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Effect of farm yard manure and press mud on fertility status of alkaline soil under maize-wheat cropping sequence

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An experiment was conducted on an alkaline clay loam soil of Golagamdi, India during 2005-2006 to study the effect of Farm Yard Manure and pressmud on fertility status of alkali soil under maize-wheat cropping sequence. The treatment consist of three levels of organic manure M_0- no manure; M_1- FYM at the rate of 10 tha^{-1}; M_2- Pressmud at the rate of 5 tha^{-1} and six fertilizer levels; F_0- no fertilizer; F_1- 75% of recommended N and P; F_2-100% of recommended N and P; F_3- 75% of recommended N and P+S+Zn+Fe; F_4-100% of recommended N and P+S+Zn+Fe; F_5- 100% of recommended N and P+foliar spray of 1% multi-micronutrient. The direct effect of FYM (M_1) and pressmud (M_2) reduced pH of soil. The maximum pH (8.26) was recorded from control after the harvest of wheat and the lowest (8.17) from F_5. The highest EC (0.38 dS m^{-1}) was recorded from F_5 followed by F_4 (0.37 dS m^{-1}) and the lowest from control (0.27 dS m^{-1}). The pressmud was more effective in reducing soil pH and increasing the EC than by FYM. The application of FYM (M_1) and pressmud (M_2) increased the available N, P, S, Fe, Zn, Cu and Mn in soil. The available N, S, Fe and Zn content under pressmud application was more than the FYM. However, the residual effect of FYM (M_1) maintained higher available P (71.49 kg ha^{-1}), K, Zn than PM (M_2). Residual effect of the pressmud (M_2) showed maximum available S (27.99 mg kg^{-1}) as compared to FYM (M_1) (15.86 mg kg^{-1}). M_2F_3 and M_2F_4 treatment combinations performed better than other combinations regarding the S and Zn content of soil. The direct effect of pressmud was higher in case of Fe content than FYM. The residual effect of both FYM (1.02 mg kg^{-1}) and pressmud (1.01 mg kg^{-1}) significantly increased DTPA extractable Mn content in soil over control (3.27 mg kg^{-1}) after wheat harvest. Direct effect of FYM on maize was found slightly depressed DTPA extractable Cu contents as compared to pressmud. However, the Cu content was increased again after the harvest of wheat.

Key words: Farm yard manure (FYM), pressmud, residual effect, electrical conductivity (EC), maize-wheat cropping.

INTRODUCTION

The loss of soil fertility, in many developing countries due to continuous nutrient depletion by crops without adequate replenishment poses an immediate threat to food and environmental securities. On an average, 49% of Indian soils have been found deficient in Zn, 15% in Fe, 3% in Cu, 5% in Mn, 33% in B and 13% in Mo (Singh, 2001). The problem of imbalance fertilizer use in case of secondary and micronutrients is even worse wherein the use is much less compared to crop requirement. So, we have to narrow down this nutrient use ratio in order to sustain the crop productivity (Tewatia, 2007; Sharma, 2011). Use of fertilizers alone in the intensive cropping system creates infertility and unfavorable physical, chemical and biological conditions of soil. The gradually deteriorating soil health can be mitigated by use of organic sources. Total estimated available nutrient value of organic resources in India is 12.80 Mt but the present utilization is about 3.75 Mt (Bhattacharyya, 2007) which may be utilized for filling about 25% nutrient needs of Indian agriculture. Results indicated that the application of organic manures (15, 7.5 and 5 tha^{-1} $year^{-1}$ of FYM, pressmud, poultry manure, respectively) in conjunction with recommended dose of N increased productivities in different cropping systems and maintained soil fertility (Antil and Narwal, 2007). Application of 15 t FYM or 7.5 t pressmud or 5 t poultry manure ha^{-1} $year^{-1}$ with or without NP fertilizers could not sustain the initial level of N but in case of P, K and micronutrients (Zn, Mn, Fe and Cu) can be maintained through (Antil and Singh, 2007; Antil and Narwal, 2007). These results indicated that fertilizer-N cannot be saved with the application of organic manures but the application of P, K and micronutrients fertilizers can be avoided. The availability of FYM is limited in India; therefore, some other sources of organics have to be sourced and they increased the OC and nutrients content of soil (Antil, 2012). The residual effect of pressmud on groundnut has been shown higher than that of FYM (Ghosh et al., 2005). Sheeba and Chellamuthu (2000) observed that the continued application of varying quantities of inorganic fertilizers and their combinations with FYM over 22 years did not alter the soil pH appreciably. The results of the long term fertilizer experiments on sorghum-sunflower cropping sequence indicated significant decrease in pH and decline in values of soil EC where N was applied through organic sources (Mairan et al., 2005).

The farm yard manure and pressmud are the effective source of plant nutrients at lower chemical fertilizer application (Dang and Verma, 1996; More, 1994; Singh et al., 1998). An amount of 25-50% of available nitrogen was obtained from the FYM (Singh et al., 1998). However, nutrient supplying capacity of FYM is restricted in the winter season (Singh et al., 1983). The application of 20 t/ha pressmud saved 25% of the recommended fertilizers. The pressmd application showed significant residual effects on the succeeding crops (Jurwarkar et al., 1993). FYM and pressmud decreased pH and exchangeable sodium percentage (ESP) of soil (Sinha and Sakal, 1993; More, 1994; Dang and Verma, 1996). On the contrarily, Datta and Gupta (1983) were noticed the increase in pH with pressmud application. Several studies have indicated that long-term and balanced application of chemical fertilizers and organic manure can generally improve soil quality than any of these applied alone (Rudrappa et al., 2006; Manna et al., 2007; Fan et al., 2008). An experiment was carried out to study the residual effect of organic manure on soil properties and available nutrients under maize-wheat cropping system in pot house study.

MATERIALS AND METHODS

The soil samples were collected from Sardar Sarovar Punarvasavat Agency (SSPA) rehabilitated site in Golagamdi, India. The physical and chemical properties of the soil before the experimentation are presented in the Table 1. Air dried 8 mm sieved soil was filled in the polythene lined earthen pots (7 kg capacity) at the rate of 6 kg soil pot^{-1}. The experiment consisted of three organic treatments and six fertilizer levels and the details are illustrated in Table 2. The experiment was tested in factorial complete randomized design (FCRD) with three replications. The sources of fertilizers used were, N- urea; P- single super phosphate; S- gypsum; Zn- $ZnSO_4$; Fe- $FeSO_4$. The N, P, S and Zn were applied as basal in the soil while Fe as applied as foliar spray at 30, 45 and 60 days after sowing. In F_5 the multi-micronutrient formulation containing 2.0, 0.5, 4, 0.3 and 0.5% of Fe, Mn, Zn, Cu and B was applied as foliar spray at the rate of 1% at 30, 45 and 60 days after sowing. The recommended dose of N and P for maize was 60 and 40 kg ha^{-1} respectively. Half dose of nitrogen and full dose of P was applied as basal and the remaining half into two splits at tillering and flowering. Maize variety GM-4 was grown as first crop during *kharif* season 2005 at the rate of 5 plants pot^{-1}. No fertilizers were applied after the harvest to study the effect of residual effect of organic manures which was applied to maize. Wheat variety GW- 496 was grown at the rate of 8 plants per pot during *rabi* 2005-2006. The recommended dose of N and P for wheat was 120 and 60 $kgha^{-1}$ respectively. Half dose of nitrogen and full dose of P was applied as basal and the remaining half into two splits at tillering and panicle initiation stage. The soil samples were collected after the harvest of wheat for residual analysis. Soil samples taken after harvest of maize and wheat were air dried, ground, passed through 2 mm sieve. The soils were analysed for physical properties (Piper, 1950; Page et al., 1982), pH and EC (1:2.5, Jackson, 1973), Organic Carbon (Walkley and Black, 1973), available N (Subbiah and Asija, 1956), available P (Olsen et al., 1954), available K (Jackson, 1973), 0.15% $CaCl_2$ extractable S (Chaudharay and Cornfield, 1966), DTPA extractable Fe, Mn, Zn, Cu (Lindsay and Norvell, 1978).

RESULTS AND DISCUSSION

Soil pH

The result revealed that the application of FYM and pressmud reduced pH of soil after the maize harvest

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Abbreviations: **FYM**, Farm yard manure; **EC**, electrical conductivity; **N**, nitrogen; **P**, phosphorus**; K,** potassium; **Zn,** zinc; **Cu**, copper; Mn, Manganese; **S,** sulphur; **Fe**, iron; **B**, boron; **Mo**, molybdenum.

Table 1. The initial physical and chemical properties of the experimental soil.

Clay (%)	40
Silt (%)	22
Sand (%)	38
Texture	Clay loam (Typic chromustert)
$pH_{2.5}$	8.23
$EC_{2.5}$ (dS m^{-1})	0.18
Organic carbon (%)	0.38
Available N (kg ha^{-1})	131.71
Available P_2O_5 (kg ha^{-1})	27.3
Available K_2O (kg ha^{-1})	306.9
Available S (0.15% $CaCl_2$ extractable, in mg kg^{-1})	8.6
DTPA extractable micronutrients (mg kg^{-1})	
Fe	7.51
Zn	0.96
Mn	5.68
Cu	1.03

Table 2. Treatments details of the experiment.

Organic treatments
M_0 = No organic
M_1 = FYM at 10 t ha^{-1}
M_2 = Pressmud at 5 t ha^{-1}
Fertility levels(six)
F_0 = No fertilizer
F_1 = 75% RD of N and P
F_2 = 100% RD of N and P
F_3 = 75% RD of N and P + Soil application of S, Zn(@ 150 kg gypsum ha^{-1} and 25 kg $ZnSO_4$ ha^{-1}, respectively) and Fe (as foliar spray at 0.25% neutralized $FeSO_4$)
F_4 = 100% RD of N and P + Soil application of S, Zn (at 150 kg gypsum ha^{-1} and 25 kg $ZnSO_4$ ha^{-1}, respectively) and Fe (as foliar spray at 0.25% neutralized $FeSO_4$)
F5 = 100% RD of N and P + multi-micronutrient formulation containing 2.0, 0.5, 4, 0.3 and 0.5% of Fe, Mn, Zn, Cu and B, respectively

*RD= Recommended Dose

(Figure 1a and b). The reduction in soil pH was mainly due to release of organic acids in the soil upon decomposition of organics (More, 1994). The noticeable reduction in soil pH due to long term manuring and fertilization was also recorded in the earlier research (Mairan et al., 2005). The decrease in pH of the soil amended with FYM might be due to the release of organic acids from the manure. The decrease in soil pH with the application of FYM and Pressmud were also reported by Sinha and Sakal (1993), More (1994) and Dang and Verma (1996). The higher reduction in soil pH with pressmud treatment may be due to the presence of acidic compounds as the product is the outcome of sulphitation process from the sugar mill. The higher rate of decomposition of organic matter is also expected during *kharif* due to high temperature in the season. The soil pH as a result of residual effect of organics again tried to shift towards alkaline reaction after the wheat harvest (Figure 1a and b). This might be attributed to the buffering action of soil and also conversion of some organic acids into bicarbonate and carbonates with time. Application of fertilizers significantly decreased the pH of soil over control. Maximum pH (8.26) was recorded from control after the harvest of wheat and the lowest (8.17) from F_5. Decrease in pH due to fertilizer application might be attributed to the nitrification and acidification processes stimulated by continuous application of fertilizers as well as by H^+ released by roots. Similar results have been reported by Wang and Yang (2003) and Guo et al. (2010).

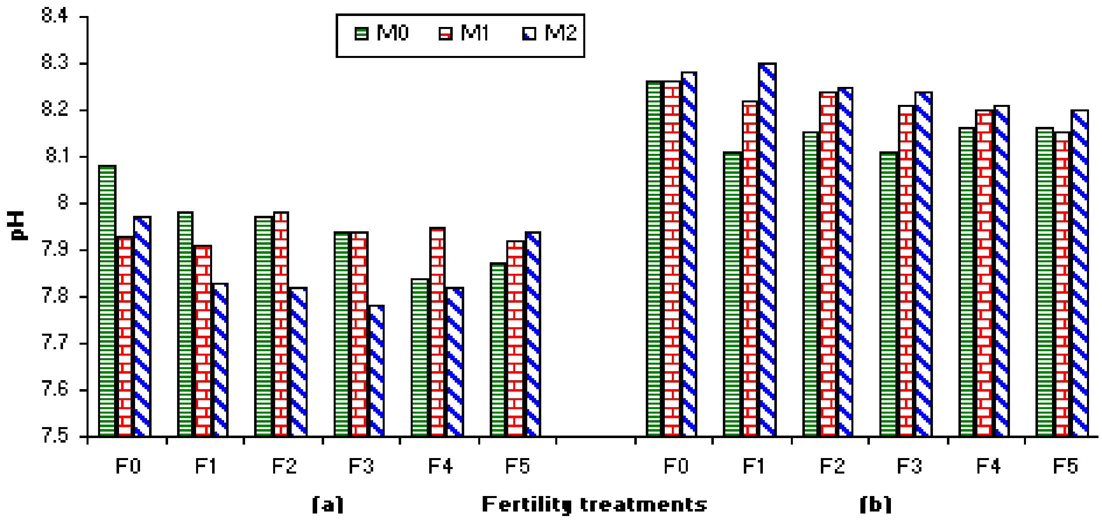

Figure 1. (a) Effect of organic and fertility treatments on pH of soil at maize harvest; (b) Effect of fertility treatments on pH of soil at wheat harvest under the influence of organic residues.

Table 3. Effect of organics on available nitrogen (kg ha^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
After maize							
No organic (M_0)	80.00	84.70	89.40	117.61	117.61	98.80	98.02
FYM (M_1)	117.60	145.80	150.50	155.20	239.90	239.90	174.82
Pressmud (M_2)	174.03	169.33	211.70	225.80	235.20	230.50	207.76
Mean	123.88	133.28	150.53	166.20	197.57	189.73	
	M		**F**			**M x F**	
S.Em. ±	3.167		4.479			7.757	
C.D. (0.05)	9.09		12.85			22.26	
C.V. (%)							
After wheat							
No organic (M_0)	51.70	61.13	65.87	55.83	61.13	51.13	57.80
FYM (M_1)	91.87	192.90	211.70	207.00	238.00	239.90	196.89
Pressmud (M_2)	152.90	211.70	221.10	221.10	232.90	225.80	210.92
Mean	98.82	155.24	166.22	161.31	177.34	172.28	
	M		**F**			**M x F**	
S.Em. ±	3.029		4.283			7.419	
C.D. (0.05)	8.69		12.29			21.29	
C.V. (%)				8.28			

Electrical conductivity (EC)

The electrical conductivity of soil after the harvest of maize and wheat was significantly influenced by the application of pressmud than FYM (Table 3). Similar result was also reported by Dang and Verma (1996) and Pasricha et al. (1996). The higher salts under fertility treatments having applied with full dose of N and P as well as micronutrients through soil application showed significantly higher (Figure 2a and b). The highest EC (0.38 dSm^{-1}) was recorded from F_5 followed by F_4 (0.37 dSm^{-1}) and the lowest from control (0.27 dSm^{-1}). The increase in the EC of the soil with continued application of fertilizers was due to the addition of salts through fertilizers and solubilization of native minerals due to the reduction in the pH of the soil (Lohan and Dev, 1998).

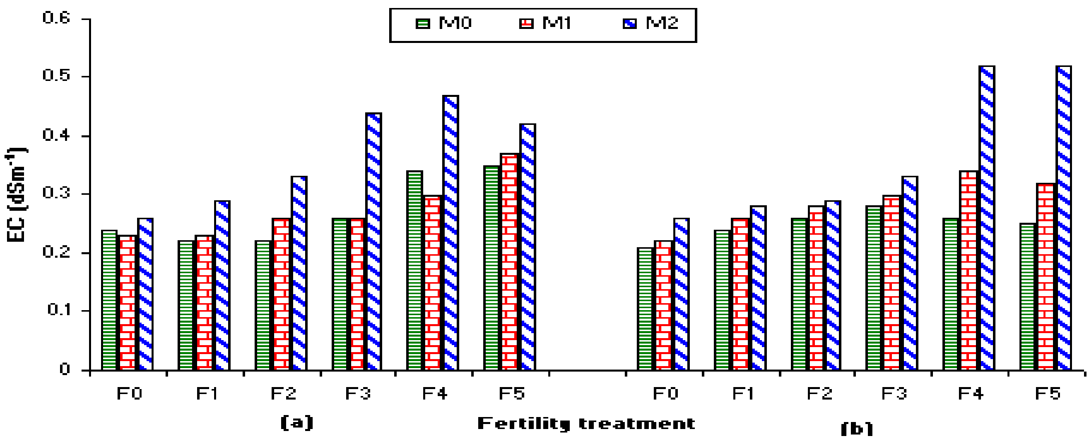

Figure 2. (a) Effect of organic and fertility treatments on EC (dS m^{-1}) of soil at maize harvest; (b) Effect of fertility treatments on EC (dS m^{-1}) of soil at wheat harvest under the influence of organic residues.

The interaction of the effect of manure and fertilizer was found significant in both FYM and pressmud. It was observed that the application of pressmud were found more effective than application of FYM in reducing soil pH and contributed more salts to increase EC in the soil after the harvest of maize and wheat (Figure 2a and b).

Available nitrogen

The result showed that the available nitrogen in soil after the harvest of maize and wheat were significantly increased with the application of FYM and pressmud over control (Table 3). It might be due to the direct addition of N from the decomposition of organic matter leads to mineralization of organically bound nitrogen. The result was in agreement with the findings of many researchers (Gill et al., 1991; Bhandari et al., 1992; Jurwarkar et al., 1993; More, 1994; Singh et at., 1998). The pressmud showed quick action in the first season which may be due to rapid decomposition of organic matter to release organic acids. Also, oxidation of S present in pressmud was expected to affect an ameliorating action on soil to provide beneficial effect by shifting soil pH towards neutrality. The lowering of soil pH might have played a major role in releasing nutrients as many nutrients are plenty towards neutrality. On the other hand, FYM continued the beneficial effect in the next season due to slower decomposition rate and application of organic materials in higher quantities compared to pressmud. The available nitrogen status of the post-harvest soil increased with increase in fertilizer application and found to be the highest in the plots receiving higher doses of fertilizers (Table 4). The similar finding has been reported by Dudhat et al. (1997). Interaction of manure and fertilizers was found to be significant. In addition to the extra quantum of N being added, the favourable soil conditions under organic manuring might have helped multiplication of soil microbes leading to rapid mineralization leading to higher available N status. The decreased available N status in the absolute control treatment may be due to the continual removal of soil N in the absence of external supply of N through fertilizers and manures.

Available phosphorus

The application of FYM and pressmud enhanced phosphorus availability (Table 4). The residual effect of FYM maintained available phosphorus at a higher level (71.49 $kgha^{-1}$) as compared to pressmud treatment (49.25 $kgha^{-1}$). It might be due to the beneficial effect of FYM in the next season due to slower decomposition rate as compared to pressmud. Narwal et al. (1990) reported that organics were superior in improving available P. It might be due solubilizing effect of organic acids on organic phosphorus and organic anions retard the fixation of P in by complexing with organic ligands and chelation of P fixing cations like Ca, Mg, Fe, Al, Zn, Mn and Cu. Phosphorus complex with humic and fulvic acids increase the availability of phosphorus to the plants. It was observed that lower levels of fertilizer application (F_0 and F_1) had shown lower available P as compared to F_2 and F_3 treatments. It might be attributed to the removal of P by maize and wheat and conversion of remaining water soluble P into insoluble forms to maintain the equilibrium conditions. The fertilizer source of P is important as their direct, residual are and cumulative effects different (Singaram and Kothandaraman, 1993; Sharma et al., 1996; Singh et al., 1988). The F_5 treatment (100% NP) which also received micronutrient formulation spray showed higher available P_2O_5 (59.57 $kgha^{-1}$) in soil. The interaction of organic manure and fertilizers was found to be significant. Similar findings were also reported by Hemalatha and Chellamuthu (2013).

Table 4. Effect of organics on available phosphorus (kg ha^{-1}) status of soil after harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
After maize							
No organic (M_0)	30.61	35.21	40.10	40.07	39.79	40.41	37.70
FYM (M_1)	78.98	78.06	55.72	64.90	66.13	72.86	69.44
Pressmud (M_2)	56.64	58.17	56.33	61.22	55.72	54.80	57.15
Mean	55.41	57.15	50.71	55.40	53.88	56.02	
	M		**F**			**M x F**	
S.Em. ±	1.213		1.715			2.970	
C.D. (0.05)	3.48		NS			8.53	
C.V. (%)	9.39						
After wheat							
No organic (M_0)	30.30	38.57	34.60	28.17	34.93	36.70	33.88
FYM (M_1)	71.93	93.00	65.00	66.07	61.33	71.60	71.49
Pressmud (M_2)	51.73	47.13	47.77	48.33	50.80	49.73	49.25
Mean	51.32	59.57	49.12	47.52	49.02	52.68	
	M		**F**			**M x F**	
S.Em. ±	1.060		1.499			2.596	
C.D. (0.05)	3.04		4.30			7.45	
C.V. (%)				8.73			

Available potassium

Direct effect of FYM and pressmud influenced significantly on the available potassium of soil (Table 5). Fixation of potassium was minimized by the complex formation with organic ligands and increase of NH_4^+ ions in the soil. Significantly low in available K_2O with pressmud (322.09 $kgha^{-1}$) was observed as compared with FYM (324.27 $kgha^{-1}$). Singh and Brar (1977) reported that practicing of continuous maize-wheat cropping sequence without K application leads to the nutrient imbalance due to utilization of the soil native K for crop production and the labile pool gets exhausted. The residual effect of FYM was higher in increasing available K than pressmud. The increase in K availability as the residual effect of FYM was due to higher microbial activities in soil which influenced the release of non-exchangeable or fixed-K forms into available forms. The fertility treatments showed non-significant on available K_2O contents in soil. The decreased availability of K may be attributed to the higher uptake of K by crops resulting in depletion of K in the absence of K addition. Application of pressmud increased the available K substantially in sandy soils has been also reported by Prasad (1996).

Available sulphur

The organic manuring and fertilization increased the available sulphur (Table 6). Direct and residual effect of the pressmud showed maximum available-S (18.56 mg kg^{-1}) as compared to FYM (15.78 mg kg^{-1}). This might be due to contribution of S from the soil through microbiological oxidation. Similar results were also reported by Sinha and Sakal (1993). Among the fertilizer levels, F_4 showed the maximum available-S content (20.86 mg kg^{-1}) followed by F_3 (20.79 mg kg^{-1}) over other treatments after the harvest of maize. Similar finding was also reported by Singh and Chhibba, (1991). The residual effect of pressmud on available S content of soil (27.99 mg kg^{-1}) was significantly higher than FYM (15.86 mg kg^{-1}). Different levels of fertilizers affect significantly on available S after the harvest of wheat. Maximum available S content of soil (29.95 mg kg^{-1}) was observed from F_4 followed by F_3 (27.65 mg kg^{-1}) and the lowest (12.40 mg kg^{-1}) from control. The decrease in available S in soil might be due to continuous removal by the crop without addition of sulphur fertilizer.

Available micronutrients

DTPA extractable Fe

The significant effect of the organics was recorded on DTPA extractable Fe in the soil after maize harvest. The Fe content of soil was significantly higher in pressmud application (8.20 mg kg^{-1}) than FYM (7.77 mg kg^{-1}). The increase of availability with the application of organic manures may be attributed to the increased solubility due to decrease the soil pH by the virtue of organic treatments. The Fe content was found to be higher in the treatments receiving fertilizers regularly (Table 7).

Table 5. Effect of organics on available potassium (kg ha^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
			After maize				
No organic (M_0)	330.17	328.53	335.50	336.17	357.10	349.87	339.56
FYM (M_1)	336.77	339.97	333.47	341.67	333.47	335.13	336.74
Pressmud (M_2)	336.57	341.70	344.97	354.83	343.10	343.37	344.09
Mean	334.50	336.73	337.98	344.22	344.56	342.79	
	M		**F**			**M x F**	
S.Em. ±	2.763		3.908			6.768	
C.D. (0.05)	NS		NS			NS	
C.V. (%)	3.45						
After wheat							
No organic (M_0)	320.30	333.47	325.23	320.30	323.00	313.73	322.77
FYM (M_1)	323.70	328.47	330.17	320.40	331.77	31380	324.72
Pressmud (M_2)	317.03	302.23	323.60	320.30	320.30	313.07	316.09
Mean	320.34	321.39	326.33	320.33	325.22	313.53	
	M		**F**			**M x F**	
S.Em. ±	2.193		3.102			5.372	
C.D. (0.05)	6.30		NS			NS	
C.V. (%)				2.90			

Table 6. Effect of organics on available sulphur (mg kg^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
			After maize				
No organic (M_0)	10.21	10.21	10.52	21.69	357.10	349.87	339.56
FYM (M_1)	11.67	13.65	15.31	18.46	333.47	335.13	336.74
Pressmud (M_2)	15.32	17.50	23.33	42.81	343.10	343.37	344.09
Mean	12.40	13.79	16.39	27.65	344.56	342.79	
	M		**F**			**M x F**	
S.Em. ±	0.443		0.626			1.085	
C.D. (0.05)	1.27		1.80			3.11	
C.V. (%)	9.75						
After wheat							
No organic (M_0)	8.97	9.88	12.63	19.12	19.12	16.81	14.42
FYM (M_1)	9.19	15.03	15.88	18.75	21.00	14.84	15.78
Pressmud (M_2)	13.53	13.81	17.76	24.49	22.45	19.29	18.56
Mean	10.56	12.91	15.43	20.79	20.86	16.98	
	M		**F**			**M x F**	
S.Em. ±	0.331		0.469			0.812	
C.D. (0.05)	0.95		1.35			2.33	
C.V. (%)				8.65			

Similar result was also reported by Hemalatha and Chellamuthu (2013). But Fe content of soil was found non-significant after wheat harvest. The decrease in DTPA extractable Fe might be due to the removal by crop and the effect of alkaline pH during wheat (Chhabra et al., 1996). It is, therefore, necessary to check the soil Fe status after maize harvest for any requirement of supplementation for sustainable crop productivity.

Table 7. Effect of fertility treatments on DTPA extractable Fe (mg kg^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
After maize							
No organic (M_0)	7.39	8.42	8.46	8.18	7.69	7.99	8.02
FYM (M_1)	7.62	7.92	7.70	7.63	7.73	8.01	7.77
Pressmud (M_2)	8.08	8.06	7.98	8.61	8.43	8.06	8.20
Mean	7.70	8.13	8.05	8.14	7.95	8.02	
	M		**F**			**M x F**	
S.Em. ±	0.095		0.134			0.232	
C.D. (0.05)	0.27		NS			NS	
C.V. (%)	5.23						
After wheat							
No organic (M_0)	7.63	7.02	7.38	7.67	6.77	7.31	7.30
FYM (M_1)	6.85	7.02	7.49	7.13	6.88	7.39	7.13
Pressmud (M_2)	7.19	7.62	7.41	7.80	7.19	7.64	7.47
Mean	7.22	7.22	7.43	7.53	6.95	7.45	
	M		**F**			**M x F**	
S.Em. ±	0.11		0.156			0.270	
C.D. (0.05)	NS		NS			NS	
C.V. (%)				6.40			

Table 8. Effect of fertility treatments on DTPA extractable Zn (mg kg^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
After maize							
No organic (M_0)	0.95	0.85	1.47	1.72	1.83	0.92	1.29
FYM (M_1)	1.13	0.91	0.83	2.07	1.96	1.53	1.41
Pressmud (M_2)	1.09	1.09	1.15	2.89	2.55	1.27	1.67
Mean	1.06	0.95	1.15	2.22	2.11	1.24	
	M		**F**			**M x F**	
S.Em. ±	0.051		0.072			0.125	
C.D. (0.05)	0.15		0.21			0.36	
C.V. (%)	14.89						
After wheat							
No organic (M_0)	0.97	1.20	1.06	1.65	1.61	1.07	1.26
FYM (M_1)	1.18	1.15	1.12	2.06	1.63	1.15	1.38
Pressmud (M_2)	1.06	1.33	1.22	1.75	1.47	1.01	1.31
Mean	1.07	1.23	1.13	1.82	1.57	1.08	
	M		**F**			**M x F**	
S.Em. ±	0.030		0.043			0.074	
C.D. (0.05)	0.09		0.12			0.21	
C.V. (%)				9.78			

DTPA extractable Zn

The effect of both organics and fertility treatments on availability of DTPA extractable Zn was found to be significant (Table 8). The organic application either through FYM or pressmud increased significantly the DTPA extractable Zn over control (1.29 mg kg^{-1}). Similar results were also observed by Gupta et al. (1986). It

Table 9. Effect of fertility treatments on DTPA extractable Mn (mg kg^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
After maize							
No organic (M_0)	5.21	4.82	5.11	5.00	4.49	4.95	4.93
FYM (M_1)	4.97	4.67	4.18	4.47	4.39	4.49	4.53
Pressmud (M_2)	4.85	5.14	6.23	6.21	5.37	4.80	5.43
Mean	5.01	4.88	5.17	5.23	4.75	4.75	
	M		**F**			**M x F**	
S.Em. ±	0.108		0.153			0.265	
C.D. (0.05)	0.31		NS			0.76	
C.V. (%)	9.24						
After wheat							
No organic (M_0)	3.13	3.25	3.14	3.39	3.27	3.45	3.27
FYM (M_1)	3.39	3.63	3.31	3.75	3.51	3.69	3.55
Pressmud (M_2)	3.66	4.01	3.90	3.39	3.39	3.79	3.69
Mean	3.39	3.63	3.45	3.51	3.39	3.64	
	M		**F**			**M x F**	
S.Em. ±	0.053		0.075			0.131	
C.D. (0.05)	0.15		NS			0.38	
C.V. (%)				6.46			

might be due to formation of complexes with humic and fulvic acids (FA) with metal ions (Tan, 1978a; Stevenson, 1976a, b). The Zn complex (Zn-FA) increased the available Zn than that of ZnSO4 (Kumar and Prasad, 1989). Pressmud application increased the Zn availability after harvest of maize. The positive influence of pressmud on Zn has also been reported by Dang and Verma (1996). The pressmud contains 130.5 mg kg^{-1} of Zn and the effect of organic acids might help in increasing available Zn status. However, the residual effect of FYM was found better than the pressmud after the harvest of wheat. Different levels of fertilizers significantly influenced the availability of Zn in soil after the harvest of maize and wheat. F_3 (2.22 mg kg^{-1}) and F_4 (2.11 mg kg^{-1}) treatments recorded maximum DTPA extractable Zn in the soil. The significantly higher availability of Zn in F_3 and F_4 treatment may be due to the direct addition of Zn through $ZnSO_4$. Similar result was also reported by Chhabra et al. (1996).

DTPA extractable Mn

Application of manure significantly influenced in DTPA extractable Mn content of soil. Data in Table 9 shows that FYM and pressmud significantly decreased the DTPA extractable Mn over control (4.93 mg kg^{-1}) (Table 9). However, the residual effect of both FYM (1.02 mg kg^{-1}) and pressmud (1.01 mg kg^{-1}) significantly increased DTPA extractable Mn content in soil over control (3.27 mg kg^{-1}) after wheat harvest. The available Mn content increased with clay and organic carbon content of soil (Chhabra et al., 1996). It indicated that the beneficial influence of the organic treatments in maintaining the higher content of available Mn over that of fertilizer application without any organic application. The overall effect of fertility treatments was found to be non-significant. It was found that all the plots that received P source in the form of single super phosphate had considerable amount of Mn in the soil. Similar results were also reported by Hemalatha and Chellamuthu (2013). The results revealed that DTPA extractable Mn in soil at maize harvest was found comparatively higher than wheat. The reduction of soil pH might have increased the solubility of Mn ultimately its availability. The interaction of organic manure and fertilizers was found to be significant. It may be due to the chelation of applied Mn by organic matter.

DTPA extractable Cu

DTPA extractable Cu was significantly influenced by organic and fertilizer treatments (Table 10). Both FYM and pressmud treatments was found reduction in available Cu. The reduction was comparatively higher under pressmud treatments. This might be due to the inverse relation of organic matter and Cu in soil. Direct effect of FYM on maize was found slightly depressed DTPA extractable Cu contents as compared to pressmud. However, the Cu content was increased again after the harvest of wheat. This can be due breakdown of

Table 10. Effect of fertility treatments on DTPA extractable Cu (mg kg^{-1}) status of soil after crop harvesting.

Organic \ Fertilizer	F_0	F_1	F_2	F_3	F_4	F_5	Mean
After maize							
No organic (M_0)	1.29	1.09	1.11	1.15	1.11	1.40	1.19
FYM (M_1)	1.12	0.99	0.96	0.97	0.95	1.33	1.05
Pressmud (M_2)	1.07	1.05	1.03	1.12	1.05	1.28	1.10
Mean	1.16	1.03	1.03	1.08	1.04	1.35	
	M		F			M x F	
S.Em. ±	0.027		0.038			0.066	
C.D. (0.05)	0.08		0.11			NS	
C.V. (%)	10.20						
After wheat							
No organic (M_0)	0.97	1.01	1.01	0.94	0.93	0.94	0.97
FYM (M_1)	0.96	0.98	1.05	1.03	1.05	1.05	1.02
Pressmud (M_2)	1.04	1.05	1.04	0.97	0.95	1.03	1.01
Mean	0.99	1.02	1.03	0.98	0.98	1.01	
	M		F			M x F	
S.Em. ±	0.010		0.014			0.025	
C.D. (0.05)	0.03		NS			0.07	
C.V. (%)				4.32			

organic residues and release of Cu in the soil solution. It is also reported that the available Cu is increased with increasing organic carbon content (Chhabra et al., 1996). The residual effect of FYM and pressmud was significantly influenced in the DTPA extractable Cu to over control (0.97 mg kg^{-1}). However, the differences due to FYM and pressmud were non-significant. Therefore, it indicated that application of organics either through pressmud or FYM irrespective of the fertility treatments to maize improved DTPA extractable Cu at wheat harvest. The increase in the available form of Cu may be attributed to the formation of Cu-chelates. There was no significant change in DTPA extractable Cu content after wheat harvest by the different fertility treatment over control F_0 (0.99 mg kg^{-1}). Super optimal application of fertilizers also resulted in higher Cu content in soil. Similar finding was also reported by Hemalatha and Chellamuthu (2013).

Conclusion

The addition of farm yard manure (FYM) and pressmud (PM) are important for supplying plant nutrients under low fertilizer applications. They can be effectively utilized for amelioration of various problematic soils including alkaline soils which has been used in the present experiment. Pressmud and FYM in conjunction with the chemical fertilizers can be recommended for more effective reduction of pH of alkaline soils and increasing macro and micronutrients of soil. Use of these organics also helps in balancing the caustic effect of Na and other bicarbonates. The pressmud, in combination with 75% or 100% of recommended doses of N and P along with the gypsum and micronutrients (soil or foliar application) may be effectively used for increasing the productivity of alkaline soils vis-a-vis improving soil health and quality.

Conflict of Interest

The authors have not declared any conflict of interest.

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