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Effect of Long-Term Fertilizer Experimentation on Growth, Yield and Availability of Nutrients in Finger millet in Alfisol soils of Bengaluru

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Long-term fertilizer experiments (LTFE) provide good opportunity to study the impact of management practices on soil properties and crop productivity. Experiment was conducted in LTFE plots of GKVK Bangalore during *Kharif* 2010. There was significant decrease in the content of available P, K and S in soil. While P build up in soil over the years was found with the application of fertilizer either at recommended dose or higher dose but the availability of K and S was drastically declined due to the application of fertilizer at 100% NP (T_9) and 100% NPK (S-free) (T_{10}). The growth parameters and yield of finger millet were relatively higher under fertilizers that included all the three major nutrients i.e., N, P and K and increased yield was noticed with application of N, P and K at higher dose. The effect of combined use of fertilizers and FYM with or without lime on crop yield was on par with the effect of NPK. The uptake of all the major nutrients by finger millet was in accordance with the yield levels obtained under the treatment. Low levels of nutrients in the soil where reflected in low uptake/low concentrations of the respective nutrients in the plant.

Key words: Finger millet,long term fertilizer experiment, growth and yield.

Millets are the most important cereals of the semi-arid zones of the world. For millions of people in Africa and Asia they are the staple crops. Among millet crops, finger millet figures prominently; ranking fourth in importance after sorghum, pearl millet and foxtail millet. Finger millet cultivation is more widespread in terms of its geographical adaptation compared to other millets. It has the ability to withstand varied conditions of heat, drought, humidity and tropical weather. It is an important staple in many parts of eastern and southern Africa, as well as in South Asia (Luigi Guarino, 2011). The global annual planting area of finger millet is estimated at around 4-4.5 million hectares, with a total production of 5 million tons of grains, of which India alone produces about 2.2 million tonnes and Africa about 2 million tonnes. The rest comes from other countries in South Asia.

Eleusine coracana (Ragi) is an annual, widely grown in the arid areas of Africa and Asia. India is a major cultivator with a total cultivated area of 15,87,000 ha. The state of Karnataka is the leading producer of finger millet, known as ragi in the region, accounting for 58 per cent of India's Ragi production. Ragi is grown in different seasons in different parts of the country. As a rainfed crop, it is sown in June-July; winter crop in September- October and irrigated summer crop in January- February in Karnataka. Ragi is grown in diverse soils, varying rainfall regimes and in areas widely differing in thermo photoperiods. The resilience exhibited by this crop is helpful in adjusting themselves to different kinds of ecological niches. It is an outstanding subsistence food crop as ragi can be stored safely for several years without any insect damage, and has been a traditional component of farmers' risk avoidance strategy in the drought-prone areas.

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Mining of nutrients, several changes in soil properties and available nutrient status have been reported due to continuous application of fertilizer. The buildup of nutrients due to continuous application of fertilizers has been reported in many places. Therefore, regular monitoring of changes in soil properties related to nutrient availability is very essential, so that suitable soil and fertilizer management strategies could be adopted in order to maintain better soil health.

In this regard long-term experiments provide the best possible means of studying changes in soil properties and its fertility level. Realizing the importance of such studies on continuous application of fertilizer and cropping, during 4th plan period the ICAR, New Delhi launched All India Co-ordinate Research Project on Long-Term Fertilizers Experiments (LTFE) under different cropping system at various agro-ecological regions. Bangalore is one of the centers to evaluate continuous cropping and fertilizer use and soil fertility and productivity in alfisols of agro-ecological region-8. Therefore, the present study was undertaken in the ongoing AICRP on long-term fertilizer experiment plot at GKVK, Bangalore with reference to the different fertilizer management practices in finger millet- maize cropping system.

Materials and Methods

Experimental site

The AICRP on Long Term Fertilizer Experiment was initiated at the Zonal Agricultural Research Station, GKVK, UAS, Bangalore at "E" block during 1986-87. The soil is classified as fine, mixed *Isothermic Kandic Paleustalfs* of Vijayapura series. The initial parameters of the experimental site were presented in Table 1. There has not been any change in fertilizer management practices since the inception of the experiment. The long term fertilizer experiment consists of permanently laid out plots in randomized block design with eleven fixed treatments was replicated four times. The following were the treatments

T_1 : NPK @ 50%
T_2 : NPK @ 100%
T_3 : NPK @ 150%
T_4 : NPK @ 100% + Hand Weeding
T_5 : NPK @ 100% + FYM
T_6 : NPK @ 100% + Lime
T_7 : NPK @ 100% + FYM + Lime
T_8 :N@100%
T_9 : NP @ 100%
T_{10} : NPK @ 100% (S-Free)
T_{11} : Control

Note:
Lime : Applied based on lime requirement
FYM : Applied @15 t ha^{-1} only during *Kharif* season
NPK @ 100% : 100: 22: 42 kg ha^{-1}
N : Urea, P: SSP & K: MOP except in T_9 and T_{10} where DAP (S-free) applied

Finger millet was cultivated in *Kharif* 2010 using GPU 28 as test variety in a plot size of 144 m^2. Two seedlings per hill of finger millet were transplanted with spacing of 30 x 10 cm. Calculated quantity of lime and FYM were applied 10 days prior to treatment plots respectively. Full quantity of P (as Single super phosphate) and K (as Muriate of potash) and half quantity of N (as Urea) were applied prior to transplanting. Remaining half quantity of N (as Urea) was applied at maximum tillering and before flowering stage. Necessary growth and yield parameters were recorded before harvesting of the crop. After the harvest of finger-millet, soil samples were collected, air dried and used for the estimation of N, P, K, Ca, Mg and S using standard procedures.

Statistical analysis

Experimental data were analyzed using analysis of variance method. All the main and interaction effects were tested at 5 per cent level of significance (Sundarraj *et al*., 1972).

Results and Discussion

Growth parameters

There existed significant difference in plant height among different treatments (Table 2). Application of NPK@150% recorded the tallest plant (112.4 cm) followed by NPK@100%+FYM (101.9 cm) and NPK@ 100%+FYM+Lime (100.9 cm). The lowest plant height of 68.1 cm was noticed in control plot. Higher number of tillers per plant was recorded in all treatments except with the application of NP@100% (3.2) and N@100% (3.1), respectively over control (4.1).

Table 1. Properties of the soil before sowing finger millet *Kharif* 2010

Treatment	pH (1:2.5)	EC (d Sm^{-1})	OC (g kg^{-1})	Available nutrients (kg ha^{-1})			Available nutrients (mg 100 g^{-1} soil)		Available nutrient (ppm)
				N	P	K	Ca	Mg	S
NPK @ 50%	5.46	0.06	5.05	188.8	48.9	131.0	5.15	1.87	37.9
NPK @ 100%	5.65	0.07	5.14	207.2	96.4	151.5	5.70	2.70	44.0
NPK @ 150%	5.01	0.10	5.33	269.4	129.0	195.8	5.85	2.56	49.1
NPK @ 100% + HW	5.63	0.08	5.22	237.1	92.0	175.0	5.72	2.59	43.2
NPK @ 100% + FYM	5.85	0.07	5.69	252.7	129.8	175.5	5.89	3.09	48.3
NPK @ 100% + Lime	5.56	0.07	5.08	215.6	94.7	153.5	7.74	2.73	42.9
NPK @ 100% + FYM+ Lime	6.14	0.10	5.65	228.4	139.8	177.3	7.83	2.98	50.7
N @ 100%	4.91	0.07	4.73	216.2	28.5	87.9	4.90	1.85	33.9
NP @ 100%	4.89	0.07	4.79	219.9	116.4	104.4	5.67	2.18	39.0
NPK @ 100% (S-free)	5.00	0.07	5.95	212.5	90.1	153.8	5.69	1.82	28.1
Control	6.15	0.06	5.21	196.1	24.0	117.0	5.31	2.25	24.3
SEm±	0.18	0.006	0.16	18.2	6.2	15.9	0.230	0.093	0.44
CD (5 %)	0.37	NS	0.49	37.1	12.6	32.5	0.679	0.274	1.31

Lime : Applied based on lime requirement
FYM : Applied @15 t ha^{-1} only during *Kharif* season
NPK @ 100% : 100: 22: 42 kg ha^{-1} (Finger Millet)
N: Urea, P: SSP & K: MOP except where DAP (S-free) applied

Significantly higher number of tillers of 6.3 per plant was recorded with the application of NPK@150% and it was on par with plots with NPK@100%+FYM and NPK@100%+FYM+Lime which recorded 6.0 tillers per plant. The highest numbers of fingers per tiller (8.1) was recorded with the application of NPK@150% and was found on par with NPK@100%+FYM (7.80) and NPK@100%+FYM+Lime (7.60). Lower numbers of fingers per tiller were recorded with the application of N@100% (5.50), NP@100% (5.70), control (6.00) and NPK@50% (6.10) respectively. There was significant difference in 1000 grain weight of finger millet due to long term fertilizer application. Significantly the higher 1000 grain weight of 3.24 g was recorded in NPK@100%+HW and it was on par with the application of NPK@150% (3.15g), NPK@100% (3.11g) and NPK@100%+FYM+Lime (3.16g), respectively. The lowest 1000 grain weight of 2.87g was recorded with no fertilization (control). The result of the present study was in accordance with findings of Duryodhana *et al*., (2004)

Table 2. Effect of long term fertilizer application on growth and yield of finger millet during *Kharif* 2010

Treatment	Plant height (cm)	No of Tillers	No of Fingers	1000 grains weight (g)	Yield (kg ha^{-1})	
					Grain	Straw
NPK @ 50%	90.2	4.5	6.1	2.88	3350	4980
NPK @ 100%	92.4	5.8	7.3	3.11	4220	7080
NPK @ 150%	112.4	6.3	8.1	3.15	4860	8300
NPK @ 100% + HW	95.2	5.7	7.2	3.24	4420	7820
NPK @ 100% + FYM	101.9	6.0	7.8	2.98	4540	8170
NPK @ 100% + Lime	94.3	5.0	7.5	2.83	4020	7090
NPK @ 100% + FYM+ Lime	100.9	6.0	7.6	3.16	4820	8290
N @ 100%	70.2	3.1	5.5	2.44	620	980
NP @ 100%	87.6	3.2	5.7	2.67	780	1250
NPK @ 100% (S-free)	91.7	4.8	7.1	3.09	4440	7280
Control	68.1	4.1	6.0	2.87	680	1110
SEm±	1.7	0.2	0.2	0.08	26	24
CD (5 %)	5.2	0.5	0.7	0.23	79	73

Lime : Applied based on lime requirement
FYM : Applied @15 t ha^{-1} only during *Kharif* season
NPK @ 100% : 100: 22: 42 kg ha^{-1} (Finger Millet)
N: Urea, P: SSP & K: MOP except where DAP (S-free) applied

The growth parameters increased significantly due to the application of NPK @ 150% and also due to the incorporation of FYM and lime to the soil along with recommended doses of NPK @ 100% + FYM and NPK @ 100% + FYM + Lime. The results indicated the response of crops to higher than the recommended dosage of fertilizers and sustenance of crop yields by the application of only fertilizers for more than twenty two years under protective irrigation.

Yield parameters

The grain yields recorded due to the combined application of different levels of fertilizers (NPK) are represented in Table 2. The trend in respect of grain yield was also similar to those of growth parameters, i.e. grain yield increasing significantly with increasing dosages of NPK. The three graded dosages of NPK, i.e. NPK@50% (3350 kg ha^{-1}), NPK@100% (4220 kg ha^{-1}) and NPK@150% (4860 kg ha^{-1}) respectively. The treatments with imbalanced use of major nutrients i.e. NP@100% (780 kg ha^{-1}), N@100% (620 kg ha^{-1}) and inadequate use of the nutrients i.e. NPK@50% (3350 kg ha^{-1}) and control (680 kg ha^{-1}) recorded lower grain yields respectively. The highest straw yield (8300 kg ha^{-1}) was recorded with the application of NPK@150% and it was on par with NPK@100%+FYM+Lime (8290 kg ha^{-1}) and significantly the lowest yield of 980 kg ha^{-1} was recorded with N@100%.

Table 3. Effect of long term fertilizer application on uptake (kg ha^{-1}) of nitrogen, phosphorus and potassium in grain and straw of finger millet.

Treatment	Uptake (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
NPK @ 50%	33.6	18.1	6.4	5.6	12.8	24.2
NPK @ 100%	54.8	29.9	11.2	9.6	24.6	37.0
NPK @ 150%	66.3	32.8	13.9	11.6	34.3	49.3
NPK @ 100% + HW	50.8	24.8	9.7	8.1	22.2	37.8
NPK @ 100% + FYM	62.6	30.5	12.0	12.0	27.6	40.6
NPK @ 100% + Lime	51.8	22.4	10.7	8.7	25.7	40.1
NPK @ 100% + FYM+ Lime	65.3	32.8	13.5	13.1	32.2	43.5
N @ 100%	7.1	3.2	1.2	0.8	2.2	3.1
NP @ 100%	7.2	4.6	3.2	1.1	3.2	3.9
NPK @ 100% (S-free)	53.5	23.5	9.8	10.6	22.5	36.3
Control	4.9	3.1	1.3	1.0	1.9	3.9
SEm±	3.0	1.9	1.9	1.1	2.2	2.1
CD (5 %)	9.3	5.6	5.6	3.2	6.5	6.2

Lime : Applied based on lime requirement
FYM : Applied @15 t ha^{-1} only during ***Kharif*** season
NPK @ 100% : 100: 22: 42 kg ha^{-1} (Finger Millet)
N: Urea, P: SSP & K: MOP except where DAP (S-free) applied

Significant increase in the yield parameters of finger millet was noticed with increase in application of NPK@150% and also due to the incorporation of FYM and lime to the soil along with recommended doses of NPK. The reason for higher yields due to FYM application may be attributed to the release of nutrients in available forms from FYM during its decomposition and the absorption of the same by the crops and also due to its nutrient and moisture

Table 4. Effect of long term fertilizer experiment treatments on some chemical parameters of post harvest soil in finger millet (*Kharif* 2010)

Treatment	pH (1:2.5)	EC (d Sm^{-1})	OC (g kg^{-1})	Available nutrients (kg ha^{-1})			Exch. nutrients (c mol (p^{+}) kg^{-1})		Available nutrients (ppm)
				N	P	K	Ca	Mg	S
NPK @ 50%	5.46	0.06	5.06	187.7	47.8	130.0	5.64	1.95	37.4
NPK @ 100%	5.35	0.07	5.17	206.2	95.4	150.4	5.80	2.60	43.5
NPK @ 150%	4.89	0.10	5.28	268.4	128.0	194.8	5.72	2.59	48.7
NPK @ 100% + HW	5.63	0.08	5.16	236.0	90.3	174.0	5.58	2.51	43.7
NPK @ 100% + FYM	5.85	0.07	5.64	262.3	128.7	184.4	5.99	3.18	47.9
NPK @ 100% + Lime	6.18	0.08	5.11	214.6	93.6	152.4	7.14	2.69	42.5
NPK @ 100% + FYM+ Lime	6.32	0.10	5.70	247.3	138.7	185.9	7.54	2.95	50.2
N @ 100%	4.81	0.07	4.65	215.2	27.5	76.9	4.91	1.99	29.0
NP @ 100%	4.85	0.07	4.70	218.9	115.4	81.4	5.64	2.14	38.6
NPK @ 100% (S-free)	5.68	0.07	5.15	214.8	89.0	152.7	5.38	1.78	20.8
Control	6.15	0.06	4.91	195.0	23.7	93.1	5.18	2.22	15.7
SEm±	0.10	0.01	0.04	7.0	2.4	4.6	0.092	0.03	0.52
CD (5 %)	0.30	0.01	0.11	21.1	7.3	13.8	0.260	0.10	1.56

Lime : Applied based on lime requirement
FYM : Applied @15 t ha^{-1} only during *Kharif* season
NPK @ 100% : 100: 22: 42 kg ha^{-1} (Finger Millet)
N: Urea, P: SSP & K: MOP except where DAP (S-free) applied

retention functions. These results corroborated with the observations made by Sharma *et al.* (2001).

Nutrient uptake

In general, nitrogen uptake by finger millet crop increased with increase in the dosages of NPK (Table 3). The uptake of nitrogen by finger millet was recorded with the application of N @ 150% (66.26 kg ha^{-1}) and the lowest in control (4.88 kg ha^{-1}). The uptake of nitrogen with the application of N @ 100% + FYM + Lime (65.32 kg ha^{-1}) and N @ 100% + FYM (62.59 kg ha^{-1}) was found to be on par with each other. A similar trend was noticed even in respect of uptake of nitrogen by straw. Highest and the lowest nitrogen uptake values of 32.82 kg ha^{-1} and 3.14 kg ha^{-1} were registered by NPK@150% and control respectively. Phosphorus uptake followed the same trend as that of nitrogen uptake. Application of NPK@150% recorded the highest uptake of 13.85 kg ha^{-1} (grain) followed by application of NPK @ 100% + FYM+ Lime (13.53 kg ha^{-1} in grain and 13.10 kg ha^{-1} in straw) and N@100% alone recorded the lowest (1.23 kg ha^{-1} in grain and 0.81 kg ha^{-1} in straw) respectively. The uptake of potassium was found to be increasing significantly with increase in NPK application. In respect of K uptake, the highest (34.26 kg ha^{-1}) and the lowest (1.87 kg ha^{-1}) values were recorded with the application of NPK@150% and control respectively. In respect of K uptake by straw, the highest of 49.27 kg ha^{-1} was noticed with the application of NPK@100%+FYM+Lime and lowest values of 3.13 kg ha^{-1} was recorded with application of N@100% alone respectively. In every respect, the trends in K uptake in grain as well as straw were similar to those of N and P.

Least uptake was observed in treatments with imbalanced application of NPK i.e. NP@100%, N@100% and control, which recorded lowest yield attributing to least availability of nutrients in soil. FYM being a good source of nutrients when added to soil along with fertilizers attributes to increase in available nutrients and converting unavailable forms of nutrients into available form, during decomposition, similar results were also reported by Raghuvanshi and Umat (1994). Further, addition of organics is known to improve soil health, which encourages proliferation of roots resulting in more adsorption of nutrients, this was in conformity with the findings of Ravankar *et al*. (1999). On the contrary, control and N alone (T_7) and only N and P (T_6) recorded lower concentration and uptake of NPK compared to other treatments in both crops (grain and straw). This implies inadequate supply of either one or more of major nutrients to the crop due to an imbalance in the supply of nutrient elements and consequent reduction in yield and uptake.

Chemical properties of soil

Soil pH

In general, the plots treated continuously with fertilizers recorded much lower values than those treated in combination with lime. A decline in soil pH was noticed with increase in the dosage of N fertilizers. Significantly higher soil pH of 6.32 was recorded in the plot treated with NPK@100%+FYM+Lime, in comparison to NPK@100% (5.35). The differential effect of treatments on soil pH was obvious in this study. There was an increase in the soil pH as a result of lime application along with FYM. Lime, upon reaction with the soil would release hydroxy ions, which in turn react with hydrogen ions in the soil and bring about reduction in acidity of soil Pradhan and Mishra (1982) and Sahu and Patnaik (1990). Soil pH decreased with the continuous application of chemical fertilizers over the years. It is a well known fact that chemical fertilizers, particularly N carriers would help in generating hydrogen ions in the soil (Tisdale *et al.,* 1985). Suresh and Mathur (1989) reported that the rise in soil pH under FYM treatment was due to the deactivation of Fe^{2+} and Al^{3+} by the chelating agents and concomitant release of basic cations upon its decomposition.

Electrical conductivity

The highest soil EC of 0.102 dSm^{-1} was recorded in NPK@100%+FYM+Lime and the lowest EC of 0.060 dSm^{-1} was observed under NPK@50%, followed by control (0.062 dSm^{-1}) and T_7 (0.068 dSm^{-1}), respectively. The limed plots contained relatively higher amounts of soluble salt than the unlimed plots. This could be attributed to the release of calcium from those materials and subsequent formation of some of the soluble salts of calcium. These results were harmony with findings of Subramanian and Kumaraswamy (1989).

Organic carbon

Significant differences among the treatments were observed in respect of organic carbon (OC) content of soil. In general OC content decreased in the plots treated only with inorganic fertilizers than the plots treated with FYM along with inorganic fertilizers. The highest OC values of 5.70 g kg^{-1} and 5.64 g kg^{-1} were recorded in NPK@100%+FYM+Lime and NPK@100%+FYM, respectively.

Organic matter is an index of the soil physical, chemical and microbiological properties from the point of view of their effect on plant growth. The plots applied with FYM had significantly higher contents of organic carbon as compared to the rest of the plots. A build up of organic matter in the soil due to continuous addition of organic manure and crop residues has been reported by several of the earlier workers (Sinha *et al.,* 1983; Patiram and Singh, 1993). The relatively higher amounts of organic carbon in the plots fertilized with only chemical fertilizers could be attributed to increased crop growth and consequent addition of biomass to the soil by way of roots and crop residues (Anon., 1992). Sudhir and Siddaramappa (1995) reported that the less increase of organic carbon of an Alfisol in plots receiving only NPK and more increase when fertilizers treated with FYM. Babhulkar *et al*. (2000) also reported that increase in organic carbon in soil due to application of FYM or in combination with fertilizers could be attributed to larger biomass production, which aid to increase OC content of soil.

Available nitrogen

There was significant difference among treatments in respect of available N content of soil. In the present study, use of FYM in combination with NPK was found to significantly increase the available N content of soil as compared to the use of only fertilizers. The increase in available N content of soil in the cases of NPK along with FYM or NPK along with lime and FYM could be ascribed to the increased organic matter and total N contents of the soil caused by combined application of organic and inorganic fertilizers. Ganapathi (1991) also reported results similar to the one observed in this study. Sudhir *et al*. (1998) reported an increase in available nitrogen content due to continuous use of FYM alone or in combination with fertilizers and decrease in available N due to continuous fertilizer application.

Available phosphorus

There was significant increase in the available of P with the application of NPK@100%+FYM+Lime (138.7 kg ha^{-1}) and NPK@100% +FYM (128.7 kg ha^{-1}) respectively. Except T_1 (50% NPK), there was significant build up of phosphorus in all the treatments over the initial status.

Incorporation of FYM in combination with fertilizers increased the available P content in the soil, due to the dissolution of native P compounds by decomposition products of FYM. Increase in available P status of soils due to addition of FYM and NPK fertilizers was observed by Lal and Mathur (1989) and Sudhir *et al*. (1998). Besides, FYM itself could contribute considerably to the available P pool of soil upon mineralization (Badanur *et al.,* 1990).

Available potassium

Significant increase in available K was noticed in all the treatments except the application of NP@100%. Application of FYM along with inorganic source of nutrients in NPK@100% (184.4 kg ha^{-1}) and NPK@100%+Lime (185.9 kg ha^{-1}) was found to be significantly higher than other treatments and on par with each other except application of NPK@150% (194.8 kg ha^{-1}) which recorded the highest available potassium content in soil. Farmyard manure is not only a direct and ready source of K (Bansal, 1992) but also aids in minimizing the leaching loss of K by retaining K ions on exchange sites of its decomposed products. Its favorable effect is evident in enhancing the solubility of insoluble K compounds during the decomposition process (Anon., 1992).

Exchangeable calcium and magnesium

Significant difference among the treatments in respect of exchangeable Ca and Mg was noticed with the application of NPK@100%+FYM+Lime and the values were 7.54 and 2.95 (c mol (p^+) kg^{-1}) respectively, Continuous application of organic manures helped to increase the exchangeable calcium and magnesium, while application of only N and K decreased the calcium and magnesium contents in the soil.

This indicated that removal of Ca by the crops is greater than that was added from external sources. Patiram and Singh (1993), concluded that the integrated treatments with chemical fertilizers along with 50 per cent or 25 per cent of organic N through FYM/GM, rice straw or Azolla resulted in significantly higher content of exchangeable Ca and Mg in the soil. At the end of seven years of cropping both exchangeable and total Ca and Mg depleted over initial value, except slight build up of Ca when 50 per cent organic N was applied through FYM (Basumantary and Talukdar, 1998).

Available sulphur

Higher available sulphur content (50.2 ppm) was recorded with the application of NPK@100%+FYM+Lime and the lowest (15.7 ppm) was in control followed by 20.8 ppm which received NPK@100% (S- free).

This indicated that regular use of SSP added substantial amounts of S to the soil and as such was responsible for increasing the available S status of soil treated with it, while the S status decreased in the plots that were not treated with it because of uptake by crops. Considerable increase in the sulphur content, which may be due to FYM addition contribution of S from sulphur containing amino acids and other organic compounds in FYM (Jagadeesh, 2000). An increase in the contents of available S in the FYM treated plots might have regularly released the organically bound S to the soil in plant available form. Shantakumari (2007), reported that addition of sulphur containing fertilizers (SSP) and FYM to the soil would substantially increase the available sulphur content of the soil in spite of raising crops one after another.

References

Anonymous, 1992. All India Coordinated Research Project on Long-Term Fertilizer Experiment (ICAR), Indian Agricultural Research Institute, New Delhi. *Annual Progress Report* for 1987-89.

Babhulkar, R.M., Wandile, W.P., Badole and Balpande, S.S. 2000. Residual effect of long-term application of FYM and fertilizers on soil properties (Vertisols) and yield of soybean. *Indian Soc, Soil Sci., **48**:* 89-92.

Badanur, V.P., Polshi, C.M. and Balachandra Naik. 1990. Effect of organic matter on crop yield and physical and chemical properties of Vertisol. *J .Indian Soc. Soil Sci.,* **38**: 426-429.

Bansal, K.L. 1992. Potassium balance in multiple cropping systems in vertisol at Jabalpur. *J. Potassium Res.,* **85**: 52-58.

Basumantary, A. and Talukdar, M.C. 1998. Long-term effect of integrated nutrient supply on soil properties in an Inceptisol of Assam. *J. Indian Soc. Soil Sci.,* **35**: 43-46.

Duryodhana, D., Krishnegowda, K.T., Kadalli, G.G. and Ashok, E.G. 2004. Uptake pattern of major nutrients at different growth stages by dry land finger millet (*Eleusine coracana* (L.) Gaertn.) from different sources and levels of nutrients. *Mysore J. Agric. Sci*., **38:** 487 – 495

Ganapathi, T. 1991. Effect of NPK, gypsum and coir pith on nutrient availability in soil, uptake and yield of rice. *M.Sc. (Ag.) Thesis*, Tamil Nadu Agric.Univ., Coimbatore.

Jagadeesh, B.R. 2000. Chemical and biochemical properties of soil subjected to permanent manurial and cropping schedule. *M.Sc* (*Agri*.) *Thesis*, UAS, Bangalore.

Lal, S. and Mathur, B.S. 1989. Effect of long-term manuring, fertilization and liming on crop yield and some physico-chemical properties of acid soil. *J. Indian Soc. Soil Sci.,* **36:** 113-119.

Luigi Guarino, 2011. Global strategy for the *ex situ* conservation of finger millet, Global Crop Diversity Trust, Rome: luigi.guarino@croptrust.org.

Patiram and Singh, K.A. 1993. Effect of continuous application of manure and nitrogenous fertilizers on some properties of inceptisol *.J .Indian Soc. Soil Sci.,* **41**: 430-433.

Pradhan, N.K. and Mishra, C. 1982. Effect of liming and organic soil amendments on crop yield and physico-chemical properties of laterite soils. *J. Indian Soc. Soil Sci.,* **30:** 180-184.

Raghuvanshi, R.K.S. and Umat, R. 1994. Integrated nutrient management in sorghum *(Sorghum bicolor)-wheat (Triticum aestivum)* cropping system. *Indian J. Agron.,* **39:** 193-197.

Ravankar, H.N., Deore, R.S. and Deshmukh, P.W. 1999. Effect of nutrient management through organic and inorganic sources on soybean yield and soil fertility. *PKV Res. J.,* **23:** 47-50.

Sahu, G.C. and Patnaik, 1990. Influence of lime and organic matter on pH and ion exchange phenomenon of some Alfisols. *J. Indian Soc. Soil Sci.,* **38**: 389-393

Shanthakumari, S. 2007. Distribution of secondary and micronutrients in an Alfisol subjected to long term fertilizer schedule and continuous cropping *M.Sc (Agri.) Thesis*, UAS, Bangalore.

Sharma, M.P., Balf, S.V. and Gupta, D.K. 2001. Soil fertility and productivity of rice *(Oryza sativa)-wheat (Triticum aestivum)* cropping system in an inceptisol as influenced by integrated nutrient management. *Indian J. Agric Sci.,* **71:** 82-86.

Sinha, B.K., Sarkar, A.K. and Srivastava, B.P. 1983. Effect of continuous application of manure and fertilizers on different forms of aluminum in an acid soil. *J. Indian Soc. Soil Sci*., **3:** 632-634.

Subramanian, K.S. and Kumaraswamy, 1989. Effect of continuous cropping and fertilization on chemical properties of soil. *J. Indian Soc. Soil Sci.,* **37:** 171-173.

Sudhir, K. and Siddaramappa, R. 1995. Role of organic manure in the maintenance of soil health and productivity. An experience from long-term fertilizers experiments at Bangalore centre. *In: Alternatives to fertilizers in sustainable Agriculture,* (ed.) Shivashankar, K. University of Agricultural Sciences. Bangalore

Sudhir, K., Mariswamy Gowda, S.M. and Srikanth, K. 1998. Long-term effect of continuous cropping and fertilizer use on sustenance of productivity and fertility of an alfisols under irrigated finger millet-hybrid maize system. In: Long-term fertility management through integrated plant nutrient system, AICRP on LTFE. ICAR, pp. 139-145.

Sundarraj, N., Nagaraju, S., Venkataramu, M.N. and Jagannath, M.L. 1972. *Design and Analysis of Field Experiments*. UAS, Bangalore.

Suresh, L. and Mathur, B.S. 1989. Effect of long- term manuring, fertilization and liming on crop yield and some physico -chemical properties of soil. *J. Indian Soc. Soil Sci.,* **36**: 113-119.

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. 1985. *Soil Fertility and Fertilizers. 4th ed,* Mac Millan Publishing Company. New York. 251 p.

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