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# Characterisation and evaluation of lignite and poultry manure-based humin on Baby corn (*Zea Mays* L.) Productivity in acid soils under greenhouse conditions

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## ABSTRACT

*A pot culture experiment under greenhouse conditions was carried out at GKVK during the summer 2018 to find out the effect of levels of lignite humin (LH) and poultry manure (PMH) based humin on growth, biomass yield and uptake of baby corn in acid soils under greenhouse condition. The results revealed that application of 100 % RDF + FYM @ 10 t ha$^{-1}$ ($T_2$: POP) recorded higher growth and yield parameters viz., plant height (93 and 139 cm at 30 & 60 DAS), number of leaves plant$^{-1}$ (7.93 and 13 at 30 & 60 DAS), root length (51.00 cm) and leaf area (4211 cm$^2$ plant$^{-1}$). Similarly, higher total fresh and dry biomass (53.94 and 42.90 g plant$^{-1}$) of baby corn at 60 DAS were recorded in the same treatment and 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$^{-1}$). In all these treatments NPK nutrients were applied as per the recommended dose of fertilizers. Significantly higher N, P, and K content in baby corn plant was recorded with $T_2$ (1.48, 0.47, and 1.13 %, respectively) followed by $T_7$, $T_3$, $T_8$ and $T_9$ treatments and found on par with each other. Significantly higher uptake of major NPK nutrients (0.64, 0.20 and 0.49 NPK g plant$^{-1}$, respectively) was observed in $T_2$ and found on par with $T_7$ and $T_3$ treatments. These results clearly indicate that the humin residue of poultry manure and lignite after extraction of humic acid can be used for baby corn cultivation to the tune of 5 t ha$^{-1}$ and 2.5 t ha$^{-1}$, respectively along with 100 % NPK + FYM (@ 5 t ha$^{-1}$ with PMH or @7.5 t ha$^{-1}$ with LH) without any detrimental effect on maize productivity.*

***Keywords-*** *FYM, Lignite based humin and Poultry manure based humin and Baby corn biomass production*

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## 1. INTRODUCTION

Organic matter is considered as the "Life of soil" due to its importance in maintaining the 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 soil fertility in a sustainable manner by utilizing locally available organic wastes because these wastes contain substantial amounts of nutrients which are necessary for 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 [7].

The most active fraction of humus is the humic substances. a group of naturally occurring, biogenic, heterogeneous organic substances that can generally be characterized as yellow to black colored high molecular weight material [13]. 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 [28].

Now a day's 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), cocopeat, pressmud, 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, the humin fraction which accounts 60-90 percent of organic manure gets very little attention. It seems to be somewhat inert but it has been described as acting like a sponge, soaking up nutrients. 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 [9]. Research on use of such huge quantity of humin generated after alkali extraction of HA/FA for crop production. Hence, a study was initiated to know the possibility of using the humin residue left after alkali extraction for maize production in acid soil.

## 2. MATERIALS AND METHODS

### *2.1 Extraction of humic substances*

In the present study two sources of manures such as lignite and

Poulty Manure (PM) were used for the extraction of humin. Lignite was procured from Neyveli Lignite Corporation of India, located at Neyveli, Tamil Nadu and poultry manure from a Poultry Farm, in 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 an end-to-end shaker. The dark-coloured supernatant containing Humic Acid (HA) and Fulvic Acid (FA) was separated by centrifugation and collected. The extraction was repeated thrice with 50 ml of extractant for complete extraction of the humic substances. The residue left after extraction is humin [24]. The humic substances (HA, FA and Humin) recovered from poultry manure and lignite were weighed and expressed in percent and further subjected for characterization. Similarly, for field experiment bulk extraction of humin was carried by treating the required quantity of poultry manure and lignite with 0.1 *N* NaOH in 100L drum capacity followed by filtering with the muslin cloth.

### *2.2 Characterization of manures and Humin*

The FYM, PM, lignite and humin residues from PM and lignite were characterized for chemical properties *viz*., pH, EC, and OC [15], and nutrient composition *viz.,* total major nutrients (N, P and K), secondary nutrients (Ca, Mg and S), sodium [21] , and micronutrients (Zn, Cu, Fe, Mn and B) [19]. They also subjected water-holding capacity (WHC) and bulk density (BD) [20].

### *2.3 Pot culture experiment*

Two sets of pot culture experiments under greenhouse condition were carried out at GKVK during *Summer* 2018 to find out the effect of levels of lignite and poultry manure-based humin on the growth and biomass yield of baby corn (Var. C.P. B472) in different type of soils separately (acid and alkali soils).

Two types of soils were collected from different locations after analyzing pH of the soils. Among those, acid soil was collected from 'E' block in the experiment block of KVK, Hadonahalli, Doddaballapura taluk, Bengaluru rural district, and alkali soil was collected from ZARS experimental plot, V. C. farm, Mandya. The soil used for the pot experiment-I for acidic soil with acidic in reaction (pH 4.48) with low electrical conductivity of 0.10 dS $m^{-1}$. The organic carbon content of soil was low (4.08 g $kg^{-1}$). The available nitrogen content was low (145.60 kg $ha^{-1}$) and medium in available $P_20_5$ (29.73 kg $ha^{-1}$) and available $K_2O$ content (267.60 kg $ha^{-1}$). The soil used for the pot experiment for the soil was alkali in reaction (pH 8.73) with an electrical conductivity of 2.22 dS $m^{-1}$. The organic carbon content of soil was low (4.71 g $kg^{-1}$). With respect to major nutrients, the available nitrogen content was medium (259.81 kg $ha^{-1}$) and medium in available $P_20_5$ (28.76 kg $ha^{-1}$) and available $K_2O$ (239.85 kg $ha^{-1}$) content (Table 1).

The experiment was laid out in a complete block design (CRD) with ten treatments. 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 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 $ha^{-1}$.

The same set of treatments were imposed separately for acid and alkali soils for which five kg of air-dried soil sample passed through 2 mm sieve was filled in plastic pots. Calculated quantity of humin residues from PM and lignite was added as per treatments along with a recommended dose of fertilizers (150: 75: 40 kg NPK $ha^{-1}$ for baby corn). The pots that received absolute control and 100 % NPK+FYM @ 10 t $ha^{-1}$ were considered as check since humin was not applied. Three baby corn seeds per pot were sown. After the germination of baby corn seeds, single plant was maintained per pot. The pots were maintained at field capacity for moisture and kept under greenhouse conditions by following timely plant protection measures. The crop was grown for 60 days and observations on growth and biomass yield were recorded.

Observations on growth parameters like plant height, number of leaves and leaf area were recorded at 30 and 60 DAS. The experiment was carried out up to 60 days and at the end, root and shoot were separated and biomass was recorded. The seeds of baby corn did not germinate in alkali soils, hence growth and yield parameters were not taken in alkali soil and parameters were considered only for acid soil. All these data's were statistically analyzed by adopting the standard procedure [11].

The initial soil samples before treatment imposition and after harvest was collected and subjected for analysis of physico-chemical properties such as soil texture, pH and EC [15], OC [34], available micro [19] and macronutrients[15]. At harvest, representative plant samples were collected treatment wise and analysed for total NPK nutrients in kernel and stover samples [29]. The uptake of these nutrients by baby corn crop was computed.

## 3. Result and discussion

### *3.1 Percent recovery of humic substances from lignite and poultry manure*

The recovery percentage of HA, FA and Humin from Lignite and Poultry Manure are presented in Table 2. Higher recovery of 25.63 % HA and 9.85 % of FA was recorded for lignite compared to poultry manure (8.38 % HA and 4.92 % FA) (Table 2). Whereas, higher recovery of humin was recorded in poultry manure (86.7 %) compared to lignite (64.52 %). The variation in recovery of humic substances might be due to elemental composition of organic sources [10].

### *3.2 Elemental composition and $E_4/E_6$ ratio of humic substances*

The humic acid extracted from lignite coal was higher in carbon and hydrogen content (56.71 and 4.78 %) and was lower in nitrogen and oxygen (2.67 and 35.84 %) content. While, poultry manure showed higher nitrogen and oxygen (5.91 and 44.64 %) content and lower in carbon and hydrogen (45.26 and 4.19 %) (Table 3). The higher carbon content and hydrogen content in humic acid extracted from lignite coal might be due to the presence of higher carbon content in lignite coal compared to poultry manure. Similar results were reported,where they found higher carbon and hydrogen content in humic acid extracted from lignitic coal. Higher nitrogen and oxygen content in humic acid extracted from poultry manure compared to lignitic coal might be due to the presence of higher nitrogen content in poultry manure compared to lignitic coal [5]. Higher nitrogen and oxygen content in humic acid extracted from poultry manure compared to other sources of humic acid extraction [10] and [2].

The $E_4/E_6$ ratio is a valid and informative index for the characterization of humic substances with respect of aromaticity [18]. In the present study, the $E_4/E_6$ ratio was higher in the humic acid extracted from poultry manure (5.26)

compared to humic acid extracted from lignite coal (4.63). Higher $E_4/E_6$ ratio indicates more aliphatic nature of the fractions [10] and it also reflects a low degree of aromatic condensation.

### *3.3 Characterization of organic manures and Humin*

The data on the chemical composition and characteristics of organic materials like FYM, poultry manure and lignite before and after alkali extraction are presented in the Table 4. The analysis of the samples revealed that the FYM was slightly acidic (pH 6.04), with 0.77 dS $m^{-1}$ electrical conductivity, 0.47 g $m^{-3}$, Bulk density, 43.86 per cent water holding capacity and 17.42 per cent organic carbon content. Lignite and poultry manure recorded acidic (4.60) and slightly alkaline (7.83) pH, respectively which after alkali extraction raised to 6.20 and 9.89, respectively. Similarly, due to alkali treatments the electrical conductivity was raised from 0.52 and 0.94 to 0.82 and 1.15 dS $m^{-1}$, respectively in lignite and poultry manure. However, the electrical conductivity is well within the permisiable limit (<4.0 dS $m^{-1}$). Among the sources, poultry manure humin was rich in nutrients compared to lignite based humin [2]. Total macro nutrients (N, P, K, Ca, Mg and sulphur) and micronurients content were recorded higher in both poultry manure and its humin compared to lignite and its humin. However, the organic carbon content was higher in lignite compared to poultry manure. All these nutrients content were found slightly lower after alkali extraction (Humin) compared to before extration.

With respect to Carbon to Nitrogen ratio, poulty manure recorded very low (11.84 & 15.45, respectively before and after alkali extraction) whereas lignite recorded very high (125.26 and 117.61, respectively before and after alkali extraction). The higher C:N in lignite is due to higher carbon and lower nitrogen content. FYM was having medium in C:N ratio (37.06).

### *3.4 Use of lignite and poultry manure-based humin on growth (30 and 60 DAS) and biomass (60 DAS) of baby corn in an acid soil*

***3.4.1 Effect on growth parameters:*** There was no significant difference observed for plant height and number of leaves per plant at 30 DAS between the treatments. However, higher plant height (93.00 cm) and number of leaves per plant (7.93 $plant^{-1}$) was observed in $T_2$: 100 % RDF + FYM @ 10 t $ha^{-1}$. Wherein, lower plant height (75.00 cm) and number of leaves per plant (6.73 $plant^{-1}$) was recorded in $T_1$, which is an absolute control (Table 5).

At 60 DAS, significantly higher plant height (139.00 cm) was observed in $T_2$: 100 % RDF + FYM @ 10 t $ha^{-1}$ followed by $T_7$: PMH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (136.00 cm), $T_8$: PMH @ 5 t $ha^{-1}$ + FYM @ 5 t $ha^{-1}$(131.33 cm) and $T_3$: LH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$(130.33 cm) (Table 5). These treatments were found on par with each other and significant or superior over all other treatments. Lower plant height was observed in $T_1$: Absolute control (116.33 cm). Similarly, higher numbers of leaves per plant were recorded in $T_2$: 100 % RDF + FYM @ 10 t $ha^{-1}$ (13.00 $plant^{-1}$) and it was at par with $T_7$: PMH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (12.33 $plant^{-1}$), $T_3$: LH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (12.33 $plant^{-1}$) and $T_8$: PMH @ 5 t $ha^{-1}$ + FYM @ 5 t $ha^{-1}$ (12.00 $plant^{-1}$) and $T_4$: LH @ 5 t $ha^{-1}$ + FYM @ 5 t $ha^{-1}$ (11.67 $plant^{-1}$). Lower number of leaves per plant were recorded in $T_1$ (10.33 $plant^{-1}$) treatment which is the absolute control.

Significantly higher root length and leaf area was recorded in $T_2$ (51.00 cm and 4211 $cm^2$ $plant^{-1}$) compared to rest of the treatments but was at par with $T_7$ (48.00 cm and 4062 $cm^2$ $plant^{-1}$) and $T_3$ (45.20 cm). Lower root length (31.40 cm and 2030 $cm^2$ $plant^{-1}$) was observed in absolute control treatment ($T_1$) (Table 5).

***3.4.2 Effect on Biomass Production:*** Significantly higher fresh and dry shoot weight of baby corn was recorded in $T_2$ (42.86 and 34.22 g $plant^{-1}$) and it was found on par with $T_7$ (41.12 and 32.75 g $plant^{-1}$), $T_3$ (40.23 and 30.03 g $plant^{-1}$) and $T_8$ (38.58 and 28.92 g $plant^{-1}$) (Table 5). Lower was recorded in absolute control treatment $T_1$(27.31and 20.93 g $plant^{-1}$). Significantly higher fresh and dry root weight was noticed in $T_2$ (11.08 and 8.68 g $plant^{-1}$) and it was statistically at par with $T_7$ (9.10 and 7.19 g $plant^{-1}$), $T_3$ (8.04 and 6.30 g $plant^{-1}$) and $T_8$ (7.75 and 5.85 g $plant^{-1}$) and lower was recorded in absolute control($T_1$: 6.28 and 4.74 g $plant^{-1}$).

Significantly higher total fresh and dry biomass was noticed in $T_2$: 100 % RDF + FYM @ 10 t $ha^{-1}$ (53.94 and 42.90 g $plant^{-1}$) over all other treatments, but was statistically at par with $T_7$: PMH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (50.22 and 39.94 g $plant^{-1}$), $T_3$: LH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (48.27 and 36.33 g $plant^{-1}$) and $T_8$: PMH @ 5 t $ha^{-1}$ + FYM @ 5 t $ha^{-1}$ (46.33 and 34.77 g $plant^{-1}$) (Table 5). Lower total fresh and dry biomass was recorded in absolute control($T_1$: 33.59 and 25.67 g $plant^{-1}$).

Significant differences were observed in growth parameters and total biomass after 60 DAS of baby corn due to application of different sources of humin as well as FYM. Application of humin by replacing FYM to the extent of 50 % with poultry manure humin (5 t $ha^{-1}$) and 25 % with lignite humin (2.5 t $ha^{-1}$) resulted in on par values in the growth parameters and total biomass yield compared to 100 % FYM treated plot. Further, increased application of poultry manure-based humin (>5 t $ha^{-1}$) and lignite-based humin (>2.5 t $ha^{-1}$) significantly decreased growth parameters and total biomass.

Increased crop growth in $T_2$ followed by humin-treated plots ($T_7$, $T_3$ and $T_8$) might be attributed to the balanced application of nutrients through organic manures *viz*., FYM, lignite and poultry manures as well as inorganic fertilizers which might increase the physiological processes in crop plants leading to higher growth and increased photosynthate. Similar effects of organic manures on crop growth are reported in sweet corn [17] and [16]. This might also be due to better utilization of NPK supply and improved physico-chemical properties of soil [23] . Integration of mineral fertilizers with organic manures might also have increased nutrient availability with slow release in soil to the tune of crop requirements [1]. Similar improvement in growth components of baby corn due to organic sources of nutrients in baby corn [32] and [17].

Further increased rate of application of poultry manure-based humin (>5 t $ha^{-1}$) and lignite-based humin (>2.5 t $ha^{-1}$) significantly decreased growth and biomass yield of baby corn at 60 DAS. This might be due to the fact that, among the fractions of humic substances, humin may be coated with hydrocarbons or lipids (fats) that were stripped during the reaction with nutrients, making them insoluble to aqueous solvents [9]. Where, humin is a highly stable formed complex product and their nutrient solubility decreases with an increased rate of application compared to humic acid and fulvic acid which is extracted from different organic sources [30]. Similarly, they observed that solubility and mobility of nutrient content in aqueous solution decreases in the order of humic acid>fulvic acid >humin in lignite-based humic fractions and they also found that nutrient availability decreased with increased humin content.

These results support the present experiment that even though the nutrient content is higher and narrower the C:N ratio in poultry manure-based humin compared to FYM with increased application rate the yield was recorded to be lower, this might be attributed to the fact that higher rate of insolubility of nutrients in humin based sources compared to other organic sources such

as FYM. Significantly increased fresh shoot weight, dry shoot weight, fresh root weight, dry shoot weight, total fresh biomass yield and total dry biomass yield of baby corn at 60 DAS might be attributed to increased growth and yield parameters *viz*., plant height, number of leaves per plant, root length and leaf area [17]. Among the two sources of humin, poultry manure-based humin recorded higher growth and biomass yield compared to the lignite based humin which might be attributed to higher nutrient content and narrow C:N ratio in poultry manure humin compared to lignite based humin [2].

***3.5 Use of lignite and poultry manure based humin on primary nutrient uptake of baby corn at 60 DAS in an acid soil***

***3.5.1 Effect on nutrient Content:*** Significantly higher N, P and K content in baby corn plant was recorded with $T_2$: 100 % RDF + FYM @ 10 t ha$^{-1}$ (1.48, 0.47 and 1.13 %, respectively) over all the other treatments, but was followed at par by $T_7$: PMH @ 2.5 t ha$^{-1}$ + FYM @ 7.5 t ha$^{-1}$ (1.42, 0.46 and 1.11 %, respectively), $T_3$: LH @ 2.5 t ha$^{-1}$ + FYM @ 7.5 t ha$^{-1}$ (1.40, 0.45 and 1.07 %, respectively), $T_8$: PMH @ 5 t ha$^{-1}$ + FYM @ 5 t ha$^{-1}$ (1.39, 0.45 and 1.06 %, respectively) and $T_9$: PMH @ 7.5 t ha$^{-1}$ + FYM @ 2.5 t ha$^{-1}$ (1.39, 0.45 and 1.06 %, respectively) (Table 6). Lower NPK content was recorded in $T_1$ (1.29, 0.41 and 0.98 %, respectively) which is the absolute control. Numerically higher value of N, P and K was observed with application of either FYM or other organic sources *viz.*, lignite and poultry manure based humin along with RDF this might be attributed to higher availability of nutrients and their supply to the roots. It might have helped in enhanced nutrient absorption and mobilisation through mineralization process [27] and [26].

***3.5.2 Effect on nutrient Uptake:*** Significantly higher N, P and K uptake by baby corn plant at 60 DAS was recorded in $T_2$: 100 % RDF + FYM @ 10 t ha$^{-1}$ (0.64, 0.20 and 0.49 g plant$^{-1}$, respectively) over all other treatments, but was followed at par by $T_7$: PMH @ 2.5 t ha$^{-1}$ + FYM @ 7.5 t ha$^{-1}$ (0.57, 0.18 and 0.44 g plant$^{-1}$, respectively) and $T_3$: LH @ 2.5 t ha$^{-1}$ + FYM @ 7.5 t ha$^{-1}$ (0.51, 0.16 and 0.39 g plant$^{-1}$, respectively) (Table 6). Lower uptake of these nutrients was recorded in $T_1$ (0.33, 0.11 and 0.25 g plant$^{-1}$, respectively) where no manures and fertilizers were applied.

Nutrients uptake is a product of nutrient content and biomass yield. Higher uptake of major nutrient in $T_2$ and other treatments compared to control might be attributed to higher concentration of nutrients (Table 6) and biomass yield (Table 5). Higher uptake of nutrient might also be due to better availability of nutrient in soil due to addition of both organic and inorganic source of nutrient and improvement in soil properties. Higher uptake of N, P and K was due to the favourable influence of major nutrients on vegetative growth which in turn absorb higher amount of nutrients from the rhizosphere resulting in higher dry matter production [25] and higher N, P and K uptake by rice with organic manure application over control [14].

Further increased application of poultry manure-based humin (>5 t ha$^{-1}$) and lignite-based humin (>2.5 t ha$^{-1}$) significantly decreased the nutrient uptake by baby corn. Decreased nutrient uptake with increased humin application might be due higher insolubility nature of these substances [12]. Besides, humin has lower nutrient content due to removal of most soluble nutrients along with humic and fulvic acids by alkali extraction. This might be the reason for decreased nutrient uptake in baby corn with an increased humin application rate. Among the sources of humin application poultry manure-based humin recorded higher nutrient uptake in baby corn plant compared to lignite-based humin which might be due to higher nutrient content in poultry manure based humin than lignite based humin [23].

***3.6 Use of lignite and poultry manure based humin on soil properties at harvest of baby corn in an acid soil***

***Effect on soil Properties:*** The nutrient status of soil after the crop harvest under different treatments is dependent on both supply of nutrients through various sources and uptake by the crop besides the losses or transformation into undesirable forms. However, significant differences were observed in the nutrient status of the soil after the harvest of baby corn plant at 60 DAS due to treatment imposition (Table 7)

***3.6.1 Effect on soil pH, electrical conductivity and organic carbon content:*** Significantly higher pH of soil after harvest of baby corn plant at 60 DAS was noticed in treatment $T_{10}$ (4.79) which received PMH @ 10 t ha$^{-1}$ compared to absolute control (4.51), $T_2$: FYM @ 10 t ha$^{-1}$ (4.45), $T_3$: LH @2.5 t ha$^{-1}$ + FYM @ 7.5 t ha$^{-1}$ (4.52) and $T_4$: LH @ 5 t ha$^{-1}$ + FYM @ 5 t ha$^{-1}$ (4.52) treatments. But found on par with rest of the treatments. Lower soil pH was recorded in the treatment $T_2$ (4.45) *i.e.* 100 % NPK + FYM @ 10 t ha$^{-1}$ (Table 7). Wherein, there was no significant difference observed for electrical conductivity in soil between the treatments at 60 DAS. However, higher electrical conductivity values in soil (0.18 dS m$^{-1}$) was recorded in $T_{10}$: PMH @ 10 t ha$^{-1}$. Wherein, the least value was noticed in the absolute control plot (0.14 dS m$^{-1}$)

There was slight increase in soil pH due to the application of organic manures *viz*., FYM and humin compared to initial soil pH. Increase in pH might be due to addition of FYM alone or in combination with fertilizer [31]. The soil pH increased with increase in rate of application of both poultry manure and lignite-based humin. This may be due to alkaline nature of humin material. Among the humin sources, poultry manure based humin was more alkali (9.89) in nature compared to lignite based humin (6.20). Hence, the treatments which received poultry manure humin have recorded higher soil pH compared to treatments that received lignite based humin.

The organic carbon content of soil increased from initial level of 4.08 to 5.13 g kg$^{-1}$ after harvest at 60 DAS. Significantly higher organic carbon content was recorded in $T_6$: LH @ 10 t ha$^{-1}$ (5.13 g kg$^{-1}$) and it was on par with $T_5$: LH @ 7.5 t ha$^{-1}$ + FYM @ 2.5 t ha$^{-1}$ (5.05 g kg$^{-1}$). Lower organic carbon content was noticed in $T_1$: control plot (4.13 g kg$^{-1}$) (Table 7).

In general, there was slight increase in soil organic carbon content due to the application of organic manures *viz*., FYM and humin compared to initial soil organic carbon status. Increased organic carbon might be due to the addition of organic matter and greater root biomass with their addition which increases the organic carbon content in the soil [4]. Similar increase in organic carbon content in soil due to application of organic manures [33], [26] and [22] . Higher organic carbon content in lignite based humin applied plots compared to poultry manure-based treatments after harvest of baby corn in soil might be attributed to higher carbon content in lignite-based humin (49.41 %) compared to poultry manure-based humin (31.38 %). Further, lignite being more resistant for mineralization compared to poultry manure might have resulted in higher accumulation of organic carbon in the soil [6].

***3.6.2 Effect on soil available major nutrients (N, $P_2O_5$ and $K_2O$):*** There was significant difference observed with respect to N, $P_2O_5$ and $K_2O$ content in soil at harvest of the baby corn plant at 60 DAS due to lignite and poultry manure based humin application (Table 7).

Significantly higher available nitrogen content in soil at 60 DAS was recorded in $T_9$: PMH @ 7.5 t $ha^{-1}$ + FYM @ 2.5 t $ha^{-1}$ (171.73 kg N $ha^{-1}$) and $T_8$: PMH @ 5 t $ha^{-1}$ + FYM @ 5 t $ha^{-1}$ (171.73 kg N $ha^{-1}$) over $T_1$: Absolute control (141.07 kg N $ha^{-1}$), $T_2$: FYM @ 10 t $ha^{-1}$ (156.40 kg N $ha^{-1}$) and $T_6$: lignite humin @ 10 t $ha^{-1}$ (153.33 kg N $ha^{-1}$) and found at par with all other treatments. Lower nitrogen content was recorded in $T_1$ (141.07 kg N $ha^{-1}$), which is an absolute control. Significantly higher available phosphorus content in soil was recorded in $T_7$: PMH @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (40.10 kg $P_2O_5$ $ha^{-1}$) over all other treatments, but was at par with $T_8$: PMH @ 5 t $ha^{-1}$ + FYM @ 5 t $ha^{-1}$ (39.78 kg $P_2O_5$ $ha^{-1}$) and $T_9$: PMH @ 7.5 t $ha^{-1}$ + FYM @ 2.5 t $ha^{-1}$ (38.13 kg $P_2O_5$ $ha^{-1}$). Lower phosphorus content was recorded in $T_1$ (26.53 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 $ha^{-1}$ (286.00 kg $K_2O$ $ha^{-1}$) over $T_1$: Absolute control (261.92 kg $K_2O$ $ha^{-1}$), $T_2$: FYM @ 10 t $ha^{-1}$ (277.64 kg $K_2O$ $ha^{-1}$), $T_3$: lignite humin @ 2.5 t $ha^{-1}$ + FYM @ 7.5 t $ha^{-1}$ (275.40 kg $K_2O$ $ha^{-1}$) and $T_6$: lignite humin @ 10 t $ha^{-1}$ (275.36 kg $K_2O$ $ha^{-1}$) and found at par with all other treatments. Lower potassium content was recorded in $T_1$ (261.92 kg $K_2O$ $ha^{-1}$), which is an absolute control.

Compared to initial soil status, addition of organic sources viz., different levels of FYM, lignite and poultry manure based humin tended to increase available nitrogen, phosphorus and potassium status of soil significantly as compared to control. The decrease in control plot might be attributed to crop uptake and loss of nutrients by leaching. Addition of FYM and humin to soil increased the nutrient availability to crop due to increased microbial activity and mineralization process, thereby ensuring their availability for longer period [8] and [21]. Higher nutrient status in 100 per cent humin applied plots compared to FYM might be attributed to increased insoluble form of nutrients as compared to FYM and it might also be due to lower nutrient uptake compared to FYM applied plots. Higher available N, P and K content was recorded in poultry manure based humin applied plots compared to lignite based treatments after harvest of baby corn. This might be attributed to higher NPK content in poultry manure-based humin compared to lignite-based humin.

## Conclusion

From the present study, it can be concluded that the application of humin residue of poultry manure and lignite after alkali extraction of humic and fulvic acids can be used for baby corn production to the tune of 5 t $ha^{-1}$ Poultry manure humin and 2.5 t $ha^{-1}$ lignite humin along with 100 % RDF and FYM (@ 5 t $ha^{-1}$ with PMH or @ 7.5 t $ha^{-1}$ with LH) without compromising on yield and nutrient uptake in acid soils.

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

| Sl. No. | Soil properties | Acid Soil | Neutral Soil |
|---|---|---|---|
| 1 | pH (1:2.5 soil:water suspension) | 4.48 | 8.73 |
| 2 | Electrical conductivity (dS $m^{-1}$) | 0.10 | 2.22 |
| 3 | Organic carbon (g $kg^{-1}$) | 4.08 | 4.71 |
| 4 | Available nitrogen (kg $ha^{-1}$) | 145.60 | 259.81 |
| 5 | Available phosphorus (kg $P_2O_5$ $ha^{-1}$) | 29.73 | 28.76 |
| 6 | Available potassium (kg $K_2O$ $ha^{-1}$) | 267.60 | 239.85 |
| 7 | Exhangeable Sodium (cmol ($p^+$) $kg^{-1}$) | 0.06 | 10.93 |
| 8 | Exchangeable calcium (cmol ($p^+$) $kg^{-1}$) | 2.90 | 6.70 |
| 9 | Exchangeable magnesium (cmol ($p^+$) $kg^{-1}$) | 0.80 | 4.07 |
| 10 | Available Sulphur (mg $kg^{-1}$) | 13.76 | 43.86 |
| 11 | DTPA Extractable iron (mg $kg^{-1}$) | 12.00 | 13.71 |
| 12 | DTPA Extractable manganese (mg $kg^{-1}$) | 14.76 | 10.15 |
| 13 | DTPA Extractable copper (mg $kg^{-1}$) | 1.04 | 1.03 |
| 14 | DTPA Extractable zinc (mg $kg^{-1}$) | 1.07 | 1.13 |

*Table 2: Recovery of humic substances extracted from different Sources (%)*

| Sources | Humic Acid | Fulvic Acid | Humin |
|---|---|---|---|
| Poultry Manure | 8.38 | 4.92 | 86.70 |
| Lignite | 25.63 | 9.85 | 64.52 |

*Table 3: Elemental composition and E4/E6 ratio of humic acid from lignite and poultry manure*

| Content of elements | Sources | |
|---|---|---|
| | Lignite | Poultry Manure |
| C (%) | 56.71 | 45.26 |

| | | |
|---|---|---|
| **N (%)** | 2.67 | 5.91 |
| **H (%)** | 4.78 | 4.19 |
| **O (%)** | 35.84 | 44.64 |
| **$E_4/E_6$ ratio** | 4.63 | 5.26 |

***Table 4: Chemical composition and characteristics of organic manures***

| Parameters | FYM | Lignite | | Poultry manure | |
|---|---|---|---|---|---|
| | | Before alkali extraction | After alkali extraction (humin) | Before alkali extraction | After alkali extraction (humin) |
| pH (1:5) | 6.04 | 4.60 | 6.20 | 7.83 | 9.89 |
| EC (ds $m^{-1}$) | 0.77 | 0.52 | 0.82 | 0.94 | 1.15 |
| OC (%) | 17.42 | 56.34 | 49.41 | 33.05 | 31.38 |
| Total N (%) | 0.47 | 0.45 | 0.42 | 2.79 | 2.03 |
| Total P (%) | 0.32 | 0.30 | 0.25 | 1.58 | 1.04 |
| Total K (%) | 0.43 | 0.43 | 0.39 | 1.97 | 1.36 |
| Total Na (%) | 0.23 | 0.07 | 0.26 | 0.53 | 0.82 |
| Total Ca (%) | 1.48 | 1.60 | 1.30 | 3.90 | 2.90 |
| Total Mg (%) | 0.73 | 0.70 | 0.50 | 1.80 | 1.40 |
| Total S (%) | 0.21 | 0.24 | 0.22 | 0.52 | 0.44 |
| Total Fe (mg $kg^{-1}$) | 1356.30 | 985.26 | 650.06 | 3750.00 | 1389.71 |
| Total Mn (mg $kg^{-1}$) | 167.24 | 174.00 | 73.45 | 533.80 | 217.95 |
| Total Cu (mg $kg^{-1}$) | 35.45 | 43.62 | 23.75 | 73.60 | 52.87 |
| Total Zn (mg $kg^{-1}$) | 72.32 | 42.25 | 41.13 | 468.00 | 183.41 |
| Total B (mg $kg^{-1}$) | 44.92 | 38.74 | 32.68 | 75.12 | 49.86 |
| BD (Mg $m^{-3}$) | 0.47 | 0.43 | 0.61 | 0.49 | 0.59 |
| MWHC (%) | 43.86 | 41.66 | 38.64 | 46.05 | 39.82 |
| C:N ratio | 37.06 | 125.26 | 117.61 | 11.84 | 15.45 |

***Table 5: Effect of lignite and poultry manure based humin on growth (30 and 60 DAS) and biomass (60 DAS) of baby corn in an acid soil***

| Treatments | Plant height (cm) | | Leaves $plant^{-1}$ | | Root length (cm) | Leaf area ($cm^2$ $plant^{-1}$) | Shoot weight (g $plant^{-1}$) | | Root weight (g $plant^{-1}$) | | Total Biomass (g $plant^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fresh | Dry | Fresh | Dry | Fresh | Dry |
| **DAS** | 30 DAS | 60 DAS | 30 DAS | 60 DAS | 60 DAS | 60 DAS | 60 DAS | 60 DAS | 60 DAS | 60 DAS | 60 DAS | 60 DAS |
| **$T_1$** | 75.00 | 116.33 | 6.73 | 10.33 | 31.40 | 2030 | 27.31 | 20.93 | 6.28 | 4.74 | 33.59 | 25.67 |
| **$T_2$** | 93.00 | 139.00 | 7.93 | 13.00 | 51.00 | 4211 | 42.86 | 34.22 | 11.08 | 8.68 | 53.94 | 42.90 |
| **$T_3$** | 87.33 | 130.33 | 7.60 | 12.33 | 45.20 | 3785 | 40.23 | 30.03 | 8.04 | 6.30 | 48.27 | 36.33 |
| **$T_4$** | 84.00 | 127.67 | 7.53 | 11.67 | 40.30 | 3395 | 34.01 | 25.65 | 7.20 | 5.71 | 41.21 | 31.36 |
| **$T_5$** | 80.67 | 123.00 | 7.53 | 11.33 | 37.20 | 2938 | 32.01 | 24.81 | 7.14 | 5.57 | 39.15 | 30.38 |
| **$T_6$** | 78.67 | 120.33 | 7.47 | 10.67 | 33.10 | 2629 | 28.30 | 22.01 | 6.55 | 5.01 | 34.85 | 27.02 |
| **$T_7$** | 91.33 | 136.00 | 7.87 | 12.33 | 48.00 | 4062 | 41.12 | 32.75 | 9.10 | 7.19 | 50.22 | 39.94 |
| **$T_8$** | 85.00 | 131.33 | 7.60 | 12.00 | 43.10 | 3501 | 38.58 | 28.92 | 7.75 | 5.85 | 46.33 | 34.77 |
| **$T_9$** | 81.00 | 125.00 | 7.47 | 11.33 | 38.60 | 3335 | 32.90 | 25.14 | 7.18 | 5.61 | 40.08 | 30.75 |
| **$T_{10}$** | 80.67 | 120.67 | 7.47 | 11.00 | 35.20 | 2826 | 29.82 | 22.82 | 7.11 | 5.36 | 36.94 | 28.18 |
| **S.Em.±** | 6.15 | 3.07 | 0.41 | 0.53 | 2.20 | 141.13 | 2.29 | 2.63 | 1.15 | 0.87 | 3.12 | 2.74 |
| **C.D. at 5%** | NS | 9.04 | NS | 1.55 | 6.50 | 416.33 | 6.75 | 7.76 | 3.39 | 2.57 | 9.22 | 8.10 |

| Treatment details | |
|---|---|
| $T_1$: Absolute control | $T_6$: 100 % Lignite humin (10 t ha$^{-1}$) |
| $T_2$: FYM @ 10 t ha$^{-1}$ (POP) | $T_7$: 25 % PM humin (2.5 t ha$^{-1}$) + FYM @ 7.5 t ha$^{-1}$ |
| $T_3$: 25 % Lignite humin (2.5 t ha$^{-1}$) + FYM @ 7.5 t ha$^{-1}$ | $T_8$: 50 % PM humin (5 t ha$^{-1}$) + FYM @ 5 t ha$^{-1}$ |
| $T_4$: 50 % Lignite humin (5 t ha$^{-1}$) + FYM @ 5 t ha$^{-1}$ | $T_9$: 75 % PM humin (7.5 t ha$^{-1}$) + FYM @ 2.5 t ha$^{-1}$ |
| $T_5$: 75 % Lignite humin (7.5 t ha$^{-1}$) + FYM @ 2.5 t ha$^{-1}$ | $T_{10}$: 100 % PM humin (10 t ha$^{-1}$) |

***Table 6: Effect of lignite and poultry manure based humin on primary nutrient content and uptake of baby corn at 60 DAS in an acid soil***

| Treatments | N | P | K | N | P | K |
|---|---|---|---|---|---|---|
| | % | | | g plant$^{-1}$ | | |
| $T_1$: Absolute control | 1.29 | 0.41 | 0.98 | 0.33 | 0.11 | 0.25 |
| $T_2$: FYM @ 10 t ha$^{-1}$ (POP) | 1.48 | 0.47 | 1.13 | 0.64 | 0.20 | 0.49 |
| $T_3$: 25 % Lignite humin (2.5 t ha$^{-1}$) + FYM @ 7.5 t ha$^{-1}$ | 1.40 | 0.45 | 1.07 | 0.51 | 0.16 | 0.39 |
| $T_4$: 50 % Lignite humin (5 t ha$^{-1}$) + FYM @ 5 t ha$^{-1}$ | 1.36 | 0.43 | 1.05 | 0.43 | 0.13 | 0.33 |
| $T_5$: 75 % Lignite humin (7.5 t ha$^{-1}$) + FYM @ 2.5 t ha$^{-1}$ | 1.36 | 0.43 | 1.05 | 0.41 | 0.13 | 0.32 |
| $T_6$: 100 % Lignite humin (10 t ha$^{-1}$) | 1.31 | 0.41 | 1.03 | 0.35 | 0.11 | 0.28 |
| $T_7$: 25 % PM humin (2.5 t ha$^{-1}$) + FYM @ 7.5 t ha$^{-1}$ | 1.42 | 0.46 | 1.11 | 0.57 | 0.18 | 0.44 |
| $T_8$: 50 % PM humin (5 t ha$^{-1}$) + FYM @ 5 t ha$^{-1}$ | 1.39 | 0.45 | 1.06 | 0.48 | 0.16 | 0.37 |
| $T_9$: 75 % PM humin (7.5 t ha$^{-1}$) + FYM @ 2.5 t ha$^{-1}$ | 1.39 | 0.45 | 1.06 | 0.43 | 0.14 | 0.32 |
| $T_{10}$: 100 % PM humin (10 t ha$^{-1}$) | 1.36 | 0.43 | 1.03 | 0.38 | 0.12 | 0.29 |
| **S.Em. ±** | 0.03 | 0.01 | 0.02 | 0.04 | 0.01 | 0.04 |
| **C.D. at 5%** | 0.10 | 0.03 | 0.06 | 0.13 | 0.03 | 0.12 |

***Table 7: Effect of lignite and poultry manure based humin on soil properties and major nutrient content in soil at harvest of baby corn***

| Treatments | pH | EC | OC | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|---|
| | | dS m$^{-1}$ | g kg$^{-1}$ | kg ha$^{-1}$ | | |
| $T_1$: Absolute control | 4.51 | 0.14 | 4.13 | 141.07 | 26.53 | 261.92 |
| $T_2$: FYM @ 10 t ha$^{-1}$ (POP) | 4.45 | 0.17 | 4.76 | 156.40 | 31.56 | 277.64 |
| $T_3$: 25 % Lignite humin (2.5 t ha$^{-1}$) + FYM @ 7.5 t ha$^{-1}$ | 4.52 | 0.15 | 4.69 | 159.47 | 32.06 | 275.40 |
| $T_4$: 50 % Lignite humin (5 t ha$^{-1}$) + FYM @ 5 t ha$^{-1}$ | 4.52 | 0.16 | 4.82 | 162.53 | 34.25 | 279.52 |
| $T_5$: 75 % Lignite humin (7.5 t ha$^{-1}$) + FYM @ 2.5 t ha$^{-1}$ | 4.56 | 0.16 | 5.05 | 162.53 | 35.07 | 279.04 |
| $T_6$: 100 % Lignite humin (10 t ha$^{-1}$) | 4.72 | 0.17 | 5.13 | 153.33 | 34.75 | 275.36 |
| $T_7$: 25 % PM humin (2.5 t ha$^{-1}$) + FYM @ 7.5 t ha$^{-1}$ | 4.56 | 0.15 | 4.39 | 168.67 | 40.10 | 285.32 |
| $T_8$: 50 % PM humin (5 t ha$^{-1}$) + FYM @ 5 t ha$^{-1}$ | 4.58 | 0.17 | 4.45 | 171.73 | 39.78 | 282.92 |
| $T_9$: 75 % PM humin (7.5 t ha$^{-1}$) + FYM @ 2.5 t ha$^{-1}$ | 4.57 | 0.17 | 4.69 | 171.73 | 38.13 | 286.00 |
| $T_{10}$: 100 % PM humin (10 t ha$^{-1}$) | 4.79 | 0.18 | 4.83 | 168.67 | 35.76 | 280.44 |
| **Initial** | 4.48 | 0.10 | 4.08 | 145.60 | 29.73 | 267.60 |
| **S.Em. ±** | 0.09 | 0.02 | 0.20 | 4.44 | 1.44 | 2.61 |
| **C.D. at 5%** | 0.26 | NS | 0.59 | 13.11 | 4.24 | 7.71 |

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