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Studies on the Effect of Fruitlet Thinning on Crop Load and Biochemical Quality of Plum Cv. Kala Amritsari

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ABSTRACT

The present investigation was carried out during the year, 2022 and 2023 at experimental orchard, Department of Horticulture, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India to improve the quality of plum fruit cv. Kala Amritsari through thinning of fruitlets under sub-tropical zone. The experiment was laid out in randomized block design with three replication consisting of ten thinning treatments viz. Ammonium thiosulphate (ATS) at 2.0%, and 4.0%; Benzyl Adenine (BA) at 150 and 300 ppm; Ethephon at 75 and 150 ppm; Hydrogen cyanamide at 0.4 and 0.8% and hand thinning. Chemical sprays were done just after fruit set (2 weeks after petal fall). The results of chemical and hand thinning were compared with unthinned trees (control). It might be concluded from the present study that among various fruit thinning chemicals and hand thinning treatments, Ethephon at 150 ppm applied 2 weeks after petal fall stage was found most effective in decreasing fruit load closely followed by ATS at 4.0% and Ethephon at 75 ppm. ATS at 4.0% applied 2 weeks after petal fall stage was found significantly most effective in thinning of fruitlets and enhancing the chemical fruit quality parameters such as total soluble solids (TSS), total sugars, reducing sugars, non-reducing sugars, pulp anthocyanin content and reducing acidity and pulp carotenoids content followed by treatment HCN at 0.8%.

KEYWORDS: Acidity, anthocyanin, chemicals, ethephon, petal, pigment, plum, thinning

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1. INTRODUCTION

Plum (*Prunus salicina* Lindl.) an important deciduous fruit crop belongs to the family Rosaceae. In terms of economic significance it is rank second only to peach among stone fruits. The Japanese plum (*Prunus salicina* L.) is a diploid species containing 16 chromosomes (2n=16) which originated in China and was first domesticated in Japan. The European plum (*Prunus domestica* L.) is a hexaploid species with 48 chromosomes (2n=6x=48) and was probably originated in Eastern Europe or Western Asia (Hamdani et al., 2022). Although, it is native to China but can be grown throughout the temperate and sub-tropical countries of the world. The evaluation of plum diversity may be essential for on-farm conservation schemes and the utilization of genetic resources for sustainable agriculture (Manco et al., 2019). Plums are one of the major fruit crops worldwide. The plum is considered a health-promoting fruit (Lammerich et al., 2020). Plums are rich in polyphenols, flavonoids, proanthocyanidins, coumarins and hydroxycinnamic acids that may be associated with health benefits (Navarro-Hoyos et al., 2021). It contains 3.6% of dietary fiber and many other nutrients including potassium 5%, copper 6% and tryptophan 3.5% (Milosevic and Milosevic, 2012). Due to remarkable high potassium and sodium contents, plums are recommended to patients suffering from hypertension (Elmegeed et al., 2005). Plums are also rich in various bioactive compounds, including anthocyanins, carotenoids and minerals. They represent a valuable addition to our diet providing essential nutritional and dietary benefits. Their intake is crucial for human health, as a high consumption of these foods leads to a significant boost in antioxidant activity within the human plasma. Plums contain significant levels of antioxidant com pounds such as neochlorogenic acid (3-O-caffeoylquinic acid) and chlorogenic acid (5-O-caffeoylquinic acid) (Trendafilova et al., 2022). Additionally, a notable quantity of cryptochlorogenic acid (4-O-caffeoylquinic acid) is also found in plums. Chlorogenic acid is widely acknowledged for its antioxidant properties, effec tively protecting human LDL (low-density lipoprotein) and acting as a scavenger against reactive oxygen and nitrogen species. It also serves as an inhibitor, preventing the formation of conjugated diene during linoleic acid oxidation. In fact, the antioxidant activity of chlorogenic acid surpasses that of vitamin C and vitamin E, as demonstrated by the Trolox equivalent antioxidant activity (Topp et al., 2012). The edapho-climatic conditions that generally limit plum vigor and affect plant phenology, fertilization, pollination and fruit set are wind, soil moisture, precipitation and temperature, i.e. low temperatures in winter and wide temperature variations in winter and spring (Eremin et al., 2017). In the north Indian states, plums varieties with chilling requirement below 300 h can be grown successfully in both plains and in sub-mountain regions under sub-tropical conditions. Plum cultivation is suitable in the areas receiving 100–125 cm well distributed rainfall throughout the growing season. The mountainous region of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and Chitrakoot (Uttar Pradesh) in north India are premium place for plum cultivation whereas, in the plains, low chill plum cultivars are cultivated throughout Punjab, Haryana and in some parts of Uttar Pradesh and Rajasthan. However, the fruit produced in plains are small in size and there is severe fruit drop due to heavy crop load, which results in to poor crop and quality and ultimately farmers fetch low prices in the market.

Cultural management is the easiest way to improve fruit quality of fruit crops. Fruit thinning is a typical fruit growing technique. Depending on the fruit species, thinning can be done chemical, manual or mechanical. Mechanical thinning is an alternative to manual thinning, which is a laborious process (Martin-Gorriz et al., 2012) and which is increasingly difficult to apply from year to year due to the shrinking availability of workforce (Greene and Costa, 2013; Martin and Calvin, 2010; Strijker, 2005). Several tests have been undertaken on thinning treatment such as blossom burning formulations, growth regulators and photosynthesis inhibitors. But removing flowers and fruitlets in the initial growth period conserves more assimilates thus decreasing competition between the vegetative and reproductive organs of the tree. This contributes to stronger vegetative growth but also stimulates the differentiation of flower buds and improves fruit quality and yield size. Chemical thinning may be carried out during flowering or shortly thereafter to reduce the load on trees during the growing period. The horticulturists all over the world have been trying to evolve some chemical treatments to thin out the excessive crop load so that the quality of the remaining fruits are improved. Continuous efforts have been made for suitability of number of chemicals which could be applied to thin out the fruits economically and without deleterious effect in the tree or fruit quality. However, such chemicals had been observed to be specific as regard to their efficacy in different agro-climatic conditions and also differential response of different cultivars. In recent years, use of chemical thinners in various fruit crops like apple, peach, plum and apricot etc. have been advocated. The desiccant ammonium thio-sulphate (ATS) has been reported to reduce fruit set in 'Packham's Triumph' (Bound and Mitchell, 2002) and 'Conference' pear (Maas et al., 2010), but had no effect on the cultivar 'Clara Frijs' (Bertelsen, 2002). The synthetic cytokinin, 6-benzyladenine (BA) [N (phenylmethyl)-1H-purine-6-amine], has shown promise as a post-bloom thinner in several cultivars (Dussi and Sugar, 2011; Schmidt et al., 2011; Theron et al., 2011). When applied at the correct time BA is a more consistent thinner of apple than carbaryl. It has no detrimental effects on mite predators (Elfving and Cline, 1993) and has a low toxicity to mammalian and arthropod species (Thistlewood and Elfving, 1992). Unlike carbaryl, BA is not a persistent chemical and is more likely to meet modern environmental and food quality guidelines. However, Blossom thinners such as ammonium thiosulfate (ATS) or lime sulfur significantly decrease the rate of pollen germination or the pollen tube length, which struggles the ovule fertilization. Thereby, the fruitlet is not formed and the flower is abscised (Myra et al., 2007). At 1.5%, ATS shows a strong thinning which is capable of decreasing half of the amount of f lowers produced by European plums, reducing yield and fruit set more severely than hand thinning, and as a consequence, increasing the fruit weight and quality (Meland, 2007). Considering the above facts in view, the present investigation was undertaken to evaluate the effect of chemical fruit thinning on bio-chemicals traits in plum cv. Kala Amritsari under semi-arid sub tropical conditions.

2. MATERIALS AND METHODS

2.1. Experimental site

The field experiment was carried out during the year 2022 and 2023 at experimental orchard, Department of Horticulture, CCS HAU, Hisar, Haryana, which was situated at an altitude of 215.2 m above mean sea level with coordinates of 29°15' North and 75°68' East of Haryana. Hisar has typically semi-arid with very hot dry summers and excessively winter weather condition. The climate was characterized by dryness, high temperature and light rainfall. Temperature reached around 45°C accompanied by hot and dry winds in May-June, however, sometimes the temperature droped to freezing point followed by occasional frost in December-January. Hisar received 80–85% of total rainfall i.e 450 mm during July to September and 10–15% during winter month i.e., December to February which was due to western disturbances.

2.2. Treatment details

The field experiment was conducted on 15 years old plum cv. Kala Amritsari with spacing 6×6 m^2. Thirty uniformly grown plants having similar growth were selected which were under uniform agronomic practices as per recommended package of practices. All plants were maintained under uniform practices of orchard management during (2022 and 2023) the study period. The experiment was laid out in Randomized Block Design with three replications by taking one tree $replication^{-1}$. Chemical sprays viz. Ammonium thiosulphate (ATS) at 2.0% and 4.0%; Benzyl Adenine (BA) at 150 ppm and 300 ppm; Ethephon at 75 ppm and 150 ppm; Hydrogen cyanamide at 0.4% and 0.8%; Control (water spray) were done after fruit set (two weeks after petal fall) and Hand thinning (hand thinning was done 3 weeks after fruit set).

2.3. Observations recorded

Crop load was measured by counting the numbers of fruit present per branch cross section area (BCSA) in four selected shoots in all directions in each replication and expressed in fruits $BCSA^{-1}$ (Table 1). Ten representative fruits were harvested at full maturity, pulp removed with sharp knife and mixed together for analysis of quality parameters from each replication. The total soluble solids (TSS) were measured by hand refractometer in the range of 0–32°Brix. The refractometer was calibrated with the help distilled water after each reading and value was expressed in °Brix. Acidity and ascorbic acid was measured as per method suggested by Anonymous, 1990. Sugars were estimated by using the method of Hulme and Narain (1993). Anthocyanin content was estimated as per the method suggested by Harborne (1973). Carotenoids were measured following the method of Hiscox and Isrealstam (1979) with minor modification and calculated as per the formulae given by Venkatarayappa et al. (1984).

3. RESULTS AND DISCUSSION

3.1. Crop load

Among the treatments such as ATS at 2%, ATS at 4%, ethephon at 75 ppm, ethephon at 150 ppm, HCN at 0.8%, BA at 300 ppm and hand thinning showed significantly lower crop load than control. The maximum crop load 17.73 and 19.32 fruits $BCSA^{-1}$ (Table 1) during both the years 2022 and 2023, respectively was observed in treatment control and minimum crop load was observed in treatment ethephon at 150 ppm during both the years followed by ATS at 4%, hand thinning and ethephon at 75 ppm. All the treatments reduced crop load which might be due to more fruitlets drop as compared to control and their distinction intensity. The result was supported by Torres et al. (2021) that ethephon at a concentration of 150 mg l^{-1} used at 30–40 DAFB achieved optimal crop load in peach. Simalarly, Meitei et al. (2013) observed that the application of ethrel at a concentration of 150 ppm at post fruit set in peach cv. Flordasun resulted in a decrease in crop load. Bound and Jones (2004) in apple noticed that crop load reduced significantly with application of 3% ATS. BA inhibits the synthesis and translocation of IAA by fruitlets which leads to more drop and reduced crop load. Giovanaz et al. (2016) noticed that crop load reduced significantly with application of BA+AG4+7 at a concentration of 400 mg l^{-1} in Jubileu peach.

3.2. Total soluble solids

Total soluble solids (TSS) was a prominent parameter which determined the quality of fruit. The chemical treatments such as ATS at 2%, ATS at 4%, ethephon at 75 ppm, ethephon at 150 ppm, HCN at 0.4%, HCN at 0.8% and hand thinning showed significantly higher total soluble solids than control (Table 1). The maximum TSS 16.33°Brix was noticed in ATS at 4% followed by HCN at 0.8%, HCN at 0.4%, ethephon at 150 ppm, hand thinning, ATS at 2% and ethephon at 75 ppm during both the years. Whereas, the minimum TSS was noticed in control treatment during both the years. This might be improved due to reduction in crop load, consequently increasing the leaf to fruit ratio, which resulted in more synthesis, transport and accumulation of sugars in the remaining fruits, thus improving the total soluble solids. The increase in the total soluble solids as a result of ATS sprays might be ascribed to increased photosynthesis and production of more assimilates due to auxin synthesis. Son (2004) reported that hand thinning significantly increased TSS per cent in apricot (*Prunus armeniaca*). Similar results were earlier reported by Meitei et al. (2013) in apple; Chandel and Sharma (2015) in nectarine; Ghazzawy et al. (2019) in date palm and Jangam et al. (2023) in banana that ethephon at 1000 ppm showed maximum and significant effect on TSS (°Brix).

3.3. Acidity

Among the various treatments studied ATS at 2%, ATS at 4%, ethephon at 75 ppm, ethephon at 150 ppm, HCN at 0.4%, HCN at 0.8% and hand thinning showed significantly lower acidity than control (Table 1). Though all treatments reduced acidity over the control but treatment ATS at 4% showed significantly lowest values of acidity and thus enhanced fruit quality. The minimum acidity was noticed in ATS at 4% followed by HCN at 0.8%, HCN at 0.4%, hand thinning, ethephon at 150 ppm, ethephon at 75 ppm and ATS at 2% and the maximum acidity 1.50 and 1.58% was noticed in control treatments during both the years. Reduction in acidity under chemical thinning treatments might be due to conversion of organic acids into sugar and dilution effect as a result of increased fruit size or might be due to increase in total soluble solids at the expense of acid content. Similarly, Meitei et al. (2013) noticed minimum acidity when ethrel applied after fruit set in peach. Dormex at 2 and 3% significantly reduced fruit acidity in apple (El-sabagh et al. (2012).

3.4. Ascorbic acid

Different concentrations of ethephon enhanced ascorbic acid significantly in plum fruit. The maximum ascorbic acid 5.45 and 5.02 mg 100 g^{-1} pulp (Table 1) was found in ethephon at 150 ppm followed by HCN at 0.8% , hand thinning, ATS at 4%, ethephon at 75 ppm, HCN at 0.4% and ATS at 2% during both the years, respectively. Whereas, minimum ascorbic acid was found in treatment control during both the years. Increase in ascorbic acid might be due to the lower rate of conversion of ascorbic acid to dehydro-ascorbic acid. Further, removing excessive fruits by fruitlet thinning prevented the energy draining of the tree which finally resulted in improvement of fruit quality. This was because of hand thinning significantly form highest leaf to fruit ratio adjustment and increased fruit weight, volume, quality. Sakhidin et al. (2019) reported in citrus that hand thinning done at 30 days after full bloom significantly affect the vitamin 'C' content. Similar results were observed by Meitei et al. (2013) that the maximum ascorbic acid content when ethrel at 150 ppm applied after fruit set in peach. Sankaran et al. (2005) noticed that dorbreak (HCN) at 1%

Table 1: Effect of different chemicals on crop load, TSS, acidity and ascorbic acid in plum cv. Kala Amritsari

Treatments	Crop load (fruit BCSA^{-1})		TSS (°Brix)		Acidity (%)		Ascorbic acid (mg 100 g^{-1} pulp)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	17.73	19.32	14.66	14.06	1.50	1.58	4.58	4.21
Hand thinning	13.68	15.20	15.42	14.84	1.38	1.48	5.38	4.92
Ammonium thiosulphate (ATS) at 2%	15.91	17.48	15.40	14.80	1.41	1.50	5.05	4.65
Ammonium thiosulphate (ATS) at 4%	13.31	15.63	16.33	15.70	1.25	1.33	5.13	4.69
Ethephon at 75 ppm	14.32	15.90	15.36	14.78	1.40	1.51	5.11	4.66
Ethephon at 150 ppm	13.27	14.82	15.48	14.82	1.39	1.49	5.45	5.02
Hydrogen cyanamide (HCN at 0.4%	16.94	18.50	15.82	15.24	1.28	1.36	5.06	4.67
Hydrogen cyanamide (HCN) at 0.8%	15.93	17.63	15.96	15.32	1.26	1.35	5.30	4.85
Benzyladenine (BA) at 150 ppm	17.29	18.53	14.76	14.22	1.48	1.57	4.74	4.37
Benzyladenine (BA) at 300 ppm	15.90	17.65	14.83	14.26	1.44	1.53	4.80	4.42
CD (p=0.05)	1.06	1.10	0.47	0.46	0.06	0.05	0.24	0.22
SEm±	0.263	0.268	0.214	0.153	0.024	0.015	0.064	0.070

increased vitamin 'c' content in pomegranate.

3.5. *Sugars*

The chemical treatments such as ATS at 2% , ATS at 4%, ethephon at 75 ppm, ethephon at 150 ppm, HCN at 0.4%, HCN at 0.8% and hand thinning showed significantly higher sugars than control. The maximum total sugars 13.06 and 12.56% (Table 2), reducing sugars 7.18 and 6.91% and non-reducing sugars 5.88 and 5.65% was noticed in ATS at 4% followed by HCN at 0.8%, HCN at 0.4%, ethephon at 150 ppm, hand thinning, ATS at 2% and ethephon at 75 ppm during both the years and the minimum total sugars was noticed in control treatments during both the years. The increase in sugars might be due to increase in photosynthetic activity and chlorophyll contents of leaves. Activity of enzyme catalase, peroxidase and polyphenoloxidase might have increased which ultimately led to higher accumulation of sugars in fruits. Moreover, this improvement might be due to reduced crop load, consequently increasing the leaf to fruit ratio, which resulted in more synthesis, transport and accumulation of sugars in the remaining fruits, thus improving the total sugars. The result was supported by Meitei et al. (2013) in peaches; Sabuz et al. (2019) in mango; Ghazzawy et al. (2019) in date palm and Jangam et al. (2023) in banana reported that ethephon spray showed maximum total sugars. Whereas, Mahawer et al. (2022) suggested that the pre-harvest treatment of 2% HCN played a beneficial role in improving fruit quality in flame seedless grapes.

3.6. *Anthocyanin content*

The chemical treatments under study such as ATS at 2%, ATS at 4%, ethephon at 75 ppm, ethephon at 150 ppm, HCN at 0.4%, HCN at 0.8% and hand thinning showed significantly higher anthocyanin content than control. Though all treatments enhanced anthocyanin content but ATS significantly responded to chemical thinning. The maximum anthocyanin content 6.67 and 6.48 mg 100 g^{-1} pulp wt. (Table 3) was observed in treatments ATS at 4% followed by HCN at 0.8%, HCN at 0.4%, ethephon at 150 ppm, hand thinning, ATS at 2% and ethephon at 75 ppm, whereas, minimum anthocyanin content was observed in control during both the years. The increase in anthocyanin content might be due to reduced fruit load and enhanced fruit size which directly improved source sink strength and thereby improving fruit quality of developing fruits. Increase in anthocyanin with ethereal spray might be attributed due upsurge in respiration and advanced the ripening of fruits. Further, Ethylene had also been reported to enhance phenylalanine ammonia lyase (PAL) activity involved in anthocyanin content biosynthesis (Murphey and Dilley, 1988). Similar increase in anthocyanin content has been observed by Meitei et al. (2013) in peach; Banday et al. (2021) in Red Delicious apple. Mahawer et al. (2022) noticed highest anthocyanin content in grapes when HCN at 2% combination with ABA at 100 ppm was applied at the end of December (at the veraison stage).

Table 2: Effect of different chemicals on sugars content in plum cv. Kala Amritsari

Treatments	Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
	2022	2023	2022	2023	2022	2023
Control	11.58	11.38	6.37	6.26	5.21	5.12
Hand thinning	12.64	12.22	6.96	6.72	5.68	5.50
Ammonium thiosulphate (ATS) at 2%	12.62	12.20	6.95	6.71	5.67	5.49
Ammonium thiosulphate (ATS) at 4%	13.06	12.56	7.18	6.91	5.88	5.65
Ethephon at 75 ppm	12.61	12.18	6.95	6.70	5.66	5.48
Ethephon at 150 ppm	12.66	12.24	6.98	6.73	5.68	5.51
Hydrogen cyanamide (HCN) at 0.4%	12.86	12.40	7.07	6.82	5.79	5.58
Hydrogen cyanamide (HCN) at 0.8%	12.94	12.50	7.13	6.88	5.81	5.62
Benzyladenine (BA) at 150 ppm	11.80	11.44	6.49	6.29	5.31	5.15
Benzyladenine (BA) at 300 ppm	11.84	11.60	6.51	6.38	5.33	5.22
CD (p=0.05)	0.27	0.24	0.14	0.13	0.12	0.10
SEm±	0.184	0.218	0.117	0.100	0.089	0.093

3.7. *Carotenoid content*

Different chemicals such as ATS at 2%, ATS at 4%, ethephon at 75 ppm, ethephon at 150 ppm, HCN at 0.4%, HCN at 0.8% and hand thinning showed significantly lower carotenoid than control (Table 3). Though all treatments enhanced carotenoid content but ATS significantly responded to chemical thinning. The maximum carotenoid content 11.30 and 11.50 mg 100 g^{-1} pulp wt. was observed

Table 3: Effect of different chemicals on pigment content in plum cv. Kala Amritsari

Treatments	Anthocyanin content (mg 100 g^{-1} pulp wt.)		Carotenoid content (mg 100 g^{-1} pulp wt.)	
	2022	2023	2022	2023
Control	5.27	4.95	11.30	11.50
Hand thinning	6.26	5.15	10.53	10.91
Ammonium thiosulphate (ATS) at 2%	6.23	5.14	10.65	10.94
Ammonium thiosulphate (ATS) at 4%	6.67	6.48	9.00	9.50
Ethephon at 75 ppm	6.20	5.13	10.66	10.97
Ethephon at 150 ppm	6.28	5.16	10.62	10.88
Hydrogen cyanamide (HCN) at 0.4%	6.47	5.37	9.58	9.40
Hydrogen cyanamide (HCN) at 0.8%	6.59	5.41	9.32	9.35
Benzyladenine (BA) at 150 ppm	5.44	5.13	10.98	11.30
Benzyladenine (BA) at 300 ppm	5.53	5.18	10.92	11.20
CD (p=0.05)	0.29	0.24	0.61	0.52
SEm±	0.087	0.079	0.142	0.178

in treatment control followed by BA at 300 ppm and BA at 150 ppm, ethephon at 150, ATS at 2%, hand thinning and ethephon at 75 ppm during both the years, whereas, minimum carotenoid content was observed in treatment ATS at 4% during both the years. Drogoudi et al. (2009) observed that light or moderate hand thinning during pit hardening resulted in optimal yields and fruit quality characteristics in the canning peach cultivar 'Andross'. This increase in carotenoid content might be due to reduced fruit load and enhanced fruit size by these chemicals, which directly improved source sink strength and thereby improving fruit quality of developing fruits. Similar, Meitei et al. (2013) noticed the highest carotenoid in peach when ethrel at 150 ppm was applied after fruit set. Yosefi et al. (2021) found increase in color content in raspberry when benzyle adenine was applied at different concentration.

4. CONCLUSION

Among various fruit thinning chemicals treatments, Ethephon at 150 ppm was found most effective in decreasing fruit load closely followed by ATS at 4.0% and Ethephon at 75 ppm. Whereas, ATS at 4.0% was found most effective in increasing fruit skin color, total soluble solids, sugars, ascorbic acid, pulp anthocyanin contents and reducing acidity and pulp carotenoids content followed by treatment HCN at 0.8% in low chilling requiring plum cultivar Kala Amritsari under subtropical pains.

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