https://doi.org/10.17221/47/2025-HORTSCI

Investigating the role of 6-BAP and 2,4-DPA in enhancing biochemical nutrients and reducing fruit drop and cracking of litchi cv. Bombai

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Citation: Sarker B.C., Islam S.S., Farhana K., Hakim M.A., Khomphet T. (2026): Investigating the role of 6-BAP and 2,4-DPA in enhancing biochemical nutrients and reducing fruit drop and cracking of litchi cv. Bombai. Hort. Sci. (Prague), 53: 148–159.

Abstract: Litchi fruit dropping is a major issue that leads to low yields while degrading biochemical nutrient qualities by fruit cracking and reduced income for litchi growers in Bangladesh. To address this, an experiment was conducted to determine the effects of biochemical nutrients and the ability to reduce fruit cracking and dropping in the litchi cv. 'Bombai' under various concentrations of 6-benzylaminopurine (6-BAP) and 2,4-dichlorophenoxyacetic acid (2,4-DPA). The study followed a two-factor factorial experiment in a randomised complete block design, using four levels for each growth regulator: control, 20, 30, and 40 ppm 2,4-DPA, and similarly for 6-BAP. Various parameters were measured, including the number of flowers, fruit retention, fruit cracking, moisture content, ash content, acidity, fruit growth, and fruit quality, as well as yield per tree. The results demonstrated that both plant growth regulators, 2,4-DPA and 6-BAP, significantly reduced fruit dropping and cracking while improving the overall quality and nutrient content of the fruits. The retention of fruits was higher with 6-BAP compared to 2,4-DPA. The highest fruit weight, length, diameter, pulp-to-seed ratio, and pulp-to-peel ratio were achieved with the 20 ppm treatments of both 2,4-DPA and 6-BAP. Additionally, biochemical fruit quality indicators, including vitamin C, vitamin A, total phenol content, and key mineral nutrients, were significantly enhanced by both growth regulators. Based on the findings, it is recommended that either 20 ppm of 2,4-DPA or 20 ppm of 6-BAP be applied three times at the pea-size, marble-size, and pre-harvest stages after fruit set to enhance fruit quality by reducing fruit crack and reducing fruit drop resulted in higher yield in litchi.

Keywords: food nutrients; fruit cracking; fruit retention; litchi; yield enhancement

Supported by the Ministry of Science and Technology, Government of the People's Republic of Bangladesh in 2022–2023 (Project No. SL 230/SRG-221230, Group: Biological Science) under special allocation for Science and Technology.

https://doi.org/10.17221/47/2025-HORTSCI

Litchi (*Litchi chinensis*) belongs to the subfamily Nepheleae of the Sapindaceae family, which consists of around 2 000 species, and is native to the South of China. It is often referred to as the queen of fruits due to its exceptional quality, juicy texture, balanced sugar-acid ratio, appealing colour, distinctive flavour, and high nutrient content (Raghavan et al. 2018). These qualities have contributed to its worldwide popularity, creating opportunities for increased export growth (Mozumder et al. 2016). In Bangladesh, litchi is cultivated on approximately 26 000 hectares, with the highest production concentrated in Dinajpur, Pabna, and Jashore districts (DAE 2023). Notably, litchis from Dinajpur, particularly from Dinajpur Sadar and Biral Upazila, are renowned for their superior taste and are a prime source for discerning buyers. Despite its potential, litchi cultivation faces several physiological challenges that limit yield and quality, such as fruit cracking, splitting, flower and fruit drop, sunburn, irregular bearing, black spot, and retarded fruit development. Among these, fruit cracking and fruitlet drop are the most significant constraints, with a majority of fruit loss occurring within the first month after fruit set (Lal et al. 2019). Fruit drops continue up to ripening, with various factors contributing to losses at different stages. The economic potential of litchi cultivation is further impacted by poor fruit set, heavy fruit drops, fruit cracking, and substandard fruit quality (Brahmachari, Rani 2001). Therefore, understanding the causes and symptoms of these physiological disorders is crucial for effective management, with variations in incidence and severity depending on locality, season, cultivar, and orchard management practices.

Research indicates that plant growth regulators (PGRs) and plant micronutrients positively influence fruit yield and phytochemical content in litchi and other crops (Sarker et al. 2021). Plants naturally regulate fruit abscission to balance crop load with nutrient availability, which often results in the drop of physiologically ripe fruits or nearly ripe fruits as part of the senescence process. Synthetic auxins, treated during the fruit development stage, have been shown to enhance fruit growth (Westwood 1993). Constantini et al. (2007) demonstrated that synthetic auxins promoted antioxidant capacity and improved nutritional quality in seedless grapes. Numerous studies have sought to prevent lichi fruit abscission through the use of synthetic auxins like NAA, 2,4,5-T, and 2,4-dichlorophenoxyacetic acid (2,4-DPA) (Stern et al. 1995). For instance, Tuan and Chung-Ruey (2013) reported that 2,4-DPA application reduced fruit cracking to 0.83 fruit cracks per cluster compared to untreated controls. Cracked fruits lose their marketable value in the fresh market and are suitable for processing only if they are free of fungal contamination. These fruits are also more susceptible to storage diseases and have a shorter shelf life. Kumar et al. (2014) stated that growth substances such as NAA, 2,4-DPA, p-chlorophenoxyacetic acid (PCPA), gibberellic acid (GA3), benzylaminopurine (BA), and cycocel (CCC) minimised fruit drops and cracking while enhancing fruit quality. The lowest fruit drop was recorded with 20 ppm PCPA, and the least cracked fruits was observed with 20 ppm NAA. Similarly, Dixit et al. (2013) found that GA3 at 10 ppm effectively enhanced fruit set, retention, and fruit size, with GA3 at 20 ppm producing the highest fruits per tree and the lowest level of fruit cracking. PGRs act as crucial messengers within the plant system, required in small quantities and at low concentrations. They often influence multiple processes, as their sites of action and biosynthesis differ. As such, using one or more PGRs can impact a range of physiological responses. While litchi cv. 'Bombai' often yields high production, issues such as fruitlet dropping and fruit cracking reduce fruit quality and ultimately impact farmers' income and market demand. Thus, improving quality and minimising yield losses are key objectives of this study. While several studies have explored litchi production, growth, and disease management, research on the application of PGRs to reduce fruit cracking and abscission remains insufficient. This study aims to address that gap, with the hope that its findings will assist farmers, producers, traders, consumers, extension workers, and researchers in improving litchi production and marketing in both domestic and international markets. By reducing fruit abscission and preventing cracking, this research aims to increase litchi yield and quality, enabling farmers to meet market demand. Furthermore, the study seeks to provide sustainable, eco-friendly technology for improving litchi production.

The objectives of this research were (1) to investigate the biochemical contents (soluble sugars, vitamins, total phenolic compounds, and protien), mineral contents (Ca, Mg, Fe, and Zn), yield characteristics, and morpho-physiological responses

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of litchi to 2,4-DPA and 6-BAP, (2) to study the effects of 2,4-DPA and 6-BAP in improving fruitlet retention and reducing at the fruit maturity stage of litchi cv. 'Bombai', and (3) to determine appropriate PGR concentrations and application timing, providing farmers with sustainable, eco-friendly tools for enhancing litchi quality and profitability.

MATERIAL AND METHOD

The experiment was conducted in a farmer's orchard located in Masimpur, Dinajpur Sadar Upazila, Dinajpur (25°38'N, 88°32'E), which is representative of the litchi-growing region. The plant species used in this study was *L. chinensis* Sonn., cv. 'Bombai'. Tested litchi plants were sprayed with two synthetically produced PGRs, such as 2,4-DPA and 6-BAP, thrice at the pea-size, marble-size, and pre-harvest stages. The origin of both PGRs is collected from China. The 2,4-DPA is a widely used systemic herbicide; however, it is now widely being used to counteract the fruitlet dropping and fruit cracking of litchi, while 6-BAP, a synthetic plant growth regulator that acts as a cytokinin, stimulates cell division and is an essential process for plant growth, fruit enlargement and quality. The experiment was designed as a two-factor factorial experiment in a randomised complete block design with three replications. Factor A consisted of two PGRs: 2,4-DPA and 6-BAP. Factor B involved four concentration levels of each PGR (0, 20, 30, and 40 ppm). Twenty-four tree plants were used for the study. Each experimental unit was a single tree, aged 10-12 years. Soil samples were collected at 0–30 cm in depth and analysed at the Soil Science Laboratory of Hajee Mohammad Danesh Science and Technology University and the Soil Resource Development Institute. The results indicated that the soil was silty loam in texture with an acidic pH. The organic matter and organic carbon content were classified as medium, while the soil exhibited high levels of available phosphorus and sulphur (Table 1).

Climatic condition. The research was conducted during the litchi growing season (February to June 2023), which coincides with the Rabi and Kharif-1 seasons. The experimental site experiences a subtropical climate. At the beginning of the season, air temperatures were relatively low but increased steadily as the season progressed into the hotter Kharif-1 period. From mid-April 2023, temperatures began to rise significantly, reaching 35 °C during the litchi fruit maturity stage. The highest recorded maximum temperature was 34.66 °C in July, while the lowest maximum temperature, 22.25 °C, was observed in January. The minimum temperature in July was 27.33 °C, and June recorded the highest rainfall, with 425 mm. Rainfall during the experimental period was generally low to moderate (Figure 1).

Fertiliser management. The field was appropriately fertilised with both macro- and micronutrients, as outlined in Table 2. Micronutrients were applied as foliar sprays, based on observed deficiencies, with the frequency and timing of application determined by the severity of the deficiency.

Field data collection. Staminate and perfect flowers were counted on tagged panicles weekly throughout the flowering season. The fruit set percentage was computed by dividing the number of fruits per panicle by the perfect flowers. Fruit drop percentages were recorded at three distinct stages of fruit development – pea, marble, and pre-harvest – based on the retained fruit at each stage, as well as by counting the dropped fruits beneath the tree. The fruit cracking was monitored every other day during the premature and maturity stages. The following growth and yield data were

Table 1. Physical and chemical properties of soil in the experimental field

Parameters	Characteristics
pH	7
Sand (%)	21.73
Silt (%)	58.07
Clay (%)	20.20
Textural class	silt loam
Bulk density (g/cm^3)	1.642
Particle density (g/cm^3)	2.27
Total N (%)	0.19
Organic matter (%)	3.98
Organic C (%)	2.31
Available P (µg/g)	105.96
Available K (meq/100 g)	0.74
Available Ca (meq/100 g)	11.37
Available Mg (meq/100 g)	4.31
Available S (µg/g)	32.60
Available Zn (µg/g)	13.84
Available B (µg/g)	0.49

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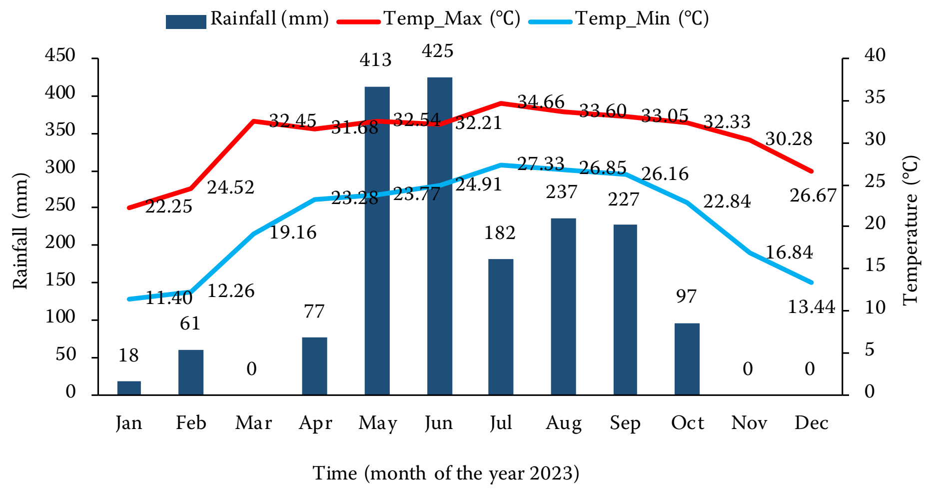

Figure 1. Monthly temperatures and rainfall during January to December of 2023

collected: the number of flowers per inflorescence per tree, the length of the flower inflorescence, the number of fruits per branch, dropped fruitlets, cracked fruits, fruit weight, length, and diameter, nut weight, length, and diameter, pulp weight, the nut-to-pulp ratio, and total yield per tree.

Chemical analysis. The following chemical analysis of fruit was determined, namely, ash, moisture, pH, acidity, crude fibre, sugars, vitamin C, minerals (Fe, Zn, Ca, Mg), and protein. Moisture content was estimated by the gravimetric method. For total sugar, the sample was analysed by the titrimetric method using Fehling's solution (AOAC 2000).

Vitamin C was determined by Ranganna's (1979) method as follows:

$$\text{Vitamin C}(\%) = \frac{\text{Titrate value} \times \text{dye factor} \times \text{volume of sample made up} \times 100}{\text{volume of sample used} \times \text{weight of juice sample} \times 1000}$$

β-carotene and vitamin A were quantified in mg/g or mg/100 mL using Igbokwe et al. (2013) method as equation:

$$\beta\text{-carotene} = 0.216 \times A663 - 0.304 \times A505 + 0.452 \times A453 \text{ (mg/g)}$$

$$\text{Vitamin A} = \frac{\beta - \text{carotene}\left(\frac{\text{mg}}{\text{g}}\right)}{0.6}$$

Calcium content was determined using the complexometric titration method, with Na_2-EDTA serving as the complexing agent. Iron concentration was measured through redox titration, where the extraction was prepared in phosphoric acid, and potassium

Table 2. Nutrient management for litchi cv. 'Bombai'

Major-nutrient		Quantities/annum/tree (g)	Time of application (in soil)
FYM	cow dung	60 000	after harvest
N	urea	600	30% after fruit set (pea size) and remaining in March
P	TSP/DAP	600	after harvesting
K	MoP	250	30% after fruit set and remaining after harvest
Ca	gypsum/lime/dolomite	500	if the soil pH is below 6
Micronutrient		concentration (g/L)	time of application (foliar)
Cu	$CuSO_4$	2	twice at 15 days interval (October–November)
Zn	$ZnSO_4$	2	twice at 15 days interval (December/January–February)
B	borax	2	2–3 times at 15 days interval (March–April)

FYM – farm yard manure; TSP/DAP – triple super phosphate/diammonium phosphate

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permanganate was used as the oxidising agent for the titration. The phenolic content was determined using the Folin-Ciocalteau method (Singleton et al. 1999), with absorbance readings recorded using a spectrophotometer (AquaMate Plus UV-Vis).

Statistical analysis. Data were subjected to the analysis of variance. Analysis of variance and mean comparison by Duncan's multiple range test (DMRT) was done by the SPSS program (version 29.0.0.0, 2022). The weather graph was done using MS Excel.

RESULTS AND DISCUSSION

Flower and fruit retention. The influence of both 2,4-DPA and 6-BAP was statistically significant in the number of flowers and demonstrated the most effectiveness, particularly at the lower concentration of 20 ppm (Table 3). The highest flowers per inflorescence (187) was observed with 20 ppm, followed closely by 30 ppm with 176 flowers. In contrast, the control treatment recorded the lowest flower count at 27.81. Notably, the application of 6-BAP also resulted in a significant increase in flower numbers, with 20 ppm exhibiting the best results compared to the control. Furthermore, all treatments improved the length of the inflorescence, with 2,4-DPA proving to be the most effective, particularly at the concentration of 20 ppm. The maximum inflorescence length observed was 29.47 cm with treatment 20 ppm 2,4-DPA, followed by 30 ppm 2,4-DPA at 176 cm and 40 ppm 2,4-DPA at 175 cm, both statistically comparable. The control treatment recorded the minimum inflorescence length of 27.81 cm. Remarkably, spraying with 6-BAP also yielded similar benefits for inflorescence length as observed with the 20-ppm concentration compared to the control.

The data clearly indicated that varying concentrations of 2,4-DPA and 6-BAP significantly reduced fruit drop across four consecutive assessments (Table 3). All treatments notably enhanced fruit retention in the litchi cv. 'Bombai', with the highest fruit retention of 38.45 fruits per bunch observed in treatment 20 ppm 2,4-DPA, closely followed by 30 and 40 ppm treatments. Conversely, the minimum fruit retention was observed in the control plants at 26.78 fruits per bunch without 2,4-DPA application. A similar trend was observed for fruit retention, with treatment 20 ppm 6-BAP yielding a maximum of 41.42 fruits per bunch, while control plants without 6-BAP spray exhibited the lowest retention at 26.93 fruits.

Table 3. Fruit retention of lichi at different times under different 2,4-DPA and 6-BAP levels (in ppm)

Treatments	Flowers/ inflorescence	Length of inflorescence	Initial fruitlets/ bunch	Fruitlets retention/bunch after 10 days	Fruit retention/ bunch after 30 days	Fruits retention/ bunch at harvest
2,4-DPA						
0	157.33^{c}	27.81^{c}	70.68^{c}	60.16^{b}	45.08^{c}	26.78^{d}
20	187.00^{a}	29.47^{a}	77.18^{a}	66.52^{a}	48.86^{a}	38.45^{a}
30	176.00^{b}	29.28^{a}	74.36^{b}	63.30^{ab}	46.91^{b}	35.75^{b}
40	175.67^{b}	28.42^{b}	71.08^{c}	60.75^{b}	44.91^{c}	32.00^{c}
SE	2.09	0.13	0.74	1.57	0.71	0.55
P < 0.05	*	*	*	*	*	*
6-BAP						
0	158.33^{c}	28.08^{b}	70.52^{d}	60.66^{c}	45.00^{c}	26.93^{d}
20	187.67^{a}	29.47^{a}	78.46^{a}	68.10^{a}	49.78^{a}	41.42^{a}
30	175.67^{b}	29.30^{a}	74.71^{b}	64.16^{b}	46.20^{b}	37.95^{b}
40	176.00^{b}	28.45^{b}	73.08^{c}	63.00^{b}	44.92^{c}	32.66^{c}
SE	1.39	0.17	0.53	0.78	0.44	0.98
P < 0.05	*	*	*	*	*	*

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; SE – standard error; means with the same letter are not significantly different at P < 0.05 level

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Fruit cracking and total fruit yield per plant. All biostimulant treatments significantly decreased fruit cracking. Notably, a marked reduction in the incidence of fruit cracking was observed with all applied substances compared to the control. Lower biostimulant concentrations proved to be more effective in mitigating fruit cracking. The lowest fruit cracking was 4.30 per plant at 30 days post-fruit setting and 23.61 per plant at harvest when using 30 ppm of 2,4-DPA. In contrast, the maximum fruit cracking was observed at 9.40 per plant at 30 days post-fruit setting and 37.33 at harvest in the control group, where no PGRs were applied. Similar results were noted with 6-BAP, indicating its effectiveness in reducing fruit cracking during the study. Thus, it is evident that both 2,4-DPA and 6-BAP significantly decreased fruit cracking in litchi cv. 'Bombai'. The overall litchi fruit yield was significantly enhanced with the application of both PGRs. The highest average yield recorded was 4 998.3 fruits per plant under treatment 20 ppm 2,4-DPA, while the control group yielded only 2 727.0 fruits. For 6-BAP, the maximum yield per plant was 5 157 fruits using 20 ppm, compared to a minimum yield of 2 786 fruits in the control group. Among the various concentrations of 2,4-DPA and 6-BAP, 20 ppm demonstrated the best performance compared to the 30 and 40 ppm (Table 4). Reduced fruit cracking in litchi applying 20 ppm BA was revealed by Mishra et al. (2012) and 10 ppm 2,4-DPA by Sahay et al. (2018). Note is that the negative impact of higher concentration of 2,4-DPA might have herbicidal effects (Yawalkar et al. 1992). Soil water and plant nutrient uptake governed by soil properties, environmental conditions especially day temperature, rainfall and soil moisture which effect on the accumulation solute in litchi fruits and minimize the pressure on skin, resulting in reduction in cracking. Auxin stimulation by 2,4-DPA and 6-BAP might be the reason for accumulation of building blocks at a faster rate and better execution of source-sink relation registering better fruit setting, increased setting and less fruit dropping along with reduced cracking (Sahay et al. 2018). The present finding was also in well agreed with Kaur (2017) for 2,4-DPA and Mishra et al. (2012) for 6-BAP.

Fruit characteristics. The application of PGRs significantly enhanced fruit weight. Notable variations were observed among the different PGR treatments and their respective concentrations. The highest average weight of litchi fruit was recorded at 27.12 g under 20 ppm 6-BAP, while the control exhibited a weight of only 23.02 g (Table 5). For 2,4-DPA, the maximum weight of an individual litchi fruit reached 27.24 g with the application of 20 ppm, compared to a minimum of 22.39 g in the control. Among the various concentrations

Table 4. Fruit cracking of lichi at different times under different 2,4-DPA and 6-BAP levels (in ppm)

Treatments	Fruit cracking after 30 days	Fruit cracking at harvest	Total fruit yield/plant
2,4-DPA			
0	9.40^{a}	37.33^{a}	2 727.00^{c}
20	4.17^{b}	26.73^{b}	4 998.30^{a}
30	4.26^{b}	24.09^{c}	4 235.70^{b}
40	4.30^{b}	23.61^{c}	4 147.00^{b}
SE	0.09	0.50	109.78
$P < 0.05$	*	*	*
6-BAP			
0	9.33^{a}	37.60^{a}	2 786.30^{c}
20	3.85^{c}	27.48^{b}	5 157.30^{a}
30	4.20^{b}	25.20^{b}	4 426.70^{b}
40	4.42^{b}	25.11^{b}	4 419.30^{b}
SE	0.12	0.41	80.12
$P < 0.05$	*	*	*

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; SE – standard error; means with the same letter are not significantly different at $P < 0.05$ level

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Table 5. Physical parameter of lichi fruit under different 2,4-DPA and 6-BAP levels (in ppm)

Treatments	Fruit weight (g)	Pulp weight (g)	Seed weight (g)	Peel weight (g)	Pulp to seed weight ratio
2,4-DPA					
0	22.39[c]	16.99[d]	3.04[a]	2.34[a]	5.57[c]
20	24.98[a]	19.98[a]	2.83[b]	2.16[a]	7.04[a]
30	23.77[b]	18.68[b]	2.88[b]	2.19[a]	6.48[b]
40	23.37[b]	18.20[c]	2.91[ab]	2.24[a]	6.25[b]
SE	0.17	0.16	0.06	0.21	0.14
$P < 0.05$	*	*	*	*	*
6-BAP					
0	23.02[c]	17.32[c]	3.09[a]	2.62	5.61[c]
20	27.12[a]	21.58[a]	2.96[b]	2.58	7.29[a]
30	26.31[b]	20.70[b]	3.02[ab]	2.58	6.85[b]
40	25.80[b]	20.24[b]	2.96[b]	2.60	6.86[b]
SE	0.26	0.24	0.04	0.05	0.12
$P < 0.05$	*	*	*	*	*

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; SE – standard error; means with the same letter are not significantly different at $P < 0.05$ level

of 2,4-DPA and 6-BAP, 20 ppm demonstrated superior results compared to the 30 and 40 ppm concentrations. Furthermore, the PGR 6-BAP was found to be more effective than 2,4-DPA in increasing fruit weight.

The application of PGRs significantly improved the weights of pulp, seeds, and peels in fruits compared to the control group. The maximum pulp weight reached 21.58 g with the treatment 20 ppm 6-BAP, while the control group recorded seed weight and peel weight at 3.09 g and 2.62 g, respectively. Similarly, 20 ppm of 2,4-DPA resulted in a maximum pulp weight of 19.98 g, with the same seed and peel weights as the control. This enhancement in fruit size and weight likely stems from the auxin properties of 6-BAP and 2,4-DPA, which promote the division and enlargement of cells, and increase the nutrient sink of the fruits (Chaudhary et al. 2006). The findings are consistent with Singh (2008), who indicated that the application of 6-BAP and 2,4-DPA enhances total fruit weight, as well as pulp, seed, and peel weights in litchi. In this study, 6-BAP demonstrated a more significant effect on fruit weight than 2,4-DPA. Both PGRs improved the average fruit weight, which is beneficial for farmers seeking higher returns. The highest pulp weight of 21.58 g was noted in the 6-BAP treatment (20 ppm), attributed to enhanced cell elongation, followed closely by 20 ppm of 2,4-DPA, which also yielded a pulp weight of 21.58 g. Statistical analysis revealed significant differences in the ratios of pulp to seed weight and pulp to peel weight. The highest average ratio of pulp to seed weight was 7.29 with 20 ppm 6-BAP, followed by 7.04 with 20 ppm 2,4-DPA. Likewise, the pulp-to-peel weight ratio was highest in the 6-BAP-treated plants, followed by those treated with 2,4-DPA. The lowest ratios were recorded in the control group, where only water was applied (Table 6).

In Table 6, there was a significant difference observed among the PGRs treatments, with the application of PGRs resulting in markedly greater lengths and diameters of both fruit and seeds in litchi compared to the control group. The longest fruit length measured 4.80 cm at a concentration of 20 ppm, while the maximum seed length reached 3.97 cm at 40 ppm of 2,4-DPA. The largest diameter of litchi fruit was recorded at 4.12 cm with 20 ppm of 2,4-DPA, whereas the control group exhibited the smallest diameter at 3.19 cm. Similarly, 2,4-DPA and 6-BAP produced a maximum fruit diameter of 3.91 cm at 20 ppm, with the control treatment yielding a minimum diameter of 3.35 cm. Significant variations were found in the lengths and diameters of litchi fruits

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and seeds. The highest seed diameter of 1.22 cm was recorded at 20 ppm of 2,4-DPA, which was statistically similar to that observed at 30 ppm; the control group displayed the lowest seed diameter of 1.22 cm. In addition, 6-BAP produced the largest seed diameter of 1.30 cm at 20 ppm, which was statistically comparable to both the 30 and 40 ppm treatments (Table 5). The observed increases in fruit size, weight, and volume with the application of specific cytokinins can be attributed to the auxin properties (NAA) that stimulate cell division and enlargement, and enhanced fruit sink strength (Chaudhary et al. 2006).

The application of PGRs led to markedly higher percentages of ash, moisture content, and total soluble solids (TSS) in the fruit compared to the control group. The highest values recorded were 24.98% moisture content, 19.98% ash, and 7.04% TSS at a concentration of 20 ppm of 2,4-DPA. Conversely, the maximum percentages for moisture content, ash, and TSS reached 7.42% at 0 ppm of 6-BAP. The highest pH level of litchi pulp juice was recorded at 3.05 in the control group, which was statistically comparable to that of the 40 ppm 2,4-DPA treatment. In contrast, the pH level for the 20 ppm 2,4-DPA treatment was 2.84. Similarly, the application of 2,4-DPA and 6-BAP resulted in the lowest pH of 3.05 for the pulp juice. Conversely, the lowest pH values were observed with the 20 ppm treatments of both 6-BAP and 2,4-DPA (Table 7).

Biochemical nutrient. Significant variations were observed among the parameters studied at different 2,4-DPA and 6-BAP levels (Figure 3). The application of 2,4-DPA and 6-BAP significantly enhanced the reducing and non-reducing, and total sugars in litchi fruit. Spraying with 20 ppm of 2,4-DPA and 6-BAP resulted in notably higher total sugar levels compared to other treatments. The highest reducing sugar content (3.97%) was recorded with 40 ppm 2,4-DPA, while non-reducing sugar (4.12%) and total sugar (1.22%) were maximised at 20 ppm 2,4-DPA. In contrast, the control group exhibited the lowest reducing, non-reducing, and total sugars (2.77, 3.19, and 1.13%) levels with the 40 ppm 2,4-DPA treatment. The treatments at 20 ppm and 30 ppm of 2,4-DPA showed similar results and were statistically comparable, while they significantly differed from the 40 ppm treatment (Figure 2).

A statistically significant variation was also observed in the total phenolic content among the litchi plants treated with different levels of 2,4-DPA and 6-BAP. The maximum phenolic content (6.24 mg/100 g) was observed in the 20 ppm 2,4-DPA

Table 6. Physical parameters of litchi fruit (pulp to peel ratio, fruit length, seed length, fruit diameter and seed diameter) under different 2,4-DPA and 6-BAP levels (in ppm)

Treatments	Pulp to peel weight ratio	Fruit length	Seed length	Fruit diameter	Seed diameter
		(cm)			
2,4-DPA					
0	7.36	3.43^{d}	2.76^{d}	3.19^{b}	1.17^{b}
20	9.28	4.80^{a}	3.13^{b}	4.12^{a}	1.22^{a}
30	8.57	4.16^{b}	2.93^{c}	3.93^{a}	1.16^{ab}
40	8.15	3.96^{c}	3.97^{a}	3.41^{b}	1.13^{b}
SE	0.80	0.0360	0.0360	0.1190	0.0268
$P \leq 0.05$	*	*	*	*	*
6-BAP					
0	6.62^{c}	3.53^{d}	2.87^{d}	3.35^{c}	1.23^{a}
20	8.35^{a}	4.07^{a}	3.09^{c}	3.91^{a}	1.30^{a}
30	8.03^{ab}	3.98^{b}	3.73^{a}	3.67^{b}	1.23^{a}
40	7.77^{b}	3.79^{c}	3.37^{b}	3.57^{b}	1.27^{a}
SE	0.16	0.03	0.06	0.06	0.03
$P \leq 0.05$	*	*	*	*	*

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; SE – standard error; means with the same letter are not significantly different at $P \leq 0.05$ level

https://doi.org/10.17221/47/2025-HORTSCI

Table 7. Moisture, ash, total soluble solid, and pH of lichi fruits under different 2,4-DPA and 6-BAP levels (in ppm)

Treatments	Moisture (%)	Ash (%)	Total soluble solid (°Brix)	pH
2,4-DAP				
0	22.37[c]	16.99[d]	5.57[c]	3.05[a]
20	24.98[a]	19.98[a]	7.04[a]	2.84[b]
30	23.77[b]	18.69[b]	6.49[b]	2.88[b]
40	23.36[b]	18.21[c]	6.25[b]	2.91[ab]
SE	0.17	0.16	0.14	0.06
$P < 0.05$	*	*	*	*
6-BAP				
0	22.386[c]	16.994[d]	5.58[c]	3.05[a]
20	24.982[a]	19.983[a]	7.04a	2.83[b]
30	23.771[b]	18.689[b]	6.49[b]	2.88[b]
40	23.365[b]	18.208[c]	6.25[b]	2.91[ab]
SE	0.1670	0.1572	0.14	0.06
$P < 0.05$	*	*	*	*

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; SE – standard error; means with the same letter are not significantly different at $P < 0.05$ level

treatment, while the control exhibited the lowest vitamin C content. The control group was significantly inferior to all other treatments in this aspect. The highest vitamin C (4.63 mg/100 g) was noted in treatment 20 ppm 2,4-DPA, whereas the control had the lowest vitamin C content. The control treatment was significantly inferior compared to all other treatments. The most effective treatment was 20 ppm 2,4-DPA, followed by 30 and 40 ppm. Significant differences were also found among treatments concerning biochemical nutrients such as β-carotene, vitamin A, and protein. The application of PGRs resulted in substantially higher levels of β-carotene and vitamin A in litchi fruits compared to the control. The maximum levels of β-carotene (8.15 mg/100 g) and vitamin A (13.46 mg/100 g), as well as protein

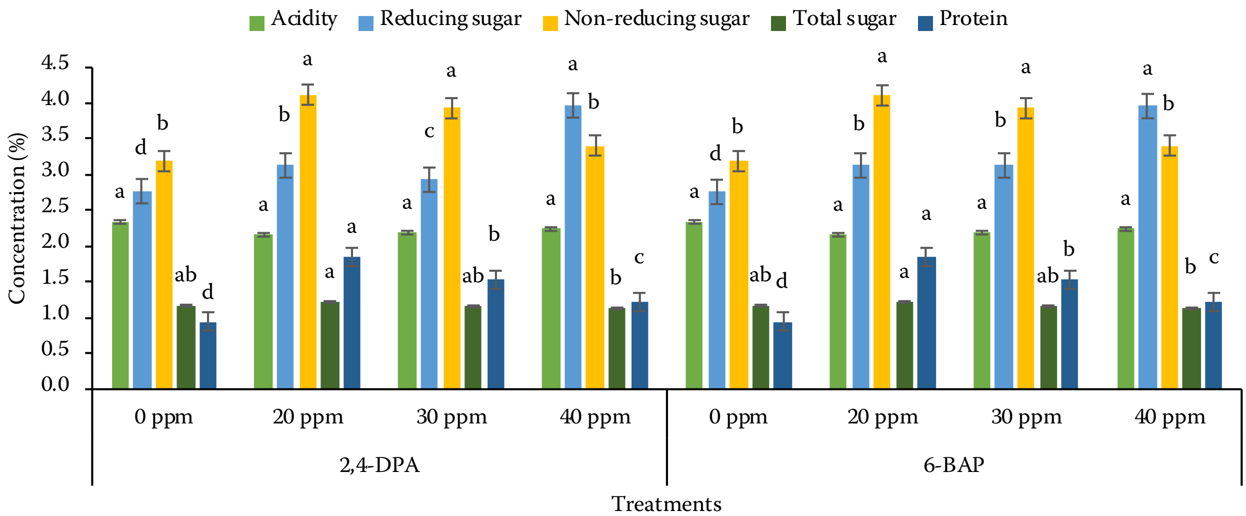

Figure 2. Biochemical properties of lichi fruits under different 2,4-DPA, and 6-BAP levels
2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; different letters indicate a significant difference at $P < 0.05$

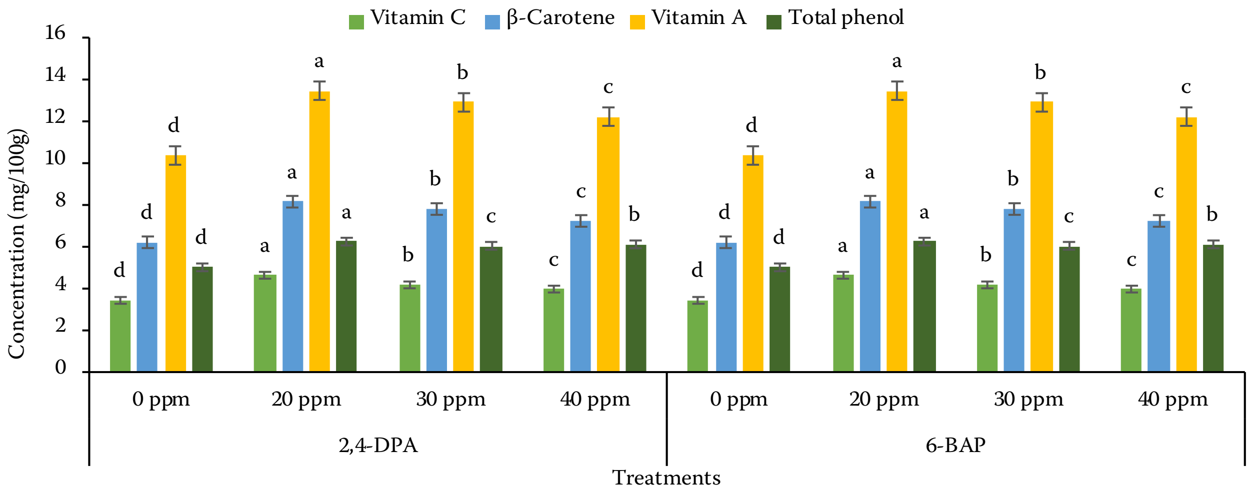

Figure 3. Biochemical food nutrients of lichi fruits under different 2,4-DPA and 6-BAP levels

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; different letters indicate a significant difference at $P < 0.05$

percentage (1.85%), were achieved with the 20 ppm 2,4-DPA treatment. Conversely, the control recorded the lowest levels of β-carotene (6.13 mg/100 g), vitamin A (10.36 mg/100 g), and protein (0.95%) (Figure 3). In the present study, it is evident that 6-BAP helped to increase TSS, reducing and non-reducing sugar, while 2,4DPA contributed to protein and higher vitamin A, respectively.

Nutrient element. Significant differences were observed among the PGRs treatments regarding the nutrient elements Ca, P, Zn, and Fe in litchi fruits. The application of PGRs resulted in substantially higher levels of Ca, P, Zn, and Fe compared to the control group. The maximum concentrations of Ca and P were recorded at 30.06 and 24.59 mg/100 g, respectively. Additionally, the highest levels of Zn and Fe were 42.86 and 42.19 mg/100 g, achieved through the application of 20 ppm 2,4-DPA and 6-BAP, respectively. In contrast, the control treatment exhibited the lowest concentrations of Ca (20.03 mg/100 g), P (20.87 mg/100 g), Zn (32.36 mg/100 g), and Fe (38.26 mg/100 g) (Figure 4).

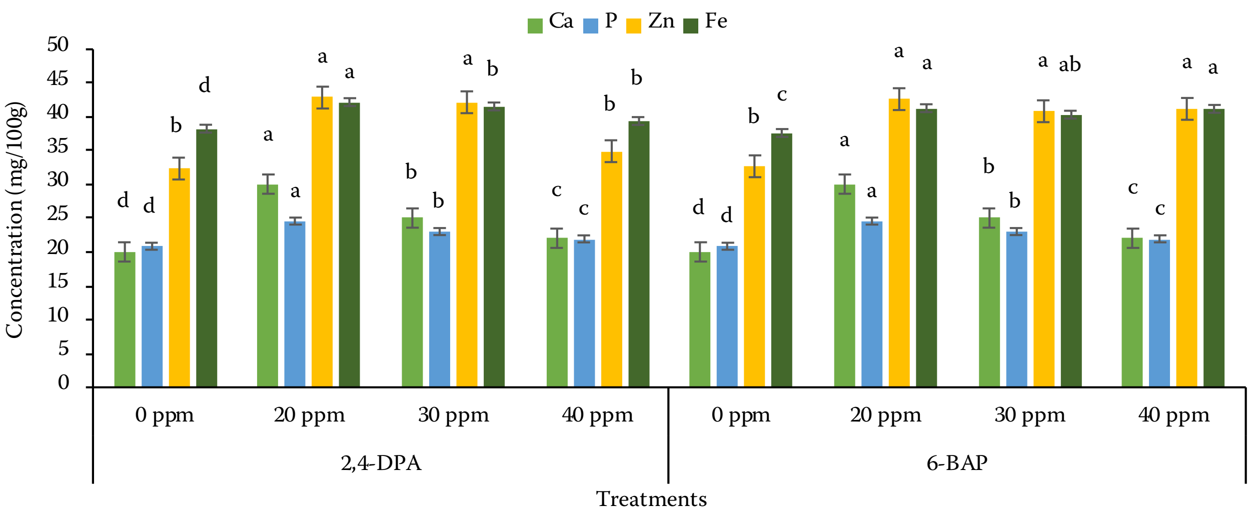

Figure 4. Nutrient elements of lichi fruits under different 2,4-DPA and 6-BAP levels

2,4-DPA – 2,4-dichlorophenoxyacetic acid; 6-BAP – 6-benzylaminopurine; different letters indicate a significant difference at $P < 0.05$

https://doi.org/10.17221/47/2025-HORTSCI

CONCLUSION

The results indicated that the 2,4-DPA and 6-BAP significantly decreased both fruit drop and cracking. The application of these PGRs also enhanced the quality and nutritional value of litchi fruits. Notably, fruit retention was greater with 6-BAP compared to 2,4-DPA. Treatments with 20 ppm of both 2,4-DPA and 6-BAP resulted in the highest increases in fruit weight, length, diameter, and the ratios of pulp to seed and pulp to peel. Additionally, fruit quality parameters, including vitamin C, vitamin A, total phenolic content, and mineral nutrients (Ca, P, Zn, and Fe), were significantly enhanced by applied PGRs. Therefore, it is recommended that 20 ppm of 2,4-DPA and 6-BAP be applied three times during the pea size, marble size, and pre-harvest stages after fruit set to improve fruit retention and fruit quality by minimising fruit cracking in litchi cv. 'Bombai'.

Acknowledgement: We thank Hajee Mohammad Danesh Science and Technology University for supporting the physical facilities.

REFERENCES

AOAC (2000): Official Methods of Analysis. 17th Ed., Washington, D.C. The Association of Official Analytical Chemist.

Brahmachari V.S., Ruby R. (2001): Effect of growth substances on productivity, cracking, ripening and quality of fruits of litchi. Orissa Journal of Horticulture, 29: 41–45.

Chaudhary B.R., Sharma M.D., Shakya S.M., Gautam D.M. (2006): Effect of plant growth regulators on growth, yield and quality of chilly (*Capsicum annuum* L.) at Rampur, Chitwan. Journal of the Institute of Agriculture and Animal Science, 27: 65–68.

DAE (2023): Litchi Cultivation. Department of Agricultural Extension. Available at https://dae.gov.bd/

Dixit A., Shaw S.S., Pal V. (2013): Effect of micronutrients and pant growth regulators on fruiting of litchi. HortFlora Research Spectrum, 2: 77–80.

Costantini E., Landi L., Silvestroni O., Pandolfini T., Spena A., Mezzetti B. (2007): Auxin synthesis-encoding transgene enhances grape fecundity. Plant Physiology, 143: 1689–1694.

Igbokwe G.E., Aniakor G.C., Anagonye C.O. (2013): Determination of β–carotene and vitamin C content of fresh green pepper (*Capsicum annnum*) fresh red pepper (*Capsicum annum*) and fresh tomatoes (*Solanum lycopersicum*) fruits. Bioscientist, 1: 89–93.

Kaur S. (2017): Effect of micronutrients and plant growth regulators on fruit set, fruit retention, yield and quality attributes in litchi cultivar Dehradun. Chemical Science Review and Letters, 6: 982–986.

Kumar A., Pandey D., Nath V., Rai R.R., Patel R. (2014): Role of plant growth regulators in litchi production. Biotech Articles, 2014: 1–4.

Kumar A., Singh A.K., Awasthi M., Verma S., Pandey S. (2024): Effect of gibberellic acid and naphthalene acetic acid on initial fruit set, drop, retention, yield and quality of ber (*Ziziphus mauritiana* Lamk.). Annals of Horticulture, 17: 76–83.

Lal N., Marboh E.S., Gupta A.K., Kumar A., Nath V. (2019): Fruit drop in litchi (*Litchi chinensis* Linn) influenced by seed and fruit borer. In: National Conf. Integrated Plant Health Management in Fruit Crops. Confederation of Horticulture Association of India, Pusa, Sept 3–4, 2019.

Mishra D.S., Kumar P., Kumar R. (2012): Effect of GA3 and BA on fruit weight, quality and ripening of 'Rose Scented' litchi. HortFlora Research Spectrum, 1: 80–82.

Mozumder S.N., Faisal A.M., Sultana D., Firoz Z.A. (2016): Effect of growth regulator and irrigation on fruit cracking and yield of litchi in the hilly area. International Journal of Advanced and Innovative Research, 5: 103–108.

Raghavan M., Das S., Ramjan M., Hazarika B., Langstieh L. (2018): Integrated nutrient management in litchi (*Litchi chinensis* Sonn.) cv. *Muzaffarpur* for yield and fruit quality at foothills of Arunachal Pradesh. International Journal of Chemical Studies, 6: 2809–2812.

Ranganna S. (1979): Manual Analysis of Fruits and Vegetables Products. New Dehli, Tata McGrwaw Hill Publishig Co. Ltd.

Sahay S., Kumari P., Mishra P.K., Kumar R. (2018): Pre-harvest foliar spray of micronutrients and growth regulators on yield attributes of litchi (*Litchi chinensis* Sonn.) 'Purbi'. Acta Horticulturae, 1211: 141–144.

Sarker B.C., Roxy A.A., Islam M.S. (2021): Effect of 6-benzyle aminopurine on morpho-physiological properties and grain yield of aromatic rice (cv. Kataribhog). International Journal of Agriculture and Medicinal Plants, 2: 16–23.

Singh G. (2008): Effect of irrigation, foliar fertilization and plant bioregulators on growth, yield and quality of pomegranate cv. G-137. [Ph.D. Thesis.] Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Singleton V.L., Orthofer R., Lamuela R.R.M. (1999): Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods in Enzymology, 299: 152–178.

https://doi.org/10.17221/47/2025-HORTSCI

Stern R.A., Kigel J., Tomer E., Gazit S. (1995): Mauritius' lychee fruit development and reduced abscission after treatment with the auxin 2,4,5-TP. Journal of the American Society for Horticultural Science, 120: 65–70.

Tuan N.M., Chung-Ruey Y. (2013): Effect of gibberellic acid and 2,4-dichlorophenoxyacetic acid on fruit development and fruit quality of wax apple. International Journal of Biology Food, Veterinary and Agriculture Engineering, 7: 28–36.

Westwood M.N. (1993): Temperate-Zone Pomology: Physiology and Culture. 3rd Ed. Portland, Timber Press.

Yawalkar K.S., Agrawal J.P., Bokde S. (1992): Manures and Fertilizers. 7th Ed. Nagpur, Agri-Horticultural Publishing House.

Received: April 1, 2025
Accepted: October 15, 2025
Published online: June 4, 2026