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Effect of NAA and zinc sulphate application on fruit drop, yield and quality attributes of mulberry (*Morus alba* L.)

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Abstract
The investigation entitled "Effect of NAA and zinc sulphate application on fruit drop, yield and quality attributes of mulberry (*Morus alba* L.)" was conducted during 2018-19. The foliar application of different concentrations of zinc sulphate (0.2, 0.4 and 0.6%) and NAA (20, 40 and 60 ppm). Significantly improved in fruit set and fruit retention (per cent). The maximum was recorded from the trees treated with zinc sulphate @ 0.4 per cent and NAA @ 60 ppm. Significantly increase in yield parameters and total yield per tree was observed in the fruits harvested from the trees treated with zinc sulphate (0.4% and 0.6%) and NAA @ 60 ppm. Significantly improved in quality parameters was observed in the fruits harvested from the trees treated with zinc sulphate @ 0.4 per cent and NAA @ 40 ppm, while acidity was minimum with zinc sulphate @ 0.4 per cent and NAA @ 40 ppm.

Keywords: Foliar spray, mulberry**,** NAA, quality, yield and zinc sulphate

Introduction
Mulberry is an important minor fruit crop belongs to the genus *Morus* under Moraceae family and Asia is considered to be the centre of origin of mulberry. It is originally a temperate fruit crop but it can be widely grown in both tropical and sub-tropical zone with of maximum 90% area in tropical zone (Datta, 1999) [8]. Commonly mulberry is extensively cultivated in plains and hilly areas and can be grown in several soil conditions up to an elevation of 3300 m above mean sea-level. It requires temperature ranging from 24 ^{0}C to 37 ^{0}C (Chattopadhyay, 1997) [5]. The total acreage of mulberry in India is around 2.82 lakh hectare and for different states, Karnataka has 1.66 lakh hectare which is a leading state in area and production in mulberry followed by Andhra Pradesh, Manipur, West Bengal, Tamil Nadu, Uttar Pradesh, Jammu and Kashmir, Assam, Madhya Pradesh and Kerala (Saroj and Awasthi, 2006) [28].
Mulberry is a multipurpose fruit tree, mostly cultivated for rearing silkworm, useful timber and in few areas used for roadside plantation but its importance, as a fruit crop should also not be undermined. There are about 100 species of the genus *Morus*, the majority of them occur in Asia, especially 24 species in China and 19 species in Japan. Several species of mulberry (*Morus alba, Morus indica, Morus nigra, Morus serrata* and *Morus lavigata*) are grown in India. (Datta, 1999) [8].
It is considered to be one of the equisite, nutritionally, medicinally and industrially valuable fruit trees beside its high industrial value. It bears heavy crop every year and gives grace economic returns involving little inputs (Saroj and Awasthi, 2006) [28]. Mulberry is a fast growing deciduous woody perennial plant and it has a deep-root system. It sheds its leaves in December-January under Haryana conditions. Blooming period starts from February onwards followed by fruit set and fruit development.
NAA is a most important growth regulator of auxin group, which reduces the fruit drop and improve fruit set and quality specially TSS (Sharma and Tiwari, 2015) [31]. Zinc plays a vital role in enzyme activities and Zinc acts as a catalyser in the oxidation and reduction process and is also of great importance in sugar metabolism (Sharma and Tiwari, 2015) [31]. NAA and zinc sulphate are reported to be effective in fruit drop control and quality improvement in several fruit crops, however limited information is available in the present agro climate conditions of Haryana with respect to mulberry.

Materials and Methods
This experiment was conducted during 2018-19, on uniform fruiting mulberry orchard of Local cultivar planted at the spacing of 10X10 m.

The experiment was carried out at experimental orchard and Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana. Experimental orchard is situated at 215.2 m above mean sea level at 29º 10' N latitude and 75º 46' E longitudes. A large variation occurs for total annual rainfall and its distribution throughout the year. The average rainfall of this area is around 450 mm, 75-80 per cent of which is received during rainy season, *i.e*., July to September, while a few occasional rainfall also occur during the months from December to February due to western disturbances. During summer months of May and June, the temperature reaches maximum up to 48°C while during winter months of December and January, the minimum temperature comes down to the freezing point. The experiment was laid out in a Factorial RBD with two replication and sixteen treatments these are of Comprises combined foliar sprays of Naphthalene acetic acid at 20, 40 and 60 ppm along with zinc sulphate at 0.2, 0.4 and 0.6% and control. The plant growth regulator and micronutrients were combine sprayed at two times. First spray was carried in the first week of March and second spray in last week of March after first spray.

Visual observations for position of No of catkins, fruit set (%) and fruit drop (%) were observed from five bearing shoots of uniform size and vigour were tagged, one in each directions i.e. North, East, South, West and one in Centre. These shoots were tagged before first spray. The number of catkins/shoot were counted before and after foliar spray and average value was computed as number of catkins per shoot. The fruit set on tagged shoots was calculated by dividing the number of fruits set to total number of flowers on tagged shoots in all the directions and calculated the average value. The number of fruits finally retained per shoot were recorded and per cent fruit drop was calculated on the basis of total number of fruit set and total number of fruits at harvest time per shoot.

The fruits were plucked up when they were matured and counted separately for each experimental tree. The fruits were harvested at different picking and number of fruits per plant was recorded. Five randomly selected fruits from each treatment were taken and length was measured with the help of centimetre scale and average fruit length were calculated and expressed in centimetre, fruit breadth was measured with the help of Vernier Callipers and the average value was taken and expressed in centimetre, weight of individual fruit was recorded on electronic balance and average weight of all the five fruits was computed in gram. The picked fruits from each experimental tree were weighed immediately after harvesting and yield per tree was recorded in kg per tree and later as computed in tonnes per hectare.

For determination of chemical parameters of fruit *viz*. acidity, total soluble solids (TSS), ascorbic acid and sugars. Ten healthy fruits were selected randomly from each tree at full maturity stage. Hand refractometer was used for determination of T.S.S. in ^{0}Brix. Acidity and ascorbic acid were estimated by standard titration method (A.O.A.C., 2000) [1]. Method given by Hulme and Narain (1993) [17] was followed for estimation of sugars.

Results and Discussion

Flowering and fruiting parameters

The present study exhibited in table-1 that there was significant improvement in the number of catkins/shoot with the foliar applications of zinc sulphate and NAA and maximum number of catkins per shoot was observed under foliar spray of $ZnSO_4$ @ 0.4 per cent (126.73) followed by $ZnSO_4$ @ 0.6 per cent (124.82). However, Maximum number of catkins/shoot was found with the foliar spray of NAA @ 60 ppm (124.82) which was at par with NAA @ 40 ppm (124.86). Interaction results were found significant and maximum number of catkins/shoot was recorded with the combination of $ZnSO_4$ @ 0.4 per cent + NAA @ 60 ppm (135.62) which was at par with $ZnSO_4$ @ 0.6 per cent + NAA @ 60 ppm (133.06) and $ZnSO_4$ @ 0.6 per cent + NAA @ 40 ppm (131.37) and $ZnSO_4$ @ 0.4 per cent + NAA @ 40 ppm (130.34) and $ZnSO_4$ @ 0.4 per cent + NAA @ 20 ppm (129.15). The increase in number of catkins/shoot due to zinc application might be attributed to the improvement in vegetative growth of plants as well as efficient transfer of photosynthates to the economic part of the plant (Dutta, 2011) [10]. NAA seems to help in enhancing the number of catkins/shoot either by promoting the growth of pollen tubes or by improving pollen germination and hereby facilitate in proper fertilization before the stigma looses its receptivity and thus directly related to retention of catkins on the shoot (Arshad and Ali 2016) [2]. The results of the present investigation are in consonance with the findings of Singh *et al.* (2015a) [32] in mango, Tagad *et al.* (2018) [36] in acid lime and Chauhan *et al.* (2019) [7] in litchi.

Table 1: Effect of NAA and zinc sulphate on number of catkins/shoot in mulberry

Micro-nutrient spray	**Total number of catkins/shoot**				
	Growth regulator spray (NAA)				
	0 ppm	**20 ppm**	**40 ppm**	**60 ppm**	**Mean**
Zinc sulphate 0%	90.56	100.10	124.18	115.08	107.48
Zinc sulphate 0.2%	101.50	120.77	113.55	121.37	114.29
Zinc sulphate 0.4%	111.83	129.15	130.34	135.62	126.73
Zinc sulphate 0.6%	118.02	116.84	131.37	133.06	124.82
Mean	105.47	116.71	124.86	126.28	
CD at 5%	Zn = 4.23, NAA = 4.23, Zn x NAA = 8.46				

Table 2: Effect of NAA and zinc sulphate on initial fruit set (%) in mulberry

Micro-nutrient spray	**Initial fruit set (%)**				
	Growth regulator spray (NAA)				
	0 ppm	**20 ppm**	**40 ppm**	**60 ppm**	**Mean**
Zinc sulphate 0%	63.02	69.16	68.87	64.48	66.38
Zinc sulphate 0.2%	64.38	67.05	65.33	72.21	67.24
Zinc sulphate 0.4%	66.03	71.31	73.18	74.07	71.15
Zinc sulphate 0.6%	65.05	70.04	70.65	71.94	69.42
Mean	64.62	69.39	69.51	70.68	
CD at 5%	Zn = 3.04, NAA = 3.04, Zn x NAA = NS				

A perusal of data in table 2 and 3 shows that significant response in the maximum fruit set was recorded under $ZnSO_4$ @ 0.4 per cent (71.15%) followed by $ZnSO_4$ @ 0.6 per cent (69.42%) but fruit retention was significantly higher with $ZnSO_4$ @ 0.4 per cent (43.81%). However, fruit set was observed maximum with the foliar application of NAA @ 60 ppm (70.68%) followed by NAA @ 40 ppm (69.51%) and NAA @ 20 ppm (69.39%) but fruit retention was significantly higher with NAA @ 60 ppm (39.77%). Interaction result of fruit retention was observed maximum with combined spray of $ZnSO_4$ @ 0.4 per cent + NAA @ 60 ppm (47.26%). This might be due to combined effect of NAA and zinc sulphate in increasing photosynthetic efficiency of plant through which the increased number of fruit were nursed properly and increasing fruit retention. Likewise, these results are confirmatory with the earlier findings of Ghosh *et al.* (2009a) [13] in pomegranate cv. Ruby, Patel *et al.* (2018) [24] and Jangid *et al*. (2018) [18] in aonla, Yadav *et al*. (2017) [39], Sau *et al*. (2018) [29] and Tirkey *et al*. (2018) [37] in guava, Sahay *et al*. (2018) [27] and Chauhan *et al*. (2019) [7] in litchi and Nartvaranant (2018) [21] in pummelo.

Table 3: Effect of NAA and zinc sulphate on fruit drop (%) in mulberry

Micro-nutrient spray	Fruit drop (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	72.7	67.1	67.0	69.2	69.0
Zinc sulphate 0.2%	68.7	65.7	67.5	62.3	66.0
Zinc sulphate 0.4%	60.8	56.7	54.6	52.7	56.2
Zinc sulphate 0.6%	59.8	60.8	59.3	56.7	59.1
Mean	65.5	62.6	62.1	60.2	
CD at 5%	Zn = 0.9, NAA = 0.9, Zn x NAA = 1.8				

Analysis of data clearly indicates in table-4 shows that fruit drop was found to be significantly minimum with the foliar application of $ZnSO_4$ @ 0.4 per cent (56.2%). However, fruit drop was minimum observed with the foliar application of NAA @ 60 ppm (60.2%). Interaction result was found significantly minimum by the combination of $ZnSO_4$ @ 0.4 per cent + NAA @ 60 ppm (52.7%). Zinc promotes the fruit retention because zinc stimulates the bio-synthesis of endogenous auxin which inhibit the abscission and facilitate the ovary to remain adjoining with the shoot resulting in reduced fruit drop. The decreases in fruit drop due to the application of an exogenous growth-regulator (NAA) might be attributable to the balance in the concentrations of endogenous hormones. These work was supported by the findings of Gill and Bal (2013) [14] in Indian jujube, and Patel *et al*. (2018) [24] in aonla, Sau *et al*. (2018) [29] in guava, Sahay *et al*. (2018) [74] and Chauhan *et al*. (2019) [7] in litchi.

Table 4: Effect of NAA and zinc sulphate on fruit retention in mulberry

Micro-nutrient spray	Fruit retention (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	27.33	32.93	32.97	30.78	31.00
Zinc sulphate 0.2%	31.33	34.28	32.54	37.71	33.96
Zinc sulphate 0.4%	39.24	43.35	45.37	47.26	43.81
Zinc sulphate 0.6%	40.20	39.23	40.73	43.32	40.87
Mean	34.53	37.45	37.90	39.77	
CD at 5%	Zn = 0.78, NAA = 0.78, Zn x NAA = 1.56				

Yield parameters

The results present in table-5 shows that the significantly longer fruits was found with the foliar application of $ZnSO_4$ @ 0.4 per cent (5.64 cm) followed by $ZnSO_4$ @ 0.6 per cent (5.60 cm). However, fruit length was observed maximum with NAA @ 60 ppm (5.52 cm) treatment.

Table 5: Effect of NAA and zinc sulphate on average fruit length (cm) in mulberry

Micro-nutrient spray	Average fruit length (cm)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	4.46	4.91	4.83	4.94	4.78
Zinc sulphate 0.2%	4.90	5.28	5.02	5.30	5.13
Zinc sulphate 0.4%	5.34	5.45	5.75	6.04	5.64
Zinc sulphate 0.6%	5.39	5.71	5.50	5.81	5.60
Mean	5.02	5.34	5.27	5.52	
CD at 5%	Zn = 0.16, NAA = 0.16, Zn x NAA = NS				

The increase in length of fruit may be that higher level of mineral nutrients (zinc) seems to have direct contribution in hastening the process of cell division and cell elongation due to which size of fruits would have increased. The fast growth of the fruit synchronized with the higher amount of auxin present therein and endogenous auxin is accountable for increasing fruit length in mulberry. Earlier such results were reported by Jangid *et al*. (2018) [18] in aonla, Yadav *et al*. (2017) [39] and Sau *et al*. (2018) [29] in guava and Sahay *et al*. (2018) [27] in litchi.

The present study reveals from table-6 shows that the significantly increased fruit breadth was recorded maximum with the foliar application of $ZnSO_4$ @ 0.4 per cent (0.86 cm) followed by $ZnSO_4$ @ 0.6 per cent (0.85 cm) and $ZnSO_4$ @ 0.2 per cent (0.84 cm). However, fruit breadth was found maximum with the foliar spray of NAA @ 40 ppm (0.85 cm) and NAA @ 60 ppm (0.85 cm) which was at par with NAA @ 20 ppm (0.84 cm).

The enlargement in fruit breadth may be that higher level of zinc caused by drawing of photosynthates as account of intensification of the sink. The enhancement in fruit breadth was due to accelerated rate of cell division and cell enlargement and lots of intercellular space with the application of higher levels of growth substances (NAA). Similar observations were recorded by Mishra *et al*. (2017) [6], Patel *et al*. (2018) [24] and Jangid *et al*. (2018) [18] in aonla, Yadav *et al*. (2017) [39] and Singh *et al*. (2017a) [34] in guava and Sahay *et al*. (2018) [27] in litchi.

Table 6: Effect of NAA and zinc sulphate on fruit breadth (cm) in mulberry

Micro-nutrient spray	Average fruit breadth (cm)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	0.80	0.82	0.83	0.83	0.82
Zinc sulphate 0.2%	0.83	0.84	0.84	0.85	0.84
Zinc sulphate 0.4%	0.84	0.86	0.88	0.87	0.86
Zinc sulphate 0.6%	0.85	0.86	0.84	0.86	0.85
Mean	0.83	0.84	0.85	0.85	
CD at 5%	Zn = 0.02, NAA = 0.02, Zn x NAA = NS				

The results of the present investigation exhibited in table-7 that there was significant increases in fruit weight was obtained with the foliar application of $ZnSO_4$ @ 0.4 per cent (3.02 g). However, fruit weight was reported maximum by foliar application of NAA @ 60 ppm (2.92 g) which was at par with NAA @ 40 ppm (2.92 g). Results of interaction was recorded significantly higher with the combined spray of $ZnSO_4$ @ 0.4 per cent + NAA @ 40 ppm (3.32 g). An increase in weight of fruit caused by accumulation of sugar and high juice per cent in zinc treated fruits. The increment in fruit weight due to foliar application of NAA might be due to the fact that NAA may have induced the auxin concentrations in the fruits which finally helped in the development of fruits as there is a perceptible correlation between the auxin content and fruit growth (Ram and Bose, 2000) [26].

These findings are in close agreement with the results of Sau *et al*. (2018) [29] and Hada *et al*. (2018) in guava, Bhatt *et al*. (2016) [4] and Bhatt *et al*. (2017) [3] in lemon and Sahay *et al*. (2018) [27] in litchi.

The data pertaining to yield of mulberry as presented in table-8 clearly indicated that the significantly increase in yield was found with the foliar spray of $ZnSO_4$ @ 0.6 per cent (26.33 kg/tree) followed by $ZnSO_4$ @ 0.4 per cent (26.23 kg/tree).

Table 7: Effect of NAA and zinc sulphate on average fruit weight (g) in mulberry

Micro-nutrient spray	Average fruit weight (g)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	2.21	2.68	3.03	2.42	2.58
Zinc sulphate 0.2%	2.40	2.83	2.68	2.90	2.70
Zinc sulphate 0.4%	2.74	2.96	3.05	3.32	3.02
Zinc sulphate 0.6%	2.87	2.84	2.90	3.03	2.91
Mean	2.56	2.83	2.91	2.92	
CD at 5%	Zn = 0.08, NAA = 0.08, Zn x NAA = 0.16				

Table 8: Effect of NAA and zinc sulphate on fruit yield (kg/tree) in mulberry

Micro-nutrient spray	Fruit yield (kg/tree)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	23.60	24.75	25.81	24.15	24.58
Zinc sulphate 0.2%	25.10	25.75	25.40	25.61	25.46
Zinc sulphate 0.4%	25.62	26.05	25.90	27.35	26.23
Zinc sulphate 0.6%	25.30	26.90	26.00	27.10	26.33
Mean	24.90	25.86	25.78	26.05	
CD at 5%	Zn = 0.31, NAA = 0.31, Zn x NAA = 0.63				

However, yield was observed maximum by the foliar application of NAA @ 60 ppm (26.05 kg/tree) which was at par with NAA @ 20 ppm and NAA @ 40 ppm (25.86 kg/tree). The interaction effect was found significant on yield and found higher yield was observed by the combined spray of $ZnSO_4$ @ 0.4 per cent + NAA @ 60 ppm (27.35 kg/tree) which was at par with $ZnSO_4$ @ 0.6 per cent + NAA @ 60 ppm and $ZnSO_4$ @ 0.6 per cent + NAA @ 20 ppm (27.10 kg/tree). Zinc helps in translocation of metabolites from source to sink which enhance to retention of more number of fruits on tree (Gurjar and Rana, 2014) [15]. NAA could be due to higher mobilization of minerals and food from one part to other parts of the plant towards the developing fruits that are most active metabolic sink, secondly, rises in weight and increases size (Gami *et al.*, 2019). This increasing trend is in close agreement with the results of Patel *et al.* (2018) [24] and Jangid *et al.* (2018) [18] in aonla. Dhakar *et al.* (2017) [9] and Sau *et al.* (2018) [29] in guava, Neware *et al.* (2017) [22] in sweet orange and Sahay *et al.* (2018) [27] in litchi.

Quality parameters

The findings of the study exhibited in table-9 that there was significant decline in the fruit acidity (0.13%) with the foliar applications of $ZnSO_4$ @ 0.4 per cent and $ZnSO_4$ @ 0.6 per cent treatment. However, acidity was decline with foliar spray of NAA @ 40 ppm (0.13%). Acidity was decreased in fruit juice when there was treated with micronutrient might be due to their exploitation in respiration and fast metabolic transformation of organic acids into sugar.

Table 9: Effect of NAA and zinc sulphate on acidity (%) in mulberry

Micro-nutrient spray	Acidity (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	0.17	0.16	0.15	0.15	0.16
Zinc sulphate 0.2%	0.16	0.15	0.14	0.14	0.15
Zinc sulphate 0.4%	0.13	0.13	0.12	0.13	0.13
Zinc sulphate 0.6%	0.14	0.14	0.12	0.13	0.13
Mean	0.15	0.14	0.13	0.14	
CD at 5%	Zn = 0.01, NAA = 0.01, Zn x NAA = NS				

Acidity is reduced by the foliar application of NAA due to it helps in inhibiting excessive polymerization of sugar and accumulation of more sugar in the cells of plant (Gaur *et al.*, 2014) [11]. Similar findings were reported by Yadav *et al.* (2018) [38], Sau *et al.* (2018) [29] and Hada *et al.* (2018) [16] in guava, Patel *et al.* (2018) [24] and Chaudhary *et al.* (2018) [6] in aonla.

It is clear from the data presented in table-10 that TSS content was found maximum (26.26%) with $ZnSO_4$ @ 0.4 per cent. However, TSS content was found maximum with the foliar spray of NAA @ 40 ppm (25.39%) followed by NAA @ 60 ppm (25.34%). The interaction results was found significantly maximum with the combined spray of $ZnSO_4$ @ 0.4 per cent + NAA @ 40 ppm (27.20%) followed by $ZnSO_4$ @ 0.4 per cent + NAA @ 60 ppm (26.95%) and $ZnSO_4$ @ 0.6 per cent + NAA @ 40 ppm (26.90%) and $ZnSO_4$ @ 0.6 per cent + NAA @ 60 ppm (26.84%).

This might be attributed to the fact that zinc is credited with certain contribution in the hydrolysis of complex polysaccharides into simple sugar, synthesis of metabolites and fast translocation of photosynthetic produces and minerals from one part to other parts of the plant to the developing fruits. The rises in TSS content might be due to auxin synthesis which in turn enhanced synthesis of metabolites and their fast translocation from one part to other parts of plants toward developing fruits.

The findings of the present study are in accordance with the results of Patel *et al.* (2018) [24], Jangid *et al.* (2018) [18] and Chaudhary *et al.* (2018) [6] in aonla. Dhakar *et al.* (2017) [9], Singh *et al.* (2017a) [34], Yadav *et al.* (2018) [38] and Hada *et al.* (2018) [16] in guava.

Table 10: Effect of NAA and zinc sulphate on TSS (%) in mulberry

Micro-nutrient spray	Total Soluble Solids (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	22.40	23.20	23.55	23.30	23.11
Zinc sulphate 0.2%	23.55	24.10	23.90	24.26	23.95
Zinc sulphate 0.4%	24.60	26.30	27.20	26.95	26.26
Zinc sulphate 0.6%	24.40	25.69	26.90	26.84	25.96
Mean	23.74	24.82	25.39	25.34	
CD at 5%	Zn = 0.24, NAA = 0.24, Zn x NAA = 0.48				

It is quite evident from table-11 that TSS/acid ratio was observed significantly maximum (206.38) when experimental trees received $ZnSO_4$ @ 0.4 per cent. However, maximum TSS/acid ratio (194.64) was obtained with foliar application of NAA @ 40 ppm. The interaction was found significantly maximum by the combined application of $ZnSO_4$ @ 0.4 per cent + NAA @ 40 ppm (226.67) followed by $ZnSO_4$ @ 0.6 per cent + NAA @ 40 ppm (224.17). A successive decrease in acid content and consistent rise in TSS reflected into an increase in TSS/acid ratio. It might be due to that the enhanced sugar and decreased leaf starch content which was due to profuse transformation of starch into sugar and its translocation into the fruits. Similar results were founded by Rajput *et al.* (2017) [25] in plum, Singh *et al.* (2017b) [35] in pomegranate, Hada *et al.* (2018) [16] in guava and Gami *et al.* (2019) [12] in ber.

A perusal of data in table-12 shows that significant increment in ascorbic acid was obtained with the foliar spray of $ZnSO_4$ @ 0.4 per cent (18.52 mg/100 ml) which was at par with $ZnSO_4$ @ 0.6 per cent (18.45 mg/100 ml).

Table 11: Effect of NAA and zinc sulphate on TSS/acid ratio in mulberry

Micro-nutrient spray	TSS/acid ratio				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	131.76	145.00	157.00	155.33	147.27
Zinc sulphate 0.2%	147.19	160.67	170.71	173.29	162.96
Zinc sulphate 0.4%	189.23	202.31	226.67	207.31	206.38
Zinc sulphate 0.6%	174.29	183.50	224.17	206.46	197.10
Mean	160.62	172.87	194.64	185.60	
CD at 5%	Zn = 2.30, NAA = 2.30, Zn x NAA = 4.59				

Table 12: Effect of NAA and zinc sulphate on ascorbic acid (mg/100 ml of juice) in mulberry

Micro-nutrient spray	Ascorbic Acid (mg/100 ml of juice)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	13.50	14.23	14.95	14.86	14.38
Zinc sulphate 0.2%	14.66	15.25	16.32	15.96	15.55
Zinc sulphate 0.4%	17.01	18.37	19.44	19.27	18.52
Zinc sulphate 0.6%	17.38	18.17	19.14	19.10	18.45
Mean	15.64	16.50	17.46	17.29	
CD at 5%	Zn = 0.16, NAA = 0.16, Zn x NAA = 0.31				

However, maximum ascorbic acid was obtained with NAA @ 40 ppm (17.46 mg/100 ml). The interaction results was noticed significantly maximum with the combined application of $ZnSO_4$ @ 0.4 per cent + NAA @ 40 ppm (19.44 mg/100 ml) which was statistically at par with $ZnSO_4$ @ 0.4 per cent + NAA @ 60 ppm (19.27 mg/100 ml) and $ZnSO_4$ @ 0.6 per cent + NAA @ 40 ppm (19.14 mg/100 ml). The higher ascorbic acid concentrations during early states of fruit growth might be attributed to proper supply of hexose sugar via photosynthetic activity when increases on spray of micronutrient ($ZnSO_4$). The higher levels of growth regulator (NAA) enhance the ascorbic acid content in fruit. It might be due to the possible catalytic impact of these growth regulators on synthesis of ascorbic acid from sugar or prevention of oxidative enzymes or both. The work of the present study are in close agreement with the findings of Jangid *et al.* (2018) [18], Chaudhary *et al.* (2018) [6] and Patel *et al.* (2018) [24] in aonla. Singh *et al.* (2015b) [33] in phalsa, Yadav *et al.* (2018) [38], Sau *et al.* (2018) [29] and Hada *et al.* (2018) [16] in guava and Bhatt *et al.* (2017) [3] in lemon. The examined data presented in table-13 shows that reducing sugar significantly higher with the foliar spray of $ZnSO_4$ @ 0.4 per cent (3.60%) which was at par with $ZnSO_4$ @ 0.6 per cent (3.57%). However, maximum reducing sugar (3.61%) was observed with the foliar spray of NAA @ 40 ppm. The interaction was found significantly between different doses of $ZnSO_4$ and NAA which was maximum (3.72%) with the combined spray of $ZnSO_4$ @ 0.4 per cent + NAA @ 40 ppm which was at par on $ZnSO_4$ @ 0.6 per cent + NAA @ 60 ppm (3.70%) and $ZnSO_4$ @ 0.6 per cent + NAA @ 40 ppm (3.68%).

Table 13: Effect of NAA and zinc sulphate on reducing sugar (%) in mulberry

Micro-nutrient spray	Reducing sugars (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	3.40	3.42	3.45	3.43	3.42
Zinc sulphate 0.2%	3.42	3.42	3.58	3.44	3.46
Zinc sulphate 0.4%	3.57	3.55	3.72	3.58	3.60
Zinc sulphate 0.6%	3.34	3.57	3.68	3.70	3.57
Mean	3.43	3.49	3.61	3.54	
CD at 5%	Zn = 0.05, NAA = 0.05, Zn x NAA = 0.09				

The increased trends in the reducing sugar concentration was possibly due to the cause that the zinc encourages hydrolysis of sugar. The probable reason might be that the growth regulator (auxin) increases hydrolysis of starch into sugar or decreases competition between the fruits for metabolites. Under the effect of growth regulator, the amino acids might have been sharp converted into sugar (Gami *et al.*, 2019) [12]. These outcomes are in close agreement with the results of Patel *et al.* (2018) [24], Jangid *et al.* (2018) [18] and Chaudhary *et al*. (2018) [6] in aonla, and Yadav *et al*. (2018) [38] in guava.
The results of present investigation exhibited in table-14 that the significant enhancement in total sugar was observed with the foliar application of $ZnSO_4$ @ 0.4 per cent (9.96%) which was at par with $ZnSO_4$ @ 0.6 per cent (9.94%). However, maximum total sugar (9.89%) was observed with NAA @ 40 ppm treatment which was at par with NAA @ 60 ppm (9.80%). The possible reason might be due to the facts that zinc and NAA are helpful in the process of photosynthesis which leads to the accumulations of oligosaccharides and polysaccharides in higher amount besides this also regulators the enzymatic activity and the enzymes that metabolize the carbohydrates into simple sugars. Likewise, Chaudhary *et al*. (2018) [6] in aonla. Yadav *et al*. (2018) [38] and Sau *et al*. (2018) [29] in guava, Sharma and Belsare (2011) [30] in pomegranate, Pandey *et al*. (2012) [23] in ber, Singh *et al*. (2015b) [33] and Kumar and Saravanan (2017) [19] in phalsa.

Table 14: Effect of NAA and zinc sulphate on total sugar (%) in mulberry

Micro-nutrient spray	Total sugars (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	9.20	9.36	9.48	9.43	9.37
Zinc sulphate 0.2%	9.40	9.58	9.70	9.62	9.57
Zinc sulphate 0.4%	9.78	9.91	10.18	9.98	9.96
Zinc sulphate 0.6%	9.55	9.86	10.22	10.16	9.94
Mean	9.48	9.68	9.89	9.80	
CD at 5%	Zn = 0.10, NAA = 0.10, Zn x NAA = NS				

It is clear from the data exhibited in table-15 shows that non-reducing sugar was found maximum (6.38%) with the foliar application of $ZnSO_4$ @ 0.6 per cent which was at par with $ZnSO_4$ @ 0.4 per cent (6.36%). However, maximum non-reducing sugar (6.29%) was observed with foliar spray of NAA @ 40 ppm which was at par with NAA @ 60 ppm (6.26%) and NAA @ 20 ppm. The possible reason for increase in total sugar in fruit pulp by foliar sprays of zinc sulphate might be due to the conversion of starch and acid into sugars in addition to the continuous mobilization of sugars from leaves to fruits. These outcomes are in close agreement with the results of Sharma and Belsare (2011) [30] pomegranate, Chaudhary *et al*. (2018) [6] in aonla. Singh *et al*. (2015b) [33] in phalsa, Yadav *et al*. (2018) [38] in guava.

Table 15: Effect of NAA and zinc sulphate on non-reducing sugar (%) in mulberry

Micro-nutrient spray	Non-reducing sugars (%)				
	Growth regulator spray (NAA)				
	0 ppm	20 ppm	40 ppm	60 ppm	Mean
Zinc sulphate 0%	5.80	5.94	6.03	6.00	5.94
Zinc sulphate 0.2%	5.99	6.16	6.12	6.18	6.11
Zinc sulphate 0.4%	6.22	6.36	6.46	6.40	6.36
Zinc sulphate 0.6%	6.21	6.29	6.55	6.46	6.38
Mean	6.05	6.19	6.29	6.26	
CD at 5%	Zn = 0.12, NAA = 0.12, Zn x NAA = NS				

Conclusion

On the basis of results obtained in the present study we can conclude that there was significant improvement in the flowering and fruiting parameters, yield parameters and quality with the foliar applications of NAA and zinc sulphate on mulberry fruit crop. Flowering and fruiting parameters were significantly improved with the foliar application of $ZnSO_4$ @ 0.4 per cent and 0.6 per cent as well as NAA @ 40 ppm and 60 ppm. Yield parameters were significantly improved with foliar applications of $ZnSO_4$ @ 0.4 per cent and 0.6 per cent as well as NAA @ 40 ppm and 60 ppm. As far as quality parameters are concerned, $ZnSO_4$ @ 0.4 per cent and 0.6 per cent as well as NAA @ 40 ppm and 60 ppm found to be effective over control treatment.

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References

1. AOAC. Official methods of analytical chemist, international, 17 Edn. Washington D.C 2000.
2. Arshad I, Ali W. Effect of foliar application of zinc on growth and yield of guava (*Psidium guajava* L.). Advances in Science, Technology and Engineering System Journal 2016;1(1):19-22.
3. Bhatt BB, Singh KK, Rawat SS. Influence of foliar application of bio-regulators and nutrients on the fruit quality of lemon (*Citrus limon* Burma.) cv. Pant Lemon-1. Int. J Curr. Microbiol. App. Sci 2017;6(4):2451-2458.
4. Bhatt BB, Rawat SS, Kumar D. Effect of foliar application of bio-regulators and nutrients on physico-chemical properties of lemon (*Citrus limon* Burma.) cv. Pant lemon-1 under subtropical condition of Garhwal region. Journal of Plant Development Sciences 2016;8(11):529-535.
5. Chattopadhyay TK. Mulberry. In: A text book on pomology (temperate fruits) 1997;4:293-308.
6. Chaudhary M, Singh DP, Singh JP, Tomar S. Effect of foliar application of PGRs and mineral nutrients on physico-chemical characteristics of aonla fruit cv. NA-7. Journal of Pharmacognosy and Phytochemistry 2018;7(4):2719-2723.
7. Chauhan AS, Kumar K, Saini PK, Singh V, Singh JP. Effect of NAA and zinc sulphate on fruiting, yield of litchi (*Litchi chinensis* Sonn.) cv. Calcuttia. Int. J Curr. Microbiol App. Sci 2019;8(3):836-843.
8. Datta RK. Mulberry cultivation and utilization in India. Central Sericultural Research & Training Institute, Central Silk Board, Srirampura, Mysore 1999.
9. Dhakar D, Barholia AK, Jatav R. Effect of phosphorus and zinc sulphate on yield attributes and quality of guava (*Psidium guajava* L.) cv. Gwalior 27. Int. J Curr. Microbiol. App. Sci 2017;6(4):16-24.
10. Dutta P, Ahmed B, Kundu S. Effect of different sources of potassium application on yield, quality and leaf mineral content of mango in West Bengal. Better Crops-South Asia 2011, 16-18.
11. Gaur B, Beer K, Hada TS, Kanth N, Syamal MM. Studies on the effect of foliar application of nutrients and GA_3 on fruit yield and quality of winter Season Guava. An Internal. Quarterly 2014;VI:479-483.
12. Gami J, Sonkar P, Haldar A, Patidar DK. Effect of pre harvest spray of $ZnSO_4$, KNO_3 and NAA on growth, yield and quality of ber (*Zizyphus mauritiana* Lamk.) cv. Seb under Malwa plateau conditions Int. J Curr. Microbiol App. Sci 2019;8(3):1977-1984.
13. Ghosh SN, Bera B, Roy S, Kundu A. Effect of plant growth regulators in yield and fruit quality in pomegranate cv. Ruby. Journal of Horticultural Science 2009(a);4(2):158-160.
14. Gill KS, Bal JS. Impact of application of growth regulators on Indian jujube. In II International Jujube Symposium 2013;993:119-124.
15. Gurjar PS, Rana GS. Influence of foliar application of nutrients and growth regulator on fruit drop, yield and fruit size and quality in Kinnow mandarin. Indian J Hort 2014;71(1):109-111.
16. Hada TS, Kanth N, Singh BK. Foliar feeding of different levels of boron and zinc on physico-chemical characters and economics of winter season guava (*Psidium guajava* L.) cultivar L-49. Int. J Pure App. Biosci 2018;6(2):162-166.
17. Hulme AC, Narain R. The ferricyanide method for determination of reducing sugars. A modification of Hegedom-Jenson Hanes Technique. Biochem. J 1993;25:1051-1061.
18. Jangid G, Mandal G, Mandal KK, Thokchom R. Foliar application of plant growth regulators to improve fruit retention, yield and quality of aonla cv. NA-7. Journal of Pharmacognosy and Phytochemistry 2018;7(3):21-26.
19. Kumar S, Saravanan S. Effect of pruning and different micronutrient on plant growth, fruit yield and quality of Phalsa (*Grewia asiatica* L.) cv. Sharbati. Journal of Pharmacognosy and Phytochemistry 2017;6(6):65-69.
20. Mishra SM, Ram D, Pandey A, Meena AK. Effect of foliar feeding of micro-nutrients on physico-chemical attributes of aonla (*Emblica officinalis* Gaertn.) cv. NA-7 under high density planting. Int. J Curr. Microbiol. App. Sci 2017;6(5):1951-1957.
21. Nartvaranant P. The influence of exogenously applied 2, 4-D and NAA on fruit drop reduction in pummelo cv. Thong Dee. International Journal of Fruit Science 2018;18(2):215-225.
22. Neware S, Yadav I, Meena B. Effect of plant growth regulators and micronutrients on growth and yield of sweet orange (*Citrus sinensis* Osbeck.) cv. Mosambi. Chem. Sci. Rev. Lett 2017;6(21):213-218.
23. Pandey A, Tripathi VK, Pandey M, Mishra AN, Kumar D. Influence of NAA, GA_3 and zinc sulphate on fruit drop, growth, yield and quality of ber cv. Banarsi Karaka. Proc. International Symposium on Minor Fruits and Medicinal Plants for Health and Ecological Security (ISMF & MP) 2012;19(22):184-187.
24. Patel Y, Yadav A, Pratap BS, Tiwari DK. Effect of foliar spray of micro nutrients on yield and quality of aonla (*Emblica officinalis* Gaertn. L.) cv. NA-6. Journal of Pharmacognosy and Phytochemistry 2018;1:1659-1662.
25. Rajput V, Sehrawat SK, Bhatia SK. Growth regulators and nutrient application reduces fruit drop and improves fruit quality in *Prunus salicina* Lindl. cv. Kala Amritsari. Int. J Pure App. Biosci 2017;5(1):735-743.
26. Ram SA, Bose TK. Effect of foliar application of magnesium and micronutrients on growth, yield and fruit

quality of mandarin orange (*Citrus reticulata* Blanco). Indian J Hort 2000;57(3):215-220.

27. Sahay S, Kumari P, Mishra PK, Rashmi K, Shrivastava P, Ahmad MF, Kumar R. Pre-harvest foliar spray of micronutrients and growth regulators on yield attributes of litchi (*Litchi chinensis* Sonn.) cv. Purbi. In V International Symposium on Lychee, Longan and Other Sapindaceae Fruits 2018;12(11):141-144.
28. Saroj PL, Awasthi OP. Mulberry. Advances in Arid Horticulture: Production Technology of Arid and Semiarid Fruits. International Book Distributing Co, Lucknow 2006;2:333-358.
29. Sau S, Sarkar S, Ghosh B, Ray K, Deb P, Ghosh D. Effect of foliar application of B, Zn and Cu on yield, quality and economics of rainy season guava cultivation. Current Journal of Applied Science and Technology 2018;28(1):1-10.
30. Sharma N, Belsare C. Effect of plant bio-regulators and nutrients on fruit cracking and quality in pomegranate (*Punica granatum* L.) cv. G-137 in Himachal Pradesh. *Acta horticulturae* 2011;890:347-352.
31. Sharma R, Tiwari R. Effect of growth regulator sprays on growth, yield and quality of guava under Malwa plateau conditions. Ann. Plant and Soil Res 2015;17(3):287-291.
32. Singh A, Yadav AL, Singh JP, Vishwakarma G. Effect of foliar spray of nutrients on yield attributing characters of mango (*Mangifera indica* L.). Res. Environ. Life Sci 2015(a);8(3):469-470.
33. Singh AK, Kumar A, Yadav AL. Effect of pruning intensity, foliar feeding of PGR and micro nutrients on physico-chemical attributes of phalsa fruits (*Grewia subinaequalis* D.C.). Res. Environ. Life Sci 2015(b);8(4):675-678.
34. Singh K, Sharma M, Singh SK. Effect of plant growth regulators on fruit yield and quality of guava (*Psidium guajava*) cv. Allahabad *Safeda*. Journal of Pure and Applied Microbiology 2017(a);11(2):1149-1154.
35. Singh K, Singh M, Meena ML, Deepa H, Dwivedi SK, Kumar S. Effect of plant bio-regulators and chemicals on fruit physico-chemical traits of pomegranate (*Punica granatum* L.) cv. Bhagwa. Journal of Pharmacognosy and Phytochemistry 2017(b);6(4):1573-1575.
36. Tagad SS, Patil MB, Patil SG, Deshpande DP. Effect of foliar application of plant growth regulators and micronutrients on growth and yield parameters of acid lime (*Citrus aurantifolia* L.) cv. Sai Sarbati. Journal of Pharmacognosy and Phytochemistry 2018;7(5):741-744.
37. Tirkey NR, Kanpure RN, Kachouli BK, Bhandari J, Patidar DK. Effect of foliar nutrition of zinc sulphate, borax and NAA on yield and quality of Guava (*Psidium guajava* L.) cv. Allahabad Safeda. International Journal of Chemical Studies 2018;6(4):2295-2298.
38. Yadav A, Ram RB, Verma RS, Kumar V, Yadav RK. Effect of foliar application of micronutrients on bio-chemical attributes of winter season guava (*Psidium guajava* L) cv. Lalit. Journal of Pharmacognosy and Phytochemistry 2018;7(2):3196-3197.
39. Yadav A, Verma RS, Ram RB, Kumar V, Yadav RK. Effect of foliar application of micronutrients on physical parameters of winter season guava (*Psidium guajava* L.) cv. Lalit. Plant Archives 2017;17(2):1457-1459.