***Original Research Article***

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


## 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~~cropping system on the changes in soil available nutrients status after harvest of 172$^{th}$ crop of maize.

**Materials and methods:** We studied the long-term effect of organic and inorganic manuring on crop yield and ~~soil  nutrient~~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 $KMnO_4$-N, Olsen-P, $NH_4OAc$-K, $K_2Cr_2O_7$–C and $CaCl_2$-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$^{-1}$ achieved highest grain yield (hybrid maize CO ~~6 ),soil~~6), soil organic ~~carbon,available~~carbon, available ~~nitrogen,available~~nitrogen, available ~~potassium,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 ~~per cent~~ % 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~~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: INM, Maize Sunflower Cropping System, Nutrient Balance, Maize Yield.*


**Comment [A1]:** replace with a keyword, not acronyms

**Formatted:** Highlight

## 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~~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 exchangeble~~non-exchangeable K from soil as FYM increased cation exchange capacity resulted in increased availability of available K besides own supply of FYM [4].

A long-term field study conducted by Alam [5] 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 .~~plots. The report given by Basak *et al*. [6] 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. ~~Thus~~Thus, present study ~~aim~~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 on-going 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~~on yield and soil fertility after harvest of maize crop (172$^{th}$ 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~~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$^{-1}$; T6, Farmyard manure (FYM) every year @ 12.5 t ha$^{-1}$; T7, Poultry manure N equivalent basis @ 11.4 t h$^{-1}$; T8, 100% NPK + Farmyard manure (FYM) @ 12.5 t ha$^{-1}$ (INM). The hybrid maize CO 6 was sown during December 2021 and harvested during April 2022. The recommended dose of N, P2O5 and K2O 250:75:75 kg ha$^{-1}$ 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$^{-1}$ (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 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~~analysis. Soil pH and EC were determined in soil:water (1:2.5 ratio) extract by potentiometric and conductometry methods respectively [7]. Available soil N was determined by the alkaline-$KMnO_4$ method [8]. Available P by sodium bicarbonate ($NaHCO_3$) extraction and subsequent colorimetric analysis [9]. Available K by using an ammonium acetate extraction followed by emission spectrometry [10]. Available S by turbidimetry method [11]. Micronutrients using DTPA extraction [12]. Soil organic carbon was determined by chromic acid wet digestion method [13].

## 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 [14] 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~~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~~1. Grain and stover yield of maize in year 2021-2022**

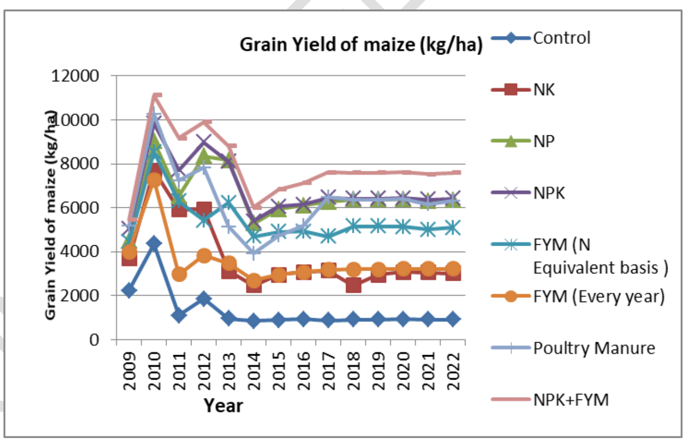
| ***Treatment details*** | ***Maize grain yield*** (kg $ha^{-1}$) | ***Stover yield*** (kg $ha^{-1}$) |
|---|---|---|
| Control | 935 | 1508 |
| NK | 3034 | 5064 |
| NP | 6415 | 6410 |
| NPK | 6475 | 9114 |
| FYM (N Equivalent ~~basis )~~basis) | 5167 | 8704 |
| FYM (Every year) | 3516 | 7640 |
| Poultry Manure | 6173 | 8886 |

| | | |
|---|---|---|
| NPK+FYM | 7786 | 12534 |
| Mean | **4938** | **7483** |
| SE(d) | **1.74** | **43.85** |
| CD (*P=.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$^{-1}$ achieved highest yield every year (Fig 1~~).Sustained~~). 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$^{-1}$) 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 gives highest yield.

This is similar to the findings of Manna *et al*. [15] who found that continuous cropping for 41 cropping cycles without a break was ~~possible.Rice~~possible. Rice grain yields were reduced as a result of ~~fertilizers.a~~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* [16].

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




## 3.2 Soil pH and EC.

The ~~long term~~long-term application of fertilizers and manures had significant effect on soil pH. Application of FYM alone @ 12.5 t ha$^{-1}$ recorded significantly lowest pH of 7.66 which was on par with NPK+FYM (7.70~~).~~() (table 1~~).Studies~~). Studies from 2008 which shows that application of organic manure leads to decease 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 )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 termlong-term addition of fertilizers or manures to a great extent (Table 3). Similar findings were also reported by Liang *et al.* [17] Arulmozhiselvan *et al*. [18] and Malarkodi *et al.* [19].

**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 )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 $kg^{-1}$ -during 1974 to 9.1 g $kg^{-1}$

in NPK+FYM during 2022 Treatment received NPK alone had higher SOC (6.31 g $kg^{-1}$) than control (4.23 g $kg^{-1}$). Application of FYM alone attained organic carbon content of 7.25 g $kg^{-1}$. (Table 4).

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

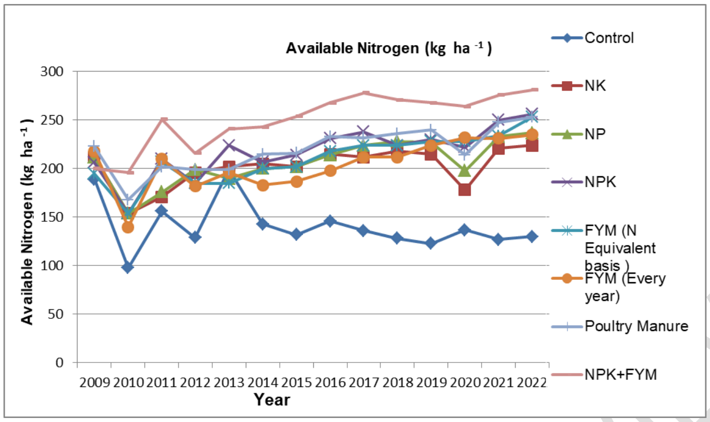
| *Treatments* | *pH* | *EC ($dS\ m^{-1}$)* | *Soil organic carbon ($g\ kg^{-1}$)* | *Available nitrogen ($kgha^{-1}$)* | *Available phosphorus ($kg\ ha^{-1}$)* | *Available potassium ($kg\ ha^{-1}$)* | *Available sulphur ($kg\ ha^{-1}$)* |
|---|---|---|---|---|---|---|---|
| Control | 8.24 | 0.20 | 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 )~~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 |
| **Mean** | **8.04** | **0.28** | **6.60** | **230** | **21.59** | **568** | **35.36** |
| **SE d** | **0.05** | **0.02** | **0.02** | **1.74** | **0.07** | **3.11** | **0.04** |
| **CV (P=0.05)** | **0.10** | **0.04** | **0.04** | **3.73** | **0.16** | **6.67** | **0.09** |

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 [20~~].Treatment~~]. Treatment received NPK alone had 49 per cent more SOC than control which might be due to enhanced root residue addition to the soil under continuous cultivation. This is in conformity with the findings of Li *et al*. [21] who reported that the balanced fertilization enhanced SOC content compared to unbalanced ~~fertilization.Over~~fertilization. Over 110 years had 15 per cent higher SOC over NPK treatment and 70 per cent higher over control. Use of FYM stimulates microbial activity which resulted enhanced polysaccharides production and stabilization of organic matter in soil which is attributed the higher SOC under FYM alone treatment [22].

## 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 $ha^{-1}$) which was 8.9 per cent higher than 100% NPK, and 117 per cent higher than ~~control(~~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**

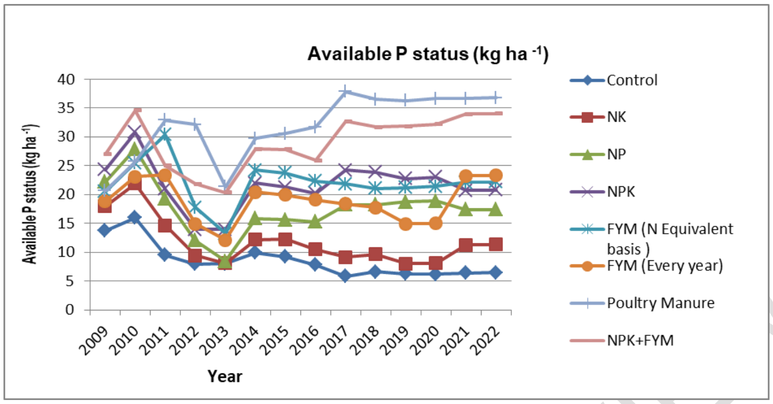



The greater availability of available N under NPK+FYM may be through direct addition of FYM, which might have helped in multiplication of soil microbes, ultimately enhancing the conversion of organically bound N to mineral form- and also increases the availability of native source [23].

### 3.5 Phosphorus

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

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

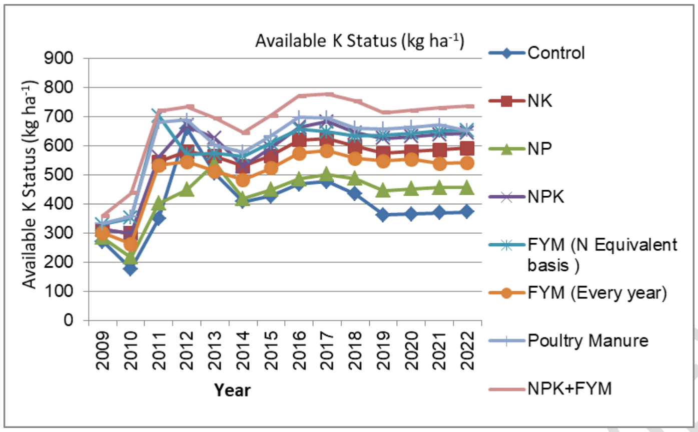



The addition of organic manures may solubilize the native P at a greater rate in soil through the release of various organic acids under irrigated conditions [24]. Sharma *et al.* [25] reported that $CO_2$ released from organic matter decomposition may wrap the sesquioxide and thereby reducing P fixing capacity of the soil in one way and on the other way the released $CO_2$ may help in formation of carbonic acid when dissolved in water and thereby involves in dissipation of native P. Omission of P leads to accelerated depletion of available P status due to complete exclusion of P in fertilizer schedule and exploitation of P from soil by continuous cropping [26]. Increased available P status in the treatments which received P fertilization might be due to continuous application of P over years contributes P to available pools after fulfilling phosphorus fixing capacity [27] .Also]. Also, the phosphatase enzymes waswere high in the FYM amended plots which further helps in increasing P availability to plants.

### 3.6 Potassium

The highest value of available K (734 kg $ha^{-1}$) 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.(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 [28], ~~.~~Santhy *et al*. [29~~] also~~] also reported similar increase in available K due to addition of FYM along with inorganic ~~fertilizers..~~fertilizers. This finding was in corroboration with Arulmozhiselvan *et al*. [30] and Malarkodi *et al*.[31].

### 3.7 Sulphur

Available S content was significantly higher in NPK+FYM treatment (41.10 kg ha$^{-1}$). The unfertilized control plot had the lower available S content (24.8 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 $SO_4$-S in the soil over years. The available S status of control plot was lower which might be due to low SOC in control plot as S is known to be an integral part of soil organic matter.

The results of the present study are also in conformity with the findings of Lavanya et al. [32] who have recorded the higher available sulphur content in the long-term fertilized soils under maize-wheat cropping system in treatment, which received SSP plus manure. Similar findings were reported by Dutta *et al*. [33] and Malarkodi *et al* [34].

### 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 mg kg$^{-1}$ ~~to~~$^{1}$ to 2.75 mg kg$^{-1}$, the available Zn ranged from 0.515 mg kg$^{-1}$ to 0.778 mg kg$^{-1}$, the available Cu ranged from 1.23 mg kg$^{-1}$ to 1.43 mg kg$^{-1}$ and the available Mn ranged from 4.56 mg kg$^{-1}$ to 6.40 mg kg$^{-1}$ (table 4~~).Control~~). 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~~content in PME field in the year 2022.**

| *Treatments* | *Fe (mg/kg)* | *~~Zn (~~(Zn (mg/kg)* | *Cu (mg/kg)* | *Mn (mg/kg)* |
|---|---|---|---|---|
| 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 )~~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~~water-soluble complexes preventing the reaction with other soil constituents and also increasing Fe content by releasing it from the native reserves [35]. Santhy *et al*. [36] and Rout *et al.* [37] 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.

### 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 [38]. 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 [39].

### 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.* [40].

### 3.8.4 DTPA – Mn content

Irrespective of treatments the soil had sufficient DTPA-Mn content of > 4.0 mg $kg^{-1}$.The$^{1}$. 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 $Mn^{2+}$ bound to organic ligands and acceleration of reduction of $Mn^{4+}$ to $Mn^{2+}$ [41]. Organic matter addition also helps in increasing the availability of Mn to crop through the mechanism of chelation [42].

The candidate manuscript does not have a robust scientific discussion, I suggest the authors incorporate the suggested paragraphs, in this way it would improve the scientific quality of the manuscript:

Numerous publications emphasize the use of organic fertilizers to maintain and improve the availability of nutrients in the soil and obtain higher yields in the cultivation of crops in tropical territories [43, 44, 45]. 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 [46].

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 [47, 48].

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 [43, 49]. Organic fertilizers can also lower the exchangeable acidity ($Al^{3+}$ and $H^{+}$) and extractable Al and Fe in acid soils that influence the retention of phosphates and other anions, reducing their availability.

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 [50, 51, 52] and finally their productivity [53, 54].

**Formatted:** Highlight

**Formatted:** Font: (Default) Arial, 10 pt

**Formatted:** Justified

## 4. CONCLUSION

Based upon above results it can be concluded that yearly application of organic manure (FYM) @ 10-15 t $ha^{-1}$ in conjunction with optimal NPK fertilizers has a pronounced effect ~~In~~in maintaining good crop ~~yield,reducing~~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~~imbalance. Therefore, for proper nutrient supply and sustaining crop productivity integrated application of organic and inorganic manures are advisable in semi –arid Alfisol.

## REFERENCES

**I SUGGEST ADDING RECENT REFERENCES WHICH ADDRESS THE ISSUE IN QUESTION IN LATIN AMERICAN TERRITORIES. SUGGESTED CITATIONS ARE FOR GENUINE SCIENTIFIC REASONS THAT EMPHASIZE THE CURRENT TOPIC OF STUDY IN CONTEXT:**

**Formatted:** Highlight


1. Regmi, AP, JK Ladha, H Pathak, E Pasuquin, C Bueno, D Dawe, PR Hobbs, D Joshy, SL Maskey, and SP Pandey. 2002. "Yield and soil fertility trends in a 20-year rice–rice– wheat experiment in Nepal." Soil Science Society of America Journal 66 (3):857-867.

2. Santhy, P, P Muthuvel, and D Selvi. 2001. "Status and impact of organic matter fractions on yield, uptake and available nutrients in a long-term fertilizer experiment." Journal of the Indian Society of Soil Science 49 (2):281-285.

3. Chaudhury, J, UK Mandal, KL Sharma, H Ghosh, and B Mandal. 2005. "Assessing soil quality under long-term rice-based cropping system." Communications in Soil Science and Plant Analysis 36 (9-10):1141-1161.

4. Moharana, PC, BM Sharma, DR Biswas, BS Dwivedi, and RV Singh. 2012. "Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6- year-old pearl millet–wheat cropping system in an Inceptisol of subtropical India." Field Crops Research 136:32-41.

5. Alam, MA. 2019. "Enhancement of soil chemical properties through long term manuring and nitrogen fertilization in Bangladesh."

6. Basak, N, A Datta, S Biswas, T Mitran, and B Mandal. 2016. "Organic amendment influences soil quality in farmers‘ field under rice-based cropping systems in IndoGangetic Plains of India." Indian Soceity of Soil Science

7. Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi, p 214. [6] Piper C. S. (1966). Soil and plant analysis. International Sci. publishres Inc., New York.

8. Subbaiah, B.V., Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. Current Sci., 25(8):259–260.

9. Olsen, S. R., Cole, C. U., Watanabe, F. S., Deen, L.A. 1954. Estimation of available phosphorus in soil by extracting with sodium bicarbonate (USDA Circular 939). Washington, DC: US Government Printing Office.

10. Stanford, S., English, L. 1949. Use of flame photometer in rapid soil test K and Ca. Agron. J., 41: 446-447.

11. Chesnin Leon, Yien, C.H. 1951. Soil Science Society of America Journal, 15 (C), 149-151.

12. Lindsay, WL, and WA Norvell. 1978. "Development of a DTPA soil test for zinc, iron, manganese, and copper." Soil Science Society of America Journal 42 (3):421-428

13. Walkley, A., Black, J.A. 1934. An estimation of digestion method for determining soil organic matter and a proposed modification of chromic acid titration method. Soil Sci., 37: 29-38.

14. Panse, V. G., Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers. Publication and information division. ICAR, New Delhi.

15. Manna, MC, A Swarup, RH Wanjari, HN Ravankar, B Mishra, MN Saha, YV Singh, DK Sahi, and PA Sarap. 2005. "Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India." Field Crops Research 93 (2-3):264-280.

16. Meena, BP, AK Biswas, M Singh, RS Chaudhary, AB Singh, H Das, and AK Patra. 2019. "Long-term sustaining crop productivity and soil health in maize–chickpea system through integrated nutrient management practices in Vertisols of central India." Field Crops Research 232:62-76.

17. Liang, Q, H Chen, Y Gong, M Fan, H Yang, R Lal, and Y Kuzyakov. 2012. "Effects of 15 years of manure and inorganic fertilizers on soil organic carbon fractions in a wheatmaize system in the North China Plain." Nutrient cycling in agroecosystems 92 (1):21-33.

18. Arulmozhiselvan, K, S Sathya, M Elayarajan, and M Malarkodi. 2015. "Soil fertility changes and crop productivity of finger millet under continuous fertilization and manuring in finger millet-maize cropping sequence." Res. Environ. Life Sci 8 (4):751-756.

19. Malarkodi, M, M Elayarajan, K Arulmozhiselvan, and B Gokila. 2019a. "Long-term impact of fertilizers and manures on crop productivity and soil fertility in an alfisol." The Pharma Innovation 8 (7):252-256.

20. Bhattacharyya, P, AK Nayak, S Mohanty, R Tripathi, M Shahid, A Kumar, R Raja, BB Panda, KS Roy, and S Neogi. 2013. "Greenhouse gas emission in relation to labile soil C, N pools and functional microbial diversity as influenced by 39 years long-term fertilizer management in tropical rice." Soil and Tillage Research 129:93-105.

21. Li, Z, M Liu, X Wu, F Han, and T Zhang. 2010. "Effects of long-term chemical fertilization and organic amendments on dynamics of soil organic C and total N in paddy soil derived from barren land in subtropical China." Soil and Tillage Research 106 (2):268-274.

22. Hemalatha, S, and S Chellamuthu. 2013. "Impacts of ~~long term~~long-term fertilization on soil nutritional quality under finger millet: maize cropping sequence." Journal of Environmental Research Development 7 (4A):1571-1576.

23. Dhaliwal, SS, RK Naresh, A Mandal, MK Walia, RK Gupta, R Singh, and MK Dhaliwal. 2019. "Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: a review." Journal of Plant Nutrition 42 (20):2873-2900.

24. Singh, YV, P Dey, R Meena, and SK Varma. 2016. "Effect of soil ~~test based~~test-based fertilizer application on yield and economics of chick pea in incectisol." Journal of Annals of Plant and Soil Research 18 (4):409-412.

25. Sharma, PK, SP Sharma, and PK Jain. 2001. "Nutrient mining in different agro-climatic zones of Himachal Pradesh." Fertilizer news 46 (8):69-74.

26. Arulmozhiselvan, K, M Elayarajan, and S Sathya. 2013. "Effect of ~~Long Term~~Long-Term Fertilization and Manuring on Soil Fertility, Yield and Uptake by Finger Millet on Inceptisol." Madras Agricultural Journal 100 (4-6):490-494.

27. Dutta, J, SP Sharma, SK Sharma, GD Sharma, and NK Sankhyan. 2015. "Indexing soil quality under long-term maize-wheat cropping system in an acidic Alfisol." Communications in Soil Science and Plant Analysis 46 (15):1841-1862.

28. Urkurkar, JS, T Alok, C Shrikant, and RK Bajpai. 2010. "Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (Oryza sativa) and wheat (Triticum aestivum) in Inceptisols." Indian journal of agricultural sciences 80 (3):208-212.

29. Arizmendi-Galicia, N, P Rivera-Ortiz, F Cruz-Salazar, BI Castro-Meza, and F GarzaRequena. 2011. "Leaching of chelated iron in calcareous soils." Terra Latinoamericana 29 (3):231-237.

30. Santhy, P, P Muthuvel, and D Selvi. 2001. "Status and impact of organic matter fractions on yield, uptake and available nutrients in a long-term fertilizer experiment." Journal of the Indian Society of Soil Science 49 (2):281-285.

31. Malarkodi, M, M Elayarajan, K Arulmozhiselvan, and B Gokila. 2019b. "Long-term impact of fertilizers and manures on crop productivity and soil fertility in an alfisol." The Pharma Innovation Journal 8 (7):252-256.

32. Lavanya, KR, GG Kadalli, S Patil, T Jayanthi, DV Naveen, and R Channabasavegowda. 2019. "Sulphur Fractionation Studies in Soils of ~~Long Term~~Long-Term Fertilizer Experiment under Finger Millet–Maize Cropping Sequence." Int. J. Curr. Microbiol. App. Sci 8 (9):1334-1345.

33. Dutta, D, DK Singh, N Subash, N Ravisankar, V Kumar, AL Meena, RP Mishra, S Singh, V Kumar, and AS Panwar. 2018. "Effect of long-term use of organic, inorganic and integrated management practices on carbon sequestration and soil carbon pools in different cropping systems in Tarai region of Kumayun hills." Indian journal of agricultural sciences 88 (4):523-529

34. Malarkodi, M, M Elayarajan, K Arulmozhiselvan, and B Gokila. 2019a. "Long-term impact of fertilizers and manures on crop productivity and soil fertility in an alfisol." The Pharma Innovation 8 (7):252-256.

35. Ylivainio, K. 2010. "Effects of iron (III) chelates on the solubility of heavy metals in calcareous soils." Environmental Pollution 158 (10):3194-3200.

36. Santhy, P, P Muthuvel, and D Selvi. 2001. "Status and impact of organic matter fractions on yield, uptake and available nutrients in a long-term fertilizer experiment." Journal of the Indian Society of Soil Science 49 (2):281-285.

37. Rout, PP, N Chandrasekaran, K Arulmozhiselvan, and D Padhan. 2017. "Effect of ~~Long Term~~Long-Term Fertilization on Soil K Dynamics and Uptake by Hybrid Maize in an Irrigated Inceptisol under Intensive Cropping." Int. J. Curr. Microbiol. App. Sci 6 (10):1049- 1061.

38. Shambhavi, S, R Kumar, SP Sharma, G Verma, SK Sharma, and RP Sharma. 2018. "Effect of 36 years of continuous cropping and fertilization on productivity, micro and secondary nutrient status and uptake by maize-wheat cropping system in western Himalayas." International Journal of Bio-resource and Stress Management 9 (2):197-202.

39. Sharma, PK, SP Sharma, and PK Jain. 2001. "Nutrient mining in different agro-climatic zones of Himachal Pradesh." Fertilizer news 46 (8):69-74.

40. Miner, GL, JA Delgado, JA Ippolito, KA Barbarick, CE Stewart, DK Manter, DSJ Grosso, AD Halvorson, BA Floyd, and RE D'Adamo. 2018. "Influence of long-term nitrogen fertilization on crop and soil micronutrients in a no-till maize cropping system." Field Crops Research 228:170-182.

41. Bhatt, MK, KP Raverkar, R Labanya, and CK Bhatt. 2018. "Effects of long-term balanced and imbalanced use of inorganic fertilizers and organic manure (FYM) on soil chemical properties and yield of rice under rice-wheat cropping system." Journal of Pharmacognosy and Phytochemistry 7 (3):703-708.

42. Gawde, N. 2017. "Long term effect of integrated nutrient management on soil nutrient status under rice-wheat cropping system in Inceptisols." Indira Gandhi Krishi Vishwavidyalaya.

43. Olivares, BO., Araya-Alman, M., Acevedo-Opazo, C. et al. 2020. "Relationship Between Soil Properties and Banana Productivity in the Two Main Cultivation Areas in Venezuela". J Soil Sci Plant Nutr. 20 (3): 2512-2524. https://doi.org/10.1007/s42729-020-00317-8

44. Olivares, B. 2016. "Description of soil management in agricultural production systems of sector hammock in Anzoátegui, Venezuela". La Granja: Revista de Ciencias de la Vida. 23(1): 14–24. https://doi.org/10.17163/lgr.n23.2016.02

45. Olivares, BO, Calero, J, Rey, JC, Lobo, D, Landa, BB, Gómez, JA. 2022. "Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression". Catena, 208, 105718. https://doi.org/10.1016/j.catena.2021.105718

46. Olivares, B. 2022. "Determination of the potential influence of soil in the differentiation of productivity and in the classification of susceptible areas to banana wilt in Venezuela". UCOPress: Spain, pp. 89-111. https://helvia.uco.es/handle/10396/22355



- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt, English (U.S.)
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt, English (U.S.)
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt, English (U.S.)
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt, English (U.S.)
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt, English (U.S.)
- **Formatted:** Font: (Default) Arial, 10 pt
- **Formatted:** Font: (Default) Arial, 10 pt, English (U.S.)

47. Olivares, B., Hernández, R. 2020. "Application of multivariate techniques in the agricultural land's aptitude in Carabobo, Venezuela". Tropical and Subtropical Agroecosystems, 23(2):1-12. https://n9.cl/zeedh

48. Montenegro, E; Pitti, J; Olivares, B. 2021. "Identification of the main subsistence crops of the Teribe: a case study based on multivariate techniques". Idesia. 39 - 3, pp. 83 - 94. http://dx.doi.org/10.4067/S0718-34292021000300083

49. Olivares, B., Pitti, J., Montenegro, E. 2020. "Socioeconomic characterization of Bocas del Toro in Panama: an application of multivariate techniques". Revista Brasileira de Gestao e Desenvolvimento Regional, 16(3):59-71. https://n9.cl/4elu2

50. Olivares, B., Verbist, K., Lobo, D., Vargas, R. y Silva, O. 2011. "Evaluation of the USLE model to estimate water erosion in an Alfisol". Journal of Soil Science and Plant Nutrition of Chile. 11 (2):71-84. http://dx.doi.org/10.4067/S0718-95162011000200007

51. Olivares, B., Lobo, D. y Verbist, K. 2015. "Aplicación del modelo USLE en parcelas de erosión bajo prácticas de conservación de suelos y aguas en San Pedro de Melipilla, Chile". Revista Ciencia e Ingeniería. 36 (1):3-10. https://n9.cl/c1l7k

52. Olivares, B., Rodríguez, M.F, Cortez, A., Rey, J.C., Lobo, D. 2015. "Caracterización físico natural de la comunidad indígena de Kashaama con fines de manejo sostenible de la tierra". Acta Nova. 7 (2):143-164. https://n9.cl/9e53qr

53. Olivares, B., López-Beltrán, M., Lobo-Luján, D. 2019. "Cambios de usos de suelo y vegetación en la comunidad agraria Kashaama, Anzoátegui, Venezuela: 2001-2013". Revista Geográfica De América Central. 2(63):269-291. https://doi.org/10.15359/rgac.63-2.10

54. Olivares, B., López, M. 2019. "Normalized Difference Vegetation Index (NDVI) applied to the agricultural indigenous territory of Kashaama, Venezuela". UNED Research Journal. 11(2): 112-121. https://doi.org/10.22458/urj.v11i2.2299