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Changes in fruit quality parameters in Japanese plum CV. Kala Amritsari with chemical flower thinning

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Abstract
The excessive flowering and fruiting leads to production of poor quality fruits in Japanese plum cv. Kala Amritsari. The crop load needs to be managed in such a way that without reducing yield, proper fruit size and quality is maintained. There are various approaches for reducing final number of fruits per tree *viz.* inhibition of fruit bud differentiation, fruitlet thinning and blossom thinning. The flower thinning chemicals (urea4% & 6%; Ammonium Thiosulphate 2% & 4%; NAA 20 ppm & 40 ppm) were applied as foliar spray at full bloom stage to reduced number of fruits and corresponding improvement in fruit quality. The fruit weight (16.61g, 14.96g) and TSS (13.80 ºBrix, 13.90 ºBrix) were recorded maximum with the application of ATS (4%) followed by ATS (2%). The quality parameters were minimum in control fruits when compared with fruits from flower thinned trees.

Keywords: kala amritsari, blossom thinning, ammonium thiosulphate, differentiation

Introduction

Japanese plum trees commonly produce an excessive number of flowers and thinning of this crop load becomes necessary to set an acceptable yield of properly sized fruits and to maximize returns. Thinning is also necessary to balance tree growth and cropping. The thinning chemicals are used primarily to reduce labour cost of hand thinning and to save time. Also bloom thinners offer the advantage of diverting photosynthates to fewer sinks and subsequently, increased fruit size (Coneva and Cline, 2006) [7]. Since many years, surfactants, fertilizers, plant growth regulators, desiccants, long-chain fatty acids and oils are being used for thinning flowers in temperate fruit crops (Byers *et al*., 2013) [5]. The performance of the blossom thinners are likely to vary by cultivar and time of application.

The thinning trails were conducted by Milic *et al*. (2011) on apple cv. Braeburn trees using ammonium thiosulfate @ 1, 2 and 3%, and potassium thiosulfate @ 0.5, 1 and 1.5% during 20% and 80% bloom. Flower thinning with ammonium and potassium thiosulfate increased the average fruit weight, but the highest chemical rates retarded fruit growth. They suggested that ATS application may be recommended as the first step in a chemical thinning program.

El-Boray *et al*. (2012) [10] reported ATS (1.5%) sprayed during full bloom on peach cv. Floridaprince as most promising bloom thinner as it reduced fruit set percentage (55.05 and 58.07% during both seasons, respectively) without harming the yield. The highest leaf area was detected at high rate of ATS (3%) followed by low rate (ATS 1.5%). Fruit quality was also found to be increased with ATS treatments and hand thinning.

The effect of different blossom thinners ammonium thiosulfate (ATS) (1%, 2%), Armothin (1.5%), Tergitol-TMN-6 (0.5%, 1%), applied on peach cv. Redhaven at 50–60% full bloom was evaluated in thinning experiments. Application of 2% ATS resulted in excessive thinning. The thinning effect of 1% ATS was also too strong in two out of three thinning experiments. (Ambrozic *et al*., 2014) [1]. Chanana *et al*. (2002) [6] applied urea (12%), ATS (6%) and dormex (0.5%) to peach cv. Pratap at full bloom stage. As a result of thinning, the fruit maturity was advanced by 4-7 days and there was an increase in fruit size and fruit quality as compared to unthinned fruits.

Therefore, in consideration with the above study, the present investigation was planned on plum cv. Kala Amritsari to demonstrate the changes in fruit size, yield and quality parameters as a result of chemical thinning using varying concentrations of ATS, urea and NAA in order to find an alternative of hand thinning.

Material and Methods

The study was carried out at the experimental farms of Department of Horticulture, CCS Haryana Agricultural University, Hisar on trees of Japanese plum cv.

Kala Amritsari for two continuous seasons during 2014-16. The trees were tagged or earmarked according to randomized block design in replicates and flower thinning chemicals were foliar sprayed at full bloom stage during the year 2015 and 2016. The treatments applied were:
Treatment 1- Urea (4%)
Treatment 2- Urea (6%)
Treatment 3- Ammonium Thiosulphate (2%)
Treatment 4- Ammonium Thiosulphate (4%)
Treatment 5- NAA (20 ppm)
Treatment 6- NAA (40 ppm)
Treatment 7- Water spray
Treatment 8- Control (no spray)

Normal package of practices recommended for the region were followed for proper up-keep of orchard. The data was collected for various biochemical changes in fruits for both years of trial in departmental laboratory after harvesting. The fruits were harvested from all four directions in each replication and ten fruits per replication were weighed to calculate average fruit weight. The fruit firmness (kg/cm^2) of randomly selected fruits was determined by a pressure tester (Digital fruit tester) which recorded the pressure necessary for the plunger to penetrate the flesh of fruits. Among biochemical parameters, total soluble solids of fresh fruits were determined at room temperature using Digital Refractometer (scale: 0- 58ºBrix) by putting a drop of juice on the screen and recording the readings. The Refractrometer was calibrated with distilled water with every use. Titratable acidity, ascorbic acid and total anthocyanin content were estimated by methods of AOAC (2000) [2]. TSS/acid ratio was calculated by dividing the average value of total soluble solids with the average value of titratable acidity. Total phenols (Swain and Hills, 1959) [20], total carotenoids (Rodriguez-Amaya, 1999) [18] and sugars (Hulme and Narain, 1931) [12] were estimated by using popular methods as suggested for other fruit crops.

Fig 1: Foliar application of flower thinning chemicals

Results and Discussion

In the present investigation, it was observed that flower thinning using foliar application of chemicals improved fruit size and quality over control trees, though the total fruit yield reduced in flower thinned treatments as a result of decrease in fruit set. The fresh fruit weight was positively influenced with the application of blossom thinners. Significant increase in fruit weight (16.61 g in year 2015 and 14.96 g in year 2016) was recorded with ATS 4% which was statistically at par with ATS 2% in both the years. Water spray treatment failed to increase fruit weight, significantly during both seasons (Table 1). The differences in fruit weight increased by two concentrations of same chemical were found to be non-significant, although each chemical enhanced fruit weight, significantly from each other.

Table 1: Effect of chemical flower thinning on fresh fruit weight and total yield in Japanese plum cv. Kala Amritsari

Treatments	Fresh fruit weight (g)		Total yield (kg/tree)	
	2015	2016	2015	2016
Urea 4%	12.72	11.05	51.42	48.58
Urea 6%	13.27	11.90	49.01	45.06
ATS 2%	16.02	13.24	43.52	39.45
ATS 4%	16.61	14.96	41.50	37.13
NAA 20 ppm	14.05	12.59	47.10	44.35
NAA 40 ppm	15.64	12.96	46.34	42.40
Water spray	9.67	9.47	52.30	48.90
Control	9.55	9.30	52.99	49.87
C.D. at 5%	0.88	0.73	2.00	1.60

As a result of chemical blossom thinning agents, total yield of trees under treatment was observed to be decreased as compared to untreated control (Table 1). It was maximum in control (52.99 kg/tree and 49.87 kg/tree) where no thinning was performed in both years, whereas, total yield gradually decreased with ATS treatments (2% and 4%) followed by NAA treatments (20 ppm and 40 ppm). Significant reductions in yield were found up to 41.50 kg/tree in year 2015 and 37.13 kg/tree in year 2016. Total yield of trees reduced during the year 2016.

Table 2: Effect of chemical flower thinning on total soluble solids, titratable acidity and TSS/acid ratio in Japanese plum cv. Kala Amritsari

Treatments	Total soluble solids (ºBrix)		Titratable acidity (%)		TSS/acid ratio	
	2015	2016	2015	2016	2015	2016
Urea 4%	11.58	11.28	1.81	1.89	6.40	5.97
Urea 6%	11.90	11.82	1.79	1.87	6.65	6.32
ATS 2%	13.58	13.50	1.55	1.74	8.76	7.76
ATS 4%	13.80	13.90	1.46	1.71	9.45	8.13
NAA 20 ppm	12.48	12.10	1.73	1.84	7.21	6.58
NAA 40 ppm	12.93	12.53	1.71	1.82	7.56	6.81
Water spray	10.58	9.63	1.86	1.94	5.69	4.96
Control	10.38	9.15	1.91	1.98	5.43	4.62
C.D. at 5%	0.40	0.28	0.07	0.04	0.82	1.06

Higher total soluble solids (TSS) were observed with chemical flower thinning treatments (Table 2). TSS value varied from 10.38 ºBrix (control) to 13.80 ºBrix (ATS 4%) in the year 2015 and from 9.15 ºBrix to 13.90 ºBrix (ATS 4%) in the year 2016. The increase in TSS was significant over control in both years. The results depict a decreasing trend in titratable acidity of fruits as a result of flower thinning. Titratable acidity reduced to minimum (1.46% and 1.71%) with the application of ATS 4% followed by ATS 2% (1.55% and 1.74%) in the years 2015 and 2016, respectively. All the treatments reduced titratable acidity, significantly as compared to control (1.91% and 1.98%), but among treatments of chemical thinning, changes in acidity per cent were non-significant. Seehuber *et al.* (2011) [19] also reported higher TSS values as a result of chemical flower thinning in temperate fruit trees.
Results show that TSS/acid ratio was influenced by chemical blossom thinning and the ratio improved (Table 2),

significantly from 5.43 to 9.45 and 4.62 to 8.13 with ATS 4% application in year 2015 and 2016, respectively. All treatments of thinning resulted in higher TSS/acid ratio as compared to control. In both years of experiment, lower and higher concentrations of chemicals did not differ, significantly. In comparison with the first year, fruits harvested during second year showed low TSS/acid ratio.

Chemical blossom thinning influenced total anthocyanin content of fruits, significantly (Table 3). Total anthocyanin content ranged from 15.53 mg/100 g to 18.28 mg/100 g (ATS 4%) in first season (year 2015) and from 14.88 mg/100 g to 17.62 mg/100 g (ATS 4%) in second season (year 2016). However, total anthocyanin content did not vary significantly among the higher and lower concentrations of same chemical (NAA and urea). Although, higher concentration lead to higher mean values of anthocyanin content, comparatively in both years.

Table 3: Effect of chemical flower thinning on total anthocyanin, β-carotene and phenol content in Japanese plum cv. Kala Amritsari

Treatments	Total anthocyanin content (mg/100 g)		β-carotene content (µg/100 g)		Phenol content (mg/100 g)	
	2015	2016	2015	2016	2015	2016
Urea 4%	16.04	15.86	10.82	11.35	82.06	81.97
Urea 6%	16.15	15.98	11.05	11.55	83.73	82.33
ATS 2%	17.86	17.06	11.80	12.36	82.70	82.26
ATS 4%	18.28	17.62	11.89	12.60	82.79	82.59
NAA 20 ppm	16.79	16.18	11.38	11.77	81.85	81.40
NAA 40 ppm	16.96	16.31	11.53	11.84	81.02	80.83
Water spray	15.89	15.12	10.33	10.74	80.51	80.07
Control	15.53	14.88	10.16	10.43	80.23	89.86
C.D. at 5%	0.20	0.21	NS	0.54	0.37	0.41

β-carotene content was observed to have a non-significant increase during the year 2015 by blossom thinning treatments, whereas, during the year 2016, β-carotene content was significantly increased from 10.43 µg/100 g to 12.60 µg/100 g with ATS 4% treatment followed by ATS 2% and NAA treatments (20 & 40 ppm). Comparatively, higher amount of β-carotene content was recorded in the fruit harvested during second season.

It is evident from the results obtained (Table 3) that phenol content was significantly increased as a result of chemical blossom thinning. Among different treatments, ATS 4% increased phenol content in fruits up to 82.79 mg/100 g and 82.59 mg/100 g in year 2015 and 2016, respectively which was statistically at par with treatment of ATS 2%. Minimum phenol content was recorded in control followed by trees sprayed with water at full bloom. Phenol content in fruits harvested in both the years did not differ, largely.

A significant effect on fruit firmness was evident as a result of chemical blossom thinning. Reduction in flower number with chemicals had lead to a decrease in fruit firmness. Fruits from tree thinned with ATS 4% were less firm (2.40 kg/cm^2 and 2.81 kg/cm^2) followed by ATS 2%. Fruit firmness increased in treatments of urea and NAA and was found maximum in control (3.45 kg/cm^2 and 3.96 kg/cm^2) in both the years (Table 4). However, different concentrations of same chemical were not significant from each other. Firmer fruits were harvested in the second season of investigation.

Table 4: Effect of chemical flower thinning on fruit firmness, ascorbic acid and overall acceptability in Japanese plum cv. Kala Amritsari

Treatments	Fruit firmness (kg/cm^2)		Ascorbic acid (mg/100 g)	
	2015	2016	2015	2016
Urea 4%	2.81	3.80	10.89	10.48
Urea 6%	3.09	3.79	10.74	10.40
ATS 2%	2.71	3.53	11.23	10.46
ATS 4%	2.40	2.81	11.69	10.97
NAA 20 ppm	2.48	3.30	10.54	9.71
NAA 40 ppm	2.49	3.03	10.69	9.68
Water spray	3.37	3.92	9.42	7.90
Control	3.45	3.96	8.85	7.70
C.D. at 5%	0.16	0.23	0.35	0.46

Slight but significant changes in ascorbic acid content were recorded in fruits harvested from blossom thinned trees. Control showed minimum ascorbic acid content (8.85 mg/100 g and 7.70 mg/100 g) whereas ATS 4% treated trees were recorded to have maximum ascorbic acid content (11.69 mg/100 g and 10.97 mg/100 g) in the year 2015 and 2016. However, among different treatments non-significant differences were found. Minor decrease in ascorbic acid was observed in fruits harvested during year 2016.

Discussion

Since 1980's, various surfactants, fertilizers, desiccants, long chain fatty acids and oils were investigated for potential flower-thinning compounds in stone fruits (Coneva and Cline, 2006) [7]. Being an agricultural fertilizer, use of ATS as a thinning compound may be easier to justify commercially. Most effective timing for ATS is when 70-90% of the flowers had opened. Thinning results obtained by Greene *et al*. (2001) on cvs. Garnet Beauty and Redhaven showed that the use of ammonium thiosulfate (1.9–2.5%) effectively reduce fruit set and number of fruits per tree which in turn improve fruit quality.

Chanana *et al*. (2002) [6] conducted an experiment with a view to improve marketable yield, fruit maturity, quality and to maintain vigour of the trees on three low chill peach cultivars, namely 'Flordaprince', 'Partap' and 'Shan-e-Punjab'. Dormex (0.5%), urea (12%) or ammonium thiosulphate (6%) for 'Shan-e-Punjab' cultivar and urea (8%) and ammonium thiosulphate (4%) for cultivar 'Partap' when applied at full bloom were found to be the best treatments. As a result of thinning there was an increase in fruit size by 20-35 percent in both cultivars as compared to unthinned fruits. Significant reduction in crop density and yield was also observed by Coneva and Cline (2006) [7] along with improved fruit size by application of 15 ml/L and 30 ml/L ammonium thiosulfate in peach cv. Red Heaven. The improved fruit size might have resulted from lager leaf area and improved leaf to fruit ratio in chemically thinned trees. A negative linear relationship exists between fruit weight and diameter on the one hand and fruit to leaf area ratio on the other (Whiting and Lang, 2004), which is why a healthy leaf area is a crucial factor that affects fruit size. Similar results were found by Basak (2006) and Bound & Wilson (2007). The increased fruit weight resulted from ATS application might be due to its ability to reduce crop load, which indirectly affects fruit weight by reducing inter-fruit competition (Coneva and Cline, 2006) [7]. Similar results were obtained by Costa *et al*. (2004).

The increase in TSS values might have attributed to increased conversion of carbon assimilates and organic acids to sugars and thereby decreasing acidity in fruits. The resulting increase in TSS and reduction in acidity percent might have contributed to higher TSS/acid rations in fruit of thinned trees. Trees of peach cultivar Flordasun (Dinesh and Yadav, 2004) [9] also showed significant improvement in fruit chemical parameters such as TSS and TSS/acid ratio over the control after flower thinning treatment.

Meland (2007) [14] also observed that unsprayed control and hand-thinned 'Victoria' plum trees treated at full bloom with a single application of 1% Armothin® or 1.5% ammonium thiosulphate (ATS) enhanced fruit quality (fruit size, soluble solid content, fruit firmness and ground and surface colour), but the results varied from year to year. All thinning compounds caused some minor leaf injury but no fruit damage. Osborne and Robinson (2008) [17] also reported similar results in cherry cv. Rising Star with the application of ATS.

All these quality parameters might have increased due to increased availability of more assimilates per fruit as a result of thinning. There might be indirect effect of fruit number on their quality and lesser fruits on trees would have received sufficient reserves to develop into improved quality fruits. The similar results were also reported by Ambrozic *et al*. (2014) [1] and Milic *et al*. (2011) in apple and El-Boray *et al*. (2012) [10] in peach.

The fruits from thinned trees were softer than control trees which might be due to more accumulation of carbon assimilate and sugars in fruits. Milic *et al.* (2015) in cherry recorded decreased fruit firmness and a slight increase in ascorbic acid along with other fruit quality parameters with application of ATS at full bloom stage. In this study, it was observed that quality parameters reduced in the second trail despite of effective thinning. This might be due to unfavourable weather conditions occurred during second year as reported by Mass (2016) [13] in apple cv. 'Elstar' trees.

Conclusion

Overall, from the investigation it can be stated that flower thinning using chemicals is helpful in reducing crop load and thereby increasing fruit size and quality. Although, the yield in thinned trees was lesser than control but the acceptability of fruits from thinned trees was more due to larger size and improved appearance.

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