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Effect of Long Term Fertilization on Soil Nutrient Status and Yield of Hybrid Maize under Finger Millet-Maize Cropping Sequence in an Irrigated Inceptisol

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Authors' contributions

This work was carried out in collaboration between all authors. Authors PPR, NCS and KA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author PPR managed the analyses of the study. Authors PPR and DP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was undertaken to evaluate the effect of long term application of inorganic fertilizers and organic manure on soil available nutrients, organic carbon and yield of hybrid maize during 2013-14 under finger millet-maize cropping sequence at TNAU, Coimbatore. The experimental results showed that the performance of hybrid maize in terms of both grain and straw yield was highest in the treatment receiving 100% NPK along with FYM (10t ha^{-1}) recording an increase in grain yield of 12.6 % over 100% NPK. Similarly the different soil fertility parameters viz., available nutrients (N, P and Zn) and organic carbon content in soil showed significant improvement with integrated application of inorganic fertilizers in combination with FYM compared to control treatment. A declining trend (471 to 605 kg ha^{-1}) from its initial level (810 kg ha^{-1}) of

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available K status was observed which shows a considerable mining of soil K under intensive cropping. However, the decline of K was of lower magnitude with 100% NPK + FYM (25.3%) and 150% NPK (27.9%) treatments indicating the need to raise the level of K fertilizer application to meet demand of crops. The fertility of the soil appears to be adversely affected due to imbalanced use of fertilizers viz., NP or N alone. Thus, balanced fertilization in combination with organic manure is necessary for sustain soil fertility and productivity of crops.

Keywords: Long term fertilization; crop yield; nutrient availability; soil organic carbon.

1. INTRODUCTION

In the present agricultural scenario food grain production has doubled world over and trebled in India since mid sixties due to introduction of green revolution with the massive application of science and technology. However, recently a noticeable decline in productivity of many intensively cultivated areas has been observed. Hence, there is a need to focus upon soil nutrient potential, nutrient balance and derivation of balance sheet, so as to bridge this gap by adopting timely measures by means of proper crop and nutrient management under intensive agriculture.

Long term fertilizer experiments (LTFE) give valuable information on effect of continuous use of fertilizers alone or in combination with and without organic manures on soil fertility and crop productivity under intensive cropping system [1]. There is an apprehension that in continuous cropping, use of imbalanced nutrients (N or NP alone) without organic manure cannot sustain the desired level crop production [2]. Hence, integrated nutrient management (INM) could be of paramount importance to sustain crop productivity besides maintaining soil fertility [3]. [4] noted that fodder-cowpea resulted in higher soil organic carbon content, available P and K in soybean-Indian mustard-fodder cowpea cropping system. The beneficial effect of green manure in rice-wheat cropping system has been recorded to be 18% in terms of rice yield [5].

With all such research background, the present study has been undertaken to evaluate the effect of continuous cropping and fertilization on soil fertility and crop productivity in an irrigated Inceptisol.

2. MATERIALS AND METHODS

The present investigation is a part of an ongoing All India Coordinated Research Project on Long term Fertilizer Experiment with finger-millet-maize cropping sequence which was initiated during 1972 at Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. During cropping period, maximum temperature ranged from 29.2 to 34.5℃ and minimum temperature ranged from 17.2 to 23.0℃ with mean rainfall of 0.8 mm. The soil of experimental site belongs to order-*Inceptisol*, having calcareous mixed black soil with sandy clay loam texture and comes under Perianaickenpalayam series of *Vertic Ustropept*. There were ten treatments each replicated four times in Randomized Block Design *viz.,* T_1 - 50% NPK, T_2 - 100% NPK, T_3 - 150% NPK, T_4 - 100% NPK + hand weeding, T_5 - 100% NPK + $ZnSO_4$, T_6 - 100% NP, T_7 - 100% N alone, T_8 - 100% NPK + FYM, T_9 - 100% NPK (-S) and T_{10} - Absolute control.

The hybrid maize variety *viz.,* CO-6 was used as test crop. The recommended dose of N, P_2O_5 and K_2O based on initial soil test was 250:75:75 kg ha^{-1}. The sources of N, P and K used were urea, single super phosphate (SSP) and muriate of potash. In sulphur free treatment, diammonium phosphate (DAP) was used instead of SSP as a source of P. Zinc was applied @ of 25 kg $ZnSO_4$ ha^{-1} along with 100% NPK in treatment T_5. Farm yard manure was applied @ 10 kg ha^{-1} with 100% NPK in treatment T_8. All the treatments except T_4 was sprayed with the pre emergence herbicide Atrazine WP at 500 g ha^{-1} (in 900 litres of water) at 3rd days after sowing (DAS) for controlling of weeds.

The soil samples were collected in all treatments at 0-15 cm depth. The organic carbon was determined by following wet digestion method [6], available N was determined by following alkaline $KMnO_4$ oxidation method [7], available P was estimated by 0.5M $NaHCO_3$ (pH 8.5) method [8], available K was tested using Neutral N NH_4OAc method [9] and available Zn was estimated using DTPA extraction method [10]. Finally both straw and grain yield of hybrid maize was recorded at harvest stage. The data on analysis of post-harvest soil samples and yield of hybrid maize were subjected to analysis of variance (ANOVA) as suggested by [11]. For statistical analysis of data, Microsoft Excel (Microsoft Corporation, USA) and AGRES window version 7.0 packages were used.

Table 1. Initial properties of the experimental soil

Properties	Initial (1972)
Particle size distribution	
Clay (%)	32.6
Silt (%)	11.8
Fine sand (%)	15.1
Coarse sand (%)	39.4
Textural class	Sandy clay loam
pH	8.20
Electrical conductivity (dSm^{-1})	0.20
Cation exchange capacity (cmol (p^+) kg^{-1})	25.2
Organic carbon (g kg^{-1})	3.0
Total N (mg kg^{-1})	428.0
Total P (mg kg^{-1})	490.0
Total K (mg kg^{-1})	3964.0
Available nitrogen (kg ha^{-1})	178.0
Available phosphorus (kg ha^{-1})	11.0
Available potassium (kg ha^{-1})	810.0
Available Zn (mg kg^{-1})	2.58
Available Mn (mg kg^{-1})	2.74
Available Cu (mg kg^{-1})	4.20
Available Fe (mg kg^{-1})	2.74

3. RESULTS AND DISCUSSION

3.1 Soil Properties

3.1.1 Available nitrogen

The data on soil available nitrogen (Table 2) showed that the treatment receiving 100% NPK + FYM (T_8) recorded the highest available N (250 kg ha^{-1}) emphasizing the superiority of FYM addition followed by the treatment receiving 150% NPK (243 kg ha^{-1}). The treatment 100% NPK + FYM (T_8) exhibited an increase of 40.4 % over initial value (1972). [12] ascribed such increase in available N to mineralization of FYM. Application of graded doses of NPK fertilizers resulted in a progressive increase in the soil available nitrogen may probably be a result of the fertilizer N directly contributing towards the available nitrogen pool and also due to the enhanced decomposition of the organic nitrogenous material [13]. The lowest available nitrogen was recorded in control (143 kg ha^{-1}). [14] and [15] reported similar finding of depletion of available N due to continuous cropping without fertilization. The removal of P and K (100% N) from fertilizer schedule also did not affect the availability of N over that of 100% NPK treatment.

3.1.2 Available phosphorus

The results from this long term fertilization experiment showed that the imposition of various treatments resulted in a highly significant variation in the soil available P (Table 2). Among the different treatments, the treatment which received FYM in addition to 100% NPK (T_8) recorded significantly higher available P (13.6 kg ha^{-1}) which was comparable with 150% NPK (12.7 kg ha^{-1}). Build up of available P with conjoint application NPK fertilizers with organics might be due to the release of organic acids during decomposition of which in turn helped in releasing P through solubilizing action of native P in soil [16]. Increasing rates of NPK application from 50% NPK to 150% NPK also resulted in higher level of available P. The presence or absence of K did not significantly influence the available P status. Withdrawal of P drastically reduces the available P status (10.4 kg ha^{-1}) under N alone (100% N) as compared to 100% NP (11.2 kg ha^{-1}). Similar trend on available P was reported by [15].

3.1.3 Available potassium

The perusal of data indicated a declining trend (471 to 605 kg ha^{-1}) from its initial level (810 kg ha^{-1}) of available K status which shows a considerable mining of soil K after forty two years of intensive cropping (Table 2). Higher level of available K (605 kg ha^{-1}) was observed in treatment receiving 100% NPK and FYM. The increase in available K in soil due to addition of FYM along with inorganic fertilizers may be attributed to the direct addition of K through FYM besides the reduction of K fixation and release of K due to the interaction of organic matter with clay [14]. [17] also reported similar increases in available K due to addition of FYM along with inorganic fertilizers. The maximum decline was observed in control followed by 100% N alone. Similar results were recorded by [18-20]. The declining trend of available K in such treatments may be due to continuous crop removal and absence of external source of K fertilizers.

3.1.4 DTPA extractable Zn

The DTPA extractable Zn in post-harvest soil of hybrid maize was found to be higher (2.073 mg kg^{-1}) in 100% NPK + $ZnSO_4$ treatment followed by 100% NPK + FYM treatment (0.987 mg kg^{-1}). The significant increase in availability of Zn in this treatment may be due to the direct addition of Zn through $ZnSO_4$. A significant build-up of available Zn due to $ZnSO_4$ application has also been reported by [21]. Similarly, the increase in Zn availability due to the application of FYM may be due to complexation or mineralization of organically bound forms of Zn in the FYM [22]. Similar findings have been reported by [23]. Lowest amount of available Zn was observed in the unmanured control which was due to the continued exhaustion of Zn. Application of optimum level of NPK fertilisers also helped in maintaining the Zn level (0.885 mg kg^{-1}).

3.1.5 Soil organic carbon

The organic carbon content ranged between 3.7 to 6.1 g kg^{-1} (Table 2). Organic carbon content of soil with an initial value of 3.0 g kg^{-1} (1972) had increased significantly and attained a maximum value of 6.1 g kg^{-1} in the treatment that has received 100% NPK along with FYM. This could be ascribed to the contribution from annual use of organic manure (FYM 10 t ha^{-1}) that might have improved the physical and biological properties of soil. These findings indicate that organic carbon content plays an important role in improving soil health [2]. Increasing levels of fertilizers has helped in improving organic carbon status of soil due to increased contribution from biomass and root stubbles. Similar findings have been reported by [24] and [25] attributing similar reasons.

3.1.6 Crop productivity

The data pertaining to the mean straw and grain yields of hybrid maize have been presented in Table 3. The data indicated that the conjoint application of 100% NPK along with farm yard manure at 10 t ha^{-1} registered significantly higher grain (6057 kg ha^{-1}) and straw yield (9379 kg ha^{-1}) of hybrid maize and showed an increase in grain yield of 12.6 % over 100% NPK. This indicates the potential use of FYM for sustaining crop productivity. Progressive increase in grain and straw yield was observed with application of graded levels of NPK addition from 50% NPK to 150% NPK. Such significant increases in maize yield at high levels of NPK fertilization [26] and due to balanced fertilizer treatment [27] under long term crop rotation has also been reported. The lowest grain (3012 kg ha^{-1}) and straw yield (5242 kg ha^{-1}) was registered in the control clearly reflected the absence of fertilizer addition. Although continuous application of 100% N alone caused an increase in yield over control but the response exhibited a reduction in the grain yield drastically (4256 kg ha^{-1}) due to imbalanced use of nutrients. The continuous exclusion of K (100% NP) and S fertilizers viz., 100% NPK (- S) recorded no adverse effect on yield of hybrid maize.

Table 2. Effect of long term fertilization on nutrient status in the post harvest soil of hybrid maize (2013-14)

Treatments	Available nutrients (Kg ha^{-1})			Av. Zn	OC
	N	P	K	(mg kg^{-1})	(g kg^{-1})
50 % NPK	178	11.4	521	0.869	5.2
100 % NPK	202	11.9	535	0.885	5.4
150 % NPK	243	12.7	584	0.925	5.7
100 % NPK + HW	196	12.4	550	0.866	5.3
100 % NPK + Zn	201	11.9	542	2.073	5.4
100 % NP	205	11.2	507	0.823	5.3
100 % N	195	10.4	499	0.752	5.0
100 % NPK + FYM	250	13.6	605	0.987	6.1
100 % NPK (- S)	209	11.5	556	0.731	5.2
Control	143	8.2	471	0.631	3.7
SEd	5.29	0.29	10.95	0.04	0.015
CD (P=0.05)	10.85	0.60	21.57	0.06	0.031

Table 3. Effect of long term fertilization on yield of hybrid maize (kg ha^{-1})

Treatments		Yield (kg ha^{-1})	
		Straw	Grain
T_1	50 % NPK	7029	5132
T_2	100 % NPK	8271	5378
T_3	150 % NPK	8514	5492
T_4	100 % NPK + HW	8149	5311
T_5	100 % NPK + Zn	8458	5432
T_6	100 % NP	8134	5213
T_7	100 % N	6933	4256
T_8	100 % NPK + FYM	9379	6057
T_9	100 % NPK (- S)	8221	5349
T_{10}	Control	5242	3012
SEd		165.78	114.32
CD (P=0.05)		328.25	232.52

4. CONCLUSIONS

It is concluded that under continuous cropping with finger millet-maize in sequence over forty one years, conjoint application of FYM along with 100% NPK not only sustained the higher yield of hybrid maize, but also improved the soil fertility by significant build-up of available N, P, Zn and organic carbon in soil. A declining trend of available K was noticed from its initial status indicating considerable mining of soil K. Hence, the results emanated from this study stresses upon the vital importance of including organic manure in the fertilizer schedule along with inorganic fertilizers for enhancing soil yield and maintaining the soil fertility in order to sustain soil productivity over a long run.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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