International Journal of Plant & Soil Science

33(21): 202-207, 2021; Article no.IJPSS.75381
ISSN: 2320-7035

Biofertilizers for Sustainable Production of Strawberry: A-Review

G. Chandra Mohan Reddy[1*], M. Santhosh Kumar[2], N. C. Mamatha[1], G. Siva Koteswara Rao[1], P. Chakradhar[1] and G. Vikas Kumar[1]

[1]Department of Horticulture, College of Horticulture, Dr. YSR Horticultural university, Anantharajupeta, Andhra Pradesh, India.
[2]AICRP, Integrated Framing System, PJTSAU, Rajendranagar, Telangana, India.

Authors' contributions

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

Article Information

DOI: 10.9734/IJPSS/2021/v33i2130673
Editor(s):
(1) Dr. Ibrahim Farah, Jackson State University, USA.
(2) Dr. Ahmed Medhat Mohamed Al-Naggar, Cairo University, Egypt.
Reviewers:
(1) Abdul Jafari Shango, World Vegetable Center, Tanzania.
(2) Dhia Ahmed Taain, University of Basrah, Iraq.
Complete Peer review History: https://www.sdiarticle4.com/review-history/75381

Review Article

Received 11 August 2021
Accepted 21 October 2021
Published 25 October 2021

ABSTRACT

Modern-day intensive strawberry cultivation relies on huge application of inorganic fertilizers, which not only disrupt the balance of nature but also reduce the economic efficiency; however, it cannot be eliminated at this time without drastically decreasing its production. Hence, to tackle these problems for sustainable production of crops, bio-fertilizers and organic manures are the best alternatives. The principle of this review is based on the goal of reducing synthetic fertilizers and other chemical input usage in strawberry production. The review discusses the diffuse nature of current reports in the literature concerning microbes as inputs towards a better use efficiency of fertilizers and the possibility of reducing the total amount of fertilizer usage and sustainable and quality strawberry production. Studies with bio-inoculants in combination with inorganic nutrients have proved that some inoculants such as Azotobactor, Azospirillum, Pseudomonas, Bacillus, Mycorrhizae fungi Aspergillus and Penicillium can increase the nutrient uptake of strawberry plant and increased fertilizers use efficiency. Biofertilizers in combination with inorganic fertilizers and organic manures have significant impact on plant growth (i.e., state some of the parameters here), yield (i.e., state some of the parameters here) and quality (i.e., state some of the parameters here). Likewise,

**Corresponding author: E-mail: reddyhorti96@gmail.com;*

organic manures improve soil physical conditions and supply all essential macro elements and microelements. These confirmations of concept studies will serve as the basis for vigorous future research into integrated nutrient management in strawberry.

Keywords: Biofertilizers; organic manures; strawberry; yield and quality.

1. INTRODUCTION

The modern-day intensive crop cultivation for increasing production requires huge application of costly chemical fertilizers and other inputs. However, indiscriminate prolonged usage of inorganic chemical fertilizers and pesticides increases the cost of production, causes soil, water and environment pollution through de-nitrification, runoff, leaching and volatilization, also adversely affects soil fauna, flora and soil fertility [1,2,3]. Hence, to tackle these problems for sustainable production of crops, bio-fertilizers and organic manures are the best alternatives. Beneficial micro-organisms like Azospirillum, Azotobactor, Pseudomonas, Bacillus, Mycorrhizae fungi Aspergillus and Penicillium present in bio-fertilizers influence plant growth and health by enhancing nutrient availability, uptake and biological activity in the rhizosphere, fixing atmospheric nitrogen, phosphorous solubilization and mobilization of phosphorous, zinc, iron to varying level and by producing phytohormones (auxins, cytokinins, gibberellins), antibiotics and secondary metabolites that help host plants to resist diseases and insect pests and withstand abiotic stress conditions [4,5].

Likewise, organic manures improve soil physical conditions and supply all essential macro elements and microelements [6,7] to fulfil plant requirements. The organic and biological resources are renewable sources, eco-friendly and available at low cost, which are of much importance in the sustainable crop production. Use of sole or co-inoculation of biofertilizers, viz Azotobacter, Azosprillum and Pseudomonas and arbuscular mycorrhizal fungi (AMF) can dissolve insoluble and leach nutrients by different mechanisms and facilitates steady supply of nutrients during plant growth [8,9,10].

The principle of this review is based on the goal of reducing synthetic fertilizers and other chemical input usage in strawberry production. The review discusses the diffuse nature of current reports in the literature concerning microbes as inputs towards a better use efficiency of fertilizers and the possibility of reducing the total amount of fertilizer usage and sustainable and quality strawberry production.

2. IMPACT OF BIOFERTILIZERS IN COMBINATION WITH FERTILIZERS AND ORGANIC MANURES ON PLANT GROWTH

Bio-fertilizers are now used in numerous agricultural and horticultural systems for reducing the cost of crop production and minimizing environmental pollution [11,12,13]. Nazir et at. [14] observed that application of recommended dose of NPK in combination of poultry manure + Azotobacter + wood ash + phosphorous solubilizing bacteria + oil cake application recorded maximum plant height, spread, number of leaves and crown diameter in strawberry, which is important in the uptake and mobilization of of nutrients from the soil to plants. Singh et al. [15] observed that application of organic and inorganic fertilizers alone and in combination with biofertilizers significantly increased plant growth in strawberry. The maximum plant height, spread, number of leaves and crown diameter, dry weight of plant with the inoculation of Azospirillum and Azotobacter along with 100 ppm nitrogen under hydroponic system of cultivation in strawberry, these inoculants are playing significant role in the nitrogen fixation and mineralization of organic elements and it may facilitate higher fertilizer use efficiency and up take nutrients [Rueda et al. 16].

Kumar et al. [17] studied effect of organic manures and biofertlizers on growth and yield of strawberry plants and they found that application of vermicompost (30 t ha^{-1}), NPK (80:100:100 kg ha^{-1}) along with Azotobacter (7 kg ha^{-1}) 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. The study by Verma et at. [18] confirmed that inoculation of PSB along with inorganic fertilizers were more impact on growth and development of plant than alone application of fertilizers. The combined application of PSB along with nitrogen 225 kg ha^{-1} and phosphorous 150 kg ha^{-1} showed to early and higher number of primary

flowers and secondary flowers in strawberry, that facilities to get higher returns.

The inoculation of biofertilizers increased the plant height, plant spread, number of leaves per plant, early flower incitation and crown diameter significantly over the control and the increase in these vegetative growth parameters attributed to timely application of nutrients aided by addition of biofertilizers that might have helped in more nitrogen fixation and its quick release along with better nutrient uptake by the plants (Zargar et al. [5]; Rayees et al. [19]; Shashank [20]. Similarly, Abu-Zahra and Tahboub [21] and Abo Sedera [22] demonstrated that strawberry plants were supplied with 100 per cent recommended dose NPK along with Azotobacter and Azospirillum inoculation induces the early flower initiation, more number flowers and higher fruit set, in fact that application of biofertilizers increase the availability of macro and micro nutrients and produces phytohormones in the plants, which forces the plant to shift from vegetative to reproduction phase earlier.

3. IMPACT OF BIOFERTILIZERS IN COMBINATION WITH FERTILIZERS AND ORGANIC MANURES ON YIELD

The application of nitrogen 225 kg ha^{-1} and phosphorous 150 kg ha^{-1} along with PSB inoculation resulted in maximum fruit weight, number of fruits per plant [19,20]. In a filed study, Kirad et al. [23] observed that higher fruit yield, fruit weight and number of fruits per plant when strawberry plants supplied with 75% recommended dose of fertilizers and 25% vermicompost along with rhizosphere bacteria culture treatment in strawberry. The strawberry plants inoculated with arbuscular mycorrhiza fungi, Plant growth promoting **bacterial** PGPB strains (*Pseudomonas fluorescens*) and 70% RDF gave positive results in terms of yield and yield attributes Verma et al. [18].

Esmatullah et al. [24] reported maximum fruit weight, fruit length and diameter, number of fruits per plant with the application of 100% recommended dose of fertilizersRDF + Vascular Arbuscular Mycorrhiza VAM @10 kg ha^{-1} + 0.4% Boron + 0.5% $ZnSO_4$ in strawberry cv. Sabrina than control plants, which might be due to potential role of VAM in solubilization of insoluble phosphorus, uptake and proliferation of beneficial organisms in the rhizosphere. Inoculants such as PGPR Plant growth promoting rhizobacteria and AMF, are playing major role in the solubilization of inorganic phosphate (Pi) and mineralization of organic phosphates and which facilitates the uptake of Pi and transfer from the AMF to plants [11,12]. This increased fruit yield per plant might be due to the increased photosynthetic ability of plants inoculated with Azotobacter, Azospirillum, which in turn might have favoured an increased accumulation of dry matter. Fruit yield is interrelated with dry matter content and application of biofertilizers in combination with nitrogen might have balance the level of hormones and nitrogen fixers known for accumulation of dry matter and their translocation [14,18].

4. IMPACT OF BIOFERTILIZERS IN COMBINATION WITH FERTILIZERS AND ORGANIC MANURES ON QUALITY

The biofertilizers inoculation significantly influenced the Total soluble solids TSS, acidity, ascorbic acid and anthocyanin content in fruits of strawberry. Rayees et al. [20] observed that strawberry fruits taken from plants supplied with 75% organic manures and 25% inorganic manures in combination with biofertilizers resulted higher juice per cent in strawberry cv. Sweet Charlie. In a lab experiment on strawberry, Singh and Singh [15] observed maximum ascorbic acid TSS (8.96 ^{0}Brix) in fruits of strawberry plants inoculated with Azotobacter and Azospirillum along with nitrogen 60 kg ha^{-1} + GA_3 100 ppm. The yield and quality parameters of strawberry were significantly increased where plants treated with microbial fertilization compared with uninoculated control plants [25]. Tripathi et al. [26] observed maximum TSS (12.20 ^{0}Brix) in fruits taken from strawberry plants supplied with combined application of 50% vermicompost, 50% inorganic fertilizers and Azotobacter inoculation than control plants.

Kumar et al. [17] found that combined application of vermicompost (25 ton/ha), Azotobacter (6 kg ha^{-1}) and NPK (70:80:80 kg ha^{-1}) resulted in significant increase in TSS and juice content of strawberry fruits. Similarly, Mahavir et al. [27] noted that maximum TSS (9.62^0 Brix) in fruits taken from strawberry plants supplied with 75% RDF + 25% Vermicompost and Azotobacter and PSB inoculation. Mishra and Tripathi (2011) observed that inoculation of Azotobacter and PSB (each at 6 Kg ha^{-1}) resulted in minimum acid content (0.58%) of strawberry fruits. Dadashpour and Jouki [28] noted that combined application of manure + Azotobacter + wood ash

+ phosphorus solubilizing bacteria + oil cake significantly increased total acid content (0.85) of strawberry fruits.

In strawberry, Cacatto et al. [29] observed that arbuscular mycorrhizal inoculation (3 kg ha^{-1}) significantly decreased the acidity in fruits, however anthocyanin and TSS percentage was increased significantly. Esmatullah et al. [24] recorded minimum acidity in fruits of strawberry plants supplied with 100% RDF + VAM @10 kg ha^{-1} + 0.4% Boron + 0.5% $ZnSO_4$. Hazarika et al. [30] noted that the treatment combination of 75% RDF (NPK 60:75:90 kg ha^{-1}) + vermicompost (5 t ha^{-1}) + Azospirillum + PSB (2 kg ha^{-1} each) inoculation recorded maximum ascorbic acid, TSS and anthocyanin content and also observed that applying biofertilizers fruit storage period also enhanced significantly in compare with complete inorganic fertlizartion. Correspondingly, Lingua et al. [31] observed that increase in fruit quality parameters such as TSS, ascorbic acid, sugars and colour, when plants are inoculated with PSB and AMF, it might be due to the solubilization of phosphate and zinc, which further increased the nutriens availability and uptake in strawberry plants.

Singh et al. [32] reported higher ascorbic acid content with inoculation of biofertilizers in strawberry, which might be due to the greater availability of sugars (fructose and glucose) and substrates for vitamin C biosynthesis when plant able to up take all essential nutrients [18,21]. Keeping in view the importance of organic manures and biofertilizers in crop production, Khalil and Agah [33] conducted a field study on the influence of organic and inorganic fertilizers on strawberry growth, yield and quality. The results depicted that maximum TSS, vitamin C and anthocyanin content in fruits of strawberry noticed where plants supplied with organic and inorganic fertilizers equally than alone. The respective increase in TSS, colour and ascorbic acid content might be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen and excretion of growth promoting substances, which accelerated the physiological process like carbohydrates synthesis [34,35,36, 37].

5. CONCLUSION

Modern-day intensive strawberry cultivation relies on huge application of inorganic fertilizers and manures, which not only disrupt the balance of nature but also reduce the economic efficiency; however, it cannot be eliminated at this time without drastically decreasing food production. Hence, there is an urgent need for integrated nutrient management that targets agricultural inputs and lowers the adverse environmental impacts of agricultural fertilizers and practices. The application of biofertilizers plays a great role in improving the soil fertility, production of crops, reducing cost of production and minimizing environmental pollution.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/75381