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Soil and Plant Nutrient Dynamics in Response to Manuring with Different Organic Wastes under Alkaline Conditions

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Abstract

Manuring with organic wastes might be an important approach for maintaining soil fertility and crop productivity. However, beneficial effects of manuring may vary depending upon the type of manure and rate of application. The present study was planned to investigate the efficiency of three different manures i.e. pressmud, farmyard manure and chicken manure applied at 2.5%, 5%, 7.5% and 10% (w/w) to affect nutrient dynamics in soil and maize (*Zea mays L*) under alkaline conditions. Results revealed that manuring with organic wastes markedly affected the soil properties, with highest effect in case of chicken manure. Soil nutrient concentrations improved by the use of organic manures and maximum increase was found with pressmud which was 17.83%, 37.60%, 48.33% and 55.29% in phosphorus (P) and 9.82%, 20.54%, 32.14% and 40.18% potassium (K) at 2.5%, 5%, 7.5% and 10%, respectively compared to control, while farmyard manure showed superiority for soil nitrogen (N). Soil micronutrients including copper, iron, zinc and manganese were also greatly affected in response to manuring. Nutrient concentrations of maize were also enhanced by the use of manures, with maximum increase in case of pressmud which was 66.96, 77.68, 93.75 and 113.39% in N, 72.73, 154.55, 218.18 and 336.36% P, and 19.75, 30.86, 49.38 and 72.84% K at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Similar trend was found in case of other nutrients. Pressmud again showed its superiority to improve grain yield i.e. 14.85%, 22.19%, 34.02% and 58.25% by the application of 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. In conclusion, pressmud showed supremacy over other manures in improving soil properties and nutrient dynamics in soil and maize plants with a consequential increase in grain yield. The beneficial effects of manuring increased with increasing the application rate.

Keywords: Chicken manure; Farmyard manure; Pressmud; Maize; Nutrients; Soil

Introduction

Soil nutrient management is the function of physical, chemical and biological processes, and have utmost importance for a successful agricultural system [1]. Chemical fertilizers being a good source of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), zinc (Zn) and manganese (Mn) can play a pivotal role in meeting plant requirements and maintaining soil fertility because nutrients are readily available, easy to control and have higher use efficiency [2]. However, long-term sole use of chemical fertilizers may deteriorate soil health due to loss of organic matter, structural compaction, reduction in water infiltration and retention, and contamination of natural resources [3-5]. Chen [6] also reported that excessive use of chemical fertilizers without manuring may result in nutrient loss, pH extremes, and soil and ground water contamination. Modern agriculture is mainly based on the intensive use of mineral fertilizers, pesticides with lower application of organic manures [7] and have drastic effects on soil fertility because of intensive cultivation, higher yield output, imbalanced fertilization, low addition of organic matter, increased soil compaction and accelerated erosion [8]. Hartemink [9] also demonstrated that soil fertility is generally constrained by low content of organic matter, poor cation exchange capacity (CEC), strong soil alkalinity/acidity, intensive cultivation, inadequate and imbalanced fertilization, strong erosion, low microbial activities, climate extremes and nutrient leaching. According to de Jesus Souza et al., [10], conventional agricultural practices usually reduce the content of soil organic matter and microbial activities, and thus disturbing the nutrient dynamics in soil. Maintenance of soil organic matter by the addition of organic wastes is a promising approach not only for improving soil fertility but also soil characteristics [11]. It has been reported that organic waste can contribute to the maintenance of soil fertility by increasing nutrients release and retention [12], soil water contents [13], CEC [14], root growth and biomass [15] and microbial activities [16] while reducing soil erosion [17] and nutrient losses [18]. Francioli et al., [19] reported that long-term use of manure improves the content of organic matter, promotes activities of soil enzymes including urease, cellulase, protease and β-glucosidase and also enhances the fungal and prokaryotic diversity. Schlegel et al., [20] reported a marked increase in the growth and activities of soil microbes, which can subsequently affect soil nutrient dynamics and soil properties. Farmyard manure

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is mainly comprised of crop residues and animal dung. According to Motavalli et al., [21], farmyard manure is a mixed composted organic material consisting of animal urine, dung, bedding materials, plant residues, and household sweepings at varying decomposition level, which carries nutrients essential for crop growth and development. Saidia and Mrema [22], reported that farmyard manure not only provides plant nutrients but also improves the content of organic matter, soil porosity, hydraulic conductivity and structural stability. Edmeades [23] reported that nutrients are released slowly from farmyard manure but retained in soil for longer time due to greater CEC, leading to enhanced soil fertility and plant growth. Shah et al., [24] reported that farmyard manure could increase organic matter content in soil by more than 29% with the subsequent improvement in soil characteristics such as structural stability, water-holding capacity while reducing bulk density. Chicken manure is also an important source of different nutrients, particularly N, P, K and micronutrients. Chicken manure contains high amounts of N (0.5-0.9 %), P (0.4-0.5 %) and K (1.2-1.7 %). It is constant in supply, environment friendly, cost-effective and produces residual effects on soil health and quality [25]. Boateng et al., [26] reported that application of chicken manure increased the soil N greater than 53%. According to Adekiya et al., [27], chicken manure markedly increased the organic matter content, soil pH, and concentration of different macro and micro nutrients in soil. However, large amount of chicken manure is needed to apply to meet crop nutrient requirements which may cause build-up of heavy metals in soil. Pressmud, a sugarcane byproduct, is another important organic manure used to improve soil properties such as water and nutrient retention capacities, aeration, porosity and organic matter [28]. Many studies, for example, Jamil et al., [29], Sheoran et al., [30], Chattha et al., [31] have reported a marked improvement in soil health and crop yield by the addition of pressmud. Some other studies, for example, Sharma et al., [32], Yaduvanshi and Swarup [33], Razzaq [34], Shah et al., [24] reported that pressmud being rich in N, P, K, organic carbon and micronutrients can serve as organic fertilizer to improve soil properties, in addition to increasing nutrients availability in soil. Undoubtedly, manuring with different organic wastes can play a vital role in nutrient management, soil health and quality and crop productivity. However, excessive application of organic manures may increase the load of heavy metals in soil [35]. Therefore, understanding the role of different organic manures and optimization their application rates to manage plant nutrients in soil and accumulation by plants is crucial. The present study was planned with the objective to investigate the effect of three different organic manures to re-build soil fertility and nutrient uptake by maize (*Zea mays L*).

Materials and Methods

The experiment was comprised of thirteen treatments including three sources of organic manures i.e. pressmud farmyard manure and chicken manure, and four levels of application i.e. 2.5, 5, 7.5 and 10% (w/w) with a common control. Experiment was planned in accordance with Completely Randomized Design (CRD) with four replications. Soil was collected from plough layer of a cultivated field under cotton-wheat system. The soil was air dried, ground and passed through 2 mm sieve. The soil was analyzed for various physico-chemical characteristics using standard procedures [36]. Selected physico-chemical characteristics of experimental soil are presented in Table 1.

Table 1: Physico-chemical characteristics of experimental soil before cultivation.

Characteristics	Unit	Value
Sand	%	43.5
Silt	%	31.8
Clay	%	24.7
Soil texture		Loamy
Saturation percentage		28.1
pH		8.2
C: N ratio		13.1
Total porosity	%	48.8
Bulk density	g cm^{-3}	1.29
Total N	%	0.15
Available P	mg kg^{-1}	8.6
Available K	mg kg^{-1}	104
Exchangeable Ca^{2+}	Cmol kg^{-1}	0.09
Exchangeable Mg^{2+}	Cmol kg^{-1}	0.28
Exchangeable Na^{+}	Cmol kg^{-1}	0.43
DTPA extractable Cu	mg kg^{-1}	0.09
DTPA extractable Fe	mg kg^{-1}	1.17
DTPA extractable Zn	mg kg^{-1}	0.72
DTPA extractable Mn	mg kg^{-1}	1.1
Total Cd	mg kg^{-1}	0.18

Table 2: Chemical characteristics of organic manures used in experimentation.

Characteristics	Unit	PM	FYM	CM
pH		6.3	6.4	6
Total N	%	1.8	1.82	1.54
Available P	mg kg^{-1}	1.83	0.25	0.89
Available K	mg kg^{-1}	0.8	0.63	0.39
EC	dS m^{-1}	1.3	1.4	1.35
Dry Matter	%	45	35	60
Moisture	%	55	65	40
Fe	mg kg^{-1}	16.82	9.8	12.1
Zn	mg kg^{-1}	246	189	204
Cd	mg kg^{-1}	8.1	1.26	4.24
Cu	mg kg^{-1}	7.45	22.52	18.3
Mn	mg kg^{-1}	5.92	26.7	9.56
Cr	mg kg^{-1}	1.63	13.67	7.67
Ni	mg kg^{-1}	1.82	6.22	3.1
Pb	mg kg^{-1}	4.62	8.98	16.26

PM: Pressmud; FYM: Farmyard manure; CM: Chicken manure.

The chemical composition of organic manures is presented in Table 2. Earthen pots (30×30×30 cm^3) were filled with 20 kg soil after lining with polythene sheet. Before filling the pots, organic manures were thoroughly incorporated into pot soil according to treatment plan. Moisture contents were maintained at 60% field capacity using tap water. After an incubation period of 45 days, four healthy maize seeds of cultivar "Neelam" were sown in each pot. After germination, two plants were maintained in each pot. Recommended rate of fertilizers

Table 3: Soil characterization in response to manuring with different organic wastes.

Treatments	MC (%)	OM (%)	SP	pH	SAR	EC
					(mmol L^{-1})$^{1/2}$	(dS m^{-1})
Control	9.85f	0.64fg	32.0g	8.1a	6.0g	1.01
PM-2.5%	12.82e	1.01f	33.4ef	7.6cd	6.64f	1.18
PM-5%	13.94de	1.63ef	34.1de	7.5d	7.27ef	1.23
PM-7.5%	15.66d	2.62d	34.9d	7.4de	7.98e	1.56
PM-10%	17.71c	3.74bc	35.0bc	7.3e	9.1cd	1.82
FYM-2.5%	12.89e	1.36ef	33.0ef	7.5d	7.18ef	1.13
FYM-5%	13.15de	2.31de	34.0de	7.4de	9.25cd	1.56
FYM-7.5%	16.23cd	3.17c	35.5c	7.3e	10.22bc	1.92
FYM-10%	22.16ab	4.40ab	36.6ab	7.2ef	11.34a	2.11
CM-2.5%	15.47d	2.21de	34.6d	7.4de	6.87f	1.19
CM-5%	18.64c	2.92cd	35.8c	7.2ef	7.12ef	1.43
CM-7.5%	21.52b	3.80bc	37.9a	7.1f	7.97e	1.58
CM-10%	25.44a	4.88a	38.3a	6.9g	8.22de	1.7

In each column, values with different letters differed significantly from each other at $p \leq 0.05$ value following Duncan's Multiple Range Test. Mean values are of four replicates (n=04).
(PM: Pressmud; FYM: Farmyard manure; CM: Chicken manure; MC: Moisture content; OM: Organic matter; SP: Saturation percentage; SAR: Sodium adsorption ratio; EC: Electrical conductivity).

i.e. N 60 mg kg^{-1} as urea, 45 mg P_2O_5 kg^{-1} as triple superphosphate and 30 mg K_2O kg^{-1} as sulfate of potash were applied. Whole of P_2O_5 and K_2O were applied at the time of sowing while N in two equal splits. Forty-five days after germination, one plant from each pot was harvested and washed thoroughly with distilled water. These plant samples were air-dried and then oven dried at 72°C in an oven (EYELA WFO-600ND; Tokyo Rikaikai Co., Ltd., Tokyo, Japan) till constant weight. Using plant grinder (MF 10 IKA-WERKE, GMBH & CO. KG, Germany), the dried plant samples were ground to 40 mesh. After grinding, 0.1 g plant samples were digested with di-acid mixture of $HClO_4$ and HNO_3 (1:2 v/v) at 250°C on the hot plate according the method described by Miller [37]. Plant Na and K were measured by flame photometer (Jenway PFP 7, ELE Instrument Co. Ltd. Felsted, UK) while Ca, Mg and micronutrients including Cu, Fe, Zn, Mn and cadmium (Cd) by atomic absorption spectroscopy (Hitachi Polarized Zeeman AAS, Z-8200, Japan). Nitrogen concentration in maize plants was determined using Kjeldhal method as described by Kjeldhal [38]. At maturity, grain yield was recorded. Post-harvest soil analysis was done for N [38], P [39], K, Ca, Mg [40], Cu, Fe, Zn, Mn and Cd [41]. The data were statistically analyzed using Statistix 8.1 (a computer-based software), the analysis of variance test was performed according to CRD factorial two way. Duncan's Multiple Range Test was used to differentiate between the significant means.

Results and Discussion

Soil characterization

Soil characteristics including moisture content, organic matter, saturation percentage, pH, sodium adsorption ratio (SAR) and electrical conductivity (EC) after harvest of maize crop were markedly influenced by all the three types of organic manures at four levels of application (Table 3). Soil moisture contents were increased by all organic manures. However, maximum increase in soil moisture contents was found in case of chicken manure which was 57.06%, 89.24%, 118.48% and 158.27% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in organic matter content in soil was also found in case of chicken manure which was 245.31%, 356.25%, 493.75% and 662.50% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in saturation percentage of soil was also noted in case of chicken manure which was 8.13%, 11.88%, 18.44% and 19.69% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum reduction in pH was noted in case of chicken manure application which was 9.46%, 12.50%, 14.08% and 17.39% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Improvement of soil properties including moisture content, organic matter and saturation percentage with manuring by different organic wastes was attributed to the development of charge sites in soil, which increased water retention in soil, resulting in higher moisture content and saturation percentage [5,33]. The organic matter in soil was very low before manuring, and increased in direct proportional to the rate of manure application. Among different manures, chicken manure caused highest increase in these properties, probably due to higher decomposition rate [27]. Reduction in soil pH with manuring might be associated with the release of organic acids on the decomposition of wastes [42]. Soil EC increased with manuring, maximum increase of 11.88%, 54.45%, 90.09% and 108.9% with 2.5%, 5%, 7.5% and 10% farmyard manure (w/w), respectively compared to control. Soil SAR was also affected by manuring, maximum increase in case of farmyard manure which was 19.67%, 54.17%, 70.33% and 89.0% at 2.5%, 5%, 7.5% and 10% (w/w) respectively compared to control. Salt build-up in soil is measured in term of EC and SAR. The differential increase in soil EC and SAR in response to manuring with different organic wastes was attributed to the presence of salts in manures [43,44]. Furthermore, salt build-up increased with the rate of manure application. Among different manures, farmyard manure caused highest salt build-up in soil followed by chicken manure and pressmud in descending order. The difference in salt accumulation with manure type was based on the salt content of manure [45]. Hao and Chang [46] reported that salt accumulation in soil was positively correlated with the rate of manure application.

Soil nutrient dynamics

Soil nutrients in term of N, P, K, Ca and Mg were significantly ($p \leq 0.05$) affected by different sources and application rates of organic manures (Table 4). Soil N was markedly affected by all sources and levels of organic manures but maximum increase in soil N concentration was found in case of farmyard manure which was 31.11%, 5.11%, 71.11% and 77.78% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil P concentration was found in case of pressmud which was 17.83%, 37.60%, 48.33% and 55.29% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil K concentration was found in case of pressmud which was 9.82%, 20.54%, 32.14% and 40.18% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil Ca concentration was also noted in case of pressmud which was 16.67%, 72.62%, 125.00% and 154.76% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil Mg concentration was again noted in case of pressmud application which was 70.59%, 182.35%, 223.53% and 279.41% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared

Table 4: Macronutrient dynamics in soil in response to manuring with different organic wastes.

Treatments	N	P	K	Ca	Mg
	(%)	(ppm)	(ppm)	(Cmol kg^{-1})	(Cmol kg^{-1})
Control	0.45g	7.18ef	112ef	0.84fg	0.34g
PM-2.5%	0.53f	8.46d	123d	0.98ef	0.58ef
PM-5%	0.61d	9.88b	135c	1.45cd	0.96c
PM-7.5%	0.67c	10.65ab	148ab	1.89ab	1.10b
PM-10%	0.78a	11.15a	157a	2.14a	1.29a
FYM-2.5%	0.59dc	7.92de	129cd	0.67gh	0.46f
FYM-5%	0.68c	8.78cd	137c	0.88f	0.68e
FYM-7.5%	0.77a	9.80bc	145c	1.12e	0.97c
FYM-10%	0.80a	10.50ab	147b	1.54c	1.02bc
CM-2.5%	0.54ef	7.20ef	122de	0.88f	0.46f
CM-5%	0.56e	7.90de	132cd	1.02ef	0.82d
CM-7.5%	0.60de	8.84cd	135c	1.28d	1.0bc
CM-10%	0.62d	9.43c	142bc	1.78ab	1.20ab

In each column, values with different letters differed significantly from each other at *p*≤0.05 value following Duncan's Multiple Range Test. Mean values are of four replicates (n=04).
(PM: Pressmud; FYM: Farmyard manure; CM: Chicken manure).

Table 5: Micronutrient dynamics in soil in response to manuring with different organic wastes.

Treatments	Fe	Zn	Mn	Cu	Cd
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Control	1.29d	0.76d	1.14g	0.10ef	0.22g
PM-2.5%	1.43c	0.81cd	1.47cd	0.17cd	0.55ef
PM-5%	1.55bc	0.84c	1.59bc	0.19c	0.79d
PM-7.5%	1.71ab	0.88bc	1.68ab	0.23b	0.94cd
PM-10%	1.89a	0.95b	1.74a	0.28a	1.49a
FYM-2.5%	1.34cd	0.80cd	1.42d	0.11e	0.29g
FYM-5%	1.42c	0.82cd	1.49cd	0.18cd	0.37fg
FYM-7.5%	1.66b	0.84c	1.53c	0.24b	0.48f
FYM-10%	1.78ab	0.88bc	1.58bc	0.28a	0.70de
CM-2.5%	1.40c	0.87c	1.43d	0.26ab	0.65e
CM-5%	1.54bc	0.94b	1.48cd	0.12e	0.88d
CM-7.5%	1.69b	0.99ab	1.51c	0.18cd	1.18bc
CM-10%	1.80ab	1.03a	1.56bc	0.21bc	1.42a

In each column, values with different letters differed significantly from each other at *p*≤0.05 value following Duncan's Multiple Range Test. Mean values are of four replicates (n=04).
(PM: Pressmud; FYM: Farmyard manure; CM: Chicken manure).

to control. The significant change in soil nutrient status in response to manuring with organic wastes was attributed to impact of organic manures on soil properties, nutrients release and retention and nutrients transformation in soil [24,30,47]. Soil nutrient dynamics were greatly affected by different sources and levels of organic manures, with highest effect in case of pressmud followed by chicken manure and farmyard manure in descending order. The highest nutrient accumulation in soil in case of pressmud was due to its high nutrient status. Saleh-e-In et al., [48] reported that pressmud contained P (8.40-9.52 %), Ca (21.30-29.97 %), K (2.51-4.08 %), Si (9.53-9.94 %), S (7.93-16.02 %) and Mg (4.14-7.75 %), and use of such pressmud could cause a marked increase in nutrient accumulation in soil. Gupta et al., [49] reported that high nutrients content of pressmud promoted soil nutrients status, leading to improved plant growth and development. Soil micronutrient contents including Cu, Fe, Zn and Mn were also markedly influenced by all the types and levels of manure application (Table 5). Maximum increase in soil Cu concentration was found in case of pressmud which was 70%, 90%, 130% and 180% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil Fe concentration was found in case of pressmud which was 10.85%, 20.16%, 32.56% and 46.51% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil Zn concentration was found in case of chicken manure which was 14.47%, 23.68%, 30.26% and 35.53% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil Mn concentration was found in case of pressmud which was found 28.95%, 39.47%, 47.37% and 52.63% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in soil Cd concentration was also found in case of pressmud which was 150%, 259%, 327% and 577% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. According to Ezhilvannan [50], pressmud contained high concentration of nutrients and organic constituents such as cellulose, sugars, proteins, waxes etc. that justified its potential to improve soil fertility and quality. Partha and Sivasubramanian [51] demonstrated that higher values of micronutrients in pressmud could the main reason for its superiority to improve micronutrients concentration in soil compared to other manures.

Table 6: Macronutrient dynamics in maize (*Zea mays* L.) in response to manuring with different organic wastes.

Treatments	N	P	K	Ca	Mg
	(%)	(%)	(%)	(%)	(%)
Control	1.12e	0.11ef	1.62e	1.12fg	0.32gh
PM-2.5%	1.87bc	0.19de	1.94c	1.62c	0.47ef
PM-5%	1.99b	0.28cd	2.12bc	1.80b	0.68d
PM-7.5%	2.17ab	0.35bc	2.42a	1.86ab	0.84c
PM-10%	2.39a	0.48a	1.80d	1.98a	1.02a
FYM-2.5%	1.56cd	0.16e	1.98c	1.36e	0.38f
FYM-5%	1.74c	0.23d	2.05bc	1.49d	0.52ef
FYM-7.5%	1.84bc	0.31c	2.16b	1.64c	0.66d
FYM-10%	1.95bc	0.33bc	1.79d	1.76b	0.87bc
CM-2.5%	1.22de	0.14e	1.89cd	1.52d	0.46ef
CM-5%	1.29de	0.18de	1.94c	1.67c	0.68d
CM-7.5%	1.66cd	0.21d	1.92cd	1.81b	0.78c
CM-10%	1.77c	0.27cd	1.97c	1.90a	0.85bc

In each column, values with different letters differed significantly from each other at *p*≤0.05 value following Duncan's Multiple Range Test. Mean values are of four replicates (n=04).
(PM: Pressmud; FYM: Farmyard manure; CM: Chicken manure).

Plant nutrient dynamics

Plant concentration of macronutrients in term of N, P, K, Ca and Mg in maize were significantly ($p \leq 0.05$) increased by all the types and levels of manure application (Table 6). Maximum increase in maize N concentration was found by pressmud application which

Table 7: Micronutrients dynamics in maize (*Zea mays L*) in response to manuring with different organic wastes.

Treatments	Fe	Zn	Mn	Cu	Cd
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Control	0.32g	0.42g	0.11	0.11e	0.28f
PM-2.5%	0.44e	0.49ef	0.14	0.22d	0.59d
PM-5%	0.52d	0.57cd	0.17	0.29c	0.82c
PM-7.5%	0.58c	0.63b	0.18	0.42b	1.14ab
PM-10%	0.69a	0.66a	0.19	0.52a	1.29a
FYM-2.5%	0.36fg	0.40g	0.13	0.15de	0.42e
FYM-5%	0.42ef	0.44fg	0.14	0.18d	0.67d
FYM-7.5%	0.53cd	0.51e	0.16	0.22d	0.82c
FYM-10%	0.59bc	0.53de	0.17	0.28c	0.98bc
CM-2.5%	0.34g	0.42g	0.12	0.19d	0.41e
CM-5%	0.37fg	0.51e	0.16	0.26cd	0.78cd
CM-7.5%	0.51d	0.57cd	0.19	0.35bc	1.02b
CM-10%	0.58c	0.65a	0.26	0.46ab	1.16ab

In each column, values with different letters differed significantly from each other at $p \le 0.05$ value following Duncan's Multiple Range Test. Mean values are of four replicates (n=04).
(PM: Pressmud; FYM: Farmyard manure; CM: Chicken manure).

was 66.96%, 77.68%, 93.75% and 113.39% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in maize P concentration was found by pressmud application which was 72.73%, 154.55%, 218.18% and 336.36% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in maize K concentration was found by pressmud which was 19.75%, 30.86%, 49.38% and 11.11% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in maize Ca was also noted by pressmud which was 44.64%, 60.71%, 66.07% and 76.79% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in maize Mg concentration was noted by pressmud which was 46.88%, 112.50%, 162.50% and 218.75% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Han et al., [52] demonstrated that manuring with organic wastes not only improved soil properties, nutrients retention and availability but also uptake by plants by improving root penetration and biomass accumulation while reducing soil pH. Pressmud also showed its superiority for improving nutrients uptake, in addition to improving soil fertility. Gupta et al., [49] found that pressmud contained relatively higher nutrients content, which became available on its decomposition, resulting in higher nutrients uptake. The concentration of micronutrients including Cu, Fe, Zn and Mn in maize was significantly ($p \le 0.05$) affected by all the types and levels of manure application (Table 7). Maximum increase in maize Cu concentration was found by pressmud which was 100%, 163.64%, 281.82% and 372.73% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Maximum increase in plant Fe concentration was found 37.5%, 62.5%, 81.2% and 115.6% at 2.5%, 5%, 7.5% and 10% pressmud (w/w), respectively compared to control. Maximum increase in plant Zn concentration was 16.6%, 35.7%, 50.0% and 57.1% at 2.5%, 5%, 7.5% and 10% pressmud (w/w), respectively compared to control. Maximum increase in plant Mn concentration was found in case of chicken manure which was 9.0%, 45.4%, 72.7% and 136%

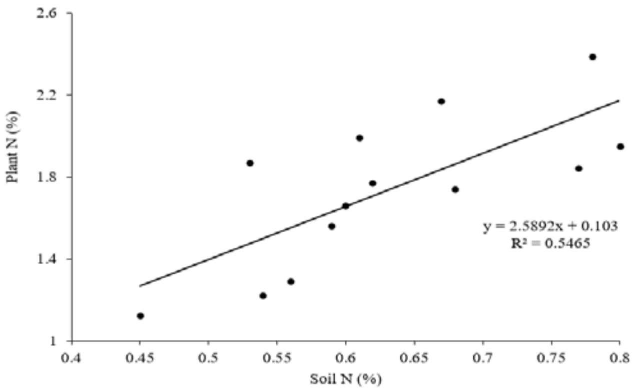

Figure 1: Relationship between soil N and plant N concentration in response to manuring with different organic wastes.

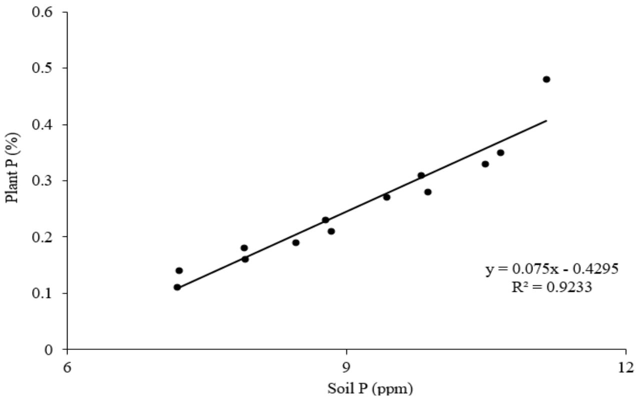

Figure 2: Relationship between soil P and plant P concentration in response to manuring with different organic wastes.

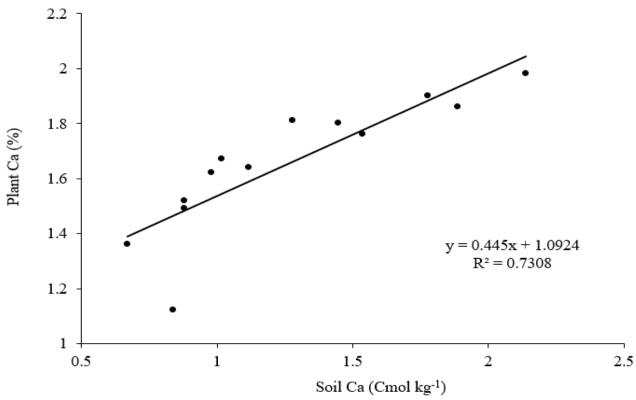

Figure 3: Relationship between soil Ca and plant Ca concentration in response to manuring with different organic wastes.

at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Pressmud showed maximum increase in plant Cd concentration which was 110.7%, 192.8%, 307.1% and 360.7% at 2.5%, 5%, 7.5% and 10% (w/w), respectively compared to control. Pressmud also proved most efficient in improving micronutrients accumulation in maize plants, probably because of higher nutrient status of pressmud. Kumar and Chopra [35] demonstrated that higher nutrients content in pressmud warranted its superiority to improve micronutrients

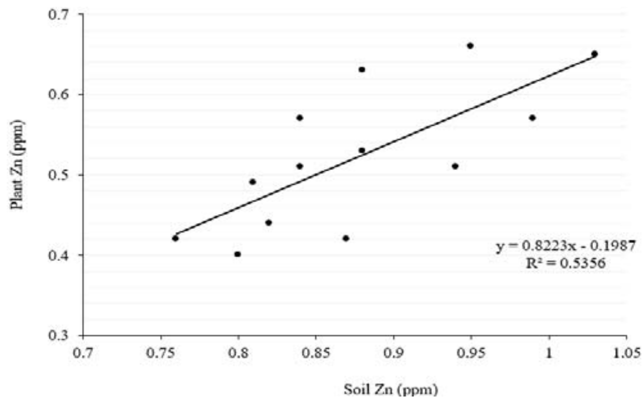

Figure 4: Relationship between soil Zn and plant Zn concentration in response to manuring with different organic wastes.

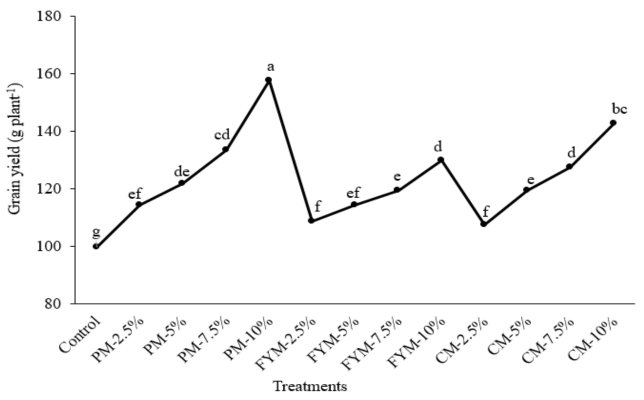

Figure 5: Grain yield of maize (*Zea mays L*) in response to manuring with different organic wastes. (Values with different letters differed significantly from each other at $p \leq 0.05$ value following Duncan's Multiple Range Test. Mean values are of four replicates (n=04). PM: Pressmud, FYM: Farmyard manure, CM: Chicken manure).

accumulation in plants. Ezhilvannan et al., [50] also reported higher nutrients accumulation in maize by the application of pressmud. Plant nutrients were positively correlated with soil nutrients; $r^2=0.54$ for N (Figure 1); $r^2=0.92$ for P (Figure 2); $r^2=0.73$ for Ca (Figure 3); $r^2=0.53$ for Zn (Figure 4)).

Grain yield

Experimental results showed that grain yield of maize in control treatment was found 99.55 g plant^{-1}. However, application of different types and levels of organic manures caused a significant ($p \leq 0.05$) increase in the grain yield of maize (Figure 5). Grain yield increased by 14.85%, 22.19%, 34.02% and 58.25% by the application of 2.5%, 5%, 7.5% and 10% (w/w) pressmud, respectively compared to control. Likewise, grain yield increased by 9.11%, 14.76%, 19.75%, and 30.38% by the application of 2.5%, 5%, 7.5% and 10% (w/w) farmyard manure, respectively compared to control. While, grain yield increased by 7.93%, 20.0%, 27.97% and 43.14% by the application of 2.5%, 5%, 7.5% and 10% (w/w) of chicken manure, respectively compared to control. The increase in grain yield of maize in the presence of different manures could be attributed to increased nutrients availability in soil [4]. Schlegel et al., [20] reported that organic manures could increase nutrients availability not only by releasing nutrients on decomposition but also preventing nutrient losses by increasing their retention in soil. Among the tested organic manures, pressmud proved most efficient to improve the grain yield of maize, probably it was rich in plant nutrients such as N, P, K, Ca, Mg, Cu, Fe and Mn. Partha and Sivasubramanian [51] demonstrated that pressmud was rich not only in plant nutrients but also proteins, fibers, sugars, fats, and waxes, and thus could greatly improve the plant growth and yield.

Conclusion

Manuring with all the three types of manures i.e. pressmud, farmyard manure and chicken manure had great potential to improve soil properties in term of moisture content, organic matter accumulation, saturation percentage and pH. Manuring not only improved soil nutrient status but also nutrient accumulation in plants. Among tested manures, pressmud showed superiority to improve soil properties and nutrient dynamics in soil and plants followed by chicken manure and farmyard manure in descending order. Effectiveness of manures to improve soil properties and nutrient dynamics increased with increasing the rate of application. Major mechanisms of manure-induced improvement in soil properties and nutrient dynamics include; i) improved organic matter content, ii) increased water retention, iii) reduction in soil pH, iv) enhanced availability of macro and micronutrients to plants, v) increased nutrients accumulation in plants.

References

1. Singh AK, Sarkar AK, Kumar A, Singh BP. Effect of long-term use of mineral fertilizers, lime and farmyard manure on the crop yield, available plant nutrient and heavy metal status in an acidic loam soil. J Indian Soc Soil Sci. 2009; 57: 362-365.
2. Liu CA, Zhou LM, Jia JJ, Wang LJ, Si JT, Li X, et al. Maize yield and water balance is affected by nitrogen application in a film-mulching ridge–furrow system in a semiarid region of China. Eur J Agr. 2014; 52: 103-111.
3. Gong W, Yan XY, Wang JY, Hu TX, Gong YB. Long-term applications of chemical and organic fertilizers on plant-available nitrogen pools and nitrogen management index. Biol Fert Soils. 2011; 47: 767-775.
4. Hoyle FC, Fang Y. Impact of agricultural management practices on the nutrient supply potential of soil organic matter under long-term farming systems. Soil Tillage Res. 2018; 175: 71-81.
5. Wang X, Yan J, Zhang X, Zhang S, Chen Y. Organic manure input improves soil water and nutrients use for sustainable maize (*Zea mays L*) Productivity on the Loess Plateau. PLoS One. 2020: 15: e0238042.
6. Chen JH. The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. In: International workshop on sustained management of the soil-rhizosphere system for efficient crop production and fertilizer use. Land Development Department, Bangkok. 2006; 1-11.
7. Gill HK, Garg H. Pesticide: environmental impacts and management strategies. Solenski S, Larramenday ML, editors. In: Pesticidestoxic aspects. IntechOpen, Rijeka. 2014; 187-230.
8. Ju XT, Xing GZ, Chen XP, Zhang SL, Zhang LJ, Liu XJ, et al. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. Proc Natl Acad Sci. 2009; 106: 3041-3046.
9. Hartemink AE. Assessing soil fertility decline in the tropics using soil chemical data. Adv Agron. 2006; 89: 179-225.
10. de Jesus Souza B, do Carmo DL, Santos RHS, de Oliveira TS, Fernandes RBA. Residual contribution of green manure to humic fractions and soil fertility. J Soil Sci Plant Nutr. 2019; 19: 878-886.

11. Ahmad R, Jilani G, Arshad M, Zahir ZA, Khalid A. Bioconversion of organic wastes for their recycling in agriculture: an overview of perspectives and prospects. Ann Microbiol. 2007; 57: 471-479.

12. Li J, Marschner P. Phosphorus pools and plant uptake in manure amended soil. J Soil Sci Plant Nutr. 2019; 19: 175-186.

13. Choudhary AK, Thakur RC, Kumar N. Effect of integrated nutrient management on soil physical and hydraulic properties in rice-wheat crop sequence in N-W Himalayas. Indian J Soil Conserv. 2008; 36: 97-104.

14. Celik I, Gunal H, Budak M, Akpinar C. Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. Geoderma. 2010; 160: 236-243.

15. Ibrahim M, Hassan A, Iqbal M, Valeem EE. Response of wheat growth and yield to various levels of compost and organic manure. Pak J Bot. 2008; 40: 2135-2141.

16. Balasubramanian D, Arunachalam K, Arunachalam V, Das AK. Water hyacinth [*Eichhornia crassipes* (Mart) Solms] engineered soil nutrient availability in a low- land rain-fed rice farming system of north-east India. Ecol Eng. 2013; 58: 3-12.

17. Bhattacharya R, Chandra S, Singh RD, Kundu S, Srivastva AK, Gupta HS. Long-term farmyard manure application effects on properties of a silty clay loam soil under irrigated wheat-soybean rotation. Soil Tillage Res. 2007; 94: 386-396.

18. Li Y, Jones DL, Chen Q, Chadwick DR. Slurry acidification and anaerobic digestion affects the speciation and vertical movement of particulate and nanoparticulate phosphorus in soil after cattle slurry application. Soil Tillage Res. 2019; 189: 199-206.

19. Francioli D, Schulz E, Lentendu G, Wubet T, Buscot F, Reitz T. Mineral *vs.* organic amendments: microbial community structure, activity and abundance of agriculturally relevant microbes are driven by long-term fertilization strategies. Front Microbiol. 2016; 7: 1446.

20. Schlegel AJ, Assefa Y, Bond HD, Haag LA, Stone LR. Changes in soil nutrients after 10 years of cattle manure and swine effluent application. Soil Tillage Res. 2017; 172: 48-58.

21. Motavalli PP, Singh RP, Anders MM. Perception and management of farmyard manure in the semiarid tropics of India. Agric Syst. 1994; 46: 189-204.

22. Saidia PS, Mrema JP. Effects of farmyard manure and activated effective microorganisms on rain-fed upland rice in Mwanza, Tanzania. *Org Agr*. 2017; 7: 83-93.

23. Edmeades DC. The long-term effects of manures and fertilisers on soil productivity and quality: a review. Nutr Cycl Agroecosyst. 2003; 66: 165-180.

24. Shah RU, Abid M, Qayyum MF, Ullah R. Dynamics of chemical changes through production of various composts/vermicompost such as farm manure and sugar industry wastes. Int J Recycl Org Waste Agric. 2015; 4: 39-51.

25. Farhad W, Saleem MF, Cheema MA, Hammad HM, Effect of poultry manure levels on the productivity of spring maize (*Zea mays L*). J Anim Plant Sci. 2009; 19: 122-125.

26. Boateng SA, Zickermann J, Kornaharens M. Effect of poultry manure on growth and yield of maize. West Afr J Appl Ecol. 2006; 9: 1-11.

27. Adekiya AO, Aboyeji CM, Dunsin O, Asamu FF, Owolabi AO, Aremu CO, et al. Poultry manure addition affects production, plant nutritional status and heavy metals accumulation in green amaranth (*Amaranthus hybridus*). Intl J Agric Biol. 2019; 22: 993-1000.

28. Dotaniya ML, Datta SC, Biswas RD, Dotaniya CK, Meena BL, Rajendiran S, et al. Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. Int J Recycl Org Waste Agric. 2016; 5: 185-194.

29. Jamil M, Qasim M, Zia MS. Utilization of pressmud as organic amendment to improve physico-chemical characteristics of calcareous soil under two legume crops. J Chem Soc Pak. 2008; 3: 145-150.

30. Sheoran S, Raj D, Antil RS, Mor VS, Dahiya DS. Productivity, seed quality and nutrient use efficiency of wheat (*Triticum aestivum*) under organic, inorganic and integrated nutrient management practices after twenty years of fertilization. Cereal Res Commun. 2017; 45: 315-325.

31. Chattha MU, Hassan MU, Barbanti L, Chattha MB, Khan I, Usman M, et al. Composted sugarcane by-product press mud cake supports wheat growth and improves soil properties. Int J Plant Prod. 2019; 13: 241-249.

32. Sharma BL, Singh S, Sharma S, Prakash V, Singh RR. Integrated response of pressmud cake and urea on sugarcane in calcareous soil. Coop Sugar. 2002; 33: 10010-1004.

33. Yaduvanshi NPS, Swarup A. Effect of continuous use of sodic irrigation water with and without gypsum, farmyard manure, pressmud and fertilizer on soil properties and yields of rice and wheat in a long term experiment. Nutr Cycl Agroecosyst. 2005; 73: 111-118.

34. Razzaq A. Assessing sugarcane filter cake as crop nutrients and soil health ameliorant. Pak Sug J. 2001; 21: 15-18.

35. Kumar V, Chopra AK. Effects of sugarcane pressmud on agronomical characteristics of hybrid cultivar of eggplant (*Solanum melongena L*) under field conditions. Int J Recycl Org Waste Agric. 2016; 5: 149-162.

36. Richards LA. Diagnosis and improvement of saline and alkali soils. US. Department. Agriculture Handbook 60 US. Gov. Printing Office, Washington, DC. 1954.

37. Miller RO. Nitric–perchloric wet acid digestion in an open vessel. Kalra Y, editor. In: Handbook of Reference Methods for Plant Analysis. CRC Press, Washington DC. 1998; 57-62.

38. Kjeldahl J. New method for the determination of nitrogen. Chem News. 1883; 48: 101-102.

39. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with NaHCO3, USDA Cir. 939, Washington, USA. 1954.

40. Doll EC, Lucas RE. Testing soils for potassium, calcium and magnesium. Walsh LM, Beaton JD, editors. In: Soil Testing and Plant Analysis. Soil Science Society of America: Madison, WI. 1974; 133-151.

41. Perkin-Elmer. Analytical Methods for Atomic Absorption Spectroscopy. The Perkin-Elmer Corporation, USA. 1996.

42. Abbasi MK, Khaliq A, Shafiq M, Kazmi M, Ali I. Comparative effectiveness of urea, poultry manure and their combination in changing soil properties and maize productivity under rainfed conditions in northeast Pakistan. Exp Agric. 2010; 46: 211-230.

43. Mufwanzala N, Dikinya O. Impact of poultry manure and its associated salinity on the growth and yield of spinach (*Spinacea oleracea*) and carrot (*Daucus carota*). Int J Agric Biol. 2010; 12: 489-494.

44. Cho WM, Ravindran B, Jung Kon K, Gwang-Hwa J, Dong-Jun L, Dong Yoon C. Nutrient status and phytotoxicity analysis of goat manure discharged from farms from South Korea. Environ Technol. 2017; 38: 1191-1199.

45. Hao X, Chang C. Effect of 25 annual cattle manure applications on soluble and exchangeable cations in soil. Soil Sci. 2002; 167: 126-134.

46. Hao X, Chang C. Does long-term heavy cattle manure application increase salinity of a clay loam soil in semi-arid southern Alberta? Agric Ecosys Environ. 2003; 94: 89-103.

47. Gill P, Singh D, Gupta RK, Urmila LH. Comparative chemical evaluation of vermicompost produced by using different organic wastes. Ghosh S, editor. In: Waste valorisation and recycling. Springer, Singapore. 2019.

48. Saleh-e-In M, Yeasmin S, Paul BK, Ahsan M, Rahman MdZ, Roy SK. Chemical studies on press mud: A sugar industries waste in Bangladesh. Sugar Tech. 2012.

49. Gupta N, Tripathi S, Balomajumder C. Characterization of press mud: a sugar industry waste. Fuel. 2011; 90: 389-394.

50. Ezhilvannan D, Sharavanan PS, Vijayaragavan M. Effect of sugar mill effluent on changes of growth and amino acid and protein contents of maize (*Zea mays L*) plants. J Ecobiotechnol. 2011; 3: 26-29.

51. Partha N, Sivasubramanian V. Recovery of chemicals from pressmud-a sugar industry waste. Indian Chem Eng Sect. 2006; 48:160-163.

52. Han SH, An JY, Hwang J, Kim SB, Park BB. The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (*Liriodendron tulipifera* Lin) in a nursery system. Forest Sci Technol. 2016; 12: 137-143.