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Effect of Vermicompost and Biochar on Physio-chemical Properties of Soil Growth and Yield Attributes of Cowpea (*Vigna unguiculata* L. Walp)

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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

A field investigation was conducted at department of soil science and agricultural chemistry under SHUATS, NAI, Prayagraj (Allahabad), Uttar Pradesh, India during Zaid season of 2023. The experimental field is located at 250 24' 30" N latitude and 810 51' 10" E longitude and 98 m above MSL (Mean -sea level).
The aim of the study was to assess "Effect of Vermicompost and Biochar on physio-chemical properties of soil growth and yield attributes of cowpea (Vigna unguiculata L. Walp). The experimental plot was laid down into a randomized block design with 9 treatments replicated thrice,

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consisting of levels of RDF, 3 levels of vermicompost (0%, 50%, 100%) ,3 levels of Biochar (0%, 50%, 100%) respectively. The result revealed that maximum bulk density (Mg m-3), particle density (Mg m-3) and soil pH are found at T1 (Absolute Control). The other best soil parameters are pore space (%), water holding capacity (%), organic carbon (%), electrical conductivity, available nitrogen (kg ha-1), available phosphorus (kg ha-1), available potassium (kg ha-1) found maximum at T9 (RDF + Vermicompost @100% (5t ha-1) + Biochar @100% (3t ha -1). Other findings showed that growth parameters like plant height (cm), length of pod (cm), no. of pod plant-1 are maximum at T9 (RDF + Vermicompost @100% (5t ha-1) + Biochar @100% (3t ha -1)) may be because of proper availability of nutrients in adequate amount. Highest yield was recorded in T9 (RDF + Vermicompost @100% (5t ha-1) + Biochar @100% (3t ha -1)).Maximum economic parameters as maximum gross return (79,960.00₹ ha-1) find at T9 (RDF + Vermicompost @100% (5t ha-1) + Biochar @100% (3t ha -1)) , best cost benefit ratio (B:C) found (1:2.6) at T9 (RDF + Vermicompost @100% (5t ha-1) + Biochar @100% (3t ha -1)) and maximum net return found (₹31,260 ha-1) at T8 (RDF+Vermicompost @100% (5t ha-1) + Biochar @50% (1.5t ha-1)).

Keywords: Soil properties; biochar; vermicompost; cowpea; etc.

1. INTRODUCTION

Soil provides a habitat for countless microorganisms, insects, and small animals, fostering essential ecological interactions. Additionally, soil acts as a natural water filter, preventing pollutants from reaching groundwater sources [1]. Moreover, it plays a crucial role in the carbon cycle, influencing climate regulation by sequestering or releasing carbon dioxide. However, soil degradation due to unsustainable agricultural practices, deforestation, urbanization, and pollution poses a significant threat to its fertility and overall ecological balance. Sustainable soil management practices are vital to ensure the preservation and conservation of this precious resource for future generations**.**

Vermicompost is a rich source of plant nutrients, which are readily available. It consists of growth enhancing substances, and beneficial microorganisms [2]. Within vermicompost, one can find a diverse array of organisms, including those capable of fixing nitrogen, solubilizing phosphorus, and decomposing cellulose. containing 1.2-1.6% N, 1.8-2.0% P2 O5 and 0.50 -0.75% K2O, growth enhancing substances such as auxins and cytokines [3,4].

Biochar is the lightweight black residue made of carbon and ashes, remaining after the pyrolysis of biomass. Biochar is defined by the International Biochar Initiative as the solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment [5,6]. Biochar is a stable solid that is rich in pyrogenic carbon and can endure in soil for thousands of years [7-9]. Properties and composition of Biochar: p^H = 9.90, EC=3.53 dSm^{-1}, B.D. = 0.19 Mg m^{-3}, P.D. = 0.58 Mg m^{-3}, WHC = 58.5%, Zn = 157 mg kg^{-1}, Mn = 214 mg kg^{-1}, Cu = 54 mg kg^{-1}, Co = 3.43 mg kg^{-1}, Ni= 17.2 mg kg^{-1}, Pb= 45.5 mg kg^{-1}, Cd = 1.84 mg kg^{-1}, P =0.09%, Na=0.99%, K = 3.22%, Fe = 0.28%, Ca = 0.38%, Mg =0.25%, Al =1.83% [10-12].

Cowpea (*Vigna unguiculata*) with chromosome number 2n=22, belongs to the family Leguminaceae, sub-family Fabaceae and genus *Vigna*. It is self-pollinated and response to photoperiod. It is mainly grown for its long pods, seeds and foliage and for fodder. It is commonly known as southern bean, yard- long bean, asparagus bean. It is also known as vegetable meat [13-15]. Cowpea is grown specially in summer season throughout India. In India, major cowpea growing states are U.P, Punjab, Haryana, Rajasthan, M.P., West Bengal, Andhra Pradesh and cowpea is cultivated in arid and semi-arid regions. Cowpea is highly responsive to fertilizer application [16]. Cowpea needs very little inputs to grow as cowpea has the capacity to fix nitrogen through its root nodule at about 30 kg ha^{-1}, that's why cowpea is suitable for intercropping as it also gives high income with low input for farmers [17-19]. It has short duration, high yielding and quick growing capacity along with high protein content and palatability. As per report claimed by Indian Council of Medical Research, the per capita availability of pulses in India is 35.5 g day^{-1} as against the minimum requirement of 70 g/day/capita [20].

2. MATERIALS AND METHODS

The present study entitled "Effect of Vermicompost and Biochar on physio-chemical

Table 1. Treatment combination of cowpea

Treatment	Treatment Description
T1	Absolute Control
T2	RDF +Vermicompost @0% + Biochar @50%
T3	RDF + Vermicompost @0% + Biochar @100%
T4	RDF + Vermicompost @50%+ Biochar @0%
T5	RDF + Vermicompost @50% + Biochar @50%
T6	RDF + Vermicompost @50% + Biochar @100%
T7	RDF + Vermicompost@100% + Biochar@0%
T8	RDF + Vermicompost @100%+ Biochar @50%
T9	RDF + Vermicompost @100% + Biochar@100%

properties of soil growth and yield attributes of Cowpea (*Vigna unguiculata* L. Walp)" field experiment was done at Central Research Farm of Department of Soil Science and Agricultural Chemistry, under Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj (Allahabad), Uttar Pradesh, India during Zaid season of 2023. 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 field is situated about 6 km away on the right bank of Yamuna river and falls under subtropical belt in the 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 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 experimental plot was laid down into a randomized block design with 9 treatment replicated thrice, consist of levels of RDF, Vermicompost (0 %, 50% ,100%), 3 levels of Biochar (0 %, 50% ,100%) respectively. In case of all the treatment combination RDF of various levels are applied to maintain and enhance the yield of cowpea.

The experimental area comprises primarily order of Inceptisol, with the soil being predominantly Alluvial. Before any tillage operations, soil samples were collected randomly from five distinct locations within the experimental plot, extracted from a depth of 0-15cm through the help of auger and khurpi. To prepare the soil samples for physical and chemical analysis, the soil samples were undergoing reduction through coning and quartering. Subsequently, the soil samples were air-dried and shifted through a 2mm sieve. The samples were preserved in polythene bags for analysis of various physical and chemical properties. After harvesting of the crop, soil samples are also collected as per different treatment combinations and then brought to laboratory for various physical parameters such as soil texture, soil colour, bulk density, particle density, porosity percentage, water holding capacity and chemical properties such as soil p^H, electrical conductivity, organic matter, available nitrogen, available phosphorus, available potassium.

In physical parameters like that bulk density, particle density, pore space and water holding capacity through method by 100 ml graduated measuring cylinder and process by (Muthuval et al., 1992).

Chemical parameters were analysed through following methods

a. Soil p^H – [21]
b. Soil EC (dS m^{-1}) - (Wilcox, 1950)
c. Organic Carbon (%) – [22].
d. Available Nitrogen (kg ha^{-1}) - Kjeldhal Method [23].
e. Available Phosphorus (kg ha^{-1}) – [24].
f. Available Potassium (kg ha^{-1}) – [25].

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Soil

A data in the Table 2 represents the value of Bulk density, Particle density, Water holding capacity, % Pore space. Soil bulk density and particle density was found non-significant whereas water holding capacity and %pore space were found significant. Bulk density increases with the increase in depth. The maximum data recorded at 0-15cm is 1.3 (Mgm^{-3}) in T1 [Absolute Control] and the minimum data recorded at 0-15 cm depth respectively is 1.268 in T9 [RDF + Vermicompost @100% + Biochar @100%]. Particle density increases with the increase in depth, the maximum data recorded at 0-15 cm depth is 2.55 in T1 [Absolute Control] and the minimum data recorded at 0-15 cm is 2.45 (M gm^{-3}) in T9 [RDF + Vermicompost @100% + Biochar @100%]. The maximum value recorded for water holding capacity was 48.49 at 0-15 cm in T9 [RDF + Vermicompost @100% + Biochar @100%] followed by 48.42 at 0-15 cm respectively in T8 [RDF + Vermicompost @100%+ Biochar @50%] and the minimum value recorded was 46.15 at 0-15cm respectively in T1 [Absolute Control]. The maximum value recorded for % pore space was 52.27 at 0-15 cm respectively in T9 [RDF + Vermicompost @100% + Biochar @100%] followed by 51.89 at 0-15 cm respectively in T8 [RDF + Vermicompost @100% + Biochar @50%] and the minimum value recorded was 43.21 at 0-15cm respectively in T1 [Absolute Control] as given in the Table 2.

3.2 Chemical Properties of Soil

A data in the Table 3 represents the value of soil p^H, EC, % organic carbon.

The maximum p^H of soil 7.05 was found at 0-15 cm in treatment T1 [Absolute Control] and p^H of soil 6.87 was found in treatment T9 [RDF + Vermicompost @100% + Biochar @100%].

The maximum EC value recorded is 0.36 dSm^{-1} in 0-15 cm depth respectively. This value was recorded in T9 [RDF + Vermicompost @100% + Biochar @100%]. The minimum EC value was recorded in T1 [Absolute Control] i.e. 0.32 dSm^{-1} at 0-15cm depth respectively. The maximum value of EC in T9 might be due to the application of 100% inorganic fertilizers which results in an increase in salt content in soil, as soil EC is directly proportional to the nutrient concentration level, and inversely proportional to the depth.

The maximum organic carbon of soil 0.67 was found at 0-15 cm in treatment T9 [RDF + Vermicompost @100% + Biochar @100%] and minimum organic carbon of soil 0.53 was found at 0-15 cm in treatment T1 [Absolute Control] respectively. The increased % organic carbon might be due to the fertilization which indirectly increases the soil organic carbon. Inorganic fertilizers improve the soil organic matter content in the soil by increasing the plant biomass which remains in the field and undergoes decomposition thus increasing the soil organic matter.

The data in the Table 4 represents the value of NPK.

The maximum available nitrogen was recorded 311.60 kg ha^{-1} at 0-15 cm depth in T9 [RDF + Vermicompost @100% + Biochar @100%] followed by 308.93 kg ha^{-1} at 0-15 cm depth in T8 [RDF + Vermicompost @100%+ Biochar @50%] and the minimum value recorded was 286.19 kg ha^{-1} at 0-15 cm depth respectively in T1 [Absolute Control]. The application of RDF together with vermicompost and biochar resulted in significantly increase of nitrogen in soil, it might be due to increased microbial activity leading to the mineralization of nutrients. The increase in the nitrogen content may be due to the synergistic effect of Nitrogen in soil. The maximum available phosphorous 28.27 kg ha^{-1} at 0-15 cm and depth respectively was recorded in T9 [RDF + Vermicompost @100% + Biochar @100%] followed by 26.47 kg ha^{-1} at 0-15 cm depth respectively was recorded in T8 [RDF + Vermicompost @100% + Biochar @50%] and the minimum value recorded was 21.02 kg ha^{-1} at 0-15 cm depth respectively in T1 [Absolute Control]. Phosphorous content increases with the increase in level of NPK whereas it decreases with an increase in level of biochar due to its antagonist effect. The maximum value of available potassium recorded was 182.54 kg ha^{-1} at 0-15cm depth respectively in T9 [RDF+ Vermicompost @100% + Biochar @100%] followed by 177.30 at 0-15cm depth respectively was recorded in T8 [RDF + Vermicompost @100% + Biochar @50%] and the minimum available potassium recorded was 152.49 kg ha^{-1} at 0-15 cm respectively in T1 [Absolute Control].

3.3 Growth Parameters

The data represented in Table 5 represents the value of plant height, no. of pod $plant^{-1}$, weight of pods $plant^{-1}$ and length of pods.

Table 2. Effect of different levels of RDF, Vermicompost and Biochar on physio-chemical properties of soil

Treatments	Bulk Density (Mg m^{-3})	Particle Density (Mg m^{-3})	%pore space	Water holding capacity (%)
T_1	1.32	2.55	43.21	46.15
T_2	1.32	2.51	43.41	47.36
T_3	1.30	2.52	44.63	47.40
T_4	1.30	2.48	45.96	47.50
T_5	1.29	2.43	47.36	48.48
T_6	1.28	2.39	49.69	48.29
T_7	1.29	2.42	51.79	48.35
T_8	1.27	2.41	51.89	48.42
T_9	1.26	2.45	52.27	48.49
F-test	NS	NS	S	S
S.Ed.(+)	0.027	0.072	1.794	1.141

Table 3. Effect of different levels of RDF Vermicompost and Biochar on soil pH electrical conductivity and organic carbon

Treatment	pH	Electrical conductivity	Organic Carbon (%)
T1	7.05	0.32	0.53
T2	7.03	0.33	0.57
T3	7.0	0.33	0.57
T4	6.96	0.32	0.59
T5	6.92	0.34	0.61
T6	6.90	0.34	0.58
T7	6.91	0.35	0.62
T8	6.88	0.35	0.61
T9	6.87	0.36	0.67
F-test	NS	NS	S
S.Ed.(+)	0.180	0.044	0.067

Table 4. Effect of different levels of RDF Vermicompost and Biochar on available NPK

Treatment	Available Nitrogen	Available Phosphorous	Available Potassium
T1	286.19	21.02	152.49
T2	287.78	21.96	155.07
T3	290.67	22.79	155.60
T4	293.03	23.24	158.01
T5	297.57	24.82	161.17
T6	300.65	25.65	166.03
T7	303.64	26.44	170.76
T8	308.93	26.47	177.30
T9	311.60	28.27	182.54
F-test	S	S	S
S.Ed.(+)	1.158	2.437	2.590

At 30 and 60 DAS the plant height recorded was maximum in T9 [RDF + Vermicompost @100% + Biochar @100%] followed by T8 [RDF +Vermicompost @100% + Biochar @50%] and the minimum plant height was recorded in T1 [Absolute Control]. The increase in plant height might be due to the role of organic substances in various physiological activities such as enzyme activation, chlorophyll synthesis, photosynthesis, cell elongation and differentiation which resulted in the vigorous growth of plant.

The maximum no. of pods plant^{-1} was recorded in T9 [RDF + Vermicompost @100% + Biochar @100%]] followed by T8 [RDF + Vermicompost @100% + Biochar @50%] and the minimum no.

of pods plant^{-1} was recorded in T1 [Absolute Control]. An increase in the No. of pods plant^{-1} might be due to an increase availability of organic matter which helps in sufficient absorption of nutrients.

The maximum length of pods plant^{-1} was recorded in T9 [RDF+ Vermicompost @100% + Biochar @100%]] followed by T8 [RDF + Vermicompost @100% + Biochar @50%] and the minimum length of pods plant^{-1} was recorded in T1 [Absolute Control].

The maximum weight of pods (q ha^{-1}) was recorded in T9 [RDF + Vermicompost @100% + Biochar @100%]] followed by T8 [RDF + Vermicompost @100% + Biochar @50%] and the minimum weight of pods (q ha^{-1}) was recorded in T1 [Absolute Control].

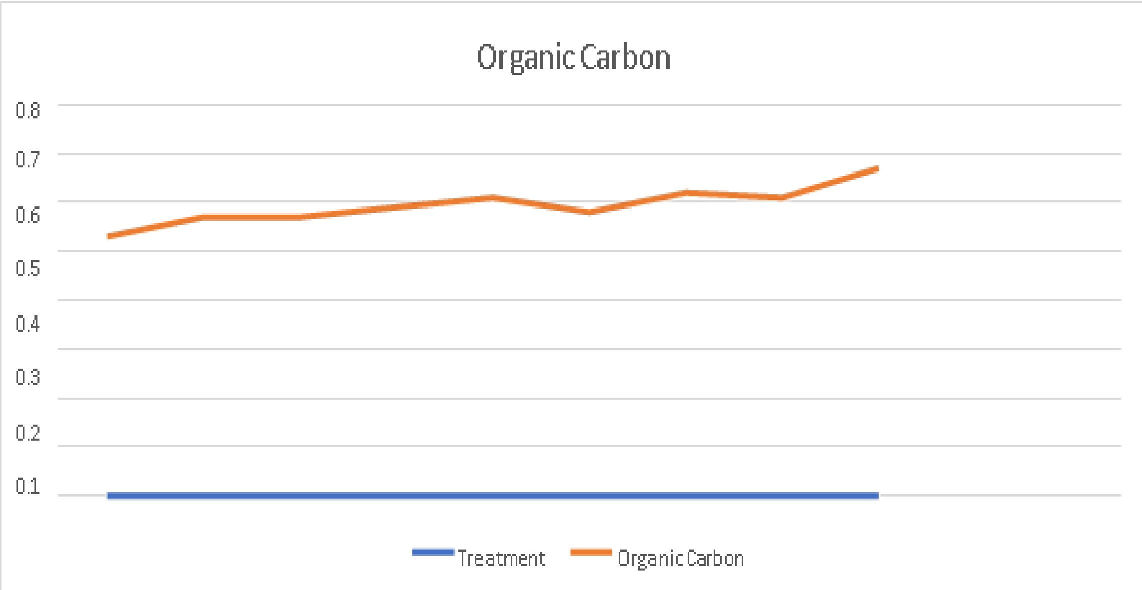

Fig. 1. Effect of RDF vermicompost and biochar on organic carbon

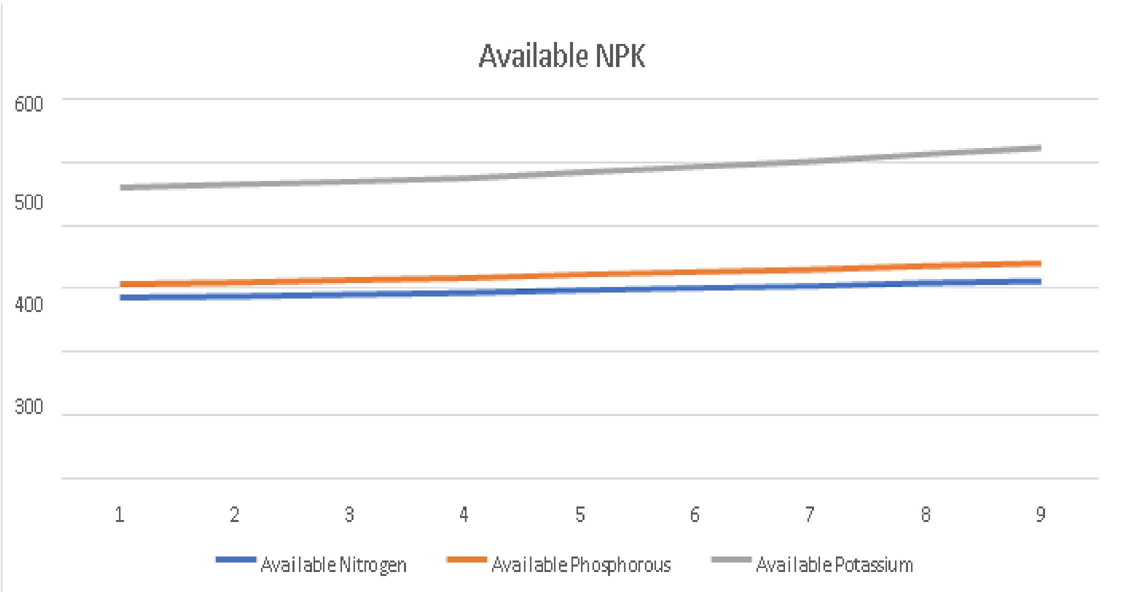

Fig. 2. Effect of vermicompost and biochar on Available nitrogen, phosphorous and potassium

Table 5. Effect of RDF Vermicompost and Biochar on Plant height, No. of pods plant^{-1}, length of pods and weight of pods

Plant height (cm)				**No. of pods Plant^{-1}**		**Length of pods (in cm)**	**Weight of pods (q ha^{-1})**
Treatment No	**Treatment Combination**	**30 DAS**	**60 DAS**	**50 DAS**	**75 DAS**		
T1	Vermicompost @0% (0t ha^{-1}) + Biochar @0% (0t ha^{-1})	18.36	44.59	4.67	10.57	10.73	47.94
T2	Vermicompost @0% (0t ha^{-1}) + Biochar @50% (1.5t ha^{-1})	18.69	44.93	4.90	11.77	10.87	50.69
T3	Vermicompost @0% (0t ha^{-1}) + Biochar @100% (3t ha^{-1})	19.24	46.58	6.10	13.88	11.40	51.57
T4	Vermicompost @50% (2.5t ha^{-1}) + Biochar @0% (0t ha^{-1})	19.56	48.27	5.47	12.33	11.87	53.49
T5	Vermicompost @50% (2.5t ha^{-1}) + Biochar @50% (1.5t ha^{-1})	21.85	50.29	6.87	15.72	13.13	61.27
T6	Vermicompost @50% (2.5t ha^{-1}) + Biochar @100% (3t ha^{-1})	23.69	52.69	9.30	18.38	14.10	58.33
T7	Vermicompost@100% (5t ha^{-1}) + Biochar@0% (0t ha^{-1})	23.93	52.89	8.33	17.36	14.32	64.31
T8	Vermicompost @100% (5t ha^{-1}) + Biochar @50% (1.5t ha^{-1})	26.45	55.47	10.50	20.32	15.17	70.59
T9	Vermicompost @100% (5t ha^{-1}) + Biochar @100% (3t ha $^{-1}$)	28.59	58.37	12.03	21.38	16.57	73.49
	F-test	S	S	S	S	S	S
	S.Ed. (+)	2.380	2.484	0.757	0.319	0.385	1.283

Table 6. Effect of Vermicompost and Biochar on Benefit Cost Ratio (CBR) on different treatment combination of Cowpea Crop: (Selling price of Cowpea (Pod yield) = Rs 1000/q)

Treatment	Yield (q ha- 1)	₹ q-1 yield	Gross return Rs ha-1	Total Cost of Cultivation	Net profit (Rs ha-1)	Benefit Cost Ratio (B:C)
T1	46.94	1000	46940	17800	29140	1:0.9
T2	47.69	1000	47690	18700	28990	1:1.4
T3	49.24	1000	49240	19600	29640	1:1.3
T4	52.93	1000	52930	32800	20130	1:1.2
T5	55.25	1000	55250	33700	21550	1:1.21
T6	62.31	1000	62310	34600	27710	1:1.8
T7	69.27	1000	69270	47800	21470	1:1.96
T8	75.69	1000	75690	49600	26090	1:2.3
T9	79.96	1000	79960	48700	31260	1:2.6

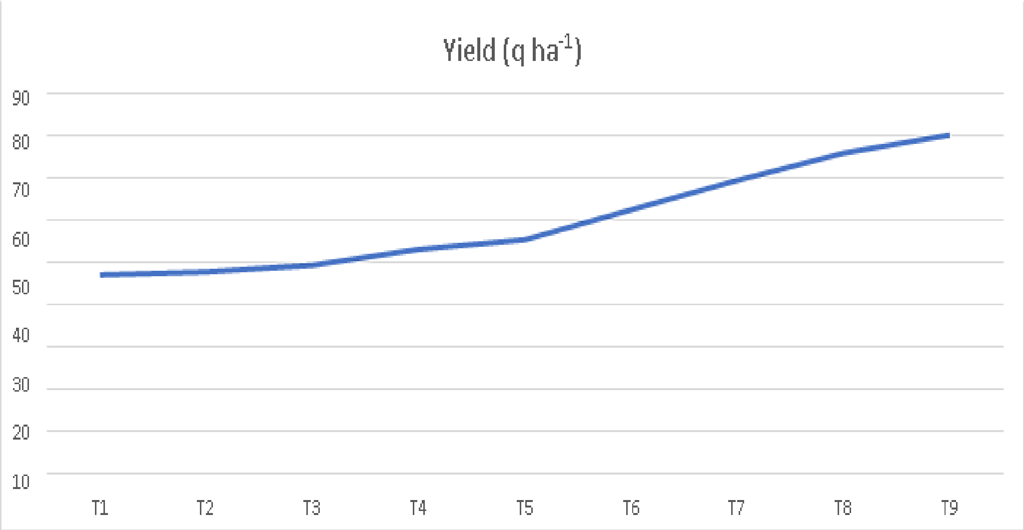

Fig. 3. Effect of different levels of RDF vermicompost and biochar on the yield of cowpea

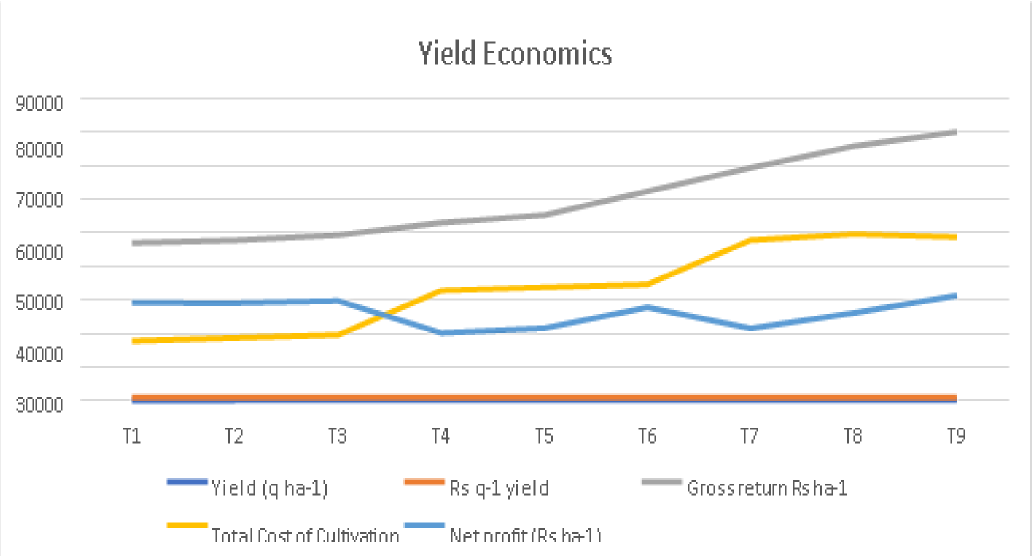

Fig. 4. Effect of different levels of RDF vermicompost and biochar on the yield economics of cowpea

4. CONCLUSION

The experimental results indicated that the application of RDF, Vermicompost and Biochar in treatment T9 (RDF + Vermicompost @100% (5t ha^{-1}) + Biochar @100% (3t ha^{-1})) significantly improved the physio chemical properties of the soil. These improvements included reduction in bulk density, particle density, and p^H, as well as an increase in pore space percentage, water holding capacity, slight enhancement in electrical conductivity, and higher levels of organic carbon and available Nitrogen, Phosphorus, Potassium. Moreover, treatment T9 exhibited the tallest plants and longest pods. Additionally, it recorded the highest number of pods per plant and the highest pod yield weight per hectare compared to other treatments.

The trial results indicated that among the various combinations of RDF, Vermicompost, Biochar levels tested in the experiment, treatment combination comprising T9 (RDF + Vermicompost @100% (5t ha^1) + Biochar @100% (3t ha^{-1})) emerged as the most effective for cultivating Cowpea (*Vigna unguiculata* L. Walp), particularly the KSP-178-Kashi Nidhi variety. This treatment demonstrated superior outcomes for both crop yield and soil physical and chemical properties. Therefore, it is recommended for achieving profitable cowpea production. Implication of integrated nutrient management practices like this can significantly contribute to maintaining soil health and optimizing cowpea yields.

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 manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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