International Journal of Plant & Soil Science

Volume 36, Issue 8, Page 289-301, 2024; Article no.IJPSS.119764
ISSN: 2320-7035

Effect of NAA and $ZnSO_4$ on Cracking and Chemical Properties of Litchi Fruits

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Authors' contributions

This work was carried out in collaboration between both authors. The planning and execution of the experiments along with the preparation and manuscript was proofreading of manuscript was done by the author and submitted to the journal. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i84857

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119764

Original Research Article

Received: 17/05/2024
Accepted: 21/07/2024
Published: 26/07/2024

ABSTRACT

An experiment was carried out in the Garden, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur (U.P.) during two subsequent years *i.e.,* 2022 and 2023 to assess the effect of NAA and $ZnSO_4$ on cracking and chemical properties of litchi fruits. The study consisted of sixteen treatments, incorporating varying levels of NAA (0, 25, 50, and 75 ppm), zinc sulphate (0, 0.2, 0.4, and 0.6%), and their combinations, which were administered in a Factorial-CRD design. The foliar application of treatments was done on January 28 and March 16 of both years *i.e.,* in 2022 and 2023, before flowering and fruit setting at pea stage on 63-year-old plants of litchi cv. Rose Scented. The results of the study indicated that plants treated with the combination of NAA @ 50ppm and zinc sulphate @ 0.4% resulted in the significantly lowest number of cracked fruit (1.23 and 1.19) and fruit cracking percent (6.31 and 6.15 %) with significant improvement in chemical property parameters of fruits such as juice content (63.63 and 64.22%), TSS (18.09 and

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***Cite as:** Rawat, Anand Singh, and V.K. Tripathi. 2024. "Effect of NAA and ZnSO4 on Cracking and Chemical Properties of Litchi Fruits". International Journal of Plant & Soil Science 36 (8):289-301. https://doi.org/10.9734/ijpss/2024/v36i84857.*

18.38^{0}Brix), total sugars (15.96 and 16.30%), titratable acidity (1.32 and 1.28%), TSS: acid ratio (13.67 and 14.31), sugar: acid ratio (12.04 and 12.66), ascorbic acid (41.22 and 41.64 mg/100g pulp) and organoleptic test (83.36 and 82.82) throughout the investigation years in the plains of Northern India.

Keywords: Litchi; NAA; zinc sulphate; fruit cracking; chemical properties.

1. INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important subtropical evergreen fruit crop belonging to the family Sapindaceae. This nut-like fruit is cultivated on a small scale in Bihar, Uttarakhand, Assam, West Bengal, Orissa, Tripura, Himachal Pradesh, and in sub-mountainous districts of Uttar Pradesh [1]. The edible portion of litchi is juicy aril which is sour and quite sweet when dried.

Litchi is a delicious and luscious fruit that has a pretty red colour, sweet aroma, and good flavor. The flavour of new fruit mash is musky and when dried, it has a harsh taste and is extremely sweet. It is handled into juice, wine, pickles, jam, jam, frozen yogurt, and yogurt [2].

Over the years, plant growth regulators (PGRs) and micronutrients have reliably supported the litchi growers by giving an excellent financial return on litchi production by impacting plant growth, fruiting behavior, and quality of fruits. The micronutrients and PGRs emphatically influence the yield and quality of litchi fruit, enhanced flowering, fruit set, and retention [3]. The best concentrations of micronutrients encourage plant growth, boost yield, reduce cracking, and enhance fruit quality [4]. For specific and fast micronutrient requirements, foliar applications are very necessary for fruit cracking and splitting during the fruiting season when extremely dry and harsh winds blow. The cracked fruit rots quickly and has no selling value. The problem of cracking is considered the main obstacle to the expansion of the litchi growing area. Zinc is critical in plant metabolic activities, going about as a metal activator for enzymes and impacting RNA and ribosome content. Fruit quality changes due to Auxin's significant effects on respiration, photosynthesis, and osmotic pressure. Keeping these in view, an experiment was planted to assess the effect of NAA and $ZnSO_4$ on the fruit cracking and chemical quality of litchi fruits in the plains of north India.

2. MATERIALS AND METHODS

The litchi trees in the Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur were well-maintained and approximately 63 years old. Sixteen litchi cv. Rose Scented plants were chosen for the study in 2022 and 2023. During the entire duration of the investigation, the whole orchard was kept under clean cultivation, and uniform practices were applied to all plants. A Factorial Completely Randomized Design with three replications and sixteen treatments was used, including four levels each of NAA (0, 25, 50 and 75 ppm) and zinc sulphate (0, 0.2, 0.4 and 0.6%) and their combinations were sprayed twice *i.e.,* before flowering (28 January) and at pea stage (16 March) during both the years. Three branches in uniform growth and vigour were selected on each tree for documentation of various parameters.

Data was collected regarding the cracking and chemical property parameters. The quantity of cracked fruits was tallied post-harvest during the fruit cleaning process and documented accordingly. Total soluble solids (TSS) were measured with the help of an Erma hand refractometer with the extracted juice and measured. The total sugars, ascorbic acid, and titratable acidity contents were determined by the techniques recommended in AOAC [5]. The organoleptic rating was recorded using a panel of five judges based on various quality attributes and marks were allotted out of a 100-point scale for the sweetness, sourness, size, and appearance of fruits. Additionally, the sugar: acid ratio was calculated by dividing the sugar values by the titratable acidity values across both years of the study.

3. RESULTS AND DISCUSSION

Fruit cracking: Foliar use of NAA at different concentrations had an impact on fruit cracking. The 50ppm concentration greatly reduced the minimum number of fruit cracking (1.51 and 1.48) and fruit cracking percent (7.82 and 7.55%) were recorded which were harvested from the plants treated with NAA @ 50ppm closely followed by 1.78 and 1.76 number and 9.08 and 8.80% from NAA @75ppm, whereas, the maximum number of fruit cracking (2.94 and 2.97) and fruit cracking percent (9.08 and 8.80%) was recorded which were produced from the plants kept under control without any application. The application of auxin may have increased the osmotic pressure of the cell sap, leading to water uptake and a reduction in fruit cracking percentage. The finding is supported by the reports of Kumar et al. [6] in Ber; Kaur [7], and Chauhan et al. [8] in Litchi.

Upon further observation of the data presented in Figs. 1 and 2, it is evident that the fruits harvested from plants treated with zinc sulphate @ 0.6% exhibited the lowest fruit cracking numbers (1.98 and 1.94) and fruit cracking percentages (10.35 and 10.76%). This was closely followed by fruits from plants treated with zinc sulphate @ 0.4%, which had 2.00 and 2.00 cracked fruits and 11.23 and 11.43% fruit cracking, respectively. The highest fruit cracking numbers (2.41 and 2.41) and fruit cracking percentages (13.76 and 13.79%) were recorded under control treatment. It has been demonstrated in the past that a zinc deficiency results in interveinal chlorosis of older leaves, which distorts the shape and appearance of fruits as well as leaves and encourages fruit cracking in Litchi. However, in the current investigation, zinc application reduced the physiological disorder, ultimately leading to fruit cracking in Litchi fruits.

Interaction effect among various concentrations of NAA and zinc sulfate were compared (Fig. 1 and Fig. 2), it was observed that the lowest number (1.23 and 1.19) and percent (6.31 and 6.15%) of cracked fruits were found in plants treated with NAA @50ppm + zinc sulphate @ 0.4%. Following closely were the results from treatment N_2Z_3, with numbers of 1.51 and 1.47 and percentages of 7.56 and 7.18% of fruit cracking. In contrast, the control group produced fruits with the highest numbers (3.42 and 3.39) and percentages (21.78 and 22.23%) of cracked fruits throughout both years of the experiment. The cellulose, hemicellulose, and pectin contribute to cell enlargement by decreasing the wall pH, so that wall loosening and growth occur auxin has been found to cause cell wall plasticization. This physiological effect of auxin may therefore reduce the cracking of fruit these findings of present experimentation greatly support the observation of Sahay et al. [9], Saraswat et al. [10], and Chauhan et al. [8] in Litchi; Kumar et al. [6] in Ber.

Juice Content: The data in Table 1 shows that the juice content of fruits was significantly influenced by NAA and zinc sulphate application compared to the control. Fruits derived from plants treated with 0.6% zinc sulphate exhibited a higher juice content of 58.47% and 59.14%, compared to fruits from plants treated with 0.4% zinc sulphate, which had juice contents of 58.46% and 59.04%. In contrast, fruits from control plants without any treatment had the lowest juice content of 56.77% and 57.40%. An adequate amount of zinc improves the auxin content and it also acts as a catalyst in the oxidation process which might increase the juice content in fruits.

The plants treated with NAA @ 50ppm yielded fruits that produced the highest juice content (62.14 and 63.00%), closely trailed by fruits treated with NAA at 75ppm, which produced juice contents of 58.56% and 59.53%. On the other hand, fruits from plants that were untreated and kept under control had the lowest juice content (54.07 and 54.62%). The results presented in orange are based on the research by Saleem et al., 2008.

Combined foliar application of NAA and Zinc sulphate significantly improved juice content in litchi fruits. The maximum juice content (63.63 and 64.22%) was recorded in fruits that were produced from the plants treated with the combination of N_2Z_2 (50ppm of NAA + 0.4% of zinc sulphate) followed by 62.57 and 63.64 % under N_2Z_3. The lowest juice content (53.22 and 53.81 %) was found in fruits from plants in the control group (N_0Z_0). The synthesis of catalytic activity of enzymes and coenzymes due to an adequate amount of zinc and auxin content and it also its effect as a catalyst in the oxidation process might have increased juice content. These findings are in close accordance with the results of Lal et al. [11] in Kinnow, and Saleem et al. [12] who also found increased juice content in sweet orange.

Total soluble solids and total sugars: Application of 0.4% zinc sulphate on plants resulted in fruits with the highest total soluble solids content (17.30 and 17.69 ^{0}Brix) and total sugar content (15.13 and 15.55%), as shown in Table 1. closely followed by fruits from plants treated with 0.6% zinc sulphate, which had total soluble solids of 17.24 and 17.38 ^{0}Brix and total sugars of 15.08 and 15.22%. In contrast, fruits have the lowest total soluble solids (16.93 and 16.84 ^{0}Brix) and total sugars (14.74 and 14.65%) content. This increase in TSS and total sugars content in fruit treated with zinc sulphate might be because zinc is credited with a definite role in the hydrolysis of complex polysaccharides into simple sugars, synthesis of metabolites, and rapid translocation of photosynthetic products and minerals from other parts of the plant to developing fruits.

Foliar spray with NAA significantly increases total soluble solids and total sugar content in fruits. Plants treated with 50ppm of NAA exhibited the highest levels of total soluble solids (17.66 and 17.95 ^{0}Brix) and total sugars (15.53 and 16.30 %) followed by (17.15 and 17.02 ^{0}Brix) of TSS and total sugars (14.99 and 14.88 %) from NAA@75ppm treated plants, whereas, the minimum total soluble solids contents (16.69 and 16.88 ^{0}Brix) and total sugars (14.46 and 14.65 %) was documented in the fruits produced from the plants kept under control. This improvement in TSS and total sugar contents with the use of NAA as a growth regulator might have caused the diversion of more metabolites towards developing fruits as a result of increasing amylase activity and thus, there is a fast conversion of starch into simple sugar thereby enhancing total soluble solid content.

When the interaction effect between the foliar spray of zinc sulphate and NAA is discussed, it is recorded that the highest total soluble solids (15.96 and 16.30 ^{0}Brix) and total sugars (15.96 and 16.30%) content (Table 1), were documented in fruits which were produced from the plant treated with the combination of N_2Z_2 (50ppm of NAA + 0.4% of zinc sulphate) closely followed by 15.46 and 16.21 ^{0}Brix of total soluble solids (15.96 and 16.30 ^{0}Brix) and total sugars (15.46 and 16.21 %) under N_2Z_3 treatment. The lowest amount of total soluble solids 14.12 and 4.17^{0}Brix and total sugars (14.12 and 4.17%) were found in fruits that were produced from the plants kept under control (N_0Z_0) without any treatment. This increase in the total soluble solids of fruits may be because plant bio-regulators and micronutrients play an important role in photosynthesis which ultimately leads to the accumulation of carbohydrates with a greater conversion of starch into sugar which ultimately results in an increase in the TSS and total sugars content of litchi fruits in the presence NAA and zinc. The adequate amount of zinc also improves the auxin content and it also acts as a catalyst in the oxidation process. The results are in close conformity with the findings of Babu and Tripathi [13] in Guava, Katiyar et al., [14], Gupta et al. [15] in Litchi, Kumar et al. [16] and Khan et al. [17] in Mango; Kumar et al. [18], Anushi et al. [19], Kumar and Tripathi [20] in Strawberry.

Titratable acidity: The application of plant bio-regulators and micronutrients on the leaves resulted in a notable decrease in the percentage of titratable acidity in the fruits (Table 2). The minimum titratable acidity (1.35 and 1.34%) was found in fruits that were produced from the plants treated with zinc sulphate @ 0.6% closely followed by (1.35 and 1.34%) from zinc sulphate @ 0.6% treated plants, whereas, the higher amount of titratable acidity (1.38 and 1.37%) was recorded in fruits which were produced from the plants kept under control without any treatment. The role of zinc in decreasing the titratable acidity of fruits might be either due to the conversion of sugar and their derivatives by relation involving reverse glycolytic pathway or growth which may be held responsible for reducing titratable acidity.

The application of NAA @ 50ppm to the plants led to the production of fruit having 1.32 and 1.29% of titratable acidity in fruits closely, followed by 1.35 and 1.33% in fruits which were produced from NAA @ 75ppm treated plants, The highest levels of titratable acidity (1.42 and 1.43%) were observed in fruit from untreated control plants. The reduction in acidity content in fruits with NAA treatment might be due to the increased TSS and total sugar content in fruits.

The concurrent application of zinc sulphate and NAA via the foliar method resulted in a significant decrease in titratable acidity levels in litchi fruits (Table 2). The minimum titratable acidity (1.32 and 1.28%) was documented in fruits that were produced from the plants treated with the combination of N_2Z_2 (50ppm of NAA + 0.4 % of zinc sulphate), followed by 1.32 and 1.284% in fruits which were produced under N_2Z_3 combination. The maximum titratable acidity content (1.47 and 1.17%) was observed in fruits that were produced from the plants kept under control (N_0Z_0). Titratable acidity content in fruits was found less with the foliar use of NAA and zinc sulphate, which might be due to an increase in the translocation of photosynthates (carbohydrates) and more metabolic conversion of acids to sugars by the reverse reaction of the glycolytic pathway which is utilized in various physiological activities. Another reason for the reduction in titratable acidity percent might be the early ripening of fruits which was induced by the plant bio-regulators and micronutrient spray due to which degradation of acids might have occurred. Results obtained during the present experimental duration are also in line with the findings of Tiwari et al. [21], Kumar et al. [18] in Aonla, Badal and Tripathi [22], Babu and Tripathi [13] in Guava; Anushi et al. [19] in Mango, and Pandey et al. [23] in Ber.

TSS: acid and sugar: acid ratio: The TSS: acid and sugar: acid ratio was significantly influenced by sole as well as combined use of NAA and zinc sulphate (Table 2). The maximum TSS: acid ratio (12.77 and 13.23) and sugar: acid ratio (1.35 and 1.34%) were found in fruits that were produced from the plants treated with zinc sulphate @ 0.6%, while the minimum TSS: acid ratio (12.28 and 12.24) and sugar: acid ratio (1.38 and 1.38%) was documented in fruits produced from the plants kept under control without any treatment. Zinc was crucial for photosynthesis in plants, leading to carbohydrate accumulation and the subsequent increase in TSS and sugar content in fruits. TSS: acid and sugar: acid ratio is ultimately raised by the fast metabolic conversion of starch and pectin into soluble substances and the speedy transfer of sugars from leaves to growing fruits finally increasing the TSS: acid and sugar: acid ratio.

Upon further observation of the data presented in Table 2, shows that the plants treated with NAA @ 50ppm produced fruits having maximum TSS: acid ratio (13.30 and 13.83) and sugar: acid ratio (1.33 and 1.30%), whereas, the minimum TSS: acid ratio (11.76 and 11.82) and sugar: acid ratio (1.42 and 1.43%) were recorded in fruits which were harvested from the plants which were kept under control without any application. The application of NAA significantly improved fruit quality, leading to an increase in TSS and sugar content, possibly due to the conversion of other polysaccharides and retained starch into soluble sugar forms. Fruit's increase in total soluble solids and total sugar content with reduced titratable acidity might be the result of an increase in the TSS: acid ratio. These findings are in close accordance with the results of Lal et al. [24] in Kinnow Mandarin, Tripathi et al. [25], Bhadauria et al. [26] in Aonla; Bal et al. [27] in Ber, and Kumar and Tripathi [20] in Strawberry. The interaction effect among the foliar spray of zinc sulphate and NAA have a non-significant effect on the TSS: acid and sugar: acid ratio during both years of experimentation.

Ascorbic acid: Upon reviewing Table 3, it is evident that the presence of zinc sulphate had a significant impact on the ascorbic acid levels in fruits. Fruits from plants treated with 0.6% zinc sulphate exhibited the highest ascorbic acid content at 37.05 and 38.51 mg/100g pulp, closely followed by fruits from plants treated with 0.4% zinc sulphate at 36.96 and 38.29 mg/100g pulp. In contrast, fruits from control plants, without any application of zinc sulphate, had the lowest levels of ascorbic acid at 35.51 and 36.84 mg/100g pulp. The increased ascorbic acid content in fruit juice might be due to an increase in the synthesis of catalytic activity of enzymes and coenzymes with the zinc application. An adequate amount of zinc also improves the auxin content which also acts as a catalyst in the oxidation process.

The plants treated with NAA @50ppm produced fruits having significantly more amount of ascorbic acid (39.83 and 40.97 mg/100g pulp) closely followed by 37.48 and 38.75 mg/100g pulp from NAA @ 75ppm treated plants, whereas, fruits with minimum ascorbic acid content (33.21 and 34.75 mg/100g pulp) was harvested from the plants which were kept under control treatment. This increased ascorbic acid content in fruit juice might be due to an increase in the synthesis of catalytic activity of enzymes and coenzymes, which are represented in ascorbic acid synthesis.

The combined use of zinc sulphate and NAA on the leaves had a significant impact on the ascorbic acid content in the fruits. The highest levels of ascorbic acid (41.22 and 41.64 mg/100g pulp) were observed in fruits harvested from plants treated with N_2Z_2 (50ppm of NAA + 0.4% of zinc sulphate), followed by 39.96 and 41.22 mg/100g pulp from N_2Z_3. The lowest levels of ascorbic acid (32.64 and 33.26 mg/100g pulp) were found in fruits from plants under control conditions (N_0Z_0). This increase in ascorbic acid content in fruit might be due to an increase in catalytic activity of enzymes and coenzymes which enhanced the ascorbic acid synthesis. An adequate amount of zinc improves the auxin content and it also acts as a catalyst in the oxidation process. These findings are in close accordance with the results of Lal et al. [24] in Kinnow Mandarin, Gautam et al. [28] in Litchi; Bal et al. [27], Kumar et al. [6], Tripathi et al. [25] in Ber, and Trivedi et al. [29] in Guava.

Table 1. Effect of foliar sprays of NAA, Zinc sulphate and their interactions on juice content, TSS and total sugars

Parameters	**Doses**	**Zinc % (Z)**									
	NAA ppm (N)	**2022**					**2023**				
		Z_0 (Control)	**Z_1 0.2**	**Z_2 0.4**	**Z_3 0.6**	**Mean (Z)**	**Z_0 Control**	**Z_1 0.2**	**Z_2 0.4**	**Z_3 0.6**	**Mean (Z)**
Juice Content (%)	N_0 Control	53.22	53.82	54.30	54.96	54.07	53.81	54.36	55.07	55.26	54.62
	N_1 25	55.39	56.13	57.06	57.07	56.41	55.47	56.53	57.00	56.99	56.50
	N_2 50	60.78	61.59	63.63	62.57	62.14	61.72	62.44	64.22	63.64	63.00
	N_3 75	57.69	58.45	58.85	59.28	58.56	58.61	58.96	59.89	60.68	59.53
	Mean (Z)	56.77	57.50	58.46	58.47		57.40	58.07	59.04	59.14	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	1.13	0.55	0.39			0.43	0.21	0.15		
	Z	1.13	0.55	0.39			0.43	0.21	0.15		
	N X Z	NS	1.11	0.78			NS	0.42	0.30		
TSS (^{0}Brix)	N_0 Control	16.40	16.59	16.86	16.90	16.69	16.45	16.72	16.74	17.62	16.88
	N_1 25	16.77	16.86	17.19	17.13	16.99	16.58	16.45	17.32	17.52	16.97
	N_2 50	17.52	17.44	18.09	17.59	17.66	17.62	17.47	18.38	18.30	17.94
	N_3 75	17.03	17.16	17.06	17.34	17.15	16.70	16.96	17.15	17.26	17.02
	Mean (Z)	16.93	17.01	17.30	17.24		16.84	16.90	17.69	17.381	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	0.44	0.21	0.15			0.44	0.21	0.15		
	Z	NS	0.21	0.15			0.44	0.21	0.15		
	N X Z	NS	0.43	0.30			NS	0.43	0.31		
Total sugars (%)	N_0 Control	14.12	14.35	14.66	14.72	14.46	14.17	14.49	14.51	15.42	14.65
	N_1 25	14.60	14.70	15.02	14.96	14.82	14.41	14.28	15.15	15.35	14.80
	N_2 50	15.39	15.30	15.96	15.46	15.53	15.50	15.35	16.21	16.30	15.84
	N_3 75	14.87	15.01	14.90	15.20	14.99	14.53	14.82	15.03	15.14	14.88
	Mean (Z)	14.74	14.84	15.13	15.08		14.65	14.73	15.22	15.55	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	0.44	0.21	0.15			0.44	0.21	0.15		
	Z	NS	0.21	0.15			0.44	0.21	0.15		
	N X Z	NS	0.43	0.30			NS	0.43	0.30		

Table 2. Effect of foliar sprays of NAA, Zinc sulphate and their interactions on titratable acidity, TSS: acid ratio and sugar: acid ratio

Parameters	Doses	Zinc % (Z)									
	NAA ppm (N)	2022					2023				
		Z_0 (Control)	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (Z)	Z_0 (Control)	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (Z)
Titratable acidity (%)	N_0 Control	1.47	1.44	1.39	1.37	1.42	1.47	1.43	1.42	1.39	1.43
	N_1 25	1.36	1.36	1.36	1.35	1.36	1.37	1.37	1.36	1.36	1.36
	N_2 50	1.33	1.33	1.32	1.32	1.32	1.31	1.30	1.28	1.28	1.29
	N_3 75	1.35	1.35	1.34	1.34	1.35	1.35	1.33	1.32	1.31	1.33
	Mean (Z)	1.38	1.37	1.35	1.35		1.37	1.36	1.34	1.34	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	0.013	0.006	0.004			0.010	0.005	0.003		
	Z	0.013	0.006	0.004			0.010	0.005	0.003		
	N X Z	0.025	0.012	0.009			0.020	0.010	0.007		
TSS: acid ratio	N_0 Control	11.12	11.51	12.12	12.28	11.76	11.17	11.67	11.77	12.66	11.82
	N_1 25	12.27	12.38	12.61	12.59	12.46	12.08	11.99	12.68	12.83	12.40
	N_2 50	13.15	13.10	13.67	13.27	13.30	13.40	13.35	14.31	14.29	13.83
	N_3 75	12.55	12.68	12.65	12.92	12.70	12.29	12.70	12.98	13.09	12.76
	Mean (Z)	12.27	12.41	12.76	12.76		12.23	12.43	12.93	13.22	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	0.37	0.18	0.13			0.32	0.15	0.11		
	Z	0.37	0.18	0.13			0.32	0.15	0.11		
	N X Z	NS	0.36	0.26			NS	0.31	0.22		
Sugar: acid ratio	N_0 Control	9.58	9.96	10.54	10.70	10.19	9.62	10.11	10.20	11.08	10.26
	N_1 25	10.68	10.79	11.02	11.02	10.88	10.50	10.41	11.10	11.25	10.81
	N_2 50	11.55	11.50	12.04	11.69	11.70	11.79	11.73	12.66	12.69	12.22
	N_3 75	10.97	11.09	11.06	11.33	11.11	10.70	11.10	11.37	11.49	11.17
	Mean (Z)	10.69	10.83	11.17	11.18		10.659	10.84	11.33	11.63	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	0.37	0.18	0.12			0.32	0.15	0.11		
	Z	0.37	0.18	0.12			0.32	0.15	0.11		
	N X Z	NS	0.36	0.25			NS	0.31	0.22		

Table 3. Effect of foliar sprays of NAA, Zinc sulphate and their interactions on ascorbic acid and organoleptic test

Parameters	Doses	Zinc % (Z)									
	NAA ppm	2022					2023				
	(N)	Z_0 (Control)	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (Z)	Z_0 (Control)	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (Z)
Ascorbic acid (mg/100g pulp)	N_0 Control	16.40	16.59	16.86	16.90	16.69	16.45	16.72	16.74	17.62	16.88
	N_1 25	16.77	16.86	17.19	17.13	16.99	16.58	16.45	17.32	17.52	16.97
	N_2 50	17.52	17.44	18.09	17.59	17.66	17.62	17.47	18.38	18.30	17.94
	N_3 75	17.03	17.16	17.06	17.34	17.15	16.70	16.96	17.15	17.26	17.02
	Mean (Z)	16.93	17.01	17.30	17.24		16.84	16.90	17.69	17.38	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	0.44	0.21	0.15			0.44	0.21	0.15		
	Z	NS	0.21	0.15			0.44	0.21	0.15		
	N X Z	NS	0.43	0.30			NS	0.43	0.31		
Organoleptic test	N_0 Control	68.23	68.77	69.26	70.61	69.22	69.31	69.90	70.38	71.71	70.32
	N_1 25	71.44	72.62	73.42	73.82	72.82	72.52	73.77	74.86	75.11	74.07
	N_2 50	79.73	80.73	82.36	81.76	81.14	80.61	81.89	83.82	82.45	82.19
	N_3 75	75.43	76.87	77.54	78.66	77.12	76.19	77.67	78.95	79.81	78.15
	Mean (Z)	73.71	74.75	75.64	76.21		74.66	75.81	77.00	77.27	
	Factors	C.D. at 5%	S.E.(d)±	S.E.(m) ±			C.D. at 5%	S.E.(d)±	S.E.(m) ±		
	N	1.12	0.54	0.38			1.12	0.54	0.38		
	Z	1.12	0.54	0.38			1.12	0.54	0.38		
	N X Z	NS	1.09	0.77			NS	1.09	0.77		

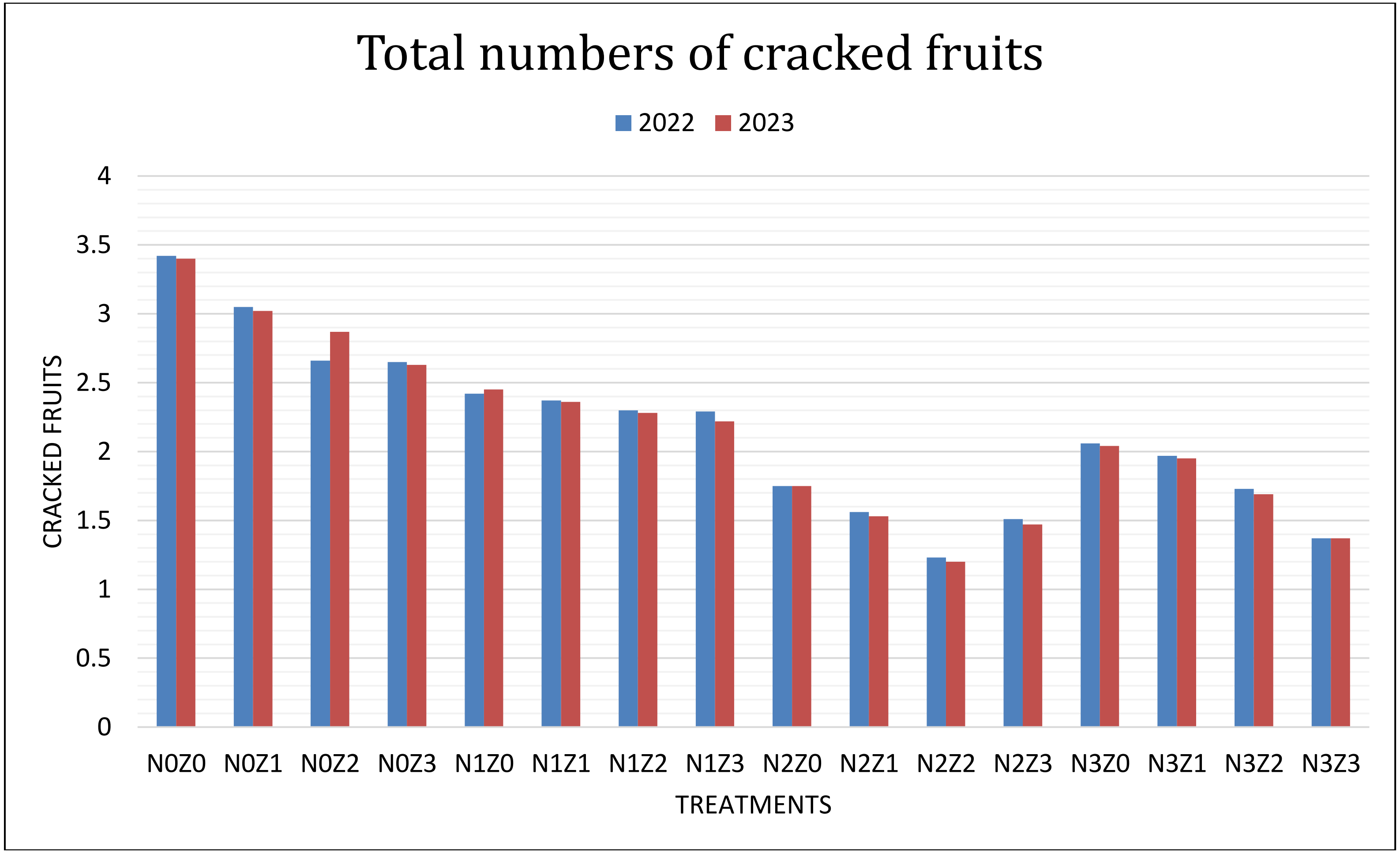

Fig. 1. Effect of foliar sprays of NAA, Zinc sulphate and their interactions on number of cracked fruits

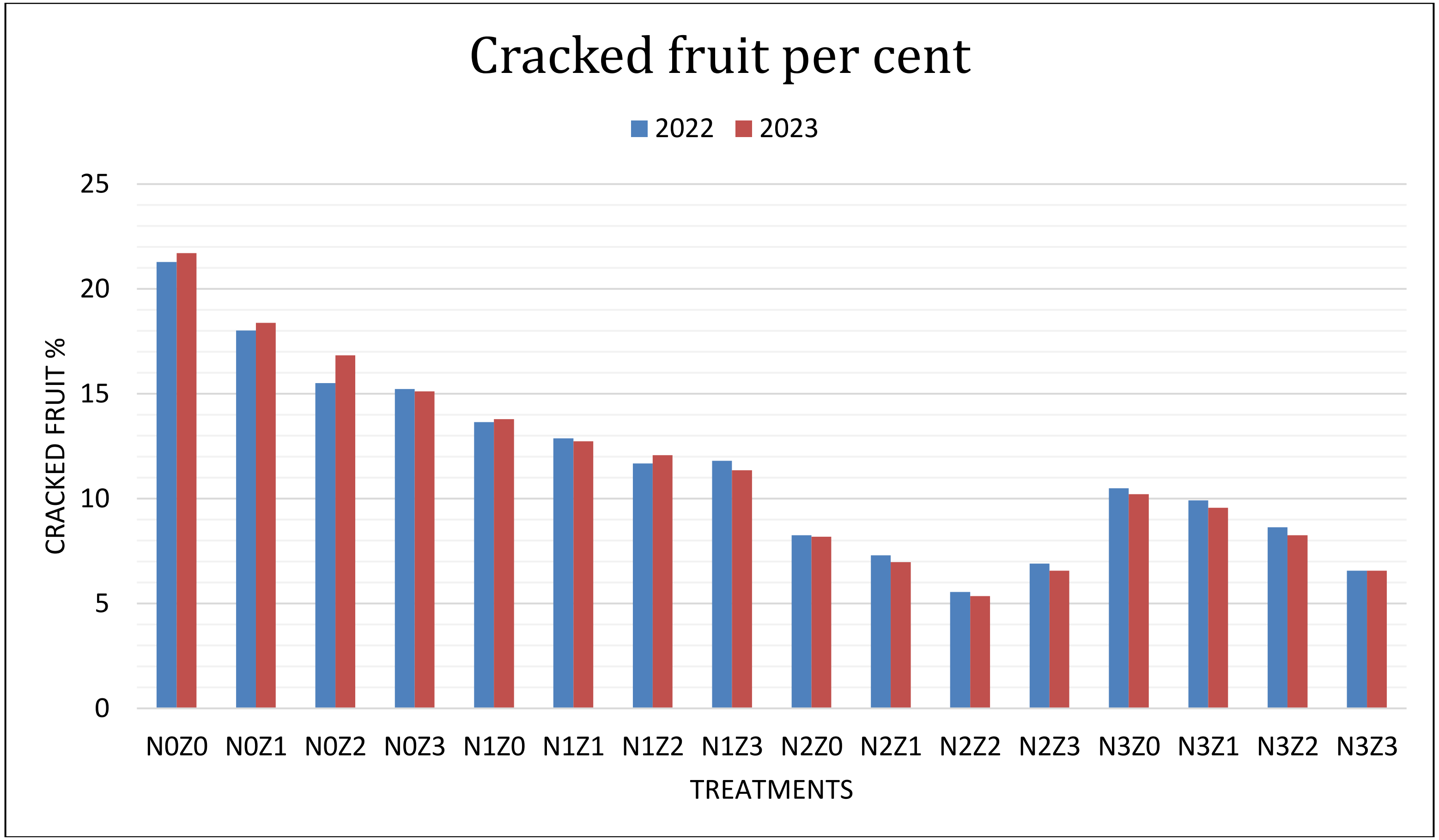

Fig. 2. Effect of foliar sprays of NAA, Zinc sulphate and their interactions on fruit cracking percent

Organoleptic Taste: The fruits harvested from the plants treated with foliar spray of micronutrient *i.e.,* zinc sulphate have considerably increased the rating of fruits, with the highest organoleptic taste rating recorded at 76.21 and 77.27 for 0.6% zinc sulfate treatment. In comparison, fruits treated with 0.4% zinc sulfate had a rating of 75.64 and 77.00. The control fruits, on the other hand, had the lowest organoleptic taste ratings of 73.71 and 74.66 (Table 3). The application of zinc also proved highly helpful in the process of photosynthesis, mobilization of food materials, and accumulation of quality constituents promoting chemical attributes like total sugars and TSS which ultimately increased the organoleptic taste values.

The organoleptic rating reached its peak under the treatment of NAA @ 50ppm, with scores of 81.14 and 82.19, closely followed by scores of 77.12 and 78.15 from fruits treated with NAA @ 75ppm during both years of the experiment. In contrast, the control treatment resulted in a minimum score of 69.22 and 70.32 for the organoleptic rating. The fruits treatment from the adequate concentration of NAA were designated as having the best taste, and mouth aroma with the highest sweetness and were also classified among those having the lowest acidity, best flavour, and best aftertaste. These findings are by the reports of Megu et al. [30] in Litchi, Mishra et al. [31]; Yadav et al. [32]; Tripathi and Viveka Nand [33] in Aonla. The interactive influence of NAA and Zinc was found to be non-significant for the organoleptic rating of fruits during both years of experimentation.

4. CONCLUSION

Based on the current study's findings, it is concluded that individual application of NAA and zinc sulphate brought about significant alterations in plant metabolism. The combined application of NAA @ 50ppm and zinc sulphate @ 0.6% demonstrated notably superior outcomes to other treatments in reducing fruit cracking and maintaining litchi fruit's chemical quality, including TSS, total sugars, ascorbic acid, and juice content with reduced acid contents. The organoleptic quality of fruits also got better with the same treatment. Therefore, based on the aforementioned results, it is recommended that litchi growers utilize 50 ppm of NAA in conjunction with 0.4% zinc sulphate to effectively reduce fruit cracking and enhance the chemical quality parameters of the fruits.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declared that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The authors acknowledge the Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology (CSAUAT), Kanpur for providing the all facilities required for the experiment.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. National Horticulture Board, Hisar, Haryana, India; 2022.
2. Nand V, Dwivedi AK, Tripathi VK. Influence of GA_3 and Zinc on Fruiting, Yield and Quality Parameters of Litchi (*Litchi chinensis* S.) cv. Dehradun. Journal of Experimental Agriculture International. 2023;45(6):20-30.
3. Singh OP, Phogat KPS. Effect of plant growth regulators on fruit drop, size, and quality of litchi cv. Calcuttia. Punjab Horticulture Journal. 1984;24(1-4):83-88.
4. Ram RA, Bose TK. Effect of foliar application of magnesium and micronutrients on growth, yield and fruit quality of mandarin orange (*Citrus reticulata* Blanco.). Indian Journal of Horticulture. 2000;57(3):215-220.
5. AOAC. Association of Official Agricultural Chemists, Washington, DC., USA. Official Methods of Analysis. 14th eds; 1980;
6. Kumar M, Dwivedi AK, Tripathi VK, Shukla A. Influence of different levels of NAA and 2, 4, 5-T on fruit quality of Indian Ber (*Zizyphus mauritiana* Lamk.). Biological Forum – An International Journal. 2023; 15(3):352-357.
7. Kaur S. Effect of micronutrients and plant growth regulators on fruit set, fruit retention, yield and quality attributes in litchi cv. Dehradun. Chemical Science Review and Letters. 2017;6(22):982-986.
8. Chauhan A. S, Kumar, K, Saini P. K, Singh V, Singh J. P. Effect of NAA and Zinc

Sulphate on Fruiting, Yield of Litchi (*Litchi chinensis* Sonn.) cv. Calcuttia. International Journal of Current Microbiology and Applied Sciences. 2019;8(3):836-843.

9. Sahay S, Kumari P, Mishra PK, Rashmi K, Shrivastava P, Ahmad M F., Kumar, R. Pre-harvest foliar spray of micronutrients and growth regulators on yield attributes of litchi (*Litchi chinensis* Sonn.) 'Purbi'. Acta Horticulturae. 2018;1211.
10. Saraswat NK, Pandey UN, Tripathi VK. Influence of NAA and zinc sulphate on fruit set, fruit drop, cracking, fruit size, yield and quality of litchi cv. Calcuttia. Journal of Asian Horticulture. 2006;2(4):255-269.
11. Lal D, Tripathi VK, Nayyer MA, Kumar S, Ahmed M, Siddiqui MW. Pre-harvest spray of gibberellic acid, NAA, and calcium nitrate on fruit retention, yield and quality of kinnow mandarin. Environment and Ecology. 2016;34(4C):2288-2292.
12. Saleem BA, Malik AU, Pervez MA, Khan AS, Khan MN. Spring application of growth regulators affects the fruit quality of 'Blood Red' sweet orange. Pakistan Journal on Botany. 2008;40: 1013-1023.
13. Babu R, Tripathi VK. Impact of foliar application of NAA, zinc and boron on growth, yield and quality parameters of guava (*Psidium guajava* L.), Progressive Agriculture. 2022;22(2):190-194.
14. Katiyar PN, Prakash O, Singh JP, Singh PC. Effect of zinc sulphate, borax and calcium nitrate on flowering, fruiting, yield and quality of Litchi cv. Dehradun. Journal of Rural Agriculture Research. 2008;8(2):49-51.
15. Gupta A, Tripathi V K, Shukla J K. Influence of GA_3, and zinc sulphate on fruit drop, yield and quality of litchi (*Litchi chinensis* Sonn.). Biological Forum-International Journal. 2022;14:1079-1083.
16. Kumar R, Tripathi VK, Tomar S, Chaudhary M. Effect of best plant bioregulators and micronutrients for achieving higher yield and quality of Mango (*Mangifera indica* L.) fruits cv. Amrapali. Journal of Plant Development Sciences. 2018;10(11):599-604.
17. Khan AU, Tripathi VK, Gautam RKS, Dwivedi A.K. Effect of GA_3, NAA and zinc sulphate on fruit retention, fruit drop, yield and quality of mango (*Mangifera indica* L.) cv. Dashehari. Biological Forum – An International Journal. 2022;14(4):320-325.
18. Kumar A, Tripathi VK, Dubey V, Katiyar NK, Tiwari P. Influence of foliar application of calcium, zinc and boron on fruit drop, yield and quality attributes of Aonla (*Embilica officinalis*) cv. NA-7. Research on Crops. 2017;18(1):91-97.
19. Anushi, Tripathi VK, Awasthi VT, Yashasvi GN. Impact of pre-harvest application of plant bio-regulators and micronutrients on fruit retention, yield and quality of Mango (*Mangifera indica* L.). Frontiers in Crop Improvement. 2021;9(3):1026-1030.
20. Kumar R, Tripathi VK. Influence of NAA, GA_3 and boric acid on growth, yield and quality of strawberry cv. Chandler. Progressive Horticulture. 2009;41(1):113-115.
21. Tiwari P, Tripathi VK, Singh A. Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield and quality attributes of Aonla. Progressive Research- An International Journal. 2017;12(6):2565-2568.
22. Badal D S, Tripathi VK. Effect of foliar application of NAA and Boron on physico-chemical parameters of winter season guava (*Psidium guajava* L.) cv. Lucknow-49. The Pharma Innovation Journal. 2021a;10(9):928-932.
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. Banarasi Karaka. International Symposium on Minor Fruits and Medicinal Plants for Health and Ecological Security. 2011;184-187.
24. Lal D, Tripathi VK, Kumar S, Nayyer MA. Effect of pre-harvest application of gibberellic acid, NAA, and calcium nitrate on fruit drop. Maturity and Storage Quality of Kinnow Mandarin. Research in Environment Life Sciences. 2015 8(4):561-564.
25. Tripathi D, Pandey AK, Pal A K, Yadav MP. Studies on the effect of plant growth regulators on fruit drop, development, quality and yield of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka. Progressive Horticulture. 2009;41(2):184-186.
26. Bhadauria AS, Tripathi VK, Singh A, Gupta S. Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield and quality attributes of aonla. Progressive Research- An International Journal. 2018;13(3):216-219.

27. Bal JS, Singh SN, Randhawa J S, Jawanda JS. Effect of plant growth regulators on fruit drop, size and quality of Ber (*Zizyphus mauritiana* Lamk.). Indian Journal of Horticulture. 1984;41(3/4):182-185.
28. Gautam S, Singh J. P, Patel S. K, Yadav S. Effect of NAA and zinc on fruiting parameters, marketable yield and quality of litchi (*Litchi chinensis* (Gaertn.) Sonn.). Biological Forum – An International Journal. 2021;13(3a):144-148.
29. Trivedi N, Singh D, Bahadur V, Prasad VM, Collis JP. Effect of foliar application of zinc and boron on yield and fruit quality of Guava (*Psidium guajava* L.). HortFlora Research Spectrum. 2012; 3:281-283.
30. Megu O, Hazarika BN, Wangchu L, Sarma P, Singh AK, Debnath P, Angami T. Effect of plant growth regulators and micronutrients on vegetative growth, flowering and yield attributes of Litchi (*Litchi chinensis* S.). International Journal Plant Soil Sciences. 2021;33:176-181.
31. Mishra DS, Kumar P, Kumar R. Effect of GA_3 and ABA on fruit weight, quality and ripening of Rose Scented Litchi. Horticulture Flora Research Spectrum. 2012;1(1):80-82.
32. Yadav S, Shukla HS, Ram RA. Studies on foliar application of NAA, GA3, Boric acid and $Ca(NO_3)_2$ on fruit retention, growth, yield and quality of Aonla (*Emblica officinalis* Gaertn.) cv. Banarasi. Horticulture Journal. 2010;23(2):64-67.
33. Tripathi VK, Viveka Nand. Effect of foliar application of boron, zinc and NAA on fruit retention, yield and quality attributes of aonla. Progressive Horticulture. 2022; 54(1):76-81.

Peer-review history:
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