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Growth Regulators and Nutrient Application Reduces Fruit Drop and Improves Fruit Quality in *Prunus salicina* Lindl. cv. Kala Amritsari

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ABSTRACT

The Japanese Plum is an important fruit crop grown in subtropical plain area of Punjab, Uttarakhand and Haryana. To observe the effect of growth regulator (NAA 10 ppm) and nutrient application (urea @ 2% and zinc sulphate @ 0.5%) the experiment was conducted at CCS HAU experimental orchards. Chemicals were sprayed in different combinations (T_1=NAA, T_2=NAA+ Urea, T_3=NAA+ $ZnSO_4$, T_4=Urea and T_5=NAA+ Urea + $ZnSO_4$) at two different times (during mid-March and mid-April) for control of fruit drop and for sustaining good quality production. Observations for fruit yield, fruit drop and quality were recorded accordingly. It was found that T_5 reduced fruit drop to minimum and improved the fruit quality as well, followed by T_4 when compared with control. Among all treatments, combination of NAA and $ZnSO_4$ performed better than others.

Key words: *Japanese plum, Growth regulators, Fruit drop.*

INTRODUCTION

Japanese plum (*Prunus salicina* Lindl.) is a temperate zone fruit having low chilling requirement cultivated on small scale in Punjab and Haryana region. The Farmers are adopting plum because of its increasing popularity among people. Among the stone fruits it ranks second in production after peaches. Fruit are rich in nutrients, anthocyanins and vitamins. Japanese plum bears heavily but the extent of pre-harvest fruit drop is much more. In spite of adequate flowering and fruiting, sometimes low fruit yield have been experienced because of low fruit retention and subsequently higher fruit drop. Pre-harvest fruit drop renders the farmer with unexpected economical loss as during fruit development period it becomes difficult to estimate the production due to uncertain pre-harvest fruit drop[14]. Several factors affect fruit drop and some of the reasons suggested are the lack of pollination and failure of fertilization, ovule abortion, and embryo degeneration, hormone content, climatic factors, inadequate soil moisture and low photosynthate level. Micronutrients and plant growth regulators (PGRs) play important role in minimizing fruit drop by increasing fruit retention[12,13]. PGRs are also capable of influencing the fruit growth. The lack of these substances results in development of abscission layer at the base of fruits which causes fruit to drop down[6].

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Zinc (Zn) is an essential trace element for plants, being involved in many enzymatic reactions and is necessary for their good growth and development. Zinc is also involved in regulating the protein and carbohydrate metabolism. Zinc availability to plants is reduced in high pH soils. Zinc uptake rate is faster in mango trees when zinc sulfate was foliar applied as compared with its soil application[23]. Fruit drop in ber cv. Sanuar-2 was reduced to minimum and the fruit quality was also improved with NAA 30 ppm as observed by Gill and Bal[8]. Synthetic auxin (2,4-D) and zinc sulphate are reported to control fruit drop in kinnow and improve yield and quality of fruits[6]. Similarly

The heavy bearing and heavy pre-harvest fruit drop is the special character of cultivar Kala Amritsari, about 60 % fruit drop takes place from fruit set to harvesting. These losses should be controlled by correcting the deficiencies of the plant so that the farmer can get the maximum yield. The present studies were therefore conducted to assess the effect of growth regulators and nutrient spray on fruit drop, yield and quality of plum fruits and to find out the most effective time of spray to control fruit drop.

MATERIAL AND METHODS

The present study was conducted on 10 years old plum trees planted at 6 x 6m distance in a sandy soil and irrigated with immerged irrigation system at horticulture experimental field at HAU, Hisar (2012-13). Thirty-three healthy trees were selected nearly similar in vigour and size. The work in this experiment aimed to study the effect of foliar spray of nutrients and growth regulators on fruit drop, yield and fruit quality of plum cv. Kala Amritsari. The experimental treatments were as follow:

Treatment 1 (T_1)-	Urea spray (2%)
Treatment 2 (T_2)-	Zinc Sulphate (0.5%) + Urea spray (2%)
Treatment 3 (T_3)-	NAA (10 ppm)
Treatment 4 (T_4)-	NAA (10 ppm) + Urea spray (2%)
Treatment 5 (T_5)-	NAA (10 ppm) + Zinc Sulphate (0.5%) + Urea spray (2%)
Treatment 6 (T_6)-	Control as water spray

These combinations of chemicals were sprayed at two different times (mid March and mid April) on marked trees. Thus, six treatments were investigated, where all treatments were arranged in a complete block randomized design and each treatment was replicated three times with one tree per replicate. The observations were subjected to statistical analysis *i.e.* analysis of variance (ANOVA) using randomized block design[15]. The physical and chemical parameters were studied as following:

Fruit set and fruit drop

Five twigs per tree in all the direction were selected. The number of fruits per twig was counted after 15 days of full bloom to determine the initial number of fruits per twig. The initial fruit set was calculated as a percentage. After recording the initial fruit set, the number of fruits per twig was recorded at mature stage just before harvesting. The percentage of retained and dropped fruits at harvest time was calculated.

Yield (Kg/tree)

In mid May, at harvest time, the numbers of fruits per twig and per tree were counted for each treatment. Tree yield in kilograms was estimated by multiplying the number of fruits per tree and the average fruit weight.

Fruit physical and quality parameters

At harvesting time, samples of 5 firm ripe (commercial ripening stage) fruits were taken from each twig to study the average of fruit weight (g), fruit length (cm), width (cm). Total soluble solids content (TSS %), fruit acidity, TSS/Acid ratio, ascorbic acid and sugars were determined as described by A.O. A. C.[3].

RESULTS

Total fruit drop (%)

Observations of fruit drop were taken from April onwards. The maximum fruit drop was observed in the month of April followed by May (Fig). Total fruit drop was affected significantly by different treatments (Table 1). Total fruit drop 32.92% was recorded minimum with the application of T_5- NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) and was found highly significant over all other treatments and control. Maximum total fruit drop 69.91% was recorded with control. There was no significant effect found in total fruit drop with time of application of treatments. The interaction between treatments and their time of application was also found non-significant.

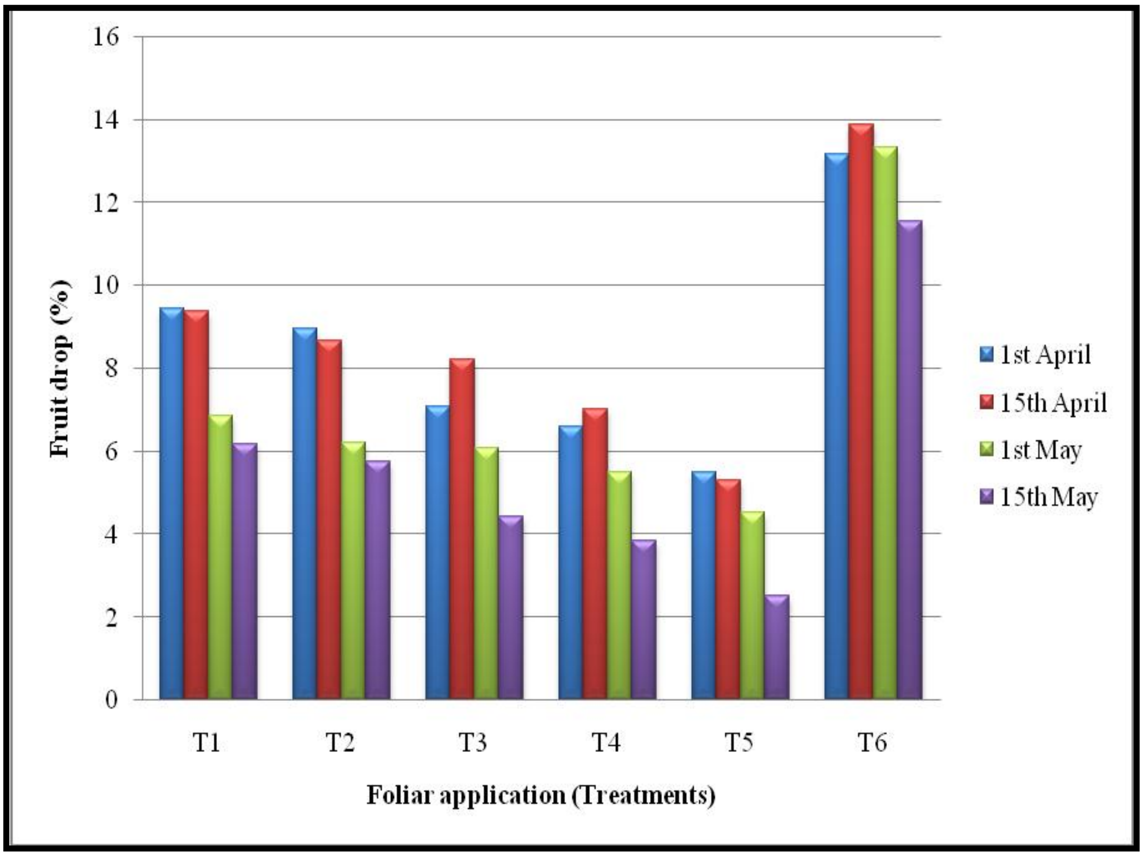

Fig: Trend of fruit drop from April to May in Japanese plum cv. Kala Amritsari

Fruit yield (kg/tree)

The fruit yield per tree was significantly affected by urea, zinc sulphate and NAA (Table 1). The maximum yield (60.26 kg/tree) was recorded with the foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) and was found statistically superior to all other treatments including control. Minimum yield (36.00 kg/tree) was recorded in control (Table 4). Fruit yield was significantly affected by the time of application of treatment. The application of the treatments during third week of April gave highest yield (50.27 kg/tree) as compared to application of the treatments during third week of March (48.51 kg/tree). There was no interaction between treatments and their time of application (Table 1).

Table 1: Effect of growth regulators and nutrient application on total fruit drop, fruit yield and weight of plum (*Prunus salicina* Lindl.)

Treatments (T)	Total fruit drop (%)			Fruit yield (kg/tree)			Fruit weight (g)		
	Time of application (A)		Mean	Time of application (A)		Mean	Time of application (A)		Mean
	3rd week of March	3rd week of April		3rd week of March	3rd week of April		3rd week of March	3rd week of April	
T_1	49.33 (44.60)	46.40 (42.92)	47.87 (43.76)	42.55	45.17	43.86	14.52	14.42	14.47
T_2	46.49 (42.96)	44.65 (41.91)	45.57 (42.43)	46.42	47.37	46.89	14.47	15.16	14.81
T_3	43.58 (41.29)	41.40 (40.02)	42.49 (40.66)	52.05	53.75	52.90	12.27	12.15	12.21
T_4	38.57 (38.35)	38.34 (38.24)	38.46 (38.29)	54.74	58.10	56.42	12.52	12.23	12.37
T_5	31.56 (34.16)	34.28 (35.82)	32.92 (34.99)	59.38	61.14	60.26	13.68	13.36	13.52
T_6	69.47 (56.44)	70.35 (56.99)	69.91 (56.72)	35.92	36.07	36.00	11.18	11.26	11.22
Mean	46.50 (42.97)	45.91 (42.65)		48.51	50.27		13.11	13.09	
C.D. ($P\leq0.05$)	T = 2.44 A= NS T x A= NS			T = 3.1 A= 1.73 T x A= NS			T = 0.42 A= NS T x A= NS		

Table 2: Effect of growth regulators and nutrient application on fruit length, breadth and volume of plum (*Prunus salicina* Lindl.)

Treatments (T)	Fruit length (cm)			Fruit breadth (cm)			Fruit volume (ml)		
	Time of application (A)		Mean	Time of application (A)		Mean	Time of application (A)		Mean
	3rd week of March	3rd week of April		3rd week of March	3rd week of April		3rd week of March	3rd week of April	
T_1	2.68	2.75	2.72	3.37	3.42	3.40	17.97	18.53	18.25
T_2	2.71	2.81	2.76	3.38	3.39	3.39	18.85	19.01	18.93
T_3	2.59	2.63	2.61	3.19	3.18	3.19	16.62	16.22	16.42
T_4	2.63	2.69	2.66	3.28	3.24	3.26	16.77	16.35	16.56
T_5	2.65	2.71	2.68	3.30	3.34	3.32	18.10	18.37	18.23
T_6	2.26	2.39	2.33	2.77	2.48	2.63	14.40	13.71	14.06
Mean	2.59	2.66		3.22	3.18		17.11	17.03	
C.D. ($P\leq0.05$)	T = 0.07 A= 0.04 T x A= NS			T = 0.18 A= NS T x A= NS			T = 0.58 A= NS T x A= NS		

The results in the Table 1 revealed that the foliar application of urea, zinc sulphate and NAA affected fruit weight significantly. The maximum fruit weight (14.81 g) was recorded with the foliar application of $ZnSO_4$ (0.5 %) + Urea (2 %) which was at par with Urea (2%). The minimum fruit weight (11.22 g) was recorded under control. This showed that urea containing treatments increased fruit weight significantly. The time of application of treatments and interaction between treatments and their time of application was not found significant.

Fruit length (cm)

The fruit length was significantly affected with respect to various treatments (Table 2). Maximum fruit length (2.76 cm) was recorded with the foliar application of $ZnSO_4$ (0.5 %) + Urea (2 %) followed by fruit length (2.72 cm) noted under the treatment Urea (2 %). The minimum fruit length (2.33 cm) was recorded under control. All the treatments showed significant increase in the fruit length as compared to control. The fruit length was significantly affected by the application time of the treatments. The maximum fruit length (2.66 cm) was recorded with foliar application during third week of April as compared to application of treatments in third week of March (Table 2). There was no interaction between treatments and their time of application.

Fruit breadth (cm)

Data presented in Table 2 revealed that the foliar application of urea, zinc sulphate and NAA affects fruit breadth significantly. Maximum fruit breadth (3.40 cm) was recorded with foliar application of Urea (2 %) followed by fruit breadth (3.39 cm) noted under the treatment $ZnSO_4$ (0.5 %) + Urea (2 %). Minimum fruit breadth (2.63 cm) was recorded under control. There was no significant difference observed in respect of fruit breadth with time of application of treatments and interaction.

Fruit volume (ml)

Data presented in Table 2 revealed that the foliar application of urea, zinc sulphate and NAA affected fruit volume significantly. Maximum fruit volume (18.93 ml) was recorded with foliar application of $ZnSO_4$ (0.5 %) + Urea (2 %). Minimum fruit volume (14.06 ml) was recorded under control. There were no significant differences in fruit volume with time of application of treatments. The interaction was also found to be non significant.

Total soluble solids (^{0}Brix)

The results depicted in Table 3 revealed that the foliar application of urea, zinc sulphate and NAA affects total soluble solids significantly. Maximum TSS (12.30 ^{0}Brix) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) which was at par with foliar application of NAA (10 ppm) + Urea (2 %). The minimum TSS (10.61 ^{0}Brix) was found under control. The total soluble solids were significantly affected by the application time of the treatments. The maximum total soluble solids (11.63 ^{0}Brix) were recorded with foliar application during third week of March as compared to application of treatments in third week of April (Table 3). There was no significant difference between treatment and their time of application.

Acidity (%)

The acidity of fruit juice is significantly affected by the foliar application of urea, zinc sulphate and NAA (Table 3). The minimum acidity (1.37%) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) which was at par with foliar application of NAA (10 ppm) + Urea (2 %), NAA (10 ppm) and $ZnSO_4$ (0.5 %) + Urea (2%).

Table 3: Effect of growth regulators and nutrient application on TSS, titratable acidity and TSS:acid ratio of plum (*Prunus salicina* Lindl.)

Treatments (T)	TSS (˚Brix)			Titratable Acidity (%)			TSS : Acid ratio		
	Time of application (A)		Mean	Time of application (A)		Mean	Time of application (A)		Mean
	3rd week of March	3rd week of April		3rd week of March	3rd week of April		3rd week of March	3rd week of April	
T_1	11.24	11.09	11.17	1.70	1.66	1.68	6.61	6.68	6.65
T_2	11.52	11.04	11.28	1.46	1.65	1.56	7.89	6.69	7.29
T_3	11.91	11.04	11.48	1.33	1.48	1.41	8.95	7.46	8.21
T_4	12.05	11.82	11.93	1.40	1.56	1.48	8.61	7.58	8.09
T_5	12.26	12.34	12.30	1.34	1.40	1.37	9.15	8.81	8.98
T_6	10.78	10.43	10.61	1.76	1.68	1.72	6.13	6.20	6.16
Mean	11.63	11.29		1.50	1.57		7.89	7.24	
C.D. (P≤0.05)	T = 0.69 A= 0.28 T x A= NS			T = 0.22 A= NS T x A= NS			T = 0.83 A= 0.45 T x A= NS		

Table 4: Effect of growth regulators and nutrient application on ascorbic acid, total and reducing sugars of plum (*Prunus salicina* Lindl.)

Treatments (T)	Ascorbic acid (mg/100g)			Total sugars (%)			Reducing sugars (%)		
	Time of application (A)		Mean	Time of application (A)		Mean	Time of application (A)		Mean
	3rd week of March	3rd week of April		3rd week of March	3rd week of April		3rd week of March	3rd week of April	
T_1	2.81	2.50	2.66	8.10	8.08	8.09	6.32	6.29	6.31
T_2	3.09	3.00	3.05	8.23	8.25	8.24	6.35	6.38	6.37
T_3	2.78	2.35	2.56	8.31	8.24	8.28	6.37	6.43	6.40
T_4	4.04	3.74	3.89	8.29	8.31	8.30	6.38	6.48	6.43
T_5	4.71	4.33	4.52	8.33	8.29	8.32	6.49	6.43	6.46
T_6	2.21	2.14	2.18	8.15	8.13	8.14	6.32	6.28	6.30
Mean	3.27	3.01		8.24	8.22		6.37	6.38	
C.D. (P≤0.05)	T = 0.42 A= 0.25 T x A= NS			T = 0.06 A= NS T x A= NS			T = 0.05 A= 0.45 T x A= 0.06		

The maximum acidity (1.87%) was found in control. No significant difference of time of application was observed. The interaction between treatments and their time of application was also found non-significant.

TSS : Acid ratio

The TSS:Acid ratio of fruit juice is significantly affected by the foliar application of urea, zinc sulphate and NAA (Table 11). The maximum ratio (8.98) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) followed by the foliar application of NAA (10 ppm) + Urea (2 %) and NAA (10 ppm) and minimum ratio (6.16) was found in control. The TSS:Acid ratio was significantly affected by the application time of the treatments. The maximum TSS:Acid ratio 7.89) was recorded with foliar application during third week of March as compared to application of treatments in third week of April (Table 3).

Ascorbic acid (mg/100g pulp)

Ascorbic acid content of fruit juice was significantly affected by the foliar application of urea, zinc sulphate and NAA. Maximum ascorbic acid content (4.52 mg/100g pulp) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) which was statistically superior to all other treatments (Table 12). Minimum ascorbic acid content (2.18 mg/100g pulp) was observed under control. The ascorbic acid content was significantly affected by the application time of the treatments. The maximum ascorbic acid content (3.27 mg/100g pulp) was recorded with foliar application during third week of March as compared to application of treatments in third week of April (Table 4). There was no interaction with treatments and their time of application.

Total sugars (%)

Total sugars of fruit were significantly affected by the foliar application of urea, zinc sulphate and NAA (Table 13). Maximum total sugars (8.32%) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) which was statistically at par with NAA (10 ppm) + Urea (2 %) and NAA (10 ppm). A minimum total sugar (8.09%) was observed with Urea (2 %). There was no significant difference in total sugar with time of application of treatments. There was no interaction between treatments and their time of application.

Reducing sugars (%)

Reducing sugars of fruit were significantly affected by the foliar application of urea, zinc sulphate and NAA. Maximum reducing sugars (6.46%) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) which was at par with the foliar application of NAA (10 ppm) + Urea (2 %) (Table 14) and minimum (6.28%) was recorded in control. There was no significant effect of time of application on reducing sugars but the interaction between foliar treatments and their time of application was observed significant, where the maximum reducing sugars were found with NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) application in during third week of March and minimum was found in control.

DISCUSSION

The foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) which was at par with the foliar application of NAA (10 ppm) + Urea (2 %) was found effective to minimize the fruit drop. The decrease in fruit drop in this study by the application of nutrient and growth regulator might be due to fulfillment in deficiency of endogenous auxin preventing the formation of abscission layer possibly through the inhibition of enzymatic activity such as pectinase[6,8.19]. Similar results were found when NAA was used efficiently controlling the pre-harvest fruit drop in plum cv. Satluj Purple as it has been reported by Singh[20]. The decrease in fruit drop by the application of NAA in combination with nutrients is possibly because the spray of NAA might have improved the internal physiology of developing fruits in terms of better supply of water, nutrients and other compounds vital for their proper growth and development[7,14]. Foliar spray of nitrogen application in form of urea might have increased the retention of the fruits by reducing the competition for nitrogen among immature fruits. Nitrogen and zinc are essential for synthesis of auxin which is vital for normal fruit growth and retention of the fruits on the trees. The results cited above are in agreement with those of Gill and Bal[8], who also obtained reduced drop with application of zinc and NAA in ber, Akhlaghi Amiri *et al*.[2] and Ghosh *et al*.[7]

Foliar application of urea, zinc sulphate and NAA decreased fruit drop and increased fruit weight, number of fruits and yield per tree over the control. Out of various combinations of urea, zinc sulphate and NAA foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %) gave maximum yield. Improvement in yield by application of micro-nutrients and plant bio regulators might be attributed to reduction in fruit drop and better availability of nutrients and growth regulators particularly the auxin, which plays an important role in fruit growth development[18]. It is reported that zinc and nitrogen applications in ber had increased fruit retention, which might have resulted into more number of fruits to reach harvest stage. Increase in yield might also be attributed to increase in the final number of fruits and reduced abscission. The significant effect of zinc sulphate in increasing fruit yield might be due to increased auxin synthesis[11]. Maibangsa and Ahmed[10] reported that auxin and GA treated pineapple fruits were heavier. This might be due to acceleration of cell division with subsequent elongation and enlargement of the cells. The application of NAA and GA_3 at pea size stage of ber fruits had probably improved the internal physiology of leaves thereby causing better translocation of vital components in fruit development and assimilation as well as utilization of photosynthates in developing fruits leading to improved quality in terms of pulp, TSS, total acid and ascorbic acid content of fresh ripe fruits. Increase in pulp TSS, total acid and ascorbic acid content of ber fruits has been observed by Gill and Bal[8] with the spray of NAA. Zinc treatment increases the fruit size due to synthesis of auxins and nitrogen increases the size of fruit because it is an important constituent for chlorophyll synthesis, hence both N and Zn increases fruit weight[4,5,6,16&17]. Positive effects of Zn on fruit size and volume is probably because of the roles of Zn played in photosynthesis through increasing chlorophyll biosynthesis and carotenoids[12].

The results obtained during present investigation demonstrated that maximum TSS (12.30 ^{0}Brix) was recorded with foliar application of NAA (10 ppm) + $ZnSO_4$ (0.5 %) + Urea (2 %). The increase in TSS value may be due to hormones directed translocation of sugars to the fruits and increase in the alpha-amylase activity, which caused conversion of starch into sugars. The increase in the total soluble solids as a result of urea and zinc sprays might be ascribed to increased photosynthesis and production of more assimilates due to auxin synthesis. The similar treatment also reduced titratable acidity of fruits to minimum. Reduced acidity in nutrient treated fruits might be due to increase in total soluble solids at the expense of acid content. The acids under the influence of nutrients might have been converted into sugars and their derivative by the reaction involving the reversal of glycolytic pathway[13,23]. Treatment-5 followed by Treatment-4 increased the sugar content of fruits as compared to control. 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 sugar in fruits. The results were in accordance with Singh *et al*.[21] that micronutrients (0.5% $ZnSO_4$) and plant growth regulators (10 ppm NAA) increased ascorbic acid in aonla fruit, Chander *et al.*[6] in kinnow, Ozkan *et al*.[14] in apples and Singh *et al*.[22] in ber.

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