in treatment T_0 (control). The increment in Leaf: fruit ratio was due to the selective manual thinning which resulted in the reduction of the crop load. Similar results have also been reported by Anthony *et al.* (2019) who observed that with increase in the level of hand thinning, L:F also increased in apple cv. "WA38".

Maximum fruit firmness (8.36 kg/cm^2) and hue angle (68.57°) were noticed under treatment T_0 (control) while the least fruit firmness (6.14 kg/cm^2) and hue angle (57.22°) were observed under treatment T_9 (NAA+BA @ 15+140 ppm).Larger fruit tend to have softer flesh probably due to larger cell size (Greene *et al.*, 1990). The reduction in fruit firmness might be due to the larger fruit size which decreases the strength of cell wall and creates lesser cohesion between the cells (Deshmukh *et al.*, 2012). These results are also in line with the finding of Link (2000) who reported that only fruit well supplied with carbohydrates attain good flavour and color and fruit thinning increase the extent and intensity of surface color in red fruit cultivars. Basak (2006) observed that on thinning apple trees with NAA, fruit color improved in apple cultivar Gala.

Table 4a:Effect of different thinning treatments on fruit length(mm), fruit breadth(mm), length: breadth,fruit weight(g), fruit volume (g/cm^3), leaf : fruit, fruit firmness (kg/cm^2) and fruit colour {hue angle(º)} in Fuji Zehn Aztec.

Treatment code	Treatment	Fruit length (mm)	Fruit breadth (mm)	Length: breadth	Fruit weight (g)	Fruit volume (cm^3)	Specific gravity (g/cm^3)	Leaf: fruit	Fruit firmness (kg/cm^2)	Fruit colour [Hue angle (º)]
T_0	Control	70.52	81.12	0.87	188.35	187.50	1.00	11.00	8.36	68.57
T_1	Hand thinning @ 2 fruitlets/cluster	75.85	86.14	0.88	205.07	192.13	1.06	27.50	7.25	61.51
T_2	Hand thinning @ 3 fruitlets/cluster	73.91	84.39	0.87	201.00	191.77	1.04	18.30	7.34	64.28
T_3	NAA @ 15 ppm	76.98	87.27	0.88	210.34	194.39	1.08	16.00	7.12	61.13
T_4	NAA @ 20 ppm	77.47	87.66	0.88	217.53	195.95	1.11	16.22	6.86	61.08
T_5	BA @ 120 ppm	72.58	83.37	0.87	192.83	188.62	1.02	15.39	7.64	65.71
T_6	BA @ 140 ppm	72.91	83.60	0.88	195.28	189.98	1.02	15.40	7.57	65.35
T_7	NAA + BA @ 15 + 120 ppm	78.80	88.80	0.89	221.22	196.25	1.12	17.59	6.67	59.22
T_8	NAA + BA @ 20 + 120 ppm	78.18	88.25	0.89	221.16	196.22	1.12	17.35	6.70	59.28
T_9	NAA + BA @ 15 + 140 ppm	79.98	89.00	0.90	224.90	197.86	1.13	18.11	6.14	57.22
T_{10}	NAA + BA @ 20 + 140 ppm	77.98	88.12	0.88	219.02	196.11	1.11	16.72	6.85	60.54
	C.D ($p \leq 0.05$)	**0.056**	**0.096**	**0.001**	**0.080**	**0.123**	**0.002**	**0.019**	**0.028**	**0.071**

Maximum SSC (15.87%),SSC/acidity ratio (40.08),total sugar content (11.07%),anthocyanin content (7.14 mg/100g),ascorbic acid content (6.94 mg/100g) and organoleptic rating (4.87 pts) wereachieved under treatment T_9(NAA+BA @ 15+140 ppm)and the minimum SSC (14.21%),SSC/ acid ratio (24.08), total sugars content (9.02%),anthocyanin content (5.17 mg/100g), ascorbic acid content (4.12 mg/100g) and organoleptic rating were attainedin (3.02 pts) treatment T_0 (control). Similar results have also been reported by Rettke and Dahlenburg (1999) in apricot. Mpelasoka*et al*. (2001) also reported an increase in the total soluble solids and total sugars with decrease in the crop load of apple cv. “Braeburn”. Such increase in total soluble solids and total sugars is due to reduced crop load, the subsequent leaf to fruit ratio is increased which results in increased synthesis, transport and accumulation of sugars in the remaining fruits, hence enhanced total soluble solids and sugars is observed. Increase in SSC: acidity ratio may be due to increase in SSC and decrease in acidity. Our results are in accordance with the findings of Samra and Shalan (2014). These results are also in agreement with the finding of Rupasinghe *et al*. (2010) who reported that sugar accumulation in apples is highly required for anthocyanin synthesis as UDP-glycosides are direct substrates for cyaniding 3-glycosides, which are pigments in apple peel and flesh. Increase in ascorbic acid might be due to the lower rate of conversion of ascorbic acid to dehydro-ascorbic acid and also due to increased SSC. Increase in ascorbic acid was observed by Meitei *et al.* (2013) by use of chemical thinners on Peach cultivar Flordasun. Our findings are also in harmony with the results Naor *et al.* (2002) who found that with increase in crop load, the overall sensory evaluation quality shows a decrease in Sauvignon blanc grape.

But, the highest titratable acidity (0.59%) was recorded under treatment T_0 (control) and the least titratable acidity (0.40%) was noticed under treatment T_9(NAA+BA @ 15+140 ppm). . Reduction in acidity under chemical thinning treatments might be due to conversion of organic acids into sugar and due to the dilution effect as a result of increased fruit size which results in changes in the quality attributes. These results are in agreement with Roussos *et al.* (2011) who reported a similar decrease in the titrable acidity in apricot.

Table 4b:Effect of different thinning treatments on SSC(%), fruit acidity(%), SSC:acidity, Total sugars (%), Anthocyanin content (mg/100g pulp), ascorbic acid content (mg/100g pulp)and organoleptic rating in Fuji Zehn Aztec.

Treatment code	Treatment	SSC (%)	Fruit acidity (%)	SSC: acidity	Total sugars (%)	Anthocyanin content (mg/100g pulp)	Ascorbic acid content (mg/100g pulp)	Organoleptic rating
T_0	Control	14.21	0.59	24.08	9.02	5.17	4.12	3.02
T_1	Hand thinning @ 2 fruitlets/cluster	14.78	0.55	26.89	10.19	6.34	5.41	3.45
T_2	Hand thinning @ 3 fruitlets/cluster	14.62	0.55	26.67	9.81	5.70	5.06	3.34
T_3	NAA @ 15 ppm	14.85	0.54	27.50	10.25	6.38	5.81	3.56
T_4	NAA @ 20 ppm	14.92	0.53	28.31	10.36	6.45	6.06	3.64
T_5	BA @ 120 ppm	14.45	0.57	25.39	9.24	5.24	4.73	3.19
T_6	BA @ 140 ppm	14.51	0.56	25.93	9.33	5.25	4.92	3.32
T_7	NAA + BA @ 15 + 120 ppm	15.43	0.45	34.38	10.56	6.63	6.57	4.16
T_8	NAA + BA @ 20 + 120 ppm	15.22	0.47	32.54	10.56	6.62	6.46	4.14
T_9	NAA + BA @ 15 + 140 ppm	15.87	0.40	40.08	11.07	7.14	6.94	4.87
T_{10}	NAA + BA @ 20 + 140 ppm	15.06	0.49	30.74	10.42	6.49	6.24	4.09
	C.D ($p \leq 0.05$)	**0.026**	**0.026**	**2.316**	**0.030**	**0.024**	**0.060**	**0.057**

Conclusion:

It is concluded from the study that T_9 (NAA+BA@15+140ppm) sprayed twenty days after full bloom maintained crop load to an optimum leveland was effective in attaining better quality and also enhanced the return bloom in Fuji Zehn Aztec.

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