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EFFECT OF BIO-FERTILIZERS AND ORGANIC MANURES ON GROWTH, YIELD AND FRUIT QUALITY OF FRUIT CROPS

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Abstract

The major problem that occurs in developing countries is poor plant growth and yield due to soil infertility. Now-a-days to increase the crop production the fertilizers or pesticides used by the farmers in excess, which usually contain high amounts of chemicals, results in poor health of soil. In agriculture, use of inorganic compounds in high quantities has an impact on the sustainability of crop production, which consequently increases cultivation cost and decreases the productivity. The use of inorganic/chemical fertilizers, especially urea to the farming land lead to soil health reduced. Our farming has switched now-a-days to old age activities such as conservation agriculture. Bio-fertilizer, in general, is organic in nature and involves living organisms that synthesize the nitrogen in the atmosphere or create an environment that is useful to plants in the land or medium (in which the species are kept). On the other hand, the cost of bio-fertilizers is low and it has no adverse impact on soils as compared to chemical fertilizers. It is recommended that bio-fertilizers should be used with the combination of FYM, compost or other organic manures which increases or improves the vegetative growth parameters like fruit quality, stem girth, fruit weight, TSS of fruit etc. It is also helpful in the reduction of the cost of production and increases the grower's income by increasing the crop yield 20-30% and it also stimulates the plant growth. However, due to lack of confidence and interest towards different bio-fertilizer practices, availability of viable culture, technical help, training programme and formulation with the elongated durability of microbes etc are some of the constraints faced by the farmers. Further, Bio-fertilizers fight against some soil-borne diseases and pathogens and provide plant protection against abiotic factors like drought and also provide sufficient nutrients to different fruit crops. Well, our agriculture objective is to get the maximum output with the minimum use of inputs. So, it is the best example for using bio-fertilizers which are low in cost instead of using chemical fertilizers or pesticides.

Key words: *Bio-fertilizers, Farmyard manure, Vermicompost, Growth parameters.*

Introduction

Because of constantly population increases, the consumption of food resources are more, resulting there is a lack of food resources. Nitrogenous fertilizers known as chemical fertilizers which are inorganic in nature and containing high cost, cause considerable damage to soil, environment and also harm the human health when it is used in high quantity. Recently, most of the countries moved for searching natural alternative which are able to replace the use of chemical/ inorganic fertilizers or pesticides and can reduce the pollution of environment as well as the cost of agricultural production (Alalaf, 2019). Among the various alternatives one of the best example are the Bio-fertilizers. Bio-fertilizers are the living substances, containing living organisms which increase the supply of primary nutrients to the main crop. There are many species of plant growth promoting rhizobacteria (soil bacteria) which mainly colonize in rhizosphere of the plants. Several PGPR acts as bio-fertilizer and promotes growth. Microorganisms mainly phosphate solubilizer, nitrogen fixer, mycorrhizae are the main source of bio-fertilizers. Micro-organisms, especially used for bio-fertilizers are the bacteria of *Lactobacillus*, *Bacillus*, *Psuedomonas,* nitrogen fixing and photosynthetic bacteria. Bio-fertilizers proved as an environmentally friendly and renewable source of nutrients. Bio-fertilizers are ready to use and when these beneficial micro-organisms are used as a live formulation it can be applied to root, soil and seed, which assembles the utility and availability of the micro-organisms and hence soil health improves (Ismail *et al.,* 2014). The more use of chemical/inorganic fertilizers in the field the more impact on physio-chemical soil properties. To avoid the use of the chemical fertilizers, many organic fertilizers

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introduced, which behave like a natural stimulators for the growth & plant development (Khan *et al.,* 2009). Bio-fertilizers are the most important components of INM in soil, which play a major role in sustainability & soil productivity. Day-by-Day these bio-fertilizer replaces the chemical or inorganic fertilizers because of their low cost, eco-friendly and renewable source of nutrients of the plants. Bio-fertilizers differ from organic and chemical fertilizers in such a way, that it cannot supply direct nutrients to crops and they are the culture of special or specific fungi and bacteria, comparatively simple and have a less cost of installation. Bio-fertilizer increases overall development of vegetative growth parameters like in higher growth rates, yield development, fruit quality, stem girth, fruit weight, TSS of fruit and also reduces acidity as compared to chemical fertilizer (Alam and Seth, 2014). In the past years, bio-fertilizers mostly used in the field crops but after seeing its benefits and advantages to the crops it has been used in the fruit crops also. Bio-fertilizers have the ability to solubilises 30-50 kg P_2O_5 /ha/year, fixes 20-200 kg N/ha/year (Hazarika and Ansari, 2007). When it applied to the seeds or soil by colonizing the plant rhizosphere, it increases the nutrients supply to the host plants. Bio-fertilizers are less costly and it has no adverse impact on soils as compared to chemical fertilizers.

Benefits of Bio-fertilizers

The benefits of bio-fertilizers are as follows: (Vikaspedia).

i. Bio-fertilizers viz. Blue Green Algae (BGA) has the ability to fix atmospheric nitrogen in the soil & make it available to the plant.

ii. Rhizobium, Bacillus and Psuedomonas are the bio-fertilizers have the ability to solubilise the phosphates into available forms by solubilising the insoluble forms of phosphates like aluminium phosphates, tricalcium etc.

iii. Bio-fertilizers promote the root/plant growth by producing anti metabolites and hormones.

iv. When it applied to soil, surface of the plant or seeds, bio-fertilizers improves the yield upto 10-25%, increases the nutrients availability without affecting the environment and soil.

v. Bio-fertilizers fight against some soil-borne diseases and pathogens and provide plant protection against abiotic factors like drought.

Causes of Poor Response of Bio-fertilizers (Sabalpara and Mahatma, 2016).

A) Storage related issues

• It might be stored in hostile conditions.

• It might be exposed to high temperature.

B) Quality related issues

• High level of contaminants.

• Insufficient population of microorganisms.

• Wrong selection of the product.

C) Usage related issues

• Not used by recommended method in appropriate doses.

• Used with strong doses of plant protection chemicals.

• High soil temperature or low soil moisture.

• Soil and environment related issues.

• Acidity or alkalinity in soil.

Types of Bio-fertilizers (Kumar *et al.,* 2017)

A) Nitrogen fixing bio-fertilizer:

• Associative symbiotic :- *Azospirillum*.

• Symbiotic:- *Rhizobium*, *Anabaena azollae, Frankia*.

• Free-living:- *Azotobacter, Nostoc, Klebsiella, Clostridium, Anabaena, Beijerinkia*.

B) Phosphorus mobilizing bio-fertilizer (PMB):

• Orchid mycorrhiza:- *Rhizoctonia solani*

• Ectomycorrhiza:- *Amanita* sp., *Boletus* sp., *Pisolithus* sp., *Laccaria* sp.

• Arbuscular mycorrhiza:- *Scutellospora* sp., *Gigaspora* sp., *Glomus* sp., *Acaulospora* sp.

• Ericoid mycorrhizae:- *Pezizella ericae*.

C) Phosphorus solubilizing bio-fertilizer (PSB):

• Fungi: A*spergillus awamori, Penicillium* sp.

• Bacteria:- *Psuedomonas striata*, *Bacillus megaterium* var. phosphaticum, *B. circulans*, *B. subtilis*

D) Plant growth promoting bio-fertilizer (PGPB):

• Psuedomonas:- *Psuedomonas fluorescens*.

E) Bio-fertilizers for Micronutrients:

• Silicate and Zinc solubilizers:- *Bacillus* sp.

Bio-fertilizers

Bio-fertilizers (*viz. Blue-green algae, Mycorrhizae, Phosphate Solubilizing Bacteria* (*PSB-*)*, Azolla, Azospirillum, Rhizobium, Psuedomonas, Azotobactor)* alone and combination with organic manures like Farmyard manure, Vermicompost, Cocopeat etc increases vegetative growth characters like stem girth, plant height, fruit yield, number of leaves per shoot, canopy spread, fruit quality, TSS, fruit weight, reduces acidity and also the usage of chemical/inorganic fertilizers or pesticides.

List of Commonly Produced Bio-fertilizers (Vikaspedia).

Name of Biofertilizers	Suitable Crops	Benefits	Suitable Remarks
BlueGreen Algae(BGA)	Wet lands like rice.	BGA fixes 20 to 30 kg N/ha.	Can be used for fishes as feed. Reduces the soil alkalinity..
Mycorrhizae	Several trees and ornamental plants.	Enhances uptake of S, Zn, P and Water. Also 30-50% increases yield,	Usually inoculated to seedlings.
Phosphate Solubilizers (there are two fungal and two bacterial species)	Application of soil for all kind of crops.	Increases production from 5 to 30%.	Rock phosphate can mix.
Azospirillum	Non-leguminous crops *i.e.* oats, Sugarcane, jowar, rice etc.	Increases production from 10 to 20%.	Produces substances that promotes the growth.
Rhizobium strains	Legumes like soybean, pulses, groundnut.	Adds 50-200 kg N/ha and 10-35% increases yield.	Results obtained better with Fodders.
Azotobacter	Treatment of soil for non-leguminous crops and also crops under dryland.	Adds 20-25 kg N/ha. 10-15% increases yield.	Also controls certain pathogens and diseases.

The functions of bio-fertilizers are as follows:

a) *Azotobacter*: It is heterotrophic bacteria which freely fixes the nitrogen when present in neutral and alkaline soils. In India, it is found in arable soils. (Sahu *et al.,* 2012) reported that *Azotobacter* can fix 0.026-20 kg N/ha/year.

b) *Azospirillum*: It has a close association of symbiosis with the complex plant system. (Contreras-Angulo *et al.,* 2019) concluded that *Azospirillum brasilense* can fix 48 kg N/ha/year.

c) *Rhizobium*: These are the symbiotic bacteria and are capable to fix atmospheric N gas within the plants root nodules (Chen *et al.,* 2006); (Sahu *et al.,* 2012) evaluated *rhizobium* fixes upto 50-300 kg N/ha/year.

d) Phosphate solubilising bacteria (PSB): When the soil is acidic or calcareous soil conditions, phosphorus in huge amounts in this soil is present but cannot be available to the plants. The bacteria usually Phosphobacterins make the insoluble form of phosphorus available to the plant and evaluated PSB saves upto 30 to 50 kg of superphosphate (Chen *et al.,* 2006).

e) PGPR: The growth of the plant can be stimulated when PGPR shows a broad variety of bacteria, present in soil. This includes fixation of nitrogen, has a good impact on plant growth and morphology, increases the availability of nutrients in the rhizosphere and it promotes the other favourable plant–microbe symbiosis. A few researchers indicated in their research that PGPR can be proven beneficial in a number of ways for multifareous action (Chen *et al*., 2006). (Ratti *et al.,* 2001) reported a combination of the *Glomus aggregatum*, AMF, *Azospirillum brasilense* and the *Bacillus polymyxa* maximizes the biomass content.

Effect of Biofertilizers and Organic Manures

Combination of bio-fertilizers + organic manures *viz*. Poultry manure, FYM and composts increases the vegetative growth parameters of fruit crops like plant height, stem girth, fruit yield, fruit size and weight etc. Different combination varies in different fruit crops which are discussed in this review paper:

1. Plant Height : Application of vermicompost + vermiculite + sand + soil + cocopeat (1:1:1:1:1) with the treatment of *Azotobacter* gives a maximum height of (13.75 cm) seedling of acid lime after the sowing of 150 days whereas in medium soil minimum height (8.82 cm) were seen in the absence of *Azotobacter* (Yadav *et al.,* 2012). Bio-fertilizer PSM @ 100 g/plant + *Azotobacter* @ 150g/plant + 50% chemical fertilizer produces the plant height of Mango (6.72 m) which is maximum followed by RDF-NPK at 500:250:500 g/plant/year + Vermicompost 2.5 kg/plant/year which was (6.24 m) as against to control (Dutta *et al.,* 2016). The tree height percentage (10.78%) of Mango plants was increased in a treatment of (PSB 50 g + 3 kg Vermicompost + *Azotobacter* 50 g) and was high in comparison to other treatments like in a (PSB 25 g + 3 kg Vermicompost + *Azotobacter* 50 g) and in a (PSB 50 g + 3 kg Vermicompost + *Azotobacter* 25 g) and control (Poonia *et al.,* 2018). The highest values of the leaf area & shoot length of the Eureka lemon trees was recorded with treatments of *Azospirillum* 25g/tree + *Azotobacter* 25g/ tree + 75% NPK /tree + *Bacillus circulans* 25g/tree + 27.5kg FYM/year and *Azospirillum* 25g/tree + *Azotobacter* 25g/tree + 50% NPK/tree + *Bacillus*

circulans 25g/tree + 55kg FYM/year followed by a treatment of *Azotobactor* 25g/tree + 27.5kg FYM/year + 75% NPK /tree in both seasons (summer & spring); whereas the lowest values were obtained with 100% NPK (1000:250:500 g/tree/year) control and other treatments of 27.5kg FYM/year + 75% NPK /tree & 55kg FYM/year + 50% NPK /tree during the both seasons (Ennab and H.A., 2016).

The treatment containing FYM (150 Kg/tree) + inorganic fertilizers (525 g/tree) + *Azotobactor* (18 g/ tree) improves the plant height of Lemon upto 10.33 percent in comparison to 5.90 percent increase under control (K. and Bal, 2014). The highest values of shoot length (43.51cm) of Valencia orange trees were recorded with treatment of (180 N units/feddan + 120 K units/ feddan + *B. circulans*) while the treatment of (180 N units/feddan + 120 K units/feddan + *Azotobactor*) and (180 N units/feddan + 120 K units/ feddan + *B. megaterium*) gave the moderate values of (39.88cm) and (40.78cm) respectively, whereas the lowest value (30.16cm) were obtained with the treatment of (140 N units/feddan + 120 K units/feddan) (Khawaga *et al.,* 2013). The maximum increase in tree height (0.47m) of Sweet Orange was recorded in the treatment of 80ml *Azotobactor* + 80ml PSB + RDF 800:400:400g NPK + 50kg FYM, whereas the minimum increase was observed in control (RDF 800:400:400g NPK + 50kg FYM) (Jugnake *et al.,* 2017). The plant height *i.e.* 190.84 cm was recorded in banana is maximum by the application of *Azotobactor* 50g + PSB 50g + 250g VAM + 50% RDF (200:160:200g NPK) + FYM when compared to other treatments and control (Patil and Shinde, 2013). The treatment containing *Azotobactor* 50 g + VAM 20 g + PSB 50 g + 50% N through vermicompost + 50% RDF gave maximum plant height of Custard Apple as against other treatments and control (Sharma and Bhatnagar, 2014). Plant height (201.95 cm) of Papaya fruit was found to be increased significantly by application of (*Azotobactor* + PSB + 100% NPK + FYM) followed by (*Azospirillum* + 100% NPK + PSB + FYM), (PSB + FYM + 50% NPK + *Azotobactor*) and (*Azospirillum* + PSB + FYM + 50% NPK) which was (199.23 cm), (198.82 cm), (196.92 cm) respectively in comparison to control (190.18 cm). It may be because of the proper combination of Bio-fertilizers + chemical fertilizers + organic manures (Srivastava *et al*., 2014).

The conclusion evaluated that the plant height (4.91 m) of Guava Fruit influenced significantly and maximum when treated by application of PSB 100 g /tree + *Azospirillum* 100 g /tree + cowdung slurry @ 10 litre / tree + 75% recommended dose of fertilizers (RDF) followed by plant height (4.80 m) having treatment of 25% NPK/tree + 75% RDF blended with cow dung slurry10 lt/tree, whereas lowest plant height (3.75m) seen under control (Chandra *et al.,* 2016). Maximum plant height (3.43 m) of Guava fruit was noted with treatment of *Azotobactor* + PSB + FYM + RDF 100% and closely followed by all the treatments comprising plant height of (3.19m) with treatment of FYM + RDF 100% and plant height of (3.24m) with treatment of Vermicompost + RDF 100 % along with the treatments of (*Azotobacter* + PSB + FYM+ RDF 75%), (*Azotobactor* + PSB+ Vermicompost + RDF 75 % +) & (*Azotobacter* + PSB + RDF 75 %) whose plant height was (3.15m), (3.19m) & (3.11m) respectively. whereas plant height (2.77 m) observed under control was minimum (Sharma *et al.,* 2018). Application of *Azotobactor* 100g + VAM 100g + TV 100g + PSB 100g + 25 kg vermicompost + Oil cake 2.5 kg + 520: 160: 450 NPK g /plant maximizes the crown height (78.3cm) of Mango plants in comparison of control and other treatments (Sharma *et al.,* 2016). Combination of *Azotobactor* 25 g + Vermicompost 10 kg + NPK 100% increases the plant height of Papaya fruit as against to other treatments and control (Yadav *et al.,* 2011). Applications of PSB 2.5 g/m^2 + *Azotobactor* 50 g/plant + half RDF- NPK 100g :100g :125g/plant increases the tree height of Papaya fruit at flowering and harvesting stage from other treatment and control (Singh *et al.,* 2013). Maximum plant height (5.79 m) of Mango fruit was in treatment of ½ 1000: 500: 1000g NPK/tree/year+ 50 kg FYM + *Azospirillum* (250 g) + Potassium mobiliser (100 g) whereas lowest (4.80 m) was in control (1000: 500: 1000 g NPK/tree/year) (Mukhim *et al*., 2017). Application of *Azotobactor* + AM + PSB + vermicompost gives maximum number of leaves (54.30), plant height (20.26 cm) of Strawberry Fruit, whereas other growth parameters were noted minimum in control (Singh *et al.,* 2015). Plants grown under treatment of *Azospirillium* 250g + FYM 50kg + 500:250:250g NPK/ tree showed maximum plant height (6.73 m) of Mango fruit compared to the control (1000:500:500g NPK/tree) (Hasan *et al.,* 2015). Number of days (7.00) held for germination was recorded minimum which is beneficial under the treatment of *Trichoderma harzianum* + Castor cake + A.M fungi which is on par with (castor cake + A.M. fungi) (7.67) whereas more number of days (10.33) taken for germination under control (Devi *et al.,* 2019).

Combination of *Azospirillium* + PSB 20 g per plant, produced the highest pseudo stem height of Banana (245.33 cm) closely followed by *Azotobactor* + PSB, which was significantly superior over control and alone application whereas maximum no. of functional leaves was counted by the application of *Azospirillium* + PSB 20g per plant followed by Azotobactor with PSB; while the minimum value was counted under control (Kumar *et al.,* 2013). The highest germination (86.11%) of Aonla fruit was recorded with regular potting mixture + cocopeat + VAM (20g/polybag) media treatment. The reason for highest seed germination may be due to the influence of cocopeat, by encouraging the media to acquire good chemical and physical properties by increasing the porosity of the medium and decreasing compactness. Vesicular *Arbuscular mycorrhiza* fungi attributed for creating favorable conditions such as, optimum moisture retention, temperature, secretions of vitamins, growth promoting substances and water absorption (Chiranjeevi *et al.,* 2018). The result was observed that treatment of Azotobactor 10 ml per tree + (AM) *Arbuscular mycorrhiza* 10 ml per tree + N and P concentration of 75% increases the tree height of Washington Navel orange trees (Mohamed and Massoud, 2017). The height of plant (10.92%) of Aonla fruits were observed maximum by the treatment containing 100% N + *Azotobactor* whereas plants treated with control gives very lowest plant height (5.70%) from the other treatments (Kour *et al.,* 2019). The result was observed that maximum percentage (8.93 %) of plant height of Guava cultivar 'L-49'comes under the treatment of PSB 50 g + Vermicompost 7.5 kg which was superior over control and other treatments. This might be due to the concept that PSB and Vermicompost plays an important role in enhancing the physical conditions and increase soil organic matter (Verma *et al.,* 2019a). The height (129.30 cm) of Dragon Fruit plant were noted maximum in the treatment of NPK75% + *Azotobactor* + FYM +PSB while control (Water spray) give very low plant height (76.13 cm) as against to the other treatments (Verma *et al.,* 2019b). The tree height of ber fruit obtained maximum in the treatment of 100% NPK + PSB + FYM (Farmyard manure) +*Azotobactor* closely associated with 75% NPK + PSB + FYM (Farmyard manure) + *Azotobactor* from the other treatments and control (Singh and Singh, 2009).

2. Stem Girth: The maximum increase in stem girth (4.16cm) of Sweet Orange was evaluated under the treatment of 80ml *Azotobactor* + 80ml PSB + 50kg FYM + RDF (800:400:400g NPK), whereas the minimum increase was observed in control (RDF 800:400:400g NPK + 50kg FYM) (Jugnake *et al.,* 2017). Application of 50g *Azotobactor* + 50g PSB + 250g VAM + FYM + 50% RDF (200:160:200 NPK) gives maximum stem girth (81.34cm) in banana (Patil and Shinde, 2013). The treatment containing *Azotobactor* 50 g + VAM 20 g + PSB 50 g + 50% N through vermicompost + 50% RDF increases the scion and rootstock girth of Custard Apple as against other treatments and control (Sharma and Bhatnagar, 2014). The maximum girth of shoot (2.06 cm) of Sapota fruit is reported in treatment of (100% RDF-1000: 500: 500 g NPK + 200g Azospirillum+200g PSB / Plant) followed by treatment of *Azospirillum* 200g + PSB 200g + 75% RDF-750:375:375 g NPK/ plant which is (1.88 cm) (Maskar *et al.,* 2018). Combination of *Azospirillium* + PSB 20 g per plant, produced the highest stem girth of Banana (63.00 cm) closely followed by *Azotobactor* with PSB, which was significantly superior over control and alone application (Kumar *et al.,* 2013). A treatment of *Azotobactor* 150g/plant + PSM 100 g/ plant + 50% Inorganic fertilizer gave maximum stem girth (79.32 cm) of Mango followed by ½ dose of NPK at 1000g:500g:1000g g/plant/year + Vermicompost 2.5 kg/ plant/year which was (70.47 cm) (Dutta *et al.,* 2016). The maximum percentage increase in rootstock girth (11.69%), scion girth (12.67%) and the number of shoots per plant (68.98%) of Mango plants in a treatment (*Azotobactor* 50 g + PSB 50 g + 3 kg Vermicompost) and was high in comparison to other treatments like in a (*Azotobactor* 50 g + PSB 25 g + 3 kg Vermicompost) and in a (*Azotobacter* 25 g + PSB 50 g + 3 kg Vermicompost) and control (Poonia *et al.,* 2018). The maximum overall percentage increase in rootstock girth (7.67%) and scion girth (7.88%) of Guava fruit was found in treatment of (Vermicompost 7.5 kg + PSB 50 g) and found very high when it compared to other treatments and control (RDF) which was (3.77%) and (3.41%) respectively (Verma *et al.,* 2019a).

3. Fruit Yield: The fruit yield is more of Eureka lemon trees with treatments of *Azospirillum* 25gm/tree + 75% NPK/tree + 27.5kg FYM/year and *Azotobactor* 25gm/ tree + *Azospirillum* 25g/tree + 75% NPK/tree + *Bacillus circulans* 25gm/tree + 27.5kg FYM/year and *Bacillus circulans* 25gm/tree + *Azospirillum* 25g/tree + *Azotobactor* 25gm/tree + 55kg FYM/year + 50% NPK/ tree in both seasons (summer and spring), whereas the lowest fruit yield were obtained with the treatment of 50% NPK/tree + 55kg FYM/year + 100% NPK control (1000g:250g:500g/tree/year) and 50% NPK/tree + *Bacillus circulans* 25gm/tree + 55kg FYM/year during the both seasons (summer & spring) (Ennab and H.A., 2016). The maximum yield *i.e.* 112.75 kg/tree of Nagpur mandarin fruit was evaluated under a treatment of VAM 500 gm/plant + 100% recommended dose of fertilizer + *Azospirillum* 100 gm/plant + PSB 100 gm/plant closely followed by a treatment of Azospirillum 100 g/plant + 100% RDF+ VAM+ PSB which were *i.e.* 99.01kg per tree yield. From control, yield of fruit increases in the range of 36 & 19 percent respectively (Hadole *et al.,* 2015). Application of *Azospirillum* 25 g/plant + PSB 25 g/plant + 10 kg FYM + 100% recommended dose of NPK/plant were beneficial to the fruit yield of banana and also for good income which was closely followed by the treatment of 50% NPK from inorganic & bio-fertilizers and 50% N, P and K through organic (*i.e.* FYM + Green manure) (Bhalerao *et al*., 2009). The highest average

yield (107.36kg) and marketable yield (105.46kg) of Sweet Oranges fruits was evaluated under a treatment of 80ml *Azotobacter* + 80ml PSB + 50kg FYM + RDF (800:400:400g NPK) while the lower average yield (86.66 kg) and marketable yield (81.63 kg) was recorded in the control RDF (8+ 250g VAM + FYM + 50% RDF (200:160:200g NPK) (Patil and Shinde, 2013). 00:400:400g NPK + 50kg FYM) (Jugnake *et al.,* 2017). The yield parameters *i.e.* bunch weight of banana (19.31 kg/tree) and (85.50 t/ha) were evaluated by the application of 50g *Azotobacter* + 50g PSB. The yield of Guava Fruit was evaluated maximum in plants which were treated with the application of 250g *Azotobacter* + 250g PSB+ 50kg FYM + (487.5g + 243.75g + 281.25g NPK)/plant in comparison to control and other treatments (Barne *et al*., 2011).

Fruit yield (46.18 kg/plant) of Papaya fruit was found to be increased significantly along the application of (*Azotobacter* + PSB + 100% NPK+ FYM) followed by (*Azospirillum* +100% NPK+PSB +FYM), (*Azotobacter* + 50%NPK + PSB + FYM) and (*Azospirillum* + 50%NPK + PSB + FYM) which was (45.40 kg/plant), (44.20 kg/plant), (44.08 kg/plant) respectively as against to control (37.10 kg/plant). It may be because of the proper combination of bio-fertilizers + chemical fertilizers + organic manures (Srivastava *et al.,* 2014). The maximum yield per tree (53.33 kg) of Sapota fruit was reported in treatment of (100% RDF-1000:500:500 g NPK + 200g Azospirillum+200g PSB /Plant) followed by treatment of (75% RDF-750:375:375 g NPK + 200g Azospirillum+200g PSB / Plant) which was (51.92 kg) (Maskar *et al.,* 2018). The results evaluated that the yield (48.23 kg /tree) of Guava Fruit influenced significantly and maximum when treated along with the treatment of PSB 100 gm per tree + *Azospirillum* 100 gm per tree + cowdung slurry @ 10 litre per tree + 75% recommended dose of fertilizers (RDF) followed by fruit yield (46.20kg/tree) having treatment of 25% N, P and K per tree + 75% RDF mixed with cowdung slurry 10 litre per tree, whereas lowest yield (26.58kg/tree) were seen under control 100% RDF-NPK (600gm:300gm :300gm/tree) (Chandra *et al.,* 2016). Maximum fruit yield (21.74kg/tree) of Guava fruit was recorded with treatment of RDF 100 % + Vermicompost + *Azotobacter* + PSB followed by all the treatments comprising with RDF 100% + FYM, RDF 100% + Vermicompost, RDF 100% + FYM + *Azotobacter* + PSB, RDF 100% + *Azotobacter* + PSB whose fruit yield was (20.41kg/tree), (20.62kg/tree), (21.11kg/tree), (20.89kg/tree) respectively whereas minimum fruit yield (13.38kg/tree) was observed with control (Sharma *et al.,* 2018).

Maximum fruit yield/tree (23.36 kg) of Mango fruit was noted in the application of treatment containing 75% RDF + *Azotobacter* 250 g + 20 kg Vermicompost + 250 g PSB/ plant followed by 75% RDF + 250 g *Azotobacter* + 40 kg Vermicompost + PSB 250g (22.93 kg) and 100% RDF + Vermicompost 40kg (21.43 kg) whereas lowest fruit yield were observed in control (Singh *et al.,* 2016). Applications of PSB 2.5 g/m^2 + *Azotobacter* 50 g/plant + half RDF-NPK 100g:100g: 125g/plant give the maximum fruit yield/ha *i.e.* 259.97 ton and marketable fruit yield/plot (299 kg) of Papaya fruit in comparison of the other treatment and control (Singh *et al.,* 2013). It has been showed that maximum number of fruits (230.31/ tree) of Mango fruit harvested was in ½ 1000 : 500 : 1000 g NPK/tree/year + 50 kg FYM + 5 kg Vermicompost + Potassium mobiliser (100 g) whereas the minimum fruits (176.71 per tree) was observed under control 1000 : 500 : 1000 g NPK/tree/year & also recorded the maximum fruit yield (60.22 kg/tree) was in ½ 1000 : 500 : 1000 g NPK/tree/year + 50 kg FYM + 5 kg Vermicompost + Potassium mobiliser (100 g) and the lowest (39.27 kg/tree) in treatment of 1000 : 500 : 1000 g NPK/tree/year + Organic mulching (10 cm thick) (Mukhim *et al.,* 2017). Maximum production of Strawberry fruit (311.26gm/plant) were evaluated with *Azotobacter* + *Arbuscular mycorrhizae* + Vermicompost + PSB while found lowest production (*i.e.* 136.59gm/plant) seen under control (Singh *et al.,* 2015). High cumulative yield of Mango fruit (58.56 kg/tree) was obtained in 250g *Azospirillium* + 50kg FYM + 500:250:250g NPK/tree followed by fruit yield (49.97 kg/ tree) in 250g *Azotobacter* + 50kg FYM + 500:250:250g NPK/tree, whereas significantly lower value (28.02 kg/ tree) was seen under control 1000:500:500g NPK/tree (Hasan *et al.,* 2015). The highest yield was found by the application of *Azotobacter* (250g) + PSB (250g) + Vermicompost (30kg) + GA3 (40ppm) closely followed by the application of *Azotobacter* (250g) + PSB (250g) + Vermicompost (30kg) + NAA (40ppm) from other treatments and control which may be because of the combination of Growth regulators + Vermicompost + Bio-fertilizers (Tomar and Pandey, 2015).

The treatment containing Vesicular *Arbuscular mycorrhizae* (VAM) 12kg/ha + *Azotobacter* 10kg/ha was found to be beneficial over other treatments and control (No treatment applied). This treatment recorded highest number of fruit yield (37.59t/ha.) or (417.73 g/ plant) of Strawberry Fruit (Singh and Saravanan, 2012). Bio-fertilizer (PSM 100 g/plant + *Azotobacter* 150g/plant) + 50% Inorganic fertilizer gave maximum fruit yield (57.20 kg/plant) of Mango followed by bio-fertilizer alone

(*Azotobactor* 150g/plant + PSM 100 g/plant) which was (54.12 kg/plant) (Dutta *et al.,* 2016). The maximum number of banana fingers was observed with *Azospirillium* + PSB 20g per plant followed by *Azotobactor* + PSB 20g per plant from other treatments and control (Kumar *et al.,* 2013). Plants treated with *Azotobactor* + *Azospirillum* + VAM exhibited maximum fruit yield (6.95 t/ha) of Guava fruit followed by a treatment of VAM + *Azotobacter* (6.17 t/ha) while minimum fruit yield comes under control (5.42 t/ha) (Dutta *et al.,* 2014). The number of Sweet orange fruits (*i.e.* 42/plant) were noted maximum with RDF NPK (240gm/ plant, 120gm/plant, 120gm/plant + Boron 2gm/plant + Zinc 10gm/plant + Sulphur 30gm/plant + mustard oilcake 1kilogram + cow-dung 10 kilogram which is near to the two treatments containing RDF + Poultry manure 10 kilogram + cow-dung 10 kilogram (*i.e.* 39/plant) and RDF + Mustard oil cake 2 kilogram + cow-dung 15 kilogram (*i.e.* 37/plant) ; while RDF alone gives the lowest number of fruits (*i.e.* 21/plant). Application of Mustard oilcake + poultry manure + cow-dung (Organic manures) normally released the nitrogen very slowly, rapidly through decomposition and take longer time (Tittarelli and Canali, 2002) which might not effect the sweet orange plants and their vegetative growth under the different treatments (Islam *et al.,* 2017).

With the maximum dose of treatment containing 500gmN, 300gmP, 300gmK (per tree/year) gave the maximum yield (*i.e.*76.3kg/tree) of Jackfruit tree whereas from this treatment benefit cost ratio (BCR) comes low which is (1.13), in contrary to it treatment containing the lowest dose of 200gmN, 100gmP, 100gmK (per tree/year) provides the highest benefit cost ratio (*i.e.*2.00). The 2nd maximum yield (*i.e.*56.3kg/tree) of Jackfruit tree comes with the organic manures containing 4 kilogram mustard cake + 4 kilogram Vermicompost + 20 kilogram Cow-dung per tree/year produced along with high 2.17 BCR and good quality fruits (Ghosh and Laishram, 2018). The yield (132.75q/ha.) of strawberry fruit was noted maximum with organic manures & Bio-fertilizers (oil cake + wood ash + Poultry manure + PSB + *Azotobactor*) as against to other treatments and control (Nazir *et al.,* 2012). The strawberry fruit yield in the variety 'Sweet Charlie' was obtained maximum with bio-fertilizers and combination of PGR (100 ppm GA3 + *Azospirillum* + *Azotobactor* + 60 kg N/ha (Singh and Singh, 2006) and it was noted that treated plant with NAA increases the juice content of strawberry fruit (Kumar *et al*., 2012). While it was noted that in the same variety *i.e.* 'Sweet Charlie' of strawberry the fruit yield (144.77gm/plant) was maximum by the application of Poultry Manure 50% + Vermicompost 50% + *Azotobactor* which is closely near to the application of FYM 50% +Vermicompost 50% +*Azotobactor* and yield was (126.74 gm/ plant), in contrary to it, the lowest fruit yield (67.14gm/plant) was seen under control (Soni *et al.,* 2018). In the Strawberry variety of 'Chandler' it was noted that highest yield of fruit (290.56gm/plant) comes with the treatment of PSB + Vermicompost + *Azotobactor* and very less fruit yield (143.99gm/plant) was observed under control (Pal *et al.,* 2019). The Strawberry Fruit yield (19.87 t/ha) in the variety 'Camarosa' produces maximum yield in the treatment of PSB 2gm/plant +75% RDF + topdressing of 25% K + *Azospirillium* 2gm/plant closely followed by PSB 2gm/plant +75% RDF + topdressing of 25% K + *Azotobactor* 2gm/plant (*i.e.* 17.41t/ha) as against to the control (treated with distilled water) (which was 12.40t/ ha) (Kumar *et al.,* 2019). The result was evaluated by the application of PSB 100gm/tree + FYM 26kg/tree/ year + potash mobilizers100 gm/tree + Azotobactor100 gm/tree gives the maximum Guava fruit yield (*i.e.*114 kg/plant) and it was seen that plant treated with no treatment *i.e.* control gives very low fruit yield (18kg/ plant) (Devi *et al.,* 2012). The highest yield (52.14 kg/ tree) of Plum fruit was noted by the application of the treatment containing 12.5% nitrogen obtained by FYM + 12.5% nitrogen from Vermicompost + 75% of N + PSB + *Azotobactor* and very low yield (38.63 kg/tree) seen under the treatment of 50% nitrogen from FYM + 50% of N (Kamatyanatti *et al.,* 2019). The result was noted that the yield (29.85 kg/tree) of Apricot fruit under the application of treatment containing 50%NPK + bio-fertilizer 60gm/tree + 12.5% cow urine + Vermicompost 30 kg/tree produces maximum as against to control and other treatments (Singh *et al.,* 2010).

4. Fruit Weight And Size: Application of vermicompost + vermiculite + sand + soil + coco-peat (1:1:1:1:1) along with the treatment of *Azotobactor* increases the stem diameter (3.35 mm) of seedling of acid lime after the sowing of 150 days. While in medium soil the diameter of stem (2.18 mm) was less in the absence of *Azotobactor* (Yadav *et al.,* 2012). Bio-fertilizer (*Azotobactor* 150g/plant + PSM 100 g/plant) + 50% Inorganic fertilizer maximize the fruit weight (285.15 g) of Mango followed by bio-fertilizer alone (*Azotobacter* 150g/plant + PSM 100 g/plant) which was (270.40g) (Dutta *et al.,* 2016). The fruit weight (149.98 g/fruit) of Nagpur mandarin is increased by the treatment of VAM 500 gm/plant + *Azospirillum* 100 gm/plant +100% RDF +PSB 100 gm/plant in comparison to control. The fruit diameter is also exhibited with similar trend (Hadole *et al.,* 2015). Application of 250 g *Azospirillum* + 250 g PSB +850:425:1000 NPK+ 100 gm borax + 100 gm $ZnSO_4$ (Zinc Sulphate) /tree/year + Vermicompost gives maximum weight (*i.e.* 273.20gm) of Mango from other treatments and control (Hasan *et al.,* 2013). The results revealed that the fruit diameter (7.46 cm) of Guava Fruit influenced significantly and maximum when treated along

with the treatment of PSB 100 gm per tree +*Azospirillum* 100 gm per tree + cowdung slurry @ 10 litre per tree + 75% recommended dose of fertilizers (RDF) followed by having treatment of 25% NPK/tree + 75% RDF (recommended dose of fertilizers) mixed with the 10 lt/ tree cowdung slurry whereas lowest diameter of fruit seen under control (100% RDF-NPK 600gm : 300gm : 300gm/ tree) (Chandra *et al.,* 2016). The weight (137g) of Guava fruit was maximum by treatment of RDF 100% + Vermicompost + *Azotobactor* +PSB followed by all the treatments comprising with RDF 100 % + FYM, RDF 100% + Vermicompost, RDF 100% + FYM + *Azotobactor* + PSB, RDF 100% + *Azotobactor* + PSB whose fruit weight was (133.5g), (134.2g), (135.9g), (134.4g) respectively, whereas minimum fruit weight (112.7g) was observed with control (Sharma *et al.,* 2018).

Applications of PSB 2.5 g/m^2 + *Azotobactor* 50 g/ plant + half RDF-NPK 100g:100g:125g/plant gives the highest fruit weight (1670g) of Papaya fruit from the control and other treatment (Singh *et al.,* 2013). The highest fruit weight (261.48 g) was in treatment of ½ 1000 : 500 : 1000 g NPK/tree/year + 50 kg FYM + 5 kg Vermicompost + Potassium mobiliser (100 g) and the lowest (211.57 g) was in treatment of 1000:500:1000g NPK/tree/year + Organic mulching (10 cm thick) (Mukhim *et al.,* 2017). The maximum weight of bunch was produced with *Azospirillium* + PSB 20g per plant followed by *Azotobactor* + PSB 20g per plant whereas the lesser yield was recorded with control because biological nitrogen fixation depends upon the available form of phosphorus (Kumar *et al.,* 2013). The fruit weight and size of Guava fruit was evaluated maximum in plants which are treated with (250g *Azotobactor* + 50kg FYM + 487.5g + 243.75g + 281.25g NPK + 250g PSB/plant) from other treatments and control (Barne *et al*., 2011). Fruit weight (0.952 kg) of Papaya fruit was found to be increased significantly along with the treatment of (*Azotobactor* + PSB + 100% NPK + FYM) nearly similar by (*Azospirillum* + PSB + 100% NPK + FYM), (*Azotobactor* + 50%NPK + FYM + PSB) and (*Azospirillum* + PSB + FYM + 50% NPK) which was (0.946 kg), (0.940 kg), (0.928 kg) respectively as against to control (0.837 kg). It may be because of the proper combination of organic manures, chemical fertilizers and bio-fertilizers (Srivastava *et al.,* 2014). Highest fruit diameter (7.91 cm), pulp weight (211.61 g) of Guava fruit were recorded in (*Azospirillum* + PSB + 10 kg Vermicompost + 100% N + 100% P_2O_5) as against to control (5.89 cm) fruit diameter (Binepal *et al.,* 2013). Plants treated with *Azotobactor* + VAM + *Azospirillum* exhibited maximum weight (132.4 g) of Guava fruit closely followed by the treatment *Azotobacter* + VAM (125.4 g) while control recorded minimum fruit weight (105.1 g) (Dutta *et al.,* 2014).

Conclusion

From the above study the result is concluded that application of bio-fertilizers with the combination of FYM, compost or other organic manures improves the growth, yield and quality parameters instead of using bio-fertilizers alone or using chemical fertilizers or pesticides. Significant improvement in yield, growth, quality and also high Benefit Cost Ratio (BCR) was recorded in different-different fruit crops with different-different treatments of bio-fertilizers. It has been noted that if chemical fertilizers used alone there is no much benefit to the fruit crop, maybe it can increase the yield but on the other hand fruit quality is very poor and it has hazard effects on the health of the soil. Further, the bio-fertilizers have various benefits like they are eco-friendly, organic in nature and have no bad effects on the health and properties of soil. Therefore it is recommended that farmers should use bio-fertilizers instead of using in excess amount/quantity of chemical fertilizers, especially urea. Because of their low cost & increasing the grower's income, keeping a view in mind, there is a need to explore the potential of bio-fertilizers in fruit crop production.

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