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STUDIES ON THE EFFECT OF FRUITLET THINNING ON FRUIT DROP, COLOR AND OTHER PHYSICAL QUALITY OF PLUM CV. KALA AMRITSARI

Parveen[1*], R.P.S. Dalal[1], Anita Kumari[2] and Chetna[3]

[1]Department of Horticulture, College of Agriculture, C.C.S. H.A.U., Hisar-125 004, Haryana, India.

[2]Department of Botany & Plant Physiology, College of Basic Science & Humanities, C.C.S. H.A.U., Hisar-125 004, Haryana, India.

[3]Department of Mathematics & Statistics, College of Basic Science & Humanities, CCS HAU, Hisar-125 004, Haryana, India.

*Corresponding author E-mail : lakra889@gmail.com

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ABSTRACT

The present investigation was carried out with the objective to improve the quality of plum fruit cv. Kala Amritsari through thinning of fruitlets under sub-tropical zone during the year the years 2022 and 2023. The experiment was laid out in randomized block design with three replications consisting of ten thinning treatments *viz*. Ammonium thiosulphate (ATS) @ 2.0%, & 4.0%; Benzyl Adenine (BA) @ 150 & 300 ppm; Ethephon @ 75 & 150 ppm; Hydrogen cyanamide (HCN) @ 0.4 & 0.8% and hand thinning. Chemical sprays were done after fruit set (2 weeks after petal fall). The results of chemical and hand thinning were compared with unthinned trees (control). It may be concluded from the present study that among various fruit thinning chemicals and hand thinning treatments, ethephon @ 150 ppm applied 2 weeks after petal fall stage was found significantly most effective in thinning of fruitlets and enhancing the physical fruit quality parameters *i.e* fruit weight, fruit size, pulp per cent, pulp/stone ratio and decreasing fruit firmness closely followed by treatment ATS @ 4.0 per cent. Further, fruit yield could not be affected significantly with any of the fruit thinning chemicals treatments.

Key words : Fruit thinning chemicals, Fruit quality, Hand thinning, Plum, Yield.

Introduction

Plum, a member of genus *Prunus* belongs to the family Rosaceae. This genus has fifteen distinct species but, three species *viz*., European plum (*Prunus domestica* L.), Japanese plum (*Prunus salicina* Lindl.) and Damson's plum (*Prunus insititia* L.) are of commercial importance. It is indigenous to China but, cultivated in all the temperate and sub-tropical countries of the world and one of the most important stone fruits of India. Plums are grown under sub-tropical conditions both in plains and in sub-mountain areas of north Indian states. Varieties with chilling requirement below 300 hours can be grown successfully. Areas receiving 100-125 cm rainfall well distributed throughout the growing season are suitable for plum cultivation. Cultural management is the easiest way to improve fruit quality of fruit crops. Plum is a drupe fruit and cultivars are quite diverse in fruit characters such as fruit size, shape, color, texture, aroma and other quality characteristics which make their fruits desirable as compared to other horticultural crops (Baden and Byrne, 2012). Mature plum fruit may have a dusty-white coating that gives them a glaucous appearance. In North India, high quality plums are cultivated in hilly region of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and Chitrakoot (Uttar Pradesh). In the plains, low chill plum cultivars are cultivated throughout Punjab, Haryana and in some parts of Uttar Pradesh and Rajasthan. At national level it has covered an area of 17930 ha with production of 69530 MT (Anonymous, 2023a) but, in Haryana it was grown on 66.2 ha with production of 1314.71 MT (Anonymous, 2023b).

Fruit thinning is a practice commonly applied in fruit

growing. Depending on the fruit species chemical, manual or mechanical thinning is used. The options of chemical thinning of stone fruit are limited but, it improves its quality and prevent alternate bearing. Tests have been conducted on thinning methods such as blossom burning formulations, growth regulators and photosynthesis inhibitors. Chemical thinning may be carried out during flowering or shortly thereafter to reduce the load on trees during the growing period. Removing flowers and fruitlets in the initial growth period preserves more assimilates thus reducing competition between the vegetative and generative 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. 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 is improved. Continuous efforts have established 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. Out of various chemicals employed to thin out the excessive fruit load in different fruit plants, Ammonium thiosulphate (ATS), Benzyl Adenine (BA), Ethephon, Hydrogen cyanamide and hand thinning *etc*. have some promising results in different fruit plants. Considering the above facts in view, the present investigation was undertaken to evaluate the effect of chemical fruit thinning on morpho-physiological traits in plum.

Materials and Methods

Experimental site

The field experiment was carried out at experimental orchard, Department of Horticulture, CCS HAU, Hisar, Haryana, which is 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 is characterized by dryness, high temperature and light rainfall. Temperature reaches around 45^{0}C accompanied by hot and dry winds in May-June, however, sometimes the temperature drops to freezing point followed by occasional frost in December-January. Hisar receives 80-85 per cent of total rainfall *i.e* 450 mm during July to September and 10-15 per cent during winter month *i.e.*, December to February which is due to western disturbances.

Treatment details

The field experiment was conducted on 15 years old plum cv. Kala Amritsari with spacing 6m×6m. 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 & 2023) the study period. The experiment was laid out in Randomized Block Design with three replications by taking one tree per replication. Chemical sprays *viz*. Ammonium thiosulphate (ATS) @ 2.0% and 4.0%; Benzyl Adenine (BA) @ 150 ppm and 300 ppm; Ethephon @ 75 ppm and 150 ppm; Hydrogen cyanamide @ 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).

Observations recorded

Fruit drop was calculated 20 days after spray from all four shoots tagged in all directions (East, West, North and South) by the difference of numbers of fruit present before spray (initially) and numbers of fruit remains after spray (finally) and divided by numbers of fruit present before spray (initially). Fruit drop per replications was calculated and expressed in per cent. Yield efficiency was measured by weight of fruit in kg per branch cross section area (BSCA) from all four shoots tagged in all directions (East, West, North and South) and calculated as per formulae given by Dalal and Brar (2012) and expressed in kg/BCSA. The total numbers of fruit per tree was collected, weighed with digital weighing balance for yield estimation and expressed in kilograms. Five representative fruits were harvested at full maturity and mixed together for analysis of physical quality parameters from each replication. Fruit weight, pulp weight and stone weight were measured by top pan electric balance and value was expressed in gram (g). Stone weight was calculated by subtracting the pulp weight from fruit weight. Fruit size were measured with the help of digital vernier calliper and expressed in centimeters (cm). Pulp per cent was measured by dividing the fruit pulp weight to total fruit weight and expressed in percentage. Pulp weight to stone weight ratio was calculated by dividing the value of pulp weight to stone weight. Fruits firmness was measured by digital penetrometer. Fruit firmness was calculated and expressed in kg/inch^2. A chroma metre of Konica Minolta, INC. 2002-2013 CR-400 Series Ver. 1.14 was used to determine color. The colorimeter was calibrated using the white and black plates that came

with the devices before measuring the colour parameter. Three parameters including L*, a* and b* were used to evaluate skin colour.

Results and Discussion

Fruit drop

All the chemical thinner used has varied interaction with fruit drop, which is concentration dependent. The chemical treatments such as ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.8 per cent, BA @ 300 ppm and hand thinning showed significantly higher fruit drop than control. The maximum fruit drop 76.73 and 78.90 per cent (Table 1) during both the years under study period was observed in treatment ethephon @ 150 ppm followed by ATS @ 4 per cent, hand thinning and ethephon @ 75 ppm while minimum fruit drop (57.12% and 59.25%) in treatment control. This is because of ethylene which inhibit the synthesis and translocation of IAA by fruits, which reducing sink strength (Ebert and Bangerth, 1982) and by inducing the separation zone in peduncle fruit drops occurred (Roberts *et al*., 2002) and also ethylene may inhibit plant photosynthesis (Untiedt and Blanke, 2001) which cause more inter-sink competition and results in abscission of weaker fruits due to nutrients starvation. The result was confirmed by Pavanello *et al*. (2017) that the application of ethephon at a concentration of 100 µl l^{-1} applied 30 days after full bloom led to an increase in both fruit drop and fruit size in European plum compared to the plants in the control group and also, Mohamed *et al*. (2020) noted that the ethephon at a concentration of 100 ppm administered two weeks after fruit set resulted in the highest percentage of fruit drop in plum. Taheri *et al*. (2012) investigated that the application of ethephon within a concentration range of 100 to 200 mg/l is effective in inducing appropriate levels of fruit abscission in "Redhaven" peaches. Whereas, ATS effectively reduced fruit set by desiccating vital female organs. ATS is effective at temperature between 14-22 ^{o}C (Bertelsen, 2002). Additionally, the researchers observed that thinned flowers aggressively and enhanced fruit drop thereby reducing sink competition among fruits. This was confirmed by Turk *et al.* (2014) that 2.00 per cent ATS (ammonium thiosulfate) solution applied during the 50-60 per cent flowering stage led to excessive thinning in the "Redhaven" peach cultivar.

Meland (2007) determined that the application of a diluted solution 1.5 per cent ATS during full bloom had several effects on the plum cultivar 'Victoria.' While, BA inhibit the synthesis and translocation of IAA by fruitlets which leads to reduced sink strength and results in smaller and weaker lateral fruit drops (Ebert and Bangerth, 1982). Similar result was observed by Silva *et al*. (2022) that guava exhibited enhanced fruit thinning efficiency at benzyladenine concentrations of 300 mg/l. Fallahi *et al*. (1992) examined that applying dormex before and during full bloom at concentrations higher than 0.75 per cent caused a reduction in fruit set and yield in plum cv. Friar. On the other hand, when dormex was applied at a concentration of 0.50 per cent at full bloom led to a decrease in both fruit set and yield in 'Simka' plums.

Yield

Fruit thinning chemicals such as ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.8 per cent, BA @ 300 ppm and hand thinning could not influenced the yield of plum. A non-significant result of yield was obtained during both the years' *i.e.*; 2022 and 2023. This may be due to non-significant effect on yield efficiency as evident from present investigation. However, the maximum numeric value (Table 1) of yield 40.26 and 42.54 kg/plant, respectively was observed in treatment hand thinning and control during the year 2022 and 2023, respectively. The minimum yield was observed in treatment HCN @ 0.8 per cent and ethephon @ 150 ppm during the year 2022 and 2023, respectively.

Yield efficiency

Yield efficiency could not be influenced significantly with any of fruit thinning chemicals such as ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.8 per cent, BA @ 300 ppm and hand thinning. A non-significant result of yield efficiency was obtained during both the years' *i.e* 2022 and 2023. However, the maximum numerical value (Table 1) of yield efficiency 0.19 and 0.21 kg/BCSA during both the years, respectively was observed in treatment BA @ 150 ppm. Whereas, minimum numerical value of yield efficiency was observed in treatment ATS @ 0.4 per cent, ethephon @ 150 ppm and hand thinning in year 2022 and 2023, respectively. This might be due to increased fruit drop with these chemicals results into increased individual fruit weight and hence, compensated the yield efficiency.

Fruit weight and fruit size

The chemical treatments such as ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.8 per cent, BA @ 300 ppm and hand thinning showed significantly higher fruit size and fruit weight than control. The maximum average fruit weight 12.82 and 13.67 g, average fruit length 2.56 and 2.54 cm

Table 1 : Effect of different chemicals on fruit drop, yield and yield efficiency in plum cv. Kala Amritsari.

Treatments	Fruit drop (%)		Yield (kg/Plant)		Yield efficiency (kg/BCSA)	
	2022	2023	2022	2023	2022	2023
Control	57.12	59.25	38.00	42.54	0.18	0.20
Hand Thinning	75.12	77.48	40.26	40.71	0.17	0.18
Ammonium Thiosulphate (ATS) @ 2 %	68.31	69.90	39.60	40.07	0.18	0.20
Ammonium Thiosulphate (ATS) @ 4 %	76.23	75.80	36.54	39.96	0.17	0.18
Ethephon @ 75 ppm	70.68	73.80	40.13	40.22	0.18	0.19
Ethephon @ 150 ppm	76.73	78.90	35.23	38.21	0.17	0.18
Hydrogen Cyanamide (HCN) @ 0.4 %	63.51	62.66	38.45	41.13	0.18	0.19
Hydrogen Cyanamide (HCN) @ 0.8 %	68.10	69.55	35.03	40.05	0.18	0.19
Benzyladenine (BA) @ 150 ppm	60.12	60.96	38.38	41.81	0.19	0.21
Benzyladenine (BA) @ 300 ppm	68.34	69.50	36.14	40.10	0.18	0.20
CD @ 5%	**6.64**	**5.85**	**NS**	**NS**	**NS**	**NS**

and average fruit breadth 2.67 and 2.62 cm during both the years *i.e* 2022 and 2023, respectively (Table 2) was observed in treatment ethephon @ 150 ppm followed by ATS @ 4 per cent and hand thinning and minimum fruit weight, length and breadth was observed in treatment control. The fruit weight, length and breadth were increased with the increase in concentration of different chemical thinners which might be due to the reduction of fruits per tree thereby increasing the leaf to fruit ratio which further resulted in increased availability of photosynthates and lesser nutritional competition among the developing fruits. Phyto-hormones further helped in cell division and enlargement thereby deposition of more photo assimilates and finally increased fruit weight. These findings were supported by Hussain *et al.* (2020) that there was increased fruit length, fruit diameter, fruit weight in nectarine when sprayed with ethephon @ 150 ppm at one week after petal fall. Similarly, Pavanello *et al*. (2017) explored that the application of ethephon at a concentration of 100 µl l^{-1} applied 30 days after full bloom led to an increase in fruit size in European plum compared to the plants in the control group. Canli and Pektas (2015) revealed in 'Acka' pears that applying 100 ppm of BA (benzyl adenine) at 14 days after full bloom resulted in significant improvements in fruit weight, fruit diameter and fruit length. Similarly, Dussi and Sugar (2010) noted that applying 125 ml l^{-1} of BA (when the fruit diameter reached 10-12 mm) had significant effects on 'Williams' Pear. The findings revealed that this treatment led to increase the average weight of each fruit. While, Stopar (2006) explored that the application of BA 150 ppm led to increase the average weight of the fruits. Whereas, Ayub *et al.* (2019) reported that the application of ATS @ 8 per cent concentration in Japanese plum increased fruit diameter and fruit mass. Similar, Giovanaz *et al.* (2013) noted in peach that ATS @ 3 per cent produced fruit with largest diameter. This was due to fact that ATS effectively reduced fruit set and might be improved the quality of remaining fruit comparison to control group (Whiting *et al*., 2006). Similar, Fallahi *et al*. (1992) found that dormex at a concentration of 0.25 per cent result in ideal fruit weight in apple. Whereas, El-Sabagh *et al*. (2012) found improvement in fruit weight, size and length of apple when treated with 2 and 3 per cent hydrogen cyanamide. It might be due to that hydrogen cyanamide reduces unwanted lateral flowers and increase the average size of the fruit produced.

Pulp weight and pulp

The chemical treatments such as ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.8 per cent, BA @ 300 ppm and hand thinning showed significantly higher pulp weight, pulp per cent than control. The maximum pulp weight 12.10 and 12.89 g and pulp 94.42 and 94.29 per cent during both the years *i.e*.; 2022 and 2023 (Table 3) was observed in treatment ethephon @ 150 ppm followed by ATS @ 4 per cent, hand thinning and ethephon @ 75 ppm. Whereas, minimum pulp weight and pulp per cent was observed in treatment control. The increase in pulp weight could be attributed to the fact that fruit thinning increased fruit size as evident from the present study which resulted in higher proportion of pulp. This increased in pulp weight may be due to increase in size of fruit and smaller size of stone of fruit. Khalil (2005) observed in plum that maximum pulp per cent was obtained with 30 per cent hand thinning which was followed by treatment ethephon @ 150 ppm. Further, increase in pulp per cent was also observed by Sud and Mishra (1990) in plum when treated

Table 2 : Effect of different chemicals on fruit weight and fruit size in plum cv. Kala Amritsari.

Treatments	Fruit weight (g)		Fruit Size (cm)			
			Fruit length		Fruit breadth	
	2022	2023	2022	2023	2022	2023
Control	10.32	11.50	1.99	2.07	2.32	2.27
Hand Thinning	12.54	13.50	2.46	2.41	2.64	2.60
Ammonium Thiosulphate (ATS) @ 2%	11.84	12.53	2.30	2.30	2.55	2.52
Ammonium Thiosulphate (ATS) @ 4%	12.73	13.66	2.52	2.50	2.65	2.61
Ethephon @ 75 ppm	12.25	12.98	2.38	2.35	2.59	2.56
Ethephon @ 150 ppm	12.82	13.67	2.56	2.54	2.67	2.62
Hydrogen Cyanamide (HCN) @ 0.4 %	10.51	11.53	2.04	2.12	2.33	2.30
Hydrogen Cyanamide (HCN) @ 0.8 %	11.67	12.40	2.09	2.20	2.51	2.50
Benzyladenine (BA) @ 150 ppm	10.64	11.70	2.15	2.16	2.34	2.33
Benzyladenine (BA) @ 300 ppm	11.72	12.47	2.24	2.25	2.52	2.51
CD @ 5%	**0.62**	**0.69**	**0.07**	**0.06**	**0.08**	**0.07**

with ethephon @ 25 ppm. These findings are similar with results of Meitei *et al*. (2013) in peach and Chandel and Sharma (2015) in nectarine. Whereas, Bhatt (2017) found that the treatment ATS @ 1.5 per cent showed maximum pulp weight followed by ethephon @ 150 ppm in Kala Amritsari plum. This was due to fact that ATS effectively reduced fruit set that might be improved the quality of remaining fruit comparison to control group. Pal *et al*. (2016) found in litchi that BA @ 25 ppm showed highest pulp weight.

Stone weight

Stone weight could not be influenced significant with any of fruit thinning chemicals. A non-significant and erratic result in stone weight was observed during both the years under study. However, a highest numeric value (Table 3) of stone weight 0.80 g during the year 2022 was observed in treatment HCN @ 0.8 per cent and lowest numeric value of stone weight 0.70 g was observed in treatment ethephon @ 75 ppm whereas, during year 2023 maximum numeric value of stone weight 0.78 g was observed in both treatments ethephon @ 150 ppm and ATS @ 4 per cent and minimum value of stone weight 0.70 g was observed in treatment control. These results are in close conformity with Bhatt (2017) in Kala Amritsari plum that minimum stone weight was in the treatment ATS @ 1.5 per cent. Whereas, Meitei *et al*. (2013) in peach observed that the maximum stone weight was found in treatment ethrel @ 150 ppm whereas, minimum stone weight was recorded in control. Gupta and Kaur (2007) found lesser stone weight with ethephon in Satluj Purple plum.

Pulp: stone ratio: Pulp: stone ratio is considered an important parameter in fruit quality and also regarded an indispensable in breeding objectives in stone fruits. The chemical treatments such as ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.8 per cent, BA @ 300 ppm and hand thinning showed significantly higher pulp/stone ratio than control. The maximum pulp/stone ratio 16.92 (Table 4) during both the years was observed in treatment ethephon @ 150 ppm followed by ATS @ 4 per cent 16.80, hand thinning 16.70, ATS @ 2 per cent 15.67, BA @ 300 ppm 15.43 and HCN @ 0.8 per cent 15.28 while, minimum pulp/stone ratio was observed in treatment control. Though all treatments enhanced pulp: stone ratio but ethephon and ATS significantly increased Pulp/stone ratio. The increase in pulp: stone ratio could be attributed to increase in fruit size and weight which resulted in to higher proportionate pulp weight and increased marginal stone weight as evident from the present investigation. These findings are similar with results of Meitei *et al*. (2013) in peach with ethrel @ 150 ppm and Chandel and Sharma (2015) with the application of 300 ppm ethephon in nectarine.

Fruit firmness

It was observed from that ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.4 per cent, HCN @ 0.8 per cent and hand thinning showed significantly lower fruit firmness than control. The maximum fruit firmness 1.96 kg/inch^2 (Table 4) during both the years was observed in treatment control and minimum fruit firmness was observed in treatment ethephon @ 150 ppm followed by HCN @ 0.4 per cent and 0.8 per cent, ethephon @ 75 ppm, ATS @ 4 per cent and ATS @ 2 per cent. Change in fruit firmness results from advanced maturity. Lower firmness was likely associated with a more advanced stage of ripening. The reduction of fruit firmness over the ripening period

Table 3 : Effect of different chemicals on pulp weight, stone weight and pulp in plum cv. Kala Amritsari.

Treatments	Pulp weight (g)		Stone weight (g)		Pulp (%)	
	2022	2023	2022	2023	2022	2023
Control	9.53	10.80	0.79	0.70	92.34	93.75
Hand Thinning	11.80	12.73	0.74	0.77	94.32	94.26
Ammonium Thiosulphate (ATS) @ 2 %	11.13	11.77	0.71	0.76	94.00	94.06
Ammonium Thiosulphate (ATS) @ 4 %	12.02	12.88	0.71	0.78	94.37	94.28
Ethephon @ 75 ppm	11.55	12.22	0.70	0.76	94.28	94.14
Ethephon @ 150 ppm	12.10	12.89	0.72	0.78	94.42	94.29
Hydrogen Cyanamide (HCN) @ 0.4 %	9.75	10.81	0.76	0.72	92.56	93.76
Hydrogen Cyanamide (HCN) @ 0.8 %	10.87	11.64	0.80	0.76	93.97	94.00
Benzyladenine (BA) @ 150 ppm	9.88	10.97	0.76	0.73	92.58	93.91
Benzyladenine (BA) @ 300 ppm	10.93	11.73	0.79	0.74	93.98	94.02
CD @ 5%	**0.66**	**0.70**	**NS**	**NS**	**0.31**	**0.18**

Table 4 : Effect of different chemicals on pulp/stone ratio and fruit firmness in plum cv. Kala Amritsari.

Treatments	Pulp/stone ratio		Fruit firmness (kg/inch^2)	
	2022	2023	2022	2023
Control	12.06	13.42	1.96	2.06
Hand Thinning	16.70	16.53	1.75	1.79
Ammonium Thiosulphate (ATS) @ 2 %	15.67	15.78	1.74	1.78
Ammonium Thiosulphate (ATS) @ 4 %	16.80	16.51	1.72	1.76
Ethephon @ 75 ppm	15.94	16.07	1.70	1.74
Ethephon @ 150 ppm	16.92	16.52	1.59	1.61
Hydrogen Cyanamide (HCN) @ 0.4 %	12.82	13.89	1.63	1.66
Hydrogen Cyanamide (HCN) @ 0.8 %	15.28	15.63	1.61	1.63
Benzyladenine (BA) @ 150 ppm	13.00	13.98	1.94	2.05
Benzyladenine (BA) @ 300 ppm	15.43	15.68	1.92	1.99
CD @ 5%	**0.98**	**0.47**	**0.05**	**0.07**

was related to the solubilization of pectic compounds or change from insoluble pectin to soluble pectin as fruit ripening progresses. These insoluble compounds are found in unripe fruits and are composed of carboxylic acids bound to calcium resulting in calcium pectate (Legua *et al*., 2011). Similar, Meitei *et al*. (2013) observed in peach that there was reduction in fruit firmness with ethrel at 150 ppm. Whereas, Rajput *et al*. (2017) noticed in plum that treatment ATS 4 per cent showed less firmness. Marchioretto *et al*. (2018) observed non-significant effect of all ATS treatments in Gala apple. Similar, Bound (2015) also observed non-significant effect of ATS and 6-BA on flesh firmness in pear. Whereas, El-sabagh *et al*. (2012) reported in apple that hydrogen cyanamide @ 1 per cent showed lower firmer fruit than control.

Fruit color ('L' coordinate)

It was cleared from treatments that ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.4 per cent, HCN @ 0.8 per cent and hand thinning showed significantly higher fruit color L=brightness than control (Table 5). The brightness (L) of fruit color is most important variable in attracting consumers. The maximum brightness 28.33 of fruit color during both the years was observed in treatment ATS @ 4 per cent followed by HCN @ 0.8 per cent, HCN @ 0.4 per cent, ethephon @ 150 ppm, hand thinning, ATS @ 2 per cent and ethephon @ 75 ppm. While, minimum brightness of fruit color was observed in treatment control. Fruit brightness might be affected by physico-chemical properties as well as ripening and pretreatments. Ghazzawy *et al*. (2019) observed in date palm that the minimum 'L' was shown by treatment ATS @ 3 per cent and ethephon 300 ppm.

Fruit color ('a'coordinate)

It was evident from different treatments that ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.4 per cent, HCN @ 0.8 per cent and hand thinning showed significantly higher

Table 5 : Effect of different chemicals on fruit color values in plum cv. Kala Amritsari.

Treatments	Fruit color (L=brightness)		Fruit color (a* coordinate)		Fruit color (b* coordinate)	
	2022	2023	2022	2023	2022	2023
Control	21.09	22.64	9.32	9.49	-2.05	-1.94
Hand Thinning	27.27	28.47	10.69	11.87	-1.94	-1.83
Ammonium Thiosulphate (ATS) @ 2 %	27.25	28.46	10.66	11.85	-1.94	-1.84
Ammonium Thiosulphate (ATS) @ 4 %	28.33	29.63	11.75	12.47	-1.23	-1.09
Ethephon @ 75 ppm	27.22	28.43	10.63	11.75	-1.95	-1.85
Ethephon @ 150 ppm	27.30	28.50	10.72	11.89	-1.92	-1.83
Hydrogen Cyanamide (HCN) @ 0.4 %	27.79	29.04	11.12	12.18	-1.26	-1.15
Hydrogen Cyanamide (HCN) @ 0.8 %	27.93	29.19	11.24	12.34	-1.24	-1.11
Benzyladenine (BA) @ 150 ppm	21.57	23.08	9.65	9.78	-2.04	-1.92
Benzyladenine (BA) @ 300 ppm	21.64	23.21	9.80	9.91	-1.99	-1.88
CD @ 5%	**0.62**	**0.64**	**0.50**	**0.43**	**0.07**	**0.06**

fruit color a* coordinates than control (Table 5). Fruit color a* coordinate is the value that characterise the colour with positive values suggesting red and negative values indicating green colour. The maximum redness a* coordinate 11.75 in fruit color was found in treatment ATS @ 4 per cent followed by HCN @ 0.8 per cent, HCN @ 0.4 per cent, ethephon @ 150 ppm, hand thinning, ATS @ 2 per cent and ethephon @ 75 ppm. While, minimum redness a* coordinate of fruit color was observed in treatment control. Fruit color might be affected by physico-chemical properties, ripening and pretreatments. Similar, result was supported by Huang *et al*. (2021) in citrus that the a*/b* ratio of peel was significantly increased by ethephon in a concentration-dependent manner. Sekse *et al*. (2011) observed in opal plum that there was increased in fruit color a* coordinate from maturity group one (MG_1) to maturity group three (MG_3) when fruits were harvested 35 days after pit hardening stage however, a corresponding decreased was found in b* coordinate.

Fruit color ('b' coordinate)

It was cleared from treatments that ATS @ 2 per cent, ATS @ 4 per cent, ethephon @ 75 ppm, ethephon @ 150 ppm, HCN @ 0.4 per cent, HCN @ 0.8 per cent and hand thinning showed significantly lower fruit color b* coordinates than control (Table 5). Fruit color b* coordinate is the value that characterise the colour with positive values suggesting yellow and negative values indicating blue colour, respectively. The maximum bluishness b* coordinate -2.05 in fruit color was found in treatment control whereas, minimum bluishness b* coordinate in fruit color was found in treatment ATS @ 4 per cent followed by HCN @ 0.4 per cent, HCN @ 0.8 per cent, ethephon @ 150 ppm, hand thinning, ATS @ 2 per cent and ethephon @ 75 ppm. The change in color occurs due to the ripening of fruit and climatic conditions of growing region. Similar, Sekse *et al*. (2011) observed in opal plum that there was decreased in fruit color b* coordinate from maturity group one (MG_1) to maturity group three (MG_3) when fruits was harvested 35 days after pit hardening stage however, a corresponding increase was found in a* coordinate.

Conclusion

It may be concluded from the present study that among various fruit thinning chemicals and hand thinning treatments, ethephon @ 150 ppm applied 2 weeks after petal fall stage was found significantly most effective in increasing fruit drop per cent followed by ATS @ 4 per cent, hand thinning and ethephon @ 75 ppm and enhancing the physical fruit quality parameters *i.e.*; fruit color, fruit weight, fruit size, pulp per cent, pulp/stone ratio and decreasing fruit firmness closely followed by treatment ATS @ 4.0 per cent. However, all chemicals treatments and hand thinning shows non-significant effect on yield, yield efficiency and stone weight parameters.

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