Soil Fertility Changes under Long-term Integrated Nutrient Management Practices on Acid Soils of Meghalaya

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ABSTRACT

The long term residual effect of integrated use of organic and inorganic nutrient sources on soil fertility was studied The integrated nutrient management experiment was conducted during 2000-2005. At the end of experiment, soils from different treatments were collected and used for this study. Application of lime and FYM along with 75% recommended NPK increased the soil pH (5.02) and decreased the exchangeable Al (0.69 meq $100g^{-1}$) whereas, control plot receiving 100% recommended NPK showed the lowest pH (4.19) and highest exchangeable Al (2.39 meq $100g^{-1}$). Combined application of FYM and biofertilizers along with 75% recommended NPK increased the organic carbon content (2.28 g $100g^{-1}$) whereas organic carbon content was decreased (1.78 g $100g^{-1}$) in the treatment receiving lime and biofertilizers along with 75% recommended NPK. Application of lime and FYM along with 100% recommended NPK increased P content (59.95 kg P_2O_5 ha^{-1}) whereas, it decreased P content (18.27 kg P_2O_5 ha^{-1}) with zero NPK. Similarly, K content was increased (293.9 kg K_2O ha^{-1}) in the treatment receiving FYM and biofertilizer along with 75% recommended NPK while it decreased (186.4 kg K_2O ha^{-1}) in control receiving zero NPK. Exchangeable base content was low (1.41 meq $100g^{-1}$) under control with 100% recommended NPK however, highest value (3.78 meq $100g^{-1}$) was observed with the treatment receiving lime and FYM along with zero NPK.

Keywords: Biofertilizers, Exchangeable Al, Exchangeable bases, FYM, Lime, Organic carbon, Phosphorus

INTRODUCTION

Some of the major problems encountered by the farmers in maize producing areas in the north-eastern regions of India are the soil acidity, inherent poor soil fertility and productivity, lack of appropriate technologies, inappropriate soil and water conservation measures and other factors such as huge soil and nutrient losses. The most dominant factors affecting maize productivity on such soils are the aluminium (Al) and iron (Fe) toxicity, phosphorus (P) deficiency, low base saturation, impaired biological activity and other acidity-induced soil fertility and plant nutritional problems (Patiram 1991; Manoj-Kumar et al. 2012). Anthropogenic factors such as inappropriate land use systems, monocropping, nutrient mining and inadequate supply of nutrients further aggravated the situation. Soil acidity management and crop productivity enhancement on such soils is therefore important for enhancing food security globally and regionally.

To alleviate the problem, integrated nutrient management (INM) is a better option as this approach utilizes available organic and inorganic nutrients to build ecologically sound and economically viable farming system. In this approach all the possible source of plant nutrients are applied based on economic consideration and the balance required for the crop is supplemented with chemical fertilizers. The combined use of

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organic and inorganic sources of plant nutrient not only pushes the production and profitability of field crops, but also it helps in maintaining the permanent fertility status of the soil (Kannan et al. 2013). It is highly desirable to make massive efforts to adopt organic sources as a source of plant nutrients as well as soil productivity in the developing countries, India in particular. Palm et al. (1997) highlighted that organic source of nutrients influence nutrient availability by the total nutrients added by controlling the net mineralization-immobilization patterns. Several authors (Bakayoko et al. 2009; Liang et al. 2011) have shown that application of organic manures in combination with lime significantly improved the soil quality due to an increase in soil organic matter content. According to Manoj Kumar et al. (2012), INM is one of the most effective ways to improve soil fertility and maize productivity in tropical soils of India. Keeping this point in view, present investigation was conducted to find out best combination of organic and inorganic fertilizers for maximum production of maize with higher income level in sustainable manner without affecting the soil qualities.

MATERIALS AND METHODS

The study was carried out in the long-term field experiment laid out in 2001 in an acid Alfisol (Typic Hapludalf) at the experimental farm of the Soil Science Division, ICAR Research Complex for North Eastern Hill (NEH) Region, Umiam, located at East Khasi Hills of Meghalaya, India. The daily temperature during a year varies widely between 2.5 °C (January) and 32.5°C (August). The average rainfall of the region is 2439 mm with high temporal and spatial variations mostly received from April to October. The experiment was conducted at a fixed site for five consecutive years (2001/02–2005/06) with a fixed cropping cycle of *Kharif* maize (*Zea mays* L. var. Vijay composite)–Rabi mustard (*Brassica campestris* L. var. TS-36). The experiment was laid out with 20 treatments in a randomized block design with four replications. The treatments were a control without any fertilizer (T0); 50% NPK (T2); 75% NPK (T3); 100% NPK (T4); Lime + Biofertilizers (T5); Lime + Biofertilizers+ 50% NPK (T6); Lime + Biofertilizers + 75% NPK (T7); Lime + Biofertilizers + 100% NPK (T8); Lime + FYM (T9); Lime + FYM +50% NPK (T10); Lime + FYM + 75% NPK (T11); Lime + FYM + 100% NPK (T12); FYM + Biofertilizers (T13); FYM + Biofertilizers + 50% NPK (T14); FYM + Biofertilizers + 75% NPK (T15); FYM + Biofertilizers + 100% NPK (T16); Lime + FYM + Biofertilizers (T17); Lime + FYM + Biofertilizers + 50% NPK (T18); Lime + FYM + Biofertilizers + 75% NPK (T19); Lime + FYM + Biofertilizers + 100% NPK (T20). N, P and K were applied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. FYM and lime were applied @ 5 t ha^{-1} and 5 q ha^{-1}, respectively.

Soil sampling was done by collecting and compositing 5 subsamples from each sampling plot in surface (0-150 mm) soils at the end of the fifth cropping cycle during 2005/06. The samples were brought to the laboratory, air-dried and sieved through a 2-mm wire mesh for the determination of soil properties. For organic matter determination, soil samples were passed through a 0.5 mm wire mesh. Thereafter, the samples were analyzed for the following soil parameters: soil pH was determined potentiometrically using distilled water at a soil-solution ratio of 1:2.5; organic carbon and available N using Walkley-Black and Kjeldhal distillation methods (Jackson 1973); available phosphorus was extracted using the Bray and Kurtz method of Jackson (1958) and Murphy and Riley (1962) for color development and quantified by measuring the percent absorbance at 880 nm using spectrophotometer. Exchangeable K, Ca, and Mg were extracted by using 1 N NH_4OAc neutralized to pH 7 and then quantified by atomic absorption spectrophotometer (AAS). Exchangeable Al was extracted by using 1 M KCl and estimated in atomic absorption spectrophotometer.

All the data were analyzed using the SPSS version 16.0 statistical package (SPSS Inc., Chicago, USA). Significance of the treatment effect was considered at 0.05 probability level. The treatment means were segregated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSIONS

Soil chemical properties:

Application of lime and other organic manures significantly affected the soil pH and exchangeable

Table 1: Effect of liming and integrated nutrient management practices on soil chemical properties

Treatments	Recommended dose of NPK (%)				
	0	50	75	100	Mean
		Soil pH (1:2)			
Control	4.70	4.65	4.24	4.19	4.45c
Lime + Biofertilizers	4.73	4.63	4.73	4.70	4.70ab
Lime + FYM	4.88	4.91	5.02	4.55	4.84a
FYM + Biofertilizers	4.73	4.55	4.33	4.66	4.57bc
Lime + Biofertilizers + FYM	4.88	4.99	4.81	4.78	4.87a
Mean	4.78a	4.75ab	4.63bc	4.57c	
		Organic carbon (g $100g^{-1}$)			
Control	2.07	1.82	1.86	2.02	1.94b
Lime + Biofertilizers	1.89	2.08	1.78	2.06	1.95b
Lime + FYM	1.83	1.92	2.01	2.13	1.97ab
FYM + Biofertilizers	1.89	2.09	2.28	2.17	2.11a
Lime + Biofertilizers + FYM	2.04	2.23	2.02	2.08	2.09a
Mean	1.94b	1.99ab	2.03ab	2.09a	
		Exch. bases (meq $100g^{-1}$)			
Control	1.63	1.63	1.5	1.41	1.54c
Lime + Biofertilizers	2.29	2.13	2	2.47	2.22b
Lime + FYM	2.38	2.31	2.71	2.52	2.83a
FYM + Biofertilizers	2.3	2.03	1.78	1.75	1.97bc
Lime + Biofertilizers + FYM	3.05	3.58	3.27	2.52	3.11a
Mean	2.43a	2.14ab	2.04ab	1.91b	

Al concentration (Table 1& 3). The mean soil pH ranged from 4.57 to 4.78 while application of different organic amendments along with lime increased the pH from 4.45 to 4.87. The treatment with lime + FYM and lime + FYM + biofertilizers showed the at par increase in soil pH in relative to control. On the other hand, there was also a significant decrease in soil pH with increased dose of NPK application. Application of 100% recommended NPK recorded the lowest soil pH (4.57) compared with no NPK application (4.78). Similarly, manures along with lime application showed considerable reduction in exchangeable Al content with the lowest value in the treatment receiving lime + FYM + biofertilizers (0.77 meq $100g^{-1}$) and the highest value was observed in the control (2.03 meq $100g^{-1}$). The increase in soil pH and reduction of soil exchangeable Al following application of manures and lime either sole or combined can be ascribed to the release of organic acids, which in turn may have suppressed Al content in the soil through chelation (Onwonga et al. 2008). Furthermore, lime when applied in the soil reacts with water leading to the production of OH^- ions and Ca^{2+} ions which displace H^+ and Al^{3+} ions from soil adsorption sites resulting in an increase in soil pH (Kisinyo et al. 2012). These findings are similar to those of Manoj Kumar et al. (2012) who found increased soil pH with application of lime and manures in acid soil.

All treatments significantly affected the soil organic carbon (SOC) and available N, P and K content of the soil (Table 1 & 2). Also, there were statistical differences in these parameters with the application of recommended dose of NPK. The SOC and available P and K content increased with increased dose of NPK application; however application of 100% NPK did not show any significant increase in available N content. In contrast, application of organic manures alone or in combination with lime statistically increased the SOC and available N, P and K content of the soil. The SOC content was highest in the treatment with FYM + biofertilizers which was statistically at par with the treatment receiving lime + biofertilizers + FYM (Table 1 & 2). Sharma and Subehia (2003) also reported greater levels of SOC under integrated treatments of organic and inorganic combinations in Alfisols. Amongst the organic manures, the treatment receiving lime +biofertilizers + FYM, FYM + biofertilizers and lime + FYM increased the available N, P and K by 1.4, 1.7 and 1.3 times, respectively in comparison to the treatment receiving no organic manures and lime. Overall,

Table 2: Effect of liming and integrated nutrient management practices on soil available N, P and K content

Treatments	Recommended dose of NPK (%)				
	0	50	75	100	Mean
		Available N (kg ha^{-1})			
Control	155.4	167.9	198.7	209.7	182.9b
Lime + Biofertilizers	195.8	209.8	225.9	240.8	218.1ab
Lime + FYM	178.6	206.3	219.7	230.1	208.7ab
FYM + Biofertilizers	204.9	219.8	233.9	264.7	230.8ab
Lime + Biofertilizers + FYM	211.3	229.7	280.7	290.7	253.1a
Mean	189.2ab	206.7ab	231.8a	247.2a	
		Avail. P_2O_5 (kg ha^{-1})			
Control	24.4	25.3	27.4	37.6	28.7b
Lime + Biofertilizers	39.4	34.7	41.1	56.2	35.4b
Lime + FYM	18.3	43.0	33.7	60.0	38.7b
FYM + Biofertilizers	34.3	44.2	43.7	76.3	49.6a
Lime + Biofertilizers + FYM	28.4	41.7	54.8	47.5	43.1ab
Mean	29.0b	37.8b	40.1b	55.5a	
		Avail. K_2O (kg ha^{-1})			
Control	186.4	187.8	212.9	228.8	204.0c
Lime + Biofertilizers	203.2	240.9	259.7	271.5	243.8b
Lime + FYM	242.1	273.8	274.4	281.8	268.0a
FYM + Biofertilizers	206.5	245.7	293.9	264.3	252.6ab
Lime + Biofertilizers + FYM	237.4	237.0	235.3	282.5	248.1ab
Mean	215.1c	237.0b	255.2ab	265.8a	

this study showed that application of manures either alone or combined with lime, NPK fertilizers or both had significant effect on soil available nutrients. These results are in agreement with those of Kihanda et al. (2004). The increase in N content may be due to supply of N content in manure through mineralization associated to the improvement of soil conditions for microorganism's development and activity as a result of manures application and an increase in soil pH due to lime application. Similarly, continuous additions of graded doses of N, P, and K without liming or organic amendments have not shown any positive effect on soil P. However, when supplemented with biofertilizer, lime and organic manures, there was an increase in soil P availability of 23.3 to 72.8 % over the control. The increased P availability may be ascribed to several mechanisms which include release of inorganic P from decaying residues, blockage of P adsorption sites by organic molecules released from the residues, a rise in soil pH during decomposition and complexation of soluble Al and Fe by organic molecules (Haynes and Mokolobate 2001). The increased K availability in soil may be attributed to the release of K from the manures, and also the increased dose of K fertilizers application. The increase in soil pH due to the application of lime is also responsible for the increased K content in soil as observed in this study (Chimdi et al. 2012).

Fertilizers and manures along with lime application had significant effect on exchangeable Ca and Mg (Table 3). The mean exchangeable Ca and Mg varied from 1.31 meq $100g^{-1}$ in control to 2.88 meq $100g^{-1}$ in lime + biofertilizers + FYM treatment. Adeleye et al. (2010) observed increased exchangeable Ca and Mg availability in the soil as a result of manure application due to the release of nutrients through manure decomposition. Rahman et al. (2002) also found increased exchangeable Ca and Mg in the soil as a result of applied manure either alone or combined with lime due to improved soil pH, as observed in this study. The increase can be attributed to the release of Ca^{2+} ions in lime through its dissociation (Chimdi et al. 2012) and to mineralization of manure with released nutrients (Shen and Shen 2001). To sum up, the study on judicious integrated nutrient management strategy revealed that application of recommended dose of inorganic fertilizer along with lime, FYM and biofertilizers to maize, if adopted properly, can lead to many-fold improvement in soil fertility in terms

Table 3: Effect of liming and integrated nutrient management practices on soil exchangeable Ca, Mg and Al (meq $100g^{-1}$)

Treatments	Recommended dose of NPK (%)				
	0	50	75	100	Mean
		Exch. (Ca+Mg) (meq $100g^{-1}$)			
Control	1.45	1.4	1.25	1.15	1.31c
Lime + Biofertilizers	2.1	1.95	1.8	2.25	2.03b
Lime + FYM	3.55	2.05	2.45	2.25	2.58a
FYM + Biofertilizers	2.1	1.8	1.5	1.5	1.73bc
Lime + Biofertilizers + FYM	2.85	3.35	3.05	2.25	2.88a
Mean	2.41a	2.11ab	2.01ab	1.88b	
		Exch. Al (meq $100g^{-1}$)			
Control	1.68	1.87	2.18	2.39	2.03a
Lime + Biofertilizers	0.87	1.14	1.22	1.13	1.01c
Lime + FYM	0.97	0.90	0.70	1.25	0.95c
FYM + Biofertilizers	1.12	1.48	1.56	1.62	1.46b
Lime + Biofertilizers + FYM	0.62	0.76	0.79	0.93	0.77c
Mean	1.05b	1.23ab	1.29ab	1.47a	

of higher available N, P, K, organic carbon and exchangeable bases on acidic soils of Meghalaya and other north-eastern states of India with similar soils.

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