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Integrated Nutrient Management in Okra [*Abelmoschus esculentus* (L.) Moench] using Bio-fertilizers

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ABSTRACT: Okra is a summer season vegetable crop, grown for its tender pods. For the environment friendly and sustainable cultivation of okra, the replacement of chemical fertilizers with the appropriate amount of bio-fertlizers may prove useful. In order to investigate the effect of various combination of chemical and bio-fertilizers on the growth and yield of okra, a field experiment was conducted at the experimental farm of Faculty of Agricultural Sciences, DAV University, Jalandhar during the summer season of 2019. The field experiment was laid out in randomized block design with three replications and ten treatments, comprising of chemical and bio-fertilizers *viz*. T_1 control, T_2 [Recommended dose of fertilizers (RDF) of *Azosprillium* spp. + 50% N + 100% P and K], T_3 (50% *Azosprillium* spp. + 75% N + 100% P and K), T_4 (*Azotobacter* spp. + 50% N + 100% P and K), T_5 (50% *Azotobacter* spp. + 75% N + 100% P and K), T_6 [50% Phosphorous solubilizing bacteria (PSB) + 50% P + 100% N and K], T_7 (PSB + 75% P + 100% N and K), T_8 (50% PSB + 50% *Azotobacter* + 50% P + 100% N and K), T_9 (50% PSB + 50% *Azosprillium* spp. + 100% N, P and K), T_{10} (50% *Azosprillium* spp. + 50% PSB + 50% N, P and K). Different growth and yield related attributes were measured and the statistical analysis was made using analysis of variance. The result of the experiment indicated that the treatment T_8 (50% PSB + 50% *Azotobacter* spp. + 50% P + 100% N and K) was found significant concerning the minimum days to 50% germination, maximum plant height, number of leaves, number of branches per plant, number of fruit per plant, average fruit weight, fruit length, fruit diameter, fruit yield per plant, fruit yield per plot and fruit yield per hectare.The present study will help the farmers to utilize the best combination of biofertilizers for increasing the yield of okra in their fields.

Keywords: Chemical fertilizers, yield, growth parameters, phosphate solubilizing bacteria, *Azosprillium* spp., *Azotobacter* spp.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is an important annual herb and vegetable crop of the rainy season, which belongs to the family malvaceaea and is cultivated for its tender pods (Benchasri 2012; Chattopadhyay *et al*., 2011; Onyenuga, 1968). India leads the world in okra production, with 6095 thousand tonnes produced from an area of 509 thousand hectares (Anonymous, 2018a). It covers 4.57 thousand hectares area in Punjab and produces 47.65 thousand tonnes per year (Anonymous, 2018b). It requires a higher day as well as the night temperatures. It has been reported that its seeds fail to germinate in the temperature below 16ºC and the severe frost can also damage the pods (Muluken *et al*., 2016).

Okra has good nutritional value and is also known as an excellent source of vitamin A, B, C, E and K as well as the minerals such as calcium, magnesium and iron *etc*. Okra is a multi-purpose crop due to various uses of the fresh leaves, buds, flowers, pods, stems and seeds (Mihretu *et al*., 2014). Okra seeds are a good source of oil and protein. Okra seeds have been used on small scale for oil production (Oyelade *et al*., 2003) as well. The alcohol extract of okra leaves reduces proteinuria and improves renal function by removing oxygen free radicals and alleviating renal tubular-interstitial diseases, and the leaves have a higher amount of protein as compared to the pod in addition to a large amount of riboflavin and folic acid (Adelusi *et al*., 2006; Liu *et al*., 2005; Kumar *et al*., 2009). Further, the okra mucilage has been used as a plasma replacement and blood volume expender. Further, it can bind with cholesterol and bile acid, which carry toxins that are dumped into the liver (Gemede *et al*., 2014). Okra is used in folk medicines in some countries as an antiulcerogenic, gastroprotective, and diuretic agent (Gurbuz *et al*., 2003). Its tender green fruits are consumed fried or cooked as a vegetables and as well as in salads, soups, and stews. Leaves of okra are further used for medicinal purposes for the treatments of many diseases like cardiovascular disorders, diabetes, digestive diseases and in some forms of cancers *etc.*, (Gemede *et al*., 2015).

To improve both the qualitative and quantitative parameters of okra, there is a need to use different fertilizers. The indiscriminate applications of inorganic fertilizers has led to a nutrient imbalance, thereby resulting in deterioration of soil health. The costs of chemical fertilizers are rising, making them unaffordable for small-scale farmers. The use of organic and inorganic fertilizers in combinations may be helpful for improving the soil conditions as well as crop yield. The application of plant nutrients through various organic sources like compost, farmyard manure, and bio-fertilizers *etc.*, are among the alternative choices for farmers for effient nutrient management in okra **(**Choudhary *et al*., 2015).

Chemical fertilizers (nitrogen and phosphorus) are considered as the major external source of essential nutrients for plant growth and development. Plants require nitrogen in large quantities for their growth and development, as it is an essential constituent of amino acids, which is the active component of protoplast, chlorophyll, proteins, and amides *etc.* It encourages vegetative growth by cell division and increases the development of stems and leaves and tends to produce succulence in okra (Sharma *et al*., 2016). Whereas, phosphorus is essential for many fundamental processes in plants like photosynthesis, respiration, and for the synthesis of nucleic acid, protein, and membrane phospholipid, *etc.*, (Dissanayaka *et al*., 2021). The phosphorus deficiency in soils can also be overcomed with the use of chemical phosphate fertilisers. Di-ammonium phosphate (DAP-46 % P_2O_5), Triple Super Phosphate (TSP-30 % P_2O_5), Single Super Phosphate (SSP-14 and 18 % P_2O_5), and Nitrophos (NP-23 % P_2O_5) are the most widely used chemical fertilisers as major sources of phosphorus (Rashid, 2005).

However, for achieving high levels of production, vegetable crop plants should be supplied with an adequate quantity of manures and/or fertilizers. Recycling of various cattle wastes and their incorporation in the soil after proper decomposition is among one of the way of improving soil health, crop yield as well as the quality. The utilization of bio-fertilizers for improving crop yield and soil health is now well established. Moreover, the biological nitrogen fixation takes place at relatively low energy input and practically at no cost. The use of phosphate solubilizing bacteria as inoculants, improves the plant phosphorus uptake and also helps in risinge crop yield. Phosphate solubilizers from the genera *viz*., *Pseudomonas*, *Bacillus*, and *Rhizobium* are mostly preffered. The formation of organic acids is considered as the primary mechanism for mineral phosphate solubilization, and acid phosphatases play a key role in this process (Rodrıiguez and Fraga 1999).

The growth promoting abilities of PSB include the ability to dissolve insoluble phosphates, fix nitrogen, produce ACC deaminase, produce siderophoreand secrete plant growth regulators like indole-3-acetic (IAA) (Emami *et al*., 2020). Further, *Azotobacter* spp. also besides providing nitrogen, can synthesizes PGRs (Plant growth regulators) like IAA and GA (Gibberllic acid). *Azospirrilium* spp. leads to increase in crop yield by improving root development and mineral uptake (Shree *et al*., 2014). Fixed forms of soil phosphates are also solubilized and mineralized by PSB. Plant growth, phosphorus solubilization, and phosphatase activities are affected by arbuscular mycorrhizal fungi (AMF), PSB, and phospho-compost (PC), which are made from phosphate-laundered sludge and organic wastes (alkaline and acidic) (El-Maaloum *et al*., 2020). *Azospirrilum* spp. fix 10-40 kg nitrogen/ha/season in many vegetable crops thereby saves 25-30% nitrogenous fertilizers, where as *Azatobacter* saves 10-20% nitrogenous fertilizers (Pathak *et al*., 2017). Among these, *Azosprillium* spp*.* as a nitrogen fixer and PSB as phosphates solubilizers have gained much importance, and there has been an encouraging response to the inoculation with *Azosprillium* and PSB. The integrated use of organic and inorganic nitrogenous fertilizers has gained attention to fulfill the farmers economic requirement as well as to manage ecological conditions on long-term basis (Chahal *et al*., 2019).

It has been observed that the sole application of bio-fertilizers or inorganic fertilizers is not able to sustain crop growth and productivity, therefore, the present investigation was carried out to study the effect of different combinations of chemical and bio-fertilizers on the growth in tearm of plant height, number of leaves per plant, and number of branches per plant, yield in term of number pf fruits per plant, fruit length and fruit width in *A. esculantus.* The present study was an attempt to study on the effect of integrated nutrient management on growth and yield of okra. Also, the objective of the study was to investigate and trace out the combination of chemical and bio-fertilizer best suited for the optimum growth and yield of okra in Jalandhar region of Punjab. Moreover, the studies of this kind also create awareness on the use of bio-fertilizers among students, researchers, agricultural extention workers and the farming community leading towards a holistic and sustainable farming goals.

MATERIALS AND METHODS

The experiment was carried out at the research farm of faculty of agricultural sciences, DAV University, Jalandhar, Punjab, India during summer seassion of the year 2019. Geographically, the research farm is located at 31º33'00 North (latitude) and 75º56'99 East (longitude) with an average altitude 230 meters. In this region the minimum and maximum temperature varies from 25ºC to 48ºC in summers (April to June), with average annual rain fall of 700 mm.

(i) Plant material: Plant material, *i.e.* okra *cv*. Arkaanamika (Agrilabhbeej Limited, Gwalior) was procured from Anil Seed Shop, Gurdaspur, Punjab. Before priming, the seeds were treated with Bavistin @ 2g/kg.

(ii) Fertilizers and Bio-fertilizers: Commercial fertilizer and biofertilizer formulations of NPK (Iffco), *Azospirillum* (syngenta), *Azotobacter* (Maharastra fertilizer india Pvt Ltd), PSB (UPL) were procured from the local market of Jalandhar, Punjab, India and tested along with the experimental formulations.

(iii) Experimental design: The experiment was laid out in Randomized Block Design (RBD) with three replications and ten treatment combinations represented in Table 1, comprising of T_1 [RDF (100:60:50 kg/ha)], T_2 (RDF of *Azosprillium* spp. + 50% N + 100% P and K fertilizers), T_3 (50% of *Azosprillium* spp.+ 75% N + 100% P and K), T_4 (RDF of *Azotobacter* spp. + 50% N +100% P and K), T_5 (50% of *Azotobacter* spp. +75% N + 100% P and K), T_6 (50% PSB + 50% P + 100% N and K), T_7 (RDF of PSB + 75% P + 100% N and K), T_8 (50% PSB + 50% *Azosprillium* spp. + 100% NPK), T_9 (PSB + 50% *Azotobacter* spp. + 50% P + 100% N and K), T_{10} (50% *Azosprillium* spp. + 50% PSB + 50% NPK). The land was prepared to tilth by repeated ploughing and harrowing. The mechanical composition of soil was *viz*., fine sand (73.2%), silt (11.2%), clay (15.6%) and chemical composition as available nitrogen (219.62 kg/ha), available phosphorous (23.10 kg/ha), available potassium (27.00 kg/ha), organic carbon (0.79%) and soil pH 8.9. The seeds of okra @15kg/hectare were manually sown in lines at a depth of 3-4 cm with a spacing of 45 cm between rows and 30 cm between plants.

Table 1: Details of all treatments.

Treatment no.	Details of the treatment
T_1	Recommended Dose of Fertilizers (RDF)
T_2	RDF of *Azosprillium* + 50% N + 100% P and K
T_3	50% *Azosprillium* + 75% N + 100% P and K
T_4	RDF of *Azotobacter* + 50% N + 100% P and K
T_5	50% *Azotobacter* + 75% N + 100% P and K
T_6	50% PSB + 50% P + 100% N and K
T_7	RDF of PSB + 75% P+100% N and K
T_8	50% PSB + 50% *Azotobacter* + 50% P + 100% N and K
T_9	50% PSB + 50% *Azosprillium* +100% N, P and K
T_{10}	50% *Azosprillium* + 50% PSB + 50% N, P and K

(iv) Inter-cultural operations: Sowing was done on 8th March, 2019 and seedlings emerged after 7-8 days of sowing. Light irrigation was given after the sowing. All other recommended inter-cultural practices (recommended package of practices, PAU Ludhiana 2019) were followed to raise the crop.

(v) Treatment with biofertilizers: The bio-fertilizers *viz*., *Azotobacter* spp., *Azosprillium* spp., and PSB were applied in the form of their commercially available formulation, through soil application near the root zone area of the plants, according to the treatment details/guidelines supplied by the manufacturer. The chemical fertilizers were applied in split doses following during cropping period. Observations with respect to growth and yield were recorded during the growth period of the crop.

(vi) Statistical analysis: The data collected was subjected to Analysis of Variance (ANOVA) in RBD with Fisher's post-hoc test to find the critical difference (CD) ammong different treatment means using SPSS software (version 15.0) to check the significant differences among treatments at $p \leq 0.05$, according to Gomez and Gomez (1984) and OPSTAT (Sheoran *et al.,* 1998).

RESULTS AND DISCUSSION

A. Effect of various combinations of chemical and bio-fertilizers on the growth of okra

The growth cherecterstics recordedin the present study *viz*., plant height, number of leaves per plant and number of branches per plant, are presented in Table 2. The application of chemical fertilizers and their different combinations with the bio-fertilizers significantly increased the plant height, number branches and leaves after 60 and 90 DAS (days after sowing), but was not-signficantly different at 30 DAS (F-test; $p \leq 0.05$). The effects of the different treatments of chemical and bio-fertilizers on the height of okra plant shows that the combination treatment T_8 (50% PSB + 50% *Azotobacter* + 50% P + 100% N and K) had maximum plant height (55.11cm), (90.26 cm) then the T_1 (39.09cm), (65.05cm) respectively on 60 and 90 DAS. The mean data pertaining to number of leaves/plant at 30, 60, 90 DAS, are presented in Table 2. Also, there was no significant differences in number of leaves at 30 DAS among the treatments, while at 60 and 90 DAS data showed a significant difference. The combination treatment T_8 (50% PSB + 50% *Azotobacter* + 50% P + 100% N and K) shows maximum number of leaves (12.53), (27.17) then the T_1 (8.50), (12.50) respectively at 60 and 90 DAS. The number of branches per plant at 30 DAS data was found to be non-significant. The number of branches per plant at 60 and 90 DAS was found maximum in T_8 (50% PSB + 50% *Azotobacter* + 50% P +100% N and K), which were found to be 2.00, 2.10, than T_1 *i.e.* 1.03 and 2.10 respectively. Therefore, a significant improvement in the above three growth parameters was recorded in okra at 60 and 90 DAS, suggesting the efficacy of incorporation of bio-fertilizers.

Table 2: Effect of various combinations of chemical and bio-fertilizers on growth of okra.

Treatments	Plant height (cm)			Number of leaves/plant			Number of branches/plant		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1	17.04	39.09	65.04	6.93	8.50	12.50	1.00	1.03	2.10
T_2	20.44	48.69	77.92	7.00	11.20	21.30	1.00	1.37	2.77
T_3	18.48	41.24	68.78	7.40	9.00	14.00	1.00	1.10	2.23
T_4	19.78	50.47	80.16	7.20	11.80	22.50	1.00	1.50	3.05
T_5	18.86	43.33	70.40	6.67	9.50	16.00	1.00	1.17	2.37
T_6	20.08	47.26	75.26	7.13	10.80	19.00	1.00	1.27	2.57
T_7	21.33	52.33	82.50	8.20	12.00	24.00	1.00	1.53	3.11
T_8	21.33	55.11	90.26	8.80	12.53	27.17	1.07	2.00	4.06
T_9	21.83	54.09	86.00	8.40	12.40	26.00	1.00	1.80	3.65
T_{10}	19.34	45.11	73.22	7.27	10.30	17.47	1.00	1.23	2.50
S.E. (m±)	**0.95**	**2.06**	**3.54**	**0.47**	**0.52**	**1.11**	**0.02**	**0.09**	**0.18**
C.D. (5%)	**N.S.**	**6.11**	**10.51**	**N.S.**	**1.54**	**3.30**	**N.S.**	**0.27**	**0.55**

Values are represented as means of three independent replicates (n = 3) for per plant height, number of leaves and number of branches; and for the comparison of means, the critical difference (CD) and S.E. (m±)were calculated (at $p \leq 0.05$).

Further, the bio-fertilizers have also been reported to increase the growth of *Hibiscus sabdariffa* (Hassan, 2009) and cruciferous vegetables (Zaki *et al*., 2012), besides okra. In okra, the maximum plant height, number of branches and number of leaves, and minimum days to the first flower were recorded with *Azotobacter* and PSB (Manivannan and Singh, 2004). It has been suggested that the increases in vegetative growth of *Hibiscus sabdariffa* (L.) and broccoli may be due to increase in the soil microbial flora, which occurs as a cause of bio-fertilization (Hassan, 2009; Zaki *et al.*, 2012).

The microbes present in the inoculants produce organic acids, which act as a powerful chelator and make phosphorous available to the plants (Randhawa, 1962; Majanbu, 1986). Moreover, *Azotobacter* may increase the concentration of beneficial soil micro-organisms and the plant nutrients availability in soil (Hamidi *et al.*, 2006).

B. Effect of various treatments on yield and yield related attributes of okra

The yield and yield related attributes were recorded in the present study (*viz*., number of fruits/plant, fruit length, fruit breadth, average fruit weight, fruit yield per plant, fruit yield per plot and fruit yield per hectare) are presented in Table 3. The present study has indicated that the number of fruits/plant, fruit length, fruit breadth, average fruit weight, fruit yield per plant (g/plant), fruit yield per plot (kg/plot), and fruit yield per hectare (q/ha) were recorded maximum in T_8 (50 % PSB + 50 % *Azotobacter* + 50 % P + 100 % N and K) as 12.33, 8.60 cm, 15.47 mm, 13.57 g, 167.47 g, 11.27 kg, and 125.36 q respectively. The best improvement in the parameters was noticed due to the treatment T_8 (50% PSB + 50% *Azotobacter* + 50 % P + 100% N and K).

Table 3: Effect of various treatments on yield and yield related attributes of okra.

Treatments	No. of fruits per plant	Fruit length (cm)	Fruit breadth (mm)	Average fruit weight (g)	Fruit yield/plant (g/plant)	Fruit yield/plot (kg/plot)	Fruit yield/ha (q/ha)
T_1	7.50	7.10	12.78	10.60	79.52	7.48	83.15
T_2	9.45	7.95	14.31	11.20	105.86	9.77	108.68
T_3	7.73	7.54	13.57	10.80	83.52	8.57	95.34
T_4	9.96	8.01	14.42	11.40	113.58	9.92	110.32
T_5	7.96	7.63	13.73	10.90	86.76	8.80	97.84
T_6	8.89	7.83	14.09	11.17	99.27	9.49	105.51
T_7	10.65	8.16	14.68	11.50	122.42	10.35	115.07
T_8	12.33	8.60	15.47	13.57	167.47	11.27	125.36
T_9	11.34	8.17	14.70	13.00	147.35	11.10	123.40
T_{10}	8.61	7.65	13.77	11.00	94.75	9.02	100.33
S.E. (m±)	**0.24**	**0.20**	**0.47**	**0.14**	**3.40**	**0.08**	**0.93**
C.D. (5%)	**0.70**	**0.60**	**1.38**	**0.42**	**10.12**	**0.25**	**2.78**

Values are represented as means of three independent replicates (n = 3) for fruit per plant, fruit length, fruit breadth, average fruit weight, fruit yield per plant, fruit yield per plot, fruit yield per hectare; and for the comparison of means, the critical difference (CD) and S.E. (m±) were calculated (at $p \leq 0.05$)

A simmilar increase in the yield of *Hibiscus sabdariffa* L. were previously reported by the application of the bio-fertilizers in combination wih chemical fertilizers (Youssef *et al*., 2014). Similiarly, the addition and amendments of bio-fertilzer and effective microorganism increased the yield of *Vigna radiata* (L.) by 84% (Javaid and Bajwa, 2011). In some other studies, it was found that the application of PSB increases the growth and yield of okra (Anandan, 2000; Prabhu *et al*., 2003). The combined effects of *Azospirillum* and PSB were found to increase okra yield (Gaur, 1990; Poi, 1998). The inoculation of PSB leads to the production of organic and inorganic acids (*e.g.*, citric acid, formic acid and acetic acid *etc*.), that may solubilize the insoluble form of phosphorus and increase its bio-availability (Bora *et al*., 2002).

The number of fruits/plant and average fruit weight had positive contributory factors to yield/plant in okra due to their direct effects. The application of both chemical and bio-fertilizers alone or in combination, enhances soil organic matter as well as the N, P and K content of the soil. Bio-fertilizers as the source of nutrients might have provided the base for better absorption of nutrients which accelerated the rate of photosynthesis and ultimately the yield of fruits**.** It was suggested that the increase in vegetative development, production, and yield attributing characters was primarily due to nutrient translocation and photosynthetic activity assimilation during the crop growth stage (Edward and Daniel, 1992). The bio-fertilizers improve the yield related attributes in the medicinal plants like *Salvia officinalis* and *Echinacea purpurea* (Marashi *et al*., 2015; Jokar *et al*., 2015).

Their application has resulted in better development, establishment, and availability and uptake of nutrients that have resulted in better vegetative growth. More count of bacterial and fungal population promotes the plant metabolic activity and results in better growth of morphological characters. Indigenous microorganisms promote growth through nitrogen fixation, dissolution of insoluble organophosphates or hydrolysis of aqueous organophosphates to inorganophosphate and produce IAA (Phua *et al.,* 2012). When *Azospirillum* was enriched with decomposed organic manures, its activity in okra enhanced fruit yield (Parvatham and Vijayan, (1989); Subbiah, 1991). *Azotobacter* and *Azospirillum S*pp. both are free living and endophytic bacteria (García-Fraile *et al*., 2015). These nitrogen fixing bacteria have the ability not only to fix nitrogen but also to release certain phytohormons of GA_3 and IAA nature which could stimulate plant growth, absorption of nutrients, and photosynthesis process, and improve seed germination (Umesha *et al.*, 2018). The application of *Azotobacter* spp. increased the plant height, stem base diameter, fresh and drymatter of maize seedlings (Iwuagwu *et al*., 2013). *Azotobacter* spp. were also reported to protect plants from root pathogens, boosts the activity of indigenous soil microorganisms, and increases *Zea mays* (L) crop yield (Mahato and Kafle, 2018; Vikhe, 2014).

CONCLUSION AND FUTURE SCOPE

From the present investigation, it is concluded that the treatment combination T_8 (50% PSB + 50% *Azotobacter* + 50% P + 100% N and K) was found the best in terms of growth and fruit yield of okra, followed by treatment T7 (RDF of PSB + 75 % P + 100 % N and K) in all the parameters and lowest readings was observed in treatment T1 (RDF) in terms of growth and yield and treatment T9 (50% RDF + 100% PSB) in terms of quality parameters. Our results suggest that T_8 combination of bio-fertilizer and chemical fertilizer may be utilized for vegetable production in sustainable and organic agricultural systems. Okra growth and nutrient build up were aided by the use of a bio-fertilizer containing beneficial bacteria and chemical fertilizer containing N, P and K, as well as possible changes in soil characteristics. The findings of the present study suggest that in addition to enhancing crop growth and yield, such approaches save mineral N fertilizers, which may have a favourable impact on long-term agricultural productivity in low-organic-matter soils. Furthermore, the prospect of preserving soil ecology and the ecosystem must not be overlooked. Biofertilizers along with chemical fertilizer might be utilised as value-added soil amendments to improve soil fertility and crop yield by supplementing organic and low chemical fertiliser rates. Incresased use of fertilizers will decrease our dependency on the chemical fertilizers, therby leading to the sustainable and eco-friendly cultivation of okra.

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Conflict of Interest. None.

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