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Long-term Effect of Integrated Nutrient Management Practices on Growth, Yield and Nutrient Uptake of Finger Millet (*Eleusine coracana* G.) in *Alfisols* under Different Cropping Systems

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Authors' contributions

This work was carried out in collaboration between all authors. Author Shilpa designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BGV managed the analyses of the study. Author HMM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to study the effect of long-term integrated nutrient management (INM) on growth, yield and nutrient uptake of rainfed finger millet during *kharif* 2019 at field unit of All India Co-ordinated Research Project for Dryland Agriculture at University of Agricultural Sciences, Bangalore, India. The experimental plot in the field was laid out in a randomized complete block design (RCBD) with 10 treatments and four replications. Growth parameters such as plant height (112.44 cm), number of productive tillers per hill (4.75), number of ear heads per hill (4.49), number of fingers per ear head (7.25), total dry matter production per hill (77.39 g) and yield parameters like grain yield (28.27 q ha^{-1}) and straw yield (32.63 q ha^{-1}) were found to be higher with application of FYM @10 t ha^{-1} + 100% RDF under finger millet- groundnut rotation (T_9). Similarly, T_9 also recorded higher uptake of nitrogen (37.03 and 26.40 kg ha^{-1}), phosphorus (6.78 and 4.57 kg ha^{-1}) and potassium (30.17 and 48.68 kg ha^{-1}) in grain and straw of finger millet, respectively. It

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implies that INM over long period of time tend to supply the plants with sufficient amount of essential nutrient elements while creating favourable physico-chemical properties of soil for healthy environment. It also safeguards soil nutrient balance in long term to an optimum level for sustaining the desired crop productivity.

Keywords: Alfisols; finger millet; INM; long-term.

1. INTRODUCTION

Finger millet is grown as an important staple crop in many parts of world like Eastern and Southern Africa, South Asia including India. In the world, finger millet area is estimated to be approximately 4-4.5 million hectares, with a 5 million tonnes of total grains production [1]. Out of the total minor millets produced, finger millet is accountable for about 85% of production in India. In India, finger millet is grown over an area of 1.19 million hectares giving an output of 1.98 million tonnes with an average productivity of 1662 kg ha^{-1} [2]. The importance of long-term fertilizer experiments in understanding the effects of continuous cropping and fertilizer or manure application on soil fertility and sustenance of crop production is widely recognized [3].

Fertilizer incorporation influence various soil properties which ultimately helps in nutrients restoration that have been taken up by the plants and maintains the soil ecosystem at the same time [4]. Continuous application of inorganic fertilizers alone or in combination with lime or farm yard manure (FYM) and cropping have potential of bringing changes in crop production, nutrient uptake, physicochemical and microbial properties of soil.

Integrated nutrient management (INM) maintains optimum level of soil fertility for maximum crop productivity from all possible organic and inorganic sources of plant nutrients in an integrated manner [5]. It is therefore, necessary to address the twin concerns of excess nutrient application as well as nutrient exhaustion in soil. Therefore, balanced fertilization with INM is best approach to cope with negative environmental impacts and soil fertility and sustainability management [6].

Keeping in view the importance of finger millet, the present long-term study was conducted with the specific objective to quantify the effect of long-term use of organic and inorganic sources of nutrients on growth, yield and nutrient uptake of finger millet under finger millet monocropping system and in rotation with groundnut in hot moist semiarid rainfed *Alfisols* in South India.

2. MATERIALS AND METHODS

A field experiment was conducted on an ongoing long-term experimental trial (41 years) at All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Bangalore, located in the Agro-climatic Zone-V, Eastern Dry Zone of Karnataka at 12°58' N latitude and 77°35' E longitude with an altitude of 929 m above mean sea level during *kharif* season of 2019-20. The soils of Dryland Agriculture Project represent the typical lateritic area and belong to *Vijaypura* series, which is a dominant soil series of Bengaluru plateau. These soils are classified as fine, kaolinitic, Isohyperthermic, *Typic Kandiustalf,* as per USDA classification. Different physical and chemical properties of soils at the initiation of experimentation are presented in Table 1. The soils are derived from granite-gneiss under sub-tropical semiarid climate and they are deep, well drained sandy loam to sandy clay loam which occurs in closely level to gently sloping land.

Test crop variety was GPU-28 and the experiment was laid down in a randomized complete block design (RCBD) with 10 treatments replicated four times. Treatments were T_1 - Control under finger millet monocropping; T_2 - FYM @ 10 t ha^{-1} under finger millet monocropping; T_3 - FYM @ 10 ha^{-1} + 50% RDF under finger millet monocropping; T_4 - FYM @ 10 t ha^{-1} + 100% RDF under finger millet monocropping; T_5 - 100% RDF under finger millet monocropping; T_6 - Control under finger millet - groundnut rotation; T_7 - FYM @ 10 t ha^{-1} under finger millet - groundnut rotation; T_8 - FYM @ 10 t ha^{-1} + 50% RDF under finger millet - groundnut rotation; T_9 - FYM @ 10 t ha^{-1} + 100% RDF under finger millet - groundnut rotation; T_{10} - 100% RDF under finger millet - groundnut rotation. FYM was applied @10 t ha^{-1} prior to experimentation in 2019 and RDF (N: P_2O_5: K_2O in 50:25:25) was through Urea, DAP and Muriate of Potash (MOP).

Table 1. Physico-chemical properties of LTFE soil prior to the experimentation in 1978

Physical properties	
Coarse sand (%)	42.00
Fine sand (%)	30.50
Silt (%)	6.20
Clay (%)	21.20
Textural class	Sandy clay loam
Maximum water holding capacity (%)	29.40
Pore space (%)	41.80
Volume expansion (%)	2.40
Bulk density (Mg m^{-3})	1.64
Chemical properties	
pH (1:2.5)	5.00
EC (dS m^{-1})	0.20
Organic carbon (%)	0.40
Available nitrogen (kg ha^{-1})	200.0
Available phosphorus (kg ha^{-1})	8.70
Available potassium (kg ha^{-1})	132.80
Exchangeable calcium (cmol (p^+) kg^{-1})	2.30
Exchangeable magnesium (cmol (p^+) kg^{-1})	0.75
Exchangeable potassium (cmol (p^+) kg^{-1})	0.30
Cation exchange capacity (cmol (p^+) kg^{-1})	7.10

Growth parameters like plant height, number of productive tillers per hill, number of ear heads per hill, number of fingers per ear head, total dry matter production per hill and yield parameters like test weight, grain and straw yield were computed by implying standard protocols. Grain and straw samples from each plot were digested with concentrated sulphuric acid (H_2SO_4) and digestion mixture (K_2SO_4: $CuSO_4.H_2O$: Selenium in 100: 20: 1) for nitrogen concentration. For phosphorus and potassium, samples were treated with di-acid mixture (HNO_3 + $HClO_4$ in 10:4) after pre-digesting with 10 ml HNO_3 (62%). Later in the digested samples, nitrogen concentration was quantified using micro Kjeldhal method, phosphorus by vanodomolybdo- phosphoric yellow colour method and potassium using flame photometer [7] and uptake for the respective nutrients was calculated as:

Macronutrient uptake (kg ha^{-1})= (Nutrient concentration (%)/100) × Biomass (kg ha^{-1})

2.1 Statistical Analysis

Methods outlined by [8] were used for the statistical analysis of the data.

3. RESULTS AND DISCUSSION

3.1 Effect of Long Term Integrated Nutrient Management on Growth and Yield Parameters of Finger Millet

Growth and yield parameters of finger millet as influenced by long term application of organic manures in conjunction with inorganic fertilizers under finger millet based cropping system are represented under Table 2.

3.1.1 Growth parameters

Treatment T_9 (FYM @ 10 t ha^{-1} + 100% RDF under finger millet- groundnut rotation) recorded significantly higher plant height (112.44 cm) and total dry matter production (77.39 g $hill^{-1}$) and it was statistically at par with T_4 (FYM @ 10 t ha^{-1} + 100% RDF under finger millet mono cropping) with plant height (111.32 cm) and total dry matter production (75.89 g $hill^{-1}$). Treatments receiving application of farm yard manure (FYM) along with 50% or 100% NPK through fertilizers resulted in increased availability of essential macro and micro nutrients with the organic manure [9] which play pivotal role as constituent of cell structures and cell metabolites, in cell osmotic relations and turgor- related processes, energy transfer reactions, enzyme-catalyzed reactions and plant reproduction [10]. Plant productivity depends on the efficient discharge of these functions and all these factors put together the plant to attain tallness.

3.1.2 Yield parameters

T_9 was observed with higher number of productive tillers per hill (4.75), number of ear heads per hill (4.49), number of fingers per ear head (7.25). However, test weight (3.28 g) was more with T_8 and T_4 which comprised of FYM @ 10 t ha^{-1} along with 50% RDF under finger millet - groundnut rotation and FYM @ 10 t ha^{-1} + 100% RDF under finger millet monocropping, respectively. Balanced nutrition increased root growth and tillering which increased the amount of interception of photosynthetically active radiation and greater photosynthesis by crop [11]. Higher test weight might be due to better grain filling ability of the crop due to easy availability of nitrogen and other nutrients from soil and fertilizers [12].

Grain and straw yield varied significantly among different treatments. Application of FYM @ 10 t ha^{-1} + 100% RDF under finger millet- groundnut rotation (T_9) recorded higher yield of grain (28.27 q ha^{-1}) and straw (32.63 q ha^{-1}) which was statistically at par with T_4 with 26.29 and 31.45 q ha^{-1} of grain and straw, respectively. Higher yield was observed with rotational cropping compared to mono cropping which signifies the importance of rotation in Indian agriculture. In rotation also, INM in form of FYM @ 10 t ha^{-1} + 100% RDF (T_9) had 21 .83% and 44.92% more yield compared to purely organic treatment comprising of FYM @ 10 t ha^{-1} (T_7) and purely inorganic treatment; 100% RDF (T_{10}). In absence of fertilization in long run, yield showed declining trend in both of the controls.

Application of only inorganic fertilizers to the crop might have resulted in insufficient amount of additional secondary and micronutrients, thus reduced growth and yield. [13] observed the similar effects of inorganics on chickpea growth. Integrated application of organic and inorganic sources showed beneficial effect on physiological process of plant metabolism and growth, thereby resulting in higher grain and straw yield. Mineralization of organic manures enhanced nitrogen which not only influenced the shoot and root growth but also favored absorption of other nutrients [14].

3.2 Effect of Long-Term Integrated Nutrient Management on Macro Nutrient Uptake in Grain and Straw of Finger Millet

Nutrient uptake in grain and straw of finger millet along with total uptake as influenced by long term application of organic manures and inorganic fertilizers under finger millet based cropping system are represented under Table 3.

3.2.1 Nitrogen uptake

Balanced application of organic manures and inorganic fertilizers both in mono cropping and rotational cropping resulted in significantly higher uptake of nitrogen over organics and inorganics alone. Integrated application of nutrients in form of FYM @ 10 t ha^{-1} + 100% RDF under finger millet- groundnut rotation (T_9) recorded higher uptake of nitrogen in grain (37.03 kg ha^{-1}) and straw (26.40 kg ha^{-1}) and total uptake was 28.88 and 48.70% higher than organically (T_7) and inorganically (T_{10}) amended plots. INM provided favorable soil environment encouraging better root proliferation, which explored larger volume of soil for nutrient absorption and ensured higher nutrient uptake [15]. Further, the mutualistic action of N and K in increasing crop productivity along with N removal had also been reported by [16]. Continuous cropping led to depletion of inherent fertility of zero fertilized plots which resulted in low N uptake in these plots due to poor crop growth [17].

3.2.2 Phosphorus uptake

Total phosphorus uptake varied from a minimum of 0.31 kg ha^{-1} in control (T_1) to maximum of 11.35 kg ha^{-1} in INM plots under rotational cropping (T_9). Significantly higher uptake in grain (6.78 kg ha^{-1}) and straw (4.57 kg ha^{-1}) of finger millet under rotation was noticed with full dose of FYM in combination with inorganic fertilizers (T_9) and it was 38.05% higher as compared to organic plots (T_7). Higher uptake in INM plots could be due to formation of organic materials which formed chelates with Al^{3+} and Fe^{3+}, lowering phosphorus fixing capacity and thus increasing its availability to plants in *Alfisols* [18]. Lower nutrient uptake under control plots could be due to lower plant population and yield as a result of continuous cropping without any external input which thereby, decreased native nutrient supply.

Table 2. Effect of continuous application of organic manures and inorganic fertilizers on growth and yield parameters of finger millet under finger millet based cropping system

Treatments	Plant height (cm)	Total dry matter production (g hill^{-1})	No. of productive tillers/hill	No. of ear heads/hill	No. of fingers/ ear head	Test weight (g)	Yield (q ha^{-1})	
							Grain	Straw
T_1	52.23	4.16	1.23	2.26	4.00	2.96	1.51	2.51
T_2	101.07	44.52	3.24	3.02	5.75	3.15	15.86	20.77
T_3	106.79	48.32	3.68	3.24	6.00	3.12	23.12	27.91
T_4	111.32	75.89	3.91	4.24	6.75	3.28	26.29	31.45
T_5	89.55	37.24	3.65	2.50	5.00	3.08	12.14	16.31
T_6	76.18	4.78	1.51	2.30	4.25	3.02	3.28	5.81
T_7	107.43	42.10	3.96	3.24	6.00	3.18	22.10	25.23
T_8	111.31	52.89	4.26	3.74	6.50	3.28	24.32	28.13
T_9	112.44	77.39	4.75	4.49	7.25	3.17	28.27	32.63
T_{10}	99.28	39.37	3.25	2.74	5.30	3.04	15.57	20.81
S.Em. ±	**6.48**	**3.28**	**0.15**	**0.15**	**0.29**	**0.14**	**1.14**	**1.39**
CD (P = 0.05)	**18.80**	**9.51**	**0.43**	**0.42**	**0.83**	**NS**	**3.32**	**4.04**

Note: T_1: Control under finger millet monocropping, T_2: FYM @ 10 t ha^{-1} under finger millet monocropping, T_3: FYM @ 10 t ha^{-1} + 50% RDF under finger millet monocropping, T_4: FYM @ 10 t ha^{-1} + 100% RDF under finger millet monocropping, T_5: 100% RDF under finger millet monocropping, T_6: Control under finger millet- groundnut rotation, T_7: FYM @ 10 t ha^{-1} under finger millet- groundnut rotation, T_8: FYM @ 10 t ha^{-1} + 50% RDF under finger millet- groundnut rotation, T_9: FYM @ 10 t ha^{-1} + 100% RDF under finger millet-groundnut rotation, T_{10}: 100% RDF under finger millet- groundnut rotation

Table 3. Effect of continuous application of organic manures and inorganic fertilizers on major nutrient uptake by grain and straw of finger millet under finger millet based cropping system

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1: Control under finger millet monocropping	1.57	1.08	2.65	0.16	0.15	0.31	0.54	1.32	1.86
T_2: FYM @ 10 t ha^{-1} under finger millet monocropping	19.35	13.29	32.64	2.70	2.08	4.78	9.53	20.41	29.94
T_3: FYM @ 10 t ha^{-1} + 50% RDF under finger millet monocropping	28.90	18.71	47.61	4.16	3.07	7.23	20.58	35.41	55.99
T_4: FYM @ 10 t ha^{-1} + 100% RDF under finger millet monocropping	33.91	23.60	57.51	5.52	4.09	9.61	27.64	45.66	73.3
T_5: 100% RDF under finger millet monocropping	14.45	9.79	24.24	1.82	1.47	3.29	6.57	14.77	21.34
T_6: Control under finger millet- groundnut rotation	3.48	2.90	6.38	0.43	0.46	0.89	1.28	3.31	4.59
T_7: FYM @ 10 t ha^{-1} under finger millet- groundnut rotation	27.18	17.93	45.11	4.20	3.03	7.23	13.45	25.73	39.18
T_8: FYM @ 10 t ha^{-1} + 50% RDF under finger millet- groundnut rotation	30.63	20.54	51.17	5.35	3.66	9.01	23.12	37.60	60.72
T_9: FYM @ 10 t ha^{-1} + 100% RDF under finger millet- groundnut rotation	37.03	26.40	63.43	6.78	4.57	11.35	30.17	48.68	78.85
T_{10}: 100% RDF under finger millet- groundnut rotation	18.84	13.70	32.54	2.49	2.08	4.57	8.63	19.36	27.99
S.Em. ±	**1.29**	**1.39**	**2.68**	**0.17**	**0.16**	**0.33**	**1.15**	**1.38**	**2.53**
CD (*P* = 0.05)	**3.75**	**4.03**	**7.78**	**0.50**	**0.47**	**0.97**	**3.35**	**3.99**	**7.34**

3.2.3 Potassium uptake

Total uptake of potassium varied from a minimum of 1.86 kg ha^{-1} in T_1 to maximum of 78.85 kg ha^{-1} in T_9. Application of FYM @ 10 t ha^{-1} + 100% RDF under finger millet- groundnut rotation (T_9) resulted in higher uptake in grain (30.17 kg ha^{-1}) and straw (48.68 kg ha^{-1}) of finger millet under rotation, which was 50.31 and 64.50% higher than T_7 and T_{10}, respectively. The increased uptake of potassium might be due to better availability of potassium from the added fertilizers and manures [19]. Effects of FYM which acts as reservoir of nutrients and would have contributed to slow release of nutrients over longer period resulted in higher uptake of nutrients in applied plots. These results are in accordance with [20] and [21].

4. CONCLUSION

Integrated use of organic manures and inorganic fertilizers under rotational cropping significantly increased the growth, yield and nutrient uptake by finger millet than sole application of organic and inorganic fertilizers. Therefore, integrated nutrient management is gaining immense importance, not just to attain higher productivity but also to achieve maximum stability in crop production under intensive farming systems.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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