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Growth, yield and quality of okra [*Abelmoschus esculentus* (L.) Moench] in response to different biofertilizers applications: A review

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Abstract

Okra is an important nutritionally rich vegetable crop valued for its tender fruits and wide adaptability to different agro-climatic conditions. With growing demand for quality of vegetables as people are becoming more health conscious, there is a demand to maintain the okra fruit quality as well as sustainable production of the crops, therefore the biofertilizers can be best substitute by minimising the chemical fertilisers and increase soil fertility as well. This review has been comprises with prior focus on applications of different biofertilizers namely *Azotobacter*, *Azospirillum*, *Trichoderma*, phosphate-solubilizing bacteria (PSB), vermicompost and vesicular-arbuscular mycorrhizae (VAM) in response to okra vegetative growth, yield and their attributes, and its fruit quality. These biofertilizers have been shown significantly responses to plant height, intermodal length, lateral branches, number of fruits per plant, fruit weight, fruit yield and biochemical parameters like vitamin C, total soluble solids (TSS) and dry matter content. Conclusively, it has been observed that the biofertilizers shows positive results, when they used in combinations with others biofertilizers then the single application. This review has collective information's regarding potentiality of biofertilizers in response to improve fruit quality and production of okra additionally maintaining soil fertility and reduce negative environmental impact concerning sustainable production.

Keywords: Okra, biofertilizers, *Azotobacter*, *Azospirillum*, *Trichoderma*, PSB

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is an important member to Malvaceae family. It is a fruiting vegetable crop found in tropical and subtropical regions of the world. Economically important, and commercially grown in India, West Africa, Turkey, Yugoslavia, Bangladesh, Iran, Afghanistan, Burma, Pakistan, Japan, Brazil, Ghana, Malaysia, Ethiopia, Cyprus, and the southern United States Nicosia *et al.* (2000) [24]. The major growing states of India are Bihar, Orissa, Uttar Pradesh, West Bengal, Andhra Pradesh, Karnataka, Assam, and West Bengal being the major producer of okra. Among the vegetables grown in India for export, okra has taken a major place. It accounts for 70% of fresh vegetable exports and has significant potential as a crop for generating foreign cash (Dhankhar and Mishra, 2004) [10].

It is a popular tropical vegetable that prefers hot, humid weather but is vulnerable to drought and low night temperatures. Its soft green fruit is used as a vegetable and is usually sold fresh, but canned and dried are also available. Okra is grown for its fibrous fruit, with round white seeds. Soft okra is used as a delicious vegetable. To a limited extent, it is used in preserved, dried, and frozen form. It contains no fat or cholesterol and is rich in fiber, so it is often used in weight loss diets. Rich in protein, calcium, potassium, and iodine. The average fresh pod has about 88% water, 0.1% fat, 8% carbohydrates, 1.8% protein, and 0.9% fiber. The highest amount of nutrients is found in seven-day-old, fresh okra pods Agbo *et al.* (2008) [11].

The high levels of vitamin C (13 mg/100g), iron (0.35 mg/100g), and calcium (66 mg/100g) in the edible fruits of okra make it a valuable source of nourishment Gopalan *et al.* (2007) [12]. Protein, vitamin A, and vitamin B are all abundant in green fruits. 7-8% of the dry matter of the fruit is made up of glucosides, mostly in the form of pulp. It has a fair amount of fiber but a lot of protein (1.8% of the dry mass). There is also a little quantity of potassium (traces),

phosphorus (56 mg/100 g), magnesium (53 mg/100 g), and calcium (66 mg/100 g).

Biofertilizers are microorganism inoculants capable of transforming nutritive components from non-usable to usable forms via a biological process. When applied to seeds, plant surfaces, or soil, these microorganisms colonize the rhizosphere or the inside of the plant and promote development by boosting the supply or availability of primary nutrients to the host plant. Biofertilizers add nutrients through the natural process of nitrogen fixation, phosphorus solubilisation, and plant growth stimulation through the manufacture of growth-promoting chemicals Shridhar, (2012)^[37].

Bio-fertilizers are a cost-effective and low-cost source of plant nutrients that do not require a non-renewable source of energy to produce, improve crop growth and product quality by providing plant hormones, and aid in sustainable crop production by maintaining soil productivity. The main problem that India has is growing the production of quality food in a sustainable manner while feeding the country's vast population and boosting farmer income. Fertiliser requirements in okra are critical for early growth and total fruit yield production. Crop productivity can be increased by combining organic and inorganic fertilizers Mal *et al.* (2013)^[17].

Okra requires a lot of manuring to be productive. Inorganic fertiliser usage without regard for soil health and microorganisms causes nutritional imbalance. As a result, there is a need to decrease the use of chemical fertilisers and stimulate the use of biofertilizers to the greatest extent possible. Biofertilizers fix a significant amount of atmospheric nitrogen in soil, promote plant development by producing organic acid and growth compounds, and make complex phosphorus available to the plant, potentially resulting in a significant reduction in the use of inorganic fertilisers. Biofertilizers are microorganisms that may mobilise native materials from non-usable to usable form via biological processes (Manohar and Bahadur, 2001)^[18].

The use of costly commercial fertilisers as needed by the crop is out of reach for most farmers. As a result, growers' alternate choice for preserving sustainable output is to apply plant nutrients through organic sources such as compost, farm yard manure and bio fertilizers (Arun and Gayathri, 2013)^[4]. Phosphate-solubilizing bacteria (PSB) help solubilize natural phosphorus from phosphate rocks and other poorly soluble forms of soil phosphorus by secreting organic acids. In addition, there are problems with applied fertilizer loss and phosphorus fixation, PSB play an important role in solubilizing 95-99% of insoluble phosphate Premsekhar and Rajashree (2009)^[32].

This review has collective information's regarding potentiality of biofertilizers in response to improve fruit quality and production of okra additionally maintaining soil fertility and reduce negative environmental impact concerning sustainable production. Considering all the above points, the present review article entitled "Growth, Yield and quality of okra [*Abelmoschus esculentus* (L.) Moench] in response to different biofertilizers applications" was comprises with the following headings:

- Effect of different biofertilizers on growth parameters of okra
- Yield and their attributes response to biofertilizers applications
- Quality traits of okra in response to different biofertilizers

Effect of different biofertilizers on growth parameters of okra

The growth parameters like plant height, number of leaves, internodal length, number of nodes, main branch and lateral

branches are the primary parts to respond and present the probable yield of the crops. If the vegetative parameters are in positive response to biofertilizers; it indicates the positive results of the crop survival and yielded good production of the fruits. There are many studies have been reviewed, collected and systematised here for the further studies and research work as well.

The phenomenon of early anthesis has found its validity from the findings of Naidu *et al.*, 2002^[22], who reported that the flower opening from appearance of bud was generally early in variety with more number of branches, leaves and higher leaf area of eggplant. Sajindranath *et al.* (2002)^[36] found that the significant increase in plant height with combination of *Azotobacter* + phosphate-solubilizing bacteria (PSB). Nuruzzaman *et al.* (2003)^[25] reported that the number of leaves per plant, stem base diameter, root length, root dry weight, leaf area index, and crop growth rate were found higher, when they applied treatment T₄ (*Azotobacter* + Cowdung 5 t/ha), T₅ (*Azospirillum* + 5 t/ha cowdung), T₆ (*Azotobacter* + *Azospirillum* + 5 t/ha cowdung) and T₈ (60% N) as compared to the others treatment in okra.

Ray *et al.* (2005)^[34] found that applying *Azospirillum* or *Azotobacter* supplemented with 15 t FYM/ha and 25:12.5:12.5 kg N.P.K/ha to okra was more advantageous for sustaining higher plant height (65.53cm). Bairwa *et al.* (2009)^[5] reported that application of 60% recommended dose of NPK through inorganic fertilizer + neem cake at 0.6 tonne/ha + Vermicompost at 1 tonne/ha + *Azotobacter* + PSB resulted in significantly maximum plant height at 90 DAS (77.80 cm) and stem base diameter (2.25 cm). Kanzariya *et al.* (2010)^[13] found the result of experiment, which indicated that treatment T₈ (75% RDF-NPK- 60:37.50:37.50 kg/ha + *Azotobacter* - 4kg) gave significantly maximum plant height at harvest (174.00 cm), number of leaves per plant (34.00) and number of pickings (12.03) with minimum days to first picking (44.00).

Anisa *et al.* (2011)^[2] applied the treatment comprising FYM double dose + *Azospirillum* + AMF + *Fratureia* each at 2 kg/ha. The results revealed that the treatment, where *Azospirillum*, AMF and *Fratureia* were inoculated along with double dose of FYM (T₈) and the treatment, where all the three biofertilizers were applied along with FYM and ¾ NPK (T₁₀) exhibited superiority in terms of growth parameters. Dhawale *et al.* (2011)^[11] determined that significantly maximum height of the plant (215.46 cm) and number of branches (3.79) were recorded at 100 DAS with treatment combination (100% RDF 100:50:50 kg/ha + Biofertilizers -*Azotobacter* and PSB @ 7.5 kg/ha soil application + 2% panchgavya spray).

Bhushan *et al.* (2013)^[6] stated that the impact of *Azotobacter* and inorganic fertilizers on growth, fruit and seed yield of okra cv. Hisar Unnat. Among all of the treatments, T₅ (*Azotobacter* + ½ N + P + K) recorded significantly higher plant height (157.2 cm), number of branches per plant (2.2) and number of nodes per plant (19.6). Prasad and Naik (2013)^[31] found that the growth parameters such as plant height at 30 and 60 DAS, number of leaves, fruit length, number of branches, fruit diameter and number of fruits/plant were observed significantly maximum in treatment receiving 50% RDF + *Azotobacter* + *Azospirillum* + PSB + FYM. Sahu *et al.* (2014)^[35] discovered that using PSB (Phosphate Solubilizing Bacteria) @ 50% in conjunction with *Azotobacter* @ 50% and a full dose of nitrogen and potash, as well as a half dose of phosphorus, resulted in significantly stronger growth observed in 45 DAS and 60 DAS of okra plants. Choudhary *et al.* (2015)^[8] found that the effect of chemical fertilizers along with biofertilizers on okra in terms of

growth and yield. Among the different treatments maximum plant height (96.03cm), was observed in treatment receiving *Azospirillum* 5 kg ha⁻¹ + RD NPK.

Rafique M. and Ortas, I. (2018) [33] found the results where the soil fertility in the semi-arid Mediterranean region is poor and mycorrhizal inoculation could be an important agricultural strategy for reducing fertilizer use and also increase the food quality. Parameters measured were seedling survival, plant growth and yield, and root colonization. Discipline test results confirmed that mycorrhizal inoculation significantly accelerated the root colonization by 51-80% irrespective of P₂O₅ application. Therefore, plant growth was observed that it is strongly dependent on AM fungi inoculation moreover to reinstate soil quality. Kujur *et al.* (2020) [14] aimed to investigate the effect of various treatments mentioned below on okra growth and yield. Various combinations of bioinoculants, vermicompost, and chemical fertilisers were used in the treatments. Among the six treatments, the treatment combining *Azotobacter* + PSB with vermicompost and 75% NPK improved the most in terms of plant height at different stages (30, 60 DAS, and at harvest) and number of leaves per plant.

Singh *et al.* (2020) [39] found that the different mixtures of bio-fertilizers and inorganic manures affected the growth, yield, quality and economics attributes of okra [*Abelmoschus esculentus* (L.) Moench]. The treatment T₁₆, which consisted of (*Azotobacter* + PSB + NPK @ 120:60:60), produced the tallest plant (167.83 cm) and the highest number of leaves (32.23). This suggests that this treatment was especially successful at boosting vegetative development in okra plants. The treatment T₁₁ (PSB + NPK @ 100:50:50, showed the highest average fruit length (13.06 cm) compared to other treatments. Treatment T₁₂ (*Azotobacter* + PSB + NPK @ 100:50:50) resulted in considerably higher values for a variety of growth measures, including the number of nodes (27.00), stem diameter (1.94 cm), days to first flower appearance (38.73) and days to 50% flowering (55.03).

Chauhan *et al.*, 2023 [7] conducted experiment to demonstrate the effects of biofertilizers on germination and growth parameters of okra crop. Among twenty one isolates, the isolates *Pseudomonas*, *Azotobacter*, *Rhizobium* and *Bacillus* have been identified. All Plant Growth Promoting *Rhizobacteria* (PGPR) were tested for vegetative traits and observed that the seedling length of P7 (33cm) is the longest among them. In the pot experiment, after 50 days plants inoculated with PGPR P11 (30cm), P12 (29cm), P20 (29cm), P3 (30cm), P5 (32cm), P7 (33cm), P8 (30cm) show longer seedling length and growth as compared to the control one.

Yield and their attributes response to biofertilizers applications

The yield and their attributes such as number of fruits per plant, fruit weight, fruit length and diameter, and yield per hectare are the main factors, which has impact on potential production of the okra cultivation in response to biofertilizers applications. Concerning literatures have been collected, compiled and systematically formulated here.

Patil *et al.* (2000) [28] reported that the use of biofertilizer (30 g *Azotobacter* /kg seeds) resulted in a higher fruit output (128.59 q/ha) in okra. Naidu *et al.* (2002) [22] found that treatment with organic manure vermicompost at the rate of 14 t/ha when applied in combination with biofertilizer PSB increase the fruits girth and higher yield as compared to treatment (nitrogen + organic manure). Furthermore, treatment with combination of (vermicompost + PSB and other biofertilizers) was at par to N

with organic manure in terms of yield in brinjal. Sajindranath *et al.* (2002) [36] found that the seed germination was increased with the application of *Azotobacter* + *Azospirillum* inoculation in okra. Prabhu *et al.* (2002) [30] studied the effect of integrated nutrient management on fruit yield of okra and their results indicated that treatment consisting 75% NPK+FYM+*Azospirillum* + VAM produced the highest yield.

Swain *et al.* (2003) [40] found that the fruit production from fertiliser N (50%) combined with bioinoculants was statistically equivalent to 100% N fertiliser alone in okra. They discovered that the application of (75 kg N/ha + *Azotobacter* + *Azospirillum*) considerably boosted fruit yield in okra over the approved dose of inorganic nitrogen alone. Patel (2005) [27] discovered that the application of treatment combination (75 kg N/ha with *Azospirillum* and *Azotobacter*) increased the potential yield of okra cv. Gujarat Okra 2. This implies that the use of nitrogen fertiliser in conjunction with biofertilizers (*Azospirillum* and *Azotobacter*) improved the yield of the okra crop. Ray *et al.* (2005) [34] found that applying *Azospirillum* or *Azotobacter* supplemented with 15 t FYM/ha and 25:12.5:12.5 kg N.P.K/ha to okra was more advantageous for sustaining higher number of fruits per plant (7.42), fruit yield (68.95q/ha) and per cent increase in yield over control (30.8).

Bairwa *et al.* (2009) [5] reported that T₆ with soil application of (neem cake + vermicompost + *Azotobacter* + PSB + 60% recommended dose of NPK) proved to be the most effective integrated nutrient management strategy for cultivating okra. This treatment resulted in the highest number of fruits (18.36), fruit yield (182.50 g/plant and 135.18 q/ha), fruit weight (17.65 g), length of fruits (12.26 cm), and thickness of fruits (1.898 cm). The fruit yield increased by 29.30% compared to the control. Mishra *et al.* (2009) [21] showed that the application of vermicompost @ 2.5 t/ha+ NPK (120:60:60 kg/ha) +PSB+ *Azotobacter* outperformed the other treatments in terms of maximum length of fruit, diameter of fruit, fresh weight of fruit, dry weight of fruit, and yield.

Kanzariya *et al.* (2010) [13] found the result of experiment indicated that treatment T₈ (75% RDF- NPK- 60:37.50:37.50kg/ha + *Azotobacter* -4 kg) gave significantly maximum productive span (44.00 days), number of pickings (12.03), average fruit weight (14.67g), number of fruits per plant (14.87), fruit yield (12168.0 kg/ha) and dry weight of pod (39.40g). Anisa *et al.* (2011) [2] determined that the treatment comprising (FYM double dose + *Azospirillum* + AMF + *Frateruria* each at 2 kg/ha), exhibited the highest relative chlorophyll content (48.73 SPAD Units) and total dry matter production (350.50 g/plant). The earliest flowering (39.67 days) and harvesting (46.33 days) were recorded in plants inoculated with AMF and *Frateruria* along with FYM (T₆). The treatment T₈ (double dose of FYM along with *Azospirillum*, AMF and *Frateruria*) recorded the maximum fruit weight (19.80 g), fruit girth (6.17 cm) and number of seeds per fruit (82.89).

Dhawale *et al.* (2011) [11] determined that the treatment T₅ produced significantly maximum fruit yield per plant (0.124 kg) and fruit yield per ha (26.99 tonnes) with treatment combination (100% RDF 100:50:50 kg/ha + Biofertilizers -*Azotobacter* and PSB @ 7.5 kg/ha soil application + 2% panchgavya spray). Bhushan *et al.* (2013) [6] stated that the impact of *Azotobacter* and inorganic fertilizers on growth, fruit and seed yield of okra cv. Hisar Unnat. Among all of the treatments, T₅ (*Azotobacter* + ½ N + P + K) recorded significantly high fruit yield (18300kg/ha) in addition to seed yield (3490kg/ha) specifically due to better overall performance of the remedy in specific yield contributing parameters that is number of nodes per plant (19.6),

number of fruits per plant (14.3), number of pods per plant (14.2), pod weight (13.9 g), seeds per pod (57.5) and seed weight per pod (6.1 g).

Prasad and Naik (2013) [31] found that the yield and yield attributes like fruit diameter and number of fruits per plant and fruit yield (196.97 q/ha) were observed significantly maximum in treatment receiving 50% RDF + *Azotobacter* + *Azospirillum* + PSB + FYM. Mal *et al.* (2014) [16] discovered that combining biofertilizers (*Azotobacter*, *Azospirillum*, and PSB) with chemical fertilisers and vermicompost improved growth and yield attributes in okra. Application of highest dose of NPK @100% in combination with vermicompost (5 t ha⁻¹) and biofertilizers with FYM increased the fruit yield of okra (cultivar Mahyco-10) considerably with yield varying between 80.00 q ha⁻¹ to 227.13 q ha⁻¹ and 80.49 q ha⁻¹ to 229.62 q ha⁻¹ during 2010 and 2011 respectively. In okra cv. Utkal Gaurav the fruit yield varied from 47.68 q ha⁻¹ to 129.84 q ha⁻¹ in 2010 and 47.27 q ha⁻¹ to 131.35 q ha⁻¹ in 2011.

Sahu *et al.* (2014) [35] discovered that using PSB (Phosphate Solubilizing Bacteria) @ 50% in conjunction with *Azotobacter* @ 50% and a full dose of nitrogen and potash, as well as a half dose of phosphorus, resulted in significantly boosted okra yield. The usage of PSB and *Azotobacter*, together with proper nutrient management, were useful in improving okra crop development and yield. Choudhary *et al.* (2015) [8] found that the effect of chemical fertilizers along with biofertilizers on okra in terms of growth and yield. Among the different treatments maximum pod weight (11.53 g), girth of pod (4.88cm), yield plant⁻¹ (139.39 g) and yield ha⁻¹ (10324.94 kg) were observed in treatment receiving *Azospirillum* 5 kg ha⁻¹ + RD NPK. The plants under the treatment of PSB 5 kg ha⁻¹ + RD NPK through chemical fertilizers had the highest length of pod (12.03 cm). Whereas the treatment of VAM 15 kg ha⁻¹ + 75% P +100% NK through chemical fertilizers had the highest number of pods per plant (13.11). The study led to a conclusion, that the maximum growth parameters, highest yield and yield attributing characters of okra could be achieved by judicious application of biofertilizers and chemical fertilizers.

Sidhya *et al.* (2015) [38] found that bio-fertilizer, organic manure, and inorganic fertilizers, alone and in combination, had an effect on okra. The influence of Bio-fertilizer, organic manure and inorganic fertilizers individually and in combination on okra cv. VRO-6 were tested. Mycorrhizal application promoted the growth and yield of okra in as all mycorrhizal combinations produced better results than sole organic manure and inorganic fertilizers. Results revealed that the combined application of mycorrhiza + 50% organic manure + 50% inorganic fertilizer or mycorrhiza + 75% organic manure +25% inorganic fertilizer produced the highest fruit yield (13.67 t/ha) and its attributes. Unless supplemented with organic manure and inorganic fertiliser, sole mycorrhizal application had no better outcomes.

Anisa *et al.* (2016) [3] conducted a study on the okra variety Arka Anamika, investigating the effects of different treatments involving farmyard manure (FYM) and three biofertilizers (*Azospirillum*, Arbuscular Mycorrhizal Fungi and *Fratureia*), as well as inorganic fertilizers, alone or in various combinations. They observed the most significant improvements in yield and yield attributing characters when a combination of all three biofertilizers was applied along with a double dose of FYM.

Rafique M. and Ortas, I. (2018) [33] found the results, where the soil fertility in the semi-arid Mediterranean region is poor and mycorrhizal inoculation could be an important agricultural strategy for reducing fertilizer use and also increase the food quality. Parameters measured were seedling survival, plant

growth and yield, and root colonization. Significant impact of P₂O₅ and AM fungi was found for pepper and eggplant yield increase as 8-35% and 6-44% respectively. Under field conditions, AM fungi with P₂O₅ application is best responding for yield enhancement. The maximum yield applied to growers has been changed to accelerate sapling survival. Kujur *et al.* (2020) [14] aimed to investigate the effect of various treatments mentioned below on okra growth and yield. Various combinations of bioinoculants, vermicompost, and chemical fertilisers were used in the treatments. Among the six treatments, the treatment combining *Azotobacter* + PSB with vermicompost and 75% NPK improved the overall yield attributes (number of fruits per plant, fruit length, fruit weight, fruit yield per plant). The treatments T₅ and T₆, which contained 75% NPK, vermicompost, *Azotobacter*, and PSB, produced the highest total yield (537.34 g and 518.58g, respectively) when compared to the other treatments.

Singh *et al.* (2020) [39] found that the different mixtures of bio-fertilizers and inorganic manures affected the growth, yield, quality and economics attributes of okra [*Abelmoschus esculentus* (L.) Moench]. The treatment T₁₁ (PSB + NPK @ 100:50:50, showed the highest average fruit length (13.06 cm) compared to other treatments. Treatment T₁₂ (*Azotobacter* + PSB + NPK @ 100:50:50) resulted in considerably higher values for diameter of fresh fruit (1.39 cm), average fruit weight (12.00 g), number of fruits per plant (22.17), fruit yield per plant (266.05 g) and the highest total yield of fruits (167.52 quintals per hectare).

Dahilig and Rosales (2023) [9] found that mycorrhiza had a positive impact on crop performance, particularly in enhancing the fruit characteristics of okra. The study indicates that fruit count per plant, fruit length, and root length are significant factors influencing the overall yield. Maximum fruit yield (31.60 t/ha), fruit length (9.20 cm) and root length (26.97 cm) was observed.

Quality traits of okra in respond to different biofertilizers

Qualitative traits are very important for the consumption of the fruits as well domestic and export marketing. The parameters of fruits quality namely seed purity chlorophyll content, vitamin C, total soluble solids (TSS), anthocyanin in red fruits of okra, and dry matter content are major traits of okra pods, which also fetches its market value. Seed quality parameters such as seed physical and genetic purity, germination percentage and seedling establishment were also collected and interpreted. In this review article, the commemorative studies have been collected, interpreted and presented in simple and understanding form to gather information's and generate further research and investigations thoughts.

Patel (2005) [27] discovered that the application of treatment combination (75 kg N/ha with *Azospirillum* and *Azotobacter*) increased the quality of okra cv. Gujarat Okra 2. This implies that the use of nitrogen fertiliser in conjunction with biofertilizers (*Azospirillum* and *Azotobacter*) improved the quality of the okra crop. Kanzariya *et al.* (2010) [13] found the result of experiment indicated that treatment T₈ (75% RDF-NPK-60:37.50:37.50kg/ha+ *Azotobacter* -4 kg) gave significantly maximum germination percentage (87.00). Anisa *et al.* (2011) [2] applied the treatment comprising FYM double dose + *Azospirillum* + AMF + *Fratureia* each at 2 kg/ha. The observed the crude protein content of okra fruit was higher in treatments, where all the three biofertilizers were applied. The treatment T₁₀ where FYM, inorganic fertilizers (¾) and biofertilizers were applied, recorded the highest beta carotene

content (94.33 µg/100g). Shelf life (6.67 days) was more in plants treated with all the three biofertilizers and FYM (T₇ and T₈). Higher nutrient content and uptake was observed in treatments where all the three biofertilizers were applied.

Olawuyi *et al.* (2012) [26] found that mycorrhiza application produced the high fruit yield when compared to other treatments. The influence of *Glomus clarum* and organomineral fertilizer on productivity of okra was studied. The arbuscular mycorrhiza fungi (AMF) and organo mineral fertilizer (OMF) were applied into 6kg soil at the rate of 5, 10 and 15 g each per plant, while the control had 0g. The result showed that the yield of plants treated with 5g AM fungi produced highest cumulative number of harvested fruit (2.17) and harvested weight per fruit (7.71g/plant) while, plants treated with 10g OMF and 5g AM fungi produced higher cumulative harvested fruit number which were not significantly different from each other. The fruit yield of okra was optimized with 5g AM fungi.

Rafique M. and Ortas, I. (2018) [33] found the results where the soil fertility in the semi-arid Mediterranean region is poor and mycorrhizal inoculation could be an important agricultural strategy for reducing fertilizer use and also increase the food quality. Parameters measured were seedling survival, plant growth and yield, and root colonization. Phosphorus percentage in plant tissues was significantly different in tomato plant (0.22-0.30%) and AM fungi increased its concentration also in other crops. AM fungi application strongly influenced nutrients concentration and improved the plant quality in all studied crops against control. Under field conditions, AM fungi with P₂O₅ application is best responding for nutrient uptake, which leads to a quality food. Therefore, plant growth and nutrient uptake is strongly dependent on AM fungi inoculation moreover to reinstate soil quality.

Kujur *et al.* (2020) [14] aimed to investigate the effect of various treatments mentioned below on okra growth and yield. Various combinations of bioinoculants, vermicompost, and chemical fertilisers were used in the treatments. Among the six treatments, the treatment combining *Azotobacter* + PSB with vermicompost and 75% NPK improved the chlorophyll content. Singh *et al.* (2020) found that the different mixtures of bio-fertilizers and inorganic manures affected the growth, yield, quality and economics attributes of okra [*Abelmoschus esculentus* (L.) Moench]. Treatment T₁₂ (*Azotobacter* + PSB + NPK @ 100:50:50) resulted in considerably higher values for total seed yield per plant (23.10 g) and other qualitative traits such as ascorbic acid (19.03 mg/100g) and total soluble solids (T.S.S) content (14.83°Brix), which indicates higher nutritional quality.

Chauhan *et al.*, 2023 [7] conducted experiment to demonstrate the effects of biofertilizers on germination and growth parameters of okra crop. Among twenty one isolates, the isolates *Pseudomonas*, *Azotobacter*, *Rhizobium* and *Bacillus* have been identified. All Plant Growth Promoting *Rhizobacteria* (PGPR) were tested for seed germination in which P14, P21, P8, P13, P17, P19 *etc.* isolates show the best germination percentage (80-90%) in comparison with the control and the seedling length of P7 (33cm) is the longest among them. In the pot experiment, after 50 days plants inoculated with PGPR P11 (30cm), P12 (29cm), P20 (29cm), P3 (30cm), P5 (32cm), P7 (33cm), P8 (30cm) show longer seedling length as compared to the control one.

Conclusion

Biofertilizers are the best alternative for the sustainable farming by minimising the chemical fertilisers and increase soil fertility. The applications of different biofertilizers namely *Azotobacter*,

Azospirillum, *Trichoderma*, phosphate-solubilizing bacteria (PSB), vermicompost and vesicular-arbuscular mycorrhizae (VAM) are considerate in response to okra vegetative growth, yield and yield attributes, and its fruit quality. They have shown significantly responses to plant height, intermodal length, lateral branches, number of fruits per plant, fruit weight, fruit yield and biochemical parameters like vitamin C, total soluble solids (TSS) and dry matter content. Conclusively, it has been observed that the biofertilizers shows positive results, when they used in combinations with others biofertilizers then the single application. In addition, they also maintain soil fertility and reduce negative environmental impact concerning sustainable production.

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