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Effect of FYM, Lime and Fertilizers on Forms of Soil Acidity and Relationship with Soil Properties in Acid Alfisol

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Abstract: The field experiment was carried out on maize crop during *kharif* 2020 at CSKHPKV, Palampur to study the effect of fertilizers and amendments on forms of soil acidity and soil chemical properties in an acid Alfisol. The application of lime with 100% NPK and integrated use of FYM, lime and 100% NPK decrease the exchangeable acidity, total potential acidity, extractable acidity, pH dependent acidity, non-exchangeable acidity and total soil acidity. There was significant increase in the soil pH, CEC, organic carbon and available nutrients (N, P, K, Ca, Mg and S) under treatment 100% NPK + 10 t FYM/ha + lime (full dose through broadcasting) which was at par with 100% NPK + 10 t FYM/ha + lime (1/10th dose through furrow application). All forms of soil acidity observed significant negative correlation with available nutrients and soil properties except soil organic carbon which showed significantly positive correlation.

Keywords: Exchangeable acidity, Total potential acidity, Extractable acidity, pH dependent acidity, Non-exchangeable acidity, Total soil acidity

Maize (*Zea mays* L.) is cultivated widely throughout the world and has the highest production among all the cereals. It is considered as one of the fastest growing cereal crops in the world becoming the largest component of global coarse-grain trade and has a high production potential compared to any other cereal crop. In India, it ranks third in production after rice and wheat. However, the production is constrained due to declining soil health. Among other crop production constraints, soil acidity has been recognized as one of the important production problems across the globe. It is important to have the knowledge of the different forms of acidity, as this will help in management of acid soils. Soil acidity management is important for enhancing food security globally and regionally. In India, acid soils comprise about 92.79 m ha, out of which 62.14 m ha have pH range between 5.6-6.5 and in Himachal Pradesh, the extent of acid soil is 1.74 m ha (Maji et al 2012). The acidic soil condition is considered as major constraints in the maize cultivation. The fertility status of the acid soils is very poor and under strongly to moderately acidic soil conditions the plant growth and development is affected to a greater extent. The plant grown on such kind of problematic soils does not give profitable return rather it lowers down the yield considerably. The most practicable management practices are the use of lime and liming material to ameliorate the soil acidity. Lime application is recommended to increase the phyto-availability of essential nutrients and ameliorate the acidity-induced fertility constraints on such soils, thus enhancing the productivity as well as maintaining the soil health. In the earlier studies, the effect of combined use of FYM, lime and fertilizers on forms of acidity and soil-physico chemical was not evaluated. Therefore, the present study was undertaken in an acid Alfisol. Furthermore, the effect of natural farming in comparison with the state recommended dose of fertilizer was also observed.

MATERIAL AND METHODS

Location: The study was conducted at the Research farm of the department of Soil Science, CSKHPKV, Palampur, situated at 32^{0}7/N latitude and 76^{0}31/E longitude in Kangra district of Himachal Pradesh during kharif 2020.

Climate and weather: The climate of the study area is characterized by mild summers, severe winters and experiences occasional snowfall during winter. The annual rainfall of the area ranges from 2500 mm to 3000 mm. In general, a major part of the rainfall (about 75 per cent) is received during monsoon period from June to September. The soil of the experimental site was silt loam in texture and classified as *Typic Hapludalf* (Soil Survey Staff 1975).

Initial soil characteristics: At the initiation of the experiment, soil of the experimental field was acidic in reaction (pH 5.9), medium in organic carbon (8.34 g/kg), medium in available Nitrogen (N) (291 kg/ha) and medium in available P and K (11.16 and 228 kg/ha), respectively.

Treatments detail: The experiment comprised of eleven treatments which were replicated thrice and laid out in a randomized block design (Table 1). The maize crop was taken as a test crop and the variety used was *kanchan gold*. The recommended dose for maize crop is 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. The sources of N, P and K were urea, single super phosphate and murate of potash, respectively for all the treatments except T_1 (control) and T_{11} (natural farming). In treatments T_2 to T_{10} half dose of N and full dose of P and K was applied at the time of sowing of maize. The remaining half nitrogen was top dressed in two equal splits at knee high and pre-tasseling stage of maize. The FYM contained 45 per cent moisture and was incorporated on dry weight basis with average N, P and K nutrient content 0.96, 0.34 and 0.63 percent respectively and mixed well in the soil before sowing. The lime requirement was determined by SMP buffer method and marketable lime ($CaCO_3$) was applied as per treatments. In treatments T_5, T_7 and T_8, full dose of lime (4t/ha) was applied in the soil uniformly through broadcasting and thereafter mixed well in the soil, whereas in treatments T_6, T_9 and T_{10}, 1/10th dose of lime (0.4 t/ha) was applied in furrows. The treatment T_{11} was introduced to compare natural farming treatment with the already existing nutrient management practices recommended by the CSK Himachal Pradesh Krishi Vishvavidyalaya Palampur. Prior to sowing, *Ghanajeevamrita* was applied and incorporated into the plots at a rate of 250 kg/ha. Before sowing, seeds were treated with *Beejamrita* at a rate of 100 ml/kg seed. Application of *Jeevamrita* @ 500 l/ha was done at the time of sowing followed by spray of *Jeevamrita* at an interval of 21 days after dilution (1:10) with water.

Physical-chemical properties of soil: Soil samples collected from a depth of 0-0.15m after the harvest of maize (*Kharif* 2020) were used for determination of various chemical properties. The processed soil samples were analyzed for forms of soil acidity viz., exchangeable acidity, total potential acidity, pH dependent acidity, extractable acidity, non-exchangeable acidity and total soil acidity. Exchangeable acidity was determined by the method as outlined by McLean (1965). 0.5 N barium chloride ($BaCl_2$)-triethanolamine (pH – 8.0–8.2) reagent as extractant was used to determine the total potential acidity (Baruah and Barthakur 1998). The pH dependent acidity was calculated by subtracting the exchangeable acidity from total potential acidity. For extractable acidity, forty gram each soil samples were extracted with NH_4OAc solution (pH 4.8) and the values were determined by colorimetric method (Baurah and Barthakur 1998). Non-exchangeable acidity was determined by subtracting the value of exchangeable acidity from extractable acidity. Total soil acidity was estimated by extracting the soil with freshly prepared sodium acetate (NaOAc) solution (pH 8.2) described by Kappen (1934).

Statistical analysis: The data collected from the field study and laboratory was analyzed by online statistical analysis tools (OPSTAT) and technique of analysis of variance (ANOVA) for randomized block design was used for interpretation of results (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Effect of FYM, Lime and the Chemical Fertilizer on Soil Properties

Soil pH: There was significant increase in the soil reaction (pH), SOC and CEC with the combined application of organic and inorganic fertilizer. The highest soil pH was recorded

Table 1. Effect of FYM, lime and fertilizers on soil pH, SOC (g/kg) and CEC (c mol (p^+)/kg

Treatment	pH	SOC	CEC
T_1: Control	5.47	8.47	11.72
T_2: 100% NPK	5.60	8.83	12.23
T_3: 100% NPK + 5 t FYM/ha	5.68	9.64	12.50
T_4: 100% NPK + 10 t FYM/ha	5.73	9.73	13.00
T_5: 100% NPK + lime (Full dose through broadcasting)	5.78	9.61	13.50
T_6: 100% NPK + lime (1/10th dose through furrow application)	5.76	9.58	12.97
T_7: 100% NPK +5 t FYM/ha + lime (Full dose through broadcasting)	5.84	10.23	13.53
T_8: 100% NPK + 10 t FYM/ha + lime (Full dose through broadcasting)	5.91	10.60	14.20
T_9: 100% NPK + 5 t FYM/ha + lime (1/10th dose through furrow application)	5.77	10.20	13.00
T_{10}: 100% NPK + 10 t FYM/ha + lime (1/10th dose through furrow application)	5.75	10.55	13.47
T_{11}: Natural Farming (*Beejamrita*+ *Jeevamrita +mulch +Ghanajeevamrita* at 21 days interval)	5.66	8.71	11.94
CD (p=0.05)	0.17	0.49	0.83
Initial	5.49	8.34	11.68

under treatment T_8 and was at par with treatments T_5, T_6, T_7, T_9 and T_{10}. The application of FYM increased soil pH which could be due to decrease in exchangeable acidity which reduces the activity of Al^{+3} ions in the soil solution due to chelation by organic molecules (Rajneesh et al 2018).Lime has neutralizing effect which decreased the exchange acidity and exchangeable Al from the soil solution resulted in the increase in soil pH from its initial value (5.49) (Meena et al 2017)

SOC: The application of amendments along with the fertilizer significantly increase which ranged from 8.47 g/kg under control (T_1) to 10.60 g/kgi n T_8.Significant increase in the SOC was under the conjoint application of the fertilizer, FYM and lime in comparison with the control (T_1) and 100% NPK (T_2) and could be attributed to the direct addition of organic carbon through FYM and the addition of crop residues and root biomass (Tabassum et al 2010). Similarly, application of lime improved soil environment resulting in higher root biomass, crop residues and stubbles of the crop (Meena et al 2017).

CEC: The cation exchange capacity (CEC) varied from the lowest value of 11.72 c mol (p^+)/kg in control (T_1) to the highest of 14.20 c mol (p^+)/kg in T_8. The increase in CEC had been found in almost all the treatments as compared to initial value, wherein the initial status of 11.68 c mol (p^+)/kg was almost maintained. The 21.1 and 16.1 per cent increase in CEC was under treatment T_8 over control (T_1) and 100% NPK (T_2), respectively. The significant increase in the CEC value of the soil in the FYM treated plots might be due to increase in pH and the formation of the organic colloid (Hemalatha and Chellamuthu 2013). The substantial effect of lime on CEC may be attributed to the rise in pH and addition of Ca through lime (Dhiman et al 2019).

Available nitrogen: Application of FYM, lime either alone or in combination with recommended dose of fertilizer increased available nitrogen content in all the treatments compared with the initial status except control and 100% NPK. The initial available N content in the soil was 291 kg/ha, which declined to 283 kg/ha in the plots receiving zero fertilization i.e.; control the highest available nitrogen was recorded in treatment T_8 which was at par with the treatments T_7, T_9 and T_{10}. The lowest value of available nitrogen was in control which was significantly inferior to the rest of the treatments. FYM incorporation may attribute to the direct addition of nitrogen into the soil. Similar findings were recorded earlier by Hemalatha and Chellamuthu (2013) and Rajneesh et al (2018). Moreover, the lime improved the biological properties of soil which increases the mineralization of organic N (Verma et al 2012).

Available phosphorus: The available phosphorus content increase in the plots treated with FYM, lime and the inorganic fertilizers over the initial status (11.16 kg/ha), whereas non-significant increase in available phosphorus was recorded under control. Application of FYM and lime along with NPK increased the available phosphorus content by 15.0 kg/ha over its initial status. The substantial build-up of available phosphorus with the application of FYM which could be due to direct addition of P through FYM, solubilization of P by the organic acids released from the organic manure and decrease in P fixation in soil due to inactivation of iron, aluminum and hydroxyl-aluminum. Similar results were recorded by Urkurkar et al (2010) and Thakur et al (2011). The application of lime reduced P fixation because of decrease in exchangeable acidity and exchangeable Al and increased mineralization of organic P in the soil (Rajneesh et al 2018).

Available potassium: Available potassium increased in

Table 2. Effect of FYM, lime and fertilizer on available N, P, K, S (kg/ha) and exchangeable Ca and Mg (c mol ((p^+)/kg

Treatment	N	P	K	S	Ca	Mg
T_1	283	11.6	222	21.6	2.59	1.18
T_2	303	12.9	240	26.4	3.03	1.33
T_3	314	13.4	246	27.3	3.05	1.43
T_4	322	13.7	249	29.2	3.11	1.54
T_5	307	14.1	251	27.4	3.26	1.64
T_6	315	13.8	250	27.3	3.21	1.55
T_7	318	14.5	265	29.7	3.56	1.83
T_8	330	15.0	271	31.4	3.59	1.88
T_9	316	14.3	259	29.5	3.44	1.69
T_{10}	323	14.8	263	30.4	3.50	1.81
T_{11}	299	12.0	235	24.6	2.84	1.21
CD (p=0.05)	15.01	0.78	12.66	3.83	0.16	0.06
Initial	291	11.16	228	24.16	2.74	1.22

almost all the treatments except control (T_1) with its initial status of 228 kg/ha. The application T_8, however, increase the potassium status of the soil to 271 kg/ha. Compared with 100% NPK, treatments T_8 and T_{10} increased available potassium content by 12.9 and 9.6 per cent, respectively. Combining FYM with 100% NPK resulted in higher available potassium content, which might be attributed to the additional supply of potassium through FYM. Furthermore, the decomposition of FYM in soils resulted in the release of organic colloids, which increases CEC (Gouravet al2019). The use of lime in combination with inorganic fertilizers increased available potassium content of soil, which could be due to the exchangeable K being replaced by Ca produced by lime (Kumar et al 2014).

Available sulphur: The lowest value (21.6 kg/ha) of the available sulphur was under no fertilization plots which was at par with the plots treated with natural farming whereas the highest (31.4 kg/ha) was observed under treatment T_8. The higher values of available sulphur in FYM treated plots might be due to the direct supply of sulphur through FYM and decomposition of FYM released organic acids, leading to release of sulphur into the soil (Patel et al 2018). The lime resulted in increase in available sulphur content which may be due to improvement in biological activity of soil which led to the enhanced mineralization of organic matter and ultimately enhancing sulphur availability (Dhiman et al 2019).

Exchangeable calcium: Unfertilized control plot recorded the lowest value of exchangeable calcium whereas the highest was obtained under the integrated application of FYM, lime and chemical fertilizers (T_8). Sole application of lime in combination with 100% NPK also showed significant increase in exchangeable calcium content. The treatments T_4 and T_5 recorded increase of 20.0 and 25.9 per cent over control, respectively. The higher content of exchangeable Ca in FYM treated plots partly due to the direct supply of Ca from organic manure and partly due to the decomposition of organic matter which release the organic acid which solubilize Ca from the native pool in the soil (Anghileri 2009, Sanjivkumar 2014). Application of lime increased the exchangeable Ca that might be attributed to supply of Ca^{2+} ions from lime ($CaCO_3$) through dissociation (Chimdi et al 2012).

Exchangeable magnesium: Control plots resulted in lower value of 1.18 c mol (p^+)/kg of the exchangeable magnesium whereas the higher of1.88 c mol (p^+)/kg was under T_8 which was statistically at par with T_{10}. Application of T_8 increased the magnesium content by 59.3 per cent over control. Significantly higher value of exchangeable magnesium due to application of FYM could be attributed to release of Mg through manure (Babu et al 2007). However, lime increased exchangeable Mg content which could be due to the improvement in soil pH which increased the availability of Mg in soil (Rahman et al 2002).

Exchangeable acidity (EA): In comparison to the initial value (4.14 c mol (p^+)/kg), the highest decrease in the exchangeable acidity was observed under treatment T_8, whereas the control recorded the highest of the exchangeable acidity over the initial value. Integrated application of FYM, lime and fertilizer decrease the exchangeable acidity. The extent of decrease in exchangeable acidity under treatment T_8 was 40.5 per cent over control. Higher exchangeable acidity may be attributed to low pH in control treatment (T_1). The application of lime proved to be the most effective practice in reducing the exchangeable acidity due to its neutralizing effect on exchangeable Al^{+3}, H^+ and other hydrolysable acid producing ions or by increased replacement of Al by Ca on the exchange site and by the subsequent precipitation of Al as $Al(OH)_3$ (Bekele et al 2018). Application of FYM significantly decreases the exchangeable acidity which might be due to neutralizing reaction of FYM which leads to the release and subsequent hydrolysis of the Ca ions. The hydroxyl ions react with both exchangeable Al^{3+} and H^+ ions to form Al $(OH)_{3,}$ respectively (Rajneesh et al 2018).

Total potential acidity (TPA): Total potential acidity varied from a lowest value of 37.7 c mol (p^+)/ kg in the plots where the recommended dose of fertilizers was applied with lime (T_5) to a highest of 56.2 c mol (p^+)/kg in the plots that received FYM along with 100% NPK (T_4). Integrated application of chemical fertilizers along with FYM and lime decreased the total potential acidity significantly over T_4. Natural farming treated plots also showed a significant decrease in the total potential acidity in comparison with treatment T_3 and T_4. Organic matter contributes to total potential acidity through the presence of functional groups like-COOH and phenolic-OH. Similar results on total potential acidity have been reported by Dhananjaya and Ananthanarayana (2010) and Pati and Mukopadhyay (2010).

The reduction of total potential acidity with the addition of lime may attribute to neutralization of hydroxyl Al and Fe polymers by lime and also neutralization of the $Al^{3+,}$ H^+ and other hydrolysable acid producing ions or increases in replacement of Al by Ca in the exchange site and precipitation of Al as Al $(OH)_3$. These results corroborate the findings of Melese and Yli Halla (2016) and Rajneesh et al (2018)

pH dependent acidity (PDA): Organically amended plots (T_3 and T_4) registered significantly higher pH dependent acidity than rest of the treatments. The pH dependent acidity varied from 34.78 to 52.82 c mol (p^+)/kg under 100% NPK + lime (full dose through broadcasting) and 100% NPK + 10 t

FYM/ha, respectively. The pH dependent acidity comprises acidity emanating from the dissociation of protons from the functional groups viz., weakly acidic carboxyl groups (R–COOH) and phenolic hydroxyl groups (R–OH) on soil organic matter, as well as acidic protons on soil mineral edges (Dhanajaya and Ananthanarayana 2010). The higher value of pH dependent acidity in 100% NPK + FYM treatment can be explained on the basis of predominance of functional groups like carboxylic and phenolic on the organic matter. Lime incorporation resulted in lowering of pH dependent acidity. This could be due to the neutralization of hydroxyl- Al and Fe polymers (Rajneesh et al 2018).

Extractable acidity (Ext.): The variation in extractable acidity was from 4.22 c mol (p^+)/kg in 100% NPK + lime (full dose through broadcasting) (T_5) to 6.49 c mol (p^+)/kg in the plots receiving 100% NPK alone (T_2). Application of lime along with 100% NPK (T_5 and T_6) showed significantly lower value of extractable acidity than rest of the treatments. Similarly, optimal dose of fertilizers (100% NPK) in combination with FYM (T_8) resulted in significantly lower value of extractable acidity compared to the 100% NPK (T_2).The application of FYM had a moderating effect on extractable acidity, which could be attributed to the decrease in the activity of Al^{3+} ions in the soil solution due to chelation by organic molecules (Bharti and Sharma 2017). Decrease in extractable acidity due to lime application can be ascribed to neutralization of Al^{3+} ions with the addition of lime and increase in the base saturation (Goulding 2016).

Non-exchangeable acidity (NEA): The non-exchangeable acidity varied from a lowest value of 1.22 c mol (p^+)/kg under 100% NPK + lime (1/10th dose of lime through furrow application (T_6)

which was at par with treatment T_5 to a maximum value of 2.98 c mol (p^+)/kg under the sole application of10 t FYM/ha along with 100% NPK (T_4). The non-exchangeable acidity comprises of H covalently bound to colloids, and monomers and polymers of Al in soil and on expanded montmorillonite interlayers. Maximum value of non-exchangeable acidity may be because of low pH. Pati and Mukhopadhyay (2010) also reported similar results of non-exchangeable acidity with pH.

Total soil acidity (TSA): The total soil acidity varied from a minimum value of 37.50 c mol (p+)/kg in 100% NPK + lime (full dose through broadcasting to a maximum value of 67.2 c

Table 3. Effect of FYM, lime and fertilizer on forms of soil acidity

Treatment	EA	TPA	PDA	Ext.	NEA	TSA
T_1	4.25	48.5	44.20	6.14	1.89	47.8
T_2	3.77	51.5	47.76	6.49	2.72	52.5
T_3	3.58	54.1	50.56	6.16	2.58	58.5
T_4	3.39	56.2	52.82	6.37	2.98	67.2
T_5	2.91	37.7	34.78	4.22	1.31	37.5
T_6	3.21	40.3	37.04	4.43	1.22	42.5
T_7	2.71	41.0	38.32	4.52	1.81	49.2
T_8	2.53	42.9	40.40	4.37	1.84	44.2
T_9	3.25	44.3	41.08	4.85	1.60	49.2
T_{10}	3.13	46.1	42.93	5.08	1.94	48.3
T_{11}	3.97	49.1	45.1	5.88	1.91	53.3
CD (p=0.05)	0.48	7.88	7.67	0.56	0.60	6.95
Initial	4.14	49.2	42.4	6.22	2.08	44.62

Table 4. Relationship of different forms of acidity with soil properties

	N	P	K	Ca	Mg	S	pH	SOC	CEC
EA	-0.82**	-0.93**	-0.94**	-0.87**	-0.95**	-0.87**	-0.95**	0.87**	-0.98**
Ext. acidity	-0.45	-0.70	-0.70*	-0.51**	-0.75**	-0.51	-0.75**	0.63	-0.76**
PDA	-0.07	-0.39	-0.38	-0.17	-0.47	-0.17	-0.46	0.29	-0.48
TPA	-0.14	-0.45	-0.45	-0.24	-0.53	-0.24	-0.52	0.36	-0.54
TSA	0.09	-0.24	-0.21	-0.00	-0.28	-0.30	-0.26	0.14	-0.35
NEA	0.05	-0.27	-0.22	-0.01	-0.27	-0.30	-0.32	0.18	-0.30

mol (p^+)/ kg in 100% NPK + 10t FYM/ ha . The application of 100% NPK + 10t FYM/ ha and 100% NPK + 5t FYM/ ha recorded 28.0 and 11.4 per cent higher total soil acidity, respectively as compared to 100% NPK . Application of lime (T_5) led to significant reduction in total acidity in comparison to 100% NPK + 10t FYM/ ha and 100% NPK, the reduction being 44.2 and 28.6 per cent, respectively. The reduction in different forms of acidity due to application of lime results in the reduction in total acidity with the addition of lime is obvious (Subehia et al 2005).

Relationship of forms of soil acidity with soil chemical properties: The pH had a negative significant correlation with all forms of soil acidity viz; EA, TPA, PDA, Ext. acidity, NEA and TSA. Soil organic carbon had a significant positive correlation with all forms of acidity indicating the role of soil humus as a source of soil acidity by dissociating H^+at varying pH. The higher positive correlation was recorded by exchangeable acidity (r= 0.87) followed by extractable acidity (r= 0.63). All forms of acidity showed a significant negative correlation with the available nutrients and the cation exchange capacity of soil (Table 4).

CONCLUSION

All forms of acidity viz., EA, TPA, PDA, Ext. acidity, NEA and TSA decreased with the application of 100% NPK + 10 t FYM/ha + lime (full dose through broadcasting). Combined application of FYM, lime and recommended dose of fertilizer improved the soil properties (pH, SOC and CEC) and it also increases the availability of the nutrients (N, P, K, Ca, Mg and S) in the soil.

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