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Impact of manuring and fertilization over long term on soil available plant nutrients in eastern dry zone of Karnataka

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Abstract
The soils collected after 31 cropping cycles (2017) from ongoing long term fertilizer experiment under finger millet-maize cropping system at GKVK, Bengaluru were studied for its available nutrients status. In long term manurial soils under finger millet and maize cropping system plant available nutrient status such as nitrogen, potassium and sulphur were maintained sustainability in all treatments, except treatment receiving 100 per cent NP and only 100% N respectively. There was high build up of available phosphorus in soil due to continuous application of phosphatic fertilizers. Calcium and magnesium content was recorded higher in lime and FYM applied treatment along with 100% NPK It was noticed that the DTPA extractable micronutrients like zinc, copper, iron and manganese status was maintained in the treatments received FYM in combination with inorganic fertilizer. Hence, application of recommended doses of fertilizer in combination with FYM helps in maintaining soil health as well as available nutrient status of soil.

Keywords: Available nutrients, fertilization, FYM, long term fertilizer experiment

Introduction
Enhancement and sustained crop production do play an important role in the improvement and soil fertility maintenance. The long term fertilizer experiments acts as repositories for valuable information regarding sustainability in agriculture and environmental quality. Long-term field experiments that test a range of treatments and are intended to assess the sustainability of crop production, and thus food security, must be managed actively to identify any treatment that is failing to maintain or increase yields. They provide a field resource and samples for research on plant and soil processes and properties, especially those properties where change occurs slowly and affects soil fertility. Long term fertilizer experiments are widely recognized with continuous cropping on soil fertility and sustenance of crop production.

Application of chemical fertilizer gives apparent high crop yield but only yield consequence may not reflect the status of the soil health, especially where soil OM is petite. Intensive cultivation of high yielding varieties of crops with application of high rates of N, P, K fertilizers tend to deplete the secondary nutrients reserve of soil at faster rate. To formulate sound fertilizer recommendation, it is essential to know the nutrient supplying capacity of the soil. Hence the present research programme is carried out to study the changes soil major, secondary and micronutrients influenced by continuous manuring with organic and inorganic fertilizers with the objective to study the status of available soil nutrients after 31 cropping cycles in long term fertilizer experiment under finger millet-maize cropping system.

Material and Methods
Location of the study area: Field study was conducted at LTFE field at ”E- 18” Block, ZARS, GKVK, UAS, Bengaluru located in Eastern Dry Zone of Karnataka at 13° 4' 37" N latitude, 77° 34' 13" E longitude with an altitude of 930 meters above mean sea level (MSL).

Collection of soil sample and soil characteristics of the study site
A composite soil sample was taken from each plot from the study area by collecting soil samples

at 0-15 cm depth after harvest of maize crop (2017). Initial properties of experimental plot is presented in Table 1.

Treatment details

The treatment details of the AICRP on long term fertilizer experiment with finger millet – maize cropping system are given in Table 2.

Table 1: Initial physico-chemical properties of soil sample of study site (1986)

Sl. No	Soil property	Value
4	pH (1:2.5 soil:water suspension)	6.17
5	Electrical conductivity (dS m^{-1})	0.059
6	Organic carbon (g kg^{-1})	0.60
7	Cation exchange capacity [c mol (p+) kg^{-1}]	12.20
8	Available nitrogen (kg N ha^{-1})	256.70
9	Available phosphorus (kg P2O5 ha^{-1})	34.30
10	Available potassium (kg K2O ha^{-1})	123.10
11	Available sulphur (mg kg^{-1})	20.34
12	Exchangeable calcium [c mol (p+) kg^{-1}]	3.25
13	Exchangeable magnesium [c mol (p+) kg^{-1}]	1.55
14	Available iron (mg kg^{-1})	5.22
15	Available manganese (mg kg^{-1})	108.40
16	Available copper (mg kg^{-1})	2.30
17	Available zinc (mg kg^{-1})	2.34

Analysis of soil samples

Soil samples collected (0-15 cm depth) from the experimental plots at harvest of maize crop (2017) were processed and subjected for analysis of various chemical properties. The analytical techniques followed for the estimation of chemical properties of soil are presented in Table 3.

Table 2: Treatments details of long term fertilizer experiment

Treatments	Fertilizer source
T_1: 50% NPK	Urea, SSP, MOP
T_2: 100% NPK	Urea, SSP, MOP
T_3: 150% NPK	Urea, SSP, MOP
T_4: 100% NPK + HW	Urea, SSP, MOP
T_5: 100% NPK + lime	Urea, SSP, MOP, lime
T_6: 100% NP	Urea, SSP
T_7: 100% N	Urea
T_8: 100% NPK + FYM	Urea, SSP, MOP
T_9: 100% NPK (S-free)	Urea, DAP, MOP
T_{10}:100% NPK + FYM + lime	Urea, SSP, MOP, lime
T_{11}: Control	…………..

In all the treatments except in treatment T_4 (100% NPK+HW), chemical weed control is practiced using appropriate weedicides. Lime was applied based on lime requirement following the method given by Shoemaker *et al*. (1961) [27] during *kharif* season

Table 3: Methods followed for the analysis of soil samples

Parameters	Methods	References
pH	Potentiometric method	Jackson (1973) [8]
EC	Conductometric method	Jackson (1973) [8]
Organic carbon	Wet oxidation method	Walkley and Black (1934) [25]
Cation exchange capacity	Ammonium acetate leaching method	Jackson (1973) [8]
Available nitrogen	Alkaline potassium permanganate Method	Subbiah and Asija (1956) [22]
Available phosphorus	Bray’s extractant method, Colorimetry	Jackson (1973) [8]
Available potassium	Ammonium acetate extractant method, Flame photometry	Jackson (1973) [8]
Available sulphur	$CaCl_2$ extractant method, Turbidimetry	Black (1965) [5]
Exchangeable calcium	Complexometric titration	Page *et al*., (1982) [14]
Exchangeable magnesium	Complexometric titration	Page *et al*., (1982) [14]
DTPA extractable Fe, Mn, Zn and Cu	Atomic absorption spectrophotometry	Lindsay and Norvell (1978) [13]

Statistical analysis of data

The data collected from experiment were subjected to statistical analysis as described by Gomez and Gomez (1984) [7]. The level of significance used in “F” and “t” test was P = 0.05. Critical difference (CD) values were calculated for the P = 0.05 whenever “F” test was found significant.

Results and Discussion

Effect of long term manuring on soil physico-chemical properties under finger millet and maize cropping system after 31 crop cycle.

The data pertaining to influence of continuous application of manures and fertilizers are presented in Table 4.

Soil pH

The changes in soil pH in long term fertilizer experiment under finger millet-maize cropping system are presented in Table 4. The results showed that plots which are treated with continuous application of fertilizers recorded significantly lower pH values than the plots treated in combination with inorganic fertilizer and FYM. The decline in soil pH was noticed with increase in dosage of nitrogenous fertilizers. Significantly, higher soil pH of 5.98 was recorded in the plot treated with 100% NKP + FYM + Lime (T_{10}) as compared to T_5 (5.54) which received 100% NPK + lime. Among different treatments T_3 (150% NPK), T_7 (100% N) and T_6 (100% NP) recorded very low pH values *i.e*. 4.40, 4.42 and 4.64, respectively.

Pradhan and Misra (1982) [15] noticed that there was increase in soil pH as result of lime application along with FYM. Upon lime application, it reacts with soil which might have helped in the release of hydroxyl ions, which reacts with hydrogen ions present in soil and brought about reduction in soil acidity. Studies carried out by Sahu and Patnaik (1990) [17]. Soil pH in treatment applied with 100 per cent NPK + FYM + Lime was well maintained compared to initial status. It was attributed to continuous application of FYM which is a good source of basic cations.

Electrical conductivity (dS m^{-1})

EC value of 0.13 dS m^{-1} was recorded significantly higher in T_{10} (100% NKP + FYM + Lime) followed by treatment T_5 receiving 100% NKP + Lime (0.11 dS m^{-1}). However, lower EC value was observed in the treatment $T_7$and T_9: 0.04dS m^{-1} that received 100% N and 100% NPK (S- free phosphatic fertilizer), respectively. Whereas, lime applied plots recorded relatively higher amounts of soluble salt than the non-limed plots.

Electrical conductivity of the soil was significantly higher in plots treated with fertilizers, lime and FYM in comparison to control plots. The soluble salt contents in all the treatments were below the critical level to have any adverse effect on plant growth. The reason for relatively higher soluble salt content in lime amended and FYM incorporated plots as compared to the plots treated with only chemical fertilizers could be attributed to the release of calcium from lime and FYM. Similar results were reported by Vig and Bhumbla (1970) [24] and Subramanian and Kumarswamy (1989) [23].

Organic carbon

Organic carbon (OC) content in soil showed significant difference among the treatments. In general, the organic carbon content in soil was found to be low in the plots that were treated with only inorganic fertilizers than the plots treated with organic manure along with inorganic fertilizers.

Table 4: Effect of long term manuring on physico - chemical properties of soil under finger millet – maize cropping system after 31 years of cropping cycle

Treatments	pH (1:2.5)	Electrical conductivity (dS m^{-1})	Organic carbon (%)	CEC (c mol (p$^+$) (kg^{-1})
T_1: 50% NPK	5.44	0.06	0.50	9.9
T_2: 100%NPK	5.05	0.08	0.54	10.4
T_3: 150%NPK	4.40	0.09	0.55	10.8
T_4: 100%NPK+HW	4.80	0.06	0.53	10.6
T_5: 100%NPK+lime	5.54	0.11	0.50	12.1
T_6: 100%NP	4.64	0.06	0.47	9.4
T_7: 100%N	4.42	0.04	0.44	8.6
T_8: 100%NPK+FYM	5.53	0.08	0.57	12.8
T_9: 100%NPK(S-free)	4.96	0.04	0.45	10.0
T_{10}:100%NPK+FYM+lime	5.98	0.13	0.65	13.6
T_{11}: Control	5.23	0.06	0.41	9.2
SEm±	0.107	0.013	0.021	0.687
CD @ 5%	0.309	0.037	0.060	1.786

Treatments which received FYM along with inorganic fertilizers recorded significantly higher OC values compared to treatments received chemical fertilizers alone. OC values was higher in T_{10} receiving 100% NPK + FYM + lime (0.65) followed by T_8 receiving 100% NPK + FYM (0.57). Significantly lower values (0.41, 0.44 and 0.45 per cent) were recorded in the plots treated with imbalanced fertilizers *i.e.*, control (T_{11}), only 100% N (T_7) and 100% NPK (S-free) (T_9), respectively.

In the present study there was a marked variation in soil organic carbon content in different treatments. Application of FYM has significantly increased organic carbon content compared to rest of the treatments. Increase in organic carbon in these treatments was due to application of FYM in combination with fertilizers Babhulkar *et al*. (2000) [3]. The positive effect of use of FYM on organic carbon content in soil was also reported by Jose *et al*. (2008) [11].

Cation exchange capacity

Application of balanced chemical fertilizers in combination with FYM and lime increased the CEC of the soil which might be attributed to higher organic colloids in these plots. The decrease in CEC values in inorganic fertilizer treated plots may be attributed to the acidifying effect of fertilizers leading to reduction in pH values in almost all the treatments and markedly in 100% N treated plot. Similar results were reported by Jagadeeshwari *et al*. (2001) [10].

Available nitrogen (kg ha^{-1})

Significant differences were noticed with respect to available nitrogen content among treatments. Significantly higher available nitrogen (235.11 kg ha^{-1}) was recorded in treatment T_{10} (100% NPK + FYM + lime) followed by T_8:100% NPK + FYM (204.43 kg ha^{-1}) over all other treatments Available nitrogen content recorded lower in treatment T_{11}: control (166.21 kg ha^{-1}).

Higher available nitrogen was recorded in treatments receiving FYM along with inorganic fertilizers. Whereas lower nitrogen content was observed in control compared to all other treatments. Similar results were reported by Sudhir *et al*. (1998) [20] with the higher available nitrogen in FYM applied plot might be due to the positive impact of the organic manure and its mineralization in to available forms.

Available phosphorus (kg ha^{-1})

The available phosphorus content of soil increased significantly in all the treatments except T_{11} (32.31 kg ha^{-1}) absolute control and T_7 (40.43 kg ha^{-1}) which received only 100% N. Significantly higher available phosphorus content was recorded in treatment (T_3) receiving 150% NPK (180.60 kg ha^{-1}) followed by treatment (T_6) receiving 100% NP (176.98 kg ha^{-1}).

Available phosphorus content was observed higher in plot applied with higher dose of single super phosphate (T_3) over other treatments. Incorporation of FYM in combination with fertilizers increased the available P content in soil compared to other treatments. The positive effect of FYM on P availability may be due to organic anions produced during the decomposition of organic matter. These anions compete with inorganic PO_4^{-3} and therefore reduced the fixation of phosphate and also acids released during decomposition of organic matter dissolves fixed P thereby increases the availability. Continuous liming reduced the soil acidity to a greater extent by neutralizing Fe and Al hydroxides there by releasing P from such oxides. Removal of labile P by the crops in soil was 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 nitrogenous and also in control plots (Srivastava, 1990) [19].

Significantly higher available phosphorus in all the plots receiving P at either recommended dose or at higher dose of phosphorus clearly justify the buildup of phosphorus in soil over the years. Build up of phosphorus in soil due to similar reasons of fertilization were reported by many workers (Anon, 2004) [2].

Available potassium (kg ha^{-1})

The available potassium content of soil increased significantly in all treatments except T_7 (70.21 kg ha^{-1}) and T_6 (75.06 kg ha^{-1}) which received only 100% N and 100% NP, respectively. Application of 150% NPK, T_3 (255.45 kg ha^{-1}) and FYM application along with inorganic source of nutrients in treatment T_{10} (255.19 kg ha^{-1}) were found to be superior compared to other treatments.

The results indicated that available potassium was higher in the plots receiving higher dose of inorganic fertilizers and also in the plots wherein FYM along with inorganic fertilizers were applied over the years. It is observed that in the treatments T_3 and T_{10} received 150% NPK and 100% NPK + FYM, respectively has significantly higher available potassium content compared to other treatments. Prasad *et al*. (1996) [16] and Sudhir *et al*. (1998) [20] have observed similar results in plots incorporated with FYM recorded relatively higher amounts of available potassium than those which were not treated with

FYM. Farmyard manure is not only a good and ready source of potassium but also helps in minimizing the leaching loss of potassium by retaining potassium ions on exchange sites of its decomposition. Favorable effect of FYM was evident in enhancing the solubility of insoluble potassium compounds during the decomposition process (Anon, 1992 and Bansal, 1992) [1, 4].

Available sulphur (mg kg^{-1})

Available sulphur content of soil differed significantly among the different treatments. The data showed that available sulphur content increased in all the treatments over T_7 (100% N). Significantly higher available sulphur content was recorded in treatment receiving 100% NP (T_6: 15.13 mg kg^{-1}) and treatment T_3 receiving 150% NPK (14.26 mg kg^{-1}). Available sulphur content of soil was recorded lower in treatment T_9 (7.40mg kg^{-1}) receiving 100% NPK-S free phosphatic fertilizer.

The available sulphur content of soil was higher in plots treated with sulphur containing fertilizers (SSP) in comparison to plots that were not treated with such fertilizers. Sulphur status was decreased in the plots (T_7) that were not treated with sulphur containing fertilizer. This clearly indicates that regular use of SSP would add substantial amount of sulphur to the soil. Jagadeesh (2000) [9] reported similar results on considerable increase in sulphur content due to addition of FYM and sulphur containing fertilizers (SSP). An increase in available sulphur content of soil under FYM treated plots (T_{10} and T_3) was ascribed to the release of organically bound S in to the soil. Similar results were reported by Lal and Mathur (1992) [12], Yifter *et al*. (2000) [26] and Shantakumari (2007) [18].

Exchangeable calcium [c mol (P$^+$) kg^{-1}]

Treatment (T_{10}) receiving 100% NPK +lime + FYM recorded 6.13 c mol (P$^+$) kg^{-1} and treatment (T_5) receiving 100% NPK+ lime recorded 5.41c mol (P$^+$) kg^{-1} of exchangeable calcium in soil which is significantly higher compared to other treatments. The treatment subjected to only application of nitrogen *i.e*., T_7 recorded the lower (3.07 c mol (P$^+$) kg^{-1}) exchangeable calcium content in soil.

The present study revealed that application of lime and FYM recorded relatively higher exchangeable calcium content than those treatment receiving only chemical fertilizers. Continuous removal of calcium without replenishment from external sources was the main reason for relatively lower amounts of available calcium found in control and N alone plots. Similar results were reported by Shantakumari (2007) [18]. The reason for increased exchangeable calcium content of soil in lime amended plots was due to the direct addition of calcium in form of calcium carbonate over the years. FYM being a good source of calcium which would have increased the exchangeable calcium content in the soil upon its decomposition.

Exchangeable magnesium [c mol (P$^+$) kg^{-1}]

The treatment (T_{10}) receiving 100% NPK + lime + FYM recorded higher magnesium content (3.03 c mol (P$^+$) kg^{-1}) followed by control (2.85 c mol (P$^+$) kg^{-1}) which was on par with T_8 treatment receiving 100% NPK+FYM [2.60 c mol (P$^+$) kg^{-1}]. Treatment subjected to application of 100% NPK *i.e*., T_4 recorded the lower (1.58 c mol (P$^+$) kg^{-1}) exchangeable magnesium content in soil.

There was a significant difference with respect to exchangeable magnesium content of soil. Higher exchangeable magnesium content was recorded in 100 per cent NPK+FYM+ lime applied treatment. Continuous cropping could considerably reduce the exchangeable magnesium reserve, if the nutrient is not supplied from the external source. This was evident in the present study, as exchangeable magnesium was relatively lower in plots applied with only NPK fertilizers, in comparison to plots treated with fertilizers and FYM and lime (T_8, T_{10} and T_5). Lime can also contribute Mg to some extent as it contains some amount of Mg as impurity. This could probably the reason for relatively higher amount of exchangeable Mg in lime amended plots compared to only chemical fertilizers containing NPK application. It was also due to FYM addition which contributed to substantial increment in Mg content upon its decomposition. Similar results were reported by Prasad *et al*. (1996) [16].

DTPA-zinc (mg kg^{-1})

Significant difference among the treatments was noticed with respect to zinc content in soil after the harvest of maize (31 crop cycles). Higher zinc content was recorded in treatment T_{10} receiving 100% NPK + FYM + lime (5.00 mg kg^{-1}), whereas significantly lower zinc content was recorded in treatment T_9: 2.02 mg kg^{-1}, which received 100% NPK (S-free).

DTPA–Copper (mg kg^{-1})

Copper content of soil after the harvest of maize had significant difference among treatments. The values were significantly higher in treatments with application of FYM compared to other treatments. Copper content was recorded higher in T_8 (1.76 mg kg^{-1}) followed by T_{10} (1.59 mg kg^{-1}), however lower value of copper (1.17 mg kg^{-1}) was recorded in treatment T_{11} (control) followed by T_1(1.32 mg kg^{-1}) treatment which received 50% NPK.

Table 6: Effect of long term manuring and fertilizers application on the availability of micronutrients in soil after 31 cropping cycles (after the harvest of maize, 2017)

Treatments	Zinc (mg kg^{-1})	Copper (mg kg^{-1})	Iron (mg kg^{-1})	Manganese (mg kg^{-1})
T_1: 50% NPK	2.68	1.32	11.48	20.33
T_2: 100% NPK	2.39	1.45	15.96	23.85
T_3: 150% NPK	2.08	1.33	16.18	24.01
T_4: 100% NPK+HW	2.23	1.41	15.52	22.76
T_5: 100% NPK+lime	3.18	1.37	10.74	20.01
T_6: 100% NP	2.96	1.49	15.63	24.73
T_7: 100% N	2.70	1.48	15.68	23.33
T_8: 100% NPK+FYM	4.79	1.76	17.53	23.64
T_9: 100% NPK(S-free)	2.02	1.40	15.12	23.84
T_{10}:100% NPK+FYM+lime	5.00	1.59	12.36	20.31
T_{11}: Control	2.93	1.17	6.06	15.23
SEm±	0.35	0.01	1.03	0.93
CD @ 5%	1.02	0.29	2.96	2.69
Initial (1986)	2.34	2.30	5.22	108.4

DTPA-iron (mg kg^{-1})

There was significant difference in DTPA extractable iron content of soil among different treatments. Application of only chemical fertilizers showed lower values of DTPA extractable iron in soil. Significant higher value was recorded in the treatment receiving FYM (T_8:17.53 mg kg^{-1}) and lower DTPA-Fe content of soil was recorded in treatment receiving 100% NPK + lime (T_5:10.74 mg kg^{-1}).

Table 5: Effect of long term manuring and fertilizers application after 31 crop cycles (after the harvest of maize) on the availability of major and secondary nutrients

Treatments	Available N (kg ha^{1})	Available P_2O_5 (kg ha^{1})	Available K_2O (kg ha^{1})	Available S (mg kg^{1})	Exch. Ca [c mol (P^+) kg^{1}]	Exch. Mg [c mol (P^+) kg^{1}]
T_1: 50% NPK	166.21	64.63	154.83	7.49	4.70	2.63
T_2: 100%NPK	175.62	95.20	177.46	11.69	4.20	1.89
T_3: 150%NPK	196.00	180.60	255.45	14.26	4.05	1.83
T_4: 100%NPK +HW	183.98	101.79	184.26	12.27	4.28	1.58
T_5: 100%NPK+Lime	185.02	82.79	190.71	13.65	5.41	2.49
T_6: 100%NP	183.98	176.98	75.06	15.13	3.93	2.15
T_7: 100%N	192.34	40.43	70.21	8.55	3.07	1.75
T_8: 100%NPK+FYM	204.43	163.98	210.94	13.42	5.09	2.60
T_9: 100%NPK(S-free)	175.62	140.07	150.45	7.40	3.49	1.96
T_{10}:100%NPK+FYM+lime	235.11	152.60	255.19	12.58	6.13	3.03
T_{11}: Control	166.21	32.31	95.28	10.50	4.49	2.85
SEm±	6.53	4.62	6.73	0.83	0.18	0.21
CD @ 5%	18.86	13.35	19.43	2.32	0.52	0.62

DTPA-manganese (mg kg^{-1})

Manganese content in soil after the harvest of maize showed significant difference among treatments. Higher amount of Mn content was recorded in treatment that was supplied with 100% NP (T_6:24.73 mg kg^{-1}) followed by 150% NPK (T_3:24.01 mg kg^{-1}). However, lower values of Mn content was recorded in control treatment T_{11}(15.23 mg kg^{-1}) without inorganic or organic manures.

It was observed that the available status was low in imbalanced fertilizer applied treatments compared to balanced fertilizer application. Higher dose of fertilizers and FYM amended plots showed appreciable quantities of iron. With respect to copper, FYM applied plots recorded higher values and might be due to the reason that FYM also contains appreciable quantities of copper, manganese and zinc. Duraisamy (1992) [6] and Sudhir and Siddaramappa., (2004) [21] have also reported that the yield and uptake of nutrients were higher in treatments receiving higher dose of fertilizer applications and substantial amounts of micronutrients remained in soil, which might be attributed to the addition of higher root biomass.

Conclusion

It was observed that plant available nutrient status such as nitrogen, potassium and sulphur were maintained sustainability in all treatments, except treatment receiving imbalanced nutrients were supplied. Secondary nutrients was recorded higher in lime and FYM applied treatment along with inorganic fertilizers. It was noticed that the DTPA extractable micronutrients like zinc, copper, iron and manganese status was maintained in all treatments in long term manurial soil. Based on the results, it can be concluded that continuous cropping without replenishment of plant nutrients and application of imbalanced fertilizer nutrients leads to low level of available nutrient status in soil and depletion of secondary nutrient reserve at faster rate under finger millet and maize cropping system. Integrated nutrient application of inorganic fertilizers and organic manures will helps in maintaining soil fertility status.

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