Residual Soil Fertility and Yield of Okra as Affected by Bio-inoculants and Bio-organicNutrient Sources

Abstract

Over the course of two kharif seasons in 2020 and 2021, a study was conducted to explore the impact of bi-inoculants(*Pseudomonas fluorescens* and *Pseudomonas lactis*)and bio-organic nutrient sources (farmyard manure, vermicompost, Beejamrit and Jeevamrit) overthe fruit yield and residual soil fertility of okra in theEntisols of Himachal Pradesh. The study was structured around seventeen treatments with different combinations of bio-inoculants, bio-formulations and nutrient sources. The investigation revealed that minimum soil pH (6.96), maximum soil organic carbon (0.76 %), available nitrogen (259.36 kg/ha) and available phosphorus (26.98 kg/ha) were obtained with treatment T_{16} [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas fluorescens*]. The maximum soil electrical conductivity (0.208 dSm^{-1}) and available potassium (174.65 kg/ha) was obtained in treatment T_{17} [Recommended Dose of Fertilizer (78N:50P:54K kg/ha)]. The highest gross income (₹2,58,760 /ha), net income (₹1,60,620 /ha) were observed in treatment T_{16} [FYM (50 q/ha) + Vermicompost (25q/ha) + Jeevamrit + *Pseudomonas fluorescens*] and the highest benefit:cost ratio (1.69) was observed in treatment T_{10} [Jeevamrit + *Pseudomonas fluorescens*]. Therefore, it is evident that using bio-organic nutrients such as farmyard manure, vermicompost, and Jeevamrit, in conjunction with the bacterium *Pseudomonas fluorescens*, is advantageous for enhancing the residual fertility of the soil and achieving sustainable cultivation of okra, while also allowing for a complete savings of 100% on fertilizers.

Keywords: Bio-inoculants;jeevamrit; okra; residual soil fertility; vermicompost

1. Introduction

Okra is a popular vegetable grown as an annual crop in tropical and subtropical regions of the world and is believed to have originated in Tropical Africa. Okra is a good source of iodine, vitamins and other vital minerals. Okra requires a substantial amount of nutrients, and without the proper nutrient levels, it may exhibit deficiency symptoms or suffer from ‘hidden hunger’ that hampers its growth (Takahashi 1981). While chemical fertilizers are widely used and favoured by farmers due to their immediate nutrient release and accessibility (Bandyopadhyay et al. 2010; Thy and Buntha 2005; Timsina 2018), they maintain high crop yields. However, the persistent and excessive application of these fertilizers has led to numerous environmental issues, such as pollution of air and water, and degradation of soil health. This includes a reduction in the soil’s natural organic carbon, increased soil salinity, and altered pH levels, all of which can ultimately impact crop yields negatively (Ali et al. 2020; Gowthamchand, Ganapathi, and Soumya 2020; Mahanta et al. 2013; Mahmood et al. 2017; Wang et al. 2008).

The overapplication of chemical fertilizers in pursuit of higher crop yields has led to detrimental effects on soil health, including micronutrient deficiencies, lack of desirable plant traits, and nutrient imbalances, all contributing to reduced agricultural output. Furthermore, the intensive use of these chemicals in farming has been linked to several environmental issues, such as increased soil salinity, accumulation of heavy metals, eutrophication of water bodies, and a rise in nitrate levels. Additionally, this practice contributes to air pollution through the release of various nitrogen oxides (NO, N2O, and NO2) due to excessive fertilization (Savci, 2012). Therefore, to cure the ills of chemical agriculture, it is necessary to minimize the application of chemical inputs by substituting them with organic nutrient sources like farmyard manure, vermicompost, jeevamrit, beejamrit and plant growth promoting rhizobacteria etc. The use of organic inputs is an eco-friendly practice where locally available inputs are used to improve soil health. These inputs work in synchronization with nature and create a balance between crop production, environment and human health (Gopinath et al., 2009).

Organic nutrient sources play an important role in the maintenance of soil physical, chemical and biological properties for sustaining better plant growth. Okra responds very well to organic manure application and is efficient in fertilizer use which is the key to its higher growth and yield. Farmyard manure is an important source of N, P and K and its addition to the soil, increases the available P and exchangeable K, Ca and Mg content (Anim et al., 2006). The utilization of decomposed farmyard manure enhances the physical structure of the soil, boosts its fertility, and contributes organic matter. Vermicompost, a type of organic fertilizer, is rich in nitrogen, phosphorus, potassium, and various micronutrients vital for plant growth (Miglani et al., 2017). The use of bio-organic materials leads to better structural integrity and reduced soil density by augmenting the organic content and achieving a balance between small and large soil pores. Organic fertilizers also enhance the soil's ability to retain moisture, its rate of water absorption, and its water conductivity (Tisdale et al., 1990; Young, 1997). Certain bio-inoculants improves seed germination, plant development, and agricultural yield by residing in the root zone and promoting growth through processes such as nitrogen fixation, nutrient solubilization (phosphorus, potassium), and siderophore production (Bhattacharya and Jha, 2012).These bio-inoculants also produce plant growth regulators like indoleacetic acid, gibberellic acid, and cytokinins, which modify the root architecture and support plant growth (Kloepper et al., 2007). Jeevamrit is one of the most important component for nutrient management.Application of jeevamrit increased the activity of microbes by solubilization and also enhanced nutrient uptake.Treatment of seed with beejamrit resulted in improvement in seed germination, seedling length and seed vigour.Organic agriculture, which incorporates these organic inputs, is a comprehensive approach and management system that benefits both the agricultural ecosystem and human health (Maritus and Vlelc, 2001). In light of these considerations, the current research was designed and executed to assess the impact of bio-inoculants (Pseudomonas fluorescens and Pseudomonas lactis) and bio-organic nutrient sources (farmyard manure, vermicompost, Beejamrit, and Jeevamrit) on the remaining soil fertility and the yield of okra fruit in the Entisols of Himachal Pradesh.

2. Materials and Methods

2.1 Experimental site

During the kharif seasons of 2020 and 2021, a field study on okra was carried out at the College of Horticulture and Forestry's research farm in Hamirpur, Himachal Pradesh, located at a latitude of 31° 41'47.6" N and a longitude of 76° 28'06.3" E, and an elevation of 650 meters above sea level. The chosen location had been free from chemical fertilizers and synthetic agrochemicals for five years prior to the start of the experiment. The Experiment comprised of 18 treatments viz., T_0 [Control], T_1 [FYM (50 q/ha) + Vermicompost (25 q/ha)], T_2 [Beejamrit + Jeevamrit], T_3 [Cow urine + Jeevamrit], T_4 [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit], T_5 [FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit], T_6 [FYM (50 q/ha) + Vermicompost (25 q/ha) + Cow urine + Jeevamrit], T_7 [FYM (50 q/ha) + Vermicompost (25 q/ha) + Pseudomonas lactis], T_8 [FYM (50 q/ha) + Vermicompost (25 q/ha) + Pseudomonas fluorescens], T_9 [Jeevamrit + Pseudomonas lactis], T_{10} [Jeevamrit + Pseudomonas fluorescens], T_{11} [FYM (100 q/ha) + Jeevamrit + Pseudomonas lactis], T_{12} [FYM (100 q/ha) + Jeevamrit + Pseudomonas fluorescens], T_{13} [Vermicompost (50 q/ha) + Jeevamrit + Pseudomonas lactis], T_{14} [Vermicompost (50 q/ha) + Jeevamrit + Pseudomonas fluorescens], T_{15} [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + Pseudomonas lactis], T_{16} [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + Pseudomonas fluorescens] and T_{17} [Recommended dose of fertilizer (78N:50P:54K kg/ha)].The soil at the farm is categorized as “non-calcic brown soils,” which show signs of profile development and belong to the Entisols soil order. The region’s climate is classified as subtropical, with average high and low temperatures of 35.9°C and 20.1°C, respectively, and an average annual rainfall of 1225 mm.Approximately 82% of the year’s total rainfall occurred during the main growing season for crops, from June to October. The soil at the research location is classified as sandy clay loam, with a composition of 58.60% sand**,** 14.60% silt, and 26.80% clay. It has a pH of 7.03, an electrical conductivity (EC) of 0.209 dS/m, and contains 0.68% organic carbon (OC). Prior to initiating the experiment, the soil was tested and found to contain 196.94 kg/ha of nitrogen, 14.67 kg/ha of phosphorus, and 156.66 kg/ha of potassium available for plant use.

2.2 Experimental design and crop management

Beejamrit: To prepare Beejamrit, begin by placing 5 kg of fresh cow dung inside a cloth and securing it with a rope. Submerge the cloth-wrapped cow dung in a bucket filled with 20 liters of water for up to 12 hours. In a separate container, mix 50 grams of lime with one liter of water and leave it overnight. The following morning, press the cow dung bundle into the same water three times in succession to extract its full potency. Incorporate a handful of soil from the field’s edge into this mixture and mix thoroughly. Finally, add 5 liters of cow urine and the lime solution, stirring well. The Beejamrit is now prepared and ready to be used according to the treatment schedule.

Jeevamrit: Jeevamrit is created by combining 10 kg of fresh cow dung**,** 10 liters of cow urine from a local breed, 1 to 2 kg of jaggery**,** 1 to 2 kg of gram flour, and a handful of fertile soil in a plastic drum. This concoction is then mixed thoroughly. For the next 5 to 7 days, it should be stirred for at least ten minutes twice daily, moving in a clockwise direction with a wooden stick. Following this, 200 liters of water are added. Once these steps are completed, the Jeevamrit is ready to be used according to the specified treatment plan.

2.3 Soil sampling and analysis

At the conclusion of a two-year experiment, soil samples were collected from the top 15 cm of the treatment plots. These samples were air-dried, sieved through a 0.2 cm mesh, and stored in cloth bags for subsequent chemical analysis. The parameters assessed included soil pH, electrical conductivity (EC), organic carbon content, and the availability of nitrogen (N), phosphorus (P), and potassium (K). Soil pH and EC were measured using a digital pH meter and an electrical conductivity meter, respectively. Organic carbon content was determined using the Chromic and Titration method proposed by Walkley and Black (1934). The Alkaline Potassium Permanganate Method was employed to determine available N, while P levels were measured using the method outlined by Olsen (Olsen et al., 1954). Available K was quantified using the Normal Neutral Ammonium Acetate Method (Merwin and Peech, 1951). The mean data values underwent analysis of variance following the approach described by Gomez and Gomez (1984) for a Randomized Complete Block Design.

2.4 Statistical and economic analysis:

The statistical analysis of soil and plant samples involved pooling the data, following the approach recommended by Gomez and Gomez (1984). This analysis aimed to determine the impact of treatments on various plant and soil parameters. Additionally, an economic assessment was conducted, considering the costs associated with different treatments and the market price of the produce. The benefit-to-cost ratio (B/C ratio) was calculated by dividing the value of marketable produce by the total cost of cultivation.

3. Results and Discussion

3.1 pH of soil

The soil pH was analyzed after harvesting of the crop, and the result tabulated in Table 1. Maximum soil pH (7.07) was obtained by the treatment T_3 Cowurine + Jeevamrit and minimum soil pH (6.96) was obtained with treatment T_{16} [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas fluorescens*]. The soil pH slightly decreased with the application of *Pseudomonas fluorescens* due to reason that it might have the ability to make insoluble phosphorus available to the plants. The solubilization effect is directly related to production of organic acids, which lower the soil pH (Kachari and Gogoi, 2020).

3.2 Electrical conductivity ofsoil (dSm^{-1})

The measurement of electrical conductivity is important, as it provides informationrelatedto theconcentration ofsolublesaltspresentin thesoil. ThedatarevealedthatthemaximumsoilEC(0.208dSm^{-1})was obtainedintreatment T17[Recommended Dose of Fertilizer (78N:50P:54K kg/ha)] after harvesting the crop. Whereas, the minimum soil EC (0.187 dSm^{-1})was foundin treatment T_{12} [FYM (100 q/ha) + Jeevamrit + *Pseudomonasfluorescens*] which was found statistically at par with treatment T_{12} [FYM (100 q/ha) + Jeevamrit + *Pseudomonas lactis*] recording 0.188 dSm^{-1} electrical conductivity of soil (Table 1).Thesefindingsarequitesimilartothefindings ofLakra et al. (2017).

3.3 SoilOrganicCarbon(%)

Themaximumsoil organic carbon(0.76 %) was recorded in treatment T_{16}[FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*] which was statistically at par with treatment T_{15} [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas lactis*] recording 0.75 % soil organic carbon. While, minimum soil organic carbon (0.61 %) was recorded in treatment T_0[Control] afterharvestingof the crop (Table 1).This may be due to an increase in microbial activities in the rhizosphere whichdecomposed organic manures andalso helped infixing the unavailableform of mineralnutrientsintoavailableformsinthesoilandimprovingorganiccarbonlevel.Similarfindings arereportedby (Brar et al. 2020; Kachari and Gogoi, 2020).

3.4 Available Nitrogen (kg/ha)

The data for available nitrogen is presented in Table 2. Maximum available nitrogen (259.36 kg/ha) was recorded in treatment T_{16}[FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*]and minimum (188.74 kg/ha) in T0 [Control] after harvesting of the crop. Overall mean for available nitrogen was 231.75 kg/ha. Fixation of atmospheric nitrogen by *Pseudomonasfluorescens* in rhizosphere and mineralization of organic manures might have increased the nitrogen and enhanced the uptake of nitrogen in plants. These results are in line with the finding of Brar et al. (2020).

3.5 Available Phosphorus (kg/ha)

Maximum available phosphorus (26.98 kg/ha) was recorded in treatment T_{16}[FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*] and minimum (14.50 kg/ha) in treatmentT0[Control]afterharvestingofthecrop (Table 2).An increase in available phosphorus in soil over the initial value, indicated that addition of organic manures and *Pseudomonasfluorescens*, increased the solubility of phosphorus by producing certain organic acids and thereby increased the available phosphorus in the soil. Similar results were recorded by (Brar *et al.,* 2020) and (Kachari and Gogoi, 2020).

3.6 Available Potassium (kg/ha)

Maximum available potassium (174.65 kg/ha) was recorded in treatment T17[Recommended Dose of Fertilizer (78N:50P:54K kg/ha)] and minimum (141.55 kg/ha) was recorded in T0 [Control] after harvesting of crop (Table 2). Greater availability of nutrients from inorganic sources might have increased available potassium in soil. Similar results were observed by Lakra et al. (2017).

3.7 EconomicsofOkra Cultivation

Data for economics of okra cultivation is presented in Table 3. Maximum gross income of (₹ 2,58,760 /ha) was obtained by treatmentT_{16} and minimum (₹ 1,00,100 /ha)was obtainedwith treatment

T_0.Maximum net income (₹ 1,60,620 /ha) was recorded by treatment T_{16}while,minimum(₹54,960 /ha)wasrecordedby treatment T_0.Highest B:C ratio (1.69) was recorded by treatment T_{10}whereas, lowest B:C ratio (0.66) was recorded bytreatmentT_4.

CONCLUSION

Treatment T_{16} was found superior for most of soil parameters Highest gross income (₹2,58,760 /ha), net income (₹1,60,620 /ha) were observed in treatment T_{16} and highest benefit:cost ratio (1.69) was observed in treatment T_{10}. Hence, it can be concluded that, application of organic manures *viz*., FYM, vermicompost and jeevamrit along with *Pseudomonasfluorescens* improves the soil available nutrients and beneficial for improving residual soil fertility, nutrient uptake, and sustainable okra production with 100% net saving of fertilizers.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Table 1. Effect of plant growth promoting rhizobacteria and organic manures on pH, EC (dSm^{-1}) and organic carbon (%) of soil

Treatment Code	Treatment Details	pH of soil	EC of soil (dSm^{-1})	Organic carbon of soil (%)
T_1	FYM (50 q/ha) + Vermicompost (25 q/ha)	7.04	0.204	0.65
T_2	Beejamrit + Jeevamrit	7.05	0.205	0.63
T_3	Cowurine + Jeevamrit	7.07	0.198	0.65
T_4	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit	7.03	0.192	0.65
T_5	FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit	7.04	0.206	0.64
T_6	FYM (50 q/ha) + Vermicompost (25 q/ha) + Cowurine + Jeevamrit	7.03	0.198	0.65
T_7	FYM (50 q/ha) + Vermicompost (25 q/ha) + *Pseudomonas lactis*	7.02	0.203	0.72
T_8	FYM (50 q/ha) + Vermicompost (25 q/ha) + *Pseudomonasfluorescens*	7.03	0.196	0.73
T_9	Jeevamrit + *Pseudomonas lactis*	7.01	0.201	0.72
T_{10}	Jeevamrit + *Pseudomonasfluorescens*	6.98	0.195	0.71
T_{11}	FYM (100 q/ha) + Jeevamrit + *Pseudomonas lactis*	7.02	0.188	0.73
T_{12}	FYM (100 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	6.97	0.187	0.74
T_{13}	Vermicompost (50 q/ha) + Jeevamrit + *Pseudomonas lactis*	7.03	0.199	0.71
T_{14}	Vermicompost (50 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	6.99	0.197	0.72
T_{15}	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas lactis*	7.01	0.202	0.75
T_{16}	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	6.96	0.201	0.76
T_{17}	Recommended dose of fertilizer (78N:50P:54K kg/ha)	7.04	0.208	0.70
	Mean	7.02	0.198	0.69
	$CD_{(0.05)}$	0.01	0.001	0.01
	SE(m)	0.01	0.002	0.00
	C.V	0.45	1.54	1.49

Table 2.Effect of plant growth promoting rhizobacteria and organic manures on available N (kg/ha), P (kg/ha) and K (kg/ha) in soil

Treatment Code	Treatment Details	Available N in soil (kg/ha)	Available P in soil (kg/ha)	Available K in soil (kg/ha)
T_0	Control	188.74	14.50	141.55
T_1	FYM (50 q/ha) + Vermicompost (25 q/ha)	208.64	17.33	148.75
T_2	Beejamrit + Jeevamrit	207.90	16.90	148.03
T_3	Cowurine + Jeevamrit	205.98	16.45	146.07
T_4	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit	206.51	17.04	149.96
T_5	FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit	235.46	19.70	163.41
T_6	FYM (50 q/ha) + Vermicompost (25 q/ha) + Cowurine + Jeevamrit	225.23	19.87	161.76
T_7	FYM (50 q/ha) + Vermicompost (25 q/ha) + *Pseudomonas lactis*	242.13	19.55	160.83
T_8	FYM (50 q/ha) + Vermicompost (25 q/ha) + *Pseudomonasfluorescens*	246.36	18.96	164.96
T_9	Jeevamrit + *Pseudomonas lactis*	213.66	22.50	150.78
T_{10}	Jeevamrit + *Pseudomonasfluorescens*	238.21	22.08	159.73
T_{11}	FYM (100 q/ha) + Jeevamrit + *Pseudomonas lactis*	248.95	21.34	162.85
T_{12}	FYM (100 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	255.54	22.52	167.29
T_{13}	Vermicompost (50 q/ha) + Jeevamrit + *Pseudomonas lactis*	236.94	21.01	163.68
T_{14}	Vermicompost (50 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	244.44	22.72	166.95
T_{15}	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas lactis*	253.44	22.07	164.84
T_{16}	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	259.36	26.98	170.27
T_{17}	Recommended dose of fertilizer (78N:50P:54K kg/ha)	254.03	23.93	174.65
	Mean	231.75	20.30	159.24
	$CD_{(0.05)}$	1.21	0.23	0.36
	SE(m)	0.42	0.08	0.12
	C.V	0.31	0.70	0.13

Table 3. Effect of plant growth promoting rhizobacteria and organic manures on economics of okra cultivation

Treatment Code	Treatment Details	Totalfruit yield(q/ha)	Totalcostof Cultivation (₹ /ha)	Gross Income (₹ /ha)	Net Income (₹ /ha)	B:C ratio
T_0	Control	50.05	45,140	1,00,100	54,960	1.21
T_1	FYM (50 q/ha) + Vermicompost (25 q/ha)	86.41	79,140	1,72,820	93,680	1.18
T_2	Beejamrit + Jeevamrit	85.00	63,945	1,70,000	1,06,055	1.65
T_3	Cowurine + Jeevamrit	82.16	63,640	1,64,320	1,00,680	1.58
T_4	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit	81.22	97,640	1,62,440	64,800	0.66
T_5	FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit	86.41	97,945	1,72,820	74,875	0.76
T_6	FYM (50 q/ha) + Vermicompost (25 q/ha) + Cowurine + Jeevamrit	83.11	97,640	1,66,220	68,580	0.70
T_7	FYM (50 q/ha) + Vermicompost (25 q/ha) + *Pseudomonas lactis*	89.25	79,540	1,78,500	98,960	1.24
T_8	FYM (50 q/ha) + Vermicompost (25 q/ha) + *Pseudomonasfluorescens*	93.97	79,640	1,87,940	1,08,300	1.35
T_9	Jeevamrit + *Pseudomonas lactis*	85.94	64,040	1,71,880	1,07,840	1.68
T_{10}	Jeevamrit + *Pseudomonasfluorescens*	86.41	64,140	1,72,820	1,08,680	1.69
T_{11}	FYM (100 q/ha) + Jeevamrit + *Pseudomonas lactis*	89.72	82,040	1,79,440	97,400	1.18
T_{12}	FYM (100 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	103.41	82,140	2,06,820	1,24,680	1.51
T_{13}	Vermicompost (50 q/ha) + Jeevamrit + *Pseudomonas lactis*	96.33	1,14,040	1,92,660	78,620	0.68
T_{14}	Vermicompost (50 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	103.88	1,14,140	2,07,760	93,620	0.82
T_{15}	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas lactis*	127.02	98,040	2,54,040	1,56,000	1.59
T_{16}	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*	129.38	98,140	2,58,760	1,60,620	1.63
T_{17}	Recommended dose of fertilizer (78N:50P:54K kg/ha)	94.91	71,051	1,89,820	1,18,769	1.67

References

Ali N, Khan MN,Ashraf M, Izaz S, Saeed HR, Abdullah M, Ahmad N, Akram HM, and Farooq M. Influence of different organic manures and their combinations on productivity and quality of bread wheat. Journal of Soil Science and Plant Nutrition.2020; 20:1949–1960.

Anim JO, Blay ET and Frempong ME.Effects of organic manure on okra production. Journal of Applied Horticulture 2006; 8:155-158.

Bandyopadhyay KK, Misra AK, Ghosh PK and Hati KM. Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean. Soil Tillage Research. 2010; 110:115–125.

BhattacharyaPN and Jha DK. Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. World Journal of Microbiology and Biotechnolology. 2012; 28:1327–1350.

Brar PS, Kaushal R, Bhardwaj G and Sharma U. Yield and fruit quality response of PGPR, bulky and folk liquid manures on okra.Journalof Pharmacognosyand Phytochemistry. 2020; 9:1385-1390.

GowthamchandNJ, Ganapathi E and Soumya TM. Effect of bulky manures and fermented liquid organics on growth, yield, nutrient uptake, and economics of French bean(*Phaseolus vulgaris* L.) under rainfed conditions. International Journal of Agriculture, Environment and Biotechnology.2020;13:51–58.

Gomez KA and Gomez AA. 1984. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley & Sons Inc. New York. 427p.

Gopinath KA, Saha S, Mina BL, Pande H, Kumar N, Srivastva AK and Gupta HS. Yieldpotentialofgardenpea(*Pisumsativum*L.)andsoilpropertiesunder organicandintegratednutrientmanagementsystems. Archivesof Agronomy and SoilScience. 2009; 55:157-167.

Kachari M and Gogoi S.Influence of organic manure and bioagents on growth, yield and quality of okra. International Research Journal of Pure & Applied Chemistry. 2020; 21:79-88.

Kloepper JW, Gutierrez EA andMclnroy JA. Photoperiod regulates elicitation of growth promotion butnot induced resistance by plant growth-promotingrhizobacteria. Canadian Journal of Microbiology. 2007; 53:159–167.

Lakra R, Swarop N and Thomas T. Effect of different levels of NPK and vermicompost on physico-chemical properties of soil, growth and yield of okra (*Abelmoschus esculentus* L.) var. Rohini.International Journal of Current Microbiology and Applied Sciences. 2017; 6:1398-1406.

MahantaD, Bhattacharya R, Gopinath KA, Tuti MD, Jeevanandan K, Chandrashekara C, Arunkumar R,Mina BL and Pandey BM. Influence of farmyard manure application and mineral fertilization on yield sustainability, carbon sequestration potential, and soil property of garden pea–French bean cropping system in the Indian Himalayas. Scientia Horticulturae. 2013; 164:414–427.

Mahmood F, Khan I, Ashraf U, Shahzad T, Hussain S, Shahid M, Abid M, and Ullah S. Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. Journal of Soil Science and Plant Nutrition. 2017; 17:22–32.

Maritus CHT andVlelc PLG. The management of organic matter in tropical soils: Nutrients cycling.Agro Ecosystems. 2001; 61:1-16.

MerwinHDandPeech M.Exchangeabilityofsoilpotassiuminthesand,siltand clayfractionasinfluencedbythenatureandcomplementaryexchangeablecations.Soil ScienceAmericanProceedings.1951;15:125-128.

Miglani A,Gandhi N, Singh N and Kaur J. Influence of different organic manures on the growth and yield of okra. International Journal of Advance Research in Science and Engineering. 2017; 6:886-892.

Olsen SR, Cole CU, Wattannabe F, andSandean DA. Estimation of available phosphorous in soil by extraction with sodium bicarbonate. (No. 939). 1954. Washington, DC: US Department of Agriculture.

Savci, S.Investigation of effect of chemical fertilizers on environment. Apcbee Procedia. 2012; 1:287-292.

Subbiah BV and Asija GL. The rapid procedure for the estimation of the available nitrogen in soils. Current Science. 1956; 25:259–260.

Takahashi, K. 1981. Physiological disorders in Chinese cabbage. Taiwan: AVRDC.

Thy S and Buntha P. Evaluation of fertilizer of fresh solid manure, composted manure, or biodigester effluent for growing Chinese cabbage (*Brassica pekinensis*). Livestock Research for Rural Development. 2005; 17:149–154.

TimsinaJ. Can organic sources of nutrients increase crop yields to meet global food demand. Agronomy. 2018; 8:214.

Tisdale SL, Nelson WL and Beaton JW. Soil Fertility and fertilizers. Macmillan Publishing Company, New York, 1990;369-75 pp.

Walkley A, and Black TA. Experimentation of vegetative method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science. 1934; 37:38–39.

WangZ, Li HSX and Malhi S. Effects of fertilization and other agronomic measures on nutritional quality of crops. Journal of the Science of Food and Agriculture. 2008; 88:7–23.

Young, A. 1997. Agroforestry for soil management. CAB International Wallingford Oxan OX10 8DE, UK, 98-100pp.