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Effect of Organic, Inorganic and Biofertilizers on Soil Characteristics and Potato Tuber Yield (*Solanum tuberosum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluates the impact of organic, inorganic, and biofertilizers on soil characteristics and potato tuber yield in the variety Kufri Ashoka. The experiment was conducted at the Vegetable Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, Uttar Pradesh, using treatments involving different combinations of fertilizers, including recommended doses of inorganic nutrients (RDF), farmyard manure (FYM), vermicompost, *Azotobacter*, and *Phosphobacteria*. Key findings demonstrated that RDF treatment (150:100:120 kg N:P_2O_5 ha^{-1}) produced the highest tuber yield (249.2 q ha^{-1}), significantly outperforming all other

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treatments. However, the organic treatment T4, which included compost, crop residue, biofertilizers, and FYM, also yielded a substantial 237.1 q ha^{-1}, with improvements in soil health attributes like increased organic carbon (3.6 g kg^{-1}) and reduced pH (7.92) and electrical conductivity (0.22 dSm^{-1}). Results indicated that the integration of organic and biofertilizers led to moderate yield gains compared to RDF but significantly enhanced soil properties, contributing to long-term soil health. Organic treatments promoted improved microbial activity and soil structure, essential for sustainable agriculture. This study highlights the effectiveness of integrated nutrient management, where combining organic and biofertilizers with inorganic nutrients can enhance crop yields while maintaining soil fertility and reducing the negative environmental impact associated with exclusive inorganic fertilizer use.

Keywords: FYM; vermicompost; azotobacter; phosphobacteria and yield.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of major crops contributing to the world's food security. (Karam *et al*., 2009). It is the most popular tuber crops in the world. Potato is one of the most important field corps not only to its local consumption but also to increase meeting income through its exportation among different countries in the world (Kandil *et al.,* 2011)**.** It is a highly input intensive crop, fertilization with inorganic sources of nutrients plays an important role for its higher production, but due to increased cost and detrimental effects on soil fertility and human health, supplementing the nutrients through organic sources like farmyard manure (FYM), vermicompost, mustard cake, neem cake, *etc.* and biofertilizers like Azotobacter and Phosphobacteria has become necessary to sustain production, improved food quality and to maintain soil health (Patel *et al.,* 2002)**.**

The major potato producing states are Uttar Pradesh, West Bengal, Madhya Pradesh, Bihar, Gujarat, Punjab, Haryana, Assam, Jharkhand and Chhattisgarh. Potatoes are a valuable commodity that can be processed and exported. Potatoes offer a low-cost energy source in the human diet and are rich in starch, as well as vitamins C and B, along with various minerals. (Raj *et al.*, 2020). Potatoes are a vital component of the world's food supply, providing essential nutrients and calories to millions of people (Beals *et al.,* 2019)**.** Developing nations in Asia currently account for over 46% of the world's total potato production. Ranked fourth among the world's most significant food crops, after rice, wheat, and maize, potatoes serve an essential function in global food security. India stands as the second-largest potato producer worldwide, following China. China and India emerged as the leading producers, collectively contributing approximately one-third of the global production. In India, the potato occupies a prominent position in the agricultural sector. The Ministry of Agriculture, Government of India, reported that in 2023, the country produced around 59.74 million metric tons of potatoes.

Organic material is used to prevent or improve the negative stresses effects in plants and yield decreasing. It is material to decrease soil salinity. Increase the organic matter, improve the soil structure and increase water and air permeability by root developing in soil. It is one the best used fertilizers (Kumari *et al.,* 2024; Shukla *et al.,* 2024).

Continuous Use of chemical fertilizers had increased the crop yield, but caused many environmental problems including soil, air and water pollution and finally human health hazards and making the crop productivity unsustainable (Eid *et al*., 2006)**.** The amount of organic matter in the soil influences the accessibility of micronutrients. Because they are cost-effective and environmentally friendly, employing organic matter and micronutrients offers significant benefits. It promotes long-term ecological sustainability and soil fertility, essential for successful crop. Bio-fertilizer, an organic product containing specific microorganisms, plays a crucial role in enhancing nutrient availability for crops. These microorganisms biologically transform inaccessible nutrients into formats readily accessible for plant uptake. The continuous application of heavy doses of chemical fertilizers without incorporating organic manures or bio-fertilizers has led to soil health deterioration. This includes physical and chemical degradation, reduced microbial activity, declining soil humus, and increased soil, water, and air pollution.

2. MARERIALS AND METHODS

Site Description: The experiment was conducted at Vegetable Research Farm of

Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya (UP). The Vegetable Research Farm lies on Ayodhya-Raebareli Road, about 43 km from Ayodhya district headquarter. Geographically, this region falls under sub-tropical climate and it is situated at $26^{0}47'$ N latitude, $82^{0}12'$ E longitude and at an Indo-Gangetic alluvial of eastern Uttar Pradesh in India. This region experiences an annual rainfall of approximately 110 cm, with 85 percent of it occurring during the monsoon season, which lasts from mid-June to the end of September. The experimental soil was silty loam in texture having the pH (8.10), EC (0.24 dSm^{-1}) and organic carbon (3.10 g kg^{-1}).

Variety Description: Kufri Ashoka variety was taken for experiment. Variety was developed through clonal selection from a segregating population derived from the hybrid EM/C-1021 x CP-1468. Central Potato Research Institute, Shimla, released this variety in 1996. Kufri Ashoka an early-maturing variety (70-80 days), suited for cultivation in Bihar, Haryana, Punjab, Uttar Pradesh and West Bengal the tubers of Kufri Ashoka are medium to large in size, white, oval-shaped, with moderately shallow eyes and white flesh. The plants are medium-tall, upright, moderately compact, and vigorous the stems are limited in number, medium-thick, lightly pigmented at the base, and characterized by poorly developed straight wings. Foliage is green. Leaves are intermediate having green rachis. Leaflets are ovate lanceolate, smooth glassy surface with entire margin, Flowers are light red purple. This variety has profuse flowering. The anthers are orange- yellow, well-developed, and exhibit medium pollen stain ability. Although the variety is susceptible to late blight, it manages to evade its impact due to its early maturity.

Soil Sampling and Analysis: Soil sampling done by Auger randomly from each replicated plot after, harvesting of rice crop and collect the sample in polythene bag plot wise. Samples are brought to Soil Science Lab ANDUAT Kumarganj Ayodhya for analysis. Soil texture, Bulk density, Soil pH, Electrical conductivity, Organic carbon.

3. RESULTS AND DISCUSSION

Physico-chemical properties of soil:

Soil pH: The effect of various treatment combinations on soil pH is presented in (Table 1). There were non-significantly affected by various treatment combinations. The highest value of pH (8.18) was recorded with T1 control and lowest value (7.92) was recorded with T4 (Compost (like NADEP method) + Crop residue incorporation +Biofertilizer (Azotobacter and Phosphobacteria) + Microbial culture to decompose crop Residue + FYM @ 25 t ha^{-1} However soil pH maintained or slight decreased to the initial value might be due to the formation of organic acids during the decomposition of organic manure and crop residues. Similar result has been reported by (Tiwari *et al*., 2021).

Electrical Conductivity (dSm-1)**:** The data regarding effect of various treatment combinations on electrical conductivity remained non-significant in between the treatments but there is slightly decrease from initial (0.31 dSm^{-1}) to harvest (0.25 dSm^{-1}). However, the lowest EC (0.22 dSm^{-1}) at harvest recorded with T4 (Compost (like NADEP method) + Crop residue incorporation + Biofertilizer (Azotobacter and Phosphobacteria) + Microbial culture to decompose crop Residue + FYM @ 25 t ha^{-1} and highest EC (0.25 dSm^{-1}) was recorded at harvest with T2 (RDF 150:100:120 N: P2O5: K2O). in potato have been presented in Table 1. The abrupt drop in electrical conductivity in treatments involving organic materials might be caused by the buffering effect of the organic matter, which reduces the concentration of ionic species in the solution, thereby lowering the EC. In FYM, the significant increase in microbial activity leads to the uptake of soluble salts by microorganisms for the growth of microbial cell mass leads to less EC when compared to vermicompost Similar result has been reported by (Tiwari *et al*., 2021).

Organic carbon (g kg^{-1})**:** The maximum organic carbon content was recorded with T4 (T3 + FYM @ 25 t/ha) at 3.6 g kg^{-1}, followed by T5 (T3 + vermicompost @ 7.5 t ha^{-1}) at 3.4 g kg^{-1}. The lowest organic carbon content was observed under the T1 control (3.0 g kg^{-1}). The increased organic carbon content due to use of enriched FYM can be attributed to higher contribution of biomass to the soil in the form of root, crop stubbles and residues but also to better root growth and plant residue addition by the growing crop at harvesting. It is an important source of soil organic matter and nutrients which after decomposition by the microorganisms becomes available to the plants. These results are in line with findings of (Tiwari *et al*., 2021; Verma *et al.,* 2024)**.**

Growth and Development studies:

Emergence percentage: The plant emergence percentage was significantly affected by the application of various organic and inorganic treatments. The plant emergence percentage higher in the treatment T2 (97.97 %) that was followed by T4 significantly superior to control (94.69 %). Organic and inorganic fertilizers are applied, then inorganic fertilizers have a quick effect on the plant, but when germination takes place then there is not much difference in the emergence of the plant the similar result is reported by Nagar *et al*., (2019)**.**

Plant height: The plant height was found also affected by the application of inorganic fertilizer to the crop. The highest plant height was recorded with the treatment T2 at 30 and 60 DAP (19.40 cm) and (48.50 cm) respectively, that was at par with the treatment T4 at 30 and 60 DAP (18.30 cm) and (47.10 cm) respectively. Biofertilizers increased the efficiency of nutrients in the soil and increased the plant height when applied in combination with fertilizers similar result reported by **Ram *et al*.,** (2017)**.**

Numbers of leaves: The number of leaves per hill were also significantly influenced by the application of organic, inorganic and biofertilizer. The maximum number of leaves at 30 DAP (16.90) and 60 DAP (53.65) were recorded in the treatment T2 (where the recommended dose of N 150: P2O5 100: K2O 120 is applied), statistically at par with T4 (16.20) at 30 DAP and T4 and T5 (52.90) (52.30) at 60 DAP respectively, significantly higher than the control treatment. Similar result has been reported by Sayed *et al*., (2014), Barman *et al*., (2018).

Yield attributes and tuber yield:

Tuber yield: The potato tubers yield was found to be significantly affected by the various organic and inorganic treatments. RDF (N : P : K = 150:100:120 kg ha^{-1}) recorded the highest tuber yield, which was significantly superior to all other nutrient treatments. This was followed by the treatment T4 (Compost (like NADEP method) + Crop residue incorporation +Biofertilizer (Azotobacter and Phosphobacteria) + Microbial culture to decompose crop Residue + FYM @ 25 t/ha). compared to control. The tuber yield under T2 was 5.10 % higher than T4 (Table 2)**.** The increased tuber yields due to integrated nutrient management of the above said fertilizer levels have resulted in more vegetative growth and accumulation of more photosynthates. Thus, there may be more translocation of photosynthates to sink. Hence, they have resulted in more tuber yield. Higher number of tubers per hill also contributed to significantly higher total tuber yield. The favourable effect of integrated nutrient management through both inorganic fertilizers and organic manures on increasing the tuber yield. Production was also noticed by Kumar *et al*. (2011); Sarkar *et al.,* (2017)**;** (Sati *et al.,* 2017)**;** (Kromann *et al*., 2017).

Grade wise tuber yield: The weight of tubers (q ha-^{1}) in different size categories (0-25g, 25-50g, 50-75g, and >75g) was significantly influenced by the various treatments. It was observed that under treatment T2, which involved the recommended dose of fertilizers (N 150: P2O5 100: K2O 120 kg ha $^{-1}$), significantly higher weights of tuber yield (14.10, 64.70, 76.50, and 102.90 (q ha-^{1}) were recorded at par T4 = T3 + FYM @ 25 t ha^{-1} with yields of 12.90, 62.20, 66.70, and 95.30 quintals per hectare. The control treatment, T1, produced the statistically lowest yield per hectare (9.50, 51.70, 58.20, and 65.10 q) across all size

Table 1. Effect of various organic, inorganic and biofertilizer on the soil properties.

Treatments	pH (1:2.5)	EC (dSm-1)	OC (g kg-1)
T1	8.18	0.24	3.0
T2	8.03	0.25	3.1
T3	7.98	0.23	3.3
T4	7.92	0.22	3.6
T5	7.94	0.23	3.4
T6	7.96	0.23	3.2
SEm ±	0.03	0.02	0.22
C.D at 5%	0.09	N/A	N/A

Table 2. Effect of various organic, inorganic and biofertilizer on the plant emergence (%), number of leaves hill^{-1} and plant height (cm).

Treatments	Emergence (%)	Number of leaves hill^{-1}		Plant height (cm)	
	30 DAP	30 DAP	60 DAP	30 DAP	60 DAP
T1	94.69	14.10	42.00	16.00	30.50
T2	97.97	16.90	53.65	19.40	48.50
T3	95.31	14.50	45.70	16.15	40.20
T4	97.03	16.20	52.90	18.30	47.10
T5	96.09	15.60	52.30	17.20	46.20
T6	95.31	14.75	47.00	16.40	44.00
SEm ±	1.05	0.36	1.39	0.14	1.53
C.D at 5%	NS	1.12	4.24	0.43	4.66

Table 3. Effect of various organic, inorganic and biofertilizer on the tuber yield (q ha-1) and grade wise tuber yield

Treatments	Tuber yield (q ha^{-1})	Weight of tuber (q ha-1)			
		(0-25 g)	(25-50g)	(50-75g)	(>75 g)
T1	184.50	09.50	51.70	58.20	65.10
T2	249.20	14.10	64.70	68.50	101.90
T3	194.40	10.30	53.60	60.40	70.10
T4	237.10	12.90	62.20	66.70	95.30
T5	229.50	11.50	61.80	65.00	91.20
T6	206.80	11.20	54.30	64.80	76.50
SEm ±	2.75	0.61	1.24	1.26	2.17
C.D at 5%	8.38	1.87	3.78	3.85	6.62

categories. The favourable effect of integrated nutrient management through both inorganic fertilizers and organic manures on increasing the different grades tuber production was also reported by Das *et al*., (2009); Kumar *et al*., (2017); Tiwari *et al.,* (2022); Chandra *et al.,* (2023).

4. CONCLUSION

On the basis of experimental results, it may be conducted that the application of various treatment the maximum yield and yield attributes, was found in treatment (T2) RDF (N : P : K =150:100:120 kg ha^{-1}). Although the organic manure treatments resulted in lower yields, but they improved the tubers quality and also improves the soil health parameters.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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