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Effect of organic manures and biofertilizers on growth, yield attributing characters and yield of okra (*Abelmoschus esculentus* (L.) moench)

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Abstract
An experiment was conducted at Horticultural Research Farm, S.K.N. College of Agriculture, Jobner during Kharif season 2017. The experiment was conducted in a randomized block design with sixteen treatments, replicated thrice. The treatments include different organic manures (control, FYM @ 20 t ha^{-1}, vermicompost @ 6 t ha^{-1} and poultry manure @ 8 t ha^{-1}) with biofertilizers (control, *Azospirillum*, PSB and *Azospirillum*+ PSB). The present investigation revealed that among organic manures application of vermicompost @ 6 t ha^{-1} recorded the highest branches plant^{-1} (6.14), leaf area index (0.49), chlorophyll content of leaf (1.79), no. of fruit plant^{-1} (22.79), fruit length (13.95 cm), average fruit weight (16.19 g)and fruit yield ha^{-1} (141.48 q ha^{-1}). Among different biofertilizers combined use of *Azospirillum*+ PSB recorded significantly higher growth parameters, yield attributing characters and yields. Due to superior fruit yield responses, vermicompost and *Azospirillum*+ PSB combined application could be a very attractive fertilizer alternative particularly for annual crops with short growth cycle such as okra.

Keywords: *Azospirillum*, biofertilizers, okra, organic manures and yield attributing characters

Introduction
India is the second largest producer of vegetables in the world and contributed 14% of world production where okra occupied an area of 528 thousand ha with an annual production of 6146 thousand metric tonnes (Horticultural Statistics at a Glance, 2017) [3].
Continuous and indiscriminate use of inorganic fertilizers has resulted in decreased nutrient uptake and adversely affected the quality of vegetables (Agarwal, 2003) [1], deteriorated soil structure and decreased soil microbial population (Ganeshe *et al.*, 1998) [2]. Use of chemical fertilizers is also associated with other problems like loss of applied nutrients through leaching, volatilization and denitrification of nitrogen and fixation of phosphorus. Besides this, the prices of chemical fertilizers are increasing tremendously and due to inherent financial strains, the marginal farmers are unable to purchase such expensive inputs in time. Reduce dependence on chemical fertilizers along with soil sustainability are vital issues in modern agriculture which can only be achieved through integrated supply of organic manures and biofertilizers. Organic manures act as a store house of plant nutrients and played direct role in supplying macro and micro nutrients and indirectly in improving the physical, chemical and biological properties of soil (Palaniappan and Siddeswaran, 1994) [5]. Biofertilizers play important role in nitrogen fixation, P solubilization, secretion of growth regulators leading increased growth parameters and yield. Therefore, the field experiment was carried out to get maximum growth, pod and economic yield of okra with standardization of organic manures and biofertilizers.

Materials and Methods
A field experiment was conducted during the *kharif* season of 2017 at the Horticulture farm, S.K.N. College of Agriculture, Jobner (Rajasthan), to evaluate effect of organic manures and biofertilizers on growth parameters, yield attributing characters and yield of okra. The soil was loamy sand in texture, having slight alkaline reaction (pH 8.1), low in available nitrogen (124.74 kg ha^{-1}), medium in available phosphorus (18.84 kg ha^{-1}) and potassium (147.50 kg ha^{-1}). The experiment was consisted of four levels of organic manures (control, FYM @ 20 t ha^{-1}, vermicompost @ 6 t ha^{-1}and poultry manure @ 8 t ha^{-1}) and four levels of biofertilizers (control, *Azospirillum*, PSB and *Azospirillum* + PSB) in randomized block design.

Okra variety 'Arka Anamika' was sown at 60 cm × 45 cm row and plant to plant spacing on 28th July, 2017 with a seed rate of 15 kg ha^{-1}.
The half dose of nitrogen and full dose of phosphorus and potassium was applied as per treatments at sowing time and the remaining dose of nitrogen through urea was applied in two equal splits at 30 and 45 DAS. The observations regarding the growth characters and yield attributing characters were recorded from five representative plants from each plot. Fresh weight of okra fruits was calculated from all the pickings. The data were analyzed using analysis of variance (ANOVA) under randomized block design following the procedure as stated by Panse and Sukhatme (1985) [6].

Results and Discussion
Effect of organic manures
Application of vermicompost @ 6 t ha^{-1} to *Kharif* okra recorded significantly higher growth parameters *viz*. plant height and no. of branches per plant at 40 DAS and harvest. Further, total chlorophyll content and leaf area index were also significantly higher with application of vermicompost @ 6 t ha^{-1} closely followed by application of poultry manure @8 t ha^{-1} (Table 1). Yield attributing characters like no. of fruits per plant (22.79), fruit length (13.95 cm), fruit weight (16.19 g) and fruit yield per plant (311.46 g) were in the highest order with application of vermicompost @ 6 t ha^{-1} compared to other organic manure treatments and control. Fruit yield data indicates that application of vermicompost @6 t ha^{-1} increased fruit yield per plot (6.11 kg) and per ha (141.48 q) compared to supply of poultry manure (5.66 kg, 130.93 q), FYM (5.13 kg, 118.78 q) and control (3.51 kg, 81.29 q). Organic manure besides providing macro and micro nutrients improves soil physico-chemical and biological properties, and its slow release pattern might have supplied nutrients in optimal congruence with crop demand improving synthesis and translocation of metabolites to various reproductive structures resulting in improvement in its yield and yield attributes (Kumari *et al*., 2010) [4]. Among the organic manures vermicompost recorded the highest yield as vermicompost is nutritionally rich and also contain growth promoting substances which induce better plant growth and yield attributes.

Table 1: Effect of organic manures and biofertilizers on growth parameters of okra

Treatment	Plant height at 40 DAS	Plant height at harvest (cm)	Number of branches per plant at 40 DAS	Number of branches per plant at harvest	Total chlorophyll content(mg/g)	Leaf area index
Organic manures						
Control (M_0)	55.61	95.80	1.94	5.59	1.044	0.37
FYM @ 20 t ha^{-1}	58.34	122.93	2.29	5.82	1.448	0.41
Vermicompost @ 6 t ha^{-1}	63.97	134.10	2.80	6.14	1.795	0.49
Poultry manure @ 8 t ha^{-1}	61.62	129.34	2.60	6.01	1.602	0.46
S.Em.±	0.85	1.67	0.10	0.05	0.053	0.01
CD (P=0.05)	2.47	4.82	0.30	0.15	0.152	0.02
Bio-inoculants						
Control	56.92	113.77	2.06	5.69	1.223	0.40
Azospirillum	60.44	121.64	2.44	5.91	1.506	0.43
PSB	59.04	119.65	2.33	5.86	1.397	0.42
Azospirillum + PSB	63.14	127.12	2.80	6.10	1.764	0.48
S.Em.±	0.85	1.67	0.10	0.05	0.053	0.01
CD (P=0.05)	2.47	4.82	0.30	0.15	0.152	0.02

Effect of biofertilizers

Table 2: Effect of organic manures and biofertilizers on yield attributing characters and yield of okra

Treatment	Number of fruits plant^{-1}	Fruit length (cm)	Fruits weight (g)	Fruit yield per plant (g)	Fruit yield plot^{-1} (kg)	Fruit yield ha^{-1} (q)
Organic manures						
Control (M_0)	18.03	10.93	10.94	209.08	3.51	81.29
FYM @ 20 t ha^{-1}	19.78	12.05	13.48	255.73	5.13	118.78
Vermicompost @ 6 t ha^{-1}	22.79	13.95	16.19	311.46	6.11	141.48
Poultry manure @ 8 t ha^{-1}	21.44	13.25	15.41	290.96	5.66	130.93
S.Em.±	0.33	0.21	0.26	7.09	0.04	0.92
CD (P=0.05)	0.96	0.62	0.74	20.49	0.11	2.65
Bio-inoculants						
Control	17.71	11.04	11.86	215.81	4.06	93.99
Azospirillum	20.91	12.87	14.16	265.87	5.30	122.64
PSB	20.57	12.45	13.86	259.53	5.22	120.94
Azospirillum + PSB	22.86	13.82	16.14	326.01	5.83	134.91
S.Em.±	0.33	0.21	0.26	7.09	0.04	0.92
CD (P=0.05)	0.96	0.62	0.74	20.49	0.152	0.02

Combined application of *Azospirillum*+PSB recorded the highest plant height and no. of branches per plant at 40 DAS and at harvest. Similarly, application of *Azospirillum*+PSB significantly improved total chlorophyll content and LAI closely followed by *Azospirillum,* PSB and control. Biofertilizers containing live and latent cells of efficient strains of nitrogen fixing, phosphate solubilizing micro-organisms which augment the availability and access of nutrient leading to higher growth of the plants. Biofertilizer treatments showed significant effect on yield attributing parameters and yield of okra. Application of *Azospirillum* along with PSB recorded significantly higher yield attributing parameters *viz*. no. of fruits plant^{-1} (22.86), fruit length (13.82 cm), fruit weight (16.14 g) and fruit yield per plant (326.01 g); fruit yield per plot (5.83 kg) and fruit yield per ha (134.91 q) of okra was recorded (Table 2). The yield of okra under *Azospirillum*+PSB was 9.0 %, 11.6% and 44.0% higher over *Azospirillum*, PSB and control, respectively. The increased in fruit yield with combined application of *Azospirillum* and PSB might be due to increased availability of both N and P nutrients resulting in higher nutrient uptake with consequent increase in yield attributes and yield.

The interaction effect of organic manures and biofertilizers on fruit yield of okra (Table 3) indicated significantly superior performance of vermicompost with *Azospirillum* + PSB that produced the highest fruit yield of 154.27 q ha^{-1} but this was at par with the performance of poultry manure with *Azospirillum* + PSB by producing grain yield of 152.28 q ha^{-1}.

Table 3: Interactive effect of organic manures and biofertilizers on fruit yield of okra (q ha^{-1})

Treatments	Control	FYM	Vermicompost	Poultry manure
Control	45.89	101.89	128.00	100.18
Azospirillum	90.53	119.24	143.87	136.92
PSB	89.46	120.18	139.77	134.34
Azospirillum + PSB	99.28	133.80	154.27	152.28
SEm	1.83			
CD (0.05)	5.30			

Conclusion

The results obtained in this experiment indicated that vermicompost 6 t ha^{-1} and *Azospirillum*+ PSB enhanced the growth characteristics, yield and yield attributes of okra than other treatments. So, good yield of okra can be achieved by judicious application of organic manures and biofertilizers.

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