A Comparative Study of the Effects of Biofertilizers and Chemical Fertilizers on Soil Physical and Biological Properties under Chickpea Crop.(*Cicer arietinum* L.)

Abstract

This study investigated the impact of solid biofertilizers and organic ameliorants on soil biological properties and chickpea yield. The experiment was conducted at the Instructional Farm of ANDUA&T Ayodhya India during the Rabi season of 2020-2021. The experiment was comprised of eleven treatments, control (T_1); (T_2); chemical fertilizers 100% RDF; (T_3)chemical fertilizers 50% RDF (T_4); FYM +Jeevamrit (T_5); Agro residue Mulch + FYM + Jeevamrit (T_6); *Rhizobium* +PSB (T_7); FYM + Jeevamrit + *Rhizobium* +PSB (T_8); T3 + FYM + Jeevamrit T9; T3 + T5, T10; T3 + T6, T11; T3 + T4 + T6, were replicated thrice in RBD. Chickpea variety KPG-59 was taken as test crop. The results showed that the application of solid biofertilizers and organic ameliorants with chemical fertilizer significantly improved some soil biological properties. The treatments that included FYM and Rhizobium + PSB showed the greatest improvements in soil health as well as chickpea yield. Soil properties as EC, OC and OM were found to be significant while physical property were non-significant.

Keyword; Jeevamrit, Organic Manure, FYM, Agro Residue Mulch, Rhizobium, PSB

1. Introduction

Leguminous crops are considered as an important component of all types of farming systems in agriculture-based countries of the world and these considered an important food source for human and animal nutrition [1]. Chickpea (*Cicer arietinum* L.) ranks third among leguminous crops after pea (*Pisumsativum* L.) and beans (*Phaseolus vulgaris* L.) and it is an important legume crop in many countries and considered a functional food source, mostly due to its high protein content (17–31% protein) [2]. Nutritionally, chickpea is a good source of proteins and can serve as an alternative to meat [3].

Nitrogen plays important role in synthesis of chlorophyll, amino acids and other organic compounds of physiological significance in plant system. Rhizobium plays an important role in increasing the availability of nitrogen to the plants and helps in boosting the production through nitrogen fixation. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 130 kg N ha-1 from atmosphere. It leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility [4]. Being a leguminous crop, chickpea has very high requirement of phosphorus (P). The P plays important roles in different processes of metabolism such as macromolecular biosynthesis, energy transfer, respiration and photosynthesis reaction [5]. Therefore, an optimum amount of P is required by the plants from early seedling stage to maturity [6]. The P is the 2nd most important macronutrient, and mineral P fertilizers and manures are commonly used as main sources of P for agricultural crops. The P deficiency is considered as a main hurdle in crop production, affecting soil fertility and productivity throughout the world [7].

Phosphate solubilizing microbes (PSMs) are increasingly used to convert inaccessible phosphate in the soil into a readily available form for plants [8]. These beneficial microbes enhance phosphate availability and uptake by plants from phosphate-deficient soils. They have also proven effective in achieving sustainability of farms by reducing the use of chemical fertilizers to some extent [9, 10]. Phosphate-solubilizing bacteria (PSB) are a type of beneficial microbes that can help to improve soil fertility by solubilizing phosphorus (P). P is an essential nutrient for plant growth, but it can be difficult for plants to access in some soils[11,12]. PSB solubilize P by excreting organic acids and enzymes, which break down the insoluble P compounds in the soil and make them more available to plants. In addition to solubilizing P, PSB also have other benefits for soil health. They can help to improve soil porosity, which allows water and air to move more freely through the soil[13].They can also help to add essential nutrients to the soil, and they can help to suppress the growth of harmful soilborne pathogens.

Organic amendments are another type of alternative to synthetic chemical fertilizers. Organic amendments, such as compost, animal manure, and crop residues, can improve soil fertility by adding organic matter to the soil. Organic matter helps to improve soil structure, water retention, and nutrient-holding capacity. It also provides a source of food for beneficial microbes, such as PSB[14]. Sources of organic amendments can increase the P availability from the existing P directly; however, indirect methods include release of organic acids [15], blockage of P fixation sites [16], and speeding up of microbial activity [17]. The use of processed manure (PM) to enhance crop production and to sustain soil fertility is being highly recommended [18, 19]. Application of rock phosphate (RP) in combination with other amendments such as manures and PSB in basic soils is considered as a better option for normal plants growth [20]. In order to develop an eco-friendly approach to nourish soils, it is better to substitute the chemical fertilizers usage with different combinations of natural or organic sources along with microbial inoculations to enhance their efficiency within agriculture cropping systems.

2. Methods and Materials

An experiment was conducted at the Student's instructional farm of ANDUA&T, Narendra Nagar (Kumarganj) Ayodhya (U.P.), during the Rabi season of 2021-2022. The experimental site is located in the sub-tropical climate zone of the Indo-gangetic plains, and has alluvial soil. The site is at 26° 47′ N latitude, 82° 12′ E longitude, and an altitude of 113 meters above mean sea level. The climate of the experimental site is sub-humid sub-tropical, with hot summers and fairly cool winters. The area receives monsoon type of rainfall with an average of 1200 mm annually. Nearly 90% of the total rainfall is received from the south-west monsoon during the months of July to September (Kharif season). The average potential evapo-transpiration (PET) of the area is 1450 mm annually, showing a moisture deficit index (MDI) of (-) 250 mm annually. Initially, the soil (0-15 cm) had a pH 8.36, EC 0.25 ds/ m, organic carbon 1.3 (g/ha), OM 2.23 (g/kg), bulk density 1.32 mg/m^{-3}, Particle density 2.54 mg/m^{-3}, Porosity 48.03 (%) and available N, P and K 183.4, 12.79 and 220.2 kg ha^{-1} respectively. The initial values of Soil Biological Activity Parameters like Fungi - 4.8 x 10^3 (cfu/sfu per gram soil), Actinomycetes. - 6.9x 10^4 (cfu/sfu per gram soil), Bacteria-8.8 x 10^6 (cfu/sfu per gram soil) and soil enzymatic activities; Dehydrogenase (55.75 µg TPF/ g soil/h), Alk. Phosphatase (118.2 µmolpnp/g soil / h.) and soil microbial activity in terms of FDA Hydrolysis (15.6 µg fluorescein/ g soil/h.).

The experiment was laid out in randomized complete block design with 3 replications. There were ten treatments consisting of T1 (Control), T2 (Soil nutrient amendment as chemical fertilizers @ (20N: 40P:0K), T3 (Soil nutrient amendment as chemical fertilizers@ half potency (10N: 20P: 0K), T4 (Organic Inputs -I [FYM + Natural liquid manure (Jeevamrit), T5 (Organic Inputs-II [Agro residue Mulch + FYM + Natural liquid manure (Jeevamrit)]), T6 (Organic Inputs-III [Biofertilizer (Rhizobium + PSB)]), T7 (Organic Inputs-IV [Organic Inputs I (FYM +Jeevamrit) + Organic Inputs III (Rhizobium + PSB)]), T7 (Organic Inputs-IV [Organic Inputs I (FYM + Jeevamrit) + Organic Inputs III (Rhizobium + PSB)]), T8 (Soil Nutrient Amendment as Chemical Fertilizers@ half potency (10N : 20P : 0K) +Organic Inputs –I [FYM + Natural liquid manure (Jeevamrit)), T9 (Soil nutrient amendment as chemical fertilizers@ half potency (10N : 20P: 0K) +Organic Inputs-II [Agro residue Mulch + FYM + Natural liquid manure (Jeevamrit)]), T10 (Soil nutrient amendment as chemical fertilizers@ half potency (10N : 20P : 0K) +Organic Inputs-III [Biofertilizer (Rhizobium + PSB)]), T11 (Soil nutrient amendment as chemical fertilizers @ half potency (10N : 20P : 0K) +Organic Inputs-IV [Organic Inputs I (FYM + Jeevamrit) + Organic Inputs-III (Rhizobium + PSB)]). In order to soil sampling was done at before sowing of crop and harvesting of the crops, the soil samples (0-15 cm depth) was taken from each plot using single auger. The samples were air dried, crushed and gravel and other particles of size more than 2 mm were removed with the help of a sieve. Field moist soil was used for analyzing all the biological parameters. All the methods and materials of the physio-chemical and biological parameters' of soil listed in the below (Table 1). The statistical analysis of the experimental data was carried out as per the methods suggested by Gomez [21].

3. Result and discussion:-

The study mentioned was a field experiment that investigated the effects of biofertilizers and chemical fertilizers on soil physical and biological properties under chickpea crop. The experiment was conducted during the Rabi season of 2020-2021 at the Student's instructional farm of Acharya Narendra Dev University of Agriculture and Technology, Narendra Nagar (Kumarganj) Ayodhya (U.P.)

3.1 Influence of different treatments on bulk density, particle density and porosity

Bulk density is an indicator of Soil compaction. It is inversely proportional to the amount of pore space in the Soil. Particle is the density of solid particle that form the Soil. Porosity refers to the number of poresin the Soil. The study found that there was no significant difference between the different inoculations of PSB, Rhizobium and organic inputs on bulk density, particle density, and porosity. However, the mean values of bulk density exhibited a variation of 1.22-1.41 Mg m−3 and followed a decreasing trend with the incorporation of organic inputs and FYM.The application of FYM in collaboration with Jeevamrit and biofertilizers significantly lowered the bulk density in comparison to the control and other treatments. This is likely due to the enhanced buildup of organic carbon content in the soil, which leads to a higher pore space and therefore a lower bulk density.

The lower bulk density values are beneficial for soil health, as they allow for better water infiltration, gas exchange, and root growth. This is important for crop production, as it can lead to improved yields and quality [22].

The average values of soil porosity and particle density exhibited a range of 47.16 to 50.19 % and 2.43 to 2.71 Mg/m^3, respectively, where the plots which received both organic and chemical fertilization possessed the highest value (Table1). The varied response of soil porosity could be ascribed to the addition of farmyard manure, and inorganic fertilization besides biofertilizersincluding phosphorus solubilizing bacteria and Rhizobium, which communally heightened the soil's organic carbon [23, 24]. Datt*et al.* [25] illustrated an improvement regarding soil porosity in response to the introduction of farmyard manure along with inorganic and biofertilizers, accounting it for a healthier environment for root proliferation, amended soil structure apart from improved water-stable aggregates—and moisture retention capacity as an upshot of the total count of storage pores. However, maximum bulk density was observed in (T_3)

and porosity was observed in (T_{11}) and minimum values are recorded in untreated plants. Particle density has the opposite influence of these treatments because particle density is inversely proportional to the bulk density. So, minimum particle density was observed in the (T_1) and the maximum particle density was observed in (T_3) plants.

Table: 1: Effect of treatments on Bulk density, particle density and porosity of Soil at harvest

S. No.	Bulk Density (Mg/m^3)	Particle Density (Mg/m^3)	Porosity (%)
T1.	1.41	2.29	47.16
T2.	1.37	2.54	50.00
T3.	1.39	2.71	48.70
T4.	1.25	2.43	48.55
T5.	1.34	2.69	50.18
T6	1.32	2.64	50.00
T7.	1.22	2.43	49.79
T8.	1.25	2.53	50.59
T9.	1.23	2.49	50.60
T10.	1.33	2.65	49.81
T11.	1.31	2.63	50.19
SEm±	**0.02**	**0.04**	**0.01**
CD (P=0.05)	**NS**	**NS**	**NS**

3.2 Influence of different treatments on pH, EC, OC and organic carbon

The soil reaction and electrical conductivity (EC) showed significant changes under various treatments (table 2). However, the highest value of soil pH was noted under treatment T_1 and lowest under T_{11}. In addition, soil pH decreases under treatments T_9, T_{10}, T_3 and T_8 owing to the FYM, organic inputs and biofetilizers. The electrical conductivity was marked highest under T1 and T2 (0.79, 0.77 dsm^{-1}) and lowest under T_{11} (0.15 dsm^{-1}). The decline in pH of the soil with the addition of manures only, or in conjunction with synthetic fertilizers and biofertilizer, could be attributed to the formation of organic acids in the course of organic matter decomposition [26]. A slight decline in soil pH upon FYM addition has also been put forth by Chandra *et al*. [27]. These findings are in line with the observations put forward by Shah *et al*. [28].

The detail analysis of soil organic carbon and organic matter pre and post harvest of soil analysis show on table and table 2. Owing to effective application of FYM, bio-fertilizer and integrated nutrient management under has shown the significant results of soil parameters increases the soil organic carbon and organic matter 1.94 (), 2.99 () maximum found in T10, T8 respectively and minimum soil organic carbon (1.34), organic matter (2.23) T1 control due to the adding of FYM, organic fertilizer and biofertilizers influence the microbial activity of soil, increases soil organic carbon. The similar results were reported by [29, 30].

Table 2: Effect of treatments on Soil pH, EC, Organic carbon and Organic matter at harvest

S. No.	**pH**	**EC (dS/m)**	**OC**	**OM**
T1.	8.29	0.79	1.34	2.23
T2.	8.25	0.77	1.42	2.44
T3.	8.16	0.73	1.65	2.84
T4.	8.2	0.67	1.63	2.81
T5.	8.25	0.55	1.88	3.24
T6.	8.23	0.49	1.39	2.39
T7.	8.21	0.30	1.37	2.36
T8.	8.19	0.41	1.74	2.99
T9.	8.08	0.41	1.35	2.32
T10.	8.1	0.18	1.94	2.31
T11.	7.98	0.15	1.69	2.91
SEm±	**0.09**	**0.52**	**0.05**	**0.086**
CD (P=0.05)	**NS**	**1.56**	**0.15**	**0.258**

3.3 Biological properties

In the present study, incorporation of organics and biofertilizers with or without chemical fertilizers triggered a manifold increase in soil enzymes and population of fungi, bacteria and actinomycetes. Such surprising improvements in microbial status may be the reason behind augmented soil health.

3.4 Microbial count

Soil Bacteria, fungal, actinomycetes of chickpea as affected by different organic bio-inputs and chemical fertilizer practices are presented in Table No.3. Data suggested that different organic bio-inputs with chemical fertilizer significantly influenced the total no. of soil bacteria, fungal, actinomycetes of chickpea. The maximum total no. of Soil Bacteria (12.53 $x10^6$cfu g^{-1} soil) were observed under 50% RDF + Rhizobium + PSB + FYM and Jeevamrit (T11) followed by 50% RDF + Rhizobium and PSB (T10). Minimum total no. of Soil Bacteria (9.54 $x10^6$cfu g^{-1} soil) was associated with control (T1). The maximum total no. of soil actinomycetes (10.75 $x10^4$cfu g^{-1} soil) was observed under 50% RDF + Rhizobium + PSB + FYM and Jeevamrit (T11) followed by 50% RDF + Rhizobium and PSB (T10). Minimum total no. of soil actinomycetes (7.64 $x10^4$cfu g^{-1} soil) was associated with control (T1). In order to maximum total no. of soil fungi was observed under T11 (50% RDF + Rhizobium + PSB + FYM and Jeevamrit) [7.50 x 10^3sfu g^{-1} soil] followed by 50% RDF + Rhizobium and PSB. Soil microbial population under chickpea suggested a significant increase in the number of bacteria, actinomycetes and fungi due to application of different organic inputs and biofertilizers. One major reason for the above may be attributed to the mode of biofertilizer application (seed bacterization), which would have further triggered the fast multiplication of rhizobia and PSB and because of increase in rhizospheric exudates, may have boosted the number of actinomyctes and fungal population as well. Also the addition of organic inputs in the form of FYM, agroresidue mulches and Jeevamrit natural manure (with multitude of beneficial soil microflora) would have improved the soil microbial population in these respective treatments. The Increase in population of bacteria, Actinomycetes and fungi as has been reported by [31] and similar findings reported by [32], corroborate the results obtained in this study.

Table 3: Effect of treatments on soil microbial population at harvest

S. No.	**Soil Microbial Population (g^{-1} soil)**		
	Bacteria ($x10^6$cfu)	**Actino- mycetes ($x10^4$cfu)**	**Fungi ($x10^3$sfu)**
T1.	9.54	7.64	5.94
T2.	9.89	9.33	6.17
T3.	9.81	9.14	6.80
T4.	9.98	8.68	6.93
T5.	10.58	8.79	7.03
T6.	11.36	9.05	6.85
T7.	11.39	8.27	6.28
T8.	10.98	9.54	6.65
T9.	11.80	9.71	7.30
T10.	11.55	9.38	6.86
T11.	12.53	10.75	7.50
SEm ±	**0.04**	**0.06**	**0.05**
CD (P=0.05)	**0.12**	**0.17**	**0.14**

3.5 Soil enzymes:

The glance of data portrayed in table illustrates a higher activity of dehydrogenase (91.57 µg TPF/ g soil/ h) in treatment (T11) followed by (T7) and lowest activity (62.29 µg TPF/ g soil/

h) under treatment T1. All treatments exhibited significant consequences in comparison to the control. In the current study, the inclusion of legumes has been recognized for a significant increase in enzyme activities, viz. dehydrogenase, owing to it the greater nutrient retention which in turn elevates dehydrogenase activity [33]. The hasty decomposition of soil organic matter assures the delivery of nutrients, rendering them accessible to micro-organisms for protoplasm synthesis. In addition, the introduction of farmyard manure in combination with inorganic and bio-fertilizers might have encouraged the microbial activity to exploit the intrinsic soil organic carbon pools, which serve as substrates for dehydrogenase enzyme [34].

The use of different listed amendments promoted a significant increase in FDA Hydrolase (µg fluorescein g^{-1} soil hr^{-1}) activity in chickpea compared to control. FDAse activity was also found to be higher in soil amendment with FYM, organic inputs and biofertilizer. Lower values were recorded for treatment receiving mineral fertilization. It was observed that FDAse activity was related with the availability of organic carbon of soil. [35] Reported similar results for FDA hydrolase. Soil alkaline phosphatase activity was also found to be stimulated in all the treatments but was highest in T11 amendments plots. The values were significantly high compared to mineral fertilizer amended cheakpea soil both at berofore and harvesting of crop. The demand for phosphorus by plants and soil microorganisms may be responsible for stimulation in the synthesis of phosphatase enzyme [36]. Increase in phosphatase activity indicates changes in quantity and quality of phosphoryl substrate [37].

Table 4 : Effect of treatments on soil enzymes activity at harvest

S. No.	FDA Hydrolase (µg fluorescein g^{-1} soil hr^{-1})	Alk. Phosphatase (µmol p-nitrophenol g^{-1} soil h^{-1})	Dehydro- genase (µg TPF/ g soil/ h)
T1.	16.24	127.65	62.29
T2.	17.68	129.20	70.14
T3.	16.83	127.71	68.16
T4.	19.57	129.19	74.58
T5.	23.01	140.97	79.05
T6.	25.12	138.20	75.26
T7.	28.01	141.76	84.14
T8.	26.51	138.39	73.65
T9.	27.00	143.62	81.42
T10.	27.92	137.28	75.23
T11.	30.74	143.15	91.57
SEm±	**0.26**	**0.49**	**0.51**
CD (P=0.05)	**0.80**	**1.49**	**1.53**

4. Summary and Conclusion

The results of this study demonstrate that the application of chemical fertilizers at half potency in combination with organic inputs can significantly improve soil health and chickpea yield. This is a cost-effective alternative to the use of high-cost commercial fertilizers, and it can help to maintain soil fertility in the long term.

The treatments that included FYM and Rhizobium + PSB showed the greatest improvements in soil health, as evidenced by the increased biological count and enzyme activities. These treatments also resulted in significant improvements in soil properties, such as EC, OC, and OM. Overall, the results of this study suggest that the gradual increase in the percentage of organic inputs in integrated nutrient management (INM) can further improve soil health and yield. This is an important finding for farmers and policymakers, as it provides evidence that INM can be a sustainable and cost-effective way to produce food.

The study concluded that biofertilizers are a more sustainable and environmentally friendly way to improve soil physical and biological properties, compared to chemical fertilizers. Biofertilizers can also help to improve chickpea crop growth and yield.

❖ In addition to the findings mentioned above, the following are some additional conclusions that can be drawn from this study:

- The use of chemical fertilizers at half potency did not have a negative impact on chickpea yield.
- The combination of chemical fertilizers and organic inputs can be more effective than either approach alone.
- The gradual increase in the percentage of organic inputs synthetic fertilizer can further improve soil health and yield.

These conclusions have important implications for farmers and policymakers. Farmers can use INM to improve soil health and yield, while policymakers can promote INM as a way to achieve sustainable agriculture.

❖ **Here are some of the limitations of the study:**

- The study was conducted in a single location, so the results may not be generalizable to other locations.

- The study was conducted over a single growing season, so the long-term effects of biofertilizers on soil physical and biological properties are not known.

Despite these limitations, the study provides valuable insights into the potential benefits of using biofertilizers to improve soil physical and biological properties. More research is needed to confirm the findings of this study and to assess the long-term benefits of using biofertilizers.

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