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Impact of integrated nutrient management on physical and chemical properties of soil under the sweet potato-green gram maize cropping system

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Abstract
The research investigation, titled "Integrated Nutrient Management in sweet potato-green gram-maize Cropping System," was conducted at the "Research Farm of Tirhut College of Agriculture" Dr. RPCAU, Dholi, Samastipur (Bihar)" over two cropping seasons, from 2023 to 2024. The experiment was set up in a split-plot design with three main plots and three sub-plot treatments. For sweet potato the main plots having chemical fertilizers namely F_1: RDF (100%) - (100:60:100 kg $N:P_2O_5:K_2O$)/ha, F_2: RDF (125%) - (125:75:125 kg $N:P_2O_5:K_2O$)/ha and F_3: RDF (75%) - (75:45:75 kg $N:P_2O_5:K_2O$)/ha. The sub plots having organic manures namely M_1: FYM @ 15 t/ha, M_2: Vermicompost @ 7.5 t/ha and M_3: No organic manure. The treatments were allocated randomly in each plot. Application of inorganic fertilizers at recommended doses did not significantly affect soil bulk density, water holding capacity, penetration resistance, pH, EC, or organic carbon. Among organic nutrient sources, FYM applied at 15 t ha^{-1} consistently improved soil physical properties by lowering bulk density and penetration resistance while enhancing water holding capacity. Chemical soil properties also benefited from FYM application, as reflected by lower soil pH and EC and higher organic carbon content.

Keywords: Sweet potato, INM, FYM, RDF, electric conductivity, penetration resistance, organic carbon, soil bulk density, water holding capacity

Introduction
The term cropping system denotes “the combination of crops and crop sequences, as well as the management techniques employed on a specific field over a period of years” (Blanco-Canqui and Lal, 2010) [3]. There are numerous agro-climatic conditions in India, which is a diverse country. A single cropping system is incompatible with a variety of agro-climatic conditions. Therefore, it is necessary to select a crop combination that is profitable for the specific farming conditions in order to optimize the cropping system's benefits. To enhance the diversity of crops, it is recommended that oilseed and legume crops be incorporated into cereals to intensify rotations, maintain or improve soil quality, reduce or eliminate tillage and maintain economic profitability of farmers. Rice followed by sweet potato followed by fallow and maize followed by sweet potato followed by fallow are common sequences in Orissa. Sweet potato is typically grown as a rainy or *kharif* season crop in Uttar Pradesh, following pulses or cereal crops. The suggested sequences for Bihar state are maize (kharif) followed by sweet potato followed by onion (Banoth *et al.*, 2025). Such cropping system generates a net income of up to Rs 35,000/ha (CTCRI 1995). Based on the availability of irrigation and economical condition of the farmers, cultivation of multiple crops in the state of Bihar is possible. But the land and labour availability is a concern to go for more number of crops in an agricultural year. In the state of Bihar, the soils are fertile and productive. One sustainable cropping system is required to maintain the soil properties. Sweet potato is a tuber crop with a good productivity in the state of Bihar which is generally grown in south India, particularly along the coast, during the summer after the second crop of rice (Nedunchezhiyan *et al.*, 2010) [5].

Materials and Methods
A field experiment was conducted at the Research Farm of Tirhut College of Agriculture, Dr.

Rajendra Prasad Central Agricultural University, located in Dholi, Muzaffarpur, Bihar, spanning two cropping seasons from 2023 to 2024. The experiment was lay out in split-plot design with three main plots and three sub-plot treatments. Treatments details were clearly depicted in Table. 1. Treatments were assigned randomly within each plot. RDF refers to the Recommended Dose of fertilizers. The plot dimensions measured 4.2 × 4.2 meters, with sweet potato vines planted at the recommended spacing of 30 × 30 cm. The process of ploughing resulted in the land being reduced to a fine tilth and subsequently levelled through levelling techniques. According to the layout, adequate irrigation channel and bund maintenance had been provided. Sweet potato was planted with vine cuttings. A 30 cm vine was taken from the upper portion of an aged vine, possessing 3-4 nodes, and subsequently planted in the field with three nodes buried in the soil. With a spacing of 30 cm × 30 cm, ensuring a uniform distance between plants and rows. Organic manures were applied one week prior to the planting of the sweet potato to ensure complete decomposition. At the time of planting, phosphorus and potassium were applied in full dosage, combined with half the dosage of nitrogen as specified in the treatment. The remaining 50% of nitrogen was applied 30 days post-planting. The evaluations concerning soil properties such as the Soil bulk density, Water holding capacity, Penetration resistance and the soil pH, EC and OC is done. The data generated for these factors underwent statistical analysis to derive logical conclusions.

Table 1: Treatments details of the experiment

Fertilizer (main plots)
F_1: RDF (100%) - (100:60:100 kg N: P_2O_5:K_2O)/ha
F_2: RDF (125%) - (125:75:125 kg N: P_2O_5:K_2O)/ha
F_3: RDF (75%) - (75:45:75 kg N: P_2O_5:K_2O)/ha
Organic manures (sub plots)
M_1: FYM @ 15 t/ha
M_2: Vermicompost @ 7.5 t/ha
M_3: No organic manure

Physical analysis of soil

Soil samples were collected at 0-15 cm depth after harvest to measure soil physical conditions by using the method which has given in Table 2.

Table 2: Methods employed to determine physical analysis of the experimental soil

Parameters	Methods	References
Soil bulk density	Core sampler	Piper,1950 [7]
Water holding capacity	Keen Raczkowski box	Piper,1966 [6]
Penetration resistance	Digital Cone Penetrometer	Ani *et al.* (2009) [1]

Chemical analysis of soil

Soil samples were collected at 0-15 cm depth before and after harvest to determine available nutrient concentration. The samples were then stored appropriately for laboratory analysis. The samples were tested for pH, EC, OC, using the method described in Table 3.

Table 3: Methods employed to determine chemical analysis of the experimental soil

Parameters	Methods	References
pH	Digital pH meter	Jackson, (1958) [4]
EC	Digital EC meter	Wilcox, (1950) [9]
Organic carbon (%)	Walkley and Black Method	Walkley and Black, (1934) [8]

Results and Discussion

The following headings provides an interpretation of the results of the experiment based on the data and statistics that are currently available.

Soil physical properties

The various treatments had a significant impact on the Soil physical properties, as clearly displayed in Table 4.

Soil bulk density

Table 4. shows data related to the bulk density of the soil. The application of varying amounts of chemical fertilizers on the sweet potato crop did not significantly alter the bulk density of the soil in either of the two cropping seasons. However, F_3: RDF (75%)/ha resulted numerically higher soil bulk density in both the experimental years. In the case of organic manure applications, there was no major variations detected across the two cropping seasons. However, treatment with no organic manure produced numerically higher soil bulk density in both the experimental years. The application of organic manure and chemical fertilizers did not have any interaction effects on soil bulk density across both the experimental years.

Water holding capacity (%)

Table 4. shows data related to the water holding capacity of soil. The application of varying amounts of chemical fertilizers on the sweet potato crop did not significantly alter the water holding capacity of soil in either of the two cropping seasons. However, F_2: RDF (125%)/ha resulted numerically higher soil water holding capacity in both the experimental years. In the case of organic manure applications, there was no major variations detected across the two cropping seasons. However, treatment with 15 t FYM/ha produced numerically higher soil water holding capacity in both the experimental years. The application of organic manure and chemical fertilizers did not have any interaction effects on water holding capacity of soil across both the experimental years.

Penetration resistance of soil (Kpa)

Table 4. shows data related to the penetration resistance of the soil. The application of varying amounts of chemical fertilizers on the sweet potato crop did not significantly alter the penetration resistance of the soil in either of the two cropping seasons. However, F_3: RDF (75%)/ha resulted numerically higher soil penetration resistance in both the experimental years. In the case of organic manure applications, there was no major variations detected across the two cropping seasons. However, treatment with no organic manure produced numerically higher soil penetration resistance in both the experimental years. The application of organic manure and chemical fertilizers did not have any interaction effects on soil penetration resistance across both the experimental years.

Table 4: Impact of integrated nutrient management practices on soil physical properties under sweet potato-green gram-maize cropping system.

Treatments	Bulk density (g/cm^3)			Water holding capacity (%)			Penetration resistance (Kpa)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
Fertilizers									
F_1	1.38	1.37	1.37	41.12	42.19	41.66	1383.10	1357.77	1370.43
F_2	1.39	1.36	1.38	41.34	42.63	41.98	1364.34	1338.92	1351.63
F_3	1.38	1.37	1.37	40.54	41.57	41.05	1410.05	1384.58	1397.32
S.Em (±)	0.006	0.005	0.006	0.54	0.59	0.56	39.69	40.17	39.93
LSD (*P*= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Organic manures									
M_1	1.37	1.36	1.36	41.72	43.34	42.53	1354.12	1326.99	1340.56
M_2	1.38	1.37	1.37	41.44	42.38	41.91	1366.92	1338.69	1352.81
M_3	1.39	1.37	1.38	39.84	40.67	40.25	1436.45	1415.59	1426.02
S.Em (±)	0.01	0.01	0.01	0.62	0.69	0.66	22.71	24.44	23.57
LSD (*P*= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS

Soil chemical properties

Soil pH

As stated in Table 5, the pH of the soil was measured at the completion of each cropping season, which occurs after the harvest of maize crop. The use of varied doses of chemical fertilizers to sweet potato resulted in no significant difference in soil pH across either of the cropping seasons. However, F_3:RDF (75%)/ha resulted to a numerically greater soil pH across both the experimental years.

Regarding applications of organic manure, there were no appreciable variations in the soil pH across either of the cropping seasons. However, treatment with no organic manure produced numerically higher soil pH in both the experimental years. The application of organic manure and chemical fertilizers did not have any interaction effects on soil pH across both the experimental years.

EC (dSm^{-1})

As stated in Table 5, the EC (Electric conductivity) of the soil was measured at the completion of each cropping season, which occurs after the harvest of maize crop. The use of varied doses of chemical fertilizers to sweet potato resulted in no significant difference in soil EC across either of the cropping seasons. However, F_3:RDF (75%)/ha resulted to a numerically greater soil EC across both the experimental years. Regarding applications of organic manure, there were no appreciable variations in the soil EC across either of the cropping seasons. However, treatment with no organic manure produced numerically higher EC of soil in both the experimental years. The application of organic manure and chemical fertilizers did not have any interaction effects on soil EC across both the experimental years.

Organic Carbon (%)

As stated in Table 4.5, the organic carbon content of the soil was measured at the completion of each cropping season, which occurs after the harvest of maize crop. The use of varied doses of chemical fertilizers to sweet potato resulted in no significant difference in organic carbon content across either of the cropping seasons. However, F_3:RDF (75%)/ha resulted to a numerically greater soil organic carbon content across both the experimental years. Regarding applications of organic manure, there were no appreciable variations in the organic carbon content across either of the cropping seasons. However, the soil's organic carbon content increased substantially across both cropping seasons after receiving the treatment of 15 t FYM/ha. The application of organic manure and chemical fertilizers did not have any interaction effects on organic carbon content across both the experimental years.

Table 5: Impact of integrated nutrient management practices on pH, EC and OC under sweet potato-green gram-maize cropping system.

Treatments	pH			EC (dSm^{-1})			OC (%)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
Fertilizers									
F_1	8.18	8.13	8.15	0.28	0.30	0.29	0.454	0.463	0.458
F_2	8.15	8.10	8.12	0.26	0.28	0.27	0.455	0.464	0.459
F_3	8.24	8.19	8.21	0.30	0.32	0.31	0.453	0.459	0.456
S.Em (±)	0.06	0.08	0.07	0.009	0.007	0.009	0.002	0.002	0.002
LSD (*P*= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Organic manures									
M_1	8.09	8.04	8.07	0.25	0.26	0.26	0.458	0.467	0.463
M_2	8.15	8.10	8.13	0.27	0.29	0.28	0.453	0.462	0.457
M_3	8.31	8.26	8.29	0.32	0.36	0.33	0.450	0.456	0.453
S.Em (±)	0.07	0.07	0.07	0.02	0.01	0.02	0.010	0.010	0.010
LSD (*P*= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

The results of the two-year field investigation clearly indicate that integrated nutrient management practices exert a positive influence on soil physical and chemical properties under the sweet potato-green gram-maize cropping system. Application of inorganic fertilizers at recommended doses did not significantly affect soil bulk density, water holding capacity, penetration resistance, pH, EC, or organic carbon; however, reduced fertilizer levels (75% RDF) tended to increase soil compaction, penetration resistance, pH, and EC numerically.

Among organic nutrient sources, FYM applied at 15 t ha^{-1} consistently improved soil physical properties by lowering bulk density and penetration resistance while enhancing water holding capacity. Chemical soil properties also benefited from FYM application, as reflected by lower soil pH and EC and higher organic carbon content. The absence of organic manure resulted in deterioration of soil physical condition and reduced organic carbon levels over time.

Overall, the integration of FYM with recommended fertilizer doses proved superior in maintaining soil health and sustainability of the cropping system. Therefore, the combined use of organic manures, particularly FYM, along with balanced chemical fertilization is recommended for sustaining soil quality and productivity under intensive sweet potato-based cropping systems in Bihar.

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Conflict of Interest
I declared that no conflict of interest related to my research. No any external funding involve during the course of experiment and analysis and publication decision.

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