

# Original Research Article

## **Residual Soil Fertility and Yield of Okra as Affected by Bio-inoculants and Bio-organic Nutrient Sources**

### **Abstract**

A two-year experiment was undertaken during kharif seasons of the year 2020 and 2021 to investigate the effect of bio-inoculants (*Pseudomonas fluorescens* and *Pseudomonas lactis*) and bio-organic nutrient sources (farmyard manure, vermicompost, Beejamrit and Jeevamrit) on residual soil fertility and fruit yield of okra in Entisols of Himachal Pradesh. The experiment consisted of seventeen treatments with varying 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<sub>16</sub> [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas fluorescens*]. The maximum soil electrical conductivity (0.208 dSm<sup>-1</sup>) and available potassium (174.65 kg/ha) were obtained in treatment T<sub>17</sub> [Recommended Dose of Fertilizer (78N:50P:54K kg/ha)]. Highest gross income (₹2,58,760 /ha), net income (₹1,60,620 /ha) were observed in treatment T<sub>16</sub> [FYM (50 q/ha) + Vermicompost (25q/ha) + Jeevamrit + *Pseudomonas fluorescens*] and highest benefit:cost ratio (1.69) was observed in treatment T<sub>10</sub> [Jeevamrit + *Pseudomonas fluorescens*]. Hence, it can be concluded that, application of bio-organic nutrient sources viz., FYM, vermicompost and jeevamrit along with *Pseudomonas fluorescens* is beneficial for improving residual soil fertility and sustainable okra production with 100% net saving of 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 be originated in Tropical Africa. Okra is a good source of iodine, vitamins and other vital minerals. Okra is a heavy feeder of plant nutrients and appropriate quantities of nutrients are essential for their growth and development otherwise physiological deficiency symptoms can occur and hidden hunger can arrest the plant development (Takahashi 1981). The use of chemical inputs undoubtedly helps in maintaining crop productivity at the optimal level. Their popularity among farmers is well recorded because of their easy availability and rapid release of nutrients to the plants (Bandyopadhyay et al. 2010; Thy and Buntha 2005; Timsina 2018). The enduring and injudicious use of chemical fertilizers has contributed to innumerable forms of environmental hazards, including air and water pollution, and soil quality via means of diminishing natural soil organic carbon content, increasing salinity, and disturbing local pH, finally affecting the crop productivity (Ali et al. 2020; Gowthamchand, Ganapathi, and Soumya 2020; Mahanta et al. 2013; Mahmood et al. 2017; Wang et al. 2008).

Excessive use of chemical fertilizers to obtain high yield has resulted in hazards to the soil, deficiency of micronutrients, non-development of good plant characters, nutrient imbalance and ultimately resulting in the poor crop yield. Heavy use of chemical inputs in agriculture results into various

problems like soil salinity, heavy metal accumulation, water eutrophication and accumulation of nitrate. It also causes air pollution by nitrogen oxides (NO, N<sub>2</sub>O, NO<sub>2</sub>) emission through heavy fertilization (Savci, 2012). Therefore, in order to cure ills of chemical agriculture, it is necessary to minimize the application of chemical inputs by substituting 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 balance between crop production, environment and human health (Gopinath et al., 2009).

Organic nutrient sources play an important role in maintenance of soil physical, chemical and biological properties for sustaining better growth of plants. Okra responds very well to organic manure application and is an 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). Application of well-rotten FYM improves soil structure, increases soil fertility and adds humus to the soil. Vermicompost is an organic manure containing adequate quantities of N, P, K and several micronutrients essential for plant growth (Miglani et al., 2017). Application of bio-organic sources leads to improve structural stability, lower bulk density of the soil by increasing both the organic fractioning of the soil and a balance between fine and coarse pores. Organic manures also improve moisture retention, water infiltration rate and the hydraulic conductivity of soil (Tisdale et al., 1990 and Young, 1997). A number of bio-inoculants enhance emergence of seed, plant growth and improve crop production, these resides in the rhizosphere of plants, increase growth by direct and indirect mechanisms like nitrogen fixation, solubilization of nutrients (P, K) and siderophore production (Bhattacharya and Jha, 2012). Plant growth regulators like IAA, gibberellic acid, and cytokinins are produced by bio-inoculants and they amend the root structure; therefore, prop up plant development (Kloepper et al., 2007). Organic farming by using organic amendments is a holistic approach and production management system that helps in improving the agro-ecosystem and human health (Maritus and Vlelc, 2001). Considering the above facts, the present study was planned and carried out to investigate the effect of bio-inoculants (*Pseudomonas fluorescens* and *Pseudomonas lactis*) and bio-organic nutrient sources (farmyard manure, vermicompost, Beejamrit and Jeevamrit) on residual soil fertility and fruit yield of okra in Entisols of Himachal Pradesh.

## **2. Materials and Methods**

### **2.1 Experimental site**

A field experiment was conducted on the okra crop during *kharif* season of the year 2020 and 2021 (pooled) at the research farm of the College of Horticulture and Forestry, Hamirpur, Himachal Pradesh (latitude 31° 41'47.6" N, longitude 76° 28'06.3"E, 650 m above mean sea level). The selected site was not treated with chemical fertilizers or any other synthetic agrochemicals for 5 years before the initiation of the experiment. The soil of the experimental farm has been classified as "non-calcic brown soils" that manifest profile development and are placed in soil order Entisols. The climate of the

study area is subtropical. The mean maximum and minimum air temperatures were 35.9°C and 20.1°C and the mean annual rainfall was 1225 mm, respectively. About 82% of the annual rainfall was received during the crop growing season (June to October). The soil of experimental site belongs to textural class: sandy clay loam (sand: 58.60%, silt: 14.60%, clay: 26.80%) with 7.03 pH, 0.209 dS m<sup>-1</sup> electrical conductivity (EC), and 0.68% organic carbon (OC) content. The values of plant-available nitrogen, phosphorus, and potassium contents in the soil before the start of the experiment were found to be 196.94, 14.67 and 156.66 kg ha<sup>-1</sup>, respectively.

## **2.2 Experimental design and crop management**

**Beejamrit:** Beejamrit was prepared using 5 kg fresh cow dung in cloth & tie it with rope. Arrange to dip this cow dung in the bucket containing 20 litres of water upto 12 hours. In other pot, add 50 gm of lime in one litre of water, let it stable for night. Next morning, squeeze the bundle of cow dung in same water thrice continuously, so that all essence of cow dung will get accumulated in it. Add handful of soil from bund of field in that water and stir well. Lastly add 5 litres of cow urine & lime water and stir well. Beejamrit is ready for application as per the treatment plan.

**Jeevamrit:** Jeevamrit was prepared using 10 kg of fresh cow dung, 10 liters (L) of cow urine of an indigenous cow, 1– 2 kg of jaggery, 1–2 kg of gram flour, and a handful of fertile soil. All these ingredients were poured into a plastic container and thoroughly mixed. The mixture needs to be stirred with the help of a wooden stick for a minimum of ten minutes in a clockwise direction twice a day for 5–7 consecutive days. Then 200 L of water was added to it. After that jeevamrit preparation was ready for application as per the treatment plan.

## **2.3 Soil sampling and analysis**

Treatment-wise composite surface (0.00–0.15 m) soil samples were collected at the end of the two-year experiment. The samples were shade dried and sieved through a 0.2 cm sieve, and stored in cloth bags for chemical analysis of parameters such as soil pH, electrical conductivity, organic carbon and for available nitrogen, available phosphorous and available potassium. The pH and EC of soil samples were measured using a digital pH meter and an electrical conductivity meter, respectively. Organic carbon content of the samples was determined using the Chromic and Titration method proposed by Walkley and Black (1934). The Alkaline Potassium Permanganate Method was used to determine available N (Subbiahand Asija, 1956), P was measured by the method given by Olsen (Olsen *et al.*, 1954) and K was measured by Normal Neutral Ammonium Acetate Method (Merwinand Peech, 1951). Mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for Randomized Complete Block Design.

## **2.4 Statistical and economic analysis:**

The data on the analysis of soil and plant samples were (pooled) analyzed statistically as suggested by Gomez and Gomez (1984) to find out the magnitude of treatment effect on various plant and soil

parameters. Economic analysis was based on the prevailing cost of input/ operations of different treatments and the price of produce. The benefit: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<sub>3</sub> Cowurine + Jeevamrit and minimum soil pH (6.96) was obtained with treatment T<sub>16</sub> [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 of soil (dSm<sup>-1</sup>)**

The measurement of electrical conductivity is important, as it provides information related to concentration of soluble salts present in the soil. The data revealed that the maximum soil EC (0.208 dSm<sup>-1</sup>) was obtained in treatment T<sub>17</sub> [Recommended Dose of Fertilizer (78N:50P:54K kg/ha)] after harvesting of crop. Whereas, the minimum soil EC (0.187 dSm<sup>-1</sup>) was found in treatment T<sub>12</sub> [FYM (100 q/ha) + Jeevamrit + *Pseudomonas fluorescens*] which was found statistically at par with treatment T<sub>12</sub> [FYM (100 q/ha) + Jeevamrit + *Pseudomonas lactis*] recording 0.188 dSm<sup>-1</sup> electrical conductivity of soil (Table 1). These findings are quite similar with the finding of Lakra et al. (2017).

#### **3.3 Soil Organic Carbon (%)**

The maximum soil organic carbon (0.76 %) was recorded in treatment T<sub>16</sub> [FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonas fluorescens*] which was statistically at par with treatment T<sub>15</sub> [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<sub>0</sub> [Control] after harvesting of the crop (Table 1). This may be due to an increase in microbial activities in the rhizosphere which decomposed organic manures and also helped in fixing the unavailable form of mineral nutrients into available forms in the soil and improving organic carbon level. Similar findings are reported by (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<sub>16</sub>[FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*] and minimum (188.74 kg/ha) in T<sub>0</sub> [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<sub>16</sub>[FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + *Pseudomonasfluorescens*] and minimum (14.50 kg/ha) in treatment T<sub>0</sub>[Control] after harvesting of the crop (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 T<sub>17</sub>[Recommended Dose of Fertilizer (78N:50P:54K kg/ha)] and minimum (141.55 kg/ha) was recorded in T<sub>0</sub> [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 Economics of Okra Cultivation**

Data for economics of okra cultivation is presented in Table 3. Maximum gross income of (₹ 2,58,760 /ha) was obtained by treatment T<sub>16</sub> and minimum (₹ 1,00,100 /ha) was obtained with treatment T<sub>0</sub>. Maximum net income (₹ 1,60,620 /ha) was recorded by treatment T<sub>16</sub> while, minimum (₹ 54,960 /ha) was recorded by treatment T<sub>0</sub>. Highest B:C ratio (1.69) was recorded by treatment T<sub>10</sub> whereas, lowest B:C ratio (0.66) was recorded by treatment T<sub>4</sub>.

## **CONCLUSION**

Treatment T<sub>16</sub> 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<sub>16</sub> and highest benefit:cost ratio (1.69) was observed in treatment T<sub>10</sub>. 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.

UNDER PEER REVIEW

**Table 1. Effect of plant growth promoting rhizobacteria and organic manures on pH, EC (dSm<sup>-1</sup>) and organic carbon (%) of soil**

Treatment Code	Treatment Details	pH of soil	EC of soil (dSm <sup>-1</sup> )	Organic carbon of soil (%)
T <sub>1</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha)	7.04	0.204	0.65
T <sub>2</sub>	Beejamrit + Jeevamrit	7.05	0.205	0.63
T <sub>3</sub>	Cowurine + Jeevamrit	7.07	0.198	0.65
T <sub>4</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit	7.03	0.192	0.65
T <sub>5</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit	7.04	0.206	0.64
T <sub>6</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Cowurine + Jeevamrit	7.03	0.198	0.65
T <sub>7</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + <i>Pseudomonas lactis</i>	7.02	0.203	0.72
T <sub>8</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + <i>Pseudomonasfluorescens</i>	7.03	0.196	0.73
T <sub>9</sub>	Jeevamrit + <i>Pseudomonas lactis</i>	7.01	0.201	0.72
T <sub>10</sub>	Jeevamrit + <i>Pseudomonasfluorescens</i>	6.98	0.195	0.71
T <sub>11</sub>	FYM (100 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	7.02	0.188	0.73
T <sub>12</sub>	FYM (100 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	6.97	0.187	0.74
T <sub>13</sub>	Vermicompost (50 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	7.03	0.199	0.71
T <sub>14</sub>	Vermicompost (50 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	6.99	0.197	0.72
T <sub>15</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	7.01	0.202	0.75
T <sub>16</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	6.96	0.201	0.76
T <sub>17</sub>	Recommended dose of fertilizer (78N:50P:54K kg/ha)	7.04	0.208	0.70
	Mean	7.02	0.198	0.69
	CD <sub>(0.05)</sub>	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 <sub>0</sub>	Control	188.74	14.50	141.55
T <sub>1</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha)	208.64	17.33	148.75
T <sub>2</sub>	Beejamrit + Jeevamrit	207.90	16.90	148.03
T <sub>3</sub>	Cowurine + Jeevamrit	205.98	16.45	146.07
T <sub>4</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit	206.51	17.04	149.96
T <sub>5</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit	235.46	19.70	163.41
T <sub>6</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Cowurine + Jeevamrit	225.23	19.87	161.76
T <sub>7</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + <i>Pseudomonas lactis</i>	242.13	19.55	160.83
T <sub>8</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + <i>Pseudomonasfluorescens</i>	246.36	18.96	164.96
T <sub>9</sub>	Jeevamrit + <i>Pseudomonas lactis</i>	213.66	22.50	150.78
T <sub>10</sub>	Jeevamrit + <i>Pseudomonasfluorescens</i>	238.21	22.08	159.73
T <sub>11</sub>	FYM (100 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	248.95	21.34	162.85
T <sub>12</sub>	FYM (100 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	255.54	22.52	167.29
T <sub>13</sub>	Vermicompost (50 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	236.94	21.01	163.68
T <sub>14</sub>	Vermicompost (50 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	244.44	22.72	166.95
T <sub>15</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	253.44	22.07	164.84
T <sub>16</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	259.36	26.98	170.27
T <sub>17</sub>	Recommended dose of fertilizer (78N:50P:54K kg/ha)	254.03	23.93	174.65
	Mean	231.75	20.30	159.24
	CD <sub>(0.05)</sub>	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 <sub>0</sub>	Control	50.05	45,140	1,00,100	54,960	1.21
T <sub>1</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha)	86.41	79,140	1,72,820	93,680	1.18
T <sub>2</sub>	Beejamrit + Jeevamrit	85.00	63,945	1,70,000	1,06,055	1.65
T <sub>3</sub>	Cowurine + Jeevamrit	82.16	63,640	1,64,320	1,00,680	1.58
T <sub>4</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit	81.22	97,640	1,62,440	64,800	0.66
T <sub>5</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Beejamrit + Jeevamrit	86.41	97,945	1,72,820	74,875	0.76
T <sub>6</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Cowurine + Jeevamrit	83.11	97,640	1,66,220	68,580	0.70
T <sub>7</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + <i>Pseudomonas lactis</i>	89.25	79,540	1,78,500	98,960	1.24
T <sub>8</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + <i>Pseudomonasfluorescens</i>	93.97	79,640	1,87,940	1,08,300	1.35
T <sub>9</sub>	Jeevamrit + <i>Pseudomonas lactis</i>	85.94	64,040	1,71,880	1,07,840	1.68
T <sub>10</sub>	Jeevamrit + <i>Pseudomonasfluorescens</i>	86.41	64,140	1,72,820	1,08,680	1.69
T <sub>11</sub>	FYM (100 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	89.72	82,040	1,79,440	97,400	1.18
T <sub>12</sub>	FYM (100 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	103.41	82,140	2,06,820	1,24,680	1.51
T <sub>13</sub>	Vermicompost (50 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	96.33	1,14,040	1,92,660	78,620	0.68
T <sub>14</sub>	Vermicompost (50 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	103.88	1,14,140	2,07,760	93,620	0.82
T <sub>15</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + <i>Pseudomonas lactis</i>	127.02	98,040	2,54,040	1,56,000	1.59
T <sub>16</sub>	FYM (50 q/ha) + Vermicompost (25 q/ha) + Jeevamrit + <i>Pseudomonasfluorescens</i>	129.38	98,140	2,58,760	1,60,620	1.63
T <sub>17</sub>	Recommended dose of fertilizer (78N:50P:54K kg/ha)	94.91	71,051	1,89,820	1,18,769	1.67

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