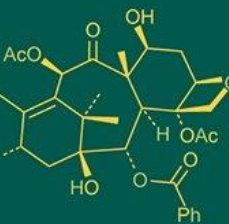
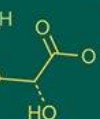
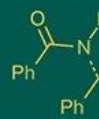


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(8): 709-717
www.biochemjournal.com
Received: 01-05-2026
Accepted: 05-06-2026

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Efficacy of foliar feeding of micronutrients and growth regulators on yield and quality attributes of litchi (*Litchi chinensis* Sonn.) cultivar 'China'

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8i.9750>

Abstract

Litchi (*Litchi chinensis* Sonn.) is considered as one of the most important sub-tropical fruits of the world. Under submountaneous zone of Punjab (India), the litchi growers are facing problem of unstable and lower marketable yield and inferior quality due to higher incidence of fruit cracking, fruit drop, low sugar content and higher fruit acidity. Keeping in mind the present investigation was conducted to study the positive effects of foliar feeding of nutrients and growth regulators on fruit drop, cracking, yield and quality attributes of litchi (*Litchi chinensis* Sonn.) cultivar 'China' in the submountaneous zone of Punjab (India). The current experiment was conducted in the Punjab Agricultural University, Regional Research Station, Gurdaspur (India) during the year 2023-24 and 2024-25. The experiment was laid out in Randomized Block Design with eleven treatments and replicated thrice with a unit of one plant in each replication of a treatment. Different concentrations of borax (0.8%, 1.0%), zinc sulphate (0.8%, 1.0%), 2,4-dichlorophenoxyacetic acid (2,4-D) (10 ppm, 20 ppm), gibberellic acid (GA₃) (10 ppm, 20 ppm), 1-naphthaleneacetic acid (NAA) (10 ppm, 20 ppm) along with control were sprayed two times, first sprayed on new growth flushes before initiation of inflorescence and second sprayed after fruit setting in litchi. The pooled data of two years revealed that application of NAA 20 ppm drastically reduced fruit drop. Borax 1.0% spray increased fruit set and reduced fruit cracking. Pericarp anthocyanin and colour were also improved with NAA 20 ppm spray application as compared to the control. Foliar spray of GA₃ 20 ppm improved the fruit yield and quality attributing parameters of fruits.

Keywords: Fruit drop, fruit cracking, growth regulators, micronutrients, fruit setting, fruit quality, fruit yield

1. Introduction

Litchi (*Litchi chinensis* Sonn.) belongs to the family Sapindaceae, and is one of the important sub-tropical fruit crops of India. Litchi is native to Southern china, particularly the provinces of Kwantung and Fukien. From China it was introduced in India by the end of the 17th century (Knight, 1980; Liang, 1981) [39, 47], where it has acclimatized so much that India is now the second largest producer of litchi, after its native place China. It is highly specific to climatic requirements, as it required cool dry winters and warm wet summers and due to this reason its cultivation is restricted to few states in our country. Litchi is grown mainly in the states of Bihar, West Bengal, Uttar Pradesh and Punjab. It is also grown in limited scale in Tripura, Orissa, Himachal Pradesh, Assam and south Nilgiri hills. In Punjab, its cultivation recommended to submountaneous tracts of Gurdaspur, Hoshiarpur, Roopnagar, SAS Nagar Mohali and Patiala districts. In India, 577 thousand metric tonnes of litchi is produced annually from 99.0 thousand hectares area (Anonymous, 2024) [2]. In Punjab, litchi is growing in an area of 3775 hactares with the production of 16540 tonnes (Anonymous, 2023) [3]. Litchi is an arillate and nut type fruit botanically which is known for its excellent quality, juicy, slightly sour and sweet taste, characteristic pleasant flavour, attractive colour and nutritional value. The fruit is rich in sugars, minerals and vitamins (Marisa, 2006) [51] and can be processed into juice, wine, pickles, jam, jelly, ice cream and yoghurt (Huang *et al.*, 2005) [33]. It comes to the market in the months of May-June when the market is full of other fresh fruits. But, inspite of the availability of different types of fruit in the market, the demand for fresh litchi is always very high due to its unique taste, flavour and colour (Hossain *et al.*, 2014) [32].

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Litchi 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 state of India. The problems responsible for low economic potential of litchi cultivation in various litchi growing regions include poor fruit set (Sarkar *et al.*, 1984)^[76], heavy fruit drop (Singh and Phogat, 1984)^[81], fruit cracking (Bhat *et al.*, 1997)^[10] and inferior fruit quality (Brahmachari and Rani, 2001)^[11]. The litchi based cropping system is affected with physiological disorder, fruit drop and fruit cracking (Lal *et al.*, 2017)^[44]. Although the litchi tree flowers profusely, but fruit setting in specific litchi cultivar varies from 1 to 50 percent, which is far higher than fruits retained till maturity (Nath *et al.*, 2021)^[57]. Around 90-95 percent fruit drop occurs up to third week after pollination (Gharge *et al.*, 2025)^[25]. 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, nutrient deficiency, insect attack and hormonal imbalances (Lal *et al.*, 2021)^[44]. The higher level of growth promoters and lower abscisic acid content are prerequisite for fruit set and afterward for fruit growth, development, and retention. The foliar application of growth regulators and micronutrients are effective in improving fruit yield and quality (Hitesh *et al.*, 2025; Piyadarshi *et al.*, 2018)^[31, 65]. Lower ratio of growth promoters to abscisic acid 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)^[91]. Therefore, plant growth regulators and micronutrients have been used for many years to alter the fruit plant behaviour for the economic benefits such as to control the vegetative growth, increase in flowering and fruit set, stimulation of maturity and ripening and improving fruit quality. It is also reported that growth substances like gibberellic acid (GA₃), borax, 1-naphthalene acetic acid (NAA) and 2,4-D (2,4-Dichlorophenoxyacetic acid) have great influence on litchi and proved beneficial in reducing the cracking and dropping of fruits and enhancing the quality of fruits along with delay in harvest (Kaur, 2017)^[38]. Gibberellic acid has been found to offer suitable means of controlling ripening process in litchi and improving fruit quality (Ray and Sharma, 1986)^[70] and other fruit crops (Lavon *et al.*, 1982)^[46]. The foliar application of nutrients and growth regulators in specific plant developmental and critical stages improves the yield and quality. Foliar application of micronutrients has gained importance because it is a well-established operation to complete and boost plant nutrition. Foliar application can meet the expense of nutrients where absorption of nutrients from the soil is unavailable due to plant stress or in adverse soil conditions (Marschner, 2012)^[52]. Application of plant growth regulators results in increased flowering, fruiting and fruit retention. Yield and quality of litchi fruit have been positively influenced by application of nutrients and plant growth regulators (Singh and Phogat, 1984)^[81]. Reduced flower induction and fruit set, leading to inferior fruit quality are caused by zinc and boron deficiency (Menzel and Simpson, 1987)^[53]. Micronutrients applied in optimum concentrations results in better plant growth which causes better flowering, higher fruit set that ultimately leads to higher yield (Ram and Bose, 2000)^[67]. Micronutrients plays

specific role in improving the growth, yield and quality of litchi even though these elements are needed in small quantities. Zinc and boron take part in various enzymatic reactions and helps in sugar accumulation in fruit from source to sink (Priyadarshi *et al.*, 2018)^[65]. Boron is the only micronutrient not only specifically associated with either photosynthesis or enzyme function, but it is also associated with the carbohydrate chemistry and reproductive system of the plant. Micronutrients such as zinc, boron and copper play an important role in litchi nutrition, especially with regard to increase the flowering, fruit setting, fruit retention, fruit size and quality. Zinc plays a vital role in the metabolic activities of plants. The principal function of zinc in plants is as a metal activator of enzymes like dehydrogenase (pyridine nucleotide, glucose-6 phosphodiesterase, carbonic anhydrase etc.). It is involved in the synthesis of tryptophane, a precursor of indole-3-acetic acid. It is associated with water uptake and water retention in plant bodies (Kumar *et al.*, 2009)^[41]. Boron is also required for photosynthetic activities, cellular differentiation, hormone metabolism and water absorption in plants. It is essentially required during reproduction phase, i.e., germination of pollen tube and fertilization, because boron deficiency produced less number of flowers which resulted in mostly sterile, deformed fruit and such type of fruits are commercially useless (Ruby *et al.*, 2001)^[71]. Plant growth regulators signalling the various metabolic processes in plants such as apical dominance, inhibition of apical dominance, regulating flowering and early ripening by using ethrel in less amounts, is very effective and significantly improves yield and quality of fruit (Choudhary *et al.*, 2013)^[16]. Plant growth regulators can also increase the ascorbic acid content in fruits by synthesis of catalytic activity of several enzymes and coenzymes which are essential in ascorbic acid synthesis (Suman *et al.*, 2017)^[83]. Although the effect of micronutrients and growth regulators in enhancing yield and quality in litchi have been investigated over the years, but the studies on the effect of foliar feeding of nutrients and growth regulators on yield and quality attributes of litchi cultivar 'China' in particular is scarce especially in the sub-montaneous zone of Punjab. Keeping in view, the present investigation was undertaken to evaluate the efficacy of foliar feeding of micronutrients (zinc and boron) and growth regulators (GA₃, 2, 4-D and NAA) on yield and quality attributes of litchi (*Litchi chinensis* Sonn.) cultivar 'China'.

2. Material and Methods

2.1 Experimental site

The present investigation on "Efficacy of foliar feeding of micronutrients and growth regulators on yield and quality attributes of litchi (*Litchi chinensis* Sonn.) cultivar 'China'" was conducted during the years 2023-24 and 2024-25 at Punjab Agricultural University, Regional Research Station, Gurdaspur. This region is sub-montaneous zone of Punjab which is situated between 32°3' N latitude, 75°22' E longitude and has an altitude of about 257 m from mean sea level having humid subtropical and dry winter climate. The sub-montaneous zone of Punjab (*kandi* region) features hilly topography with *shivalik* foothills, undulating terrains, and deep, coarse-textured sandy loam to silt loam coarse textured soils.

2.2 Selection of plants and treatments detail

Litchi plants (25-30 years old) grown in the orchard were selected for this experiment on the basis of their uniformity in appearance, growth habit, free from visual symptoms of pests and disease occurrence. Different doses of borax (0.8%, 1.0%), zinc sulphate (0.8%, 1.0%), 2,4-dichlorophenoxyacetic acid (2,4-D) (10 ppm, 20 ppm), gibberellic acid (GA₃) (10 ppm, 20 ppm), 1-naphthaleneacetic acid (NAA) (10 ppm, 20 ppm), along with control were tested. Zinc sulphate (ZnSO₄) and borax were sprayed on new growth flushes before initiation of inflorescence, whereas 2,4-D, GA₃ and NAA were sprayed after fruit setting in litchi. The experiment was planned out in a randomized block design and each treatment was replicated thrice with a single tree as a treatment unit. The spray solution was prepared by dissolving the calculated dose of growth regulators (laboratory grade) in alcohol, then made the final volume in water along with spreader Tween-20 (0.01%). The control trees were sprayed with plain water without any micronutrients and growth regulators. The cultural practices were adopted as per 'Package of Practices for Cultivation of Fruit Crops', Punjab Agricultural University, Ludhiana (2025).

2.3 Observations recorded

Twenty terminal flowering shoots per plant were randomly selected in each direction of tree canopy and tagged for recording various observations viz. fruit set(%), fruit drop(%), fruit cracking(%), fruit colour, fruit yield (kg/tree), fruit weight (gm), fruit length(cm) & fruit breadth (cm), nut length (cm) & breadth (cm), nut weight (gm), pulp weight (gm), peel weight (gm), TSS (%), acidity (%), sugars(%), ascorbic acid (mg/100 ml) and anthocyanins (mg/100 g⁻¹ pericarp). Number of fruits in each tagged panicles were counted after fruit set before the plants sprayed and the percentage was worked out after counting the final fruit set, fruit drop and fruit cracking about one week prior to harvesting. Fruit yield was estimated by weighing all fruits during harvesting and was expressed in kg/plant. The fruit weight, pulp weight, stone weight and peel weight were measured using digital balance and expressed in gram. Fruit length & breadth and nut length & breadth were measured with digital vernier's calipers and expressed in cm. Total soluble solids percentage of fruit juice was recorded using digital hand refractometer (Atago, Japan) at 20 °C with necessary correction factor, while acidity percentage 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 and ascorbic acid were analyzed as per (AOAC, 2005) [4]. Pericarp anthocyanin content was determined as per spectroscopy method suggested by Ranganna (1991) [69]. The technique involves extraction of anthocyanin using ethanolic hydrochloric acid and measurement of colour at 535 nm wavelength against ethanolic hydrochloric acid (used as blank).

2.4 Statistical analysis

The recorded experimental data were statistically analyzed by using one-way analysis of variance (ANOVA) with Randomized Block Design (RBD) as suggested by Gomez and Gomez (2010) [28] by using SPSS software.

3. Results and Discussion

3.1 Fruit set

Significant higher fruit set (92.62%) in comparison with other treatments including the control were noticed in plants sprayed with borax 1.0%, whereas the control treatment had the lowest fruit set (60.25%) (Table 1). According to Liu (1986) [48], 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) [36]. Borax response was more positive due to boron, which plays an important role in translocation of carbohydrates, auxin synthesis and increased pollen viability and fertilization. Similarly, maximum fruit set, fruit retention, fruit size, fruit weight and fruit yield were observed in foliar application of 0.4% borax in litchi cultivar 'Dehradun' (Kaur, 2017) [38]. Borax on increasing the fruit setting with reduced fruit drop on date palm cultivar 'Barhi' (El-Sharabasy and Ghazzawy, 2019) [21].

3.2 Fruit drop

The trees sprayed with NAA 20 ppm registered lowest fruit drop (8.26%) compared to rest of treatments (Table 1) and maximum fruit drop (48.21%) was observed in control treatment. The reduction of fruit drop by NAA 20 ppm application is mainly due to the effect of auxin which helps to reduce the disintegration of cells and thereby reduces fruit drop (Noggle and Fritz, 1989) [58]. Generally auxin helps in cell division, cell enlargement, cell elongation and reduction in abscission layer (Salisbury and Ross, 1992) [75]. Similarly Sahay *et al.*, (2018) [73] also reported minimum fruit drop with the use of NAA 20 ppm in litchi cultivar 'Purbi'. These findings align with the results of Badal *et al.*, (2021) [6] in guava, Tripathi *et al.*, (2022) [86] in aonla and Kumar *et al.*, (2023) [40] in ber.

3.3 Fruit Cracking

1-naphthalene acetic acid plays a significant role in reduction of pericarp fruit cracking. The fruit cracking was minimum (3.51%) with application of borax 1.0% and maximum fruit cracking (46.18%) was noted in control treatment (Table 1). The reducing of fruit cracking by foliar application of borax might be attributed to the fact that boron is important nutrient for plant growth/development, flowering and fruiting. Borax plays major role in cell wall membrane function, cell wall strength and development, cell division, fruit and seed development, sugar transport. The reducing effect on fruit cracking percent in response to application of boron was mainly attributed to its important role in the extension of plant cell walls through building of pectins and water uptake. This might be due to beneficial effect of boron in general improvement and extension of plant cell wall through its association with cell wall pectins. The role of boron application in reducing fruit cracking may probably be due to translocation of sugars and synthesis of cell wall material. Similarly Haqmal *et al.*, (2022) [29] reported that foliar application of 0.3% borax was quite effective in minimizing fruit cracking in pomegranate cv. Mridula. Likewise Singh *et al.*, (2022) [79] also reported minimum fruit cracking with borax (0.4%) in litchi cultivar 'Dehradun'. Similarly Baloda *et al.*, (2023) [9] noted that four sprays of borax 0.3% during the 3rd week of April, 1st

week of May, and last week of May and 2nd week of June proved to be the best treatment in reducing the fruit cracking in pomegranate.

3.4 Fruit yield

Litchi plants sprayed with GA₃ 20 ppm had highest fruit yield (150.52kg/tree) as compared to rest of the treatments (Table1). Exogenous application of gibberellic acid (GA₃) increases cell size and intercellular spaces coupled with more accumulation of water and nutrients in greater amount. This may have improved the fruit size and weight which ultimately enhanced yield. The above results were in accordance with Parauha and Pandey (2019) [61] in mango and Singh *et al.*, (2021) [80] & Purohit *et al.*, (2019) [66] in guava. Pre-harvest spray of GA₃ 100 ppm recorded significantly maximum fruit weight and fruit yield of sapota cultivar 'Kalipatti' (Bagul *et al.*, 2021) [7]. Maximum fruit set, retention and yield of rambutan fruit were obtained by preharvest foliar spray of GA₃ 300 ppm (Uddin *et al.*, 2024) [87]. Gibberellic acid with various concentrations at the different developmental stages, increases both quality and yield in grapes (Pahi *et al.*, 2020) [59].

3.5 Fruit length& fruit breadth (fruit size) and fruit weight

From the Table1, it has been noted that with the foliar spray of GA₃ 20 ppm, the maximum fruit length (4.75 cm), fruit breadth (4.15 cm) and fruit weight (25.32 gm) were observed in litchi fruits as compared to other treatments applied. The study showed that concentration of gibberellic acid 250 ppm, it helped to increase the fruit size (fruit length & fruit breadth), fruit weight, total soluble solids and ascorbic acid level in cape gooseberry (Kumar *et al.*, 2017) [42]. These results are in close conformity with the findings of Tohamy *et al.*, (2012) [85] and Kaur *et al.*, (2013) [37] in Cape gooseberry. Also fruit size and pulp weight were increased with GA₃ 300 ppm preharvest foliar spray in Rambutan fruits (Uddin *et al.*, 2024) [87]. Gibberellic acid is one of the critical regulators for carbohydrate translocation to the sink from the source. As a result of this partitioning, the growth of sink tissues is induced (Iqbal *et al.*, 2011) [34], resulting in higher fruit size and weight. Cell division, elongation, and enlargement are major effects of gibberellin in plants. In the present study, GA₃ might have played critical roles in raising sink potential through boosting cell quantity or controlling cell division, such as plastid biogenesis and DNA amplification, or by altering the duration or speed of dry mass deposition of developing fruits (Davies, 1995) [18]. These observations are comparable with the findings of Kaur (2017) [38] in litchi, where preharvest GA₃ application resulted in increased fruit length, width and weight compared to control. Similar effects were obtained by applying GA₃ on the other fruits viz. pear (Canli and Pektas, 2015) [13], sweet cherries (Sabir *et al.*, 2021) [72], pineapple (Li *et al.*, 2011) [46], Japanese plum (Erogul and Sen, 2015) [22], custard apple (dos Santos *et al.*, 2016) [19], blueberry (Zang *et al.*, 2016) [92] and mango (Ahmed *et al.*, 2012; Vishwakarma *et al.*, 2022) [1, 88].

3.6 Nut length& Nut breadth (nut size) and Nut weight

From Table1 and 2, It has been noted that minimum nut size in terms of nut length (1.31cm) nut& breadth (1.12 cm) and nut weight (2.32 gm) were observed in GA₃ 20 ppm spray and maximum vales of these parameters were noticed in

control treatment. The present findings of reduced nut/seed weight and size can be attributed to and supported by the effectiveness of gibberellic acid in inducing parthenocarpy in many fruits, including apples (Galimba *et al.*, 2019) [24], pears (Liu *et al.*, 2018) [49], cherries (Sabir *et al.*, 2021) [72], loquats (Mesejo *et al.*, 2010) [54] and custard apples (dos Santos *et al.*, 2016) [18]. dos Santos *et al.*, (2016) [19] also observed a considerable reduction in the total seed weight and number of seeds in custard apple with the application of gibberellic acid. Ahmed *et al.*, (2012) [1] also noted minimization of stone weight in mango due to the use of GA₃. Similarly, litchi seed weight was also reduced with GA₃ 100 mg/litre⁻¹ application (Chen *et al.*, 2014) [15]. Likewise reduction in seed weight was observed with gibberellic acid spray treatment in litchi as reported by Kaur (2017) [38] and also reported in sugar apples by Pereira *et al.*, (2019) [62].

3.7 Pulp weight (gm) and peel weight (gm)

The litchi sprayed with GA₃ 20 ppm had significantly maximum fruit pulp weight (21.65 gm) with minimum peel weight (1.35 gm) as compared to rest of treatments (Table 2). Fruits obtained from panicles treated with GA₃ 20 ppm had a maximum pulp weight of rambutan fruits (Uddin *et al.*, 2024) [87]. Increase in pulp weight after GA₃ treatment was obtained by Pereira *et al.*, (2014, 2019) [63, 62] in atemoya and sugar apple, by dos Santos *et al.*, (2016) [19] in custard apple, by Sahay *et al.*, (2018) [73] in litchi, by Ahmed *et al.*, (2012) [1] in mango, by Saleem *et al.*, (2007) [74] in sweet orange and by Ramezani and Shekafandeh (2009) [68] in olive. Pulp weight increased with GA₃ application and the fruit size increasing even after reaching physiological ripeness until harvest maturity, causing local swelling of the pericarp, ultimately reducing the thickness of the skin. The opposite process occurred for control fruits, where further low fruit size with minimal fruit surface area did not reduce skin thickness. The present results are consistent with the findings of Chang and Lin (2006) [14] in litchi, Pozo *et al.*, (2000) [64] in mandarin, and Fidelibus *et al.*, (2002) [23] in orange.

3.8 Total soluble solids (TSS)(%) and total sugars(%)

Total soluble solids (TSS) (25.46%) and total sugars (22.65%) contents of litchi fruits significantly highest in GA₃ 20 ppm application on the panicles (Table2) and the control treatment had lowest values. Similarly, maximum value of total soluble solids and total sugars were reported in preharvest foliar spray of GA₃ 300 ppm treatment to rambutan fruit (Uddin *et al.*, 2024) [87]. As gibberellic acid is closely related to the carbohydrate partitioning in the reproductive organ (Wang *et al.*, 2020) [89], exogenous application of GA₃ probably increased the total soluble solids contents of fruits under treatment compared to control. The study showed that increasing the concentration of gibberellic acid 250 ppm it helped to increase the fruit size, fruit weight, total soluble solids and ascorbic acid level of cape gooseberry (Kumar *et al.*, 2017) [42]. The results are in line with the findings of Hifny *et al.*, (2017) [30] in washington navel orange, Li *et al.*, (2011) [46] in pineapple and Mishra *et al.*, (2017) [55] litchi fruits. Gibberellic acid induced TSS increment was also observed in mango (Ahmed *et al.*, 2012) [1], litchi (Kaur, 2017) [38], blueberry (Zang *et al.*, 2016) [92], and sweet cherry (Canli and Orhan, 2009) [12]. The increase in TSS by the application of GA₃

might be due to the effect of enhanced photosynthetic efficiency, more dry matter accumulation in plants and better partitioning of photo assimilates and nutrients from leaves to the developing sink organs (Sharma and Singh 1990)^[77]. The improvement in sugar content in fruits due to GA₃ spraying can be explained by the fact that the application of this hormone probably enhanced the physiological functions of the plant, which resulted in the acceleration of the translocation of essential components in the fruits and the subsequent photosynthesis by the growing rambutan fruits (Ghosh *et al.*, 2009)^[26]. Possibly, Kaur (2017)^[38] showed an 18.5% increase in sugar levels in GA₃ treated litchi panicles compared to the control.

3.9 Acidity (%)

Gibberellic acid treatment showed significant changes in the titratable acidity (TA) content of litchi fruits (Table 2). Lowest fruit acidity value 0.35%) was noted in foliar spray of GA₃ 20 ppm to litchi plants and highest acidity value (0.49%) was observed in control treatment. Similarly, minimum value of acidity were reported in GA₃ 300 ppm treatment to rambutan fruits (Uddin *et al.*, 2024)^[87]. The lowering titratable acidity trends in the fruits of GA₃ treated panicles may be due to conversion of organic acids into soluble sugars during fruit development and maturation as observed by Souza *et al.*, (2019)^[82] in cashewnut. Likely, minimum TA contents in fruits of *Pyrus communis* L. resulted in GA₃ application (Gilani *et al.*, 2021)^[27]. Almost identical phenomena in TA accumulation in the sink after preharvest gibberellic acid were also noted by Yadav *et al.*, (2022)^[90] in mango, by Moradinezhad *et al.*, (2020)^[56] in pomegranate, and by Talat *et al.*, (2020)^[84] in kinnow mandarin fruits.

3.10 Ascorbic acid (mg/100 ml)

Higher vitamin C content imparts higher nutritive value to fruits. Data in Table 2 shows that the content of vitamin C was recorded higher (41.36 mg/100 ml) in the GA₃ 20 ppm treated fruits than in non-treated control (24.18 mg/100 ml). These results were in line with the findings of Sindhu and Sighrot (1993)^[78] who reported maximum ascorbic acid content in GA treated fruits. Foliar application of different

concentrations of gibberellic acid significantly increased the ascorbic acid content of cape gooseberry fruits (Kumar *et al.*, 2017)^[42]. Awad and Al-Qurashi (2012)^[5] used gibberellic acid in the cultivation of date palms of the 'Barhee' variety and showed a positive influence of hormonisation on the vitamin C level in the fruit. Application of GA₃ significantly increased the vitamin C content in grapes (Kaplan *et al.*, 2019)^[35].

3.11 Fruit colour and anthocyanins (mg 100 g⁻¹ pericarp)

It has been observed that litchi plants sprayed with NAA 20 ppm produced fruits having dark red peel colour with highest anthocyanin content (25.53 mg100 g⁻¹ pericarp) as compared to rest of treatments (Table 2). This is due to the transcript levels of key anthocyanin regulatory, biosynthetic and transport genes were significantly up regulated upon fruit exposure to NAA (Clayton-Cuch *et al.*, 2021)^[17]. Similarly, Balbontin *et al.*, (2018)^[8] noted a decrease in hue angle with increase in anthocyanin content among sweet cherry subjected to different hormonal treatments. Dutta *et al.*, (2011)^[20] also found the impact of plant growth regulators on anthocyanin content of litchi fruits. The chroma value indicates the quantitative measure for colourfulness or purity of colour. The present results indicated higher chroma value in NAA treated fruits over 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 growth 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)^[60]. Ripening and anthocyanin production was enhanced by the synthetic auxin 1-naphthaleneacetic acid (NAA) application to sweet cherry trees during the straw-color stage of fruit development (Clayton-Cuch *et al.*, 2021)^[17]. Ma *et al.*, (2021)^[50] also reported that NAA treatments accelerated the colour changes from green to orange in the gibberellin (GA) and prohydrojasmon (PDJ) treated citrus fruit during the ripening process.

Table 1: Effect of micronutrients and plant growth regulators on yield components of litchi fruit.

Treatments	Fruit Set (%)	Fruit Drop (%)	Cracking (%)	Fruit Length (cm)	Fruit breadth (cm)	Nut Length (cm)	Nut Breadth (cm)	Fruit Yield (kg/tree)	Fruit colour
Borax 0.8%	73.58	35.28	8.32	3.21	2.85	2.40	2.15	82.46	Medium red
Borax 1.0%	87.12	22.10	3.51	4.05	3.56	1.91	1.63	100.05	Red
Zinc sulphate 0.8%	79.05	33.18	13.25	3.36	2.96	2.31	2.05	86.18	Medium red
Zinc sulphate 1.0%	92.62	20.14	10.46	4.30	3.70	1.72	1.51	108.11	Red
2,4-D 10 ppm	65.41	27.02	28.17	3.42	3.12	2.25	1.96	90.13	Pink
2,4-D 20 ppm	77.18	15.36	20.38	4.41	3.81	1.58	1.32	118.33	Pink
GA3 10 ppm	67.35	30.51	26.12	3.86	3.45	2.05	1.76	95.21	Light Pink
GA3 20 ppm	82.36	18.22	16.44	4.75	4.15	1.31	1.12	150.52	Light Pink
NAA 10 ppm	69.18	25.10	22.56	3.62	3.26	2.16	1.86	92.06	Medium red
NAA 20 ppm	85.15	8.26	14.18	4.52	3.95	1.46	1.25	130.15	Dark Red
Control	60.25	48.21	46.18	3.10	2.76	2.55	2.31	60.45	Pink
CD (p = 0.05)	4.55	3.53	2.72	0.61	0.55	0.37	0.42	28.15	-
SE(m)	1.53	1.19	0.92	0.20	0.19	0.12	0.14	9.47	-

Table 2: Effect of micronutrients and plant growth regulators on quality parameters of litchi fruit.

Treatments	Pulp weight (gm)	Stone weight (gm)	Peel weight (gm)	Fruit weight (gm)	TSS (%)	Acidity (%)	Sugars (%)	Ascorbic acid (mg/100 ml)	Anthocyanins (mg100 g ⁻¹ pericarp)
Borax 0.8%	15.26	3.60	2.60	21.46	19.6	0.47	12.25	29.61	19.26
Borax 1.0%	18.02	2.95	2.05	23.02	21.12	0.41	16.18	36.40	21.51
Zinc sulphate 0.8%	15.65	3.51	2.47	21.63	19.84	0.46	13.28	30.58	19.52
Zinc sulphate 1.0%	18.5	2.81	1.85	23.16	21.72	0.39	16.65	37.50	22.15
2,4-D 10 ppm	16.15	3.36	2.38	21.89	19.95	0.45	14.21	32.08	20.14
2,4-D20 ppm	19.05	2.68	1.76	23.49	22.28	0.38	17.45	39.65	23.10
GA ₃ 10 ppm	17.63	3.12	2.16	22.91	20.72	0.42	15.34	34.53	21.05
GA ₃ 20 ppm	21.65	2.32	1.35	25.32	25.46	0.35	22.65	41.36	25.53
NAA 10 ppm	16.74	3.25	2.25	22.24	20.36	0.43	14.75	33.28	20.53
NAA 20 ppm	19.76	2.52	1.52	23.80	22.46	0.36	18.26	38.21	23.65
Control	13.5	4.01	3.04	20.55	19.05	0.49	15.52	24.18	18.21
CD (p = 0.05)	1.83	0.75	0.62	2.18	1.23	0.02	1.56	1.76	2.34
SE(m)	0.62	0.25	0.21	0.74	0.41	0.01	0.53	0.59	0.79

4. Conclusion

The present investigation concluded that among the eleven different concentrations of growth regulators and micronutrients applied at new growth flushes before initiation of inflorescence and after fruit setting in litchi, the foliar application of NAA 20 ppm after fruit setting significantly managed the fruit drop and also improved the fruit colour and pericarp anthocyanin pigments. Borax 1.0% spray increased fruit set and also reduced fruit cracking. Also foliar spray of GA₃ 20 ppm improved physical and chemical quality attributes of litchi cultivar 'china' growing under submountaneous zone of Punjab.

5. Acknowledgments

Author thanks the Punjab Agricultural University, Regional Research Station, Gurdaspur (India) for all support in conducting the experiment.

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