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Effect of nano urea and nano dap conjugated with potassium on physical and chemical properties of soil, growth and yield of okra crop (*Abelmoschus esculentus* L.) var. Sudha

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Abstract
A field experiment was conducted to evaluate the physical and chemical properties of soil in department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (UP). In the Randomized Block Design experiment, three levels of nano urea (0%, 50%, and 100%) and three levels of nano DAP (0%, 50%, and 100%) conjugated with potassium (recommended dose 100%) were employed. The results showed that the application of Nano urea and Nano DAP Conjugated with Potassium significantly enhanced the soil properties, growth, and yield of okra. The highest growth and yield were recorded by T_9 [100% Nano Urea @ 1.23 l ha^{-1}+ 100% Nano DAP @ 1.23 l ha^{-1} + K RD @ 83.3 kg ha^{-1}], which was followed by T_8 [100% Nano Urea @ 1.23 l ha^{-1} + 50% Nano DAP @ 0.615 l ha^{-1} + K RD @ 83.3 kg ha^{-1}]. The lowest growth and yield were recorded by T_1 [0% Nano Urea @ 0 l ha^{-1} + 0% Nano DAP @ 0 l ha^{-1} + K RD @ 83.3 kg ha^{-1}]. In addition to Nano urea and Nano DAP conjugated with potassium increased percentage pore space (48.59%), water holding capacity (45.99%), electrical conductivity (0.36 dS m^{-1}), and available nitrogen (284.16 Kg ha^{-1}), phosphorus (34.63 Kg ha^{-1}), and potassium (256.03 Kg ha^{-1}) and decrease in bulk density (1.29 Mg m^{-3}), Partical density (2.40 Mg m^{-3}), soil pH (7.47). The highest benefit cost ratio (1: 6.195), and net profit (212,266.60) and found highest yield 112.5 q ha^{-1} on the T_9.

Keywords: Nano urea, nano DAP, potassium, growth, soil properties, yield, B: C ratio, okra

1. Introduction

Soil plays a critical role in many ecological processes, including nutrient cycling, water filtration, carbon sequestration and habitat creation. Soil quality is influenced by various factors such as climate, topography, vegetation and human activities. Laishram *et al.* (2014) [7] Soil health is the capacity of soil to function within natural or managed ecosystem boundaries to sustain plant productivity, to maintain or enhance water and air quality, and support human health and habitation Karlen *et al.* (1997) [4] Okra (*Abelmoschus esculentus* (L.) known as lady's fingers, bhindi in India, krajiab kheaw in Thailand, okra plant, ochre, okoro, quimgombo, quimgombo, gombo, kopi arab, kacang bendi and bhindi in South East Asia. However, in Middle East it is known asbamia, bamya or bamieh and gumbo in Southern Kader *et al.* (2010) [5]. In the many geographical regions where it is cultivated, okra (*Abelmoschus esculentus* L.), a member of the Malvaceae family, is also referred to by a number of colloquial names, including bhindi, okura, quimgombo, bamia, gombo, and lai long ma. It is also frequently known as lady's finger. Okra is thought to have started in the area close to Ethiopia, where Egyptians regularly grew it in the 12th century. From there, it spread throughout the Middle East and North Africa. Okra is a common garden and farm crop that is grown mostly in tropical and subtropical regions of the world. It is an annual shrub. Elkhalifa *et al.* (2014) [2] Okra plants, particularly the leaves and stems, can be used as fodder for livestock, including cattle, goats, and sheep. The high fiber content and moderate protein levels in okra foliage make it a valuable supplemental feed source, especially during periods of fodder scarcity or drought.

Feeding okra to animals provides essential nutrients, including protein, vitamins, and minerals, which contribute to animal health, growth, and productivity Islam *et al.* (2018) [3].

Nano urea contains 4% nitrogen by weight in its nano form. A half bottle of nano urea with better use efficiency can effectively reduce up to one bag of urea. Application of nano urea has a considerable advantage in terms of a safe and clean environment with the reduction in the application of conventional bulk urea. Mix 2 to 4 ml of nano urea liquid in one liter of clean water and spray on crop leaves. Midde *et al*. (2022) [8] IFFCO Nano DAP is an efficient source of available nitrogen (N) and phosphorus (P2O5) for all the crops and helps in correcting the Nitrogen & Phosphorus deficiencies in standing crops. Nano DAP formulation contains Nitrogen (8.0% N w/v) and Phosphorus (16.0% P2O5 w/v). Nano DAP (Liquid) has advantage in terms of surface area to volume as its particle size is less than 100 Nano meter (nm).

2. Materials and Methods

Table 1 displays the specific combination of treatments. The field experiment had been carried out during the Zaid season 2023 at the Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (UP), central research farm of the department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, The university's campus is situated on the Yamuna River's right bank, four to five kilometers away, with roughly 25°47'69" N latitude and 81°85'74" E longitude as its geographic coordinates. Chaphekar *et al.* (1986) [1] the elevation above mean sea level is 98 meters (322 feet). representing the North Alluvium Plain Zone (0-1% Slope) and the Agro-Ecological Sub Region (Agro-Climatic Zone, Upper Gangetic Plain). In May, the average maximum temperature was 45.120 C, while in August, the average minimum temperature was 27.900 C Singh *et al.* (2016) [9]. In this area, 1100 mm of rain falls on average each year. Before the tillage operation, soil samples were randomly taken from one location in the trial plot at a depth of 0 to 15 cm and 15-30 cm. afterwards, the soil sample's volume was decreased by quartering and conning the composite soil samples. After that, they were allowed to air dry before being sieved through a 2 mm screen to get ready for both chemical and physical analysis. After harvesting, a physical study of the soil was done. A sample of the crop's harvested soil was taken from the field after 75 days. Textural class, soil color, bulk density (Mg m^{-3}), particle density (Mg m^{-3}), pore space percentage, and water holding capacity percentage were among the physical attributes examined. Following post-harvest activities, soil chemical analysis was conducted to determine the following: pH, EC dS m^{-1}, organic carbon percentage, accessible N kg ha^{-1}, P kg ha^{-1}, and K kg ha^{-1}. With three replications and a randomized block design, the trial was set up with a 2 × 2 m plot size for an okra crop seed rate of 8 kg ha^{-1}.

3. Results and Discussion

3.1 Soil Parameters

The soil characteristics are significantly impacted by the composition of nano urea and nano DAP when combined with K. The improvement of soil characteristics is associated with an increase in pore space percentage, Upadhyay *et al*, (2023) [11] water holding capacity percentage, organic carbon, accessible nitrogen, phosphorus, and potassium (Table 2). Demonstrated the application of various levels of N, P, and conjugated potassium (recommended dose 100%) on soil after rolling Ettleson *et al*, (2023) [10]. Due to no application of N, P, and conjugated with K, treatment T_1 has the lowest data observed pore space 42.80 and 42.46%, water holding capacity 40.46 and 38.23%, and treatment T_9 has the highest data pore space 48.59% and 48.26%, water holding capacity 45.20% and 45.20% at 0–15 cm and 15–30 cm depth of soil, respectively. also, in Table 3. The results indicate that in the 0- 15 cm and 15-30 cm depth of soil, the highest bulk density (T_1) is 1.26 Mg m-3 and 1.29, and the lowest particle density (T_9) is 1.07 Mg m^{-3} and 1.10 Mg m^{-3}, pH 7.10 and 7.22, and Organic carbon 0.31 and 0.29%, respectively. Particle density (T_1) is 2.36 Mg m^{-3} and 2.40 Mg m^{-3}, and pH 7.44 and 7.47. According to Table 4, Treatment T_9 has the highest EC values 0.39 and 0.32 dsm^{-1}, nitrogen levels 284.16 and 282.12 kg ha^{-1}, phosphorus levels 34.63 and 31.37, potassium levels 256.03 and 255.59 kg ha^{-1}, and T_1 has the lowest EC values 0.21 and 0.19 dS m^{-1}, nitrogen levels 263.10 and 262.94 kg ha^{-1}, phosphorus levels 20.33 and 18.20 kg ha^{-1}, and potassium levels 0–15 cm and 15–30 cm in the soil depths 0–15 cm and 15–30 cm, respectively.

Table 1: Methodology employed for analysis

Particulars	Method employed
Bulk density (Mg m^{-3})	Graduated Measuring Cylinder
Partical density (Mg m^{-3})	Graduated Measuring Cylinder
Pore space (%)	Graduated Measuring Cylinder
Soil pH (1:2)	pH meter (Glass electrode)
Soil EC (dS m^{-1})	EC meter (Conductivity Bridge)
Organic Carbon (%)	Wet Oxidation Method
Available Nitrogem (Kg ha^{-1})	Kjeldhal Method
Available Phosphorus (Kg ha^{-1})	Colorimetric method
Available Potassium (Kg ha^{-1})	Flame photometric method

Table 2: Treatment combination of green gram

S. No.	Treatment combination	Symbol
T_1	0% Nano Urea @ 0 l ha^{-1} + 0% Nano DAP @ 0 l ha^{-1} + K RD @ 83.3 kg ha^{-1}	$I_1V_1R_1$
T_2	0% Nano Urea @ 0 l ha^{-1} + 50% Nano DAP @ 0.615 l ha^{-1} + K RD @ 83.3 kg^{-1}	$I_1V_2R_2$
T_3	0% Nano Urea @ 0 l ha^{-1} + 100% Nano DAP @ 1.23 l ha^{-1} + K RD 83.3 kg ha^{-1}	$I_1V_3R_3$
T_4	50% Nano Urea @ 0.615 l ha^{-1} + 0% Nano DAP @ 0 l ha^{-1} + K RD @ 83.3 kg ha^{-1}	$I_2V_1R_1$
T_5	50% Nano Urea @ 0.615 l ha^{-1} + 50% Nano DAP @ 0.615 l ha^{-1} + K RD @ 83.3 kg ha^{-1}	$I_2V_2R_2$
T_6	50% Nano Urea @ 0.615 l ha^{-1} +100% Nano DAP @ 1.23 l ha^{-1}+ K RD @ 83.3 kg ha^{-1}	$I_3V_3R_3$
T_7	100% Nano Urea @ 1.23 l ha^{-1} + 0% Nano DAP @ 0 l ha^{-1} + K RD @ 83.3 kg ha^{-1}	$I_3V_1R_1$
T_8	100% Nano Urea @ 1.23 l ha^{-1} + 50% Nano DAP @ 0.615 l ha^{-1} + K RD @ 83.3 kg ha^{-1}	$I_3V_2R_2$
T_9	100% Nano Urea @ 1.23 l ha^{-1} + 100% Nano DAP @ 1.23 l ha^{-1} + K RD @ 83.3 kg ha^{-1}	$I_3V_3R_3$

Table 3: Effect of different levels of Nano Urea (N), Nano DAP (P), Conjugated with potassium on physical properties of soil.

Treatments	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Pore space (%)		Water holding capacity (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	1.26	1.29	2.36	2.40	42.80	42.46	40.46	38.23
T_2	1.23	1.23	2.32	2.36	43.5	43.16	40.66	40.65
T_3	1.21	1.20	2.31	2.34	44.23	43.86	41.40	41.06
T_4	1.20	1.19	2.30	2.31	44.73	44.40	41.55	41.12
T_5	1.18	1.17	2.28	2.29	45.96	45.78	43.26	42.57
T_6	1.15	1.14	2.25	2.27	46.93	46.28	44.04	43.64
T_7	1.13	1.12	2.24	2.24	47.80	47.01	44.45	44.00
T_8	1.10	1.11	2.22	2.23	47.99	47.66	45.01	44.86
T_9	1.07	1.10	2.21	2.22	48.59	48.26	45.99	45.20
F-test	S	S	S	S	S	S	S	S
S. Em. (±)	0.01	0.01	0.01	0.01	0.57	0.59	0.57	1.46
C.D.@5%	0.01	0.01	0.02	0.02	1.22	1.23	1.22	3.09

Table 4: Effect of different levels of Nano Urea (N), Nano DAP (P), Conjugated with potassium on chemical properties of soil.

Treatments	pH		EC (dS m^{-1})		Organic Carbon (%)	
	0-15 cm	15-30 cm	0-15 cm	15- 30 cm	0-15 cm	15-30 cm
T_1	7.44	7.47	0.21	0.19	0.47	0.47
T_2	7.41	7.45	0.23	0.20	0.47	0.46
T_3	7.40	7.43	0.25	0.20	0.45	0.45
T_4	7.36	7.44	0.26	0.23	0.43	0.42
T_5	7.35	7.39	0.28	0.25	0.42	0.40
T_6	7.32	7.36	0.30	0.26	0.37	0.37
T_7	7.30	7.33	0.31	0.29	0.34	0.33
T_8	7.23	7.28	0.34	0.31	0.33	0.31
T_9	7.10	7.22	0.36	0.32	0.31	0.29
F-test	S	S	S	S	S	S
S. Em. (±)	0.01	0.03	0.01	0.01	0.01	0.02
C.D.@5%	0.03	0.07	0.03	0.03	0.03	0.04

Treatment	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	263.10	262.94	20.33	18.20	229.75	227.82
T_2	264.86	263.89	21.45	19.20	233.41	231.74
T_3	267.55	266.45	23.87	20.51	238.00	236.97
T_4	270.55	268.93	25.98	21.18	243.31	240.47
T_5	275.47	271.72	26.58	23.48	245.89	245.02
T_6	278.96	273.29	29.89	24.54	247.7	245.43
T_7	279.55	275.49	31.71	26.02	250.58	249.03
T_8	281.05	278.62	33.22	29.36	253.37	252.23
T_9	284.16	282.12	34.63	31.37	256.03	255.59
F-test	S	S	S	S	S	S
S.Em. (±)	0.70	1.30	0.85	0.35	1.11	1.37
C.D.@5%	1.49	2.76	1.80	0.74	2.36	2.91

Based on the physical and chemical qualities, the T_9 treatment is the best, followed by the T_8 and T_7 treatments. In the end, the application of Nano urea and Nano DAP Conjugated with Potassium shows promise for improving the soil's fertility. Out of all the treatments, T_1 exhibits the least impact on soil metrics.

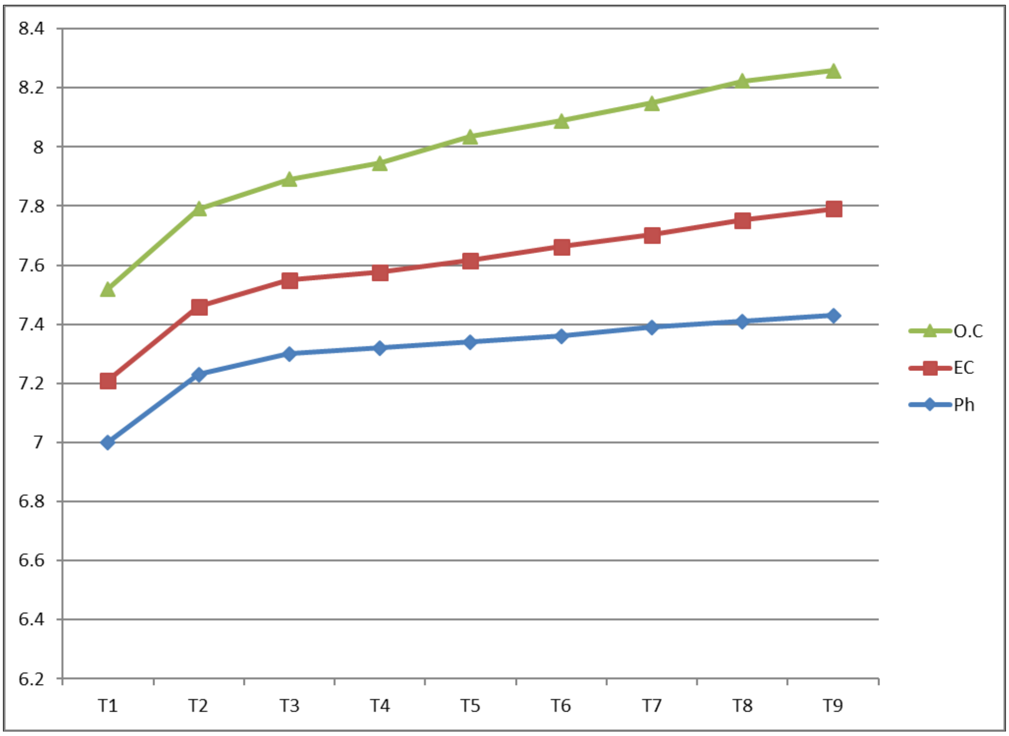

Fig. 1: Effect of different levels of pH, EC (dS m^{-1}) and Organic Carbon (%) in soil.

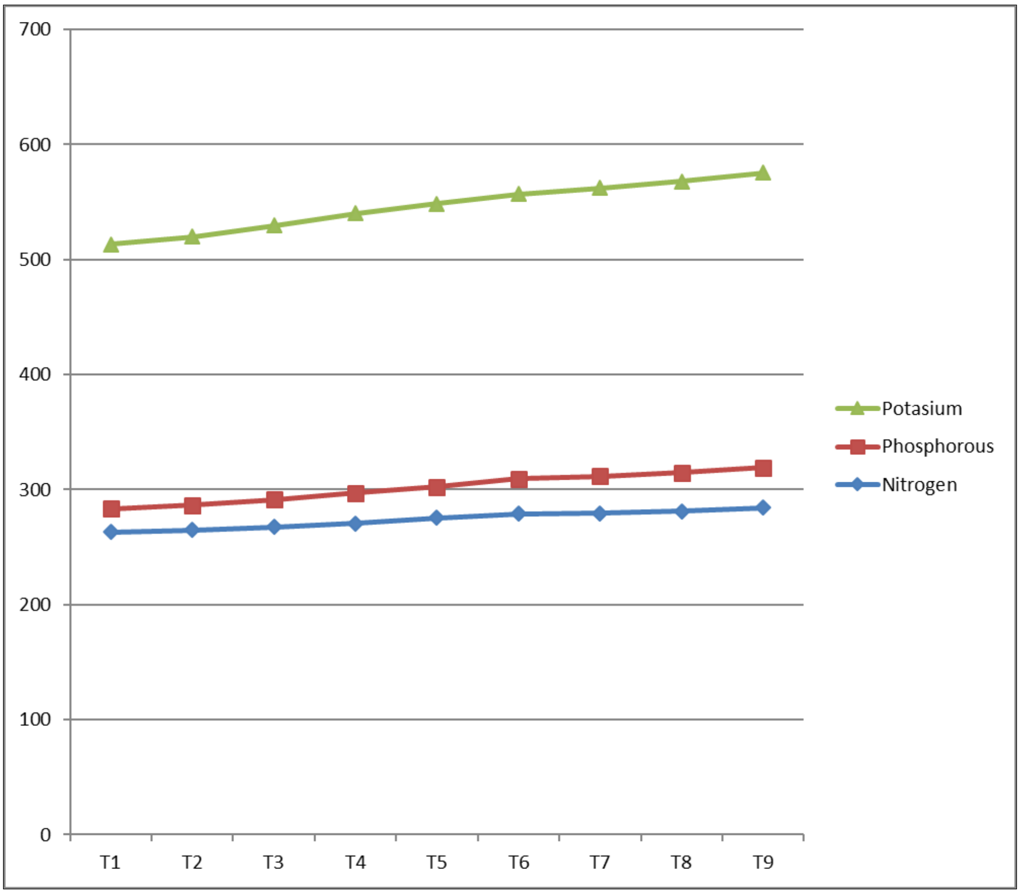

Fig. 2: Effect of different levels of Nitrogen (kg ha^{-1}), Phosphorous (kg ha^{-1}) and Potassium (kg ha^{-1}) in soil

3.2 Economy of okra Crop

As indicated by Table 5 below. In terms of the economy of the various treatments, treatment T9 yields the maximum net profit of ₹212,266.60 with a cost-benefit ratio of 6.19; on the other hand, treatment T_1 records the lowest net profit of ₹117,875.00 with a cost-benefit ratio of 1:415.

Table 5: Effect of different treatment combination on cost benefit ratio (C: B) of okra crop.

Treatments	Yield (q ha^{-1})	Selling rate (Rs q^{-1})	Gross return (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net Profit Rs. ha^{-1})	Benefit Cost ratio
T_1	69	2250	155250	37375	117,875.00	1:415
T_2	74	2250	166500	38362.22	128,137.78	1:4.340207631
T_3	79	2250	177750	40268	137,482.00	1:4.414175027
T_4	85	2250	191250	37670.2	153,579.80	1: 5.076957383
T_5	91	2250	204750	39117.42	165,632.58	1:5.234240909
T_6	95	2250	213750	40563.2	173,186.80	1:5.26955467
T7	100.1	2250	225225	37965.4	187,259.60	1:5.932375268
T_8	105	2250	236250	39411.62	196,838.38	1:5.994424994
T_9	112.5	2250	253125	40858.4	212,266.60	1:6.195176512

4. Conclusion

The experiment's findings showed that applying K, Nano DAP, and Nano Urea in treatment T_9 [100% Nano Urea @ 1.23 l ha^{-1} + 100% Nano DAP @ 1.23 l ha^{-1} + K RD @ 83.3 kg ha^{-1}] had the greatest impact on enhancing the physico-chemical properties of the soil, as evidenced by improvements in pH 7.44, bulk density 1.26 Mg m^{-3} , particle density 2.36 Mg m^{-3}, and water holding capacity 45.99% as well as increases in pore space 48.59% , water holding capacity, electrical conductivity 0.36 ds m^{-1}, percentage of organic carbon 0.47%, and available nitrogen 284.16 kg ha^{-1}, phosphorus 34.63 kg ha^{-1} , and potassium 256.03 kg ha^{-1}. In a similar vein, treatment T_9 produced the highest plant height 122.34, number of leaves 39.03, number of branches 29.36, number of fruits per plant 21.56, and yield 112.5. It is also noted that, with a cost-benefit ratio of 6:195, treatment T_9 produced a maximum gross return of ₹ 253125 ha^3 and a net return of ₹ 212266.60 ha^3.

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6. Competing Interests

Authors have declared that no competing interests exist.

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