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Long-Term Impact of Inorganic Fertilizers and Manures on Maize Yield and Soil Nutrient Status in a Calcareous *Inceptisol* in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Long Term Fertilizer experiment was initiated to monitor the continuous manuring and fertilization under intensive cropping changes in soil properties concerning to physical, chemical and biological characteristics and crop productivity. The experimental soil belongs to sandy clay loam soil (*Vertic Ustropept*) with ten different nutrient management practices followed and replicated thrice by the adoption of Randomised Block Design (RBD). Continuous use of inorganic fertilizer along with Farmyard manure (FYM) could increase the soil nutrients such as $KMnO_4$ – Nitrogen, Olsen – Phosphorous and NNH_4OAc – Potassium over five decades. The results revealed that the use of inorganic fertilizer conjoint with FYM at 10t ha^{-1}significantly increased the kernel yield of maize by18.1% and 20.3% higher than 150% NPK and 100% NPK plots in sandy clay loam soil. The important indicator for soil fertility concern is Soil Organic Carbon (SOC) and the build-up of SOC was found in NPK+FYM at 10t ha^{-1} treatment recorded from 3.0 g kg^{-1} (1972) to 7.8 g kg^{-}1 (2023). Soil fertility status of the experiment after 50 years had reported as medium in $KMnO_4$- N, medium to high in Olsen - P, high in NNH_4OAc - K and medium in SOC status in an *Inceptisol*. From the study, revealed that, the application of inorganic fertilizer along with FYM at 10 t ha^{-1} achieved a greater yield and better soil health in a sustainable manner.

Keywords: Farmyard manure; SOC; inorganic fertilizers and soil fertility.

1. INTRODUCTION

“Soil is a vital natural resource and Soil quality is the combined effect of management on most soil properties which influences crop productivity and sustainability” [1]. “The maintenance of soil health is not only important in increasing agricultural production but also essential for sustaining the higher productivity of crops” [2]. “Soil fertility is the most important factor which controls crop productivity. Soil-related constraints affecting crop yield such as nutritional disorders can be assessed by evaluating the soil fertility status. Soil testing provides information about the nutrient status of the soil from which fertilizer recommendations can be made for maximizing crop productivity” [3].

In recent years, intensive farming practices using high-yielding cultivars with imbalanced fertilization have resulted in over mining of native soil nutrients that adversely affects crop production and soil fertility status [4,5]. “Since a large amount of nutrients has to be applied to soil in a chemical form which may have an impact on soil properties and soil productivity in the long term. Long Term Fertilizer experiment was initiated to monitor the changes in soil properties as a result of the continuous addition of organic manures and inorganic fertilizer under intensive cropping concerning the physical, chemical and microbiological characteristics of the soil concerning its productivity. The integrated application of organic manures and inorganic fertilizers is the best-recognized strategy of Integrated Nutrient Management to improve soil fertility and also enhancing crop yields” [6].

“Maize (*Zea mays*) is the most important coarse cereal crop that belongs to the Poaceae family. It is widely used for cattle feed, poultry feed and also for human consumption” [7]. “Maize is adapted to a wide range of soil and agro-climatic conditions but is sensitive to water logging hence, it is known as the Queen of Cereals. It is a more nutrient-exhausting crop. Globally, India ranks fourth in area and seventh in production among maize-growing countries, Maize is grown on 9.2 million hectares in India, it accounts for around 4% of global maize area and 2% of total production” (DACNET, 2020). In India, Maize is the third most important cereal crop next to Rice and Wheat.

In this article, an attempt has been made to highlight the Importance of Integrated Nutrient Management (INM) practices in maintaining soil health and improving crop yield and productivity.

2. MATERIALS AND METHODS

2.1 Experimental Site and Climate

The study area is located at the Research farm of Tamil Nadu Agricultural University, Coimbatore district of Tamil Nadu, India. The Long Term Fertilizer Experiment (LTFE) started in 1972 at 11^o N latitude, 77^o E longitude with an elevation of 426.7 m above MSL with Finger millet- Maize cropping sequence under irrigated condition, soil classified as *Inceptisol* having black calcareous sandy clay loam soil (*vertic ustropept*) belongs to Periyanaickenpalayam soil series. The climate of Coimbatore is tropical characterized by hot and humid summers and cold winters. The Southwest monsoon (June-September) majorly contributes to Coimbatore, the average annual precipitation ranges between 550 mm to 900 mm.

2.2 Experimental Details

LTFE also includes two crops per year, Finger Millet – Maize cropping sequence raised during summer and kharif seasons; respectively with ten treatment combinations and three replications, the plots are randomized by Randomized Block Design (RBD). The treatment details were T_1-control, T_2-100% N, T_3-100% NP, T_4- 100% NPK, T_5-100% NPK+FYM at 10 t ha^{-1}, T_6-100% NPK+ Zn, T_7- 150% NPK T_8- 50% NPK, T_9-100% NPK+HW and T_{10}-100% NPK (- S). In this study, a Maize hybrid (COHM 6) as a test crop and ten treatments with three replications were taken for investigation.

The recommended dose of fertilizer (RDF) for Maize hybrid was 250, 75 and 75 kg of N, P and K ha^{-1} respectively. At the time of sowing 50% of RDF N was applied as urea and 100% of RDF of P and K were applied as Single Super Phosphate (SSP) and Muriate of Potash (MOP) respectively for all the treatments except for T_9 (100% NPK – S) DAP can be used as a source. Another 50% of N was applied in two equal splits during knee high stage and pre-tasselling stages of crop growth. For INM (100% NPK + FYM) treatment plots were applied with 10 t ha^{-1} of FYM for every crop.

2.3 Soil Sampling, Processing and Analysis

The soil samples were collected from 50 years old Long Term Fertilizer Experiment from the individual treatment plots after the harvest of Finger millet and Maize; respectively at a depth of 0 – 15 cm. The soils were air dried, ground and sieved to pass through 2 mm sieve. The processed soil samples were used for the determination of various soil physical and chemical properties by following standard procedures. The power of hydrogen (pH) and Electrical Conductivity (EC) was determined in the soil and water suspension in the ratio of 1:2.5 by potentiometric and conductometric methods; respectively (Jackson 1973), Available N in soil was estimated by alkaline $KMnO_4$ method (Asija and Subbaiah 1956), Available P in soil was estimated by $NaHCO_3$ extractions and determined colourimetrically (Olsen et al 1954). Available K in soil was estimated by using neutral normal Ammonium Acetate extractions followed by Emission spectroscopy (Standford and English 1949). Soil organic carbon was determined by the chromic acid wet digestion method (Walkley and Black 1934).

2.4 Statistical Analysis

The recorded data from the field experiment were analysed for their significance (p=0.05) by statistical procedure appropriate for Randomized Block Design outlined by Gomez and Gomez 1985.

3. RESULTS AND DISCUSSION

3.1 Initial Physical, Physico- Chemical and Chemical Properties of Soil during 1972

The initial property of experimental soil analyzed for various physical, physico-chemical and chemical properties. The pH of the soil was found to be alkaline, and the primary nutrient status of the soil was found to be low in $KMnO_4$-N, medium in Olsen - P, high in NNH_4OAc - K and medium in SOC status in a Sandy Clay Loam soil (Table 1).

3.2 Long Term Fertilization on Soil Physico Chemical Properties of Maize Crop in an *inceptisol*

3.2.1 Soil reaction (pH) and Electrical Conductivity (d Sm^{-1})

The soil pH and EC changed slightly from 1972, currently, soil reaction of the research soil was alkaline and pH ranges from 8.07 to 8.40 (Table 3.) specifies that there is no significant influence of pH on soil due to buffering capacity of the soil. The slight changes in the pH was due to the release of organic acids and the continuous addition of inorganic fertilizers and organic manures. Likewise, EC ranges from 0.51 to 0.63 (Table 3.) indicating that there is no significant impact of EC on different fertilization treatments [8].

Table 1. Initial physical, physico- chemical and chemical properties of soil during 1972

Characteristics of Soil	(1972) Value
Particle size analysis	
Clay (%)	32.6
Silt (%)	11.8
Fine sand (%)	15.1
Coarse Sand (%)	39.4
Soil textural class	Sandy clay loam
Physicochemical and chemical properties	
pH (1:2.5 soil: water suspension)	8.20
Electrical conductivity (dS m^{-1})	0.20
Organic carbon (g kg^{-1})	3.0
Cation exchange capacity [c mol (p+) kg^{-1}]	25.5
Available nitrogen (kg N ha^{-1})	178.0
Available phosphorus (kg ha^{-1})	11.0
Available potassium (kg ha^{-1})	810.0

3.3 Long Term Fertilization Effects on Soil Chemical Properties of Maize in an *inceptisol*

3.3.1 Soil Organic Carbon SOC (g kg^{-1})

Soil Organic Carbon (SOC) is the important factor which governs soil fertility [9]. The continuous application of inorganic fertilizers and organic manures over five decades in a Finger millet – Maize sequence has increased the SOC content from 3.0 g kg^{-1} to 7.8 g kg^{-1} [10]. The SOC concentration has increased significantly under different fertilized and unfertilized treatments from control to 150% NPK (4.0 g $kg^{-1}$to 7.8 g kg^{-1}) (Table 2). The maximum SOC concentration was recorded in 100% NPK + FYM at 10 t ha^{-1} plot at the rate of 7.8 g kg^{-1} followed by 150% NPK at 7.1 g kg^{-1} [11] and [12]. The treatments like 100% NPK > 100% NPK +Zn >100% NPK +HW are on par with each other and 100% NP & 100% NPK- S are also on par with each other. The minimum SOC concentration was recorded in the control plot at the rate of 4.0 g kg^{-1}

3.3.2 Soil Available Nitrogen (kg ha^{-1})

Nitrogen is one of the major plant nutrients which imparts green colour to plants and encourages vegetative growth. The continuous application of inorganic fertilizers and organic manures has significantly influenced the available N status in the soil under different management treatments and the available N content in the Experimental soil was found to be medium and ranged from 260 to 408 kg ha^{-1} (Table 3). The maximum available N content was recorded in (100% NPK + FYM at 10 t ha^{-1}) plot of 408 kg ha^{-1} followed by 150% NPK plot of 378kg ha^{-1} [13]. However, the treatments like 100% NPK > 100% NPK +Zn >100% NPK +HW are on par with each other. The 100% NPK plots showed a declined availability of N content to other treatments. The minimum available N content was recorded in control plots of 260 kg ha^{-1}. The combined application of inorganic nitrogenous fertilizer along with FYM has increased the mineralization of the organic form of N to Inorganic forms.

3.3.3 Soil Available Phosphorous (kg ha^{-1})

Phosphorous is also a primary macronutrient which plays an important role in energy storage and transfer. The available P content in the research area was found to be medium to high under different treatments and the values ranged between 16.13 to 29.32 kg ha^{-1} (Table 3). The maximum available P content was recorded in (100% NPK + FYM at 10 t ha^{-1}) plot of 29.32 kg ha^{-1} followed by 150% NPK plot of 28.27 kg ha^{-1} [14] and [15]. Other treatments like 100% NP > 100% NPK>100% NPK +Zn are on par with each other. The minimum available P content was recorded in control plots of 16.13 kg ha^{-1}. Under acidic conditions (pH < 6), P is fixed as $AlPO_4$ and $FePO_4$ and in alkaline (pH > 8) conditions fixed as a $CaPO_4$. The greater P content in the INM treatment plot was due to the presence of Organic Matter that leads to the formation of organophosphate compounds that are more soluble and also increase the quantity of organic P to inorganic P.

3.3.4 Soil available potassium (kg ha^{-1})

Potassium is the third most important primary nutrient absorbed by plants in larger amounts than the other nutrients. The available K content in the research soil was found to be high since the start of the experiment in (1972). The use of high-yield cultivars and inorganic fertilizers has significantly exhausted the soil K under different treatments and ranged between 236 to 642 kg ha^{-1} (Table 3). The maximum available K content was recorded in (100% NPK + FYM at 10 t ha^{-1}) plot of 642 kg ha^{-1} followed by 150% NPK plot of 564 kg ha^{-1} [16]. Other treatments like 100% NPK > 100% NPK +Zn >100% NPK +HW were observed to be at par with each other. The minimum available P content was recorded in control plots of 236 kg ha^{-1}. The application of NPK with FYM has increased the K availability in soil due to the release of fixed K ions in the exchangeable sites [17].

3.4 Long Term Fertilization on Kernel and Stover Yields of Maize (kg ha^{-1}) in an *Inceptisol*

The continuous application of inorganic fertilizers and organic manures caused significant variation in kernel and straw yield of Maize in an *inceptisol* (Fig. 1). The maximum kernel and Stover yield of Maize recorded in the 100%NPK + FYM at 10 t ha^{-1} plot of were 6898 kg ha^{-1} and 9356 kg ha^{-1}; respectively followed by 150% NPK plot 5643 kg ha^{-1} and 8978 kg ha^{-1} [18]. The minimum kernel and straw yield of Maize was recorded in the control plot of 2872 kg ha^{-1} and 4317 kg ha^{-1}; respectively. The yield increase in 100% NPK + FYM at 10 t ha^{-1} plot obtained was 18.1% and 20.3% higher than 150% NPK and 100% NPK

Table 2. Long term fertilization on soil Physico–chemical and chemical properties of Maize (kg ha^{-1}) in an *Inceptisol* (Initial samples of 115th crop)

Treatments	pH	EC dSm^{-1}	SOC g kg^{-1}	Soil available N Kg ha^{-1}	Soil available P Kg ha^{-1}	Soil available K Kg ha^{-1}
Control	8.09	0.52	4.0	227	11.09	259
50 % NPK	8.21	0.58	5.4	276	16.76	318
100% N	8.25	0.62	5.1	285	12.98	295
100% NP	8.46	0.58	6.0	289	18.94	307
100% NPK	8.23	0.57	6.3	321	19.08	476
100% NPK+ FYM	8.30	0.65	7.8	357	21.99	538
100% NPK +Zn	8.22	0.59	6.6	309	18.67	482
100% NPK +HW	8.15	0.56	6.4	302	18.54	475
100% NPK- S	8.36	0.63	6.1	293	17.91	434
150% NPK	8.18	0.62	7.1	336	20.76	502
SEd	**1.222**	**0.0097**	**0.148**	**7.3533**	**0.4369**	**10.2525**
CD (P= 0.05)	**2.5673**	**0.0205**	**0.311**	**15.449**	**0.918**	**21.54**

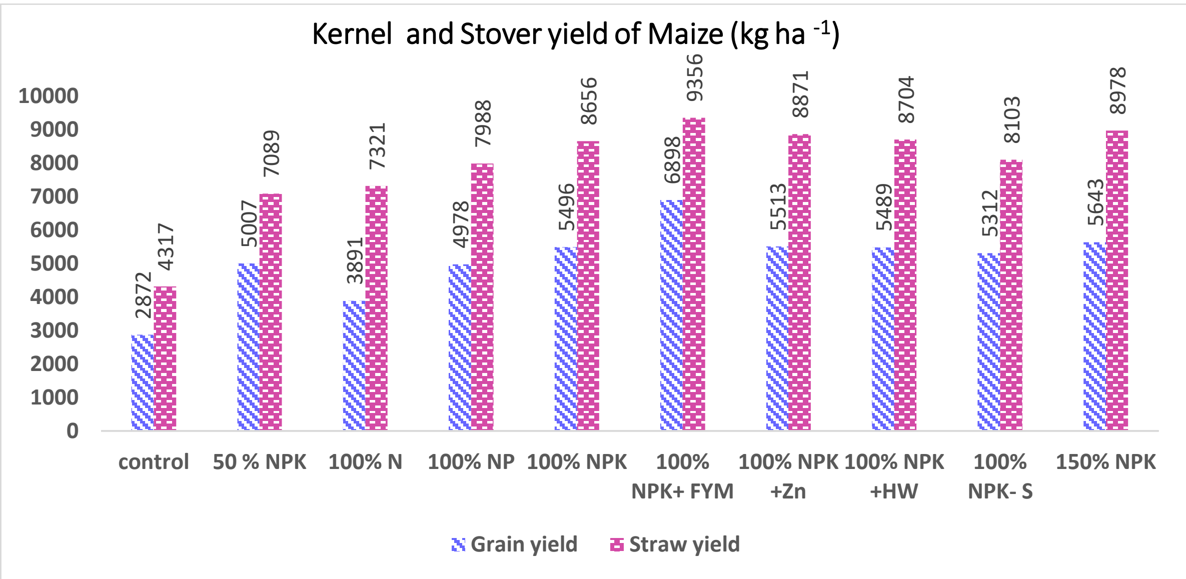

Fig. 1. Long term fertilization on kernel and straw yields of maize (kg ha^{-1}) in an *Inceptisol*

Table 3. Long term fertilization on soil Physico–chemical and chemical properties of Maize (kg ha^{-1}) in an *Inceptisol* (post-harvest samples of 115th crop)

Treatments	pH	EC dSm^{-1}	Soil available N Kg ha^{-1}	Soil available P Kg ha^{-1}	Soil available K Kg ha^{-1}
control	8.07	0.51	260.3	16.13	236
50 % NPK	8.20	0.57	301.3	21.27	376
100% N	8.25	0.63	314.3	19.53	312
100% NP	8.40	0.59	339.7	24.77	327
100% NPK	8.23	0.57	363.7	25.30	558
100% NPK+ FYM	8.27	0.67	408.7	29.32	642
100% NPK +Zn	8.21	0.60	366.7	25.50	497
100% NPK +HW	8.16	0.53	356.0	24.43	508
100% NPK- S	8.34	0.62	338.3	24.25	478
150% NPK	8.15	0.63	378.0	28.27	564
SEd	**0.1977**	**0.0154**	**6.6191**	**0.4255**	**11.4556**
CD (P=0.05)	**0.4154**	**0.03**	**13.095**	**0.8939**	**24.068**

plots; respectively. This might have been due to the conjoint application of NPK + FYM that significantly improved the soil physical, chemical and biological properties of soil leading to the increase in the yield and productivity of the soil in a sustained manner [19] and [20].

4. CONCLUSION

The present study revealed that the application of a recommended dose of fertilizer along with the organic manure (i.e. 100% NPK + FYM at 10 ha^{-1}) was considered to be effective among different nutrient management treatments under the sandy clay loam of the Maize crop. Balanced application of nutrients would improve the physical, chemical and biological properties of the soil as well as maintaining the soil fertility and also enhance the productivity of Maize crops under irrigated condition. Based on these findings, the study demonstrated that combining inorganic fertilizer with 10 t ha^{-1} of FYM resulted in higher crop yields and improved soil fertility in a sustainable manner.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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