MINI REVIEW

Biofertilizer and Organic Manures in Strawberry Production

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Abstract

Strawberries, those delightful and nutritious jewels, are indeed a treat for the taste buds, but their journey from seed to fruit involves more than meets the eye. While inorganic fertilizers are a significant source of nutrients, an overreliance on these chemical concoctions can be detrimental to both soil health and the environment. This is where the superhero of sustainable agriculture enters the scene: bio-fertilizers. Bio-fertilizers are the unsung champions in the quest for eco-friendly farming. Unlike their chemical counterparts, bio-fertilizers contain living microbial inoculants, offering plants a nutritional boost that conventional fertilizers may miss. Striking the right balance is crucial, as excessive use of inorganic fertilizers and pesticides, especially on fruits like strawberries that are enjoyed without peeling, can pose risks to human health. Strawberries' growth, yield, and quality are intricately linked to the judicious use of organic manures and biofertilizers. These bioagents not only enhance nutrient availability for the plants but also contribute to the soil's long-term fertility. It's a win-win, ensuring a bountiful harvest while preserving the health of the land. In the grand symphony of nutrient management for strawberries, adopting integrated nutrient management (INM) practices emerge as a key player. By carefully orchestrating a mix of organic and inorganic inputs, INM becomes a guardian of long-term soil fertility. This, in turn, becomes the bedrock for sustained strawberry development, ensuring not just quantity but also harvest quality. So, as we savor those tiny, delectable strawberries, it's worth appreciating the behind-the-scenes choreography of nutrient management that contributes to their growth, yield, and the luscious quality of fruits.

Keywords: Strawberry, Organic manure, Biofertilizer, Integrated nutrient management.

Highlights

- Boost soil fertility sustainably.
- Enhance strawberry quality naturally.
- Reduce chemical dependency in farming.
- Support eco-friendly agricultural practices.
- Promote economic viability and consumer appeal.

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Introduction

The strawberry plant, scientifically known as *Fragaria x ananassa* Duchesne, is a member of the Rosaceae family and boasts a chromosomal number of 2n = 8x = 56. This globally cherished fruit is a monoecious octoploid hybrid originating from *Fragaria chiloensis* and *Fragaria virginiana*. Renowned for their nutrient-dense composition, including vitamins A, C, fiber, and calcium pectate, strawberries are delicious and contribute to a low-calorie carbohydrate intake, primarily consisting of water (90%). The presence of plant phenols, such as ellagic acid, further accentuates the potential health benefits, particularly in cancer prevention. Maharashtra stands out as the leading strawberry-producing state in India, with flourishing commercial cultivation in regions like U.P., Jammu & Kashmir, Punjab, Uttrakhand, and the lower hills of Himachal Pradesh. With its delightful aroma and nutritional richness, the strawberry remains a fruitful delight in both culinary and agricultural landscapes. Kumar *et al.,* (2012, 2015), Singh and Saravanan (2012).

As highlighted by Kumar et al., (2015), bio-fertilizers are living microorganisms naturally present in the soil or freely living in association with plants. This symbiotic relationship between plants and microorganisms, such as those from the genera *Azospirillum* and *Azotobacter.* (Rueda *et al.,* 2016), involve an exchange where plants receive essential nutrients like nitrogen and phosphorus, while microorganisms receive carbon sources and other chemicals from the plant. This mutually beneficial connection contributes to the growth and yield of horticultural crops. Studies, including those by Singh *et al.,* (2015), have demonstrated that the application of bio-fertilizers can enhance crop output by 15 to 30%. Additionally, bio-fertilizers play a pivotal role in producing hormones, vitamins, and other growth elements vital for vegetative growth and development, as noted by Mishra and Tripathi (2011). The efficient nitrogen-fixing abilities of these microorganisms, particularly in the root system, contribute to soil fertility. Beneficial microorganisms, when used in lieu of chemical fertilizers, promote plant development and maintain soil health and productivity. The rhizosphere, or root nodules, harbors a concentration of these microorganisms, allowing for rapid growth and metabolism. Various bacterial species found in the rhizosphere have been shown to benefit crop growth, quality, and yield. In the case of strawberries, growth-promoting rhizobacteria (GPR) includes isolates from the genera *Azospirillum* and *Azotobacter*, colonizing plant roots, stimulating development, and, in some cases, providing protection against diseases. Depending on the bacterial strain, these microorganisms employ either direct or indirect mechanisms to supply plants with essential chemicals for their growth and health. Overall, the use of bio-fertilizers represents a sustainable approach to agriculture, promoting both plant development and environmental well-being.

In achieving optimal strawberry fruit yield, a harmonious combination of inorganic and organic fertilizers and the integration of bio-fertilizers proves advantageous. This balanced approach not only enhances yield but also contributes to the sustained productivity and health of the soil. The current study aims to investigate the impact of farmyard waste and bio-fertilizers on the development and quality of strawberries, recognizing the importance of environmentally friendly and sustainable practices in agricultural systems.

- Organic manure's effects on strawberry output, quality, and vegetative development.
- Biofertilizer's effects on strawberry vegetative development, production, and quality
- The combined effects of biofertilizer and organic manure on strawberry quality, yield, and vegetative development.

Organic manure's effects on strawberry output, quality, and vegetative development

Being the most important and commonly used bulky organic manure, organic manure, The augmentation of strawberry yield is a nuanced endeavor that necessitates a judicious amalgamation of both inorganic and organic fertilizers, incorporating the invaluable role of bio-fertilizers. In an intricate exploration involving two distinct strawberry varieties, namely RU-1 (Festival) and RU-2 (AOG), subjected to an array of organic manures encompassing cow dung, mustard oil cake, and poultry manure, the pinnacle of productivity was discerned through the combined application of cow dung, mustard oil cake, and poultry manure. This holistic approach yielded the festival variety's maximal output, registering an impressive 19.14 t/ha. Rashid *et al.,* (2018).

Table 1: Organic manure's effects on strawberry output, quality, and vegetative development

S. No	*Treatment*	*Yield*	*References*
1.	100% RDF + 100% FYM (6 t/ha) + 100% Vermicompost (2 t/ha)	58.94 q/ha	Singh *et al.,* (2021)
2.	Vermicompost T_1 250 Kg da^{-1}	408.04 g/Plant	Sayğı *et al.,* (2022).
3.	100 %+ RDN through vermicompost + Jeevamruth @500 ml per pot at two stages + Beejamruth seedling treatment.	350.79 g/ Plant	Sahana *et al.,* (2020)
4.	Vermicompost (25 t/ ha-^{1}) + Azotobactor (6 kg ha^{-1}) + NPK (70:80:80 kg ha^{-1})	335.82 g/ Plant	Karma *et al.,* (2017)
5.	Organic + mineral fertilizers as a foliar application (F5)	326.49 g/plant	Khalil *et al.,* (2017)

Farmyard waste and organic manures ascend to pivotal positions within the realm of agricultural practices. Their impact extends beyond the mere augmentation of crop output, delving into the intricacies of direct improvements spurred by hormone-induced growth actions and heightened respiration via enhanced cell permeability. The process of biological degradation inherent in these organic amendments furnishes the plants with accessible forms of essential nutrients such as nitrogen, phosphorus, and potassium, contributing substantively to the growth and sustenance of crops Prasad *et al.,* (2017). Compelling evidence from various studies underscores the efficacy of organic fertilizers in elevating strawberry fruit production. Notably, the judicious application of farmyard manure (FYM) in conjunction with NPK fertilizers has been linked to a noteworthy surge in strawberry yields, with the pinnacle achieved through the application of 40 tons of FYM coupled with 60 kg/ha of NPK fertilizers. Rueda *et al.,* (2016). The strategic integration of vermicompost, an expeditiously produced organic waste derivative facilitated by the symbiotic interaction between earthworms and microorganisms, has emerged as a promising avenue for fostering accelerated plant growth. When applied at a rate of 10 t/ha with recommended NPK, vermicompost has exhibited a substantial augmentation in flower and runner production, attesting to its efficacy as a growth stimulant. Arancon *et al.,* (2004). Further substantiating the role of vermicompost, studies have expounded on its significant impact on strawberry growth parameters and yield. Notable improvements were observed in vermicompost-treated plants, including a 37% increase in leaf areas, 37% in plant shoot biomass, 40% in numbers of flowers, 36% in numbers of plant runners, and a 35% increase in marketable fruit weights. Arancon *et al.,* (2004). This trend is reinforced by findings showcasing the superiority of vermicompost-treated plants in terms of leaf numbers, runner numbers, fruit numbers, plant height, single fruit weight, overall fruit weight, brix content, and ultimate yield. Rahman *et al.,* (2018). Moreover, the synergistic application of farmyard manure supplemented with *Azotobacter* has been discerned as a potent strategy for promoting strawberry growth and development (Table 1) (Fig. 1). Underpinning this approach, a study revealed comparable plant height, spread,

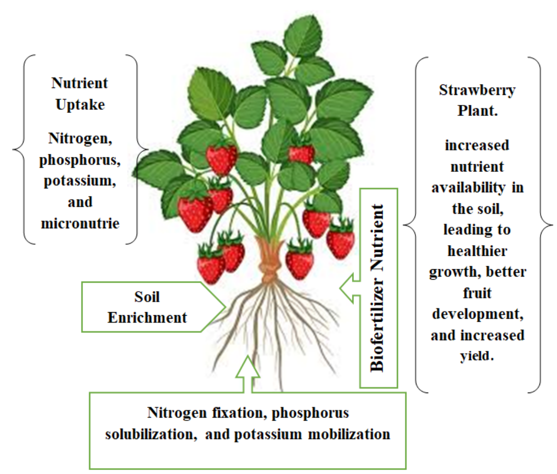

Fig. 1: Strawberry vegetable growth, yield, and quality effected by biofertilizer

fruit weight, and size between plants receiving nitrogen from 25% farmyard manure supplemented with *Azotobacter* and those deriving nitrogen from urea in tandem with *Azotobacter*. Negi *et al.,* (2021). In essence, the orchestration of organic amendments, including vermicompost and farmyard manure, emerges as a nuanced yet indispensable strategy in cultivating and enhancing strawberry yield. This multifaceted approach not only serves to optimize crop output but also aligns with sustainable agricultural practices, fostering soil health and long-term productivity. The dynamic interplay of organic fertilizers, bio-fertilizers, and meticulous agricultural strategies represents a harmonious symphony orchestrating the flourishing growth of the coveted strawberry crop.

Biofertilizer's effects on strawberry vegetative development, production, and quality

Fertilizers are now used in numerous agricultural and horticultural systems to reduce crop production costs and minimize environmental pollution. Antoun *et al.,* (2012); Hazarika *et al.,* (2007); Nazir *et al.,* (2006) and Edwards *et al.,* (1998). The bulk of Beneficial bacteria that may release nutrients are known as biofertilizers. They are made commercially available from source materials and plant wastes under the soil when certain strains are applied to biological fertilizers. By enhancing biological nitrogen fixation, nutrient availability and uptake, and stimulating natural hormones, biofertilizers aid in improving crop output and quality (Fig. 2). They don't pose a threat to people, the environment and animals, and their use contributes to the reduction of pollution in our environment. Mosa *et al.,* (2014). Furthermore, it is said that After planting at 30, 60, 90, and 120 days, substantial differences in plant height were identified due to the usage of biofertilizers. At 120 DAP, treatment T5 (RDF + *Azospirillum* @ 7 kg/ha + phosphate solubilizing bacteria @ 6 kg/ha) was found to have the maximum plant height (31.20 cm) and the whole proportion of leaves on a plant (41.90). Bhagat *et al.,* (2019). When comparing the control treatment to the biofertilizer treatment, height, leaves per plant, crown diameter, and leaf area, The dry weight per plant underwent substantial adjustments. Hassan *et al.,* (2015) investigated how strawberry plant development and yield were affected by organic manures and biofertilizers (Table 2), and they discovered that applying vermicompost (30 t ha-1), NPK (80:100:100 kg ha-^{1}) with *Azotobacter* (7 kg ha-1) in addition inoculation significantly enhanced the plant growth, such as plant height, spread, crown diameter, shoot, root and total dry weight and fruit yield in compare with control plants. Kumar *et al.,* (2015) highlighted that Vermicompost application (30 t/ha) in addition to *Azotobacter* (7 kg/ha) greatly enhanced the strawberry cv. Chandler's plant size (19.45 cm), leaf count (63.60), number of runners per plant (5.34), maximum flower count (67.48), and fruit set (39.21). Combined when vermicompost, *Azotobacter*, PSB, and in a study by Raturi *et al.,* (2023), the application of arbuscular mycorrhiza (AM) had a significant impact on various growth parameters and yield of strawberry plants. The measured parameters included plant height, spread, number of leaves, leaf area, and overall fruit yield. The study revealed that the treatment involving *Azotobacter* Application + AM + PSB + vermicompost resulted in strawberry plants' highest number of leaves (54.30) and plant height (20.26 cm). Additionally, other growth factors exhibited notable improvements compared to the control group. The maximum strawberry fruit yield (311.26 g/plant) was observed with the application of *Azotobacter* + Arbuscular mycorrhizae + vermicompost + PSB, while the lowest yield (136.59 g/plant) was recorded in the control group. Furthermore, Sahoo *et al.,* (2005) explored different quantities of biofertilizers, specifically *Azotobacter* and *Azospirillum*, and found that applying 6 kg/ha of *Azotobacter* + *Azospirillum* significantly enhanced the growth of fertilized strawberry plants. This suggests that the appropriate application of biofertilizers can positively influence strawberry plant development. Another study by Sood *et al.,* (2018) emphasized the importance of applying plant growth regulators and biofertilizers in optimal amounts to achieve substantial improvements in strawberry plant growth, fruit quality, and overall yield.

The combined effects of biofertilizer and organic manure on strawberry quality, yield, and vegetative development

The investigation focused on assessing strawberries' quality, yield, and growth utilizing a combination of biological fertilizers and organic waste. Sweet Charlie varieties exhibited noteworthy

Table 2: Biofertilizer's effects on strawberry vegetative development, production, and quality

S. No	*Treatment*	*Yield*	*References*
1	RDF + *Azospirillum* @ 7 kg/ha + Phosphate Solublizing Bacteria @ 6 kg/ha + VAM @ 10 kg/ha	355.84 q/h	Bhagat *et al.,* (2020)
2	Phosphobacter 5kg ha^{-1}+ Azatobacter 5 kg ha-^{1}+ FYM 6 t ha^{-1} + Vermicompost 3 t ha^{-1}+ Poultry Manure 3 t ha^{-1}	683.46 gm/ Plot	Pradeep *et al.,* (2018)
3	25% recommended dose of inorganic fertilizers +75% recommended dose of manur	26.81 t/h	Wani *et al.,* (2023)
4	VC + Azoto. + PSB + AM	311.26 g/Plant	Kumar *et al.,* (2015)
5	Trichoderma + Vermicompost + *Azotobacter* + PSB + VAM	111.08 g/plant	Kumar *et al.,* (2020)

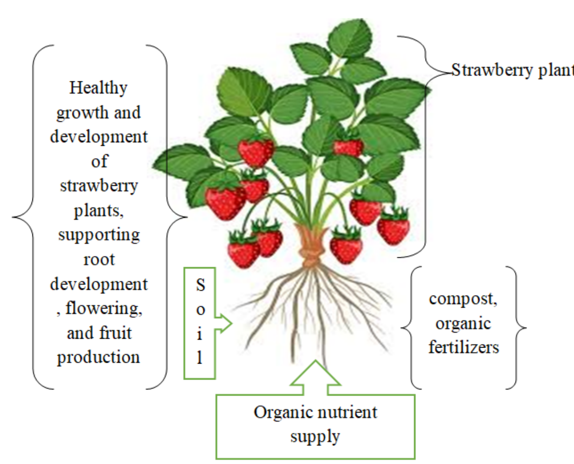

Fig. 2: Strawberry vegetable growth, yield, and quality effected by organic manure

results, with a maximum plant height reaching 19.61 cm, a total leaf count of 21.11, 30.41 blooms per plant, and 20.41 fruits per plant. The fruits demonstrated a maximum length of 3.70 cm, width of 3.20 cm, and a weight of 11.83 g. The yield of the fruit was recorded at 144.77 g/plant, 2.32 kg/plot, and 7.72 t/ha. These positive outcomes were attributed to the synergistic use of vermicompost (50%), poultry manure (50%), and *Azotobacter*. Soni *et al.,* (2018) and Kumar *et al.,* (2015) demonstrated that the incorporation of organic matter into biofertilizer for strawberry plants positively impacted vegetative development parameters, including fruit setting and total soluble solids. In a separate investigation, the all-encompassing nutrient management approach showcased remarkable outcomes. The incorporation of poultry manure, vermicompost, *Azotobacter*, and Phosphate Solubilizing Bacteria (PSB) yielded unparalleled results, manifesting in the highest crop yield at 112.63 g per plant. Notably, this strategy also enhanced the quality metrics with Total Soluble Solids (TSS) registering at 7.050 B, and ascorbic acid content reaching 53.42 mg/100 g of pulp. The longevity of the produce saw an extension to 5.69 days, underscoring the robust shelf life achieved through this methodology. Moreover, the economic perspective painted a favorable picture, as the strawberry crops treated with PSB, *Azotobacter*, farmyard manure (FYM), and vermicompost boasted the highest benefit-cost ratio (B:C ratio) at an impressive 1:3.64. Jain *et al.,* (2017). Bio-fertilizers, derived from plant roots or agriculturally generated soil, represent eco-friendly organic materials that pose no harm to plants, soil, climate, or the environment. They play a pivotal role in atmospheric nitrogen fixation, phosphorus solubilization, and the stimulation of plant growth hormones (PGH). Azotobacter, Phosphate Solubilizing Bacteria (PSB), and Azospirillum contribute to nitrogen fixation and phosphorus solubilization, enhancing soil fertility and biological activity. Notably, strawberry plants treated with *Azotobacter* demonstrate significantly increased yields, producing larger fruits in infected plants. Rana and Chandal (2003). It was shown that adding organic matter and biofertilizer to strawberry plants boosted their vegetative development parameters, such as fruit setting and total soluble solids. The holistic nutrient management methodology profoundly influenced strawberries, exerting considerable effects on yield, quality, shelf life, and economic dimensions. Notably, the strategic deployment of poultry manure, vermicompost, *Azotobacter*, and phosphate solubilizing bacteria (PSB) yielded outstanding results. This regimen produced the highest yield per plant at 112.63 g and elevated quality parameters, as evidenced by total soluble solids (TSS) measuring at 7.050 B and ascorbic acid content reaching 53.42 mg/100 g of pulp. Furthermore, the longevity of the strawberries experienced a notable extension, reaching 5.69 days, showcasing the effectiveness of this approach in preserving shelf life. Strawberry crops treated with farm yard manure (FYM), vermicompost, *Azotobacter*, and PSB exhibited the greatest benefit-cost (B:C) ratio of 1:3.64, indicating favorable economic returns. Jain *et al.,* (2017). the utilization of 25% nitrogen in conjunction with a modified Farm Yard Manure (FYM) containing *Azotobacter* resulted in notable growth metrics. The tallest plant achieved a height of 21.24 centimeters, accompanied by a spread of 28.16 cm and a leaf area of 74.95 cm^2. The fruit displayed dimensions with a length of 37.62 mm, width of 28.01 mm, and a weight of 15.87 g, comparable to plants receiving 100% nitrogen in the form of urea and *Azotobacter*. Evaluating vegetative growth metrics under the 50% recommended dose of fertilizers (RDF)+ treatment, specifically FYM with 50 g of *Azotobacter*, 50 g of phosphate solubilizing bacteria (PSB), and 250 g of vesicular arbuscular mycorrhiza (VAM) per plant, the treatment sequence with 50% RDF+ FYM+ *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM (250 g/plant) in Randomized Block Design (RBD) produced the tallest plant (18.67 cm) and the highest leaf count (18.67). In treatment, T2, the maximum yield per plant reached 173.42 g. Patil *et al.,* (2013). The treatment employing 100% recommended dose of fertilizers (RDF) + *Azospirillum* + PSB demonstrated the highest yield per plant (304.73 g). This treatment also resulted in elevated concentrations of non-reducing sugars, total sugars, sugar to acid ratio, total soluble solids (TSS), and vitamin C. Conversely, under the same treatment, the fruit exhibited the lowest weight (15.68 g), length (3.61 cm), and reducing sugar content. Subraya *et al.,* (2017). In their exploration, the investigation meticulously scrutinized the repercussions of employing organic manure, encompassing Farm Yard Manure, vermicompost, and press mud, in tandem with biofertilizers such as *Azotobacter*, phosphate solubilizing bacteria, and *Azospirillum*, on an array of parameters. The findings unveiled a flourishing scene, with plant height reaching a notable 23.59 cm, a lush abundance of leaves at 12.67 per plant, the inaugural bloom making its debut at 61.06 days after planting (DAP), an impressive count of 15.33 flowers per plant, the genesis of the first fruit transpiring at 72.80 days, and a prolific yield of 8.33 fruits per plant. Furthermore, treatments involving vermicompost and phosphate solubilizing bacteria (PSB) significantly influenced Total Soluble Solids (TSS) at 10.75° Brix, titratable acidity at 0.82, ascorbic acid content at 57.24 mg/100 g of fruit, total sugars at 5.95%, and juice content at 79.50%. These parameters exhibited no significant changes in their content under these treatments. Kumar *et al.,* (2015). In a strawberry research trial utilizing Azotobactor, *Azospirillum*, Farm Yard Manure (FYM), and NPK, an exploration of the effects of organic manure revealed noteworthy results. Specifically, in treatment T12, which consisted of Azotobactor (50%) + *Azospirillum* (50%) + NPK (50%) + FYM at 105 days after planting (DAP), several growth parameters were observed. The plant exhibited maximum growth at 19.25 cm, the highest quantity of leaves on a plant was recorded at 18.80 cm, the maximum length of leaves measured 8.80 cm, and the greatest width of leaves was documented at 10.94 cm. Lata *et al.,* (2013). In the Vermi + *Azoto* + PSB treatment, the highest quantity of runners within a plant (6.77) and crown per plant (5.16) were observed. On the other hand, the treatment FYM + Vermi + Poultry manure + Azoto + PSB exhibited the highest abundance of blooms per plant (59.91) and fruit set per plant (49.60). Additionally, the vermicompost treatment had the highest proportion of fruit set per plant (84.05%). The treatment FYM + Poultry manure + Azoto + PSB + Vermi had the shortest days to fruit set (6.47 days). Finally, in the Vermi + PSB + Azo treatment, the maximum yield per plant (290.56 g), highest plot production (2.90 kg), and the highest yield per hectare (145.26 qt) were reported. Srivastav *et al.,* (2019) delves into integrated nutrient management (INM) 's outcomes

Table 3: "Effect of organic manure and Biofertilizer on strawberry crop

S. No	Treatment	Yield	References
1.	50% vermicompost+50% poultry manure	7.72 ton/hac	Soni *et al.,* (2018)
2.	Azotobactor+100% nitrogen/hac. Trough urea	372.89 quintal/hac	Umar *et. al.,* (2009)
3.	50% RDF + Vermicompost + *Azotobacter*"	9.66 fruit/plant	Singh *et. al.,* (2021)
4.	100% RDF+ *Azospirillum*+ PSB	304.73 gm yield/plant	Subraya *et al.,* (2017)
5.	Vermicompost+PSB	8.33 fruit/plant	Kumar *et al.,* (2015)
6.	50%RDF+Azotobactor+Vermicompost	9.66 fruit/plant	Singh *et al.,* (2021)
7.	Vermicompost + *Azotobacter* + PSB	145.26quntal/hac	Srivastav *et al.,* (2019)

on strawberries' growth, yield, and quality characteristics. Winter down runners of Strawberry var. were transplanted at a spacing of 30 x 30 cm in the first week of November. Among the treatments, T7 (50% recommended dose fertilizer + Vermi + *Azotobacter*) exhibited the highest plant height, leaf surface area, total number of leaves per plant, chlorophyll content, and plant spreading, while the control group showed the lowest values. Biochemical measures, including fruit weight, length, TSS, ascorbic acid content per 100 gm pulp, and acidity, were all higher in T7 than other treatments, reflecting an enhanced yield per plant. Singh *et al.,* (2021) (Table 3).

Conclusion

In conclusion, the findings from studies on strawberries strongly support the use of organic compounds and biofertilizers as effective means to enhance various vegetative characteristics and overall fruit quality. The positive impact on plant height, blossom, leaf numbers, and fruit development, including total sugar content, acidity, TSS, and vitamin C, underscores the potential benefits for both agricultural productivity and environmental sustainability. By advocating for the adoption of bio-fertilizers and organic manures, farmers can contribute to soil health, maintain fertility, and ultimately boost fruit production, leading to improved market availability and better economic prospects for farmer communities.

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Author's Contribution

Mr. Amrit Kumar Singh Planning of the study, review and editing of MS. Prof. Mohd Haris Siddiqui: Conceptualization of idea, administration and supervision of the study. Dr. Md. Abu Nayyer's correction is as per the suggestion of the reviewer and editor. Mr. Anupam Singh reviewed and editing of MS and correction as per suggestion from reviewer and editor. Mr. Devashish Rai and Mr. Abhijeet Srivastava Conceptualization of idea and writing original draft of manuscript. Mr. Dheer Pratap and Kushal Vaishya collection of review literature and compilation.

Conflict Of Interest

We have no conflicts of interest to disclose.

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