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Land degradation due to P depletion under intensive cropping

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Abstract

A Long Term Fertilizer Experiment (LTFE) is in progress at Tamil Nadu Agricultural University Farm, Coimbatore since 1972 in a medium black soil. A fixed crop rotation of finger millet, maize and fodder cowpea is being followed. Crop yield and soil fertility status monitored during the 17th/ 18th cropping sequence indicated a declining trend in crop yield and total as well as available P content of soil in those input systems which excluded P addition. The reduction was the highest in the system which involves continuous addition of N alone wherein the reduction from an initial value of 490 to 423 ppm in total P and 4.92 to 2.00 ppm in available P over a period of 20 years in this system. Compared to this system the yield increase in the input system involving balanced fertilization coupled with farm yard manure addition was two to four fold over a period of 20 years.

Additional keywords : Long term fertilizer experiments soil fertility.

Introduction

Maintaining and improving soil fertility for sustainable agriculture will become rather crucial in the future because of the increasing complexity of nutritional problems and environmental related issues. Intensive cropping under inadequate soil fertility management will exert tremendous pressure on soil leading to degradation. Faulty nutrient management will definitely influence the fertility status of the soil in the long run. This is especially so in an intensive irrigated agriculture. In order to assess the effect of different nutrient input management systems on soil fertility and crop yield, the Indian Council of Agricultural Research (ICAR) sponsored the Long Term Fertiliser Experiments in 11 agroclimatic regions of India during 1972. In this paper, the results of the Long Term Fertilizer Experiment in progress since 1972 at Tamil Nadu Agricultural University Farm (11°N latitude, 77°E longitude and at an altitude of 426.7m above MSL) is reviewed.

Materials and methods

The experimental soil is medium black (Vertic Haplustepts) with initial Olsen'P level of 4.9 mg kg^{-1} and total P of 490 mg kg^{-1} at 0-15 cm depth. Annually three irrigated crops are being raised, viz. finger millet (*Eleusine coracana Gaertn.*) during June to September, maize (*Zea mays*) from October to January and cowpea (fodder) (*Vigna ungiculata*) during March to April in a fixed rotation. There are ten treatments each replicated four times in a net plot size of 200 m^2.

The treatments are control (unfertilized), 100% optimal N alone, 100% optimal NP, 50% optimal NPK, 100% optimal NPK, 150% optimal NPK, 100% NPK+$ZnSO_4$, 100% NPK + FYM (farm yard manure), 100% NPK with HW (Hand Weeding) and 100% optimal NPK (S free source). The optimal amounts of N, P_2O_5 and K_2O (100% NPK) are 90:45:17.5, 135:67.5:35 and 25:50:0 kg ha^{-1}, respectively, are used in all the treatments as sources of N, P and K except in 100% NPK (S free) treatment where diammonium phosphate, urea and muriate of potash are the nutrient sources. The $ZnSO_4$ is applied @25 kg ha kg^{-1} only to maize and FYM @ 10.0 tonnes ha^{-1} only to finger millet. In 100% NPK with HW treatment, weeding is done by hand whereas in other plots chemical weed control is followed.

For the present investigation, soil samples were collected to represent four depths, viz. 0–15, 15–30, 30–45 and 45–60 cm from each plot of the experiment after the harvest of cowpea (fodder) in 17th cycle and finger millet and maize in 18th cycle (September 1991 to June 1993). They were analysed for Olsen's (Olsen *et al.* 1954) and total P (Pemberton 1945). Besides, crop was recorded at harvest and total dry matter yield was computed.

Results and discussion

Crop yield : Higher crop yield was obtained (Table 1) in the system which has farm yard manure addition as one of the components in addition to the balanced fertilization. The increase in crop yield in this system was around 167, 352 and 356 per cent over control in cowpea, finger millet and maize, respectively due to enhanced availability of nutrients in addition to better soil environment for biological activity being conferred by the organic matter addition through farm yard manure. This was in evidence in the investigation of earlier periods also (Subramanian and Kumaraswamy, 1989; Muthuswamy *et al.* 1990).

Table 1. Effect of treatments on crop yield and dry matter production (t/ha)

Treatment	Cowpea	Finger millet			Maize		
		Grain	Straw	Drymatter	Grain	Straw	Drymatter
Control	0.9	0.9	1.9	2.8	0.9	3.3	4.2
100% N	1.2	0.9	2.2	3.1	1.1	3.2	4.3
100% NP	2.1	3.1	6.4	9.5	3.5	6.2	9.7
50% NPK	1.9	2.5	5.4	7.9	3.4	6.4	9.8
100% NPK	2.0	3.2	7.5	10.7	3.6	6.8	10.4
150% NPK	2.3	3.5	7.9	11.4	3.6	6.8	10.4
100% NPK + $ZnSO_4$	2.2	3.2	7.3	10.5	2.8	7.3	10.1
100% NPK + FYM	2.4	3.9	8.9	12.8	3.9	8.5	12.4
100% NPK + HW	1.8	3.2	7.1	10.3	3.2	5.8	9.0
100% NPK (S free)	2.1	3.4	7.3	10.7	3.3	6.8	10.1
CD (0.05)	0.18	0.23	0.91	0.92	0.40	1.8	2.0

Soil fertility : The Olsen's P level in the surface soil samples varied from 2.0 to 10.5 mg kg^{-1} (Table 2). Among the treatments, 100% NPK + FYM recorded the highest level of P availability in the surface layer. Also the addition of 150% NPK had shown a beneficial effect. Phosphorus availability was found to increase with increase in the amounts of applied NPK in the 0-15 and 15-30 cm layers. This trend under these treatments is due to enhanced quantum of P addition (Nambiar andAbrol 1989; Alok Kumar and Yadav 1993) and also due to the favourable influence of added organic manure on P availability (Muthuswamy *et al.* 1990). Similar trend was also reported from various other centres of LTFE in India under similar experimental situations (Nambiar and Ghosh 1984).

Table 2. Effect of treatments on available P (Olsen's P) content in soil(mg/kg)

Treatments	Cowpea				Fingermillet				Maize			
	Depth (cm)				Depth (cm)				Depth (cm)			
	0–15	15–30	30–45	45–60	0–15	15–30	30–45	45–60	0–15	15–30	30–45	45–60
Control	2.3	2.0	1.0	0.5	2.3	2.0	1.0	0.5	2.0	2.0	1.0	0.5
100% N	2.7	2.3	1.0	0.5	2.3	2.3	1.0	0.5	2.0	2.0	1.0	0.5
100% NP	6.8	4.7	2.1	1.3	7.0	4.7	2.5	1.7	8.3	5.3	2.7	1.7
50% NPK	4.8	3.7	2.1	1.0	5.5	4.0	2.0	1.0	6.3	4.3	2.0	1.0
100% NPK	6.6	4.5	2.6	1.5	7.0	4.8	2.3	1.7	8.0	5.0	2.7	1.5
150% NPK	7.5	4.7	3.0	2.0	7.8	5.0	3.3	2.0	9.5	5.5	3.3	1.5
100% NPK + $ZnSO_4$	6.9	4.5	2.1	1.6	7.3	4.7	2.5	1.7	8.5	5.0	2.7	1.5
100% NPK + FYM	9.0	5.7	3.8	2.0	9.3	6.0	3.7	2.0	10.5	6.3	3.7	1.7
100% NPK + HW	6.5	4.7	2.8	1.7	6.7	4.7	2.5	1.5	7.7	5.0	2.5	1.5
100% NPK (S free)	6.6	4.7	2.0	1.5	7.0	5.0	2.5	1.5	8.3	5.0	2.7	1.5
CD (0.05)	Depth		0.43			0.34				0.35		
	Treatment		0.68			0.53				0.56		

Compared to the initial level there is build up in the Olsen's P content in the 0-15 cm layer in those systems which comprise continuous addition of P and a negative trend could be observed in those systems without P addition. Concentration of Olsen's P was the least in 100% N alone and control treatments. The build up of P was the maximum in the system which has all the major nutrient input coupled with farm yard manure. The depthwise distribution showed a decline in the concentration of Olsen's P with depth. The trend with regard to the effect of treatments and depth on P availability was similar under all the three crops in the rotation.

Total P ranged from 458 to 920 mg kg^{-1} in the 0–15 cm soil layer (Table 3). Phosphorus reserve in soil as reflected by total P content decreased uniformly with depth irrespective of the treatments. Treatment effect on total P could be observed only in the 0–30 cm layer as in the case of available P 100% NPK + FYM. The differences in total P among the treatments were apparent in the subsurface layers. Total P in soil was found to increase with graded levels of fertilizer NPK in 0–30 cm layer. As in the case of available P, 100% N alone and control treatments showed low level of total P at all depths. With the advancement of intensive cropping there was a decrease in the total P in soil in the 0–30 cm layers. The decrease was maximum [490 ppm (initial) - 423 ppm (at the end of 18th cycle) = 67 ppm] in 100% N alone treatment in surface soil after the harvest of maize crop.

Table 3. Effect of treatments on total P content in soil (mg/kg)

Treatments	Cowpea				Fingermillet				Maize			
	Depth (cm)				Depth (cm)				Depth (cm)			
	0–15	15–30	30–45	45–60	0–15	15–30	30–45	45–60	0–15	15–30	30–45	45–60
Control	463	387	308	306	460	386	308	309	458	385	307	307
100% N	428	376	305	303	425	375	304	303	423	374	304	303
100% NP	698	492	338	317	716	495	339	318	747	501	341	319
50% NPK	580	419	315	310	586	419	315	309	598	422	316	310
100% NPK	686	470	330	313	699	475	331	313	730	480	333	314
150% NPK	854	546	353	321	877	553	356	321	920	563	359	322
100% NPK + $ZnSO_4$	706	480	335	316	720	483	336	316	753	488	337	316
100% NPK + FYM	752	522	340	319	772	526	341	319	803	533	343	316
100% NPK + HW	672	466	332	315	687	468	333	313	718	472	334	314
100% NPK (S free)	705	488	332	315	724	491	333	316	755	496	335	316
CD (0.05)	Depth			36.1			43.5			47.8		
	Treatment			57.2			68.8			57.6		

The build up in P reserve and availability in soil in the surface layer was the result of low rates of P removal by the crop (Table 4) which was far less than the quantity applied. It is quite natural that the P status of soil will undergo noticeable change with cropping because its requirement and uptake are the least among the essential elements, namely N and K. The maximum quantity of P applied (150% NPK) to finger millet and maize was 70 and 101 kg/ha and for cowpea 75 kg/ha. On the other hand, the average quantity of P removed by the crops in the previous cropping cycles varied from 1.0 (control) to 4.4 (100% NPK+FYM) kg mg^{-1} in cowpea, 3.3 to 19.4 kg mg^{-1} in finger millet and 2.8 to 13.0 kg

ha^{-1} in maize (Anonymous, 1992). These data (Table 4) indicate the mismatch between P removal and its replenishment through fertilizer/manure addition and therefore the build up in total P reserve in the experimental soil is quite justifiable.

Table 4. Effect of treatments on total P uptake (kg/ha)

Treatments	Crop uptake		
	Cowpea	Finger millet	Maize
Control	1.0	3.3	2.8
100% N	1.3	4.1	3.6
100% NP	3.2	13.4	8.8
50% NPK	3.0	10.5	8.7
100% NPK	3.4	14.8	10.2
150% NPK	4.1	17.1	12.3
100% NPK + $ZnSO_4$	3.9	14.1	9.2
100% NPK + FYM	4.4	19.4	13.0
100% NPK + HW	3.2	13.7	8.2
100% NPK (S free)	3.5	13.7	9.5
CD (0.05)	0.58	1.47	2.29

Lower P concentrations observed under N alone and control treatments were due to crop removal in the absence of external source of P supply through fertilizers and manures. Phosphorus being an immobile element, in a medium black soil with about 33 per cent by clay content, the surface applied nutrient is concentrated in the surface layers owing to the absence of clay migration.

Conclusions

The results of the present investigation clearly indicated that for sustaining soil fertility with respect to P nutrition, addition of P either through fertilizer or manure or through the combination of both is essential under intensive cropping systems. Even though the P requirement is relatively less compared to the other major nutrients, input management system devoid of P addition will definitely lead to land degradation with respect to soil fertility consequent to the depletion of phosphorus.

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