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Effect of Long Term Fertilization and Manuring on Soil Fertility, Yield and Uptake by Finger Millet on Inceptisol

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In the long term fertilizer experiment started in the year 1972 at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore under finger millet -maize cropping sequence on an Inceptisol, the effect of continuous fertilization and manuring on yield, uptake and changes in available nutrients status of finger millet crop was studied in the year 2011. The experiment consisted of ten treatments which were replicated four times in randomized block design with a plot size of 20 m X 10 m. Application of 100 per cent NPK along with FYM @ 10 t ha^{-1} recorded significantly higher grain and straw yields than all other treatments. Uptake of NPK by both grain and straw and soil available NPK and organic carbon were also significantly higher in the above mentioned treatment. Next in order, the yield and available nutrients were higher under 150% NPK which was significantly higher than 100% NPK. Non-inclusion of PK in N alone treatment resulted in decline in crop productivity and available nutrient status. Further, continuous application of 100 % NPK along with $ZnSO_4$ @ 25 kg ha^{-1} increased soil available Zn over other treatments.

Key words: Long-term fertilization, manuring, yield, uptake, available nutrients, finger millet

Continuous and intensive cropping without adequate restorative practices may pose threats to sustainability of agriculture. In order to maintain the native soil fertility and prescribe balanced fertilization monitoring of changes in nutrient status of the soil becomes inevitable. Fertilizer recommendations are often derived from nutrient uptake pattern of crops that focus on optimizing nutrient inputs with regard to achieving high net return in the crop to which the nutrient was applied. The maintenance of the soil health is essential not only for maximizing agricultural production but also vital for sustaining the higher productivity levels (Velu and Subramaniam, 2012).

Long -term fertilizer experiment under intensive cropping sequences in different agro- ecological regions have provided ample evidence of rapid exhaustion of soil nutrients. The present investigation is pertaining to the finger millet crop of the year 2011 which is 96th crop in finger millet – maize cropping sequence of AICRP-ICAR-Long Term Fertilizer Experiment (LTFE) being conducted since 1972 in Tamil Nadu Agricultural University, Coimbatore.

Materials and Methods

In Long Term Fertilizer Experiment conducted in TNAU, Coimbatore continuous experimentation with finger millet – maize cropping sequence is practiced. The experimental soil (Periyanaickenpalayam soil series) is sandy clay loam in texture and taxonomically grouped under *Vertic Ustropept*. There are ten treatments viz., 50 % NPK, 100 % NPK, 150 % NPK, 100 % NPK + Hand weeding (HW), 100 % NPK + $ZnSO_4$ @ 25 kg ha^{-1} ($ZnSO_4$ applied once in a year for maize), 100 % NP, 100 % N, 100 % NPK + FYM, 100 % NPK (Sulphur free source of fertilizer) and Control (unmanured and unfertilized) which were replicated four times with the plot size of 200 m^2. The finger millet crop (var. CO 13) - 96th crop was sown on raised bed nursery and transplanted in the main field by adopting standard agronomic practices. AICRP-ICAR recommended nutrient schedule (100 % NPK 90:45:17.5 kg ha^{-1}) of N, P_2O_5 and K_2O kg ha^{-1} was applied. Farm yard manure was applied at 10 t ha^{-1}. Except T_4, other treatments received soil application of pre emergence herbicide. Instead of SSP, DAP was used as source of P to eliminate supply of sulphur in the treatment T_9. The plant N was estimated by following the procedure of microkjeldhal digestion and distillation method (Bremner and Mulvaney, 1982), plant P by triple acid extraction and vanadomolybdo phosphoric yellow color method (Jackson, 1973) and plant K by triple acid extraction and flame photometry (Piper, 1966). Based on the uptake of nutrients (in kg ha^{-1}) apparent use efficiency (AUE) was worked out separately for N, P & K.

$$AUE (\%) = \frac{(\text{Uptake in treated plot (kg ha}^{-1}) – (\text{Uptake in control plot (kg ha}^{-1}) \times 100}{\text{Level of fertilizer nutrient applied (kg ha}^{-1})}$$

pH and EC were determined in soil : water (1 : 2.5 ratio) extract by potentionmetric and conductometry methods respectively (Jackson, 1973). Organic carbon was estimated by chromic acid wet digestion method (Walkley and Black, 1934). Available N in soil was estimated by alkaline permanganate method

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(Subbiah and Asija, 1956), available P by Colorimetry method (Olsen *et al*., 1954), available K by Neutral Normal Ammonium Acetate method (Stanford and English, 1949) and available micronutrients (Zn, Cu, Fe & Mn) by DTPA extractable method (Lindsay and Norvell, 1978) . Physiochemical properties of post harvest soil of previous maize crop were used as initial soil test values for finger millet crop. Maize and finger millet crops were raised between January to May (Summer period) and June-September month (Monsoon period) respectively.

Results and Discussion

Grain and straw yield

Grain and straw yield of finger millet under finger millet- maize cropping sequence significantly varied from 1874 kg ha^{-1} to 2571 kg ha^{-1} and 4035 kg ha^{-1} to 5237 kg ha^{-1} respectively. The highest grain (2571 kg ha^{-1}) and straw (5237 kg ha^{-1}) yields were recorded in the treatment that received integrated application of 100% NPK + FYM (T_8) followed by the treatment that received 150 % NPK, whereas the lowest yields were recorded in control (Table 1). The treatment T_8 proved its superiority by recording 10.6 per cent and 37.2 per cent increase in grain yield over 100 % NPK and control respectively. The increased yield in T_8 might be due to the sustained fertility by the addition of nutrients both in organic and inorganic forms. This result was in corroboration with finding of Tolanur and Badanur (2003). Continuous application of nitrogenous fertilizers alone adversely affected the soil productivity resulting in drastic reduction in yield of finger millet to the tune of 14.4 per cent compared to 100% NPK. This might be due to improper root growth and development that may be attributed to the absence of required quantity of P to the plants. Similar results were also reported by Santhy *et al*. (2000). The results also revealed that treatment T_2 recorded the highest yield compared to control and which was on par with T_4, T_5, T_6 and T_9. Hand weeding practice, DAP application and omission of K in treatment schedule did not significantly affected the yield of finger millet.

Uptake of nutrients

Uptake of NPK in both grain and straw was significantly influenced by continuous addition of fertilizers with or without FYM (Table 2). The results revealed higher N uptake in the integrated nutrient management (T_8) treatment which could be due to increased apparent use efficiency (Table 2) and slow mineralization and release of N from farmyard manure which might have satisfied the N requirement of the crop throughout the growth and maturity stages. Kamalakumari and Singaram (1996) in their study on an *Inceptisol* reported that the increased N uptake in the treatments receiving 100 per cent NPK+FYM may be due to the beneficial effects of organic manure in increasing and sustaining the availability of nutrients in the soil. An increased biomass coupled with higher N content in the produce resulted in significantly higher N uptake by finger millet. The uptake of N was the lowest in the plots receiving no fertilizer or manure due to absence of external source of essential major nutrient supply to the plants. The lowest yield in control plot is due to lower N uptake. Nitrogen uptake in the grain and straw increased with progressive increase in the supply of NPK to the crop, because of higher availability of N and higher biomass yield.

Grain, straw and total P uptake increased with progressive increase in the supply of NPK to the crops, because of higher availability of this nutrient and higher biomass yield. Increased P uptake by the crops with N and P application might be attributed to their effect on the formation of active and prolific roots, resulting in increased foraging capacity of the plants. Application of NPK at 100 % of optimum level along with FYM @ 10 t ha^{-1} increased the uptake significantly as compared to the application of 100 % NPK alone. This might be attributed to the increased apparent use efficiency of the nutrients (Table 2) and FYM in respect of nutrient uptake. Application of FYM adequately mobilizes phosphorus slowly and steadily throughout the life cycle of the crop. Similar findings were reported by Anil Kumar *et al*. (2003). The lowest P uptake was observed in 100 % N alone. Prasad *et al*. (1996) reported that the lowest uptake of P in the N alone treatment might be due to the reduced P availability in the soil.

table 1. Long term effect of treatments on grain and straw yield of finger millet

Treatment		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	50 % NPK (45:22.5:8.75)	2169	4545
T_2	100 % NPK (90:45:17.5)	2324	4746
T_3	150 % NPK(135:67.5:26.25)	2445	4958
T_4	100 % NPK + HW (90:45:17.5)	2289	4664
T_5	100 % NPK + Zn (90:45:17.5)	2383	4988
T_6	100 % NP (90:45)	2311	4875
T_7	100 % N (90)	2032	4133
T_8	100 % NPK + FYM (90:45:17.5)	2571	5237
T_9	100 % NPK (- S) (90:45:17.5)	2285	4807
T_{10}	Control	1874	4035
SEd		50	112
CD (0.05%)		86	190

Potassium uptake under 100% NP treatment was comparable to that under 100 % NPK (Table 2). This was due to the non limiting K supply from the experimental soil which is high in K and also due to the higher biomass yield. The highest K uptake in

100 % optimum NPK with FYM and 150 % NPK was due to higher crop yield and higher availability of K from the soil. Potassium uptake in control as well as N alone treatment was low owing to low dry matter yields even though the soil supply with respect to K was non limiting (Muthuvel *et al*.,1998). The efficiency of applied K exceeded 100 per cent which might be due to luxury consumption of K from soil.

Soil reaction (pH) and Electrical Conductivity

The soil reaction (pH) of the soil varied from 8.74 to 8.83 (Table 3). There was no significant change among the treatments studied due continuous application of different levels of inorganics either alone or with FYM. This is in accordance with the findings of Vidya (2003) who reported that the normal quantity and nature of the fertilizers being applied are such that they do not alter the soil pH appreciably. Besides, the experimental soil itself is highly buffered due to its calcareous nature. Similar to pH, EC values were also not significantly influenced by the treatments. In addition to that variation in EC values was noticed in post harvest soil of finger millet when compared to initial value. This might be due to heavy rainfall occurred during the harvest of previous maize crop.

Table 2. Long term effect of treatments on uptake and apparent use efficiency of nutrients of finger millet (96th crop)

Treatment	Grain uptake (kg ha-1)			Straw uptake (kg ha-1)			Total uptake (kg ha-1)			Apparent use efficiency of nutrients (%)		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	27.12	3.90	21.48	52.27	4.45	65.00	79.39	8.35	86.48	35.27	15.24	180.80
T_2	30.44	4.18	23.47	59.32	5.17	71.18	87.39	9.35	94.65	26.52	9.84	137.09
T_3	32.03	5.38	25.18	59.49	5.35	75.36	91.52	10.73	100.54	20.74	8.61	113.83
T_4	29.07	4.12	23.12	55.50	4.66	66.69	84.57	8.78	89.81	23.39	8.58	109.43
T_5	30.74	4.53	24.31	60.30	5.64	75.32	90.60	10.17	99.63	30.09	11.67	165.54
T_6	29.35	4.16	23.80	57.52	5.22	73.12	86.87	9.38	96.92	25.94	9.91	-
T_7	24.58	2.64	19.91	43.81	3.43	54.97	68.39	6.07	74.88	5.41	-	-
T_8	33.68	5.66	27.00	65.98	6.13	82.22	99.66	11.79	109.22	40.16	15.27	220.34
T_9	29.47	4.11	22.85	57.69	5.05	70.67	87.16	9.16	93.52	26.27	9.42	130.63
T_{10}	21.55	1.69	17.80	41.97	3.23	52.86	63.52	4.92	70.66	-	-	-
SEd	1.06	0.16	0.99	2.04	0.19	2.02	2.57	0.25	2.36	-	-	-
CD (0.05%)	1.81	0.28	1.69	3.47	0.32	3.44	4.38	0.43	4.02	-	-	-

Soil organic carbon

Soil organic carbon content ranged from 3.6 g kg-1 in absolute control to 5.9 g kg-1 in the treatment of 100 % NPK + FYM (Table 3). Continuous application of graded levels of NPK from 50 % to 150 % was accomplished by a corresponding increase in the organic carbon content which might be due to enhanced rate of crop litter and root residue addition to the soil under continuous cultivation. The highest organic carbon content (5.9 g kg-1) was recorded under 100 % NPK + FYM (T_8), possibly due to higher organic matter addition to the soil. This is in conformity with the finding of Rajshree *et al.* (2005) who reported that application of higher rates of FYM increased organic carbon which would stimulate the growth and activity of micro organisms. The control and 100 % N treatments recorded the least organic carbon, probably due to low dry matter production and hence low return of crop residues to the soil. Organic carbon content in post harvest soil of finger millet was found to be low when compared to pretransplanting soil. Noticeable variations in temperature and rainfall might be the reason for variation in organic carbon values.

Available nutrients status of soil

The post harvest available nitrogen status of the soil ranged from 158 kg ha-1 to 210 kg ha-1. The decreased available N (158 kg ha-1) status in absolute control may be due to the continuous removal of soil N in the absence of external supply of N through fertilizers and manures (Table 4). The increase in available N status due to organic manure application along with inorganic fertilizer would be due to the multiplication of soil microbes leading to enhanced conversion of organically bound N into inorganic forms during mineralization. Immobilization of N also leads to maintenance of definite level of available N under the addition of organic matter and crop residue management (Mairan *et al*., 2005).

The lowest available P status was found in control (6.67 kg ha-1) while a high value of 24.73 kg ha-1 was recorded in 100 % NPK + FYM (Table 4). Available P status of the soil was the lowest in control due to exclusion of P fertilizers from the nutrient schedule. Available P status was significantly higher in treatments receiving P fertilizers than in the treatments without P. Higher availability of P in 100 % NPK + FYM treatment may be attributed to the solubilisation of P by the organic acids released from the organic manures, reduction of P fixation in the soil due to chelation of P fixing cations like Ca, Mg, Fe, Al, Zn, Mn and Cu and also due to enhanced microbial activity. Significant reduction in available P status of the soil under 100 % N may be due to the imbalanced fertilization by complete exclusion of fertilizer P. These results were similar to that of the trends from various LTFEs in India reviewed by Anand Swarup (2002). The results also revealed that there was an observed significant change in build up of available P when compared to initial value.

table 3. Long term effect of treatments on pH, EC, OC of finger millet (96th crop)

Treatment	Physiochemical properties before 96th crop(Initial value)			Physiochemical properties after 96th crop		
	pH	EC (dS m^{-1})	OC (g kg^{-1})	pH	EC (dS m^{-1})	OC (g kg^{-1})
T_1	8.68	0.17	5.0	8.77	0.75	4.2
T_2	8.63	0.17	5.7	8.83	0.58	4.6
T_3	8.60	0.21	6.0	8.80	0.53	4.8
T_4	8.54	0.17	5.5	8.78	0.65	4.3
T_5	8.64	0.20	5.7	8.79	0.63	4.8
T_6	8.56	0.22	5.6	8.81	0.64	4.3
T_7	8.57	0.20	4.5	8.76	0.77	4.2
T_8	8.53	0.24	6.6	8.81	0.58	5.9
T_9	8.65	0.17	5.4	8.81	0.59	4.5
T_{10}	8.67	0.17	3.8	8.74	0.79	3.6
SEd	0.066	0.032	0.26	0.049	0.100	0.13
CD (0.05%)	NS	NS	0.45	NS	NS	0.22

Available K status ranged from 513 kg ha^{-1} in control to 723 kg ha^{-1} in 100 % NPK + FYM treated plots (Table 4). The increase in the availability of K through addition of FYM may be due to the decomposition of organic matter and release of nutrients. The decreased availability of K in N, NP and absolute control treatments may be attributed to the higher uptake of K by crops resulting in depletion of K in the absence of K addition. This finding was in corroboration with Sindhu Prudvinath (2012).

The DTPA extractable micronutrients (Zn, Fe, Mn and Cu) in post harvest experimental soil ranged from 0.94 to 3.57, 1.38 – 1.56, 3.69 – 4.78 and 0.58 - 0.66 mg kg^{-1} respectively (Table 4). There was no significant change in DTPA extractable micronutrients except Zn. Significantly higher availability of Zn was noticed in 100 % NPK + $ZnSO_4$ and 100 % NPK + FYM treatment. This might be attributed to the fact that good amount of Zn was contributed by $ZnSO_4$ and FYM. Application of optimum level of fertilizers also helped in increasing Zn level in the soil towards sufficiency (Hemalatha, 2009). In addition to that, except Zn all the other micronutrients recorded lower values when compared to initial value. This might be due to continuous removal of micronutrients by the crops under intensive cropping in finger millet –maize cropping sequence.

Table 4. Long term effect of treatments on available nutrient status of finger millet

Treatment	Available nutrient status (kg ha^{-1})						Available micronutrient status (mg kg^{-1})							
	Before 96th crop - Initial value			After 96th crop			Before 87th crop - Initial value				After 96th crop			
	N	P	K	N	P	K	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn
T_1	130	17.67	595	175	18.29	583	0.23	1.00	3.71	7.59	1.09	0.62	1.56	3.69
T_2	151	20.12	740	190	20.70	636	0.26	1.14	4.11	9.64	1.11	0.64	1.54	4.52
T_3	158	22.60	798	199	22.98	676	0.49	1.59	4.24	10.89	1.44	0.59	1.45	4.47
T_4	149	18.90	719	194	19.23	630	0.30	1.14	4.14	8.88	1.46	0.58	1.44	4.61
T_5	157	19.60	685	195	20.50	626	1.09	1.25	4.22	9.88	3.57	0.59	1.46	4.13
T_6	149	17.64	480	196	18.28	617	0.22	1.05	3.82	9.60	1.07	0.58	1.40	4.78
T_7	152	11.06	502	183	11.64	584	0.19	0.96	3.73	7.60	0.99	0.59	1.38	4.67
T_8	164	24.03	865	210	24.73	723	0.54	1.65	4.36	11.03	1.48	0.58	1.43	4.54
T_9	154	20.75	697	188	21.72	602	0.35	1.15	4.13	9.56	1.11	0.59	1.50	4.18
T_{10}	112	6.08	455	158	6.67	513	0.11	0.93	3.50	6.88	0.94	0.66	1.55	3.74
SEd	2.89	0.44	32.89	4.90	0.52	20.44	0.005	0.021	0.033	0.13	0.54	0.06	0.14	0.80
CD (0.05%)	4.92	0.75	56.02	8.35	0.89	34.81	0.011	0.043	0.068	0.28	0.92	NS	NS	NS

Conclusion

The present investigation concluded that application of 100 % NPK @ 90:45:17.5 kg N: P_2O_5:K_2O ha^{-1} along with FYM @ 10 t ha^{-1} significantly increased the grain and straw yield of finger millet. Available nutrients, uptake and apparent use efficiency of nutrients was also found to be high under this INM practice. Next in order, the yield and available nutrients were high under 150% NPK which was significantly higher than 100% NPK. Non-inclusion of K in 100% NP and non inclusion of P and K in 100% N treatment significantly reduced available P and K when compared to 100% NPK. The uptake and apparent use efficiency of nutrients was found to be higher in INM practice.

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