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System productivity of the sweet potato-green gram-maize cropping system under Integrated Nutrient Management (INM)

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Abstract
One cropping system is incompatible with a diverse array of agro-climatic conditions in India. The soils of Bihar are characterized by fertility and productivity. Farmers mostly choose the rice-wheat cropping system, but it reduces crop diversity, which has an effect on the long-term viability of agriculture. This experiment aimed to investigate the impact of integrated nutrient management (INM) on the growth and yield indices of sweet potato, considering the previously mentioned factors. The field experiment took place at the Research Farm of Tirhut College of Agriculture, RPCAU, in Dholi, Muzaffarpur, Bihar, over two cropping seasons from 2023 to 2024. The experiment lay out in split-plot design comprising three main plots and three sub-plot treatments. The three main plots for sweet potato applied chemical fertilizers as follows: 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 experimental subplots involved organic manures: M_1: FYM @ 15 t/ha, M_2: Vermicompost @ 7.5 t/ha, and M_3: No organic manure. Treatments were assigned randomly to each plot. The findings indicated that chemical fertilizer application of F_2: RDF (125%) - (125:75:125 kg N:P_2O_5:K_2O)/ha along with organic manure application of M_1: FYM @ 15 t/ha recorded significantly higher sweet potato equivalent yield of green gram, sweet potato equivalent yield of maize and system productivity in the sweet potato - green gram - maize cropping system.

Keywords: Sweet potato, System productivity, INM, FYM, RDF, sweet potato equivalent yield

Introduction
Sweet potato (*Ipomoea batatas*) is a widely cultivated tuber crop grown in India. It belongs to the *Convolvulaceae* family and is locally known as "Sakar Kand" in India (Shubha *et al*., 2018) [9]. Bihar is a major producer of sweet potatoes due to its fertile soils and favourable climate, making it an important region for its cultivation (Singh *et al*., 2016) [10]. India's varying agro-climatic conditions require sustainable cropping systems that improve productivity and maintain soil health. The rice-wheat cropping system, commonly utilized in Bihar, has led to diminished crop diversity, a decline in soil fertility and a deterioration of soil physical and chemical properties, thereby impacting long-term agricultural sustainability (Nedunchezhiyan *et al*., 2010) [7]. Many research findings have shown that neither mineral fertilizers nor organic sources alone can result in sustainable productivity (Godara *et al*., 2012; Satyanarayana *et al*., 2016; Yadav *et al*., 2021) [1, 8, 12]. Many researchers have concluded the beneficial effect of integrated nutrient management (Mahajan *et al*., 2008) [4] Diversified cropping systems that include leguminous and root crops serve as an effective alternative for enhancing soil health and resource efficiency. The sweet potato-green gram-maize cropping system represents an innovative strategy that improves soil fertility, optimizes nutrient cycling, and enhances economic returns for farmers. Cropping system also generate huge employment (Nedunchezhiyan *et al*. 2008) [6]. Legumes, such as green gram, enhance soil nitrogen content, which positively impacts subsequent crops like maize (Guertal *et al*., 1997) [2]. Furthermore, sweet potato enhances soil structure and facilitates improved nutrient absorption for subsequent crops. Integrated Nutrient Management (INM), which merges chemical fertilizers with organic manures, is acknowledged as an effective approach for sustaining soil health while optimizing crop yield and system productivity (Gunjal,

2019) [3]. Sweet potato converts biological yield into economic yield more efficiently than other crops and produces more biomass per unit area per unit time (Nedunchezhiyan and Byju 2005) [5]. This research evaluates the effect of integrated nutrient management on the productivity of the sweet potato - green gram - maize cropping system.

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. while, spacing for green gram 30 × 10 cm and for maize it is 60 × 20 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. The treatments mentioned in the Table 1. are applicable only to sweet potato crop. Sweet potato was planted in the winter season with vine cuttings, which is followed by the summer green gram and finally the maize crop was grown as kharif crop. 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. 100% recommended dosages of chemical fertilizers (for Bihar) were applied for green gram and maize crop in all the experimental plots. RDF for maize – (120:60:150-N:P:K/ha) and green gram – (20:45:20-N:P:K/ha). Organic manures are not applied for the green gram and maize crop; however, green gram stubbles are not removed from the field before sowing of the maize crop. Regular cultural practices were followed to ensure proper crop development. Sweet potato equivalent yields of green gram and maize was calculated by the economic returns of the green gram and maize divided by the sweet potato price (Rs/kg). System productivity is derived by sum of total of sweet potato yield + sweet potato equivalent yield of green gram + sweet potato equivalent yield of maize.

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

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.

Sweet potato equivalent yield of green gram (t/ha)

The sweet potato equivalent yield of green gram was significantly influenced by the various treatments, as shown in Table 2.

Table 2: Impact of Integrated Nutrient Management (INM) practices on system productivity (t/ha) of sweet potato - green gram - maize cropping system.

Treatments	Sweet potato equivalent yield of green gram (t/ha)			Sweet potato equivalent yield of maize (t/ha)			System productivity (t/ha)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
Fertilizers									
F_1	3.70	3.77	3.74	4.88	5.10	4.99	28.78	29.41	29.09
F_2	4.01	4.15	4.08	5.52	5.64	5.58	31.26	32.37	31.82
F_3	3.46	3.54	3.50	4.54	4.75	4.65	26.63	27.02	26.82
S.Em (±)	0.10	0.10	0.10	0.13	0.12	0.12	0.57	0.60	0.58
LSD (*P*= 0.05)	0.40	0.39	0.39	0.51	0.50	0.50	2.23	2.38	2.31
Organic manures									
M_1	3.92	4.07	3.99	5.38	5.50	5.44	30.71	31.57	31.14
M_2	3.84	3.94	3.89	5.22	5.43	5.33	30.04	30.82	30.43
M_3	3.41	3.47	3.44	4.35	4.55	4.45	25.92	26.41	26.16
S.Em (±)	0.07	0.08	0.08	0.07	0.07	0.07	0.45	0.33	0.39
LSD (*P*= 0.05)	0.22	0.24	0.23	0.20	0.21	0.20	1.40	1.01	1.20
Interaction									
F × M	NS	NS	NS	NS	NS	NS	NS	S	NS

With fertilizer application, the maximum sweet potato equivalent yield of green gram was recorded as 4.01 t/ha and 4.15 t/ha at harvest in both cropping seasons with treatment F_2. While the minimum sweet potato equivalent yield of green gram were recorded as 3.46 t/ha and 3.54 t/ha with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum sweet potato equivalent yield of green gram was recorded as 3.92 t/ha and 4.07 t/ha with treatment M_1 at harvest in both cropping seasons. While the minimum sweet potato equivalent yield of green gram was recorded as 3.41 t/ha and 3.47 t/ha with treatment M_3 at harvest in both cropping seasons. There was no interaction effect observed between chemical fertilizer and organic manure application in both the cropping seasons with the sweet potato equivalent yield of green gram. The F_2 treatment balanced the NPK composition, which made it easier for plants to get and use nutrients, especially nitrogen and phosphorus, which are needed for growth and development. The sweet potato crop left the field in optimal condition, enabling the quick establishment and growth of the newly sown green gram crop. The organic matter in FYM (M_1 treatment) served as a nutrient source for beneficial soil microorganisms. The microbes improved nutrient cycling by

doing things like fixing nitrogen and dissolving phosphorus. This made it easier for the green gram plants to get the nutrients they needed, which increased the seed yield and in turn, the green gram's sweet potato equivalent yield. Gunjal (2019) [3] observed comparable results.

Table 3: Interaction effect of fertilizer levels and organic manures on the system productivity (2023-24) of sweet potato - green gram - maize cropping system.

Treatments	Organic manures			Mean
Fertilizers	M_1	M_1	M_1	
F_1	31.27	30.81	26.16	29.41
F_2	35.58	34.05	27.51	32.37
F_3	27.88	27.63	25.57	27.02
Mean	31.57	30.82	26.41	
S.Em (±)	0.57			
LSD (*P*= 0.05)	1.76			

Significantly higher system productivity in the second cropping season was obtained (Table 3.) in F_2 -125% RDF which receiving M_1-15 t FYM/ha which was statistically similar with F_2M_2 treatment. While, the lowest system productivity was recorded with the F_3M_3. F_2M_1 recorded 39.14% more system productivity then the F_3M_3.

Sweet potato equivalent yield of maize (t/ha)

The sweet potato equivalent yield of maize was significantly influenced by the various treatments, as shown in Table 2. With fertilizer application, the maximum sweet potato equivalent yield of maize was recorded as 5.52 t/ha and 5.64 t/ha at harvest in both cropping seasons with treatment F_2. While the minimum sweet potato equivalent yield of maize were recorded as 4.54 t/ha and 4.75 t/ha with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum sweet potato equivalent yield of maize was recorded as 5.38 t/ha and 5.50 t/ha with treatment M_1 at harvest in both cropping seasons. While the minimum sweet potato equivalent yield of maize was recorded as 4.35 t/ha and 4.55 t/ha with treatment M_3 at harvest in both cropping seasons. There was no interaction effect observed between chemical fertilizer and organic manure application in both the cropping seasons with the sweet potato equivalent yield of maize. The balanced NPK in the F_2 treatment made it easier for plants to get and use nutrients, especially nitrogen and phosphorus, which are needed for growth. The sweet potato crop left the field in optimal condition, facilitating rapid growth of the green gram crop. The cultivation of the green gram enhanced the physical, biological and chemical properties of the soil. The cultivation of green gram enhances soil nitrogen levels, which are crucial for nutrient-demanding crops such as maize. The M_1 treatment supplied organic matter, essential nutrients for beneficial soil microbes. The microbes' nutrient cycling, which included nitrogen fixation and phosphorus solubilization, made more nutrients available for the maize crop, which led to more seeds being produced. The identified factors contribute to an enhancement in the sweet potato equivalent yield of maize. Nedunchezhiyan *et al.* (2010) [7] observed comparable results.

System productivity (t/ha)

The system productivity was significantly influenced by the various treatments, as shown in Table 2. With fertilizer application, the maximum system productivity was recorded as 31.26 t/ha and 32.37 t/ha at harvest in both cropping seasons with treatment F_2. While the minimum system productivity were recorded as 26.63 t/ha and 27.02 t/ha with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum system productivity was recorded as 30.71 t/ha and 31.57 t/ha with treatment M_1 at harvest in both cropping seasons. While the minimum system productivity was recorded as 25.92 t/ha and 26.41 t/ha with treatment M_3 at harvest in both cropping seasons. There was an interaction effect was observed between chemical fertilizer and organic manure application in second the cropping season with the system productivity. The F_2 treatment increased nutrient availability. This resulted in increased crop biomass and improved return of crop residues (roots, shoots and leaves) to the soil. Higher doses of NPK fertilizers improved microbial activity. M_1 treatment is characterized by a high concentration of organic matter. The application resulted in substantial organic residues that decompose over time. The addition of FYM improved microbial activity in the soil ecosystem. This changes also improved soil structure and aggregation, thus safeguarding organic carbon in the soils. The addition of crop residues from green gram, as well as root residues from sweet potato and maize, improved the nutrient content in the soil. These parameters directly enhanced the yields of component crops within the cropping system, thereby improving the overall productivity of the system. Tang *et al.* (2022) [11] as well as Guertal *et al.* (1997) [2] observed comparable results.

Conclusion

Research shows that Integrated Nutrient Management (INM) can improve crop yields as well as system productivity without negatively impacting soil quality or environmental health. INM may provide a greater financial return by generating a higher yield. The study's results show that using FYM organic manure at a rate of 15 t/ha along with RDF 125% - (125:75:125 kg $N:P_2O_5:K_2O$/ha) can result higher sweet potato equivalent yield of green gram, sweet potato equivalent yield of maize and system productivity in the sweet potato - green gram - maize cropping system.

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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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