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Long-term effect of integrated nutrient management on soil macronutrient status in finger millet mono-cropping system

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Abstract
Soil macronutrients were studied on *Alfisols* with a 40-years old experiment at All India Co-ordinated Research Project for Dry land Agriculture (AICRPDA), Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru, during *kharif* 2018. Results indicated that continuous application of chemical fertilizers and manures increased the micronutrient availability in soil and uptake by finger millet. Long term integrated nutrient management showed significant higher values of available N of 345.35 kg ha^{-1}, P_2O_5 of 66.58 kg ha^{-1}, K_2O content of 136 kg ha^{-1}, for soils in a treatment T_5 FYM @ 10 t ha^{-1} + 100% RDF. Lower values were recorded for the control T_1 where no fertilizer was added. Similar trend of results were reported Nutrient content and nutrient uptake by finger millet for Application of FYM @ 10 t ha^{-1} + 100% RDF over a period of 40 years significantly increased the macronutrient content in soil and uptake by finger millet as against 100% NPK treatment and control.

Keywords: inorganic and organic fertilizers, soil micronutrient

Introduction
Nutrients are the basic input to soil paid its dividends for enhancing yield levels thereby showing its major role and continue to do so in future also for enhancing crop yield. Its timely availability is very crucial for crop production. Fertilizers need to be used rationally in order to avoid a negative ecological impact and undesirable effects on sustainability of crop production. Hence, nutrient management is a key issue in not only achieving higher biomass through its content and uptake in any plants but also for maintaining soil fertility thereby sustainability. Macronutrients are required by crops in the largest amounts. They support the most essential functions of the plant, protecting it, and promoting its growth. Nitrogen is one of the most expensive essential nutrients to supply for any crops and judicious supply is a key factor in enhancing use efficiency with minimal environmental impact. Phosphorus is an essential macro-element, required for metabolic processes such as photosynthesis, energy transfer, synthesis and breakdown of carbohydrates. Potassium playing a major role in imparting drought resistance an disease resistance, it is very essential for the crop plants. In this context, plant nutrients need to be supplied in balanced proportion and adequate quantity envisaging the fertilizer prescriptions need to be based on soil and location specific rather than state or regional recommendations. Also management approaches substantially influence the soil processes and nutrient dynamics. It is observed that continuous use of inorganic fertilizers leads to deterioration in soil chemical, physical, and biological properties and soil health (Mahajan *et al.*, 2008) [13]. The negative impacts of chemical fertilizers, coupled with escalating prices, have led to growing interests in the use of organic fertilizers as a source of nutrients (Satyanarayana *et al.*, 2002) [21]. Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously is the most effective method to maintain a healthy and sustainably productive soil. Emerging evidence indicated that integrated soil fertility management involving the judicious use of combined organic and inorganic resources is a feasible approach to overcome soil fertility constraints. Therefore, the study presented here evaluated effects of long-term applications of crop residue incorporation and organic manure on available macronutrients (N, P_2O_5, K_2O) and uptake by micronutrients by finger millet were studied.

Materials and Methods

A field experiment was conducted during *kharif* 2018 at All India Co-ordinated Research Project for Dry land Agriculture (AICRPDA), Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru on an ongoing long-term (40 years) experimental trail. The soil of the experimental site at Dry-land Agriculture Project is sandy clay loam in texture belongs to Vijayapura soil series. This is classified as fine, *Kaolinitic, Isohyperthermic, Typic kandiustalf* as per USDA classification. The soil was sandy clay loam in texture, with a bulk density of 1.64 Mg m^{-3} and slightly acidic in reaction (pH of 5.00) with a electrical conductivity of 0.20 d Sm^{-1}, low in organic carbon content (0.40%) and low in available N (200.00 kg ha^{-1}), low in available P_2O_5 (8.70 kg ha^{-1}) and low in available K_2O (132.80 kg ha^{-1}). The experiment consisted of 8treatments which were arranged in a randomized block design with three replications general information of experiment is presented in Table 1 and treatment details were presented in Table 2. Soil available N of soil was distilled with 25 mL of 0.32 per cent potassium permanganate ($KMnO_4$) and 25 mL of 2.5% NaOH. The ammonia released was trapped in 4% boric acid containing mixed indicator and titrated against standard sulphuric acid (Subbiah and Asija, 1956). Available P_2O_5 in soil samples were extracted with Bray's-1 reagent (NH4F+HCl). Phosphorus content in the extract was determined by ascorbic acid-molybdate complex method and the blue colour intensity was recorded at 660 nm using spectrophotometer (Jackson, 1973). Available potassium in soil was estimated by extracting the soil with neutral normal ammonium acetate (pH 7.0) and measuring potassium in the extract using a flame photometer as outlined by Jackson (1973).

Table 1: General information of experimental details

Location	:	AICRPDA, Bengaluru, UASB, GKVK, Bengaluru 65
Season	:	*Kharif* 2018
Design	:	RCBD
Treatments	:	08
Replications	:	03
Crop	:	Finger millet
Variety	:	GPU 28
Seed rate (kg ha^{-1})	:	12.5
Spacing	:	30 cm x 10 cm
Gross plot size	:	13 x 3.3 sq. m
Net plot size	:	12.4 x 2.9 sq. m
RDF	:	50:50:25 (N: P_2O_5: K_2O) kg ha^{-1}
Organic source	:	FYM 10 tons ha^{-1}
	:	Maize residues 5 tons ha^{-1}
Duration	:	110-115 days

Table 2: Treatment details in long-term effect of integrated nutrient management

T_1	Absolute control
T_2	100% RDF
T_3	FYM @ 10 t ha^{-1}
T_4	FYM @ 10 t ha^{-1} + 50% RDF
T_5	FYM @ 10 t ha^{-1} + 100% RDF
T_6	Maize residue @ 5 t/ha
T_7	Maize residue @ 5 t ha^{-1} + 50% RDF
T_8	Maize residue @ 5 t ha^{-1} + 100% RDF

Results and Discussion

Effect of long-term integrated nutrient management on macronutrient nutrient status of soil

The trend of available macronutrients like nitrogen, phosphorous, potassium in the soil remains same after the harvest of finger millet (Table 3). It is observed that the available status was low in imbalanced fertilizer compared to the balanced fertilizer and FYM applied plots.

Table 3: Effect of long-term integrated nutrient management on available primary nutrients content of soil

Treatments	N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T_1: Absolute control	99.53	61.39	7.47	5.69	41.00	61.33
T_2: 100% RDF	194.19	208.67	17.96	19.98	63.17	74.67
T_3: FYM @ 10 t ha^{-1}	216.54	224.38	23.56	24.29	63.98	88.16
T_4: FYM @ 10 t ha^{-1} + 50% RDF	313.46	322.83	46.52	45.38	76.00	104.00
T_5: FYM @ 10 t ha^{-1} + 100% RDF	345.35	385.00	66.58	79.33	90.13	136.00
T_6: Maize Residue @ 5 t ha^{-1}	156.17	172.76	17.66	19.83	59.29	68.49
T_7: Maize Residue @ 5 t ha^{-1} + 50% RDF	218.10	237.64	34.09	38.12	64.17	89.00
T_8: Maize Residue @ 5 t ha^{-1} + 100% RDF	222.39	253.00	35.05	44.21	69.61	96.00
S.Em ±	10.65	13.52	2.08	2.60	4.01	6.24
CD at 5%	32.32	41.00	6.32	7.88	12.17	18.92

Available nitrogen

There was significant difference among treatments with respect to available N content of soil. In present study, use of FYM in combination with NPK was found to significantly increase the available N content of soil when compared to the use of only fertilizers. Among the treatments with graded doses of fertilizers, T_5 (FYM @ 10 t ha^{-1} + 100% RDF) recorded highest available N of 345.35 kg ha^{-1} and 385.00 kg ha^{-1} (before sowing and at harvest, respectively) than followed by T_4 (FYM @ 10 t ha^{-1} + 50% RDF) 313.46 kg ha^{-1} and 322.83 kg ha^{-1} (before sowing and at harvest, respectively) and T_8 (Maize residue @ 5 t ha^{-1} +100% RDF) 222.39 kg ha^{-1} and 253.00 kg ha^{-1} (before sowing and at harvest, respectively). Whereas, lower value of 99.53 kg ha^{-1} and 61.39 kg ha^{-1} (before sowing and at harvest, respectively) was obtained for T_1 (control).

Available N content of soil recorded significant differences among the different treatments. Application of inorganic and organic fertilizers recoded a direct relationship between available N and organic matter content of the soil (Black, 1993) [7]. The increase in available N content of soil in the treatment receiving 100% NPK along with FYM could be attributed to the increased organic matter and total N contents of the soil. Kamaljit. (2007) [11] and Singh and Sarkar (1998) [23] in a long-term experiment.

The results revealed that significantly higher available nitrogen content of soil was observed in treatment with application of 100% NPK + FYM. Whereas lower nitrogen content was recorded in control compared to all other treatments. Similar results were reported by Lokesh *et al.* (2015) [12], Prakash *et al.* (2003) [18]. That the higher available nitrogen in FYM applied treatment might be due to better biological activities and its effect on mineralization of nitrogen.

Available phosphorus

There was significant difference among treatments with respect to available P_2O_5 content of soil. In present study, use of FYM in combination with NPK was found to increase available P_2O_5 content significantly in soil when compared to the use of only fertilizers. Among the treatments with graded doses of fertilizers, T_5 (FYM @ 10 t ha^{-1} + 100% RDF) recorded highest available P_2O_5 of 66.58 kg ha^{-1} and 79.33 kg ha^{-1} (before sowing and at harvest, respectively) than followed by T_4 (FYM @ 10 t ha^{-1} + 50% RDF) 46.52 and 45.38 kg ha^{-1} (before sowing and at harvest,) and T_8 (Maize residue @ 5 t ha^{-1} + 100% RDF) 35.05 and 44.21 kg ha^{-1} (before sowing and at harvest, respectively). Whereas lower value of 7.47 and 5.69 kg ha^{-1} (before sowing and at harvest, respectively) was obtained for T_1 (control).

FYM itself could contribute considerably to the available P pool of soil upon mineralization (Badanur *et al.*, 1990) [5]. Build-up of phosphorus in soil due to similar reasons of fertilization has been reported by many workers (Anon, 2004) [3]. FYM in combination with NPK release organically bound P during decomposition of organic matter, solubilization of soil P by organic acids produced during decomposition of organic matter. Continuous application of FYM also reduced the activity of polyvalent cations such as Ca, Fe and Al due to chelation, which in turn, considered being responsible process for reduction in P-fixation (Gupta *et al.*, 1988) [8]. The application of FYM increased P because of its P content and possibly by increasing retention of P in soil. A positive effect of FYM on P availability was also observed by Roy *et al.* (2001) [20]. This might be due to the fact that the major P fraction added through FYM was in the organic pool, which mineralized slowly with time (Yadvinder *et al.*, 2004) [29].

Further in control the available phosphorus content declined (16.6 kg ha^{-1}) when compared to initial value after 28 years of cultivation. Removal of labile P by the crops in a soil not nourished by the addition of P from external sources might be the reason for significant reduction in available P content of the soil in plots treated with only fertilizer and also in control plots (Srivastava, 1985 and Vinutha *et al*., 2010) [24, 28].

Available potassium

There was considerably significant difference among treatments with respect to available K_2O content of soil. In present study, use of FYM in combination with NPK was found to increase significantly the available K_2O content of soil when compared to the use of only fertilizers. Among the treatments with graded doses of fertilizers, T_5 (FYM @ 10 t ha^{-1} + 100% RDF) recorded highest available K_2O content of 90.13 and 136 kg ha^{-1} (before sowing and at harvest, respectively) then followed by T_4 (FYM @ 10 t ha^{-1} + 50% RDF) 76 and 104 kg ha^{-1} (before sowing and at harvest, respectively) and T_8 (Maize residue @ 5 t ha^{-1} +100% RDF) 69.61and 96 kg ha^{-1} (before sowing and at harvest). Whereas lower value 41.00 and 61.33 kg ha^{-1} (before sowing and at harvest, respectively) was observed in T_1 (control).

The plots incorporated with FYM also had relatively higher amounts of available K. Farmyard manure is not only a direct and ready source of K (Bansal, 1992) [6] but also aids in minimizing the leaching loss of K by retaining K ions on exchange sites of its decomposed products. Its favourable effect is evident in enhancing the solubility of insoluble K compounds during the decomposition process (Anon, 1992) [2]. The differential release pattern of non-exchangeable K from the soil reserve besides variation in K uptake by the crop is responsible for such differences in the available K status of the soil (Svotwa *et al.*, 2007) [25]. It seems that the crop requirements were partly met from the released K and both the applied K and the released K brought out to build up of available K in the soil Organic materials resulted in a build-up of soil K because FYM generally contains high amounts of K. Considerable build-up of K under FYM + NPK treatment in a long-term fertilizer experiment was reported by others (Nand Ram, 1998; Poonia *et al.*, 1986; Mehta *et al.*, 1988) [16, 17, 14]. It also might be due to release of nonexchangeable K could have resulted in the increased available K (Ramchandrappa *et al.*, 1986) [19]. Regular application of FYM resulted in build of potassium. The present results corroborated the findings of Jaskulska *et al.* (2014) [10].

Effect of long-term integrated nutrient management on macronutrients content and uptake by grain and straw of finger millet

The data pertaining to macronutrient content and uptake by finger millet crop as influenced by application of different levels of fertilizer are presented in Table 4 and 5.

Table 4: Effect of long-term integrated nutrient management on major nutrients content in grain and straw of finger millet

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Absolute control	0.97	0.92	0.12	0.07	0.32	0.56
T_2: 100% RDF	1.30	1.01	0.16	0.09	0.37	0.72
T_3: FYM @ 10 t ha^{-1}	1.44	1.06	0.16	0.11	0.40	0.77
T_4: FYM @ 10 t ha^{-1} + 50% RDF	1.68	1.14	0.23	0.16	0.49	1.09
T_5: FYM @ 10 t ha^{-1} + 100% RDF	1.86	1.18	0.28	0.18	0.52	1.24
T_6: Maize Residue @ 5 t ha^{-1}	1.27	0.99	0.14	0.08	0.34	0.67
T_7: Maize Residue @ 5 t ha^{-1} + 50% RDF	1.48	1.14	0.16	0.12	0.41	0.82
T_8: Maize Residue @ 5 t ha^{-1} + 100% RDF	1.52	1.16	0.18	0.14	0.46	0.92
S.Em ±	0.08	0.07	0.01	0.01	0.02	0.07
CD at 5%	0.23	0.20	0.04	0.02	0.06	0.20

Table 5: Effect of long-term integrated nutrient management on uptake of major nutrients by grain and straw of finger millet

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Absolute control	0.91	1.72	0.11	0.13	0.30	1.00
T_2: 100% RDF	15.27	18.89	1.62	1.72	4.29	13.44

T_3: FYM @ 10 t ha^{-1}	18.12	24.67	2.00	2.53	4.97	17.73
T_4: FYM @ 10 t ha^{-1} + 50% RDF	30.38	25.30	4.15	3.54	8.93	23.61
T_5: FYM @ 10 t ha^{-1} + 100% RDF	38.99	29.64	5.87	4.60	10.96	31.16
T_6: Maize Residue @ 5 t ha^{-1}	9.70	12.74	1.07	0.98	2.63	8.72
T_7: Maize Residue @ 5 t ha^{-1} + 50% RDF	22.86	24.68	2.53	2.68	6.37	17.75
T_8: Maize Residue @ 5 t ha^{-1} + 100% RDF	24.82	24.61	2.95	3.06	7.46	19.51
S.Em ±	1.48	1.04	0.13	0.07	0.42	0.75
CD at 5%	4.47	3.15	0.39	0.22	1.28	2.27

Nitrogen

Nitrogen content in grain and straw differed significantly with different levels of fertilizer applied, significantly higher N content in grain (1.86%) and straw (1.18%) was recorded in T_5 treatment which received FYM @ 10 t ha^{-1} + 100% RDF and it was on par with T_4 (FYM @ 10 t ha^{-1} + 50% RDF) grain (1.68%) and straw (1.14%). The lower N concentration of grain (0.97%) and straw (0.92%) was observed in T_1 absolute control.

Nitrogen uptake by grain and straw differed significantly with varied levels of fertilizer nutrients applied, significantly higher N uptake in grain (38.99 kg ha^{-1}), straw (29.64 kg ha^{-1}) was observed in T_5 treatment which received FYM @ 10 t ha^{-1} + 100% RDF and it was on par with T_4 (FYM @ 10 t ha^{-1} + 50% RDF) grain (30.38 kg ha^{-1}) and straw (25.30 kg ha^{-1}). The lower N concentration of grain (0.91 kg ha^{-1}) and straw (1.72 kg ha^{-1}) was observed in T_1 absolute control.

Phosphorus

Phosphorus content in grain and straw differed significantly with varied levels of fertilizer applied, significantly higher P content in grain (0.28%), straw (0.18%) was recorded in T_5 treatment receiving FYM @ 10 t ha^{-1} + 100% RDF and it was on par with T_4(FYM @ 10 t ha^{-1} + 50% RDF) grain (0.23%) and straw (0.16%). The lower P concentration of grain (0.12%) and straw (0.07%) was observed in T_1 absolute control.

Phosphorus uptake in grain and straw differed significantly with different levels of fertilizer nutrients applied, significantly higher P uptake by grain (5.87 kg ha^{-1}), straw (4.60 kg ha^{-1}) was recorded in T_5 treatment which received FYM @ 10 t ha^{-1} + 100% RDF and it was on par with T_4(FYM @ 10 t ha^{-1} + 50% RDF) grain (4.15 kg ha^{-1}) and straw (3.54 kg ha^{-1}).The lower P concentration of grain (0.11kg ha^{-1}) and straw (0.13 kg ha^{-1}) was observed in T_1 absolute control.

Potassium

Potassium content in grain and straw differed significantly with different levels of fertilizer nutrients applied, significantly higher K content in grain (0.52%), straw (1.24%) was recorded in T_5 treatment which received FYM @ 10 t ha^{-1} + 100% RDF and it was on par with T_4(FYM @ 10 t ha^{-1} + 50% RDF) grain (0.49%) and straw (1.09%). The lower K concentration of grain (0.32%) and straw (0.56%) was observed in T_1 absolute control.

Potassium uptake by grain and straw differed significantly with different levels of fertilizer nutrients applied, Significantly higher K uptake in grain (10.96 kg ha^{-1}), straw (31.16 kg ha^{-1}) was recorded in T_5 treatment which received FYM @ 10 t ha^{-1} + 100% RDF and it was on par with T_4 (FYM @ 10 t ha^{-1} + 50% RDF) grain (8.93 kg ha^{-1}) and straw (23.61 kg ha^{-1}). The lower K concentration of grain (0.30 kg ha^{-1}) and straw (1.0 kg ha^{-1}) was observed in T_1 absolute control.

The higher level of nitrogen, phosphorus and potassium made conducive for extensive root proliferation, which explored a greater volume of soil and absorb larger quantities of nutrients, which correlated positively with dry matter production, and concentration of nutrients in the plant under higher level of nutrient supply. Similar findings were recorded by Upendra *et al.* (2014) [27].

This increased uptake of nitrogen which might be due to higher grain and straw yield. This may be due to improved utilization of applied nitrogen in the presence of sufficient potassium and FYM. Similar positive interaction between N and K was reported by Thippeswamy (1995) [26] who reported that the uptake of N and K was found to increase significantly with the levels and split application of K in finger millet. Similarly FYM enhanced available N, through mineralization process and increased efficiency of applied N.

Similar findings were reported by Abida *et al.* (2007) [1] who reported that nitrogen uptake was improved with P and K application compared to their sole application. Application of phosphorus increased root proliferation might be due to increased levels of P resulted in the better utilization of nitrogen by the finger millet. Similar findings were reported by Jagathjothi *et al*. (2010) [9].

The lower uptake of K was noticed in treatments where there was no addition of K. This implies that inadequate supply or absence of any one major nutrient to the crop would result in imbalance in the supply of nutrient elements and consequent reduction in yield, nutrient use efficiency and uptake. These results are in conformity with the findings of Anon. (2006) [4].

Significantly higher nutrient content and uptake (N, P and K) was observed in treatments T_5. Lower nutrient content and uptake was observed in treatment supplemented with chemical fertilizer alone and also in control, which may be due to low availability of nutrients in soil. This showed the beneficial effect of balanced application of organic and inorganics. The higher nutrient uptake with organic manure might be attributed to solubilisation of native nutrients, chelation of complex intermediate organic molecules produced during decomposition of added organic manures, their mobilization and accumulation of different nutrients in different plant parts (Sharma *et al.,* 2013 and Nambiar., 1994) [22, 15].

Conclusions

Macronutrient content in the soil was increased and more pronounced in FYM @ 10 t ha^{-1} + 100% RDF. Application of FYM @ 10 t ha^{-1} + 100% RDF over a period of 40 years significantly increased the macronutrient content in soil and uptake by finger millet as against 100% NPK treatment and control. For sustaining soil quality and crop productivity supplementing the inorganics with organics is the best strategy. This clearly indicated the complete supply of all the essential nutrients in sufficient amounts in balanced ratio during the crop growth period.

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