International Journal of Plant & Soil Science

Volume 38, Issue 8, Page 633-640, 2026; Article no.IJPSS.164157
ISSN: 2320-7035

Effect of Pusa Hydrogel and Phytohormones on Vegetative Growth, Floral Parameters and Fruit Development of Strawberry (*Fragaria* × *ananassa* Duch) var. Winter Dawn

Hemant Kushwaha [a++*], Deepak Lall [a#], Shilpa Rana [a#], Vijay Bahadur [a†] and Dipak Kumar Bose [b†]

[a] *Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj-211 007, (U.P.), India.*
[b] *Department of Agricultural Extension and Communication, Faculty of Agriculture (FoA), Naini Agricultural Institute (NAI), Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj-211 007, (U.P.), India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i86246

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/164157

Original Research Article

Received: 30/05/2026
Accepted: 06/08/2026
Published: 07/08//2026

Abstract

Strawberry (*Fragaria* × *ananassa* Duch.) is an economically important fruit crop valued for its nutritional quality and consumer preference. Optimising vegetative growth, flowering, and fruit development through efficient moisture management and the use of plant growth regulators is essential for improving crop

---

[++] *Research Scholar;* [#] *Assistant Professor;* [†] *Professor;*
**Corresponding author: E-mail: kushwahahemant630@gmail.com;*

Cite as: *Kushwaha, H., Lall, D., Rana, S., Bahadur, V., & Bose, D. K. (2026). Effect of Pusa Hydrogel and Phytohormones on Vegetative Growth, Floral Parameters and Fruit Development of Strawberry (Fragaria × ananassa Duch) var. Winter Dawn. International Journal of Plant & Soil Science, 38(8), 633–640. https://doi.org/10.9734/ijpss/2026/v38i86246*

performance under field conditions. The present investigation was conducted from November 2025 to March 2026 at the Department of Horticulture, Naini Agricultural Institute, Faculty of Agriculture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh, India, to evaluate the effects of Pusa hydrogel and phytohormones on the vegetative growth, floral parameters, and fruit development of strawberry (*Fragaria* × *ananassa* Duch.) var. Winter Dawn. The experiment was arranged in a randomised block design (RBD) with three replications and twelve treatments: T0, control (water spray); T1, Pusa hydrogel 30 g; T2, Pusa hydrogel 60 g; T3, Cycocel 650 ppm; T4, Cycocel 1250 ppm; T5, triacontanol 100 ppm; T6, triacontanol 150 ppm; T7, Cycocel 400 ppm + Pusa hydrogel 25 g; T8, Cycocel 450 ppm + Pusa hydrogel 35 g; T9, Cycocel 500 ppm + Pusa hydrogel 45 g; T10, Cycocel 550 ppm + Pusa hydrogel 55 g + triacontanol 150 ppm; and T11, Cycocel 600 ppm + Pusa hydrogel 65 g + triacontanol 175 ppm. Significant differences were observed among treatments for vegetative growth, floral parameters, and fruit development. Treatment T10 recorded superior values for plant height (19.86 cm), number of leaves per plant (18.50), plant spread (23.64 cm), and petiole length (15.68 cm) at 120 days after transplanting. It also recorded 63.67 days to first flowering, 70.55 days to first harvest, 26.40 flowers per plant, 24.17 fruits per plant, fruit weight of 18.37 g, fruit length of 5.86 cm, fruit diameter of 4.10 cm, and fruit set of 91.54%.

Keywords: Pusa hydrogel; phytohormones; vegetative growth; floral parameters; fruit development; strawberry and winter dawn.

1. Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is recognised as one of the most important temperate small-fruit crops cultivated worldwide because of its appealing appearance, pleasant aroma, flavour, and nutritional value. Cultivated strawberry is an octoploid species (2n = 8x = 56) belonging to the family Rosaceae and is believed to have originated through natural hybridisation between *Fragaria virginiana* and *Fragaria chiloensis* in Europe during the eighteenth century (Hancock, 1999; Maas, 1998). Strawberry fruits are classified as a functional food because of their rich nutritional profile and health-promoting phytochemicals. They are good sources of vitamin C, folates, dietary fibre, potassium, and manganese and are also rich in phenolic compounds, flavonoids, anthocyanins, and ellagic acid. These bioactive compounds possess antioxidant, anti-inflammatory, antimicrobial, and anticancer properties that may contribute to reducing oxidative stress and the risk of cardiovascular disease, diabetes, and certain cancers. Increasing consumer awareness of healthy diets has substantially increased global demand for strawberries over the past decade (Giampieri *et al.*, 2012; Afrin *et al.*, 2016; Aaby *et al.*, 2012). Pusa hydrogel, developed by the Indian Agricultural Research Institute (IARI), is a biodegradable, superabsorbent polymer capable of absorbing several hundred times its weight in water and gradually releasing it to plant roots. Incorporating Pusa hydrogel into the root zone improves soil-moisture retention, reduces nutrient leaching, enhances root proliferation, and improves plant resilience under drought conditions. Previous studies have reported improvements in vegetative growth, flowering, fruit yield, and water-use efficiency in horticultural crops following hydrogel application. These characteristics make Pusa hydrogel a promising technology for sustainable strawberry cultivation under changing climatic conditions (Narjary *et al.*, 2012; Abobatta, 2018). Recent syntheses and experimental evidence indicate that the effects of hydrogels on soil-water retention and crop responses depend on polymer characteristics, application rate, soil texture, and irrigation regime; therefore, crop-specific field evaluation remains necessary (Piccoli *et al.*, 2024; Abdelghafar *et al.*, 2024). Plant growth regulators (PGRs) are important tools in modern horticulture for regulating physiological processes and improving crop productivity. Among these, CCC (Cycocel; chlormequat chloride) is a recognised growth retardant that inhibits gibberellin biosynthesis, thereby reducing internodal elongation, increasing chlorophyll content, improving photosynthetic efficiency, and enhancing assimilate distribution towards reproductive organs. Appropriate concentrations of CCC have been reported to improve flowering, fruit set, yield, and quality in several fruit crops, including strawberry (Rademacher, 2015; Singh *et al.*, 2020). Triacontanol is another important growth regulator. It is a naturally occurring long-chain primary alcohol ($C_{30}H_{62}O$) that was first isolated from alfalfa wax. Triacontanol promotes photosynthesis and chlorophyll production, improves nutrient absorption and enzyme activity, and enhances carbohydrate accumulation, thereby supporting vegetative growth, fruit yield, and fruit quality. Several studies have reported positive effects of triacontanol on growth, flowering, fruit size, total soluble solids, vitamin C content, and the shelf life of horticultural crops (Ries, 1991; Naeem *et al.*, 2012). Recent literature continues to identify plant growth regulators as important determinants of strawberry growth and reproductive performance, although the magnitude and direction of the response may vary with the regulator, cultivar, concentration, and environmental conditions (Hasan *et al.*, 2022; Gautam & Mishra, 2024; Gejji & Varma, 2025; Khajeh Sorkhoeih *et al.*, 2025). However, limited information is available on the combined application of Pusa hydrogel, Cycocel, and triacontanol for regulating the vegetative growth, flowering, and fruit development of strawberry cv. Winter Dawn under the agroclimatic conditions of Prayagraj. Therefore, the present study was undertaken to evaluate the effects of Pusa hydrogel and selected phytohormone treatments, applied individually and in combination, on the vegetative growth, floral parameters, and fruit development of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn.

2. Materials and Methods

The present investigation, entitled 'Effect of Pusa hydrogel and Phytohormones on vegetative growth, floral parameters and fruit development of Strawberry (*Fragaria* × *ananassa* Duch.) var. Winter Dawn', was conducted during 2025–2026 at the Research Field, Department of Horticulture, Naini Agricultural Institute, Faculty of Agriculture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. Prayagraj District lies within the subtropical belt of south-eastern Uttar Pradesh and experiences extremely hot summers and fairly cold winters. Planting material comprising intact root balls and healthy, disease-free runners of strawberry var. Winter Dawn was purchased from AKS Strawberries in Rajgrah District, Himachal Pradesh. The experiment comprised 12 treatments arranged in a randomised block design (RBD), with each treatment replicated three times. The treatments were T0 [control (water spray)], T1 (Pusa hydrogel 30 g), T2 (Pusa hydrogel 60 g), T3 (Cycocel 650 ppm), T4 (Cycocel 1250 ppm), T5 (triacontanol 100 ppm), T6 (triacontanol 150 ppm), T7 (Cycocel 400 ppm + Pusa hydrogel 25 g), T8 (Cycocel 450 ppm + Pusa hydrogel 35 g), T9 (Cycocel 500 ppm + Pusa hydrogel 45 g), T10 (Cycocel 550 ppm + Pusa hydrogel 55 g + triacontanol 150 ppm), and T11 (Cycocel 600 ppm + Pusa hydrogel 65 g + triacontanol 175 ppm). Each plot measured 1 × 1 m (1 m^2), with a spacing of 45 cm between rows and 30 cm between plants. Each treatment comprised six plants per m^2. Observations were recorded for vegetative-growth parameters, namely plant height (cm), number of leaves per plant, plant spread (cm), and petiole length (cm); floral parameters, namely days to first flowering, number of flowers per plant, number of fruits per plant, and days to first harvest; and fruit-development parameters, namely fruit length (cm), fruit diameter (cm), fruit weight (g), and fruit set (%). The data recorded during the investigation were subjected to analysis of variance (Fisher, 1950).

2.1 Mechanism of Pusa Hydrogel

Polymers are carbohydrate-based materials extensively used in the production of physical and chemical hydrogels because of their availability, modifiable functional groups, biocompatibility, and other useful properties. By carefully selecting the monomer or polymer type and the reactions used for hydrogel formation, hydrogels can be customised for specific applications. The two principal methods of hydrogel formation are chemical and physical cross-linking. Pusa hydrogel is a semi-synthetic superabsorbent polymer that supports essential plant requirements and is widely used in agricultural practice. It is incorporated into the soil in which seeds are planted and remains close to the roots. As soil moisture declines with increasing temperature, Pusa hydrogel absorbs water and swells to approximately 300 times its original volume.

2.2 Preparation of Cycocel (CCC) Foliar Spray

Cycocel (2-chloroethyltrimethylammonium chloride) solutions were prepared at concentrations of 400, 450, 500, 550, 600, 650, and 1250 ppm by dissolving the appropriate quantity of Cycocel in distilled water. The quantity required for each litre of solution was calculated using the formula: Required quantity (mg) = Desired concentration (ppm) × Volume of solution (L). Accordingly, 400, 450, 500, 550, 600, 650, and 1250 mg of Cycocel were separately dissolved in one litre of distilled water to obtain the specified concentrations. The solutions were mixed thoroughly until the Cycocel had completely dissolved and were freshly prepared before each application. Foliar application was performed with a hand-operated knapsack sprayer during the morning or evening to ensure uniform foliage coverage and reduce evaporative losses.

2.3 Preparation of Triacontanol Foliar Spray

Triacontanol solutions at concentrations of 100, 150, and 175 ppm were prepared by accurately measuring 100, 150, and 175 mg of triacontanol, respectively. Because triacontanol has limited solubility in water, each measured quantity was first dissolved in a small volume of ethyl alcohol and then diluted to one litre with distilled water with continuous stirring to obtain a uniform solution. Fresh solutions were prepared before each application. The foliar sprays were applied uniformly to the crop with a hand-operated sprayer during the cooler parts of the day to maximise leaf absorption and minimise spray loss through rapid evaporation.

3. Results and Discussion

Data on the vegetative growth of strawberry (*Fragaria* × *ananassa* Duch.) var. Winter Dawn, as influenced by the application of Pusa hydrogel and phytohormones, are presented in Table 1. Plant height was significantly affected by the treatments. The greatest plant height at 120 DAT (19.86 cm) was recorded with T10 (Cycocel 550 ppm + Pusa hydrogel 55 g + triacontanol 150 ppm), which was statistically at par with T11 (Cycocel 600 ppm + Pusa hydrogel 65 g + triacontanol 175 ppm). The minimum plant height (12.44 cm) was recorded in the control (T0). These findings are in close agreement with those of Singh and Bhardwaj (2025), Katel *et al.* (2022), and Singh *et al.* (2020). The number of leaves per plant was also significantly affected by the treatments. The greatest number of leaves per plant at 120 DAT (18.50) was recorded with T10, which was statistically at par with T11 and T7 (Cycocel 400 ppm + Pusa hydrogel 25 g). The minimum number of leaves per plant (11.14) was recorded in T0. These findings are consistent with those reported by El-Beltagi *et al.* (2022), Kumar *et al.* (2012a), Singh and Bhardwaj (2025), and Singh (2025). Plant spread was significantly affected by the treatments. The greatest plant spread at 120 DAT (23.64 cm) was recorded with T10, which was statistically at par with T11 and T7. The minimum plant spread (15.89 cm) was recorded in T0. Petiole length was also significantly affected by the treatments. The greatest petiole length at 120 DAT (15.68 cm) was recorded with T10, which was statistically at par with T11. The minimum petiole length (9.24 cm) was recorded in T0. These findings are in close agreement with those reported by Singh *et al.* (2020), Singh and Bhardwaj (2025), Saima *et al.* (2014), El-Beltagi *et al.* (2022), and Pang *et al.* (2020). Data on the effects of different concentrations of Pusa hydrogel and phytohormones on the floral parameters of strawberry (*Fragaria* × *ananassa* Duch.) var. Winter Dawn are presented in Table 1. The treatments significantly reduced the number of days to first flowering. The minimum number of days to first flowering (63.67) was recorded with T10, whereas the maximum (71.45) was recorded in T0. Treatment T11 was statistically at par with T10. These findings are consistent with those reported by Singh *et al.* (2020), Singh and Bhardwaj (2025), Kumar *et al.* (2012a), and Saima *et al.* (2014). The treatments also significantly reduced the number of days to first harvest. The minimum number of days to first harvest (70.55) was recorded with T10, whereas the maximum (84.70) was recorded in T0. Treatment T11 was statistically at par with T10. These findings are consistent with those reported by Singh *et al.* (2020) and Kumar *et al.* (2012b). The treatments significantly increased the number of flowers per plant. The maximum number of flowers per plant (26.40) was recorded with T10, whereas the minimum (12.37) was recorded in T0. Treatment T10 was followed by T11, T7, T8 (Cycocel 450 ppm + Pusa hydrogel 35 g), and T9 (Cycocel 500 ppm + Pusa hydrogel 45 g). These findings are in close agreement with those reported by Singh *et al.* (2020), Kumar *et al.* (2012a), Sood *et al.* (2018), Islam and Mohammad (2020), Manai *et al.* (2024), and El-Beltagi *et al.* (2022). The treatments significantly increased the number of fruits per plant. The maximum number of fruits per plant (24.17) was recorded with T10, whereas the minimum (7.31) was recorded in T0. Treatment T10 was followed by T11, T7, T8, and T9. These findings are in close agreement with those reported by Singh *et al.* (2020), Kumar *et al.* (2012a), Pang *et al.* (2020), and Katel *et al.* (2022). The treatments significantly increased fruit set. The maximum fruit set (91.54%) was recorded with T10, whereas the minimum (59.12%) was recorded in T0. Treatment T10 was followed by T11, T7, and T8. The greater fruit set observed in the present study is consistent with the findings of Kumar *et al.* (2012a), Singh *et al.* (2020), and Singh (2025). The treatments significantly increased fruit weight. The maximum fruit weight (18.37 g) was recorded with T10, whereas the minimum (10.48 g) was recorded in T0. Treatment T10 was followed by T11 and T7. These findings are in close agreement with those reported by Singh *et al.* (2020). The treatments significantly increased fruit length. The maximum fruit length (5.86 cm) was recorded with T10, whereas the minimum (4.19 cm) was recorded in T0. Treatment T10 was followed by T11 and T7. These findings are in close agreement with those reported by Singh *et al.* (2020). The treatments significantly increased fruit diameter. The maximum fruit diameter (4.10 cm) was recorded with T10, whereas the minimum (2.76 cm) was recorded in T0. Treatment T10 was followed by T11. These findings are in close agreement with those reported by Singh *et al.* (2020).

Table 1. Effect of Pusa hydrogel and Phytohormones on vegetative growth, floral parameters and fruit development of Strawberry *(Fragaria* × *ananassa* Duch*)* var. Winter Dawn

Treatments Notation	Vegetative growth, floral parameters and fruit development											
	Plant Height (cm)	**Number of Leaves per Plant**	**Plant Spread (cm)**	**Petiole Length (cm)**	**Days to taken First Flower**	**Days taken to First Harvest**	**Number of Flowers per Plants**	**Number. of Fruit per Plants**	**Fruit Set (%)**	**Fruit Weight (g)**	**Fruit Length (cm)**	**Fruit Diameter (cm)**
T_0	12.44	11.14	15.89	9.24	71.45	84.70	12.37	7.31	59.12	10.48	4.19	2.76
T_1	15.29	13.09	17.26	11.35	70.79	81.94	15.21	9.20	60.46	12.24	4.93	3.09
T_2	15.79	13.75	18.37	11.74	70.08	80.21	16.30	10.45	64.15	12.47	5.01	4.57
T_3	17.08	17.28	21.29	12.43	67.31	75.36	18.36	14.33	78.08	14.11	5.37	3.67
T_4	16.72	17.17	21.10	13.02	68.47	77.13	18.19	14.07	77.38	14.05	5.23	3.51
T_5	16.36	15.58	20.21	13.08	69.72	79.60	17.38	12.33	70.92	13.19	5.05	3.35
T_6	16.63	15.76	20.19	12.26	69.06	78.07	18.05	13.44	74.47	13.47	5.13	3.43
T_7	18.42	18.09	23.05	13.32	65.65	72.98	23.20	19.49	84.01	16.27	5.63	3.92
T_8	18.06	17.64	21.52	13.24	65.97	73.51	22.54	18.37	81.51	14.47	5.56	3.89
T_9	17.22	17.40	20.44	13.09	66.12	74.00	20.52	16.37	79.76	14.32	5.50	3.81
T_{10}	**19.86**	**18.50**	**23.64**	**15.68**	**63.67**	**70.55**	**26.40**	**24.17**	**91.54**	**18.37**	**5.86**	**4.10**
T_{11}	18.69	18.29	23.33	15.37	64.58	71.73	24.13	21.42	88.78	17.20	5.73	4.07
C.D.	**0.178**	**0.374**	**0.276**	**0.322**	**0.540**	**0.523**	**0.280**	**0.221**	**1.631**	**0.201**	**0.065**	**0.587**
SE(m)	**0.060**	**0.127**	**0.093**	**0.109**	**0.183**	**0.177**	**0.095**	**0.075**	**0.553**	**0.068**	**0.022**	**0.199**
SE(d)	**0.085**	**0.179**	**0.132**	**0.154**	**0.259**	**0.251**	**0.134**	**0.106**	**0.782**	**0.097**	**0.031**	**0.281**
C.V.	**0.619**	**1.359**	**0.788**	**1.476**	**0.468**	**0.400**	**0.848**	**0.862**	**1.262**	**0.831**	**0.721**	**9.357**

4. Conclusion

The study showed that the combined application of Pusa hydrogel and phytohormones influenced the vegetative growth, flowering behaviour, and fruit development of strawberry var. Winter Dawn. Among the treatments, T10, comprising Cycocel 550 ppm + Pusa hydrogel 55 g + triacontanol 150 ppm, recorded the best numerical performance for plant height, number of leaves, plant spread, petiole length, number of flowers, number of fruits, fruit set, fruit weight, fruit length, and fruit diameter. It also reduced the number of days to first flowering and first harvest compared with the control. Under the conditions of the present experiment, this treatment appeared to be more effective than the other treatment combinations.

5. Limitation

The experiment was conducted at one location, during one growing period, and with a single strawberry cultivar. Consequently, the observed treatment responses may vary under different soils, climates, irrigation regimes, cultivars, or application schedules. The study evaluated vegetative, floral, and fruit-development traits but did not report long-term soil effects or an economic assessment of the treatment combinations. Multi-location and multi-season validation would therefore be necessary before making broad production recommendations.

Acknowledgement

The authors are very grateful to the Department of Horticulture, Naini Agriculture Institute, Faculty of Agriculture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, for providing necessary facilities, research field, laboratory, academic support, and resources to prepare this manuscript. Apart from this, I would also like to acknowledge my student advisory committee (SAC) members for their valuable guidance, encouragement, and helpful suggestions throughout the research journey.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

References

Aaby, K., Mazur, S., Nes, A., & Skrede, G. (2012). Phenolic compounds in strawberry (*Fragaria* × *ananassa* Duch.) fruits: Composition in 27 cultivars and changes during ripening. *Food Chemistry, 132*(1), 86–97. https://doi.org/10.1016/j.foodchem.2011.10.037

Abdelghafar, R., Abdelfattah, A., & Mostafa, H. (2024). Effect of super absorbent hydrogel on hydro-physical properties of soil under deficit irrigation. *Scientific Reports, 14*, Article 7655. https://doi.org/10.1038/s41598-024-57786-5

Abobatta, W. F. (2018). Impact of hydrogel polymer in agricultural sector. *Advances in Agriculture and Environmental Science: Open Access, 1*(2), 59–64. https://doi.org/10.30881/aaeoa.00011

Afrin, S., Gasparrini, M., Forbes-Hernández, T. Y., Reboredo-Rodríguez, P., Mezzetti, B., Varela-López, A., Giampieri, F., & Battino, M. (2016). Promising health benefits of the strawberry: A focus on clinical studies. *Journal of Agricultural and Food Chemistry, 64*(22), 4435–4449. https://doi.org/10.1021/acs.jafc.6b00857

El-Beltagi, H. S., Ismail, S. A., Ibrahim, N. M., Shehata, W. F., Alkhateeb, A. A., Ghazzawy, H. S., El-Mogy, M. M., & Sayed, E. G. (2022). Unravelling the effect of triacontanol in combating drought stress by improving growth, productivity, and physiological performance in strawberry plants. *Plants, 11*(15), Article 1913. https://doi.org/10.3390/plants11151913

Fisher, R. A. (1950). *Statistical methods for research workers* (11th ed., rev.). Hafner Publishing Company.

Gautam, M. K., & Mishra, S. (2024). Impact of plant growth regulators on growth, fruit yield and quality of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn. *Journal of Experimental Agriculture International, 46*(7), 1205–1212. https://doi.org/10.9734/jeai/2024/v46i72672

Gejji, M., & Varma, S. (2025). Impact of plant growth regulators on performance of strawberry plant: A review. *Journal of Advances in Biology & Biotechnology, 28*(5), 860–868. https://doi.org/10.9734/jabb/2025/v28i52349

Giampieri, F., Tulipani, S., Alvarez-Suarez, J. M., Quiles, J. L., Mezzetti, B., & Battino, M. (2012). The strawberry: Composition, nutritional quality, and impact on human health. *Nutrition, 28*(1), 9–19. https://doi.org/10.1016/j.nut.2011.08.009

Hancock, J. F. (1999). *Strawberries*. CABI Publishing. https://www.cabi.org/bookshop/book/9780851993393

Hasan, S. Z. U., Hassan, I., Khan, M. A., Jilani, G., & Asghar, S. (2022). Morphological and biochemical response of strawberry to salicylic acid application. *Plant Cell Biotechnology and Molecular Biology, 23*(5–6), 26–33. https://doi.org/10.56557/pcbmb/2022/v23i5-67415

Islam, S., & Mohammad, F. (2020). Triacontanol as a dynamic growth regulator for plants under diverse environmental conditions. *Physiology and Molecular Biology of Plants, 26*(5), 871–883. https://doi.org/10.1007/s12298-020-00815-0

Katel, S., Mandal, H. R., Kattel, S., Yadav, S. P. S., & Lamshal, B. S. (2022). Impacts of plant growth regulators in strawberry plant: A review. *Heliyon, 8*(12), Article e11959. https://doi.org/10.1016/j.heliyon.2022.e11959

Khajeh Sorkhoeih, M., Hamidi Moghaddam, A., & Seyedi, A. (2025). Different biochemical and morphological responses of the strawberry cultivars to salicylic acid and heat shock. *BMC Plant Biology, 25*, Article 1208. https://doi.org/10.1186/s12870-025-07108-2

Kumar, R., Bakshi, P., Srivastava, J. N., & Sarvanan, S. (2012). Influence of plant growth regulators on growth, yield and quality of strawberry (*Fragaria × ananassa* Duch.) cv. Sweet Charlie. *The Asian Journal of Horticulture, 7*(1), 40–43. https://researchjournal.co.in/online/TAJH/TAJH%207%281%29/7_A-40-43.pdf

Kumar, R., Saravanan, S., Bakshi, P., & Bandral, J. (2012). Influence of plant bio-regulators and picking time on yield of strawberry (*Fragaria × ananassa* Duch.) cv. Sweet Charlie. *The Asian Journal of Horticulture, 7*(1), 137–139. https://researchjournal.co.in/upload/assignments/7_137-139.pdf

Maas, J. L. (Ed.). (1998). *Compendium of strawberry diseases* (2nd ed.). APS Press. https://doi.org/10.1094/9780890546178

Manai, M., Fiorillo, A., Matuozzo, M., Li, M., D'Ambrosio, C., Franco, L., Scaloni, A., Fogliano, V., Camoni, L., & Marra, M. (2024). Phenotypical and biochemical characterization of tomato plants treated with triacontanol. *Scientific Reports, 14*, Article 12096. https://doi.org/10.1038/s41598-024-62398-0

Naeem, M., Khan, M. M. A., & Moinuddin. (2012). Triacontanol: A potent plant growth regulator in agriculture. *Journal of Plant Interactions, 7*(2), 129–142. https://doi.org/10.1080/17429145.2011.619281

Narjary, B., Aggarwal, P., Singh, A., Chakraborty, D., & Singh, R. (2012). Water availability in different soils in relation to hydrogel application. *Geoderma, 187–188*, 94–101. https://doi.org/10.1016/j.geoderma.2012.03.002

Pang, Q., Chen, X., Lv, J., Li, T., Fang, J., & Jia, H. (2020). Triacontanol promotes the fruit development and retards fruit senescence in strawberry: A transcriptome analysis. *Plants, 9*(4), Article 488. https://doi.org/10.3390/plants9040488

Piccoli, I., Camarotto, C., Squartini, A., Longo, M., Gross, S., Maggini, M., Cabrera, M. L., & Morari, F. (2024). Hydrogels for agronomical application: From soil characteristics to crop growth: A review. *Agronomy for Sustainable Development, 44*, Article 22. https://doi.org/10.1007/s13593-024-00958-4

Rademacher, W. (2015). Plant growth regulators: Backgrounds and uses in plant production. *Journal of Plant Growth Regulation, 34*(4), 845–872. https://doi.org/10.1007/s00344-015-9541-6

Ries, S. K. (1991). Triacontanol and its second messenger 9-β-l(+)-adenosine as plant growth substances. *Plant Physiology, 95*(4), 986–989. https://doi.org/10.1104/pp.95.4.986

Saima, Z., Sharma, A., Umar, I., & Wali, V. K. (2014). Effect of plant bio-regulators on vegetative growth, yield and quality of strawberry cv. Chandler. African Journal of Agricultural Research, 9(22), 1694–1699. https://doi.org/10.5897/AJAR2013.7357

Singh, S. V. (2025). Effect of Pusa hydrogel and plant growth regulators on growth, yield and quality parameters of strawberry (*Fragaria × ananassa* Duch.) cv. Chandler. *International Journal of Horticulture and Food Science, 7*(1), 109–112. https://doi.org/10.33545/26631067.2025.v7.i1b.253

Singh, S. V., & Bhardwaj, A. K. (2025). Effect of Pusa hydrogel and plant growth regulators on vegetative growth of strawberry (*Fragaria × ananassa* Dutch.) cv. Chandler. *International Journal of Science and Engineering Science Research, 1*(2), 61–67. https://doi.org/10.63671/ijsesr.v1i2.34

Singh, S., Mishra, S., Jamwal, S. S., & Bahadur, V. (2020). Effect of Pusa hydrogel and plant growth regulators on vegetative growth, flowering and fruiting of strawberry (*Fragaria × ananassa* Dutch.) cv. Chandler. *International Research Journal of Pure and Applied Chemistry, 21*(6), 17–24. https://doi.org/10.9734/irjpac/2020/v21i630172

Sood, M. K., Kachawaya, D. S., & Singh, M. C. (2018). Effect of bio-fertilizers and plant growth regulators on growth, flowering, fruit ion content, yield and fruit quality of strawberry. *International Journal of Agriculture, Environment and Biotechnology, 11*(3), 439–449. https://doi.org/10.30954/0974-1712.06.2018.4

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/164157