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Effects of planting methods and integrated nutrient management on yield, nutrient uptake, and soil nutrient availability in finger millet (*Eleusine coracana* G.)

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Abstract
A field experiment was conducted in Settividuthi village, Pudukkottai district, Tamil Nadu, from April to August 2020, to study the effects of integrated nutrient management and planting techniques on the yield, nutrient uptake, and soil nutrient availability of finger millet (*Eleusine coracana* G.). A total of eighteen treatments were evaluated in a split plot design with three replications. The sub-plot treatments consisted of six nutrient management techniques, whereas the main plot treatment comprised planting techniques. Results indicated that the primary plot treatment, utilizing the SRI planting technique, achieved higher grain yield and nutrient uptake. In the planting methods, the SRI method yielded a grain output of 3244 kg/ha and a straw output of 6320 kg/ha, that were significantly higher than those from conventional transplanting and direct sowing. With respect to nutritional availability, there was no significant difference among the planting methods regarding the soil's available NPK, organic carbon content, and microbial population after harvest. The direct sowing method, however, yielded numerically higher values of soil available NPK, organic carbon content, and microbial population in post-harvest soil. The treatment of the sub-plot that leads to maximum finger millet yield, nutrient uptake, and availability is 75% RDF combined with pressmud at a rate of 25 kg/ha and seaweed extract granules at the same rate. Under the control plot (S_1), the nutrient uptake was observed to be the lowest.

Keywords: SRI method, split plot design, finger millet, nutrients uptake

Introduction

Millets have the capacity to guarantee food and nutritional security and are among the foods that show promise in the fight against hunger and malnutrition. India is the world's greatest producer of a variety of millets, with finger millet accounting for almost 85% of all millets produced (Divya, 2011) [4]. The term "nutritious millet" is frequently used to describe finger millet (*Elusine coracana* L. Gaertn). Continuous cropping, poor crop stands under direct sowing, low mineral fertilizer use, low rates of organic matter application, improper cultivation techniques, etc., all contribute to finger millet's lower production.

One of the key agronomic techniques to increase the output of finger millet crops is planting technique. In order to ameliorate the situation of impoverished households in Madagascar that farm rice, the System of Rice Intensification (SRI) was created in the 1980s (De Laulanie, 1993) [3]. The finger millet crop, known as the System of Ragi Intensification, was developed using the same ideas. By improving the efficiency of applied nutrients, correcting marginal deficiencies of secondary and micronutrients, and creating favorable soil physical conditions, the combined use of organic manures and inorganic fertilizers in integrated nutrient management helps to maintain yield stability (Gill and Walia, 2014) [5]. Applying pressmud improves the soil and provides an alternative supply of crop nutrients. It is also a valuable source of organic manure. Because it is high in sugar and includes a significant number of vital plant nutrients, it is utilized to preserve soil fertility and improve agricultural yields (Banulekha, 2007) [1]. The amount of garbage that is transported to landfills is decreased, environmental pollution and degradation are reduced, and agricultural land productivity is raised when organic fertilizer made from urban solid wastes is used for crop production and soil rehabilitation. Seaweed extracts may benefit agriculture through a number of mechanisms, including improved photosynthetic efficiency and carbon assimilation, delayed senescence, antimicrobial, anti-feedant, and insect repellent properties, decreased transpiration, improved stomatal conductance, modulation of root exudates, and effective uptake of water and nutrients (Khan *et al*., 2009) [10]. One natural resource that shows promise for usage as a substitute to boost crop yields is humic acid (HA). Found in soil, peat, and lignite's, it is a naturally occurring polymeric organic molecule that is created when organic materials decompose (Sharif *et al*., 2002) [15].

Materials and Methods

A field experiment was conducted from April to August 2020 (Chiththirai Pattam) in Settividuthi village, Pudukkottai district, Tamil Nadu, India, to investigate how planting practices and integrated nutrient management affect finger millet yield, nutrient uptake, and availability. Situated at a latitude of 10°24'N and a longitude of 79°45'E, the field experiment is positioned 88 meters above mean sea level. Outside of the monsoon season, the town experienced a dry environment with minimal precipitation. The ragi crop was watered with 36.30 mm of rain over six days of rain. The mean temperature is 34.12 °C, with a maximum temperature ranging from 31.65 °C to 36.95 °C. With a mean of 27.57 °C, the minimum temperature falls between 25.91 °C and 28.91 °C. The mean relative humidity is 66 percent, with a range of 58 to 79 percent. The experimental field's soil type was sandy clay loam. The soil had medium levels of accessible P, high levels of available K, and low levels of available N. Split plot design was used for the experiment, which was reproduced three times using three primary plot treatments: M_1 (direct sowing), M_2 (conventional planting, or transplanting), and M_3 (System of Ragi Intensification). S_1- Control (no organic or inorganic fertilizers), S_2- 100% RDF (Recommended fertilizer dose), S_3-75% RDF + Pressmud @10t ha^{-1} + humic acid granules @25 kg ha^{-1}, S_4-75% RDF + town compost @10t ha^{-1} + humic acid granules @25 kg ha^{-1}, S_5-75% RDF + Pressmud @10t ha^{-1} + seaweed extract granules @25 kg ha^{-1}, and S_6-75% RDF + town compost @10t ha^{-1} + seaweed extract granules @25 kg ha^{-1} are the six subplot treatments. Finger millet variety CO 15 was utilized as the test variety. The direct sown approach involved using the sow method to plant the recommended number of seeds at a spacing of 22.5 cm × 10 cm. In traditional planting, aged ragi seedlings were moved to their designated plots with two or three seedlings per hill, and they were spaced 30 cm apart by 10 cm. In the mat nursery, fifteen-day-old ragi seedlings were transplanted with one seedling hill-1 and a 25 cm x 25 cm spacing for the SRI method. After being gathered from the Arignar Anna sugar mills in Kurunkulam, Thanjavur district, Tamil Nadu, the pressmud was placed in a shaded area to cure. It was employed in the experiment in accordance with the treatment plan six months later. In accordance with the treatment schedule, the town compost was applied to experimental plots after being gathered from Karambakkudi municipality in Pudukkottai District. Granular fertilizers, specifically humic acid and seaweed extract granules, were applied using eM Power and BIOVITA granules, respectively. When the ragi crop was transplanted or sown, both granular fertilizers were applied basally in accordance with the treatment schedule. Biometrical observations of finger millet yield, nutrient availability, and nutrient uptake in post-harvest soil were documented. As recommended by Panse and Sukhatme (1978) [11], statistical analysis was performed on the experiment data.

Table 1: Experimental details

Particulars	Experiment
Season	April - August 2020
Gross plot area	5 × 4 m
Net plot area	4.55 × 3.8 m (Direct sown method) 4.4 × 3.8 m (Conventional method) 4.5 × 3.5 m (SRI method)
Design	Split plot
Replication	Three

Table 2: Nutrient composition of pressmud and town compost

Nutrient content	Nitrogen (%)	Phosphorous (%)	Potassium (%)
Pressmud	1.24	0.93	0.87
Town compost	0.96	0.65	0.72

Results and Discussion

Yield

The yield potential of ragi is significantly influenced by planting method and integrated nutrient management.

The SRI-grown ragi crop produced a considerably greater grain yield (3244 kg ha^{-1}) and straw yield (6320 kg ha^{-1}) than the other planting methods. The intricate link between vegetative phase growth and yield parameters also affects yield. Better crop growth and development led to improved yield qualities, which in turn had a direct impact on grain production, resulting in higher yield under the SRI approach. Jayadeva *et al*. (2008) [8] have reported similar results.

Plots treated with 75% RDF + pressmud @ 10 t ha^{-1} + seaweed granules @ 25 Kg ha^{-1} (S_5) showed considerably greater grain yields of 3730 Kg ha^{-1} and straw yields of 6722 Kg ha^{-1} among the different INM treatments. This may be because pressmud provides plants with a balanced pattern of nutritional release, including nutrients that are readily absorbed by plants, such as soluble K, exchangeable Ca, Mg, and P, as well as available N (Harikesh *et al*., 2017) [6]. Additionally, increased microbial diversity and activity, as well as higher uptake of essential plant nutrients, enhanced photosynthesis activity, which in turn improves the translocation of phtotosynthates from source to sink, leading to higher grain and straw yields.

Planting techniques and integrated nutrient management techniques have a substantial interaction effect. The maximum grain yield of 4155 kg ha^{-1} and straw yield of 7100 kg ha^{-1} were recorded by the SRI technique treatment combination with application of 75% RDF + pressmud @ 10 t ha^{-1} + seaweed extract granules @ 25 kg ha^{-1} (M_3S_5). These may have been caused by less plants per unit area and wider spacing, which led to increased root volume, length, and dry weight with abundant nutrient availability, light intensity, and water availability. This allowed the plant to efficiently extract nutrients from a larger volume of soil using the SRI method, which in turn produced higher grain and straw yields (Sathya *et al*., 2013) [14].

Nutrient uptake

Planting techniques have a major impact on the ragi crop's nutrient uptake. The SRI approach showed a significantly higher uptake of NPK among the planting techniques. Taller plants and more biomass in this treatment may be the cause of this, as these factors directly affect nutrient intake. This is further explained by the fact that immature seedlings cultivated using the SRI approach developed a deeper and more extensive root system, which led to a better nutrient uptake (Barison, 2002) [2]. Additionally, the SRI creates soil conditions that are favorable for several soil microorganisms and mycorhizal fungi, which improve the plant's uptake of nutrients (Uphoff and Randriamiharisoa, 2002) [17]. The direct sowing approach was used to record the reduced NPK uptake. This might be related to faulty root growth, which has poor efficiency in the uptake of applied and native soil nutrients, resulting in decreased uptake of nutrients.

Plots treated with 75% RDF + pressmud @ 10 t ha^{-1} + seaweed extract granules @ 25 kg ha^{-1} (S_5) showed significantly higher NPK uptake in comparison to other INM practices. This was primarily because the combined application of inorganic fertilizer and pressmud had improved the soil environment and encouraged the proliferation of the root system, which resulted in better absorption of water and nutrients from the deeper layer and consequently higher DMP, which in turn had a direct reflection in NPK uptake. Additionally, seaweed extract granules contain bioactive compounds, primary and secondary nutrients, and other components that help plants absorb nutrients from the soil by promoting the growth of roots and improving the root-to-shoot ratio. Under control, N, P, and K intake was the lowest (S_1).

Nutrient uptake was significantly impacted by the relationship between planting techniques and nutrient management strategies. The maximum uptake of NPK was seen in the ragi crop grown by SRI planting with plots receiving 75% RDF + pressmud 10 t ha^{-1} + seaweed extract granules 25 kg ha^{-1} (M_3S_5). Higher root growth and a larger amount of soil available for individual hills to absorb nutrients under wider spacing are the reasons for the higher nutrient uptake in crops that are widely spaced. Jacob and Syriac have also shown higher nutrition uptakes at wider spacing (2005) [7].

Additionally, the combination of inorganic fertilizers, organic manure, and biostimulants has made enough readily available plant nutrients available during crucial crop growth periods. This has led to proper nutrient absorption, translocation, and assimilation, which has increased the plant's dry matter accumulation and nutrient contents and, consequently, its uptake of elemental nutrients. Patil *et al.* (2018) [12] have also obtained similar results.

Availability of NPK

The amount of N, P, and K in the post-harvest soil was not significantly impacted by the various planting procedures. Nevertheless, postharvest soil study showed that the direct seeded approach registered quantitatively greater values. In comparison to other planting techniques, this may be because of the inadequate root system development, which results in less nutrient uptake by ragi plants and a higher availability of NPK in post-harvest soil. Using the SRI planting approach resulted in numerically low values of post-harvest soil accessible nutrients (N, P, and K). This could be because improved root growth allows the crop to remove the most nutrients possible, which results in low NPK status in post-harvest soil (Revathi *et al.*, 2012) [13].

Plots treated with 75% RDF + pressmud @ 10 t ha^{-1} + seaweed extract granules @ 25 kg ha^{-1} showed greater values for accessible N, P, and K in post-harvest soil (S_5). The beneficial role of pressmud and inorganic fertilizer in mineralizing native soil and its nutrient content by fostering favorable conditions for microbial and chemical activities that increased the soil's available nutrient pool may be responsible for the notable increase in the soil's available nitrogen, phosphorus, and potassium content following crop harvest. The soil's available nutrient status increases after the crop is harvested because not all of the available nutrients are absorbed by the plant; some stay in the soil. These outcomes were consistent with Jha *et al.* (2001) [9] findings. Furthermore, seaweed extracts contain phyto-hormones, minerals, vitamins, amino acids, and enzymes that improve the availability of both native and added nutrients in post-harvest soil. In post-harvest soil accessible N, P, and K, the interaction effect between the main and sub-plots was not found to be significant.

Table 3: Effect of methods of planting and integrated nutrient management on yield, nutrient uptake and availability of finger millet

Treatment	Yield (kg ha^{-1})		Nutrient uptake (kg ha^{-1})			Availability (kg ha^{-1})		
	Grain	Straw	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Methods of planting								
M_1	2417	5414	53.19	15.96	41.34	213.73	29.77	271.50
M_2	2861	6052	62.93	18.88	48.92	212.72	29.05	268.77
M_3	3244	6320	71.37	21.41	55.47	211.87	28.86	266.97
S.Em±	95	114	2.83	0.79	2.19	0.66	0.57	0.74
CD (P=0.05)	347	338	6.55	1.85	4.96	NS	NS	NS
Integrated nutrient management								
S_1	1480	4328	32.57	9.77	25.31	203.31	24.71	262.83
S_2	2357	5651	51.85	15.56	40.30	206.61	26.56	267.45
S_3	3357	6423	73.86	22.16	57.41	217.47	31.72	272.48
S_4	2887	6119	63.51	19.05	49.37	213.80	28.04	266.89
S_5	3730	6722	82.06	24.62	63.78	219.20	33.49	275.21
S_6	3233	6329	71.12	21.34	55.28	215.58	29.83	269.63
S.Em±	56	96	2.18	0.63	1.25	0.59	0.62	0.84
CD (P=0.05)	293	229	5.74	1.58	3.57	1.80	1.85	2.80
Interaction M x S								
M_1S_1	1105	3783	24.31	7.29	18.90	204.34	24.38	264.87
M_1S_2	1968	5035	43.30	12.99	33.65	207.54	27.95	269.07
M_1S_3	2897	5969	63.73	19.12	49.54	218.01	32.53	275.22
M_1S_4	2482	5490	54.60	16.38	42.44	214.52	28.85	269.62
M_1S_5	3261	6332	71.74	21.52	55.76	219.73	34.28	277.87
M_1S_6	2792	5876	61.42	18.43	47.74	216.16	30.63	272.40
M_2S_1	1494	4384	32.87	9.86	25.55	203.31	25.42	262.82
M_2S_2	2358	5925	51.88	15.56	40.32	206.18	26.82	267.46
M_2S_3	3381	6467	74.38	22.31	57.82	217.74	31.46	272.02

M_2S_4	2878	6414	63.32	18.99	49.21	213.75	27.77	266.38
M_2S_5	3774	6735	83.03	24.91	64.54	219.52	33.26	274.81
M_2S_6	3279	6388	72.14	21.64	56.07	215.85	29.57	269.13
M_3S_1	1842	4816	40.52	12.16	31.50	202.29	24.35	260.82
M_3S_2	2745	5994	60.39	18.12	46.94	206.11	27.92	265.82
M_3S_3	3794	6832	83.47	25.04	64.88	216.65	31.17	270.22
M_3S_4	3301	6452	72.62	21.79	56.45	213.13	27.52	264.67
M_3S_5	4155	7100	91.41	27.42	71.05	218.35	32.95	272.97
M_3S_6	3627	6723	79.79	23.94	62.02	214.72	29.30	267.37
S.Em±	233	176	4.96	1.24	3.26	2.96	1.83	2.97
CD (P=0.05)	586	583	10.49	3.39	7.52	NS	NS	NS

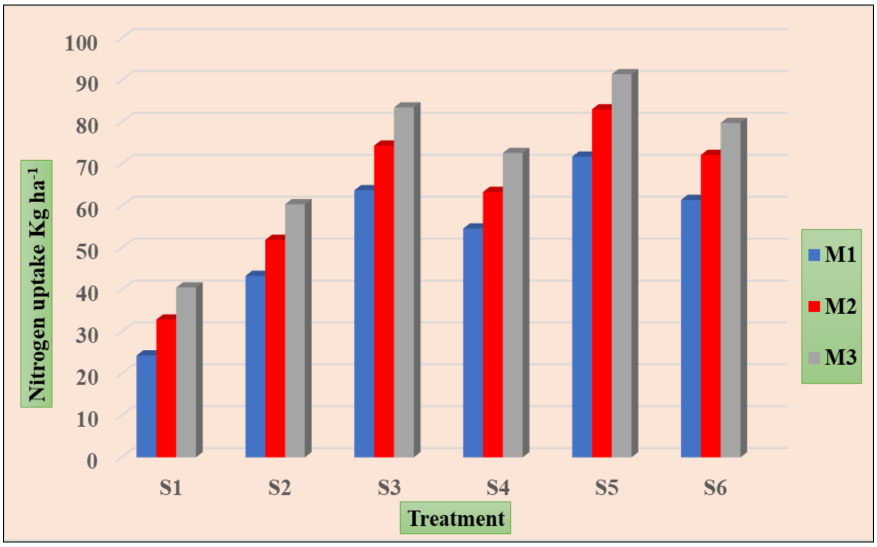

Fig 1: Effect of methods of planting and INM practices on nitrogen uptake kg ha^{-1} in ragi

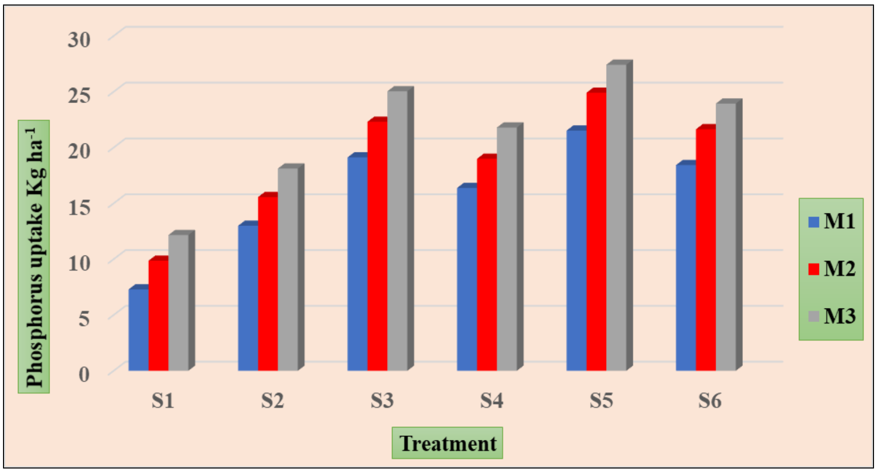

Fig 2: Effect of methods of planting and INM practices on phosphorus uptake kg ha^{-1} in ragi

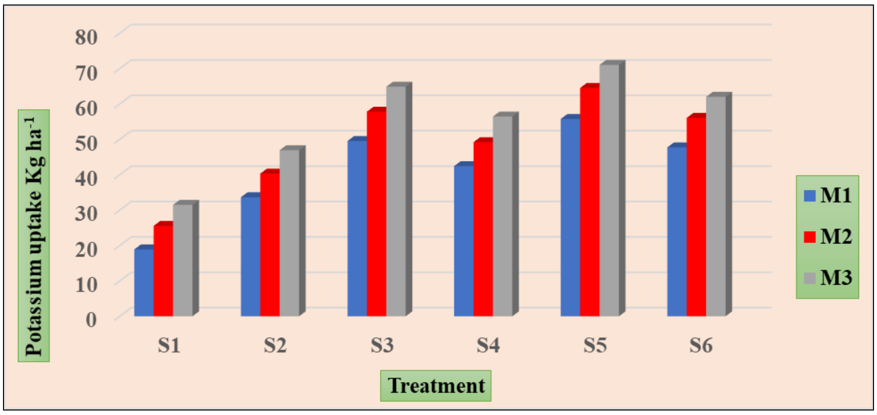

Fig 11: Effect of methods of planting and INM practices on potassium uptake kg ha^{-1} in ragi

Conclusion
The study unequivocally showed that, in comparison to traditional transplanting and direct sowing methods, the System of Ragi Intensification (SRI) method greatly increased the grain and straw yield as well as nutrient uptake when combined with 75% RDF, pressmud at 10 t ha^{-1}, and seaweed extract granules at 25 kg ha^{-1}. Better crop production and soil health were a result of this integrated approach's balanced nutrient availability, increased microbial activity, and improved root growth. The SRI approach outperformed direct sowing in terms of total productivity and nutrient usage efficiency, despite the latter showing slightly higher post-harvest nutrient availability.

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Conflict of Interest
The authors declare that they have no conflict of interest.

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