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Effect of NAA on fruit drop and quality attributes of litchi (*Litchi chinensis*)

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Abstract

The study envisaged the effect of synthetic auxin on fruit drop, cracking, yield and quality attributes of litchi (*Litchi chinensis* Sonn.) cultivars, *viz*. Dehradun and Calcuttia in sub mountaneous zone of Punjab (India). The experiments were conducted at four locations for both cultivars, during 2021 and 2022. The different concentrations of NAA (10, 20, 30, 40 ppm) along with the control (water spray) were applied 10 days after fruit setting (DAFS). The pooled data of two years revealed that application of NAA (20 ppm) drastically reduced fruit drop, cracking index, enhanced fruit retention and quality attributes, i.e. fruit weight, pulp: stone ratio, TSS and total sugars. Pericarp anthocyanin and; a^* and *hue* angle (h^*) colour coordinates were also improved with NAA treatments as compared to the control. Fruit yield/plant was better with NAA and it ranged from 5.67 to 19.55 % in 'Dehradun' and 7.40 to 17.33 % in 'Calcuttia' cultivar over the control. The application of NAA (20 ppm) effectively reduced the incidence of fruit drop, cracking, improving fruit retention and juice quality.

Key words: Auxin, Fruit drop, Cracking, Colour development, Fruit setting

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Litchi (*Litchi chinensis* Sonn.) is well known for its dietic attributes such as higher content of sugars, vitamins, organic acids, phenolic acids, phytochemicals, anthocyanin, minerals etc. It provides good return to growers of Punjab (Singh *et al*., 2022). It is gown in 4,518 ha with a total production of 74,974 MT and productivity of 16.60 tonnes/ha (MA&FW, 2024-25). The litchi-based cropping system is affected with physiological disorders, fruit drop and cracking (Lal *et al*., 2017). Although, litchi tree flowers profusely but fruit setting in specific litchi cultivars varies from 1 to 50 per cent, which is far higher than fruits retained till maturity (Nath *et al*., 2021). Around 90-95 per cent fruit drop occurs up to third week after pollination (Gharge *et al*., 2025). The initial wave of fruit drop is mainly due to improper pollination, poor fertilization, and embryo abortion but fruit drop, during later fruit developmental stages, is ascribed to the lack of assimilates, irrigation, environmental factors, insect attack and hormonal imbalances (Lal *et al*., 2021). The higher level of growth promoters and lower abscisic acid (ABA) content are prerequisite for fruit set and afterward for fruit growth, development, and retention (Yuan *et al*., 2002). The foliar application of growth regulators is effective in improving fruit yield and quality (Hitesh *et al*., 2025; Piyadarshi and Hota, 2021). Lower ratio of growth promoters to ABA and ethylene concentrations may induces the formation of pre-mature abscission layer in pedicel that results in more loss of fruit productivity (Yuan and Carbaugh, 2007). Keeping in view physiological fruit drop in litchi, present investigation was intended to compare the efficacy of NAA in management of physiological disorders and fruit quality parameters.

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MATERIALS AND METHODS

The experiment was laid out in sub-mountane regions of Punjab (encompassing districts Hoshiarpur and Pathankot) situated between 30°9' to 32°05' N and 75°32' to 76°12' E, and 32°21' N and 75°31' E to 75°46' E, respectively during 2021 and 2022 on both uniform and healthy plants of 'Dehradun' and 'Calcuttia' litchi cultivars. The experimental plants were sprayed with NAA (Naphthalene acetic acid) (10, 20, 30, 40 ppm) after 10 days fruit set. The spray solution was prepared by dissolving the calculated dose of NAA (Lab. grade) in alcohol; then final volume in water along with spreader Tween 20 (0.01%). The control trees were sprayed with plain water (10 litres/plant). The cultural practices were adopted as per 'Package of Practices for Cultivation of Fruit Crops', Punjab Agricultural University, Ludhiana (2025).

Fifteen terminal flowering shoots / plant were randomly selected in each direction of tree canopy and tagged for recording various observations. The data on fruit retention, marketable yield and quality parameters were assessed and pooled estimates for four locations for each cultivar was worked out. Number of fruits in each tagged panicles were counted after fruit set before

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the plants sprayed and the percentage was worked out after counting the final fruit set about one week prior to harvesting. Fruit yield was estimated by weighing all fruits during harvesting and was expressed in kg/plant. Twenty fruits plant were harvested at physiological maturity for computing their average physico-chemical attributes. The fruits were weighed using digital balance and the average weight was expressed in 'g'. Fruit size (length, breadth, thickness) was measured with digital Vernier's Calipers' and expressed in 'mm'.

The pulp/stone was calculated based on fruit pulp weight and seed weight. Fruit cracking index (CI) was determined by counting total number of cracked fruits/ panicle, dividing it with total number of fruits and percentage was worked out (Haq and Rab, 2012). TSS (%) of fruit juice was recorded using digital hand refractometer (Atago, Japan) at 20°C with necessary correction factor, while acidity per cent was determined by titrating fruit juice with N/10 NaOH using phenolphthalein (1%) as an indicator. The acidity was expressed in maleic acid content. Juice sugars were analyzed as per (AOAC, 2005). Hue angle was determined by measuring the colour coordinates ($a^*$and b^*values wherein a^* value depicts the proportion of red to green colour, and b^* value specifies the proportion of yellow to blue colour) on each of 20 fresh fruits using ColorFlex EZ, (Hunter Associates Laboratory, Inc, USA). The hue angle was calculated by:

$$\text{Hue angle } (h^\circ) = \arctan (b^*/a^*)$$

Pericarp anthocyanin content was determined as per spectroscopy method suggested by Ranganna (1991). The technique involves extraction of anthocyanin using ethanolic HCl and measurement of colour at 535 nm wavelength against ethanolic HCl (used as blank).

The randomized block design (RBD) was followed with both experiments. Each experiment included four treatments and one control. Each treatment included three replications and one plant was taken as a unit. The experiment was conducted at four different locations (village Mamun, Nangal in Pathankot and Gangian, Darapur in Hoshiarpur) for each cultivar in litchi growing regions. The pooled data for different locations were analyzed with SAS package from SAS Institute Inc. (version 93, USA). To compare the variations in treatment means, the least significant difference method was employed as a post hoc analysis.

RESULTS AND DISCUSSION

Significant higher fruit retention in comparison with other treatments including the control was noted in plants sprayed with NAA (20 ppm) and values were 32.7 and 30.5% in Dehradun and Calcuttia cultivars, respectively; wherein, control had the values of 20.88 % and 22.62 %, respectively (Table 1). According to Liu (1986), levels of naturally occurring auxins are drastically reduced in litchi fruits during embryo development after 4-5 to weeks of fertilization. As a result, disintegration of cell wall and middle lamella of abscission zone occurs in pedicel due to more activity of hydrolytic cellulase and polygalacturonase enzymes (Kaur *et al.*, 2021). The spray of NAA improves the endogenous auxin content of fruits which subsequently, promotes fruit retention. Mostafa and El-berry (2020) also found that auxins promote carbohydrates mobilization from leaves to developing fruit lets and enhanced fruit retention per cent. Hence, balance between plant growth promoters and inhibitors control fruit abscission. These findings corroborate the results of Ghosh *et al.* (2012).

Table 1: Effect of NAA on physical attributes of litchi cultivars, pooled data for four locations

Treatment	Fruit retention (%)	Fruit yield (kg/ plant)	Fruit weight (g)	Fruit length (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Pulp weight (g)	Pulp: stone ratio	Fruit cracking index (%)
Dehradun									
NAA 10 ppm	25.05^{c}	79.70^{bc}	20.40^{b}	33.8^{a}	31.2^{a}	29.6^{a}	15.33^{a}	4.16^{b}	12.18^{b}
NAA 20 ppm	32.70^{a}	90.15^{a}	22.78^{a}	35.9^{ab}	32.7^{a}	31.9^{ab}	15.99^{a}	4.63^{a}	6.43^{d}
NAA 30 ppm	29.63^{b}	86.43^{ab}	20.80^{b}	35.00^{ab}	31.8^{a}	30.5^{ab}	15.45^{a}	4.13^{b}	6.22^{d}
NAA 40 ppm	28.50^{b}	82.80^{abc}	20.70^{b}	34.9^{b}	32.0^{a}	30.2^{bc}	15.52^{a}	4.10^{b}	9.16^{c}
Control	20.88^{d}	75.45^{c}	19.00^{c}	31.4^{c}	30.8^{a}	28.1^{c}	14.27^{b}	3.92^{b}	19.45^{a}
Calcuttia									
NAA 10 ppm	26.28^{c}	87.40^{ab}	20.90^{b}	34.0^{a}	32.5^{a}	29.9^{a}	14.47^{bc}	5.07^{b}	6.21^{b}
NAA 20 ppm	30.50^{a}	95.48^{a}	23.93^{a}	37.1^{a}	34.2^{a}	33.7^{a}	15.87^{a}	5.55^{a}	3.04^{d}
NAA 30 ppm	28.98^{b}	91.58^{a}	21.30^{b}	36.5^{a}	33.9^{a}	33.0^{a}	15.13^{ab}	5.08^{b}	2.92^{d}
NAA 40 ppm	27.46^{c}	90.53^{a}	21.05^{b}	36.2^{b}	34.3^{a}	32.7^{b}	15.26^{ab}	4.98^{b}	4.35^{c}
Control	22.62^{d}	81.45^{b}	19.40^{c}	32.7^{b}	29.5^{b}	28.8^{b}	13.62^{c}	4.76^{c}	9.59^{a}

Least square means with same denotation are not significantly different ($p \leq 0.05$)

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In Dehradun and Calcuttia cultivars, plants sprayed with NAA (20 ppm) significantly improved fruit yield by 19.55 and 17.33 per cent, respectively over the control. Fruit yield of Dehradun and Calcuttia cultivars varied from 79.7 to 90.15 kg/plant and 87.40 to 95.48 kg/plant, respectively, compared to the control (75.45 and 81.45 kg/plant, respectively). Arunadevi *et al.* (2019) also reported that exogenous applications of NAA significantly improved fruit retention due to balance between internal concentration of auxins that inhibits the degradation of abscission layer which may result in production of higher fruits. The application of NAA may stimulate auxins that enhances source-sink relationship which in turn had higher fruit set and fruit retention (Sahay *et al.*, 2018), reduced fruit drop and substantially improved fruit yield over the control.

The trees sprayed with NAA (20 ppm) registered highest fruit weight of 22.78 g and 23.93 g in Dehradun and Calcuttia, respectively compared to other treatments (Table 1). The enhancement in fruit weight ranged from 7.37 to 25.95 % with NAA treatments compared to the untreated plants in both the litchi cultivars. Fruit size was also significantly highest with foliar spray of NAA (20 ppm) in both the cultivars except fruit breadth of Dehradun over the control. In Dehradun, significantly highest pulp weight of 15.99 g was registered with NAA (20 ppm), followed by 15.52 g in NAA (40 ppm), 15.45 g in NAA (30 ppm) and 15.33 g in NAA (10 ppm) than lowest (14.27 g) in the control. It ranged from 15.87 g in NAA (20 ppm) to 13.26 g in the control in Calcuttia cultivar. Pulp:stone ratio was also significantly influenced with the application of NAA (20 ppm) than the rest of treatments; however, NAA (10, 30 and 40 ppm) treatments were statistically non-significant with each other in both litchi cultivars. An increment in pulp:stone of 18.11 per cent in Dehradun and 16.6 per cent in Calcuttia litchi cultivar was noted with NAA (20 ppm) treatment over the control, followed by NAA (10 ppm) in Dehradun and NAA (30 ppm) in Calcuttia.

The application of NAA increases the concentration of auxins within the fruits that promotes the fruit growth and development, which in turns improves fruit weight. NAA plays significant role in reduction of pericarp fruit cracking index in both litchi cultivars. The susceptibility to cracking intensity in fruits of Dehradun cultivar was more, hence cracking index (CI) was registered maximum in untreated fruits of Dehradun (19.45 %) than Calcuttia (9.59 %). The CI was minimum in Dehradun and Calcuttia cultivars with application of NAA (30 ppm) to the tune of 6.22 and 2.92%, respectively and these values were statistically at par with NAA (20 ppm) and values were 6.43 and 3.04 %, respectively. According to Sahay *et al.* (2018), application of NAA may stimulate auxins that enhance source-sink relationships resulting in higher percentage of fruit setting, retention and lesser cracking.

Auxin application improves the water uptake by increasing the osmotic pressure of cell sap which, may reduce fruit cracking (Saraswat *et al.*, 2006). Gill and Bal (2009) also reveal that foliar spray of NAA at pea size stage substantially enhances the inherent physiology of leaves and translocation of photosynthates during ber fruit development. The susceptibility of litchi fruits to cracking may be associated with the deterioration in IAA level in fruits which in turn decreases the levels of *LcXET1* (gene involved in cell wall metabolism) in pericarp; however, NAA application significantly enhanced levels of LcXET1 mRNA in pericarp of treated fruits which, resulted in reduced fruit cracking as reported by Lu *et al.* (2006). Similarly, Kaur *et al.* (2024) observed that foliar application of NAA (10, 20, 30 ppm) significantly reduced fruit splitting by 5.69, 5.27 and 6.16 per cent as compared to 13.25 per cent in the untreated Daisy mandarin grown under central zone of Punjab.

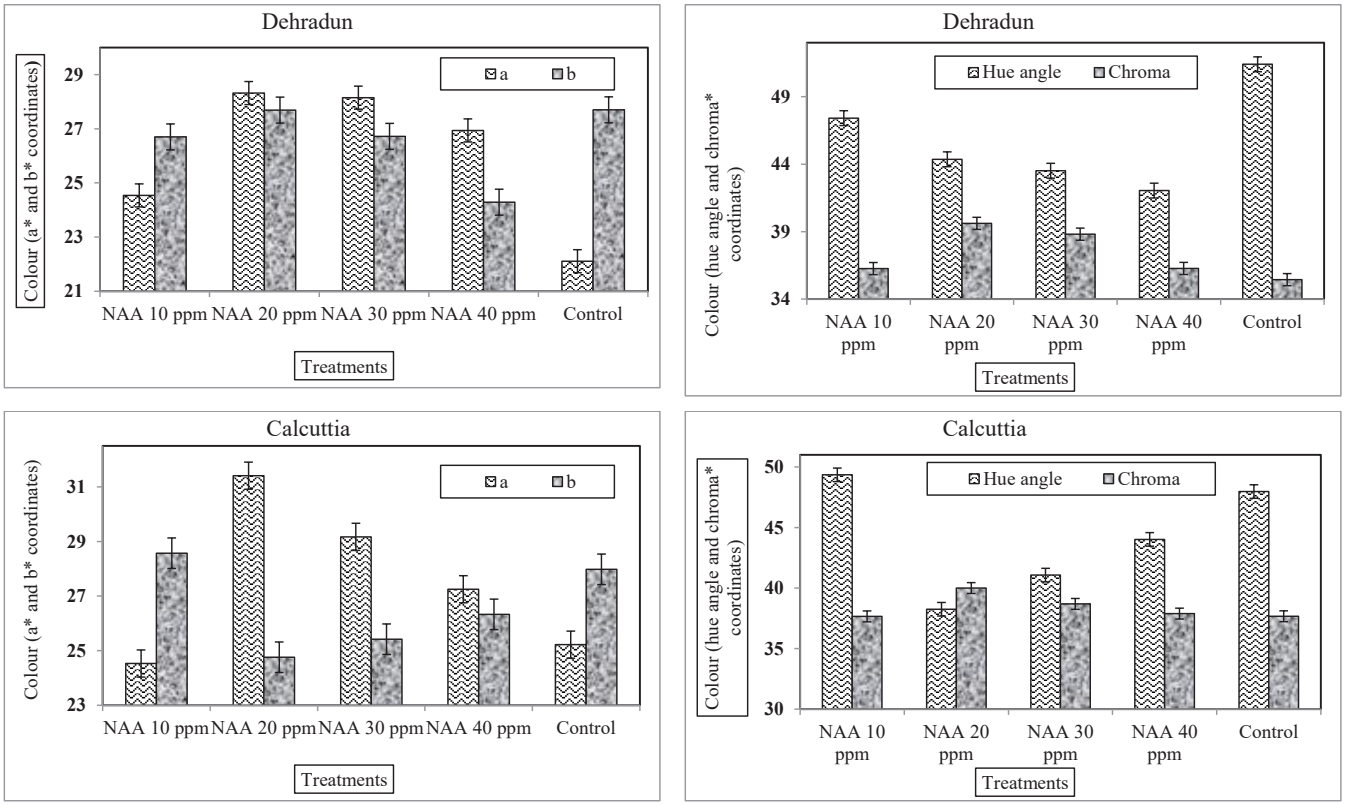
Apart from physical quality parameters, foliar sprays of auxins also remarkably produced fruits of better-quality attributes (Table 2). TSS and TSS:acid among NAA treated plants ranged from 18.78 to 19.83% and 30.55 to 37.3 % in Dehradun and 20.38 to 22.25% and 28.03 to 33.2 % in Calcuttia cultivar, respectively. Overall, foliar application of NAA significantly improved TSS, total sugars content and TSS:acid. A significant influence of NAA was also observed in different proportion of sugars content of fruit pulp. The highest percentage of reducing sugars was witnessed with treatment of NAA (20 ppm) (11.55 % in Dehradun and 12.20 % in Calcuttia) than rest of treatments. Similarly, maximum total sugars in both cultivars were also observed considerably with NAA treatments compared to the control. This may be attributed that auxin promotes rapid mobilization of photosynthates, minerals in developing fruits and increases cell membrane permeability that accelerates the breakdown of organic acids (stored in cell vacuole). Kaur *et al.* (2024) also confirmed that NAA as plant growth regulator enhanced fruit quality of Daisy mandarin.

The effect of auxins on pericarp a^*, b^* and hue angle coordinates depicted the degree of redness to greenness and yellowness to blueness and saturation of redness, respectively. It is obvious that 'a^*', 'b^*' and hue angle (h^*) coordinates were substantially influenced with NAA treatments (Fig. 1). In Dehradun, significantly higher 'a^*' coordinate was registered with NAA 20 ppm (28.32), followed by NAA 30 ppm (28.15) and NAA 40 ppm (26.94) than the rest of treatments. However, coordinate values of 'b^*' ranged from 24.29 to 27.69 in plants treated with NAA

Table 2: Effect of NAA on fruit chemical attributes of litchi cultivars, pooled data for four locations

Treatment	TSS (%)	T.S.S/acid	Reducing sugars (%)	Total sugars (%)	Anthocyanin (mg100 g^{-1}pericarp)
Dehradun					
NAA 10 ppm	18.78^{c}	30.55^{d}	10.86^{b}	14.18^{bc}	13.50^{b}
NAA 20 ppm	19.83^{a}	37.3^{a}	11.55^{a}	14.86^{a}	13.15^{c}
NAA 30 ppm	19.40^{b}	35.0^{b}	11.11^{ab}	14.40^{b}	14.48^{a}
NAA 40 ppm	19.03^{c}	33.9^{c}	11.00^{ab}	14.51^{b}	15.00^{a}
Control	18.33^{d}	28.9^{d}	10.22^{c}	14.0^{c}	11.33^{d}
Calcuttia					
NAA 10 ppm	20.65^{b}	28.90^{bc}	10.86^{bc}	14.71^{b}	20.33^{ab}
NAA 20 ppm	22.25^{a}	33.20^{a}	12.20^{a}	15.74^{a}	21.85^{a}
NAA 30 ppm	21.08^{b}	29.83^{b}	11.32^{bc}	14.98^{b}	20.13^{ab}
NAA 40 ppm	20.38^{b}	28.03^{c}	11.44^{ab}	15.00^{b}	19.73^{b}
Control	19.25^{c}	25.48^{d}	10.63^{c}	14.45^{b}	16.81^{c}

Least square means with same denotation are not significantly different ($p \leq 0.05$)



Vertical bars symbolize ±SE of means for 3 replicates.

Fig. 1 Effect of NAA treatments on pericarp colour in litchi cultivars

treatments. Likewise, '*b**' coordinate was observed the higher under the control in both cultivars depicting more yellowish pericarp colour.

Foliar application of NAA causes significant reduction in hue angle coordinate and notable enhancement of pericarp anthocyanin content. These findings corroborated with those of Balbontín *et al.* (2018) and they noted a decrease in hue angle with increase in anthocyanin content among sweet cherry subjected to different hormonal treatments. Dutta *et al.* (2011) also found the impact of PGRs on anthocyanin content of litchi fruits. The chroma value indicates the quantitative measure for colourfulness or purity of colour. The results indicated higher chroma value in NAA treated fruits over

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the control. Pericarp colour gradually changed from green to pink and finally red during fruit maturation. These transitions are not uniform across fruit surface which might be responsible for the comparative decrease in chroma values. Plant bio-regulators effectively improved fruit yield and quality due to better supply of nutrients, water and other compounds required for their growth and development that in turn produced fruits of superior size, quality and ultimately greater yield (Pandey, 1999).

CONCLUSION

Thus, application of NAA (20 ppm) after 10 days from fruit setting significantly managed physiological disorders which led to more fruit production and improved physical and chemical quality attributes of Dehradun and Calcuttia litchi cultivars growing under sub tropical climatic conditions of North India.

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