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SOIL ACIDITY AND HEALTH OF AN ALFISOL UNDER SOYBEAN- WHEAT CROPPING SYSTEM IN AN ACID SOIL OF JHARKHAND

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ABSTRACT

A long term fertilizer experiment (LTFE) has been in progress since 1972-73 at Ranchi (India) in an acidic red loam soil (Paleustalf) with pH 5.3 to provide an insight on the effect of continuous cropping and nutrient use on soil health and crop production. The experiment consists of ten treatments replicated four times in a RBD with a cropping system soybean – potato – wheat (from 1972-79), soybean – toria –wheat (from 1980-85) and soybean – wheat (since 1986 – 87). The prime objective of the long term fertilizer experiment in operation for four decades under soybean based cropping systems in acid soil was for sustainable crop production & maintenance of soil health with different combinations of organic and inorganic fertilizers has clearly brought out that integrated use of organic or lime with recommended dose of NPK sustains crop production and maintains physical, chemical and biological properties of soil. Crop responses to different nutrients in inorganic, organic and their combination were in the order, NPK+FYM/lime > NPK > NP > N. Higher sustainable yield index in NPK+ FYM/ lime suggest the need of lime and FYM application along with recommended inorganic plant nutrients. The results indicate that continuous application of nitrogen alone as urea reduced the soil pH by 0.8 unit in 38 years. Application of lime raised the soil pH by 0.8 unit whereas addition of FYM @ 15t/ha annually stabilized the soil pH and maintained a higher soil organic carbon status. Application of lime or FYM along with recommended dose of NPK recorded lowest reduction in exchangeable Ca content of soil. Total microbial population of soil increased with application of lime or FYM along with recommended NPK. Highest SMBC& SMBN was observed under 100% NPK+FYM and lowest under 100% N treatment. Application of FYM along with recommended NPK has edge over application of lime along with recommended NPK in terms of crop productivity, sustainable yield index and maintenance of soil health indicators.

Key Words: Crop productivity, soybean, SYI, nutrient balance, soil health indicators

INTRODUCTION

Acid soils comprise nearly 50% of the world's potentially arable land which cause significant reduction in crop productivity. In India about 30 % of the total cultivable area (49 M ha) is acidic in nature (Panda, 2007). Cultivated acid soils with pH less than 5.5 (25 m ha) pose problems in soil and crop management. Major constraints limiting crop production in acid soils are - coarse texture, low soil organic matter, high infiltration rate, soil crusting, low pH, low CEC, poor base saturation high exchangeable Al, Fe and Mn and high P fixing capacity with deficiency of B and Mo in many cases. In general, rainfed farming is practiced in the acid soils and low yields are obtained due to low or no use of fertilizers in these soils (Sarkar *et al.,* 2007). The present investigation was carried out to study the influence of continuous use of plant nutrient management practices on crop productivity, sustainability and changes in physical, chemical and biological properties of soil in an acid soil under humid tropical climatic condition.

MATERIALS AND METHODS

A long term fertilizer experiment was started during 1972-73 at Ranchi (India) in an acidic red loam soil (Paleustalf) and pH 5.3 with low to medium in available nutrient status to provide an insight on the effect of cropping and nutrient use on the health of an acid soil. The climate of the experimental site is sub-tropical. The mean annual temperature is 23.1^0 C with maximum of 34.5^0 C during April and minimum of 6.8^{0}C in January. Total annual precipitation is about 1400 mm. The soil of the experimental site is acidic, yellow- red in colour with sandy clay loam texture. The experiment consists of ten treatments replicated four times in a randomized block design with a cropping system soybean – potato – wheat (from 1972-79), soybean – toria –wheat (from 1980-85) and soybean–wheat (since 1986 – 87). The fertilizer dose based upon initial soil test for soybean and wheat is 25: 60:40 (N: P: K) + Rhizobium culture and 80:60:40(N: P: K) respectively. The treatment details are as follows : T_1 (50% NPK + Weedicide), T_2–(100% NPK + weedicide), T_3 (150% NPK+Weedicide), T_4 (100% NPK + Hand weeding), T_5 (100% NPK+lime+weedicide), T_6 (100% NP + weedicide), T_7 (100% N + weedicide), T_8 (100% NPK + FYM + weedicide), T_9 (100% N(S)PK +weedicide) and T_{10} (control), lime @ 4 q ha^{-1} (applied in furrows) and farmyard manure @ 15 t

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ha^{-1} is applied during monsoon season only. Data related to grain yield, straw yield were collected after the harvest of each crop and analyses for nutrient concentration in the crops was carried out by standard methods as described by Tandon (1999). Soil samples from each plot were collected after harvest of wheat 2009-10. Soil analysis was done following standard procedures, for physical properties as described by Singh, (1980), chemical properties as described by Tandon 1999 and biological properties as described by Chhonkar *et al.*, (2007).

RESULTS AND DISCUSSION

After four decades of experimentation, it was found that the average yield of soybean under different treatments varied from 2.97 to 19.02q ha^{-1}. Productivity of soybean was highest with NPK + FYM and NPK + Lime plots with proper management. Lower yield level during 2009-10 was mainly due to low rainfall (900mm). Imbalanced use of plant nutrient such as N (-PK) or NP (-K) resulted in significant reduction in crop yields. Use of acid forming fertilizer such as ammonium sulphate brought about drastic reduction in soybean yield (Table 1).

Table 1: Effect of continuous use of fertilizer, manure, lime and weedicide on grain yield of soybean during 2009-10 and 2010-11

Treatments	2009-10 (q ha^{-1})	2010-11 (q ha^{-1})	Mean (1973-10) (q ha^{-1})
50% NPK + W	11.80	14.5	12.84
100% NPK + W	16.15	18.1	15.60
150% NPK + W	17.89	19.4	15.38
100% NPK +HW	16.14	17.6	15.61
100% NPK + Lime + W	17.98	23.0	18.22
100% NP + W	9.40	7.2	8.65
100% N + W	1.41	5.9	2.97
100% NPK + FYM +W	22.51	23.5	19.02
100% N (S) PK + W	3.30	14.0	6.66
Control	2.25	4.1	5.84
CD (P=0.05)	2.41	2.29	
CV (%)	13.96	10.7	

Sustainable yield index (SYI) indicates a progressive management practice capable of producing high yields over years. SYI of soybean and wheat varied with the treatments. Increase in SYI in NPK + lime or NPK+FYM over NPK alone reveal the beneficial effect of liming or manuring in acids soils (Table 2). Higher sustainable yield index values with lime + NPK treatment (0.60 for soybean) as compared to NPK treatment (0.48) suggest that it is possible to get 18 q ha^{-1} of Soybean in acid soils over years. Omitting K (100%NP) resulted in lower value of SYI (0.21 and 0.29 for soybean and wheat, respectively).

Table 2: Sustainable Yield Index of crops (1972-2007)

Treatments	Soybean	Wheat
	0.10	0.03
100% N + W	0.01	0.02
100% NP + W	0.21	0.29
100% NPK + W	0.48	0.35
100% NPK + Lime + W	0.60	0.40
100% NPK + FYM +W	0.62	0.43

Bulk density of soil decreased with FYM application. Available soil moisture status (Table 3) of different plots reveal that lime and FYM resulted in higher available soil moisture (8.6 to 9.6%) compared to N, NP or NPK treated plots (8.0 to 8.3%).

Table 3: Bulk density and available water of soil as affected by continuous cropping, fertilizer, lime and weedicide use

Treatments	Bulk Density (Mg m^{-3})	Avail. water (%)
Control	1.59	6.6
100% N + W	1.59	8.3
100% NP + W	1.60	8.0
100% NPK + W	1.58	8.3
100% NPK + Lime + W	1.59	8.6
100% NPK + FYM +W	1.53	9.6

Changes in pH after the harvest of soybean crop (2010-11) compared to the initial value reveal highest reduction in only N treated plots where a decline of 0.9 units was observed. In general, there was a decline in soil pH due to addition of in organic fertilizers applied alone compared to that with lime (Mahapatra *et.al.* 2007). Lime application along with recommended dose of NPK resulted in increase in pH by 0.8 units under unfertilized plot (Table 4).

Table 4: Effect of continuous cropping and nutrient us on avail. nutrient status of soil after soybean (2010-11)

Treatment	pH	Org. C (g kg^{-1})	Avail. P (Kg ha^{-1})	Avail. K (Kg ha^{-1})	Avail. Ca *(cmol (P^{+}) Kg^{-1})*	Avail. Mg *(cmol (P^{+}) Kg^{-1})*	Avail. S (mg kg^{-1})
Control	5.4	3.5	7.5	89.6	1.44	0.83	7.7
100% N	4.5	4.0	15.4	98.9	0.72	0.44	8.0
100% NP	4.8	4.2	167.5	71.3	1.56	0.60	8.2
100% NPK	4.8	4.0	142.2	99.0	1.26	0.52	7.8
100% NPK + Lime	6.2	3.6	145.9	90.3	2.53	0.76	7.6
100% NPK+FYM	4.9	4.9	216.5	117.8	1.64	0.70	10.7
CD (P=0.05)		0.2	29.95	17.02	0.27	0.16	3.2

After 38 years of intensive cropping it was observed that in general, there was a decline in organic carbon content of the soil in all the treatments except 100% NPK+FYM treatment. Application of FYM @ 15 t ha^{-1} during the Kharif season along with recommended NPK was able to maintain the soil organic carbon status (Table 4).

Table 5: Effect of continuous cropping and nutrient use on available nutrient status of soil after wheat (2010-11)

Treatment	pH	Org. C (g kg^{-1})	Avail. P (Kg ha^{-1})	Avail. K (Kg ha^{-1})	Avail. Ca (cmol (P^+) Kg^{-1})
Control	5.0	3.4	8.1	93.7	2.1
100% N	3.9	3.7	10.8	70.9	0.82
100% NP	4.3	3.7	136.9	69.9	1.85
100% NPK	4.2	3.8	149.9	103.5	1.61
100% NPK + Lime	5.3	3.3	100.5	96.5	2.76
100% NPK+FYM	4.5	4.6	266	133	1.84
CD (P=0.05)	0.21	0.3	23.77	18.37	0.27

Available P status of the soil reveal a building P-treated plots (Table 5). After 40 years of intensive cropping it was observed that there was a decline in available K content of the soil from the initial value of 157.7 Kg K ha^{-1} in all the treatments and the decrease ranged from 43 to 93 kg K ha^{-1} with the highest value observed in 100%NP treatment. Exchangeable Ca status in soil decreased significantly in N, NP and NPK plots. Application of lime or FYM along with recommended dose of NPK arrested such decline in exch. Ca in acid soil.

Nutrient balance in soybean-wheat cropping sequence

There was a negative balance of N and K in soil even under the best management practices (NPK + lime or FYM) for soybean-wheat cropping system in the acid soil. Results (Table 6) point out that low use of K fertilizers resulted in mining of soil K

Table 6: Nutrient balance under soybean-wheat cropping sequence

Treatments	Nutrient additions through fertilizers (kg ha^{-1} yr^{-1})			Nutrient removal by soybean-wheat (kg ha^{-1} yr^{-1})			Nutrient balance after harvest of wheat (kg ha^{-1} yr^{-1})		
	N	P	K	N	P	K	N	P	K
Control	0	0	0	42.8	4.0	21.4	-42.8	-4.0	-21.4
100% N	145	0	0	60.0	6.0	22.3	84.9	-6.0	-22.3
100% NP	145	26.2	0	140.0	16.7	90.0	5.0	9.5	-90.0
100% NPK	145	26.2	66.7	218.5	22.9	99.5	-73.5	3.3	-32.8
100% NPK + Lime	145	26.2	66.7	271.0	31.0	132.5	-126.0	-4.8	-65.8
100% NPK + FYM	145	26.2	66.7	295.7	35.7	185.0	-150.7	-9.5	-118.3

reserve to a considerable extent. Further, increasing P application level will probably result in higher nodulation in crops like soybean and maintain a positive N balance in soil through biological nitrogen fixation in acid soils which are offer P deficient.

Soil biological properties

Total microbial population of soil increased with application of lime or FYM with NPK and was in the order 100% N < control~~100% NPK < 100%NP <100% NPK + lime < 100% NPK + FYM. Similar trend was found for microbial respiration. Above results corroborate the findings of Mishra *et. al,* (2008) and Manna *et al.* (2005). Application of FYM or lime in combination with chemical fertilizers (Table 7) significantly increased the soil microbial biomass carbon (SMBC) & soil microbial biomass nitrogen (SMBN). The results are in agreement with the findings of Wanjari *et al.,* (2013).

Table 7: SMBC, SMBN, PMN and DHA after harvest of rabi cropsin long term fertilizer experiment at Ranchi

Treatment	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})	PMN (mg kg^{-1})	DHA (TPF/ soil/24 hrs)
Control	139.5	34.79	13.92	19.4
100% N	182.0	37.88	12.68	14.3
100% NP	180.0	34.33	13.73	15.0
100% NPK	199.0	30.33	12.13	16.0
100% NPK + Lime	269.5	39.08	12.30	23.3
100% NPK + FYM	284.0	42.88	12.78	19.2

SMBC-Soil microbial biomass carbon; SMBN- Soil microbial biomass nitrogen; PMN- Potentially mineralisable nitrogen; DHA – Dehydrogenase activity. Potentially mineralisable nitrogen was not affected by the treatments while liming positively influenced the dehydrogenase activity of the acid soil.

The response of crops to different fertilizer treatments were in order of NPK+FYM/lime > NPK > NP > N but the degree of response varied with crops. Imbalanced and continuous use of N alone produced highest decline in yield and had deleterious effect on soil health and long term crop productivity in a P deficient acid soil. Higher sustainable yield index in NPK+ FYM/ lime suggested the need of integrated use of lime or manure application along with recommended fertilizers for increasing and sustaining crop production in an acid soil. The response of applied P was higher in Rabi while that of K in Kharif. FYM application along with recommended dose of chemical fertilizer improved the physical, chemical, biological properties of the acid soil. In general, a buildup of available phosphorus relative to the level of application of fertilizer was observed. Decline in available N, K and exchangeable Ca due to continuous cropping was observed which needs to be looked into. Thus, to sustain the productivity of crops in acid Alfisol, balanced plant nutrient management is essential. This should be proceeded by lime application to ensure a use in soil pH with associated benefits in the improvement of physical, chemical and biological properties of soil.

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