

### **Original Research Article**

## **INTEGRATED EFFECT OF ORGANIC AND INORGANIC MANURING ON CROP YIELD AND SOIL NUTRIENT BALANCE IN THE ON-GOING CENTURY-OLD PERMANENT MANURIAL EXPERIMENT.**

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### **ABSTRACT**

**Aim:** The present study reports the results of continuous application of different rates of N, P and K and organic manure to a Maize-Sunflower cropping system on the changes in soil available nutrients status after harvest of 172<sup>th</sup> crop of maize.

**Materials and methods:** We studied the long-term effect of organic and inorganic manuring on crop yield and soil nutrient management under Maize–Sunflower cropping system in 112 years old Permanent Manurial Experiment Field. Significant build-up in soil fertility in terms of alkaline  $\text{KMnO}_4\text{-N}$ , Olsen-P,  $\text{NH}_4\text{OAc-K}$ ,  $\text{K}_2\text{Cr}_2\text{O}_7\text{-C}$  and  $\text{CaCl}_2\text{-S}$  as well as DTPA-Fe, Mn, Cu, Zn were assessed under eight treatments consist of Unfertilized Control, NP, NP, NPK (Chemical Fertilizer Alone), FYM (N Equivalent Basis), FYM (Every Year), Poultry Manure and NPK+FYM.

**Result and discussion:** Recorded data from 2008 shows that continuous application as 100%NPK+FYM @12.5 t ha<sup>-1</sup> achieved highest grain yield (hybrid maize CO 6), soil organic carbon, available nitrogen, available potassium, available sulphur and micronutrients content. Highest P recorded in poultry manure on nitrogen equivalent basis than INM irrespective of the crops. Inorganic fertilizer application alone resulted in a pH of >8.0, whereas fertilizer and manure application as well as manure application alone resulted in a pH of < 8.0 in soil. The increase in available S in INM, NPK alone might be due to single super phosphate (SSP) and FYM which contained about 12 and 0.74 % of S, respectively. Thus, considering soil-quality conservation and crop yield, 112 years of study indicated that combined application of NPK and organic manure is a better nutrient-management option in this irrigated maize sunflower cropping system.

**Conclusion:** These results conclude that for better crop yield and soil quality, integrated usage of organic and inorganic nutrient should be advocated in the Maize-Sunflower cropping system under Alfisol.

*Keywords: Integrated Nutrient Management, Maize-Sunflower Cropping System, Nutrient Balance, Maize Yield.*

### **1. INTRODUCTION**

The Permanent Manurial Experiment was started from the year 1909 at Tamil Nadu Agricultural University, Coimbatore, in order to assess the impact of continuous addition of organic and mineral fertilizers on crop yield and soil quality. Conducting a long-term experiment at fixed site with continuous cropping will help to monitor the changes in soil quality and crop yields sustainability and also guide in developing strategies for fertilizer management while minimizing the environmental degradation. To study changes in nutrient

dynamics, variation in yield trends, assessing soil quality and system, nutrient dynamics and risk management, long-term fertilization experiments are very useful [1].

Chemical indicators such as pH, EC, available nutrients and organic carbon will emanate information about plant health, the nutritional requirements of plant and their availability for uptake by plants. Long-term addition of balanced level of NPK and NPK in conjunction with FYM enhanced the available N pool of the soil [2]. Also, Choudhary *et al.* [3] suggested that the imbalanced fertilization caused reduction in available P which may be due to formation of stable compounds like ammonium phosphate and ferric phosphate under low pH conditions. The treatment applied with FYM resulted more release of non-exchangeable K from soil as FYM increased cation exchange capacity resulted in increased availability of available K besides own supply of FYM [4].

This change in the use of organic fertilizers for chemical fertilizers in the fertilization of crops, is currently causing the soil to suffer from an accelerated depletion of organic matter and a nutritional imbalance, and that over time it loses its fertility and productive capacity. In addition, the inappropriate use of chemical fertilizers or their abuse, without taking into account the lack of other nutrients that limit crop productivity, leads to the emergence of environmental problems and the deterioration of other natural resources [5, 6].

Due to the favorable effects that organic fertilizers provide to the soil, it could be said that they must be essential in the use and management of this resource to improve and maintain its organic component, its characteristics of a living entity, its physical, chemical and biological fertility [7, 8, 9] and finally their productivity [10, 11]. Thus, present study aims to assess the nutrient response of semi arid tropical soil as influenced by organic and inorganic nutrients.

## 2. MATERIAL AND METHODS

### 2.1 Experimental site

The current study, which took place between 2021 and 2022, was part of an ongoing project at the century-old Permanent Manurial Experiment (PME) in Tamil Nadu Agricultural University (11°N, 77°E) Coimbatore, India, to analyse the effects of long-term nutrient management on yield and soil fertility after harvest of maize crop (172<sup>th</sup> crop). The climate of this site is Semi-arid to sub-tropical. The mean annual rainfall is about 674.2 mm with 34.3°C maximum mean annual temperature and 21.7°C minimum mean annual temperature. The cropping sequence followed is Maize–Sunflower having irrigated cropping situation. The soil is classified as Typic Haplustalfs comes under Palathurai Soil series which is derived from sandy loam texture.

### 2.2 Treatment details

The experiment included two crops per year, sunflower (June-October) and maize (November-February). The treatments are T1, Control (unfertilized and unmanured); T2, 100% NK; T3, 100% NP; T4, 100% NPK; T5, Farmyard manure (FYM) N equivalent basis @ 50 t ha<sup>-1</sup>; T6, Farmyard manure (FYM) every year @ 12.5 t ha<sup>-1</sup>; T7, Poultry manure N equivalent basis @ 11.4 t ha<sup>-1</sup>; T8, 100% NPK + Farmyard manure (FYM) @ 12.5 t ha<sup>-1</sup> (INM). The hybrid maize CO 6 was sown during December 2021 and harvested during April 2022. The recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O 250:75:75 kg ha<sup>-1</sup> was applied to maize. The sources of N, P and K used were urea, single super phosphate and muriate of potash, respectively for all the treatments. For treatments T6 well-decomposed farmyard manure (FYM) at 12.5 t ha<sup>-1</sup> (fresh-weight basis) with an average nutrient composition of 0.5% N, 0.23% P and 0.53% K was broadcasted 20 days before sowing and mixed with soil.

### 2.3 Soil analysis

“Grain and straw yield of maize was recorded and expressed in  $\text{kg ha}^{-1}$ . Soil samples were collected from the upper 15 cm soil depth in triplicate from each plot after the harvest of maize crop. The samples were collected, air-dried, passed through a 2 mm mesh, and stored at 4°C. The subsamples were further ground to pass through a 0.25 mm mesh for SOC analysis. Soil pH and EC were determined in soil: water (1:2.5 ratio) extract by potentiometric and conductometry methods respectively” [12]. “Available soil N was determined by the alkaline- $\text{KMnO}_4$  method” [13]. “Available P by sodium bicarbonate ( $\text{NaHCO}_3$ ) extraction and subsequent colorimetric analysis” [14]. “Available K by using an ammonium acetate extraction followed by emission spectrometry” [15]. “Available S by turbidimetry method [16]. Micronutrients using DTPA extraction” [17]. “Soil organic carbon was determined by chromic acid wet digestion method” [18].

## 2.4 Statistical method

The data were analyzed by using analysis of variance (ANOVA) and mean comparison by LSD as suggested by Panse and Sukhatme [19] at 5 percent significance level for concluding on the influence of various treatments.

## 3. RESULTS AND DISCUSSION

### 3.1 Crop yield

Application of fertilizer nutrients either alone or in combine with FYM greatly influence grain and Stover yield of maize. Generally, plots with any fertilization produced significantly higher crop yield than the unfertilized plots. Current year data also shows highest grain and stover yield for NPK+FYM compare to NPK and organic manures (Table 1).

**Table 1. Grain and stover yield of maize in year 2021-2022**

<i>Treatment details</i>	<i>Maize grain yield</i>	<i>Stover yield</i>
	<b>(<math>\text{kg ha}^{-1}</math>)</b>	<b>(<math>\text{kg ha}^{-1}</math>)</b>
Control	935	1508
NK	3034	5064
NP	6415	6410
NPK	6475	9114
FYM (N Equivalent basis)	5167	8704
FYM (Every year)	3516	7640
Poultry Manure	6173	8886
NPK+FYM	7786	12534
Mean	<b>4938</b>	<b>7483</b>

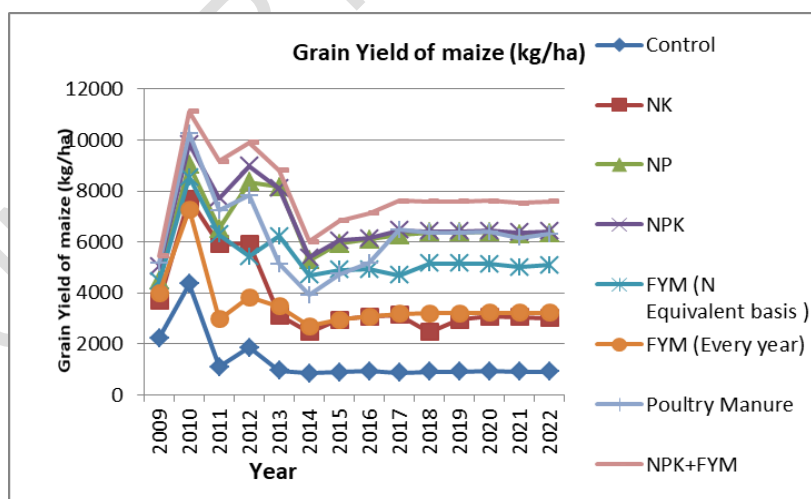
SE(d)	1.74	43.85
CD ( $P=0.05$ )	3.73	94.06

Data on mean grain yield from 2008 onwards revealed that continuous application as 100%NPK+FYM @12.5 t ha<sup>-1</sup> achieved highest yield every year (Fig 1). Sustained soil fertility by repeated addition of FYM and NPK fertilizers and effective utilization of applied nutrients which increase sink capacity and nutrient uptake by maize. Treatments received only organics every year (FYM @ 12.5 t ha<sup>-1</sup>) showed 50 per cent reduction in grain yield when compared to NPK. Unbalanced and organic manure alone applied plot did not result in better grain and stover yield compare to NPK and NPK+FYM plot. Quick availability of inorganic fertilizers and slow release of nutrient from FYM gives availability of nutrients during complete growth period and thereby NPK+FYM give highest yield.

This is similar to the findings of Manna *et al.* [20] who found that continuous cropping for 41 cropping cycles without a break was possible. Rice grain yields were reduced as a result of fertilizers. A Significant increase from 27.8–60.5 percent to that of wheat (1.9–35.3 percent) as a percentage of the total yields. Similar result was also reported by Meena *et al* [21].

Organic fertilizers are highly variable in their physical characteristics and chemical composition, mainly in their nutrient content; the constant application of them, over time, improves the physical, chemical, biological and sanitary characteristics of the soil. Before chemical fertilizers appeared in their different forms, the only way to supply nutrients to plants and replace those extracted from the soil by crops was through the use of organic fertilizers. The use of chemical fertilizers favored increases in crop yields [22]. Similar studies also carried out in tropical territories to evaluate the use of organic fertilizers to maintain and improve the availability of nutrients in the soil and obtain higher crop yields. [23, 24, 25].

**Fig 1. Effect of continuous fertilization on maize yield in PME field**



### 3.2 Soil pH and EC.

The long-term application of fertilizers and manures had significant effect on soil pH. Application of FYM alone @ 12.5 t ha<sup>-1</sup> recorded significantly lowest pH of 7.66 which was

on par with NPK+FYM (7.70) (table 1). Studies from 2008 which shows that application of organic manure leads to decrease in soil pH.(Table 2).

**Table 2. Effect of continuous fertilization on pH in PME field**

Treatments	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Control	8.29	8.19	8.56	8.39	8.59	8.86	8.29	8.16	8.12	8.14	8.14	8.23	8.25	8.26
NK	8.08	8.43	8.42	8.33	8.57	8.85	8.08	8.17	8.13	8.16	8.16	8.2	8.21	8.22
NP	8.14	8.48	8.39	8.29	8.79	8.72	8.06	8.07	7.98	8.16	8.16	8.2	8.2	8.21
NPK	8.14	8.48	8.39	8.29	8.79	8.72	8.06	8.07	7.98	8.16	8.16	8.2	8.15	8.17
FYM (N Equivalent basis)	8.29	8.43	8.42	8.42	8.56	8.63	8.08	7.95	7.63	7.65	7.65	7.75	7.99	7.99
FYM (Every year)	8.2	8.36	8.46	8.42	8.69	8.72	7.84	7.71	7.54	7.56	7.56	7.98	7.86	7.86
Poultry Manure	8.32	8.52	8.37	8.45	8.68	8.71	8.15	8.14	8.11	8.15	8.15	8.2	7.92	7.91
NPK+FYM	8.15	8.28	8.51	8.47	8.67	8.69	8.03	8.00	8.04	7.98	7.98	7.99	7.63	7.64

The treatments which received organic manures either alone or in combination with NPK lower pH may probably due to organic acids released during decomposition of organic matter resulting lower pH. Over the years, electrical conductivity of the soil was not significantly influenced by the long-term addition of fertilizers or manures to a great extent (Table 3). Similar findings were also reported by Liang *et al.* [26] Arulmozhiselvan *et al.* [27] and Malarkodi *et al.* [28].

There are studies that establish that organic fertilizers, due to their own characteristics in their composition, are humus formers and enrich the soil with this component, modifying gaps in the properties and characteristics of the soil such as its reaction (pH), variable loads, exchange capacity ionic, chelation of elements, availability of phosphorus, calcium, magnesium and potassium, and of course the microbial population, making it more appropriate for the good development and yield of crops [29, 30]. Organic fertilizers can also lower the exchangeable acidity ( $\text{Al}^{3+}$  and  $\text{H}^+$ ) and extractable Al and Fe in acid soils that influence the retention of phosphates and other anions, reducing their availability.

**Table 3. Effect of continuous fertilization on EC in PME field**

Treatments	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Control	0.18	0.1	0.06	0.16	0.08	0.07	0.22	0.26	0.28	0.3	0.2	0.26	0.19	0.2
NK	0.13	0.14	0.05	0.09	0.07	0.03	0.21	0.26	0.23	0.24	0.26	0.26	0.24	0.25
NP	0.15	0.12	0.05	0.11	0.08	0.04	0.2	0.27	0.26	0.28	0.27	0.28	0.25	0.27
NPK	0.16	0.12	0.05	0.11	0.08	0.04	0.2	0.27	0.26	0.28	0.27	0.28	0.26	0.28
FYM (N Equivalent basis)	0.16	0.12	0.07	0.09	0.09	0.06	0.17	0.19	0.18	0.22	0.19	0.28	0.27	0.27
FYM (Every year)	0.17	0.11	0.04	0.1	0.09	0.03	0.15	0.21	0.17	0.19	0.21	0.19	0.29	0.29
Poultry Manure	0.16	0.12	0.07	0.09	0.07	0.05	0.15	0.22	0.23	0.25	0.22	0.26	0.28	0.3
NPK+FYM	0.19	0.09	0.05	0.12	0.09	0.07	0.19	0.22	0.24	0.28	0.22	0.24	0.32	0.31

### 3.3 Soil organic carbon (SOC) content.

Soil organic carbon (SOC) content improved over the initial status even in the control plot. The conjoint application of 100% NPK with FYM brought about a significant increase in the SOC content of soil than the unfertilized and unmanured control. Continuous adoption of NPK+FYM enhanced the SOC content from 1.8 g kg<sup>-1</sup> during 1974 to 9.1 g kg<sup>-1</sup> in NPK+FYM during 2022. Treatment received NPK alone had higher SOC (6.31 g kg<sup>-1</sup>) than control (4.23 g kg<sup>-1</sup>). Application of FYM alone attained organic carbon content of 7.25 g kg<sup>-1</sup>. (Table 4).

**Table 4. Effect of continuous fertilization on Nutrient content in PME field in the year 2022.**

<i>Treatments</i>	<i>pH</i>	<i>EC (dS m<sup>-1</sup>)</i>	<i>Soil organic carbon (g kg<sup>-1</sup>)</i>	<i>Available nitrogen (kg ha<sup>-1</sup>)</i>	<i>Available phosphorus (kg ha<sup>-1</sup>)</i>	<i>Available potassium (kg ha<sup>-1</sup>)</i>	<i>Available sulphur (kg ha<sup>-1</sup>)</i>
Control	8.24	0.20	4.23	128	6.47	370	24.80
NK	8.22	0.24	5.18	223	11.36	588	30.46
NP	8.27	0.27	5.46	235	17.40	461	35.49
NPK	8.23	0.27	6.31	256	30.60	643	39.56
FYM (N Equivalent basis)	7.86	0.30	7.35	235	23.16	582	36.95
FYM (Every year)	7.86	0.30	7.25	232	22.16	544	36.87
Poultry Manure	7.95	0.31	7.93	251	27.60	625	37.66
NPK+FYM	7.66	0.32	9.10	279	33.99	734	41.10
<b>Mean</b>	<b>8.04</b>	<b>0.28</b>	<b>6.60</b>	<b>230</b>	<b>21.59</b>	<b>568</b>	<b>35.36</b>
<b>SE d</b>	<b>0.05</b>	<b>0.02</b>	<b>0.02</b>	<b>1.74</b>	<b>0.07</b>	<b>3.11</b>	<b>0.04</b>
<b>CV (P=0.05)</b>	<b>0.10</b>	<b>0.04</b>	<b>0.04</b>	<b>3.73</b>	<b>0.16</b>	<b>6.67</b>	<b>0.09</b>

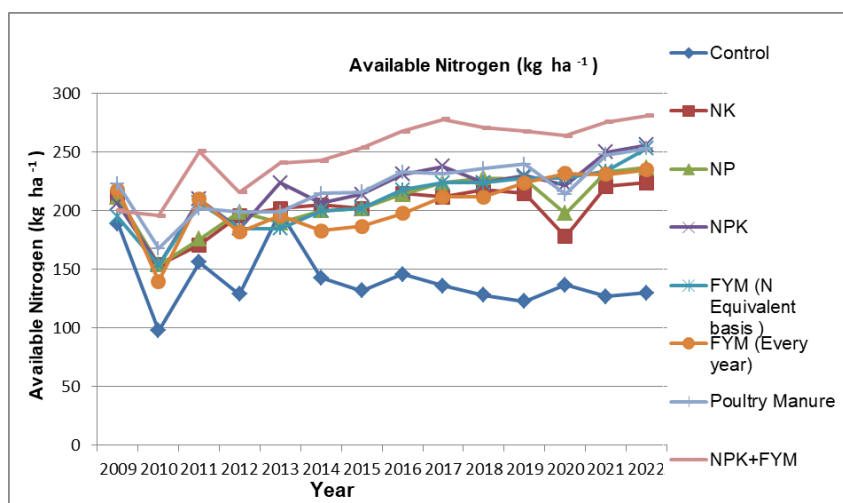
“Plot under NPK + FYM contained 44 per cent and 115 per cent higher SOC content than NPK and control plots, respectively most probably due to greater root biomass added through better crop growth” [31]. Treatment received NPK alone had 50 per cent more SOC than control which might be due to enhanced root residue addition to the soil under continuous cultivation.

“FYM increases microbial activity, resulting in increased polysaccharide formation and organic matter stability in soil, which is attributed the greater SOC with FYM alone treatment” [32]. The addition of organic matter addition to soil enhanced the soil C stock even in annual crops [33]. Repeated applications of fertiliser N alone, N with FYM or chicken manure or urban compost, or FYM alone resulted in substantial increases in organic C and total N in both surface and subsurface soils when compared to initial conditions [34]. The addition of an organic source may have boosted soil microbial activity and generated a favourable environment for the synthesis of organic C and N molecules [35].

### 3.4 Nitrogen

Great improvement was noted in available N for NPK + FYM when compared to NPK. Overall, under NPK+FYM the available N was highest (279 kg ha<sup>-1</sup>) which was 8.9 per cent higher than 100% NPK, and 117 per cent higher than control (Table 4). Data recorded from 2008 shows that available nitrogen status was significantly altered by the continuous adoption of fertilization and manuring (Fig 2).

**Fig 2. Effect of continuous fertilization on Nitrogen availability in PME field**

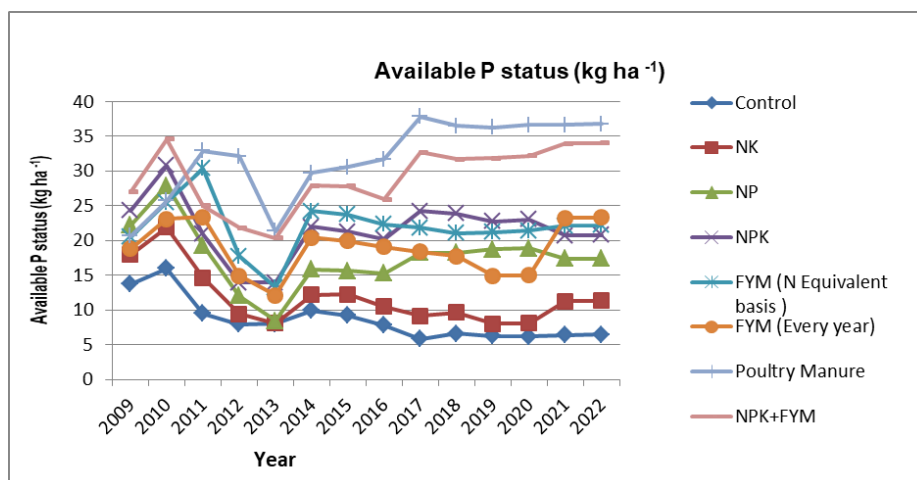


Hema *et al.* [36] observed that the application of 75% organic with 25% inorganic will improve the soil organic carbon, available macro and micronutrients such as N, P, K, Fe, Zn, Mn and Cu under Vertisol. The greater availability of available N under NPK+FYM may be through direct addition of FYM, which might have helped in multiplication of soil microbes, ultimately enhancing the conversion of organically bound N to mineral form and also increases the availability of native source [37]. The availability of C from organic inputs may promote the mineralization of N from soil organic matter, hence increasing the amount of N available to the growing crop [38].

### 3.5 Phosphorus

There was a substantial build-up of available P content over the years. Available P recorded the highest ( $33.99 \text{ kg ha}^{-1}$ ) in the treatment that received NPK+FYM. Whereas, the omission of P ( $11.36 \text{ kg ha}^{-1}$  in NK alone) and unfertilized control recorded lower available P status ( $6.47 \text{ kg ha}^{-1}$ ) (fig 3).

Fig 3. Effect of continuous fertilization on Posphorus content in PME field



“The addition of organic manures may solubilize the native P at a greater rate in soil through the release of various organic acids under irrigated conditions” [39]. Sharma *et al.* [40] reported that CO<sub>2</sub> released from organic matter decomposition may wrap the sesquioxide and thereby reducing P fixing capacity of the soil in one way and on the other way the released CO<sub>2</sub> may help in formation of carbonic acid when dissolved in water and thereby involves in dissipation of native P. Also, the phosphatase enzymes were high in the FYM amended plots which further helps in increasing P availability to plants.

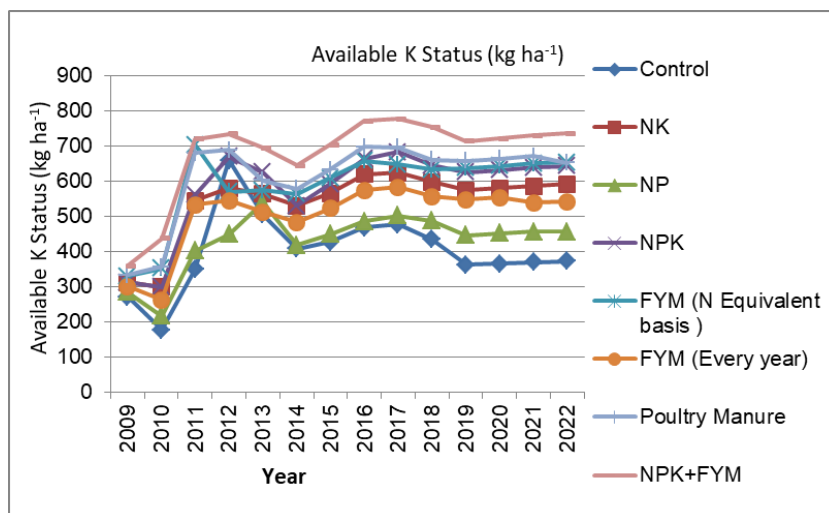
The increase in P availability might be due to organic molecules being chelated with Al, rendering it inactive, or P reactions, according to Michalak *et al.* [41]. The increase in P might be attributed to increased phosphatase activity and microbial biomass P in the soil, as well as mineralization of organically bound phosphate in the organic resources [42].

### 3.6 Potassium

The highest value of available K (734 kg ha<sup>-1</sup>) was observed in NPK+FYM treatment (table 1). Unbalanced fertilization and skipping of K had lower K status. The available K under NPK+FYM was 14 per cent higher than the available K in the NPK treatment. Substantial decrease in available K status was observed under control and NP alone may be attributed to continuous crop removal and absence of external source of K fertilizer (fig 4).

Fig 4. Effect of continuous fertilization on potassium content in PME field





“The increase in the availability of K through addition of FYM may be due to the decomposition of organic matter and release of K besides the reduction of K fixation and release of K due to the interaction of organic matter with clay” [43]. Santhy *et al.* [44] also reported similar increase in available K due to addition of FYM along with inorganic fertilizers. This finding was in corroboration with Arulmozhiselvan *et al.* [45] and Malarkodi *et al.* [46].

### 3.7 Sulphur

Available S content was significantly higher in NPK+FYM treatment ( $41.10 \text{ kg ha}^{-1}$ ). The unfertilized control plot had the lower available S content ( $24.8 \text{ kg ha}^{-1}$ ) (table 1). Overall, the combined application of inorganic and organic nutrients significantly enhanced the nutrients availability in soil as compared to inorganic alone and organic alone application. The increase in available S in INM, NPK alone might be due to single super phosphate (SSP) and FYM which contained about 12 and 0.74 per cent of S, respectively. This indicates that continuous addition of S through SSP in combination with FYM helped in the build-up of  $\text{SO}_4\text{-S}$  in the soil over years.

The current findings are also comparable with those of Lavanya *et al.* [47], “who found a greater accessible sulphur content in long-term fertilised soils under maize-wheat cropping systems in treatment that received SSP + manure”. Similar findings were reported by Dutta *et al.* [48] and Malarkodi *et al.* [49]. A long-term field study conducted by Alam [50] revealed that the available S content increased in soil with long-term manure application for 26 years. As about 90 per cent of the soil sulphur is derived from organic source, which might be the major reason for the increased sulphur content in organic manure treated plots.

### 3.8 Micronutrients

The data on DTPA extractable micronutrients revealed that application of NPK along with FYM showed significant increase in available Fe, Zn, Cu and Mn. The available Fe ranged from  $1.43 \text{ mg kg}^{-1}$  to  $2.75 \text{ mg kg}^{-1}$ , the available Zn ranged from  $0.515 \text{ mg kg}^{-1}$  to  $0.778 \text{ mg kg}^{-1}$ , the available Cu ranged from  $1.23 \text{ mg kg}^{-1}$  to  $1.43 \text{ mg kg}^{-1}$  and the available Mn ranged from  $4.56 \text{ mg kg}^{-1}$  to  $6.40 \text{ mg kg}^{-1}$  (table 4). Control recorded the lowest available micronutrients. In general irrespective of treatments the soil was deficient in DTPA-Fe and DTPA-Zn content while sufficient in DTPA-Cu and DTPA-Mn content (Table 5).

Table 5. Effect of continuous fertilization on micronutrient content in PME field in the year 2022.

<i>Treatments</i>	<i>Fe (mg/kg)</i>	<i>Zn (mg/kg)</i>	<i>Cu (mg/kg)</i>	<i>Mn (mg/kg)</i>
Control	1.43	0.515	1.23	4.56
NK	2.14	0.643	1.28	5.22
NP	2.35	0.682	1.33	5.32
NPK	2.56	0.964	1.39	5.74
FYM (N Equivalent basis)	1.94	0.698	1.37	5.57
FYM (Every year)	1.85	0.689	1.36	5.53
Poultry Manure	2.24	0.778	1.38	5.64
NPK+FYM	2.75	1.065	1.43	6.64
Mean	2.16	0.755	1.35	5.53
SE d	0.02	0.020	0.01	0.17
CV (P=0.05)	0.04	0.042	0.02	0.36

### **3.8.1 DTPA – Fe content**

“The DTPA extractable Fe content was found to be higher in NPK+FYM. The enhancement in the DTPA-Fe due to the integrated addition of FYM and NPK may be ascribed to their ability to form chelation with Fe and form stable water-soluble complexes preventing the reaction with other soil constituents and also increasing Fe content by releasing it from the native reserves” [51]. Santhy *et al.* [52] and Rout *et al.* [53] also reported an increase in Fe content in soil with application of organic manure. Control recorded the lowest level of available Fe which was attributed to the continued exhaustion of Fe in the absence of external Fe source.

The addition of organic matter to soil improves the water soluble and exchangeable forms of micronutrients in the soil, resulting in increased micronutrient uptake. The report given by Basak *et al.* [54] from an experiment on effect of organic amendment on soil quality revealed that the micronutrients such as Fe, Zn, Mn and B were the highest in FYM imposed treatments in rice-potato-sesame based cropping system.

### **3.8.2 DTPA – Zn content**

The DTPA extractable Zn content was highest in NPK+FYM and lowest in control. The Zn content was found to be higher in treatments receiving NPK+FYM and balanced NPK. The increase in Zn availability due to the application of FYM in combination with NPK may be due to complexation of mineralization of organically bound forms of Zn in the FYM [55].

Zinc is well-known to form moderately stable chelates with organic ligands, which reduce their vulnerability to fixation, adsorption, and precipitation. The chelating agents released through decomposition of organic matter could have disallowed various processes that prevent micronutrient availability such as oxidation, precipitation and leaching [56]. Zn, Cu, B, and Mo are less susceptible to redox changes, hence soil organic matter binds more towards Zn than Fe and Mn [57].

### **3.8.3 DTPA – Cu content.**

Irrespective of treatments the soil had sufficient DTPA-Cu content. Treatments had significant and slight influence on available Cu content. The availability of Cu in soil was markedly highest in plot receiving NPK+FYM and NPK and lowest in control. The increase in

available form of Cu in the soil due to application of organic manure may be attributed to formation of Cu chelates.

The mass of available Cu usually resides in the organically bound fraction provides available Cu to soil solution was reported by Miner *et al.* [58]. Dhaliwal *et al.* [59] in rice-wheat cropping system observed an overall improvement of Zn and Cu in the soil with the addition of FYM.

### **3.8.4 DTPA – Mn content**

Irrespective of treatments the soil had sufficient DTPA-Mn content of  $> 4.0 \text{ mg kg}^{-1}$ . The available Mn content in the soil was the lowest in control and highest in treatments receiving NPK+FYM. Application of FYM alone with NPK increased the available Mn content of soil and attributed this increased availability to the release of  $\text{Mn}^{2+}$  bound to organic ligands and acceleration of reduction of  $\text{Mn}^{4+}$  to  $\text{Mn}^{2+}$  [60].

Organic matter addition also helps in increasing the availability of Mn to crop through the mechanism of chelation [61]. Walia *et al.* [62] noticed an increase in DTPA-Mn, which might be attribute to the conversion of  $\text{Mn}^{4+}$  to  $\text{Mn}^{2+}$ , greater solubility under submerged circumstances, and the chelating effect of organic manures.

## **4. CONCLUSION**

Based upon above results it can be concluded that yearly application of organic manure (FYM) @  $10\text{-}15 \text{ t ha}^{-1}$  in conjunction with optimal NPK fertilizers has a pronounced effect in maintaining good crop yield, reducing the soil pH and improving nutrient status in soil. In addition to yield gain organic manure has also significantly increased the availability of limiting nutrients in soil and thus maintained the fertility status of different soils. Continuous application of nitrogenous fertilizers alone and unfertilized control were markedly reduced the yields and nutrient imbalance. Therefore, for proper nutrient supply and sustaining crop productivity integrated application of organic and inorganic manures are advisable in semi –arid Alfisol.

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