Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 2403-2408
Received: 02-09-2019
Accepted: 04-10-2019

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Effect of lignite and poultry manure based human application on soil properties in an acid soil of eastern dry zone of Karnataka

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Abstract
A field experiment was conducted at Krishi Vigyan Kendra, Hadonahalli, and Bangalore rural district, to study the effect of lignite human (LH) and poultry manure humin (PMH) application on soil properties after harvest of maize crop in an acid soil of eastern dry zone of Karnataka. The experiment was laid in RCBD comprising ten treatments and three replications. The results revealed that significant variation was observed on soil properties due to application of Farm Yard Manure (FYM), LH and PMH. Slight increase in soil pH and EC was recorded due to humin application and highest pH (4.94) and EC (0.19 dS m^{-1}) were higher in T_{10} (PMH @ 10 t ha^{-1}) treatment. The soil organic carbon was (5.18 g kg^{-1}) higher in lignite based humin @ 10 t ha^{-1} treated plot. The available major nutrients (160.68, 35.87 and 282.60 N, P_2O_5 and K_2O, kg ha^{-1} respectively) status of post-harvest soil was significantly higher in T_9 (PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1}). Higher exchangeable Ca and Mg (3.23 and 1.17 c mol (p+) kg ha^{-1}, respectively) was recorded in T_2 (100% RDF + FYM @ 10 t ha^{-1}) and higher available sulphur (16.01 kg ha^{-1}) in T_9. The DTPA extractable micronutrients (13.63, 14.44, 1.22, 1.21 and 0.34 mg kg^{-1} of Fe, Mn, Zn, Cu and B respectively) were higher in T_2 and all these parameters were recorded lower in control plot (T_1) where no manures and fertilizers were applied. Significantly higher maize kernel (8070 kg ha^{-1}) and stover yield (9948 kg ha^{-1}) were recorded in treatment T_2 and which was found on par with treatment T_7 (PMH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1}) and T_3 (LH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1}) and T_8 (PMH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1}). These results suggest that FYM can be substituted to the extent of 5 t ha^{-1} with PM humin or 2.5 t ha^{-1} with lignite based humin without any detrimental effect on soil properties and without compromising the yield of maize.

Keywords: FYM, lignite based humin and poultry manure based humin and soil properties

Introduction
Organic matter is considered as the "life of soil" due to its importance in maintaining fertility of the soil, the depletion of the same will become a major threat to food security in the years to come. Hence, there is a need to improve the soil fertility in a sustainable manner by utilizing the locally available organic wastes because these wastes contains substantial amount of nutrients which are necessary for the plant growth in addition to maintaining of soil health. It helps in improving soil physical, chemical and biological properties of soil. However, to improve the organic matter content of soils many management techniques have been adopted such as crop rotation, plough techniques, green manuring and application of animal residues, humic acids and humates (Doran, 2003) [7]. The most active fraction of humus is the humic substances. Hayes *et al.* (1989) [12] described them as a group of naturally occurring, biogenic, heterogeneous organic substances that can generally be characterized as yellow to black coloured high molecular weight material. This group of organic substances can be fractionated in terms of their solubility in acid and alkali into (i) yellowish fulvic acid that is soluble in acid and alkali; (ii) blackish humic acid that is insoluble in acid but soluble in alkali, and (iii) humin that is insoluble both in acid and alkali (Stevenson & Cole, 1999) [21]. Nowadays use of humic acid and/ fulvic acid is very common in crop production especially horticulture crops as it influences many soil properties (soil application) and helps in mobility and absorption of nutrients in the plant (foliar application). Thus humic acid derived from organic wastes like farm yard manure (FYM), coco peat, press mud, coffee pulp, sewage sludge, poultry manure (PM), urban compost etc. which have substantial quantities of humic materials are of great importance in maintaining soil organic matter levels especially in semi-arid tropics of India. However, among the fractions of humic substances, humin fraction which accounts 60-90 per cent of organic manure gets very little attention. It seems to be somewhat inert but it has been described as actinglikeasponge, soaking up nutrients. Gary Zimmer (2003) [10] reported that the

humin may be a humic substance in association with mineral oxides or hydroxides (from the reaction). Alternatively, humin may be coated with hydrocarbons or lipids (fats) that were stripped during the reaction, making them insoluble to aqueous solvents. No research data is available on use of such huge quantity of humin generated after alkali extraction for crop production and their effect on soil properties. Hence, a study was initiated to know the effect of application of humin residue on soil properties after harvest of maize crop in an acid soil.

Material and Methods

Extraction of humic substances

Two sources of manures such as lignite and Poultry Manure (PM) were used for extraction of humin. Lignite was procured from Neyveli Lignite Corporation of India, located at Neyveli, Tamil Nadu and poultry manure from Poultry Farm, Doddaballapura, Bengaluru rural district. Laboratory scale extraction of humic substances from selected organic manures was carried out by taking 10 gram of air dried sample into a 250 ml conical flask to which 100 ml 0.1 *N* NaOH was added, stoppered and shaken for 24 hours using end to end shaker. The dark coloured supernatant containing Humic Acid (HA) and Fulvic Acid (FA) were separated by centrifugation and collected. The extraction was repeated thrice with 50 ml of extractant for complete extraction of the humic substances. The residues left after extraction is humin (Schnitzer and Skinner, 1968) [18]. The humic substances (HA, FA and Humin) recovered from poultry manure and lignite were weighed and expressed in per cent and further subjected for characterization. Similarly for field experiment bulk extraction of humin was carried by treating required quantity of poultry manure and lignite with 0.1 *N* NaOH in 100L drum capacity followed by filtering with muslin cloth.

Field experiment

A field experiment was conducted during *kharif* 2018 at Krishi Vigyana Kendra, Hadonahalli, Bengaluru rural district, Karnataka to study the influence of lignite and poultry manure based humin on soil properties after harvest of maize (*Zea mays* L.) crop in acid soil of eastern dry zone of Karnataka. The initial soil properties of the experimental site, was sandy loam in texture with acidic in reaction (pH 4.48) and low in electrical conductivity (0.10 dS m^{-1}). The soil was los in organic carbon content (4.08 g kg^{-1}) and available nitrogen (145.60 kg ha^{-1}) whereas medium in available P_20_5 (29.73 kg ha^{-1}) and available K_2O content (267.60 kg ha^{-1}). The available Ca and Mg contents were 2.90 and 0.80 c mol (p+) kg^{-1}, respectively and low in sulphur content (13.76 mg kg^{-1}). The DTPA extractable micronutrients (Fe, Mn, Zn and Cu) content were found to be sufficient (12.00, 14.76, 1.04 and 1.07 mg kg^{-1}, respectively) but the available boron was found deficient (0.33 mg kg^{-1}). The cation exchange capacity and exchangeable sodium percentage of soil were 14.80 c mol (p+) kg^{-1} and 0.65% , respectively (Table 1). The field experiment was laid out in a randomized complete block design with ten treatments, replicated thrice. The Lignite Humin (LH) and Poultry Manure Humin (PH) were applied at different doses (0, 2.5, 7.5 & 10 t ha^{-1}) in combination with FYM (Farm Yard Manure) applied in such a way that the total quantity of humin and FYM is equivalent to 10 t ha^{-1}. The treatment combinations include, T_1: Absolute control, T_2: FYM @ 10 t ha^{-1} (POP),T_3: LH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1}, T_4: LH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1}, T_5: LH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1}, T_6: LH @ 10 t ha^{-1}, T_7: PH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1}, T_8: PH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1}, T_9: PH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} and $T_{10:}$ PH @ 10 t ha^{-1}. In all the treatments except absolute control, Recommended Dose of Fertilizer (RDF) for maize was applied commonly @ 150:75:40 kg ha^{-1} NPK. The FYM and various combinations of FYM with lignite and poultry manure based humin were applied as per the treatments 15 days before sowing and mixed well with the soil properly. Entire dose of P and K were applied at the time of sowing whereas, N was applied in three equal splits at basal, 30 and 50 days after sowing (DAS). The initial soil samples before treatment imposition was collected and subjected for analysis physico-chemical properties such as soil texture, pH and EC by Jackson (1973) [13], OC (Walkley and Black, 1934) [23], available micro (Lindsay and Norvell, 1978) and macro nutrients as outlined by Jackson (1973) [13]. At harvest, soil samples were collected treatment wise and analysed for pH, EC, available major, secondary and micronutrient content in soil using standard procedure as outlined earlier. The kernel and stover yield of maize were recorded and expressed in kg per hectare. All these data’s were statistically analysed by adopting standard procedure outlined by Gomez and Gomez (1984).

Table 1: Properties of initial soil sample of the experimental site

Sl. No.	Soil properties	Value
1	Mechanical Analysis	
	Sand (%)	77.16
	Silt (%)	9.64
	Clay (%)	13.19
	Textural Class	Sandy loam
2	pH (1:2.5 soil:water suspension)	4.48
3	Electrical Conductivity (dS m^{-1})	0.10
4	Organic carbon (g kg^{-1})	4.08
5	Available nitrogen (kg ha^{-1})	145.60
6	Available phosphorus (kg P_2O_5 ha^{-1})	29.73
7	Available potassium (kg K_2O ha^{-1})	267.60
8	Exchangeable Sodium (cmol (p^+) kg^{-1})	0.06
9	Exchangeable calcium (cmol (p^+) kg^{-1})	2.90
10	Exchangeable magnesium (cmol (p^+) kg^{-1})	0.80
11	Available Sulphur (mg kg^{-1})	13.76
12	DTPA Extractable iron (mg kg^{-1})	12.00
13	DTPA Extractable manganese (mg kg^{-1})	14.76
14	DTPA Extractable copper (mg kg^{-1})	1.04
15	DTPA Extractable zinc (mg kg^{-1})	1.07
16	Hot water soluble Boron (mg kg^{-1})	0.33

Results and Discussion

Significant differences were observed in the soil properties and nutrient status after the harvest of maize crop due to treatment imposition and the results are presented in Table 2-3.

Table 2: Effect of lignite and poultry manure based humin on soil properties and major nutrients content in soil after harvest of maize

Treatments	pH	EC	OC	N	P_2O_5	K_2O
		dS m^{-1}	g kg^{-1}	kg ha^{-1}		
T_1: Absolute control	4.49	0.13	4.26	131.84	24.01	249.52
T_2: FYM @ 10 t ha^{-1} (POP)	4.45	0.17	4.92	148.32	31.65	273.60
T_3: 25% Lignite humin (2.5 t ha^{-1}) + FYM @ 7.5 t ha^{-1}	4.51	0.14	4.75	152.44	32.15	273.79
T_4: 50% Lignite humin (5 t ha^{-1}) + FYM @ 5 t ha^{-1}	4.53	0.15	4.89	156.56	32.74	276.64
T_5: 75% Lignite humin (7.5 t ha^{-1}) + FYM @ 2.5 t ha^{-1}	4.56	0.15	5.12	160.68	33.61	275.97
T_6: 100% Lignite humin (10 t ha^{-1})	4.72	0.16	5.18	152.44	31.97	273.07
T_7: 25% PM humin (2.5 t ha^{-1}) + FYM @ 7.5 t ha^{-1}	4.61	0.14	4.52	156.56	34.71	280.25
T_8: 50% PM humin (5 t ha^{-1}) + FYM @ 5 t ha^{-1}	4.64	0.15	4.65	156.56	34.89	281.28
T_9: 75% PM humin (7.5 t ha^{-1}) + FYM @ 2.5 t ha^{-1}	4.74	0.17	4.69	160.68	35.87	282.60
T_{10}: 100% PM humin (10 t ha^{-1})	4.94	0.19	4.75	156.56	34.25	274.05
Initial	4.48	0.10	4.08	145.60	29.73	267.60
S.Em. ±	0.06	0.01	0.06	2.76	0.96	2.88
C.D. at 5%	0.18	0.02	0.19	8.19	2.85	8.56

Table 3: Effect of lignite and poultry manure based humin on secondary and micronutrient content in soil after harvest of maize

Treatments	Na	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	c mol (p+) kg^{-1}			kg ha^{-1}	mg kg^{-1}				
T_1: Absolute control	0.9	2.8	0.8	13.30	11.6	12.0	0.9	0.9	0.2
T_2: FYM @ 10 t ha^{-1} (POP)	1.07	3.23	1.17	13.95	13.63	14.44	1.22	1.21	0.34
T_3: 25% Lignite humin (2.5 t ha^{-1}) + FYM @ 7.5 t ha^{-1}	1.12	3.10	1.03	14.71	13.32	14.13	1.14	1.17	0.31
T_4: 50% Lignite humin (5 t ha^{-1}) + FYM @ 5 t ha^{-1}	1.38	3.03	0.97	15.25	12.53	13.34	1.19	1.15	0.31
T_5: 75% Lignite humin (7.5 t ha^{-1}) + FYM @ 2.5 t ha^{-1}	1.56	2.97	0.93	15.79	12.41	13.21	1.20	1.12	0.30
T_6: 100% Lignite humin (10 t ha^{-1})	1.73	2.90	0.90	14.49	12.33	13.14	1.23	1.10	0.28
T_7: 25% PM humin (2.5 t ha^{-1}) + FYM @ 7.5 t ha^{-1}	1.08	3.07	1.07	15.36	13.33	14.14	1.09	1.18	0.31
T_8: 50% PM humin (5 t ha^{-1}) + FYM @ 5 t ha^{-1}	1.23	3.00	1.03	15.36	12.51	13.32	1.25	1.15	0.31
T_9: 75% PM humin (7.5 t ha^{-1}) + FYM @ 2.5 t ha^{-1}	1.63	2.83	0.97	16.01	12.42	13.23	1.17	1.13	0.29
T_{10}: 100% PM humin (10 t ha^{-1})	1.85	2.83	0.93	14.82	12.19	12.12	1.29	1.12	0.29
Initial	0.06	2.90	0.80	13.76	12.00	14.76	1.04	1.07	0.33
S.Em. ±	0.89	2.90	0.80	13.76	1.07	13.12	0.20	1.03	0.30
C.D. at 5%	0.04	NS	NS	NS	NS	NS	NS	0.02	0.01

Table 3: Effect of lignite and poultry manure based humin on secondary and micronutrient content in soil after harvest of maize

Treatments	Na	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	c mol (p+) kg^{-1}			kg ha^{-1}	mg kg^{-1}				
T_1: Absolute control	0.93	2.83	0.83	13.30	11.63	12.00	0.96	0.98	0.27
T_2: FYM @ 10 t ha^{-1} (POP)	1.07	3.23	1.17	13.95	13.63	14.44	1.22	1.21	0.34
T_3: 25% Lignite humin (2.5 t ha^{-1}) + FYM @ 7.5 t ha^{-1}	1.12	3.10	1.03	14.71	13.32	14.13	1.14	1.17	0.31
T_4: 50% Lignite humin (5 t ha^{-1}) + FYM @ 5 t ha^{-1}	1.38	3.03	0.97	15.25	12.53	13.34	1.19	1.15	0.31
T_5: 75% Lignite humin (7.5 t ha^{-1}) + FYM @ 2.5 t ha^{-1}	1.56	2.97	0.93	15.79	12.41	13.21	1.20	1.12	0.30
T_6: 100% Lignite humin (10 t ha^{-1})	1.73	2.90	0.90	14.49	12.33	13.14	1.23	1.10	0.28
T_7: 25% PM humin (2.5 t ha^{-1}) + FYM @ 7.5 t ha^{-1}	1.08	3.07	1.07	15.36	13.33	14.14	1.09	1.18	0.31
T_8: 50% PM humin (5 t ha^{-1}) + FYM @ 5 t ha^{-1}	1.23	3.00	1.03	15.36	12.51	13.32	1.25	1.15	0.31
T_9: 75% PM humin (7.5 t ha^{-1}) + FYM @ 2.5 t ha^{-1}	1.63	2.83	0.97	16.01	12.42	13.23	1.17	1.13	0.29
T_{10}: 100% PM humin (10 t ha^{-1})	1.85	2.83	0.93	14.82	12.19	12.12	1.29	1.12	0.29
Initial	0.06	2.90	0.80	13.76	12.00	14.76	1.04	1.07	0.33
S.Em. ±	0.89	2.90	0.80	13.76	1.07	13.12	0.20	1.03	0.30
C.D. at 5%	0.04	NS	NS	NS	NS	NS	NS	0.02	0.01

Soil reaction (pH)

Significantly higher pH of soil after harvest of maize was noticed in treatment T_{10} (4.94) which received poultry manure based humin @ 10 t ha^{-1} compared to rest of the treatments. This was followed by treatment T_6 (4.72) which received lignite humin 10 t ha^{-1}. Lower soil pH was recorded in the treatment T_2 (4.45) *i.e.* 100% NPK + FYM @ 10 t ha^{-1} (Table 2). A slight increase in soil pH after harvest of maize crop has occurred due to the application of FYM and humin compared to initial soil pH. Further, soil pH increases with increasing rate of application of humin which might be due to alkaline nature of humin. Among sources of humin, poultry manure humin being more alkaline compared to lignite humin, hence, caused slightly higher soil pH compared to lignite based humin application. Besides, the increase in soil pH is due to buffering action of manures applied. Similar buffering action was reported due to application of manures by Babu and Reddy, 2000 and Sahebgouda, 2018.

Electric conductivity (dS m^{-1})

The EC of soil differed significantly due to application of different levels of lignite and poultry manure based humin (Table 2). Significantly higher EC was recorded in plots applied with PMH @ 10 t ha^{-1} (0.19 dS m^{-1}) followed by T_9: PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1}(0.17 dS m^{-1}) and T_2: FYM @ 10 t ha^{-1} (0.17 dS m^{-1}). The lower EC was noticed in control (0.13 dS m^{-1}). A slight increase in soil EC after the harvest of maize crop has occurred due to the application of FYM and humin compared to initial soil EC. The increase in soil EC is due to addition of soluble salts by these added manures. Similarly increase in soil EC was reported by many works due to addition of organic manures (Warman *et al.*, 2004 and Punitha. 2016) [24, 16].

Soil organic carbon

The organic carbon content of soil increased from initial level of 4.08 to 5.18 g kg^{-1} due to application of LH @ 10 t ha^{-1} (5.18 g kg^{-1}) and it was on par with LH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} (5.12 g kg^{-1}). Lower organic carbon content (4.26 g kg^{-1}) was noticed in T_1: control plot (Table 2). Higher organic carbon content in lignite based humin applied plots compared to poultry manure humin based treatments after harvest maize crop in soil might be attributed to higher carbon content in lignite based humin compared to poultry manure based humin. Addition of organic matter and greater root biomass with their addition which might have increased the organic carbon content in soil (Chandra Kant *et al*., 2017) [4].

Primary nutrients

There was significant difference observed with respect to available N, P_2O_5 and K_2O content in soil at harvest of the maize crop due to FYM, lignite and poultry manure based humin application (Table 2).

Significantly higher available nitrogen content in soil (160.68 kg ha^{-1}) was recorded in T_9: PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} and T_5: lignite humin @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} over all other treatments, but followed at par with T_4: lignite humin @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (156.56 kg ha^{-1}), T_7: PMH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (156.56 kg ha^{-1}), T_8: PMH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (156.56 kg ha^{-1}) and T_{10}: PMH @ 10 t ha^{-1} (156.56 kg ha^{-1}). Lower nitrogen content was recorded in T_1 (131.84 kg N ha^{-1}), which is an absolute control. Significantly higher available phosphorus content in soil was recorded in T_9: PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} (35.87 kg P_2O_5 ha^{-1}) over all other treatments, but followed at par with T_8: PMH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (34.89 kg P_2O_5 ha^{-1}), T_7: PMH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (34.71 kg P_2O_5 ha^{-1}), T_{10}: PMH @ 10 t ha^{-1} (34.25 kg P_2O_5 ha^{-1}) and T_5: lignite humin @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} (33.61 kg P_2O_5 ha^{-1}). Lower phosphorus content was recorded in T_1 (24.01 kg P_2O_5 ha^{-1}), which is an absolute control. Significantly higher available potassium content in soil was recorded in T_9: PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} (282.60 kg K_2O ha^{-1}) over all other treatments, but followed at par with T_8: PMH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (281.28 kg K_2O ha^{-1}), T_7: PMH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (280.25 kg K_2O ha^{-1}), T_4: lignite humin @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (276.64 kg K_2O ha^{-1}) and T_5: lignite humin @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} (275.97 kg K_2O ha^{-1}). Lower potassium content was recorded in T_1 (249.52 kg K_2O ha^{-1}), which is an absolute control. The available major nutrients status of soil after the harvest of crop increased significantly due to application of different levels of FYM, lignite and poultry manure based humin as compared to unfertilized control. The decrease in nutrient status in control plot might be due to crop uptake. On the other hand the higher available major nutrients status in treated plots might be attributed to addition of these elements through organic as well as inorganic sources *viz*., FYM, lignite and poultry manure based humin. Similar results were observed by Elayarajan *et al*. (2015) [9] and Shashi (2003) [19]. No much variation in major nutrient content was observed among the sources and rate of humin applied.

Sodium [c mol (p+) kg ha^{-1}]

Significantly higher available sodium content in soil was recorded in T_{10}: PMH @ 10 t ha^{-1} (1.85 c mol (p+) kg^{-1}) over rest of the treatments and lower content was recorded in T_1 (0.93 c mol (p+) kg^{-1}), where no manures and fertilizer were given (Table 3). Significant increase in soil sodium content was observed due to application of poultry manure and lignite based humin compared to control and initial value. But still the values of sodium content in soil were within the normal soil. Hence, it was not affected the soil properties and crop growth. Slight increase in sodium content due to application of humin was due to their alkali extraction.

Secondary macro nutrients

Numerically higher exchangeable calcium and magnesium content in soil was with T_2: 100% RDF + FYM @ 10 t ha^{-1} [3.23 and 1.17 c mol (p+) kg^{-1}]. Wherein, least content of calcium [2.83 c mol (p+) kg^{-1}] was recorded in T_1: absolute control, T_9: PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} and T_{10}: PMH @ 10 t ha^{-1}. Whereas, least content of magnesium was recorded in T_1 [0.83 c mol (p+) kg^{-1}], which is an absolute control (Table 3). However, higher sulphur content in the soil was with T_9: PMH @ 7.5 t ha^{-1} + FYM @ 2.5 t ha^{-1} (16.01 kg ha^{-1}). Wherein, least sulphur content was recorded in T_1 (13.30 kg ha^{-1}), which is an absolute control. Slight increase in Ca, Mg and S content in post harvest soil was observed due to application of FYM and humin manure compared to without manure application. Calcium, magnesium and sulphur content in organic sources might have helped in increasing these nutrients content of soil. Release of organic acids upon decomposition of organic sources *viz*., FYM, lignite and poultry manure based humin might have solubilized the native free lime which released Ca and Mg in free ionic forms which might have also contributed for increased Ca and Mg content during mineralization process. This finding was confirmed with Singh e*t al.* (1999) [20] and Punitha (2016) [16] who revealed that higher amount of secondary nutrients in soil due to combined application of organics with inorganic fertilizers.

Micronutrients

Significant difference was observed in DTPA extractable micro nutrients content for Zn and B and non significant with respect to Fe, Mn, and Cu in soil after harvest of maize crop and data are presented in the Table 3. Numerical variations for Fe, Mn and Cu content in soil were observed between the treatments. The content of these nutrients in soil was found higher with T_2: 100% RDF + FYM @ 10 t ha^{-1} (13.63, 14.44 and 1.29 mg kg^{-1} of Fe, Mn and Cu respectively). Wherein, least content was recorded in T_1 (11.63, 12.12 and 0.96 mg kg^{-1} of Fe, Mn and Cu respectively), which is an absolute control. Significantly higher available Zn content in soil was recorded in T_2: 100% RDF + FYM @ 10 t ha^{-1} (1.21 mg kg^{-1}) over rest of the treatments, but was at par with T_7: PMH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (1.18 mg kg^{-1}), T_3: lignite humin @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (1.17 mg kg^{-1}) and T_8: PMH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (1.15 mg kg^{-1}), T_4: lignite humin @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (1.17 mg kg^{-1}). Lower available zinc was recorded in T_1 (0.98 mg kg^{-1}), which is an absolute control plot. Whereas, significantly higher available boron content in soil was recorded in T_2: 100% RDF + FYM @ 10 t ha^{-1} (0.34 mg kg^{-1}) over rest of the treatments and lower available zinc was recorded in T_1 (0.27 mg kg^{-1}). Higher content of micronutrients due to application organic sources *viz*., FYM, lignite humin and poultry manure humin along with RDF might be attributed to more favourable conditions either through an increase in solubility of native nutrients source due to release of organic acids or release of nutrients from the organic source or possible stimulation of root absorption. The increase in concentration of the micronutrients in soil might be due to production of natural chelating agents from the organic material that helped in keeping Fe, Mn, Zn, Cu and B in soluble and more available forms for plants. Punitha (2016) [16] reported that water soluble complexes formed by organic manures (urban solid waste compost or drum compost) prevented the formation of insoluble complexes of these micronutrients with soil constituents which might have increased their availability. Duhan and Mahendra, (2002) [8] and Chhibba (2000) [6] have reported the steady improvement in organically bound Fe, Mn and Cu in green manured soil after continuous cultivation of rice. Chandrakant *et al*., (2018) [5] and Kumar and Babel (2011) [14] reported that availability of micronutrients content increased significantly with increase in organic matter content of soil.

Kernel and Stover yield (kg ha^{-1})

Significantly higher maize kernel and stover yield was with T_2: 100% RDF + FYM @ 10 t ha^{-1} (8070 and 9948 kg ha^{-1}) over all other treatments, but was statistically at par with T_7: PMH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (7711 and 9255 kg ha^{-1}), T_3: LH @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1} (7662 and 8877 kg ha^{-1}) and T_8: PMH @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} (7470 and 8844 kg ha^{-1}). Lower kernel yield was recorded in absolute control (3885 and 3907 kg ha^{-1}) (Table. 4). Application of inorganic fertilizers in combination with FYM, PM and lignite based humin significantly increased the stover and kernel yield of maize over control. This increase in yield might be attributed to increased growth and yield parameters *viz*., plant height, number of leaves per plant, cob length, number of rows per cob, number of kernels per row and test weight (Ashok and Jayadeva. 2013) [1]. Though application of humin in combination with FYM did not increase the maize yield significantly over POP, but found on par with POP when FYM was replaced with humin to the extent of 5.0 t ha^{-1} for PM humin and 2.5 t ha^{-1} for lignite based humin. Further increased application of PM humin (>5 t ha^{-1}) and lignite based humin (>2.5 t ha^{-1}) significantly decreased kernel and stover yield of maize compared to POP treatment. This suggest that FYM can be replaced to the extent of 5 t ha^{-1} with PM humin or 2.5 t ha^{-1} with lignite based humin without compromising the yield of maize. Even though higher nutrient content in poultry manure based humin compared to FYM but still recorded lower yield with increased application rate of PM humin, this might be attributed to higher amount of insolubility of nutrients content in humin based sources compared to FYM, because humin is a highly stable formed complex product and their nutrient solubility decreases with increased rate of application compared to humic acid and fulvic acid which is extracted from different organic sources. Similar results were noticed by Theng in 1999, where mobility and solubility of nutrient content in aqueous condition decreases in the order of humic acid>fulvic acid >humin in lignite based humic fractions and they also found that nutrient availability decreases with increased humin content. Among two sources of humin, application of poultry manure based humin resulted in higher grain and stover yield compared to corresponding doses of lignite humin. This higher yield might be attributed to higher nutrient content in poultry manure compared to lignite based humin (Avinash *et al*., 2017) [2].

Conclusion

From the present study, it can be concluded that application of humin residue of poultry manure and lignite after alkali extraction of humic and fulvic acids helps in significant increase in available major, secondary and micronutrients content in soil after harvest of maize crop due to application of FYM, lignite and poultry manure based humin compared to control plots without any detrimental effect on soil properties.

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