International Journal of Bio-resource and Stress Management

https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM November 2024, 15(11): 01-11

Article AR5721a

Research Article

Stress Management

DOI: HTTPS://DOI.ORG/10.23910/1.2024.5721a

Flowering, Fruiting and Yield of Litchi cv. Rose Scented as Influenced by Naphthalene Acetic Acid and Zinc Sulphate

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ABSTRACT

An experiment was carried out in the Garden, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh (208002), India during two subsequent years *i.e.,* from January to May, 2022 and 2023, to assess the flowering, fruiting, and yield of litchi cv. Rose Scented as influenced by the application of Naphthalene acetic acid and Zinc sulphate. There were sixteen treatments including four levels of NAA (0, 25, 50, and 75 ppm), zinc sulphate (0, 0.2, 0.4 and 0.6%), and their combinations applied in Factorial–CRD. The foliar application of NAA and Zinc sulphate was made on January 28 and March 16 during both years before flowering and fruit set at the pea stage. The results of the experiment showed that plants treated with NAA @ 50 ppm with zinc sulphate @ 0.4% took the minimum days for flowering (20.40) and increased length of panicle (22.87 cm), and number of panicles (182.65) plant^{-1}. It also increased the total number of fruit sets (258.90) panicle^{-1} and simultaneously maintained the fruit count at the pea stage (47.42), pit hardening stage (38.84), and at fruit ripening stage (27.13) of the pooled mean. The same treatment enhanced fruit sets (63.37 %), reduced fruit drop (91.37%), increased fruit retention (8.61%) and marketable yield (82.48 kg plant^{-1}). It was concluded that the application of NAA at 50ppm and zinc sulphate at 0.4% significantly impacted the maximum fruit set, retention, fruiting characters and marketable yield of litchi fruit in the plains of northern India.

KEYWORDS: Fruit drop, litchi, NAA, yield, zinc sulphate

Citation* (VANCOUVER)*: Rawat and Tripathi, Flowering, Fruiting and Yield of Litchi cv. Rose Scented as Influenced by Naphthalene Acetic Acid and Zinc Sulphate. *International Journal of Bio-resource and Stress Management,* 2024; 15(11), 01-11. HTTPS://DOI.ORG/10.23910/1.2024.5721a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 18th August 2024 RECEIVED in revised form on 26th October 2024 ACCEPTED in final form on 12th November 2024 PUBLISHED on 20th November 2024

1. INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is a very important subtropical evergreen fruit crop, belongs to the family Sapindaceae. It is a nut type of fruit cultivated commercially to a limited extent in Bihar, Uttarakhand, Assam, West Bengal, Orissa, Tripura, and Himachal Pradesh and also grown in sub-mountainous districts of Uttar Pradesh *i.e.,* Saharanpur and Muzaffarnagar. Muzaffarpur in Bihar grows the best quality of litchi. The litchi fruits also known as "Natural rasgulla" are considerably rich in sugar. The litchi fruit consists of about 60% juice, 8% rags, 19% seeds and 13% peel, which varies depending on the variety and climate where it is grown (Nath et al., 2016). The main chemical components are carbohydrates, organic acids, vitamins, pigments, proteins, and fats. The sugar content of Indian varieties varied from 6.74–18.0% with an average of 11.8%. In addition to sugar, litchi is also a rich source of vitamin C from 40.0–90 mg 100 g^{-1}, protein (0.8–0.9%), lipid (0.3%), pectin (0.43%) and minerals, especially calcium, phosphorus, and iron 0.7% (Aykroyd et al. 1966).

Litchi fruit is delicious and luscious with an attractive red colour, sweet aroma, and good taste. It is a sweet, dry fruit with white translucent juicy pulp and large seeds. The taste of fresh fruit pulp is musky and when dried, it has a sour taste. It is rich in carbohydrates, vitamins, and minerals such as magnesium, iron, calcium, copper, phosphorus, and potassium. It is processed into juice, wine, pickles, jam, jelly, ice cream and yogurt.

Plant growth regulators are today used in almost all crops and play important roles in many physiological phenomena. GA_3 stimulates growth, flowering, fruit set, increases fruit size and also has the effect of stimulating flowering, pollination and fruit quality (Moon et al., 2003).

Plant growth regulators (PGRs) and micronutrients have consistently boosted economic returns in litchi production by influencing flowering and fruiting behaviour along with plant growth. Both micronutrients and PGRs have positive impact on litchi yield and quality, enhancing flowering, fruit set and retention. Foliar application is beneficial for providing specific micronutrient requirements in a faster rate. Zinc plays an important role in the metabolic activities of plants. It is an activator of enzymes such as dehydrogenase (pyridine nucleotide, glucose–6, phosphodiesterase, carbonic anhydrase, etc.). It synthesizes tryptophan, a precursor of IAA (Kumar et al., 2009). Zinc deficiency adversely affects flowering, fruit size, growth and quality. Auxin significantly affects respiration, photosynthesis and osmotic pressure, leading to changes in fruit quality. Recognizing the significance of zinc and NAA on flowering, fruiting and marketable yield production of litchi, this experiment was designed and executed. NAA is an important growth regulator of the auxin group that helps to limit fruit drop, improve fruit set rate and fruit quality, especially TSS. By applying NAA–TSS and the ascorbic acid content in the fruit is increased and the acidity is reduced. NAA reduces the number of seeds in the fruit. It also helps in fruiting more and promotes flowering (Sharma and Tiwari, 2015). Nayak et al. (2024) noted better response for the higher number of marketable fruits and yield in plants treated with 0.3% Borax in litchi.

As mentioned above, this study was aimed to improve the flowering, fruiting attributes, and yield attributes and quality of the rose-scented cultivar of Litchi.

2. MATERIALS AND METHODS

The litchi trees were about 63 years old but properly maintained in the Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur Uttar Pradesh (208002), India. Sixteen uniform plants of litchi cv. Rose Scented were selected for the present investigations during two subsequent years of Zaid (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. Factorial Completely Randomized Design was used with three replications and sixteen treatments *viz.,* four levels each of NAA (0, 25, 50, and 75 ppm) and zinc sulphate (0, 0.2, 0.4 and 0.6%), and their combination 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 for each tree.

Observations were recorded on various flowering, fruiting, and yield parameters. Data on days taken to flowering were observed by counting, length of panicle in each treatment was measured in centimetres with the help of a meter scale, while the number of fruits was counted at different stages *i.e.,* fruit set, pea stage, pit hardening stage, ripening stage, and harvesting stage, respectively. Data for fruit set, drop, retention, and marketable yield were also recorded using standard techniques and methodology.

All the data recorded during both years of experiments and then pooled were subjected to statistical analysis under the two-factor in Factorial-CRD as described by Snedecar and Cochran (1987). Valid conciliations were drawn after the determination of the significance of difference between the treatments at 5% level of probability. The critical difference was calculated to compare the treatment means.

3. RESULTS AND DISCUSSION

3.1. *Days taken to flowering*

The application of different concentrations of NAA and zinc sulphate significantly affects the days taken to flowering (Table 1). In plants treated with the foliar application of NAA, the minimum days taken to flowering (21.26) was found in plants treated with NAA @ 50 ppm, closely followed by (23.19 days) found with NAA 75 ppm treatment. In contrast, the maximum days taken to flowering (27.01) was recorded in plants kept under control treatment. The minimum days taken to flowering with the NAA application due to the translocation of carbohydrates, which improves plant nutrition, which is mostly affected by auxin. These metabolic changes in the present investigation helped in early flowering. A similar finding was reported by Sahay et al. (2018) in litchi.

The data on the minimum days taken to flowering (23.55) was recorded with the application of 0.6% zinc sulphate closely followed by (23.69) under 0.4% zinc sulphate application, while plants kept under control treatment took maximum days taken to flowering (24.79). The minimum days taken to flowering were recorded when zinc was used in higher concentrations. This decrease in the days taken to flowering may be due to the reason that zinc is a micronutrient that plays an important role in photosynthesis, which increases the carbon ratio in the plants, and accelerates early flowering. Similar findings were reported by Sharma et al. (2005), Saraswat et al. (2006) and Gupta et al. (2022) in litchi.

Table 1: Effect of foliar sprays of NAA, Zinc sulphate and their interactions on flowering parameters

Parameters	Doses	Zinc % (Z)				
	NAA ppm (N)	Z_0 Control	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (N)
Days taken to flowering	N_0 Control	27.56	27.51	26.62	26.35	27.01
	N_1 25	25.62	25.42	24.94	24.65	25.16
	N_2 50	22.08	21.81	20.40	20.76	21.26
	N_3 75	23.91	23.57	22.80	22.48	23.19
	Mean (Z)	24.79	24.57	23.69	23.56	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.08	0.03	0.02		
	Z	0.08	0.03	0.02		
	N×Z	0.16	0.07	0.05		
Length of panicle (mm)	N_0 Control	15.65	17.09	17.26	17.78	16.94
	N_1 25	18.22	19.20	19.24	19.50	19.04
	N_2 50	21.92	22.49	22.87	22.56	22.46
	N_3 75	20.08	20.75	20.86	21.34	20.76
	Mean (Z)	18.97	19.88	20.06	20.30	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.04	0.02	0.01		
	Z	0.04	0.02	0.01		
	N×Z	0.08	0.04	0.03		
Number of panicles	N_0 Control	162.78	165.12	166.95	168.38	165.81
	N_1 25	169.67	171.37	172.87	174.40	172.08
	N_2 50	178.92	180.07	182.65	181.38	180.76
	N_3 75	175.55	176.60	177.01	178.04	176.80
	Mean (Z)	171.73	173.29	174.87	175.55	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.03	0.01	0.01		
	Z	0.03	0.01	0.01		
	N×Z	0.06	0.03	0.02		

The interaction effect between NAA and zinc sulphate application were found to be significant on days taken to flowering. The treatment combination of N_2Z_2 (50 ppm NAA and 0.4% zinc sulphate) resulted in the minimum number of days (20.40) taken to flowering closely followed by N_2Z_3 (50 ppm NAA and 0.6% Zinc sulphate) treatment combination of the pooled mean of investigation. Whereas, the maximum days (27.56) taken to flowering was recorded with control (N_0Z_0) treatment. The minimum days taken to flowering might be due to the reason that the application of NAA and zinc sulphate ensures a better supply of nutrients and more food formation, which ensures more food formation in the plants, which ensures early flowering. Similar results were also observed in litchi by Saraswat et al. (2006), Sahay et al. (2018) and Kumar et al. (2018) in mango.

3.2. Length of panicle (mm)

The application of different concentrations of NAA and zinc sulphate showed significant effect on the length of panicles of the pooled mean of investigation (Table 1). Plants treated with the foliar application of NAA 50 ppm produced a maximum length of panicle (22.46 mm), closely followed by (20.76 mm) found with NAA 75 ppm treated plants, whereas the minimum length of panicle (16.94 mm) was recorded in plants kept under control. The higher length of panicles with the application of NAA might be due to the substance's role in cell division, cell elongation, and increased intracellular spaces, which is mostly affected by auxin and these metabolic changes in the present investigation helped in the increased length of panicle. A similar finding agrees with Sahay et al. (2018) in litchi.

The maximum length of panicle (20.30 mm) was recorded with the application of 0.6% zinc, closely followed by (20.06 mm) from 0.4% zinc sulphate application, while plants kept under control produced the minimum length of panicle (18.97 mm). The increase in panicle length might be due to the application of zinc sulphate and its role in nitrogen metabolism, phytohormones regulation, and active cell proliferation, improving plant nutrition and auxin synthesis, which elongated the length of panicle in litchi plants. Similar findings agreed with Sharma et al. (2005), Saraswat et al. (2006) and Gupta et al. (2022) in litchi.

The interaction effect of NAA and zinc sulphate application was found to be significant on the length of panicles. The treatment combination of N_2Z_2 induced the maximum length of panicle (22.87 mm), closely followed by N_2Z_3 treatment combination (Table 1). Whereas, the minimum length of panicle (15.65 mm) was recorded in plants kept as control (N_0Z_0) of the pooled mean of investigation. Higher length of panicle during experimental period might be due to the NAA application have substantial role in cell division, and cell elongation in plants. Similar results were also observed in litchi by Saraswat et al. (2006) and Sahay et al. (2018).

3.3. Number of panicles plant^{-1}

The application of different concentrations of NAA and zinc sulphate can significantly effect on the number of panicles plant^{-1} (Table 1). Plants treated with the foliar application of NAA 50 ppm during of the pooled mean of investigation produced the maximum number of panicles (180.76) plant^{-1}, closely followed by NAA @ 75 ppm treated plants with recorded (176.80) of panicles plant^{-1}, whereas, the minimum (165.81) of panicles plant^{-1} was recorded in plants kept under control treatment. Higher number of panicles with the application of NAA might be due to its role in cell division, cell elongation and increased intracellular spaces increasing the plant growth, which were mostly affected by auxin and these metabolic changes in the present investigation helped in an increased number of panicles. These findings aligned with the reports of Sahay et al. (2018) in litchi. The maximum number of panicles of the pooled mean of investigation was recorded with the application of 0.6% zinc (175.55), closely followed by 174.87 from 0.4% zinc sulphate, while plants kept under control showed the minimum number of panicles (171.73) plant^{-1}. The maximum number of panicles was recorded when zinc sulphate was used with higher concentration. This increased the number of panicles with the application of zinc sulphate could be attributed to its role in nitrogen metabolism, phytohormones regulation, and active cell proliferation. These findings agreed with the reports of Sharma et al. (2005), Saraswat et al. (2006) and Gupta et al. (2022) in litchi.

The interaction effect of NAA and zinc sulphate application was found to be significant effect on the number of panicles of the pooled mean. However, the treatment combination of N_2Z_2 induced the maximum number of panicles (182.65), closely followed by N_2Z_3 which was recorded (181.38) of number of panicles plant^{-1}. Whereas, the minimum number of panicles (162.78) was recorded in plants kept as control (N_0Z_0) of the pooled mean. Higher number of panicles per plants might be due to the application of NAA and zinc sulphate for better supply of nutrients, which ensures more food formation in the plants can resulted the greater number of panicles. Similar results were also observed in litchi by Saraswat et al. (2006) and Sahay et al. (2018).

3.4. Fruit sets panicle^{-1}

The application of different concentrations of NAA and zinc sulphate can significantly affect fruit sets panicle^{-1} of the pooled mean (Table 2). Plants treated with the foliar application of NAA 50 ppm resulted in the maximum fruit sets panicle^{-1} (254.84), closely followed by NAA @ 75 ppm treatment (244.39), whereas, the minimum fruit sets panicle^{-1} (218.28) was recorded in plants kept under control treatment of the pooled mean. Higher fruit set panicle^{-1} with the application of NAA might be due to the formation of sugars from polysaccharides and a decrease in acid content during maturity and ripening period, which was mostly affected by auxin and these metabolic changes in the present investigation might have helped improve and increased fruit set. Similar findings reported by Quereshi et al. (2011) and Sahay et al. (2018) in litchi. The maximum fruit sets panicle^{-1} (241.78) was recorded with the application of zinc sulphate 0.6%, closely followed by (240.09) from 0.4% zinc sulphate application, while plants kept under control treatment showed minimum fruit sets panicle^{-1} (232.94) of the pooled mean. The maximum fruit sets were recorded when zinc was used in a medium concentration. This increase in the fruit sets might be due to the zinc sulphate plays an important role in the translocation of carbohydrates, improves plant nutrition, auxin synthesis and increases pollen viability and fertilization, which accelerates fruit sets in litchi plants. These findings agreed with the reports of Sharma et al. (2005), Saraswat et al. (2006) and Gupta et al. (2022) in litchi.

The interaction effect of NAA and zinc sulphate was found to be significant on fruit sets panicle^{-1} of the pooled mean. The treatment N_2Z_2 induced the maximum (258.90) of fruit sets panicle^{-1} closely followed by N_2Z_3 treatment

Table 2: Effect of foliar sprays of NAA, Zinc sulphate and their interactions on fruit set panicle^{-1}, fruit count at pea and pit hardening stage

Parameters	Doses	Zinc % (Z)				
	NAA ppm (N)	Z_0 Control	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (N)
Fruit set panicle^{-1}	N_0 Control	212.50	215.41	219.68	225.54	218.28
	N_1 25	228.20	232.56	236.10	236.50	233.34
	N_2 50	250.43	253.72	258.90	256.33	254.84
	N_3 75	240.62	242.48	245.71	248.76	244.39
	Mean (Z)	232.94	236.04	240.09	241.78	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	1.12	0.54	0.38		
	Z	1.12	0.54	0.38		
	N×Z	2.24	1.09	0.77		
Fruit count at the pea stage	N_0 Control	36.92	37.70	39.43	39.84	38.47
	N_1 25	40.72	41.67	42.40	43.06	41.96
	N_2 50	45.67	46.58	47.42	47.04	46.67
	N_3 75	43.48	44.11	44.31	45.14	44.26
	Mean (Z)	41.70	42.51	43.39	43.77	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.05	0.02	0.01		
	Z	0.05	0.02	0.01		
	N×Z	0.10	0.04	0.03		
Fruit count at the pit hardening stage	N_0 Control	30.72	31.23	32.23	32.95	31.78
	N_1 25	33.40	33.79	34.61	34.83	34.16
	N_2 50	37.17	37.95	38.84	38.33	38.07
	N_3 75	35.26	35.97	36.27	36.99	36.12
	Mean (Z)	34.13	34.73	35.49	35.77	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.019	0.009	0.006		
	Z	0.019	0.009	0.006		
	N×Z	0.038	0.018	0.013		

combination. The minimum (212.50) of fruit sets panicle^{-1} was recorded with control (N_0Z_0) treatment combination of the pooled mean (Table 2). Similar findings reported by Quereshi et al. (2011) and Sahay et al. (2018) in litchi.

3.5. Fruit count at the pea and pit hardening stage

Zinc sulphate concentrations gradually increased fruit count at the pea stage and also maintained well to at pit hardening stage. Fruit count at the pea stage and the pit hardening stage was also influenced significantly with 50 ppm of NAA application and the maximum fruit count at the pea stage (466.67) and the pit hardening stage (38.07) was recorded with the application of 75 ppm of NAA of the pooled mean (Table 2). Whereas, the minimum fruit count at the pea stage (38.47) and the pit hardening stage (31.78) were achieved in plants that were kept under control (N_0) treatment during of the pooled mean. It is commonly known that when auxin concentration rises, low fruit production is caused by low auxin levels and lack of ultimate cell fracturing in the middle lamella or close to the abscission layer. By inhibiting the enzymes that make pectin soluble, auxin treatment to the fruits inhibits these alterations in the middle lamella, resulting in maximum fruit count at the pea stage and improved fruit count at the pit hardening stage. These findings aligned with the results of Tiwari et al. (2017) and Tripathi and Viveka Nand (2022**)** in aonla.

Plants treated with 0.6% zinc sulphate showed a significant effect with maximum fruit count at the pea stage (43.77) and the pit hardening stage (35.77) followed by 0.4% zinc sulphate application with recorded 43.39 of fruit count at pea stage and 35.49 of fruit count at pit hardening stage, respectively of the pooled mean. Untreated plants *i.e.,* control treatment recorded with minimum fruit count at the pea stage (41.70) and the pit hardening stage (34.13), respectively of the pooled mean. This higher number of fruit count at the pea and pit hardening stage in litchi plants might be due to the reason that the application of zinc sulphate plays an important part in the formation of middle lamella which is an important part of plant cells along with calcium pectate for important role in the strengthening of pedicel attached to the proximal end of fruit which resulted in higher number and maintained fruit count. These findings aligned with the results of Saraswat et al. (2006), Gupta et al. (2022) in litchi, Shubham et al. (2022), Anushi et al. (2021) in mango and Tripathi et al. (2018) in aonla.

The interaction effect between NAA with zinc sulphate was found significant with respect to fruit count at pea stage and pit hardening stage of the pooled mean. The treatment combination of N_2Z_2 (NAA 50 ppm with zinc sulphate 0.4%) results in maximum fruit count at pea stage (47.42) and pit hardening stage (38.84), closely followed by N_2Z_3 (50 ppm NAA and 0.6% zinc sulphate), whereas, the minimum fruit count at pea stage (36.92) and pit hardening stage (30.72) was recorded under control. Other treatment combinations also increased fruit count at the pea and pit hardening stage as compared to the control treatment. Similar results were also observed in litchi by Saraswat et al. (2006) and Sahay et al. (2018).

3.6. Fruit count at the ripening stage

Fruit count at the ripening stage was also observed significantly affected by the application of 50ppm NAA treatment with maximum fruit count at the ripening stage (26.55) closely followed by 75 ppm NAA *i.e.* 25.13 fruit count at the ripening stage (Table 3). Whereas, the minimum fruit count at the ripening stage (21.31) was achieved in plants kept under control (N_0) treatment of the pooled mean. It is commonly known that when auxin concentration rises, low fruit production is due to low auxin levels and lack of ultimate cell fracturing in the middle lamella or close to the abscission layer. By inhibiting the enzymes that make pectin soluble, auxin treatment to the fruits inhibits these alterations in the middle lamella, resulting in maximized fruit count at the ripening stage. Similar findings aligned with the results of Tiwari et al. (2017) in aonla.

Zinc sulphate concentrations maintained a higher fruit count at the ripening stage that were treated with 0.6%, which shows a significant maximum fruit count at the ripening stage (24.62) followed by 0.4% zinc sulphate with 23.36 fruit count at the ripening stage. While control plants resulted in a significantly minimum fruit count at the ripening stage (23.43) of the pooled mean. This higher number of fruit count at the ripening stage in litchi plants might be due to the zinc sulphate plays an important part in the formation of middle lamella which is an important part of plant cells along with calcium pectate which plays an important role in the strengthening of pedicel attached to the proximal end of fruit which resulted in higher and maintained fruit count. These findings agreed with the results of Saraswat et al. (2006) in litchi, Kumar et al. (2018a) in mango and Tripathi et al. (2018) in aonla.

The interaction effect between NAA with zinc sulphate application was found significant on fruit count at the ripening stage of the pooled mean (Table 3). The treatment combination of NAA 50 ppm with zinc sulphate 0.4% (N_2Z_2) application can result in the maximum fruit count at the ripening stage (27.13) closely followed by N_2Z_2 (NAA 50 ppm and 0.6% zinc sulphate), whereas, the minimum fruit count at ripening stage (26.62) and minimum fruit count at ripening stage (20.43) was recorded under (N_0Z_0) control. Other treatment combinations also increased fruit count at the ripening stage as compared to the control. Similar results were also observed in litchi by and Sahay et al. (2018).

Table 3: Effect of foliar sprays of NAA, Zinc sulphate and their interactions on fruit count at ripening stage, number of fruits panicle^{-1} and fruit set %

Parameters	Doses	Zinc % (Z)				
	NAA ppm (N)	Z_0 Control	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (N)
Fruit count at the ripening stage	N_0 Control	20.43	21.21	21.55	22.06	21.31
	N_1 25	22.45	22.68	23.64	24.00	23.19
	N_2 50	26.13	26.32	27.13	26.62	26.55
	N_3 75	24.71	24.85	25.14	25.81	25.13
	Mean (Z)	23.43	23.77	24.36	24.62	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.019	0.009	0.007		
	Z	0.019	0.009	0.007		
	N×Z	0.038	0.019	0.013		
No. of fruits panicle^{-1}	N_0 Control	15.86	16.67	17.09	17.41	16.76
	N_1 25	17.76	18.47	19.28	19.47	18.74
	N_2 50	21.27	21.63	22.28	22.12	21.82
	N_3 75	19.82	20.13	20.82	20.27	20.26
	Mean (Z)	18.67	19.23	19.87	19.82	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.043	0.021	0.015		
	Z	0.04	0.02	0.01		
	N×Z	0.08	0.04	0.02		
Fruit set (%)	N_0 Control	54.46	54.83	55.98	56.16	55.35
	N_1 25	56.43	56.99	57.25	57.95	57.15
	N_2 50	61.30	61.74	63.37	62.70	62.27
	N_3 75	58.53	59.55	60.17	60.71	59.74
	Mean (Z)	57.68	58.27	59.19	59.38	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.03	0.01	0.01		
	Z	0.03	0.01	0.01		
	N×Z	0.07	0.03	0.02		

3.7. Number of fruits panicle^{-1}

The number of fruits in panicle^{-1} was significantly affected by the application of 50 ppm NAA recorded with the maximum number of fruits in panicle^{-1} (21.82) closely followed by 75 ppm NAA recorded with 20.26 of fruits (Table 3). Whereas, the minimum number of fruits panicle^{-1} (16.76) was achieved in plants kept under control (N_0) of the pooled mean. It is commonly known that when auxin concentration rises, low fruit production is caused due to low auxin levels and lack of ultimate cell fracturing in the middle lamella or close to the abscission layer. By inhibiting the enzymes that make pectin soluble, auxin treatment to the fruits inhibits these alterations in the middle lamella, resulting in the maximize the number of fruits panicle^{-1}. A similar finding agreed with the results of Tiwari et al. (2017) in aonla.

Zinc sulphate concentrations maintained a higher number of fruits in panicle^{-1} that were treated with 0.4% zinc sulphate showed a significant effect on the maximum number of fruits in panicle^{-1} (19.87) followed by 0.6% zinc sulphate with recorded 19.82 of fruits panicle^{-1}. While the control treatment resulted in a significantly minimum number of fruits panicle^{-1} (18.67) of the pooled mean. This increased number of fruits panicle^{-1} in litchi plants might be due to the application of zinc sulphate is an important part of the formation of middle lamella which is an important part of plant cells along with calcium pectate which plays an important role in the strengthening of pedicel attached to the proximal end of fruit which resulted in higher and maintained number of fruits. These findings aligned with the results of Saraswat et al. (2006) in litchi and Tripathi et al. (2018) in aonla.

The interaction effect between NAA with zinc sulphate was found significant on the number of fruits panicle^{-1} of the pooled mean (Table 3). The treatment combination of NAA 50ppm with zinc sulphate 0.4% (N_2Z_2) results in the maximum number of fruits panicle^{-1} (22.28) closely followed by N_2Z_3 (NAA 50ppm and 0.6% zinc sulphate), whereas, the minimum number of fruits panicle^{-1} (15.86) was recorded under (N_0Z_0) control treatment. Similar results were also observed in litchi by and Sahay et al. (2018).

3.8. Fruit sets (%)

The application of different concentrations of NAA and zinc sulphate significantly affects fruit sets of the pooled mean (Table 3). The maximum fruit sets (62.27%) were found in plants that were treated with the foliar application of NAA 75 ppm, closely followed by NAA 50ppm treatment, whereas, the minimum fruit sets (55.35%) were recorded in plants kept under control treatment. Higher fruit sets with the application of NAA might be due to the formation of sugars from polysaccharides and a decrease in acid content during maturity and ripening period which are mostly affected by auxin and these metabolic changes in the present investigation helped in increased fruit sets. These findings agreed with the reports of Kumar et al. (2023a) in ber, Sahay et al. (2018), Radha et al. (2023), Kumar et al. (2023b) in litchi and Badal and Tripathi (2021) in guava.

The maximum fruit sets (59.38%) were recorded with the application of 0.4% zinc sulphate, closely followed by (58.19%) from 0.6% zinc sulphate application, while plants under control treatment showed the minimum fruit sets (57.68%) of the pooled mean. This increase in the fruit sets might be due to the zinc sulphate is a micronutrient that plays an important role in the translocation of carbohydrates, improves plant nutrition, and auxin synthesis, and increases pollen viability and fertilization, which accelerates fruit set in litchi plant when used in optimum concentration. Similar findings were reported by Sharma et al. (2005), Gupta et al. (2022) in litchi and Babu and Tripathi (2022) in guava.

The interaction effect of NAA and zinc sulphate was found to be significant on fruit sets. The treatment combination of N_2Z_2 induced maximum fruit sets (63.37%) closely followed by (62.70%) with the N_2Z_3 treatment combination. The minimum fruit sets (54.46%) were recorded in plants kept under (N_0Z_0) control treatment of the pooled mean (Table 3).

3.9. Fruit drop and fruit retention (%)

Fruit drop and fruit retention were significantly influenced by NAA application on the minimum fruit drop (91.45%) and maximum fruit retention (8.54%) were recorded with 50pm of NAA during the investigation period (Table 4). The maximum fruit drop (92.33%) and minimum fruit retention (7.65%) were achieved in plants kept under control (N_0) during the investigation period. It is commonly known that when auxin concentration rises, low fruit production is caused by low auxin levels and lack of ultimate cell fracturing in the middle lamella or close to the abscission layer. By inhibiting the enzymes that make pectin soluble, auxin treatment to the fruits inhibits these alterations in the middle lamella, resulting in minimized fruit drop and improved fruit retention. These findings align with the results of Tiwari et al. (2017), Tripathi and Viveka Nand (2022) in aonla, Lal et al. (2015) in Kinnow, Kumar et al. (2023a) in ber, Kumar et al. (2023b) in litchi, Quershi et al. (2011), Badal and Tripathi (2021) in guava and Radha et al. (2023) in litchi.

Zinc sulphate concentrations gradually reduced the fruit drop and increased fruit retention percentage. Plants treated with 0.4% of zinc sulphate showed significant minimum fruit drop (91.75%) and maximum fruit retention (8.23%) followed by 0.6% zinc sulphate with 91.78% of fruit drop and 8.21% of fruit retention, respectively of the pooled mean. Whereas, the control plants can significantly the maximum (92.03%) of fruit drop and minimum fruit retention (7.95%) of the pooled mean. The reduction of fruit drop and increased fruit retention in litchi plants might be due to the application of zinc sulphate plays an important part for the formation of middle lamella which is an important part of plant cells along with calcium pectate and strengthening of pedicel attached to the proximal end of fruit which resulted in less fruit drop. Similarly, the reduction in fruit drop by the spray of zinc sulphate may also be due to the indirect action of zinc sulphate in auxin synthesis that delayed the formation of the abscission layer during the early stages of fruit development, which ultimately increased fruit retention. Similar findings reported by Babu and Tripathi (2022) in guava; Qureshi et al. 2011) and Gupta et al. (2022) in litchi; Tripathi and Kumar (2022) in mango.

The interaction effect between NAA with zinc sulphate application was found non-significant with respect to fruit drop and fruit retention (Table 4). The treatment combination of N_2Z_2 (NAA 50ppm and zinc sulphate 0.4%) was recorded the minimum fruit drop (91.37%) with maximum fruit retention (8.61%), closely followed by N_2Z_3 (NAA 50ppm and 0.6% zinc sulphate), whereas, maximum fruit drop (92.56%) and minimum fruit retention (7.43%) was recorded under control of the pooled mean.

Other treatment combinations also reduce fruit drop and maximize fruit retention as compared to control. Similar results were also observed in litchi by Saraswat et al. (2006) and Sahay et al. (2018).

3.10. Marketable yield (kg plant^{-1})

All the cracked and other blemished fruits were isolated from the overall yield of litchi fruit in order to calculate the yield of marketable fruits (Table 4). The treatment of NAA 50 ppm was recorded the yield plant^{-1} was significantly maximum, yield plant^{-1} (77.78 kg) followed by 68.50 kg yield of marketable fruits plant^{-1} with the application of 75 ppm of NAA. Whereas, the minimum yield of marketable fruits 48.45 kg plant^{-1} was recorded under control treatment. The benefit of the yield caused by NAA application may be related to the physiological actions in the plants, also prevented fruit drop, reduced cracking, and significantly decreased the number of imperfect fruits, improving production and marketable yield. The above findings were aligned with the reports of Yadav et al. (2010), Tripathi and Viveka Nand (2022) in aonla, Saraswat et al. (2006), Kumar et al. (2023b), Badal and Tripathi (2021) in guava and Radha et al. (2023) in litchi.

The foliar application of zinc sulphate considerably increased the production of marketable fruits with a significant

Table 4: Effect of foliar sprays of NAA, Zinc sulphate and their interactions on fruit retention, drop and marketable yield kg plant^{-1}

Parameters	Doses	Zinc % (Z)				
	NAA ppm (N)	Z_0 Control	Z_1 0.2	Z_2 0.4	Z_3 0.6	Mean (N)
Fruit retention (%)	N_0 Control	7.43	7.71	7.76	7.72	7.65
	N_1 25	7.80	7.95	8.21	8.18	8.03
	N_2 50	8.44	8.52	8.61	8.58	8.54
	N_3 75	8.14	8.20	8.27	8.45	8.26
	Mean (Z)	7.95	8.09	8.21	8.23	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.04	0.02	0.01		
	Z	0.04	0.02	0.01		
	N×Z	0.08	0.04	0.03		
Fruit drop (%)	N_0 Control	92.56	92.29	92.24	92.2	92.33
	N_1 25	92.19	92.03	91.78	91.82	91.96
	N_2 50	91.54	91.47	91.37	91.41	91.45
	N_3 75	91.85	91.79	91.72	91.53	91.72
	Mean (Z)	92.03	91.89	91.78	91.75	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.05	0.02	0.01		
	Z	0.05	0.02	0.01		
	N×Z	0.11	0.05	0.03		
Marketable yield (kg plant^{-1})	N_0 Control	42.90	47.61	50.51	52.79	48.45
	N_1 25	54.84	58.05	61.61	63.19	59.42
	N_2 50	74.18	76.65	81.27	79.02	77.78
	N_3 75	65.45	68.04	69.78	70.72	68.50
	Mean (Z)	59.34	62.59	65.79	66.43	
	Factors	CD (p=0.05)	SEd±	SEm±		
	N	0.03	0.01	0.01		
	Z	0.03	0.01	0.01		
	N×Z	0.07	0.03	0.02		

maximum fruit yield (66.43 kg) plant^{-1} was recorded with 0.6% zinc sulphate followed by 65.79 kg yield plant^{-1} was found under 0.4% zinc sulphate application. Whereas, the lowest yield of 59.34 kg plant^{-1} of marketable fruits was exhibited under control treatment of the pooled mean. Zinc sulphate aids in the movement of metabolites from source to sink, which increases the retention of more fruits on trees which ultimately increases the fruit yield in plants. Similar findings reported by Chaturvedi et al. (2005) in strawberry; Kumar et al. (2017) in aonla; Babu and Tripathi (2022) in Guava; Gupta et al. (2022) in litchi; and Tripathi and Kumar (2022) in mango.

The interactive influence of NAA and zinc sulphate application was found to be significant on the yield of marketable fruits plant^{-1}. However, the treatment combination of N_2Z_2 showed the maximum yield of marketable fruits (81.27 kg) plant^{-1} closely followed by the treatment combination of N_2Z_3 with recorded 79.02 kg plant^{-1} yield of marketable fruits plant^{-1}. Whereas, the minimum yield of marketable fruits (42.90 kg) plant^{-1} was recorded under control (N_0Z_0) treatment of the pooled mean (Table 4). An increase in yield due to NAA or zinc sulphate application may be attributed to their better effects on increased levels of IAA, which increases yield. Rapid fruit development and the greater mobilization of food materials from the site of production to storage organs under the influence of NAA and zinc sulphate results in more yield of marketable fruits. The application of zinc sulphate and NAA may have increased yield because zinc was found to be extremely beneficial in the process of photosynthesis, which mobilizes food material and accumulates quality constituents that promote physical attributes like fruit size and weight. NAA significantly reduced fruit drop and accelerated the physiological processes in the plants, both of which contributed to an increase in output. The present findings were reports of Saraswat et al. (2006) in litchi; Shukla et al. (2011) and Tripathi and Viveka Nand (2022) in aonla.

4. CONCLUSION

The application of NAA 50 ppm with 0.4% zinc sulphate played a significant role in enhanced fruit sets, reduced fruit drop and days taken for flowering, increased fruit retention, and fruiting characters; which at last expanded the marketable yield plant^{-1} in litchi plants.

5. ACKNOWLEDGMENT

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.

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