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Influence of Different Organic Amendments on Fe, Mn, Cu and Zn Availability in Indian Soils

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A B S T R A C T

This experiment was carried out to investigate the stabilizing influence organic amendments on soil reaction and micronutrient availability. Three different soil types (viz. acid, neutral and sodic soil) were considered for our experiment to represent soils of the whole country. Soils were incubated with FYM and vermicompost at different doses and incubated at field capacity for 4 weeks. Subsamples at predetermined duration were analyzed for soil reaction, organic carbon (OC), available micronutrients, microbial biomass carbon and nitrogen. The pH for acid soil was found to increase from 5.40 to 5.91, whereas it showed a decreasing trend for neutral (from 7.58 to 7.09) and sodic soil (from 9.36 to 8.81). This change of pH was closely related with change in soil OC content at different durations. However acid and neutral soil reported stronger correlation (R^2=0.93 and 0.94 respectively) than sodic soil (R^2=0.71). All three soils contained micronutrient well above the critical limit, indicating higher availability of them. Still their content was significantly modified during the entire experiment. However the modification was not merely similar for all the micronutrient, and varied according to their elemental chemistry. The concentration of available Fe (12.11-15.26, 7.51-8.46 and 6.37-7.93 mg/kg soil for acid, neutral and sodic soil respectively) and Mn (4.4-5.03, 2.15-4.02 and 3.08-4.5 mg/kg soil respectively) was increasing initially and then started to decrease with time. Micronutrient Zn was increasing (8.76-11.15, 7.85-10.10, 2.86-5.45 mg/kg soil for acid, neutral and sodic soil respectively) throughout the duration, whereas soil available Cu content decreased steadily (1.87-1.10, 1.59-0.99, 1.46-0.93 mg/kg for acid, neutral and sodic soil respectively). All the micronutrient was well correlated to changes in soil pH and OC. However their strength varied in terms of soil type and micronutrient in consideration.

Introduction

The plant nutrient elements likeiron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) are traditionally classified as micronutrients and have been recognized recently as major limiting factors in modem agricultural production. The functional roles of micronutrients are well established and most of these are involved in the structure activation of important enzyme systems in plants (DalCorso *et al.,* 2014 and references therein).

With the advent of fertilizer responsive, high yielding varieties of crops and hybrids with high management practices, productivity increased several fold resulting in drain of soil reserves of micronutrients. But willful reimbursement consists mainly of nitrogen, phosphorus, potassium and secondary nutrients calcium, magnesium and sulphur. The wide spread incidence of micronutrient deficiency reported for different crops is an example of low availability of micronutrients in Indian soils leading to low productivity.

Though parent material determines the total micronutrient content of soil, its availability to plants depends on several other factors influencing sorption/dissolution processes of the individual (Kumpiene *et al.,* 2008). Soil pH, redox potential, type of soil constituents, cation exchange capacity, soil organic matter content and soil microbial populations are among them. Cationic micronutrients such as Fe, Mn and Zn are mostly affected by soil pH level and are much soluble at lower pH values (Sillanpää, 1982). Their presence even at toxic level is reported elsewhere around the world (Broadley *et al.,* 2007). However, availability of Cu in soil is largely influenced by OM content (Sillanpää, 1982). Its strong affinity to several functional groups of OM renders its availability to plants. Application of organic amendments to soil is reported to stabilize the soil pH as well as OM content (Bevacqua and Mellano, 1993). Organic matter exhibits buffering capacity in slightly acid, neutral and alkaline range which helps to maintain uniform reaction in the soil. Organic matter helps in the formation of chelate with heavy metals and forms stable complexes with Fe, Mn, Zn, Cu and other polyvalent cations which may enhance the availability of micronutrients to higher plants. However, their chelation and/or retention are dependent on several soil factors, such as soil reaction, state of OM decomposition and stability constant of the chelated comoplex. Low molecular weight Fulvic acid form chelates are relatively weaker than high molecular weight Humic acid and Humin (Kumpiene *et al.,* 2008).

The distribution and availability of micronutrient in Indian soils varies with type parent material, agro-climatic zone, soil type and cropping pattern. Acid soils of India exhibits prevalence of Fe, Mn, Zn and Cu over other micronutrients. However their concentration is very less or become unavailable in sodic or saline-sodic soil. Presence of high level of Fe, Mn, Zn and Cu in lower pH soil may sometime pose threat to higher production. Whereas, their non-availability at high pH may render crop production. Reclamation of these problematic soils is very important in present day context for sustainable crop production.

The amelioration of acid or sodic soils with chemical amendments is an established technology. However increasing cost of the chemicals and labor hinders their wide adaptation. The adoption of cost effective biological amelioration methods using living or dead organic matter using crops, stems, straw, green manure, barnyard manure, compost, sewage sludge is more viable option (Wang and Li 1990; Matsumoto *et al.,* 1994; Mahdy 2011). Addition of organic matter to the soil improves the not only physical but chemical and biological properties of soil during its degradation in the soil.

However different types of organic amendments from various source differs in their chemical composition. Thus the change brought by them varies in extent or degrees with type of organics applied. Farm yard manure is rich in carbon than vermicompost, whereas the later is rich in nitrogen. Vermicompost being rich in nitrogen are more reactive and are rich in functional groups which can easily bind with metals and form chelate. They contain 17-36% of humic acid and 13-30% fulvic acid of the total concentration of organic matter (Orlov and Biryukova, 1996). Keeping this in mind, we carried out an experiment to investigate the effect of organic amendments on different types of soils of India and with incubation duration.

It was hypothesized that organic amendments will react differently with different soil types and will stabilize soil pH, OC and micronutrient at level better for crop growth. In order to test the hypothesis, we conducted a laboratory experiment (during January-February, 2012) where acid, neutral and sodic soils were incubated for 6 weeks with FYM and vermicompost and chemical changes were recorded accordingly.

Materials and Methods

Surface soils (top 0 to 20 cm) were sampled following standard methods from different places of India representing acidic, neutral and sodic soil. Acidic soil (under Oxisol soil order) was collected from Jamtara, Jharkhand. Sodic soil from Rajasthan was derived from the order Aridisol and neutral soil from Nadia, West Bengal comes under the Inceptisol order. Samples were brought to laboratory at BCKV, Mohanpur, West Bengal for incubation study. The pre-experimental physical, chemical and biological properties of the experimental soils are appended in Table 1. The temperature varied from 12 to 36ºC at the experimental site.

Collected soil samples were first air dried and passed through 5 mm sieve. Afterwards, FYM and vermicompost were added @0.5 and 1% on soil weight basis (Table 2) and mixed thoroughly. The setup was then incubated for six weeks for soil reaction to take place. Water was added to them frequently to maintain field capacity moisture level. The sub-sampling was done at 7, 14, 28 and 42 days of incubation (DOI) and analyzed for available micronutrients, organic carbon content and soil pH.

Soil pH was determined by using soil suspension in water in the ratio of 1:2.5 (Jackson, 1973) with glass electrode pH meter (Model: Systronics, 335). Organic carbon content of soil samples was determined following the method of Walkley and Black (Walkley and Black, 1934; Jackson, 1973). DTPA extractable soil available cationic micronutrients were measured following Lindsay and Norvell (1978) using an Atomic Absorption Spectrophotometer (Perkin Elmer, Model Aanalyst 100) at Dept. of ACSS, BCKV. Microbial biomass carbon and nitrogen were determined by fumigation extraction procedure, developed by Joergensen *et al.*, (1995) and Brookes *et al.*, (1985) respectively.

All statistical computations were done using SPSS software (SPSS Inc., 2010) following methods meant for completely randomized design (CRD). Duncan's multiple range test (DMRT) at 5% level of significance was followed to compare the treatment means (Gomez and Gomez, 1984). Sigmaplot (v10) was used for graphical presentation of the data set.

Results and Discussion

Effects of organic amendments and incubation duration on soil pH and SOC

Soil pH: The changes in soil pH with incubation duration have been reported in Figure 1. Generally the pH for acid soil was increasing whereas it decreased for neutral and sodic soil. Soil pH for acid soil varied from 5.32 to 6.19 (avg. 5.66) during the entire incubation period. It was decreasing with incubation period for all the treatments. However, better results were found for soil treated with higher dosage of organic manure irrespective of source. Treatment T_4 and T_2, where soils were treated with 0.5% vermicompost and 1 % FYM respectively, exhibited higher change in soil pH compared to T_1 and T_3 receiving only 0.5 % FYM and 0.25 % vermicompost respectively. Increase in pH in acid soil might be partly due to the saturation effect of the soil and also partly due to the soil reduction resulting from the application of organic matter. Release of organic reducing substances, formed during decomposition of organics may reduce Aluminum and Iron oxides causing soil pH to rise, as the protons are consumed in course of reduction of oxides (Wong *et al.,* 1998). Similar results were reported elsewhere (Haimi and Huhta, 1987; Melgar- Ramirez and Pascual-Alex, 2010). A small increment in soil pH was also recorded in controlled plot, where soil pH has changed from 5.39 to 5.73. Slaking and breaking down of soil aggregates during the incubation period and subsequent release of basic cations (like Ca^{2+}, Mg^{2+}) and decomposition of inherent soil OM might have raised the pH for controlled treatment. Though organics were found to decrease soil pH for neutral and sodic soil, only a little change was found for both of the soil. Soil pH varied from 6.98 to 7.65 (avg. 7.29) and 9.42 to 8.69 (avg. 9.00) for neutral soil and sodic soil respectively. Release of organic acids and CO_2 resulting from the decomposition of applied organic matter might have decreased the soil pH. Greater influence was recorded in treatments having higher dose of organics (Treatment T_4 and T_2) regardless of their source than T_1 and T_3, containing lesser amount of OM. Performance of vermicompost was found better due to accumulation of relatively higher amount of CO_2 in the presence of nitrogen rich vermicompost (Krezel,1991). Similar reports were reported elsewhere (Pawar and Patil, 2007; Azarmi *et al.,* 2008).

Soil OC: Changes in SOC has been reported in Figure 2. Generally acid soil contained higher amount of OC followed by sodic and neutral soil. It varied from 0.40 to 0.82 % in different DOI and treatments. Lower soil pH in acid soil may inhibit the soil microorganism population and their activity from decomposing OC than neutral soil. Oxides and hydroxide of Fe and Al may also help in protecting OC from being oxidized (Wagaiand Mayer, 2007). The dispersed soil particles in sodic soil may not protect OC from being oxidized, thus lowering OC content (Nelson, 1997). All the treatments including control (T_1) showed increasing OC content with incubation durations. Humic substances may contain many higher forms of organic compounds, which become available upon microbial decomposition with time. Thus easily oxidisable soil OC level may increase with incubation durations. Addition of external organics has undergone bio-decomposition and increased soil OC level. Incubation and disturbance (alternate wetting and drying) may have led to breaking down of soil aggregate brining aggregate and oxide protected OC to oxidisable form (Davidson and Ackerman 1993; Murty *et al.,* 2002), which might have increased OC content in controlled treatment. Treatment T_4 has resulted in maximum increase if soil OC content followed by T_2, T_1 and T_3. Higher amount of FYM and Vermicompost was applied in T_2 and T_4, thus increasing soil OC level. Similar findings (Ramachandra *et al.*, 2011; Mohan and Chandaragiri, 2007) were reported where higher OC concentration was found by the sole addition of vermicompost than the single application of FYM or other manures.

Effects of OM, pH and incubation duration on soil micronutrient availability

Our experimental soil contained available micronutrients well above the critical limit. The concentration of Fe was highest in soil, followed by Zn, Mn and Cu. However their concentration in soil with incubation duration varied differently according to their elemental characteristics.

Fe and Mn: Acid soil contained higher amount of Fe and Mn than neutral and sodic soil. Lower pH of soil has led to increased dissolution of Fe and Mn in the soil solution, increasing available Fe content in acid soil. Whereas, higher pH in neutral and sodic soil discourage oxide bound Fe and Mn to come into soil solution, decreasing their availability in soil. Figure 3 and 4 shows the changes in available Fe and Mn content in soil with incubation duration respectively. The amount of DTPA extractable Fe and Mn content in sodic soil increased initially up to 28 DOI and thereafter decreased gradually irrespective of treatments. However, little deviation from this trend was found for acidic and neutral soil.

Available Fe content in acid soil was peaked at 14 DOI and started decreasing afterwards. The magnitude of such changes, however, varied with treatments. The greater amount of DTPA extractable Fe and Mn was recorded in soils amended with organic material, being highest in the treatment T_4 where vermicompost @ 0.5% was applied during the days of incubation, followed by T_2 and T_3. However the effect of T_2 and T_3 was statistically at per. Similar trend, but with much lower magnitude was noticed for controlled treatment (T_0). The microbial decomposition of added OM and subsequent reduction of higher oxidized (Fe^{3+}, Mn^{4+}) form to available lowed oxidized (Fe^{2+}, Mn^{2+}) form has added available Fe and Mn to the soil during the initial period of the experiment. Afterwards, microbial assimilation of available Fe and Mn or oxidation to non-available higher oxidized form might have rendered the available Fe and Mn concentration in soil (REF). Such decrease due to organic resource material might be partly due to the reduction of ferric iron to ferrous iron and partly due to the acceleration of the reduction process.

Zn: Acid soil contained highest amount of Zn followed by neutral soil (Fig. 5). Soil available Zn was much lower in sodic soil. It varied from 7.79 to 13.44 mg/kg (avg. 9.77 mg/kg) in acid soil during the entire incubation duration. Whereas it ranged between 4.98 to 12.82 mg/kg (avg. 8.89 mg/kg) and 1.56 to 6.80 mg/kg (avg. 3.89 mg/kg) in neutral and sodic soil respectively. The availability of Zn in soil is affected by soil pH, OM content, presence of various other cations and minerals like P, Ca, Al, Mn and Fe oxides, (Kumpiene *et al.*, 2008; Broadley *et al.*, 2007; DalCorso *et al.*, 2014).

The progressively increase in DTPA extractable zinc might be explained by the formation of chelating complex with organic material and also due to the slow mineralization of applied organic matter in soil which after extracting the zinc from the different insoluble compounds, successively formation of ligand complex and after decomposition of organic matter, zinc become slowly unavailable. Similar reports are available elsewhere (Sanchez-Monedero *et al.*, 2004; Kizilkaya, 2004).

Table.1 Physical and chemical properties of experimental soils

Properties	Acidic	Neutral	Sodic
Place	Jharkhand	West Bengal	Rajasthan
Order	Oxisol	Inceptisol	Aridisol
pH	5.7	7.58	9.3
Bulk density (g/cc)	1.35	1.6	1.58
EC	-	-	0.33
Ex Al (mg/kg)	18.96	-	-
OC (%)	0.4	0.12	0.12
Available N (kg/ha)	82.79	59.76	62.09
DTPA Fe (mg/kg)	8.72	5.48	7.56
DTPA Cu (mg/kg)	2.47	1.92	2.16
DTPA Mn (mg/kg)	3.48	2.66	1.91
DTPA Zn (mg/kg)	4.5	5.7	1.25
MBC (ug/gm)	15.28	5.68	20.85
MBN (ug/gm)	2.5	3	2

Table.2 Chemical properties of organic amendments used in the experiment

Characteristics	FYM	Vermicompost
Moisture (%)	40%	60%
pH	6.52	6.37
Organic carbon	31.35	22
Total carbon (%)	47	31
Available nitrogen (kg/ha)	476.67	413.952
Total nitrogen (kg/ha)	0.97	1.26
C:N	32.32:1	17.46:1
DTPA extractable Zn (mg/kg)	18.93	20.38
DTPA extractable Mn (mg/kg)	12.42	15.82
DTPA extractable Fe (mg/kg)	21.44	26.33
DTPA extractable Cu (mg/kg)	4.78	5.92
MBC (ug/g)	240	270
MBN (ug/g)	35	42

Table.3 Pearson correlation between parameters (p<0.5)

	DOI	*pH*	*OC (%)*	*DTPA-Fe*	*DTPA-Mn*	*DTPA-Cu*	*DTPA-Zn*
DOI	1.00						
pH	-0.04	1.00					
OC (%)	0.54	-0.62	1.00				
DTPA-Fe (mg/kg)	0.14	-0.79	0.78	1.00			
DTPA-Mn (mg/kg)	0.38	-0.37	0.74	0.69	1.00		
DTPA-Cu (mg/kg)	-0.72	-0.36	-0.27	0.09	-0.29	1.00	
DTPA-Zn (mg/kg)	0.29	-0.78	0.67	0.64	0.42	-0.13	1.00

Fig.1 Changes in soil pH with treatments and incubation duration

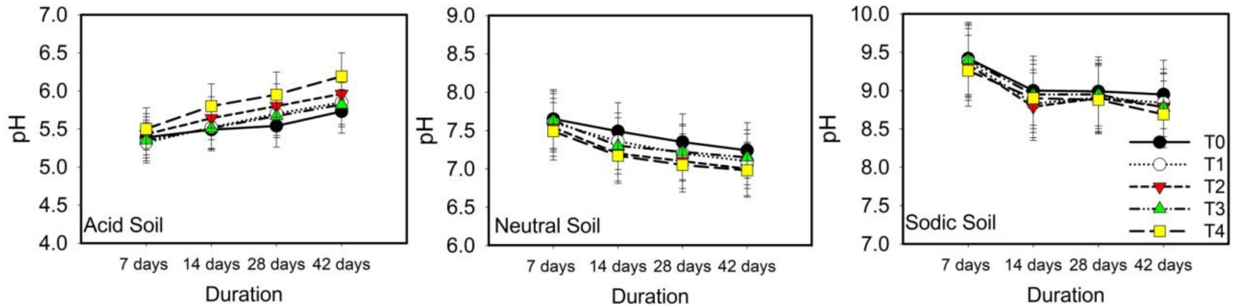


Fig.2 Changes in soil organic carbon content with treatments and incubation durations

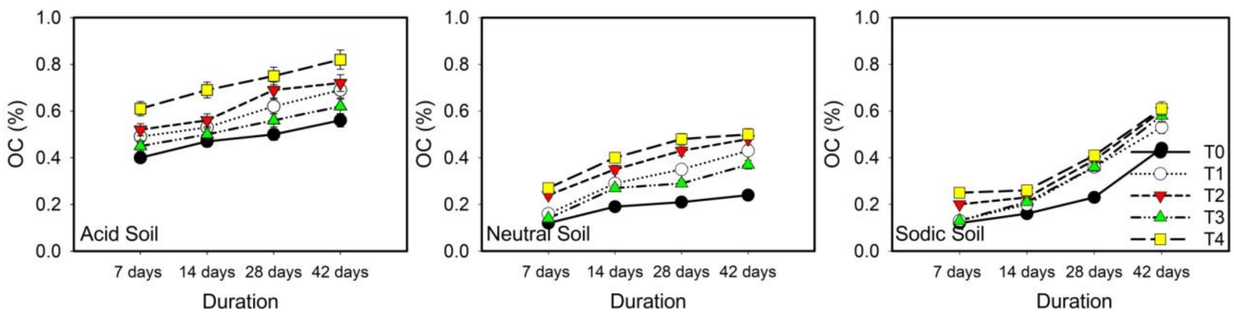


Fig.3 Changes in soil DTPA extractable Fe content with treatments and incubation durations

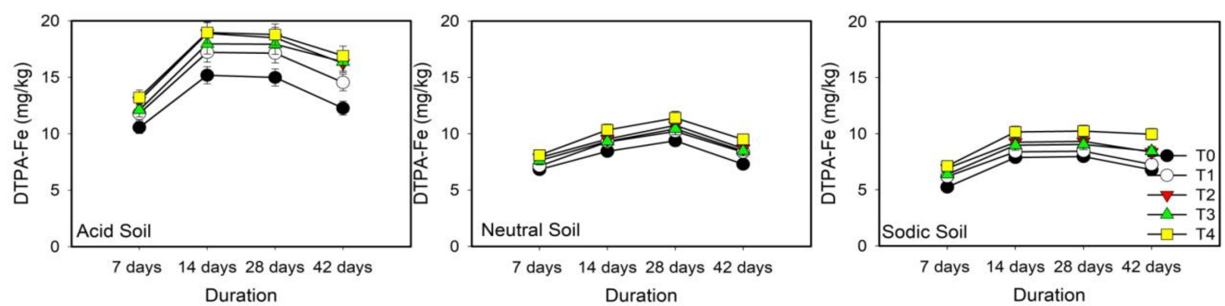


Fig.4 Changes in soil DTPA extractable Mn content with treatments and incubation durations

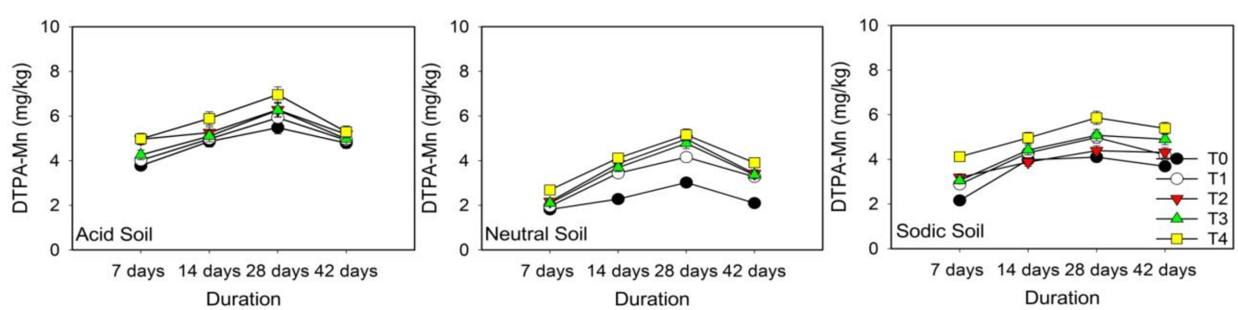


Fig.5 Changes in soil DTPA extractable Zn content with treatments and incubation durations

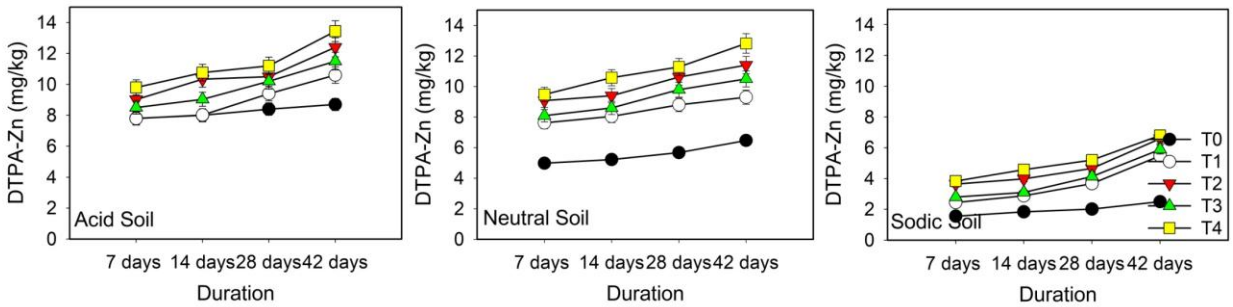


Fig.6 Changes in soil DTPA extractable Cu content with treatments and incubation durations

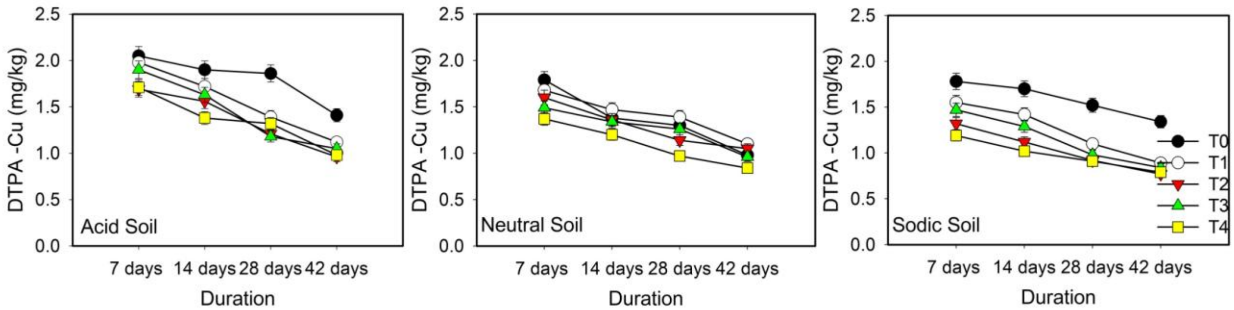
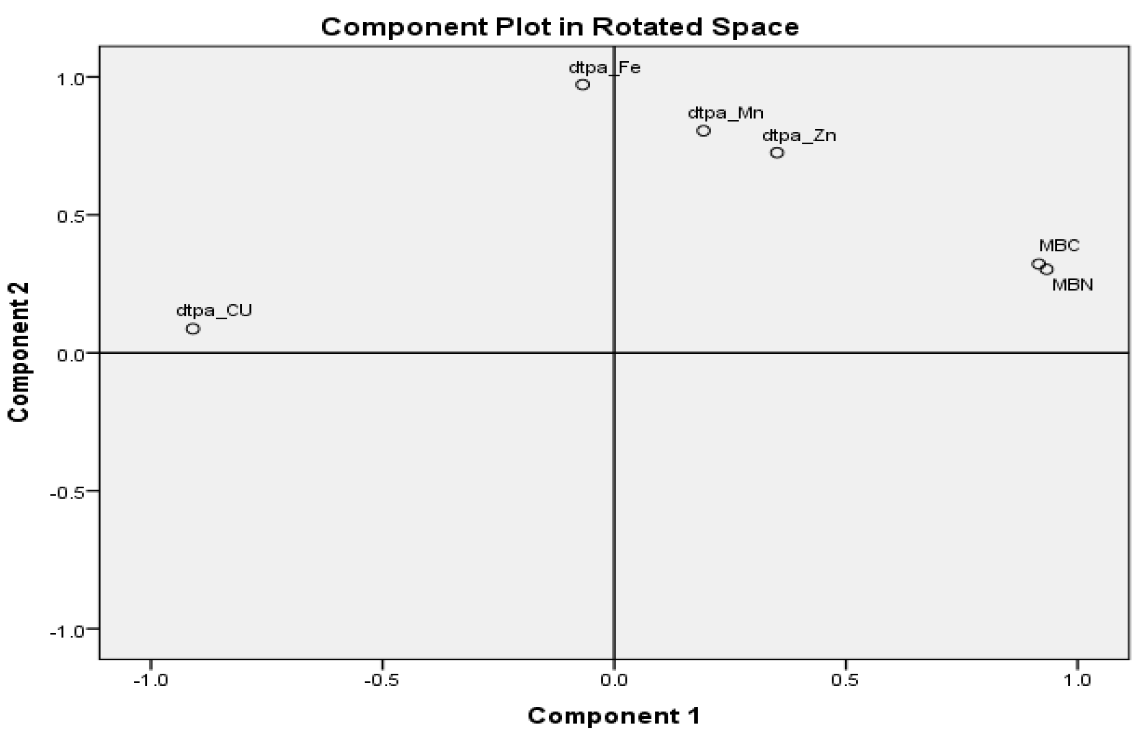


Fig.7 Principle component analysis of micronutrients



Cu: Copper and Zn apparently are absorbed through common carrier sites (Bowen, 1987). Our experimental soil was rich in Zn concentration, reducing Cu concentration in soil. Availability of Cu varied from 0.96 to 2.05, 0.84 to 1.79 and 0.89 to 1.78 respectively for acid, neutral and sodic soil respectively. Figure 6 shows changes in available Cu content in soil at different incubation duration. The concentration was decreasing in all the soil, which was unlike other micronutrients. The Cu concentration was negatively correlated with soil pH for acid soil (r=-0.91), but positively in neutral (r=0.88) and sodic (r=0.69) soil. Generally mild acid soil shows higher mobility of Cu (Kumpiene *et al.*, 2008). Increase in soil pH of acid soil might result in lower Cu mobility, thus its solubility in them. Copper is known to form strong bond with OM in soil, reducing its availability (Balasoiu *et al.*, 2001). Similar strong correlation between Cu and OM irrespective of soil type was found in our study (Table 3). We have found strong correlation Application of organic amendments results in higher Cu sorption on clay mineral surfaces forming organo-mineral complex (Arias *et al.*, 2002; Hizal and Apak, 2006). Increase in OM with incubation duration in our soil might have resulted in lower available Cu concentration in soil.

Principle component analysis of micronutrients (Fig. 7) shows that soil available Fe, Mn, Zn and Cu are controlled by different factor(s). Component I explains 56.25 % of total variation whereas Component II explains 27.48% of total variation. Component I controls soil available Fe, Mn and Zn whereas Cu concentration was controlled by Component II.

We have carried out an experiment to investigate the possible influence of organic amendments on soil reaction, OM content and available micronutrient with different incubation duration. It was hypothesized that organic amendments will improve soil health in terms of OM content, soil pH and available micronutrients. It was found that soil pH for acid soil was increasing while it decreased for sodic soil. Organic matter content of all soil type increased substantially. However different trends were found for available micronutrients according to their elemental characteristics. The availability of Fe, Mn and Zn were increased during incubation with organic amendments. However availability of Cu was decreased with time.

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