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Research Article

Integrated Nutrient Management for Chick Pea Cultivation to Improve Soil Fertility

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Abstract: Declining soil fertility and nutrient imbalances are critical challenges in sustainable agriculture, particularly in chickpea cultivation. This study aimed to evaluate the effectiveness of integrated nutrient management (INM) strategies to enhance soil fertility, nutrient availability, and crop productivity. Conducted during the rabi season of 2023–2024 at Lovely Professional University, the experiment utilized six treatments in a randomized block design (RBD). These treatments combined organic, inorganic, and biofertilizers, including farmyard manure (FYM), vermicompost, and Rhizobium inoculants, with varying proportions of recommended dose fertilizers (RDF). Soil properties, including pH, electrical conductivity (EC), organic carbon (OC), and primary nutrients (N, P, K), were assessed at different growth stages. Results revealed that INM practices improved nutrient availability and maintained soil health. Treatment T6 (75% RDF + FYM + Rhizobium) demonstrated the highest nutrient retention, with nitrogen, phosphorus, and potassium levels at harvest measuring 261.67, 27.99, and 141.29 kg ha^{-1}, respectively. Organic carbon levels remained stable across treatments, while pH exhibited a slight decline, indicating controlled acidification. Electrical conductivity was highest in T6 (0.50 dS m^{-1}), reflecting effective nutrient management. The findings emphasize the potential of INM to optimize nutrient uptake, enhance crop productivity, and reduce chemical fertilizer dependency. This holistic approach ensures sustainable soil management and offers an ecologically viable solution for resource-limited farmers. Future studies should investigate the long-term implications of INM on soil biodiversity and environmental health.

Keywords: Chickpea, INM, Organic manure, Biofertilizer, Chemical fertilizers

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1. Introduction

Chick Pea (*Cicer arietinum*) primarily self-pollinates and have a limited tendency for natural cross-pollination. Their ability to fix atmospheric nitrogen makes them valuable members of the legume family, contributing significantly to soil fertility. Due to their high amino acid content, Chickpeas complement cereals by addressing amino acid deficiencies in human diets (Nene, 2006). contain approximately 26% protein, 1.3% fat, 57% carbohydrates, 2.1% minerals, and 3.2% fiber, making them nutritionally important (Singh et al., 2013). In agricultural systems, Chickpeas play a critical role in crop rotation, enhancing soil health and sustainability (Wang et al., 2012).

Declining soil nutrient levels pose significant challenges to sustainable agriculture, particularly for economically disadvantaged farmers. Rising fertilizer costs limit the use of chemical fertilizers, reducing yields. Therefore, a balanced approach involving the judicious use of biological and mineral fertilizers is necessary to maintain soil fertility (Tan et al., 2005). Relying solely on one fertilizer type is ineffective, as no single nutrient source can fully meet crop demands. Instead, a synergistic application of diverse fertilizers, including organic and inorganic types, is recommended to sustain production and quality while minimizing reliance on chemical fertilizers (Hazra, 2016).

"Integrated Nutrient Management" (INM) promotes the combined use of chemical and organic fertilizers to maintain soil fertility and ensure crops receive essential nutrients for optimal growth. This holistic approach is ecologically, socially, and economically sustainable, improving yields through the strategic application of organic, chemical, and biofertilizers (Kanala et al., 2021). INM techniques include the use of farmyard manure (FYM), compost, green manures, crop residues, chemical fertilizers, and biofertilizers, all of which contribute to crop and soil improvement (Selim, 2018). This integrated strategy emphasizes the complementary use of organic and biofertilizers with inorganic nutrients, demonstrating the complexity and effectiveness of INM. Combining biological and mineral fertilizers enhances productivity, profitability, and soil fertility (Kannan et al., 2013). A key feature of INM is its ability to integrate various fertilizer sources effectively. This ensures optimal nutrient management, uniform application of fertilizers, and improved nutrient uptake by plants, leading to higher yields without disrupting soil nutrient balance or harming the environment.

Despite their potential, average seed yields in chickpea cultivation remain below optimum levels. Chickpea productivity is particularly affected by poor nutrient management in acidic soils. To address this, biofertilizers such as *Rhizobium* and chemical fertilizers can be applied via soil or foliar methods. These approaches enhance the availability of soil nutrients and neutralize soil pH. Consequently, a study was conducted in 2021–2022 at Lovely Professional University's experimental field in Phagwara, Punjab, India, to evaluate the effectiveness of INM in terms of soil health, nutrient uptake, crop quality, and economic benefits during chickpea cultivation.

2. Materials and Methods

The study, focusing on soil science and agricultural chemistry, was conducted at the research fields of the Lovely Professional University School of Agriculture during the rabi season of 2023–2024. Soil texture analysis classified the soil as sandy clay loam. Initial chemical testing revealed that the soil contained 0.30% organic carbon, 200 kg ha^{-1} of available nitrogen, 26.77 kg ha^{-1} of available phosphorus, and 109.76 kg ha^{-1} of available potassium. The experiment was designed using a randomized block design (RBD), which included 6 treatments and 3 replications.

Table 1. Treatment details of the experiment

Symbol	Treatments
T1 (Control)	100 % RDF (N:P:K::15:30:30)
T2	75% RDF+ Vermicompost (2.5 t/ha)
T3	75% RDF+ FYM (5 t/ha)
T4	75% RDF+ Rhizobium (7.5 kg/ha)
T5	75% RDF+ Vermicompost+ Rhizobium(7.5 kg/ha)
T6	75% RDF+ FYM (5 t/ha)+ Rhizobium(7.5 kg/ha)

The experimental plots measured 5 m × 2 m, with a planting spacing of 20 cm × 30 cm. Urea was used to supply nitrogen, single super phosphate for phosphorus, and muriate of potash (MOP) for potassium. Farmyard manure (FYM) and vermicompost were evenly applied to the soil before sowing. *Rhizobium* inoculation was carried out by mixing it with molasses at a rate of 7.5 kg ha^{-1}. The chickpea variety PBG-7 was sown on November 18, 2023, under irrigated conditions and harvested on March 25, 2024. Soil and plant samples were collected at various growth stages for analysis.

Plant and seed samples were ground and digested using a di-acid mixture (HNO_3: $HClO_3$ in a 3:1 ratio). Nitrogen levels were analysed using the Kjeldahl method (Jackson, 1973). Phosphorus was tested using the yellow colour method (Jackson, 1973), and potassium was determined through the flame photometer method (Jackson, 1973). Soil pH was measured with an electronic glass electrode (Jackson, 1967), and electrical conductivity was assessed using the electrical conductivity method (Jackson, 1968). Organic carbon was tested using the rapid titration method (Walkey and Black, 1934), available nitrogen with the alkaline potassium permanganate method (Subbaiah and Asija, 1956), available phosphorus using Olsen's method (Olsen et al., 1954), and available potassium through the flame photometer method (Merwin and Peech, 1950).

3. Results and Discussion

The observations related to soil characteristics, plant nutrient attributes, and nutrient uptake were statistically analysed and tested for significance. The results from all treatments and parameters are presented in detail, supported by tables, figures, and graphs for clarity and better comprehension.

3.1 Soil pH: The soil pH across all treatments showed a slight but consistent decline from 60 days after sowing (DAS) to harvest, indicating a minor acidification over time. Despite this, the soil remained in the alkaline range, with pH values ranging from 8.27 (T1 at harvest) to 8.32 (T6 at harvest). The mean pH at harvest was 8.30 with low variability (SD = 0.02), suggesting minimal treatment impact on pH levels. Treatments such as T1 and T6 exhibited a relatively more stable trend, while others, like T5, showed higher pH fluctuations. The decline in pH could be attributed to organic matter decomposition or microbial activity, which release acids into the soil.

3.2 Electrical Conductivity (EC): The electrical conductivity of the soil increased slightly from 60 DAS to harvest across most treatments, suggesting a gradual rise in soil ionic concentrations. T6 showed the highest EC at harvest (0.50 dS m^{-1}), indicating a higher nutrient load or salt accumulation, while T1 consistently had the lowest EC (0.32 dS m^{-1} at harvest). The mean EC at harvest was 0.40 dS m^{-1} with moderate variability (SD = 0.06). These results suggest that treatments such as T5 and T6 may involve higher fertilizer inputs, potentially improving nutrient availability but also risking salt build-up in the soil over time.

3.3 Organic Carbon (OC): Organic carbon levels in the soil showed remarkable stability across all treatments and stages, with values consistently ranging between 0.32% and 0.36%. The mean OC at harvest was 0.33%, and variability was negligible (SD = 0.01), indicating that the treatments had minimal impact on organic matter content during the study period. This stability may reflect a balance between organic matter inputs (e.g., residues or amendments) and decomposition. Treatments like T5 and T6 exhibited slightly higher OC at intermediate stages, suggesting improved organic inputs or microbial activity. Soil pH, EC and organic carbon values are tabulated in Table 2.

Table 2. Physico chemical properties of soil

Treatment	pH			EC			OC		
	60 DAYS	90 DAYS	HARVEST	60 DAYS	90 DAYS	HARVEST	60 DAYS	90 DAYS	HARVEST
T1	8.53	8.38	8.27	0.29	0.30	0.32	0.34	0.35	0.32
T2	8.54	8.38	8.30	0.35	0.33	0.37	0.34	0.34	0.34
T3	8.55	8.40	8.30	0.30	0.34	0.37	0.34	0.32	0.33
T4	8.58	8.34	8.30	0.39	0.36	0.39	0.33	0.35	0.34
T5	8.60	8.48	8.31	0.44	0.39	0.45	0.32	0.36	0.34
T6	8.60	8.36c	8.32	0.48	0.40	0.50	0.33	0.35	0.33
Mean	8.57	8.40	8.30	0.38	0.35	0.40	0.33	0.35	0.33
SD	0.03	0.05	0.02	0.08	0.04	0.06	0.01	0.01	0.01

3.4 Available Nitrogen (N): Nitrogen content in the soil decreased significantly from 60 DAS to harvest, reflecting substantial nitrogen uptake by plants. Among treatments, T6 retained the highest nitrogen levels at harvest (261.67 kg ha^{-1}), while T1 had the lowest (198.62 kg ha^{-1}). The mean nitrogen level at harvest was 227.68 kg ha^{-1}, with higher variability (SD = 23.22) due to differences in treatment effects. T6's superior nitrogen availability indicates a likely higher fertilizer application or efficient nitrogen management, while T1's lower levels suggest the need for additional nitrogen supplementation.

3.5 Available Phosphorus (P): Phosphorus levels in the soil also declined over time but showed less variability compared to nitrogen. At harvest, T6 had the highest phosphorus content (27.99 kg ha^{-1}), while T1 had the lowest (18.51 kg ha^{-1}). The mean phosphorus level at harvest was 22.57 kg ha^{-1} with moderate variability (SD = 3.66). T6's higher phosphorus levels suggest effective phosphorus fertilization or reduced leaching, while T1's lower values point to limited phosphorus availability or higher plant uptake.

3.6 Available Potassium (K): Potassium levels decreased moderately from 60 DAS to harvest across all treatments, indicating gradual plant uptake and potential leaching. T6 maintained the highest potassium levels at harvest (141.29 kg ha^{-1}), while T1 had the lowest (118.77 kg ha^{-1}). The mean potassium level at harvest was 131.64 kg ha^{-1}, with low variability (SD = 8.62), suggesting a relatively uniform potassium distribution among treatments. T6's superior potassium retention highlights effective nutrient management, while T1's lower levels may necessitate better potassium supplementation strategies. Table 3 depicts the amount of N, P and K in the soils of different plots treated with integrated nutrient management (INM).

Table 3. Primary nutrient (N, P, K) content of soil

Treatment	Available Nitrogen (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	60 DAS	90 DAS	HARVEST	60 DAYS	90 DAYS	HARVEST	60 DAYS	90 DAYS	HARVEST
T_1	282.76	257.93	198.62	35.32	26.63	18.51	187.35	132.94	118.77
T_2	285.51	274.17	210.12	38.21	28.94	20.13	152.32	141.07	125.21
T_3	300.96	282.25	221.03	39.20	29.64	21.22	163.74	148.35	130.84
T_4	315.62	288.79	228.45	38.13	30.84	21.49	158.42	145.92	134.06
T_5	318.39	297.62	246.21	36.52	31.30	26.09	165.27	154.84	139.69
T_6	330.29	303.66	261.67	36.49	31.88	27.99	167.56	162.12	141.29
Mean	305.59	284.07	227.68	37.31	29.87	22.57	165.78	147.54	131.64
SD	19.08	16.58	23.22	1.44	1.92	3.66	11.90	10.24	8.62

5. Conclusions

This study highlights the effectiveness of integrated nutrient management (INM) in enhancing soil fertility and nutrient dynamics during chickpea cultivation. The combination of organic, inorganic, and biofertilizers proved to be a sustainable approach, with T6 (75% RDF + FYM + Rhizobium) demonstrating the highest nutrient retention and availability, particularly for nitrogen, phosphorus, and potassium, at harvest. The stable organic carbon levels and controlled pH variations observed across treatments indicate that INM practices maintain soil health while minimizing degradation. By integrating multiple nutrient sources, INM strategies optimize plant nutrient uptake, improve soil quality, and reduce reliance on chemical fertilizers. These findings underscore the potential of INM to achieve sustainable agricultural practices, especially for farmers with limited resources. Future studies should focus on the long-term benefits of INM, including its impact on soil biodiversity and broader environmental sustainability.

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