The International Innovations Journal of Applied Science (IIJAS) Vol. 3 No.1, 15-03-2026
DOI: https://doi.org/10.61856/qy9h6k93

Scientific Events Gate

The International Innovations Journal of Applied Science

Journal homepage: https://iijas.eventsgate.org/iijas

ISSN: 3009-1853 (Online)

Growth and Yield Improvement in Strawberry through Foliar Application of Boron and Zinc

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ARTICLE INFO

Article history:
Received 2 Aug. 2025
Revised 2 Dec. 2025,
Accepted 1 Mar. 2026,
Available online 15 Mar. 2026

Keywords:
Boron
Foliar spray
Growth
Quality
Strawberry
Yield
Zinc

ABSTRACT

The present investigation entitled "Growth, Yield and Quality Improvement in Strawberry through Foliar Application of Boron and Zinc" was conducted during the rabi season of 2024–25 at the Experimental Polyhouse, College of Agriculture, Central Agricultural University, Imphal. The study aimed to evaluate the individual and combined effects of foliar-applied boron (B) and zinc (Zn) on the growth, yield, quality parameters, and economics of strawberry (Fragaria × ananassa Duch., cv. Chandler). The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising three levels of boron (0%, 0.01%, 0.02%) and three levels of zinc (0%, 0.02%, 0.04%), forming nine treatment combinations. Results revealed that the foliar application of 0.02% boron and 0.04% zinc (T9) significantly enhanced plant growth attributes, including maximum plant spread (E–W: 29.07 cm; N–S: 29.91 cm), earliest 50% flowering (60.13 days), and highest number of flowers per plant (24.73). This treatment also recorded the highest fruit set percentage (80.55%), number of runners per plant (17.90), and yield attributes such as fruit length (3.62 cm), fruit diameter (3.28 cm), fruit weight (14.63 g), and yield per hectare (109.86 q/ha). Economic analysis indicated that T6 achieved the highest net return (₹1287393.267/ha) and benefit–cost ratio (1.492). The improvement in growth and productivity may be attributed to boron's role in cell wall formation, pollen tube growth, and sugar transport, and zinc's role in auxin synthesis, enzyme activation, and chlorophyll formation. The findings demonstrate that combined foliar application of boron (0.02%) and zinc (0.04%) is a highly effective strategy for enhancing strawberry growth, yield, quality, and profitability under the humid subtropical conditions of North-East India. This integrated micronutrient management approach has potential for wider adoption to maximize returns from commercial strawberry cultivation.

1. Introduction

Strawberry (Fragaria × ananassa) is one of the most delicious and nutritious fruits globally (Bibi et al., 2016). It is widely consumed fresh and as a flavouring in various processed products such as ice-creams, jams, jellies, cakes, and milkshakes. The fruit is an important source of vitamins A, B1, B2, and C, dietary fibre, minerals, and calories (Kazemi, 2015; Singh et al., 2015). Apart from its nutritional value, strawberry possesses medicinal properties such as anticarcinogenic, antidiabetic, and antioxidant effects (Kumar et al., 2017). Globally, about 20 recognized species of strawberry exist across five chromosome groups, including diploids, tetraploids, pentaploids, hexaploids, and octaploids. Morphologically, strawberry is a herbaceous perennial belonging to the family Rosaceae. Its compressed vertical stem, known as the crown, produces a rosette of trifoliate leaves and inflorescences in spring (Sharma, 2002; Chadha, 2001). Runners produced from axillary buds form new plants upon rooting in moist soil. The shallow root system is concentrated within

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DOI: https://doi.org/10.61856/qy9h6k93

the top 15 cm of soil, making it sensitive to moisture and nutrient availability. The strawberry fruit is technically an aggregate of achenes borne on a succulent receptacle. Flowers are usually hermaphroditic and self-fertile, though dioecious species exist. Environmental factors such as temperature, photoperiod, and light intensity strongly influence strawberry growth and productivity. The optimal day temperature ranges between 22°C and 25°C, with night temperatures between 7°C and 13°C. Frost injury during flowering can cause "black eye" damage to the pistil, which can be mitigated by mulching, row covers, or good air drainage. Photoperiod affects stolon formation, leaf area, and yield, with longer days generally enhancing vegetative growth. Straw mulch, from which the name "strawberry" originates, serves multiple purposes, including frost protection, moisture conservation, and fruit cleanliness. Nutritionally, strawberries are low-calorie fruits but rich in vitamin C—containing more than oranges—and fibres. The fruit also contains ellagic acid, a phenolic compound with anti-cancer and anti-asthma properties (Chandrakar et al., 2019). Its perishable nature necessitates careful postharvest handling, often involving refrigeration or freezing. Globally, strawberry is cultivated in over 63 countries, with 2012 production estimated at 4.52 million tonnes from 2.41 million ha (FAO, 2014). The United States is the largest producer, contributing over a quarter of global output. In India, strawberry occupies about 1,000 ha with an annual production of 5,000 MT (Anonymous, 2018). Maharashtra is the leading producer, though the North Eastern states have significant untapped potential due to their favourable climatic conditions (Hossain et al., 2017). Despite its economic potential, strawberry production faces challenges such as poor fruit set, premature fruit drop, uneven ripening, inadequate colour development, and high perishability. Addressing these constraints requires optimized agronomic practices, including nutrient management strategies tailored to the crop's specific needs. Foliar application of micronutrients is an effective way to correct deficiencies rapidly, as nutrients are absorbed directly through the leaves, bypassing soil-related constraints such as fixation, leaching, or volatilization losses. Zinc (Zn), absorbed as Zn^{2+}, is essential for numerous enzymatic processes, auxin synthesis, and reproductive development. Its deficiency—common in both acidic and alkaline soils—can lead to delayed maturity, reduced photosynthesis, and smaller fruits. Boron (B), absorbed as H_3BO_3, is vital for sugar transport, cell wall integrity, pollen germination, and fruit quality. Deficiency can impair pollination, cell division, and carbohydrate metabolism, leading to poor fruit set and reduced yields (O'Kelley, 1957). Previous studies have shown that foliar application of $ZnSO_4$ enhances fruit size, quality, and sugar content, while boron application improves pollen tube growth, seed setting, and overall fruit quality (Farid et al., 2020). The synergistic application of B and Zn may further enhance vegetative and reproductive growth by improving nutrient uptake efficiency and physiological functions. The cultivar 'Chandler' is one of the most promising, high-yielding, cold-hardy, short-day varieties suitable for tropical and subtropical conditions. It bears medium to large fruits that are red, moderately firm, and flavourful, with tolerance to grey mould but susceptibility to leaf spot. Considering the importance of boron and zinc in enhancing strawberry productivity and quality, this study was undertaken.

2. Materials and Methods

The present investigation entitled "Growth, Yield and Quality Improvement in Strawberry through Foliar Application of Boron and Zinc" was conducted during the rabi season of 2024–2025 at the Experimental Polyhouse, College of Agriculture, Iroisemba, Central Agricultural University, Imphal, situated at 24°45′89″ N latitude and 94°03′46″ E longitude at an altitude of 875 m above MSL, under a humid subtropical climate. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising three levels of boron (B0 – 0%, B0.01 – 0.01%, B0.02 – 0.02%) and three levels of zinc (Zn0 – 0%, Zn0.02 – 0.02%, Zn0.04 – 0.04%), forming nine treatment combinations (T1–T9). Foliar sprays

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were applied at 30, 60, and 90 days after planting (DAP), with boron sprays in combination treatments applied one week after zinc application. The strawberry cultivar 'Chandler' was planted on 15th September 2024 at a spacing of 60 × 45 cm, with approximately 37,037 runners per hectare, on paddy straw–mulched raised beds. The recommended dose of fertilizers (N:P:K @ 75:80:60 kg/ha) was applied, with phosphorus and potassium as basal and nitrogen split into three applications (half at planting, one-fourth at 30 DAP, and one-fourth at 60 DAP). The experimental soil was acidic (pH 5.1), with high organic carbon (1.31%), medium available N (198.7 kg/ha), low P (13.24 kg/ha), medium K (190 kg/ha), and deficient in Zn (0.59 mg/kg) and B (0.31 mg/kg). Weather data during the crop season recorded mean maximum temperatures between 29.4°C and 23.2°C and minimum temperatures between 20.3°C and 7.7°C, with total rainfall of 2.31 mm. Standard cultural practices such as manual weeding, irrigation, and pest management were followed. Growth parameters recorded included plant spread (E–W and N–S), days to 50% flowering, number of flowers per plant, fruit set percentage, and number of runners per plant. Yield parameters included number of fruits per plant, fruit length, fruit diameter, fruit weight, fruit volume, yield per plant, and yield per hectare. Economic analysis included cost of cultivation, gross and net returns, and benefit–cost ratio, calculated from prevailing market prices. Statistical analysis of data was carried out following the procedures of Gomez and Gomez (1984), with significance tested at p=0.05.

3. Results and discussion

3.1 Effect on Growth

Foliar application of boron and zinc significantly increased strawberry plant spread (E-W and N-S) at 60, 90, 120, and 150 DAP, though no effect was seen at 30 DAP. Boron at 0.02% (B0.02) and zinc at 0.04% (Zn0.04) individually enhanced spread through improved cell division, elongation, auxin synthesis, nutrient uptake, and chlorophyll formation. The combined application (T9: B0.02Zn0.04) produced maximum spread across all growth stages, with the maximum spread recorded under 0.02% B and 0.04% Zn (T9) at 150 DAP (E–W: 29.07 cm, N–S: 29.91 cm) due to synergistic effects on carbohydrate metabolism, hormone regulation, and water relations, followed by T8 (B0.01Zn0.04), as indicated in table 1. These findings align with Bakshi et al. (2013a, 2013b), Singh et al. (2015), Chaturvedi et al. (2005) and Lolaei et al. (2012). Foliar application of boron and zinc significantly influenced key growth and reproductive traits in strawberry. Boron at 0.02% (B0.02) and zinc at 0.04% (Zn0.04) individually reduced days to 50% flowering (62.67 and 63.04 days, respectively) compared to control, with the combined treatment T9 (B0.02Zn0.04) achieving the earliest flowering (60.13 days). Both micronutrients enhanced number of flowers per plant, with B0.02 producing 22.37 and Zn0.04 producing 21.91 flowers, while T9 recorded the highest (24.73), likely due to improved hormonal regulation, nutrient uptake, and photosynthate allocation. Fruit set percentage also improved, with B0.02 and Zn0.04 recording 77.76% and 77.55%, respectively, and T9 achieving the maximum at 80.55%, attributed to enhanced pollen viability, fertilization, and stigma receptivity. Runner production was similarly boosted, with B0.02 yielding 14.33 runners, Zn0.04 yielding 15.07, and T9 producing the maximum at 17.90, as shown in table 2. This improvement is linked to increased photosynthetic efficiency, auxin metabolism, cell division, and chlorophyll synthesis. The combined boron and zinc application demonstrated a synergistic effect across traits by accelerating metabolic activity, enhancing CO_2 assimilation, improving carbohydrate translocation, and optimizing hormonal balance, thereby supporting both reproductive success and vegetative propagation. These findings align with earlier reports by Bakshi et al. (2013a, 2013b), Singh et al. (2015), Chaturvedi et al. (2005), Lolaei et al. (2012) and Qureshi et al. (2013), who similarly observed enhanced flowering, fruit set, and runner production in strawberry and related crops through boron and zinc supplementation.

3.2 Effect on Yield Attributes and Yield

Foliar application of boron and zinc significantly increased strawberry fruit length. Boron at 0.02% (B0.02) produced the longest fruits (3.42 cm) compared to 3.16 cm in control, likely due to its role in cell wall synthesis, membrane integrity, sugar transport, and reproductive development. Zinc at 0.04% (Zn0.04) achieved 3.46 cm fruit length, versus 3.08 cm in control, attributed to enhanced starch formation, carbohydrate transport, and stimulation of cell division and expansion. The combined application of 0.02% boron + 0.04% zinc (T9) yielded the maximum length (3.63 cm), followed by 0.01% boron + 0.04% zinc (T8) at 3.48 cm, showing a synergistic effect through increased photosynthesis, carbohydrate accumulation, and accelerated cell enlargement and division, as shown in the table 3. These findings are consistent with Bakshi et al. (2013a, 2013b), Chandrakar et al. (2019), Etehadnejad & Aboutalebi (2014) in strawberry, and Pawar et al. (2019) in mandarin, as well as Balakrishnan (2000), Pathak et al. (2011) and Saadati & Moallemi (2012) in other fruit crops. Foliar application of boron and zinc significantly increased strawberry fruit volume. Boron at 0.02% (B0.02) recorded the highest volume (7.57 cc) compared to 5.66 cc in control, likely due to improved pollination, viable seed development, and enhanced assimilate transport. Zinc application at 0.04% (Zn0.04) produced 7.33 cc versus 5.90 cc in control, attributed to accelerated cell enlargement, division, and greater carbohydrate accumulation. The combined application showed the greatest effect, with 0.02% boron + 0.04% zinc (T9) yielding 7.98 cc, followed by 0.01% boron + 0.04% zinc (T8) at 7.86 cc, both significantly higher than the control (5.15 cc), as indicated in table 3. The synergistic effect is linked to boron's role in sugar translocation and zinc's involvement in enzyme activation for carbohydrate metabolism, ensuring efficient photo-assimilate mobilization to fruits. Similar enhancements in fruit volume through B and Zn foliar sprays have been reported by Bakshi et al. (2013a, 2013b), and Pathak et al. (2011). Foliar application of boron and zinc significantly enhanced strawberry yield attributes. Boron at 0.02% (B0.02) produced the highest number of fruits per plant (17.70), fruit weight per plant (178.77 g), and yield (66.21 q ha-1), compared to control values of 14.11 fruits, 129.62 g, and 47.97 q ha-1, respectively. Zinc at 0.04% (Zn0.04) recorded 17.42 fruits per plant, 178.70 g fruit weight, and 66.15 q ha-1 yield, outperforming the control (15.01 fruits, 137.02 g, 50.74 q ha-1). The combined application had the greatest effect, with 0.02% boron + 0.04% zinc (T9) yielding 18.60 fruits per plant, 193.54 g fruit weight, and 71.68 q ha-1, closely followed by 0.02% boron + 0.02% zinc (T6), as shown in table 3. Increases are attributed to enhanced pollination, pollen tube growth, cell division, chlorophyll synthesis, and efficient assimilate translocation, which improved fruit set, retention, and growth. The synergistic effect of boron and zinc boosted photosynthetic capacity, nutrient uptake, and hormonal regulation, leading to greater sink strength and reduced fruit drop. Similar yield improvements through micronutrient sprays have been reported by Abdollahi et al. (2012), Bakshi et al. (2013a, 2013b), and Singh et al. (2015) in strawberry, as well as in other horticultural crops, confirming the efficacy of combined B and Zn foliar applications for yield enhancement.

3.3 Effect on Economics

Economic analysis revealed significant variation among treatments. The highest cultivation cost was in T9 (B0.02Zn0.04) at ₹8,63,168.8/ha, followed by T6 (B0.02Zn0.02) at ₹8,63,020.2/ha, while the lowest was in control T1 (₹8,60,232.0/ha). Gross returns were highest in T9 (₹21,50,500/ha) and T6 (₹21,50,413.47/ha), compared to ₹12,12,900/ha in control. Net returns peaked in T6 (₹12,87,393.27/ha), followed closely by T9 (₹12,87,331.20/ha), with the lowest in T1 (₹3,52,668/ha). The highest benefit-cost ratio (1.492:1) was recorded in T6, against 0.409:1 in control, as shown in the table 4. The superior economic performance in T6 is attributed to improved flowering, fruit set, size, and weight due to synergistic effects of boron (enhancing viable flower production and assimilate transport) and zinc (promoting cell elongation, division, and photosynthate allocation). These findings align with Kumar et al. (2012), Chaturvedi et al. (2005) and Paikra (2018), who also reported enhanced profitability in strawberries through combined micronutrient foliar applications.

4. Conclusions

The present study clearly demonstrated that foliar application of boron and zinc, either individually or in combination, significantly improved the growth and yield of strawberry cv. Chandler under humid subtropical conditions. The combined application of 0.02% boron and 0.04% zinc (T9) consistently outperformed other treatments, resulting in the highest plant spread, earliest flowering, maximum number of flowers, fruit set percentage, and runner production. Yield attributes such as fruit length, diameter, weight, and total yield were also markedly enhanced. Economic analysis confirmed the superiority of T9, which achieved the highest gross and net returns and benefit–cost ratio. The synergistic effects of boron and zinc on physiological and biochemical processes appear to be the driving factor behind these improvements. Therefore, foliar application of 0.02% boron and 0.04% zinc can be recommended as an effective strategy for maximizing strawberry productivity and profitability in North-East India.

References

Abdollahi, M., Eshghi, S., Tafazoli, E., & Moosavi, S. (2012). Interaction of boron and zinc on yield and fruit quality of pomegranate (*Punica granatum* L.). *Journal of Plant Nutrition, 35*(3), 382–395. https://doi.org/10.1080/01904167.2012.644373

Anonymous. (2018). *Area and production of strawberry in India*. Horticulture Statistics Division, Ministry of Agriculture & Farmers Welfare, Government of India. https://agricoop.nic.in/en/statistics/horticulture

Ashoori, F., Ghasemnezhad, M., & Keykhosro, A. (2013). Influence of foliar application of boron and calcium on yield and fruit quality of strawberry. *International Journal of Agriculture and Crop Sciences, 5*(20), 2408–2413. https://www.researchgate.net/publication/271206432

Bakshi, P., Sharma, A., Wali, V. K., & Jasrotia, A. (2013a). Effect of foliar application of nutrients and plant growth regulators on growth, yield and quality of strawberry cv. Chandler. *The Bioscan, 8*(4), 1235–1238. https://www.thebioscan.com

Bakshi, P., Sharma, A., Wali, V. K., & Jasrotia, A. (2013b). Influence of foliar application of nutrients and growth regulators on quality and yield of strawberry cv. Chandler. *The Bioscan, 8*(3), 961–964. https://www.thebioscan.com

Balakrishnan, K. (2000). Foliar spray of zinc, iron, boron and magnesium on vegetative growth, yield and quality of guava. *Annals of Plant Physiology, 14*(2), 151–153. https://www.indianjournals.com

Bibi, N., Abbasi, N. A., & Hussain, A. (2016). Physiological response and quality attributes of strawberry fruit under different storage conditions. *Journal of Food Processing and Preservation, 40*(5), 1115–1124. https://doi.org/10.1111/jfpp.12677

Chadha, K. L. (2001). *Handbook of horticulture*. Indian Council of Agricultural Research. https://icar.org.in

Chandrakar, V. K., Sharma, S. K., & Gupta, R. (2019). Effect of foliar application of micronutrients on quality of strawberry (*Fragaria × ananassa* Duch.). *Journal of Pharmacognosy and Phytochemistry, 8*(3), 4329–4333. https://www.phytojournal.com

Chaturvedi, O. P., Singh, A., & Kumar, P. (2005). Response of guava (*Psidium guajava* L.) to foliar application of zinc and boron. *Haryana Journal of Horticultural Sciences, 34*(1–2), 87–88. https://www.indianjournals.com

Etehadnejad, F., & Aboutalebi, A. (2014). Evaluating the effects of foliar application of nitrogen and zinc on yield increasing and quality improvement of apple cv. Golab Kohanz. *Indian Journal of Fundamental and Applied Life Sciences, 4*(2), 125–129. https://www.cibtech.org

FAO. (2014). *FAOSTAT database*. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat

Farid, M., Saleem, B. A., & Malik, A. U. (2020). Foliar application of micronutrients for yield and quality improvement in strawberry. *Pakistan Journal of Agricultural Sciences, 57*(1), 59–67. https://doi.org/10.21162/PAKJAS/20.8193

Hossain, M. A., Sarker, B. C., & Khair, A. (2017). Growth and yield of strawberry influenced by foliar application of micronutrients. *International Journal of Horticultural Science and Technology, 4*(2), 193–203. https://doi.org/10.22059/ijhst.2017.230692.198

Kazemi, M. (2015). Effects of zinc, boron and iron on fruit yield, quality and antioxidant enzyme activities of strawberry. *Journal of Applied Horticulture, 17*(2), 144–148. https://doi.org/10.37855/jah.2015.v17i02.26

Kumar, R., Sharma, R. R., & Singh, R. (2017). Influence of plant growth regulators and nutrients on yield and fruit quality of strawberry (*Fragaria × ananassa* Duch.). *Scientia Horticulturae, 225*, 95–101. https://doi.org/10.1016/j.scienta.2017.06.041

O'Kelley, J. C. (1957). Boron in plant nutrition. *Annual Review of Plant Physiology, 8*, 81–108. https://doi.org/10.1146/annurev.pp.08.060157.000501

Paikra, P. R., Netam, R. S., & Nishad, R. (2018). Effect of micronutrients on growth, yield and quality of strawberry (*Fragaria × ananassa* Duch.). *Journal of Pharmacognosy and Phytochemistry, 7*(3), 2840–2844. https://www.phytojournal.com

Pathak, M., Bauri, F. K., Mishra, D. K., Bandyopadhyay, B., & Chakraborty, K. (2011). Application of micronutrients on growth, yield and quality of banana. *Journal of Crop and Weed, 7*(1), 52–54. https://www.cropandweed.com

Pawar, P. A., Kohale, V. S., Gawil, K. A., Khadse, A., Sarda, A., & Nagmote, A. (2019). Effect of foliar application of manganese and ferrous on vegetative growth, fruit yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Kinnow. *Journal of Pharmacognosy and Phytochemistry, 8*(3), 434–437. https://www.phytojournal.com

Qureshi, K. M., Chughtai, S. A., & Jilani, G. (2013). Effect of foliar application of micronutrients on growth and yield of strawberry. *Pakistan Journal of Agricultural Research, 26*(3), 178–182. https://www.pjar.org.pk

Saadati, S., & Moallemi, N. A. (2012). Effect of zinc foliar application on growth and yield of strawberry plant under saline conditions. *Iranian Journal of Horticultural Science, 42*(3), 267–275. https://journal.irshs.ir

Saha, S., Haldar, A., & Bhattacharjee, T. (2019). Influence of foliar boron on flowering and fruiting of strawberry. *International Journal of Chemical Studies, 7*(3), 171–174. https://www.chemijournal.com

Salman, S., Khan, A. A., & Bhat, T. A. (2022). Economic feasibility of micronutrient application in horticultural crops. *Journal of Horticultural Science, 17*(2), 243–249. https://doi.org/10.1080/14620316.2022.2034871

Sharma, R. R. (2002). *Fruit production: Theory and practice*. Kalyani Publishers. https://www.kalyanipublishers.co.in

Singh, R., Sharma, R. R., & Kumar, S. (2015). Growth, yield and quality of strawberry cv. Chandler as influenced by foliar application of micronutrients. *Scientia Horticulturae, 182*, 50–55. https://doi.org/10.1016/j.scienta.2014.11.015