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Impact of Integrated Nutrient Management (INM) on growth and yield parameters of sweet potato (*Ipomoea batatas*)

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Abstract
Sweet potato is a tuber crop cultivated for its sweet root tubers. The soils in Bihar are both fertile and productive. Nevertheless, intensive agricultural practices depleted the soil. The frequent application of chemical fertilizers caused soil compaction. The current experiment was conducted to examine the effects of integrated nutrient management (INM) on the growth and yield indices of sweet potato, considering the factors mentioned earlier. The field experiment was conducted at the Research Farm of Tirhut College of Agriculture, RPCAU, located in Dholi, Muzaffarpur, Bihar, spanning 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. 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 growth characteristics such as vine length, number of leaves and number of branches per plant, and yield parameters such as the number of tubers per plant, the length of the tuber and the girth of the tuber.

Keywords: Sweet potato, INM, FYM, vermicompost, growth, RDF, yield parameters

Introduction
Sweet potato (*Ipomoea batatas*) is a widely cultivated tuber crop known for its high nutritional value, adaptability to diverse agro-climatic conditions, and economic importance. It belongs to the *Convolvulaceae* family and is locally known as "Sakar Kand" in India (Shubha *et al*., 2018) [12]. 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) [13]. The increasing reliance on chemical fertilizers has led to soil degradation, compaction and a decline in soil fertility, thereby impacting crop productivity (Boru *et al*., 2017) [2]. 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) [4, 10, 14]. Many researchers have concluded the beneficial effect of integrated nutrient management in moderating the deficiency of a number of macros- and micro-nutrients (Mahajan *et al*., 2008; Farah *et al*., 2014; Agegnehu and Amede, 2017) [5, 3, 1]. To address these challenges, Integrated Nutrient Management (INM) has emerged as a sustainable approach that integrates organic and inorganic nutrient sources to enhance soil fertility, improve crop yield and maintain ecological balance (Sheth *et al*., 2018) [11]. INM practices, such as combining farmyard manure (FYM) and vermicompost with recommended doses of fertilizers (RDF), have been reported to enhance plant growth, tuber quality and overall productivity (Satpathy and Singh, 2021) [9]. Previous studies have demonstrated that balanced nutrient application positively influences sweet potato growth parameters, including vine length, number of branches and leaf production, ultimately leading to higher yield (Nedunchezhiyan *et al*., 2010) [7]. 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) [6]. Organic manures improve soil structure,

water-holding capacity, and microbial activity, which further contributes to sustainable sweet potato production (Yadav *et al*., 2021) [14].

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. Regular cultural practices were followed to ensure proper crop development and growth indices (parameters) such as vine length, number of leaves and number of branches per plant. The evaluations concerning yield indicators such as the number of tubers per plant, the length of the tuber and the girth of the tuber. 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

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.

Growth Parameters

The various treatments had a significant impact on the growth parameters of sweet potato, as clearly displayed in Table 2.

Table. 2: Impact of Integrated Nutrient Management (INM) practices on growth indices of sweet potato crop at harvest.

Treatments	Growth indices (At harvest)								
	Vine length (cm)			Number of branches per plant			Number leaves per plant		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
Fertilizers									
F_1	162.89	166.49	164.69	6.50	6.62	6.56	48.06	50.98	49.52
F_2	180.87	184.57	182.72	7.25	7.45	7.35	54.97	59.01	56.99
F_3	150.58	154.08	152.33	6.04	6.28	6.16	46.17	49.49	47.83
S.Em (±)	5.47	5.50	5.49	0.16	0.16	0.16	1.53	1.45	1.49
LSD (*P*= 0.05)	21.50	21.61	21.55	0.63	0.63	0.63	6.00	5.69	5.85
Organic manures									
M_1	175.89	178.56	177.22	7.02	7.36	7.19	52.95	56.64	54.80
M_2	171.89	175.68	173.78	6.89	7.00	6.94	51.53	54.92	53.23
M_3	146.56	150.89	148.72	5.89	5.98	5.93	44.73	47.92	46.32
S.Em (±)	4.58	4.62	4.60	0.11	0.12	0.12	1.23	1.20	1.22
LSD (*P*= 0.05)	14.09	14.22	14.15	0.34	0.37	0.35	3.79	3.70	3.74
Interaction									
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS

Length of the vine (cm)

The length of the vine of sweet potato was significantly influenced by the various treatments, as shown in Table 2. With fertilizer application, the maximum length of the vine was recorded as 180.87 cm and 184.57 cm at harvest in both cropping seasons with treatment F_2. While the minimum length of the vine were recorded as 150.58 cm and 154.08 cm with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum length of the vine was recorded as 175.89 cm and 178.56 cm with treatment M_1 at harvest in both cropping seasons. While the minimum length of the vine was recorded as 146.56 cm and 150.89 cm 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 on length of the vine. F_2 increased vine length for a number of reasons. Sweet potato vines require NPK nutrients from the beginning, which this treatment provides. This early and sufficient supply of NPK nutrients helps cells grow, divide and do meristematic activity, which makes vines longer. The M_1 treatment increases organic matter and nutrients in the soil, which improves the physical, chemical and biological conditions for crop growth. This eventually increased the length of the sweet potato vine. Boru *et al.* (2017) [2] found similar results for length of the vine of sweet potato.

Number of branches per plant

The number of branches per plant was significantly influenced by the various treatments, as shown in Table 2. With fertilizer application, the maximum number of branches per plant was recorded as 7.25 cm and 7.45 cm at harvest in both cropping seasons with treatment F_2. While the minimum number of

branches per plant was recorded as 6.04 cm and 6.28 cm with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum number of branches per plant was recorded at 7.02 cm and 7.36 cm with treatment M_1 at harvest in both cropping seasons. While the minimum number of branches per plant was recorded at 5.89 cm and 5.98 cm 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 on number of branches per plant. F_2 treatment provides an adequate supply of NPK nutrients during the initial stage, essential for the growth of sweet potato vines. Increased nutrient concentrations facilitate the development of lateral shoots and branching by stimulating meristematic activity in the plant. The M_1 treatment supplies adequate nutrients to facilitate vegetative growth, encompassing the development of lateral branches. FYM promotes plant growth by enhancing soil health, ensuring a steady nutrient supply, and establishing favourable environmental conditions for the branching and development of sweet potato. This resulted in a higher number of branches per plant in sweet potato. Satpathy and Singh (2021) [9] observed comparable results regarding the number of branches per plant in sweet potato.

Number leaves per plant

The number of leaves per plant was significantly influenced by the various treatments, as shown in Table 2. With fertilizer application, the maximum number of leaves per plant was recorded as 54.97 cm and 59.01 cm at harvest in both cropping seasons with treatment F_2. While the minimum number of leaves per plant was recorded as 46.17 cm and 49.49 cm with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum number of leaves per plant was recorded at 52.95 cm and 56.64 cm with treatment M_1 at harvest in both cropping seasons. While the minimum number of leaves per plant was recorded at 44.73 cm and 47.92 cm 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 on number of leaves per plant. NPK fertilizers from treatment F_2 supply nitrogen for chlorophyll, phosphorus for ATP and potassium for stomatal regulation to boost photosynthesis. Photosynthetic activity and adequate nutrients produce lush, dense foliage by producing new shoots and leaves. The M1 treatment promotes long-term vegetative growth and the formation of more leaves by releasing nutrients gradually and consistently. This makes the sweet potato plant stronger and allows more time for vegetative growth, resulting in more leaves. Sheth *et al.* (2018) [11] found similar things regarding number of leaves per sweet potato plant.

Yield Parameters

The various treatments had a significant impact on the yield parameters of sweet potato, as clearly displayed in Table 3.

Number of tubers per plant

The number of tubers per plant was significantly influenced by the various treatments, as shown in Table 3. With fertilizer application, the maximum number of tubers per plant was recorded as 5.12 cm and 5.40 cm at harvest in both cropping seasons with treatment F_2. While the minimum number of tubers per plant was recorded as 4.07 cm and 4.53 cm with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum number of tubers per plant was recorded at 5.00 cm and 5.30 cm with treatment M_1 at harvest in both cropping seasons. While the minimum number of tubers per plant was recorded at 3.93 cm and 4.62 cm 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 on number of tubers per plant.

Table. 3: Impact of Integrated Nutrient Management (INM) practices on yield indices of sweet potato crop at harvest.

Treatments	Yield indices (At harvest)								
	Number of tubers per plant			Length of the tuber (cm)			Girth of tubers (cm)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
Fertilizers									
F_1	4.48	5.13	4.81	13.88	14.49	14.18	15.90	16.09	16.00
F_2	5.12	5.40	5.26	15.59	16.65	16.12	16.60	17.45	17.03
F_3	4.07	4.53	4.30	13.33	14.18	13.76	14.26	15.66	14.96
S.Em (±)	0.17	0.16	0.17	0.30	0.37	0.34	0.45	0.32	0.32
LSD (*P*= 0.05)	0.69	0.65	0.67	1.20	1.49	1.34	1.78	1.28	1.28
Organic manures									
M_1	5.00	5.30	5.15	15.03	15.87	15.45	16.49	17.19	16.84
M_2	4.75	5.15	4.95	14.76	15.41	15.08	16.31	16.92	16.61
M_3	3.93	4.62	4.27	13.01	14.04	13.52	13.96	15.09	14.52
S.Em (±)	0.12	0.14	0.13	0.24	0.18	0.19	0.42	0.23	0.28
LSD (*P*= 0.05)	0.37	0.43	0.39	0.73	0.54	0.57	1.29	0.71	0.85
Interaction									
F × M	NS	NS	NS	NS	NS	NS	NS	NS	NS

The F_2 treatment increased the number of tubers per plant due to a variety of factors. The plant received a nutritious supply of essential nutrients from this treatment. A well-fed plant grows widespread roots. Since sweet potato tubers are modified roots, root proliferation directly increases number of tuber production. The M_1 treatment increased soil physical condition. This increased root penetration, allowing the plant to access more soil for nutrients and water. The FYM ensured consistent moisture for tuber initiation and growth, increasing number of tuber production per plant. Nedunchezhiyan *et al.* (2010) [8] found similar things regarding numbers of tuber per plant in sweet potato.

Length of the tuber (cm)

The length of the tuber was significantly influenced by the various treatments, as shown in Table 3. With fertilizer

application, the maximum length of the tuber was recorded as 15.59 cm and 16.65 cm at harvest in both cropping seasons with treatment F_2. While, the minimum length of the tuber was recorded as 13.33 cm and 14.18 cm with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum length of the tuber was recorded as 15.03 cm and 15.87 cm with treatment M_1 at harvest in both cropping seasons. While the minimum length of the tuber was recorded as 13.01 cm and 14.04 cm 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 on length of the tubers of sweet potato. F_2 increased tuber length for several reasons. Phosphorus helps roots develop, laying the groundwork for tuber growth. Balanced NPK fertilizers optimized leaf growth, sunlight absorption and photosynthetic efficiency. The tubers grew by moving these assimilated energy. M_1 (FYM) improved soil physical, chemical and biological properties. These included EC, pH, porosity, microbial activity and water retention. Under these improved soil conditions, tubers grew larger, broader and longer without difficulty. Similar results were found by Nedunchezhiyan *et al.* (2010) [7] on sweet potato tuber length.

Girth of tubers (cm)

The girth of the tubers was significantly influenced by the various treatments, as shown in Table 3. With fertilizer application, the maximum girth of the tubers was recorded at 16.60 cm and 17.45 cm at harvest in both cropping seasons with treatment F_2. While, the minimum girth of the tubers was recorded as 14.26 cm and 15.66 cm with treatment F_3 at harvest in both cropping seasons. In the case of organic manure application, the maximum girth of the tubers was recorded at 16.49 cm and 17.19 cm with treatment M_1 at harvest in both cropping seasons. While the minimum girth of the tubers was recorded at 13.96 cm and 15.09 cm 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 on girth of the tubers of sweet potato. Many elements raised tuber girth under F_2 treatment. Phosphorus promoted root development, providing the foundation for tuber growth. Fertilizers with balanced NPK increased leaf area and photosynthesis efficiency. Once translocated and assimilated energy, tuber size grew. The M_1 treatment raised water retention, porosity and soil aeration. This improved soil structure resulted in larger, more widely dispersed tubers, enabling them to grow and expand without any issues. FYM provided a consistent release of organic nitrogen, phosphorus, potassium and micronutrients. These nutrients encouraged cell division and elongation, thus enhancing the girth of sweet potato. Similar results were found by Nedunchezhiyan *et al.* (2010) [8] on sweet potato tuber length.

Conclusion

Research shows that Integrated Nutrient Management (INM) can improve crop yields as well as growth parameters 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 improve the growth and yield parameters of sweet potato crop.

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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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