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Effect of Tillage Practices and Integrated Nutrient Management on Soil Physicochemical Properties and Yield of Cowpea (*Vigna unguiculata* L. Walp) at Uttar Pradesh, India

Koushik Pati [a++*], Arun Alfred David [a#], Tarence Thomas [a†], Ram Bharose [a‡], Neha Toppo [a^] and Iska Srinath Reddy [a^]

[a] Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Allahabad - 211007 (U.P.), India.

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

A field investigation was conducted at Central Research Farm of Department of Soil Science and Agricultural Chemistry at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India during *Zaid* season of 2023. The experimental plot was laid down into a randomized block design with 9 treatments replicated thrice, consist of 3 levels each of tillage practices and RDF (0 %, 50%, 100%) and 1level of vermicompost (5 t ha $^{-1}$). Results revealed that

[++] M.Sc. Student;
[#] Associate Professor;
[†] Professor;
[‡] Assistant Professor;
[^] Ph. D Scholar;
**Corresponding author: E-mail: koushikpati99@gmail.com;*

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maximum bulk density (1.29 Mg m^{-3}) and soil pH (7.10) were found in T_1 (Tillage @ 0% + RDF @ 0% +VC @ 5t ha^{-1}). The others soil parameters like porosity (55.60 %),water holding capacity (46.63 %), organic carbon (0.49 %), electrical conductivity(0.25 dS m^{-1}), available Nitrogen (331.54 kg ha^{-1}), available Phosphorus (28 kg ha^{-1}), available Potassium (193.73 kg ha^{-1}) were recorded maximum in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) .Whereas best yield (150.56 q ha^{-1}) was also recorded in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) .Economic parameters like gross return (₹271008.00 ha^{-1}) and net return (₹152323.00 ha^{-1}) were found to be maximum in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) and best cost benefit ratio (C: B) was recorded as (1:2.28) in treatment T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}). Integrated approach of application of RDF (NPK), vermicompost along with 100% tillage practices found to be the best treatment as the soil parameters and plant growth parameters significantly affected with the different levels of nutrient and tillage practices.

Keywords: Tillage; soil; yield; NPK; vermicompost; cowpea; etc.

1. INTRODUCTION

Soil health refers to the ability of soil to operate effectively within the parameters of its ecosystem and land management practices, supporting the vitality of plants and animals, promoting ecological diversity, enhancing primary productivity, and maintaining environmental integrity. As Soil is a dynamic body, the potentiality of soil to supply nutrients adequately is very important for plant growth & development. When soil inherent all the physical and chemical properties in between a well -maintained range, is known as healthy soil. Integrated nutrient management is one of most important approach to maintain the soil health and maintains a good soil condition with the help of application of various alternate nutrient sources as organic amendments which maintains proper supply of nutrients along with keeping soil healthy.

Cowpea, being a leguminous crop, requires minimal nitrogen, especially in small amounts during the early stages of its growth cycle. However, nitrogen remains crucial for its overall growth and development as it constitutes vital components such as amino acids, proteins, nucleic acids, enzymes, and alkaloids [1]. Phosphorus is one of the vital mineral nutrients for pulse crops like cowpea, plays a crucial role in root growth and development, biological nitrogen fixation, seed germination, flowering, cell division, synthesis of fats and starches [2,3]. Potassium is the third major macronutrient which is very essential for the plant growth after nitrogen and phosphorus. In case of drought conditions, potassium actively maintains turgidity in plant cells and regulates stomatal activities and helps in water regulation and stress management [4-6].

Vermicompost plays an important role in production of cowpea as it supplies various macro and micro nutrients, promotes proper plant growth and yield. It is a rich source of plant nutrients, which are readily available consists of growth-enhancing substances, and beneficial microorganisms. Within vermicompost, one can find a diverse array of organisms, including those, capable of fixing nitrogen, solubilizing phosphorus, and decomposing cellulose with 1.2-1.6%N, 1.8-2.0% P_2O_5, 0.50 -0.75% K_2O, and growth enhancing substance such as auxins and cytokines [7]

Cowpea is cultivated in arid and semi-arid regions throughout the world. In India major cowpea growing states are U.P., Punjab, Haryana, Rajasthan, M.P., West Bengal, Andhra Pradesh. It has short duration, high yielding, and quick growing capacity along with rich source of protein, carbohydrates, fibres, potassium etc [8-11]. As per report claimed by Indian Council of Medical Research, the per capita availability of pulses in India is 35.5 g day^{-1} against the minimum requirement of 70 g day^{-1} $capita^{-1}$. It needs very little inputs to grow as cowpea have the capacity to fix nitrogen through root nodule at about 30 kg ha^{-1}, that's why cowpea is suitable for intercropping as it also gives higher income with low input for farmers [12].

Tillage is the mechanical manipulation of soil or breaking of soil clods for making an even seed bed. Depending upon various factors such as the crop, soil type, climate, and farming objectives, tillage practices in leguminous crops may vary. Zero tillage practices in leguminous crops are designed to establish an ideal seedbed, control weeds, retain soil moisture, and encourage robust crop development [13-16]. This approach minimizes soil erosion and preserves the soil structure by avoiding any disruption. 100% Tillage encompasses enhanced soil structure and tilth, which diminish weed competition, along with better aeration, soil moisture, and nutrient availability. Together, these improvements likely fostered superior root development, resulting in notable plant growth. Similar results were observed by Anjum et al. [17] and Karki et al., [18]

2. MATERIALS AND METHODS

Cowpea seed variety KSP-178-Kashi Nidhi was used for cultivation. The place falls under subtropical belt in the south east of Uttar Pradesh and agro-ecological sub region [North Alluvium plain zone (0-1 % slope)] and Agro-climatically zone under upper Gangetic plain region. The experimental field is located at 25^0 24' 30" N latitude and 81^0 51' 10" E longitude and 98 m above MSL (Mean-sea level). The field is situated at about 6 km away from Prayagraj city on the right bank of river Yamuna and south east of Uttar Pradesh, thus the location faces extremely hot summer and cold winter seasons. In the time of summer temperature rises maximum up to 46-48^0 C and seldom falls as low as 4 ^{0}C- 5^0 C. The relative humidity of the research location ranges between 20 to 94 percent. Annual average rainfall of this area recorded about 1100 mm whereas monsoon happens mostly on July-September.

The trial was laid down into a randomized block design with 9 treatments replicated thrice, consist of 3 levels of tillage practices (0 %, 50% ,100%), 3 levels of RDF (0 %, 50% ,100%) ,1 level of vermicompost (5 t ha $^{-1}$) respectively. Before any tillage operations soil samples were collected randomly from five distinct locations within the experimental plot and after harvesting of the crop soil samples also collected as per different treatment combinations plot wise; extracted from a depth of 0-15cm. To prepare the soil samples ;they were undergoes reduction through coning and quartering and subsequently, the soil samples were air-dried and shifted through a 2 mm sieve and preserved in polythene bags and then brought to laboratory for analysis of various physical parameters such as soil texture, soil colour, bulk density (Mg m^{-3}), particle density (Mg m^{-3}), porosity percentage(%), water holding capacity (%) and chemical properties such as soil pH, electrical conductivity (dS m^{-1}), organic Carbon(%), available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}), available potassium (kg ha^{-1}) by standard methodology (pH :Jackson,[19] ; E.C.: Wilcox,[20]); organic carbon: Walkley and Black, [21]; av. nitrogen: Subbiah and Asija, [22]; av. phosphorus: Olsen et al*.* [23]; potassium: Toth and Prince,[24].

3. RESULTS AND DISCUSSION

The experiment data presented that the effect of tillage practices, inorganic fertilizers and vermicompost significantly affected various soil properties. Tillage encompasses enhanced soil structure and tilth, which diminish weed competition, along with better aeration, soil moisture, and nutrient availability. Together, these improvements likely fostered superior root development, resulting in notable plant growth and increase of yield. Result of this field experiment in Table.2,3,4 revealed that soil bulk density and pH is decreasing with the increasing level of vermicompost and found maximum in T_1 (Tillage @ 0% + RDF @ 0% +VC @ 5t ha^{-1}) *i.e.* 1.29 Mg m^{-3} and 7.10 respectively, where, minimum pH found to be 6.80 and bulk density around 1.07 Mg m^{-3} in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}). Electrical conductivity (0.25 dS m^{-1}), porosity (55.60%), water holding capacity (46.63 %), Organic Carbon (0.49 %), available Nitrogen (331.54 kg ha^{-1}), available Phosphorus (28 kg ha^{-1}), available Potassium (193.73 kg ha^{-1}) found significantly maximum with the increased nutrient doses and best found in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}). Whereas, T_1 treatment combination showed lowest values in electrical conductivity (0.19 dS m^{-1}), particle density (2.59 Mg m^{-3}), pore space (43.42%), water holding capacity (40.77 %), Organic Carbon (0.28 %), available Nitrogen (297.17 kg ha^{-1}), available Phosphorus (17.70 kg ha^{-1}), available Potassium (144.71 kg ha^{-1}). T_9 has showed the greatest potential to enhance soil health by improving various soil parameters.

Results also revealed that maximum pod yield *i.e.,* 150.56 q ha^{-1} found in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) and minimum pod yield was recorded in T_1(Tillage @ 0% + RDF @ 0% +VC @ 5t ha^{-1}) *i.e.,* about 87 q ha^{-1}.

Economic parameters like gross return (₹271008.00 ha^{-1}) and net return (₹152323.00 ha^{-1}) were found to be maximum in T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) and best cost benefit ratio (C: B) was recorded as (1:2.28) in treatment T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}).

Table 1. Treatment combination of cowpea

Treatments	Treatment Combination	Symbols
T_1	Tillage @ 0% + RDF @ 0% +VC @ 5t ha^{-1}	$T_1 I_1 V$
T_2	Tillage @ 0% + RDF @ 50% +VC @ 5t ha^{-1}	$T_1 I_2 V$
T_3	Tillage @ 0% + RDF @ 100% +VC @ 5t ha^{-1}	$T_1 I_3 V$
T_4	Tillage @ 50% + RDF @ 0% +VC @ 5t ha^{-1}	$T_2 I_1 V$
T_5	Tillage @ 50% + RDF @ 50%+VC @ 5t ha^{-1}	$T_2 I_2 V$
T_6	Tillage @ 50% + RDF @ 100% +VC @ 5t ha^{-1}	$T_2 I_3 V$
T_7	Tillage @ 100% + RDF @ 0% +VC @ 5t ha^{-1}	$T_3 I_1 V$
T_8	Tillage @ 100% + RDF @ 50% +VC @ 5t ha^{-1}	$T_3 I_2 V$
T_9	Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}	$T_3 I_3 V$

[Note: VC- Vermicompost i.e., used enriched with PSB @ 1 kg tonne^{-1} of Vermicompost]

Table. 2. Effect of Tillage practices at different levels of NPK and Vermicompost on soil physical parameters at 0-15 cm depth

Treatment	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Porosity (%)	Water holding capacity (%)
T_1	1.29	2.59	43.42	40.77
T_2	1.28	2.60	44.34	41.05
T_3	1.27	2.59	45.49	41.67
T_4	1.25	2.59	46.58	42.34
T_5	1.23	2.60	47.65	42.53
T_6	1.25	2.60	47.03	43.52
T_7	1.12	2.59	52.74	43.93
T_8	1.14	2.60	52.10	44.85
T_9	1.07	2.61	55.60	46.63
F-Test	S	NS	S	S
S.Em. (±)	0.34	0.04	0.45	0.27
C.D.@5%	0.72	0.08	0.96	0.57

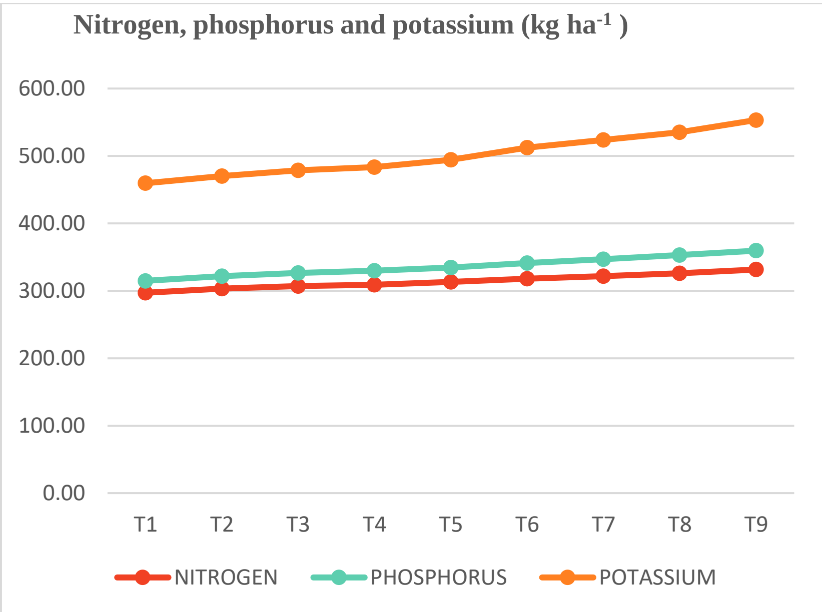

Fig. 1. Graphical representation of Treatment combination vs nitrogen, phosphorus, and potassium

Table 3. Effect of Tillage practices at different levels of NPK and Vermicompost on soil chemical parameters at 0-15 depth

Treatment	pH W/V (1:2.5)	EC (dS m^{-1})	Organic Carbon (%)	Av. nitrogen (kg ha^{-1})	Av. phosphorus (kg ha^{-1})	Av. potassium (kg ha^{-1})
T_1	7.10	0.19	0.28	297.17	17.70	144.71
T_2	6.97	0.21	0.30	303.45	18.22	148.30
T_3	6.77	0.22	0.32	307.22	19.21	152.32
T_4	7.13	0.17	0.37	309.19	20.53	153.97
T_5	7.01	0.23	0.39	313.13	21.47	159.95
T_6	6.91	0.24	0.41	318.08	23.21	171.06
T_7	7.11	0.18	0.43	321.94	25.02	176.92
T_8	7.04	0.20	0.46	326.23	26.81	182.08
T_9	6.80	0.25	0.49	331.54	28.00	193.73
F-Test	S	S	S	S	S	S
S.Em. (±)	0.09	0.02	0.02	1.63	4.87	2.96
C.D.@5%	0.20	0.03	0.03	3.45	10.33	6.28

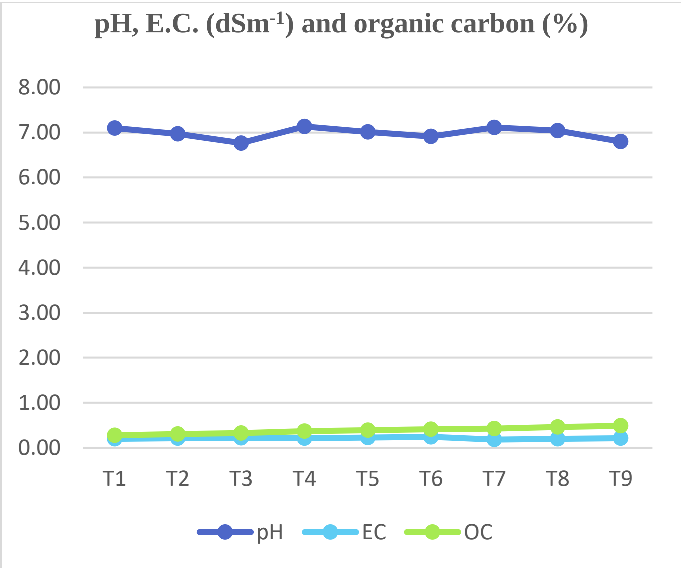

Fig. 2. Graphical representation of Treatment combination vs pH, E.C. and organic carbon

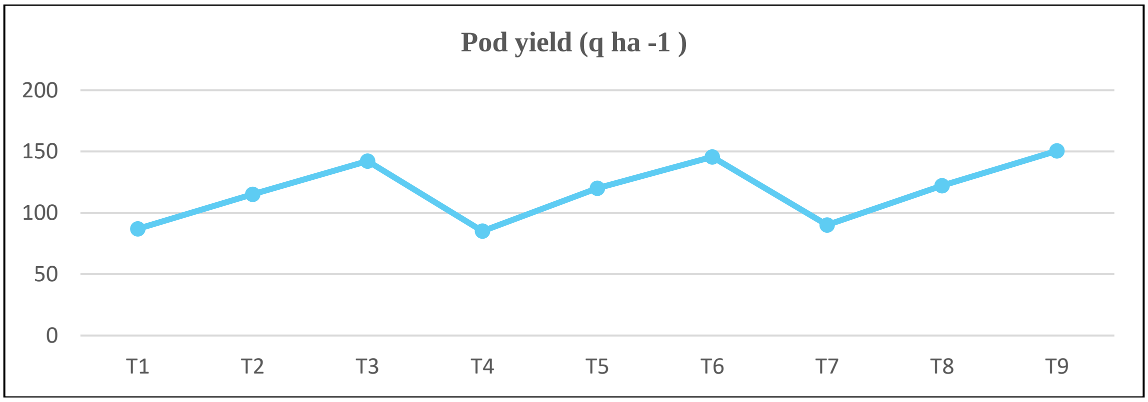

Fig. 3. Graphical representation of Treatment combination vs Pod yield (q ha^{-1})

Table 4. Effect of different treatment combinations on cost benefit ratio (C: B) of Cowpea

Treatments	Yield (q ha^{-1})	Selling price (₹ q^{-1})	Gross return (₹ ha^{-1})	Total cost of Cultivation (₹ ha^{-1})	Net profit (₹ ha^{-1})	C:B ratio
T_1	87	1800	156600	111750	44850.00	1:1.40
T_2	115.26	1800	207468	114517.5	92950.50	1:1.81
T_3	142.23	1800	256014	117285	138729.00	1:2.18
T_4	85.11	1800	153198	112450	40748.00	1:1.36
T_5	120	1800	216000	115217.5	100782.50	1:1.87
T_6	145.57	1800	262026	117985	144041.00	1:2.22
T_7	90.12	1800	162216	113150	49066.00	1:1.43
T_8	122.23	1800	220014	115917.5	104096.50	1:1.90
T_9	150.56	1800	271008	118685	152323.00	1:2.28

4. CONCLUSION

The experimental results showed that the application of Tillage, Vermicompost and Inorganic fertilizers in treatment T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) significantly affected the physico -chemical properties of the soil. These results included a reduction in bulk density and pH, but no significant changes were recorded in particle density. Whereas porosity, water holding capacity and electrical conductivity showed significant variations including organic carbon, available Nitrogen, Phosphorus, Potassium. Moreover, treatment T_9 exhibited the tallest plants and longest pods. Additionally, it has recorded the highest number of pods per plant and the greatest pod yield weight per hectare compared to other treatments.

Based on this trial results, we can conclude that among the various combinations of Tillage Practices, N, P, K, Vermicompost levels tested, T_9 (Tillage @ 100% + RDF @ 100% +VC @ 5t ha^{-1}) has emerged as the most effective for cultivating Cowpea (*Vigna unguiculata* L. Walp), particularly for the KSP-178-Kashi Nidhi variety. 100 % Tillage encompasses enhanced soil structure and tilth, which diminish weed competition, along with better aeration, soil moisture, and nutrient availability. Together, these improvements likely fostered superior root development, resulting in notable plant growth and ensures quality yield. This treatment demonstrated superior outcomes for both crop yield and soil physical and chemical properties. Therefore, it is recommended for achieving profitable Cowpea production but it is important to note that it may differ depending on the different soil type of different areas. Employing integrated nutrient management practices like this can significantly contribute to maintaining soil health and optimizing Cowpea yields.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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