

## **EFFECT OF FLY ASH AND SOIL AMENDMENTS TO MAIZE CROP ON SOIL REACTION, DEHYDROGENASE & UREASE ACTIVITIES, SOIL MICROBIAL BIOMASS CARBON AND YIELD IN ALFISOLS**

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**Abstract:** Field experiments were conducted in *Alfisols* of central research station, Orissa University Agriculture & Technology, Bhubaneswar, India during 2013-14 with maize as the test crop to study the effect of Fly ash and soil amendments (lime, gypsum) with or without addition of farm yard manure (FYM) on dehydrogenase and urease activity. Integrated use of lime+flyash+FYM resulted in 66 % higher dehydrogenase activity over control (16.54 µg TPF/g soil/h). Combined application of FYM with lime, gypsum or fly ash recorded higher dehydrogenase activity as compared to their sole application. Urease activity in lime (72.5 µg urea/g soil/h) or fly ash (70.74 µg urea/g soil/h) treatment was at par, but higher than gypsum or control treatment. Application of lime alone or with FYM resulted in 20-23 % higher microbial biomass carbon (MBC) as compared to control. Integrated use of lime+fly ash+FYM recorded maximum MBC (366.22 mg C /g soil) among all treatment combinations. Maize grain yield was increased over control (38.6q/ha) by 27 % when lime was applied. Inclusion of FYM enhanced the use efficiency of lime, gypsum or fly ash. Combined application of flyash with FYM was as effective as lime treatment. Conjunctive application of lime+flyash+FYM recorded maximum grain yield (57.72 q/ha) among all treatment combinations.

**Keywords:** Maize, Fly ash, Dehydrogenase, Urease activity, Microbial biomass carbon.

### **Introduction**

The thermal power plants in India consume more than 430 million-tons of coal and produces fly-ash around 145.42 million-tons out of which only 58.48% is being utilized for construction of roads and embankments, production of cement, mine-filling, reclamation of low-lying areas, agriculture, making bricks and tiles and others [1]. Odisha generated about 24.52 million tonnes of fly ash in 2013-14 and utilizes only 61%. It is likely to touch 100 million tonnes per year by 2020 [2]. A huge quantity of fly ash is now being dumped in ash ponds around thermal power stations which cause environmental problems. Fly ash has a great potential for use in wasteland reclamation and Agriculture.

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The application of lignite fly ash reduced the growth of several soil borne pathogenic microorganisms as reported by Karpagavalli and Ramabadran [3], whereas the population of *Rhizobium* sp. and P-solubilizing bacteria were increased under the soil amended with either farmyard manure or fly ash individually or in combination [4].

Microorganisms are the main source of enzymes in soils [5], and thus the composition of the soil microbial communities strongly affects the potential of a soil for enzyme-mediated substrate catalysis [6]. Soil enzymes (intracellular and extracellular) are the mediators and catalysts of biochemical processes important in soil functioning such as nutrient mineralization and cycling, decomposition and formation of soil organic matter, and decomposition of xenobiotics (i.e., pesticides). Specifically, the assessment of the activities of hydrolases can provide information on the status of key reactions that participate in rate limiting steps of the decomposition of organic matter and transformation of nutrients in soils. Thus, knowledge of several soil enzyme activities can provide information on the soil degradation potential [7]. Further, it has been reported that any change in soil management and land use is reflected in the soil enzyme activities, and that they can anticipate changes in soil quality before they are detected by other soil analyses [8].

The use of amendments is a factor affecting enzymatic activities in the soil [9]. The inclusion of organic manure, such as FYM, increases soil microbial biomass by incorporating additional microorganisms into the system and stimulating growth of autochthonous microbiota through the incorporation of new carbon sources [10].

There are little studies about the effect of fly ash on biological properties of acidic *Alfisols*. We hypothesized that a positive effect on soil biological properties is produced when these are amended by fly ash and FYM. Hence, the objective of this study was to determine the effect on soil microbial biomass carbon and enzymatic activities as a result of applying fly ash, lime and gypsum alone or in combination with FYM to an *Alfisol* cropped with maize (*Zea mays* L).

### **Materials and Methods**

A field experiment was carried out for three seasons during 2013-14 in upland Agronomy field, Central Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha. The experiment was laid out in a randomized block design with three replications and eight treatments consist of- T<sub>1</sub> – control (received no amendments), T<sub>2</sub> - lime @ 0.2 LR, T<sub>3</sub>- gypsum @ 2.5 q/ha, T<sub>4</sub> - Fly ash @ 40 t/ha, T<sub>5</sub> - lime @ 0.2 LR +FYM @ 10 t/ha, T<sub>6</sub> - gypsum @ 2.5 q/ha+ FYM @ 10 t/ha, T<sub>7</sub>- Fly ash @ 40 t/ha + FYM @ 10 t/ha and

T<sub>8</sub> - lime @ 0.2 LR+ Fly ash @ 40 t/ha + FYM @ 10 t/ha. The properties of the soil (0-15 cm) of the experimental site had sandy loam texture (69.2% sand, 22.3% silt and 8.5% clay), bulk density 1.63 Mg m<sup>-3</sup> and water holding capacity of 26.48%. The soil was acidic in reaction (pH 4.6), low in N (82.1 mg/kg), medium in P (6.54 mg/kg) and K (58.03 mg/kg). The organic carbon content of the soil was 3.82 g/kg, ECEC 2.93 cmol(+)kg<sup>-1</sup> and lime requirement value of 1633.33 kg CaCO<sub>3</sub>/ha. Exchange acidity of initial surface soil was 0.44 cmol(+)kg<sup>-1</sup> with 0.11 cmol(+)kg<sup>-1</sup> of exchangeable Al<sup>3+</sup>. The initial Ca and Mg (available) content of the soil was 1.35 and 0.92 cmol(+)/kg, respectively. The available sulphur content of initial soil was 10.5 mg/kg. The DTPA extractable Fe, Mn, Zn and Cu were 51.44, 37.5, 0.86 and 1.04 mg/kg, respectively. The DTPA extractable Cd, Pb and Cr were found 0.012, 0.14 and 0.18 mg/kg, respectively. The physical-chemical properties of the Fly ash (IMFA, Chaudar) used in study were presented in Table 1. Different size of the particles present in fly ash were; 0.02 to 2 mm - 41.2 %, 0.002 to 0.02 mm - 49.6 % and <0.002mm-6.2 % indicating that Fly ash can be easily mixed with soil since its particles sizes were comparable with size of soil separates. The bulk density is 0.98 Mg m<sup>-3</sup> which was lower than the soil but its water holding capacity (47.5 %) can be compared with fine textured soil. It was neutral in reaction with pH value of 6.7 and EC of 0.16 dS m<sup>-1</sup>. Organic carbon content of fly ash was 1.55 g kg<sup>-1</sup>. Fly ash contains appreciable amount of available P (12.18 mg kg<sup>-1</sup>), K (72.8 mg kg<sup>-1</sup>) and S (39.26 mg kg<sup>-1</sup>). The available Ca and Mg content in fly ash was 2.12 and 1.46 cmol(+)/kg, respectively. The DTPA extractable Fe, Mn, Zn and Cu were 105.94, 65.73, 1.92 and 1.14 mg/kg, respectively. Some of the heavy metal such as Cd, Pb and Cr were also determined. The DTPA extractable Cd, Pb and Cr were found 0.04, 0.4 and 0.2 mg/kg, respectively in fly ash. The content of total Cr, Pb and Cd was 40 ppm, 10.5 ppm and 4.0 ppm, respectively. The maize crop was sown during mid July 2013 with recommended dose of fertilizer (NPK @120:60:60 kg/ha, respectively) through urea, SSP and MOP. Required quantities of amendments (lime, gypsum, flyash and FYM) were thoroughly mixed with soil before sowing. The crop was rainfed and received 1410 mm of rainfall during growth period. Soil samples for bio-chemical analysis were collected from the rhizosphere layer (0-15 cm) two times- at 40 and 60 days of sowing, air dried, processed and analyzed in the laboratory for pH, soil microbial biomass carbon, soil dehydrogenase and urease activities as described below.

### Soil Microbial Biomass Carbon

Soil MBC was estimated employing fumigation and extraction procedure as described by Vance *et al.* [11]. The process involved collection of filtrate using Whatman filter paper No. 2 after shaking unfumigated soil (20 g) with 0.5 M K<sub>2</sub>SO<sub>4</sub> for 30 minutes. Similarly, another set of filtrate was collected using fumigated soil exposed to ethanol free chloroform for 24 h. Organic carbon in both the extract was analyzed using the method of digestion titration. For digestion of organic carbon 10 ml of filtrate was transferred into a conical flask and 10 ml of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> followed by 20 ml of conc. H<sub>2</sub>SO<sub>4</sub> were added and then entire content was digested for 30 minutes at 170°C. After the content in the flask cooled, 25 ml distilled water and 5 ml orthophosphoric acid were added to the digested material and titrated against 0.04 M ferrous ammonium sulphate with ferroin as the indicator.

$$\text{MBC} = \text{EC fumigated soil} - \text{EC unfumigated soil} / \text{Kc}$$

Where,

EC = Extractable carbon

Kc = 0.379 (Kc is the K<sub>2</sub>SO<sub>4</sub> extract efficiency factor, [12])

### Soil Dehydrogenase Activity

Determination of soil dehydrogenase activity is generally done by adding alternative electron acceptors to soil samples. Water-soluble tetrazolium salts are the preferred oxidants because they form water-insoluble coloured formazans which can be measured spectrophotometrically. Dehydrogenase activity in the soil sample was determined by following the procedure as described by Klein *et al.* [13]. One gram of air dried soil was taken in an air tight screw capped test tubes (15 ml capacity) and 0.2 ml of 3 % solution of 2,3,5-triphenyl tetrazolium chloride (TTC), 0.5 ml of 1 % glucose solution were added to each test tube. The bottom of the tube tapped gently to drive out all trapped oxygen, and thus a water seal is formed above the soil. Ensure that no air bubbles are formed. The tubes were incubated at 30°C for 24 h. After incubation, 10 ml methanol was added and shaken vigorously. Then it was allowed to stand for 6 h. Clear pink coloured supernatant was withdrawn and readings were taken with a spectrophotometer at a wave length of 485 nm. The concentration of formazon formed in the soil sample was determined using graded concentrations of formazon. The results were expressed in microgram of triphenyl formazon (TPF) formed per gram of soil per hour ( $\mu\text{g TPF h}^{-1} \text{g}^{-1} \text{soil}$ ).

### Soil Urease Activity

The assay of urease activity in soils involves estimation of urea hydrolysis in soils by determination of the urea remaining after incubation of soil with urea solution at 37°C [14]. Five gram of fresh soil sample (<2 mm, determine moisture content gravimetrically) were taken in 125 ml polypropylene (PP) bottles and treated with 5 ml of urea solution (10 mg urea). The bottles were capped and incubated at 37°C. The samples were replicated four times. After 5 h, the caps were removed, added with 50 ml of 2M KCl-PMA solution, capped again and shaken for 1h. The soil suspension was filtered through suction. An aliquot of 1-2 ml of the extract containing up to 200 mg L<sup>-1</sup> of urea were taken in 50 ml volumetric flask. The volume was made to 10 ml with 2M KCl-PMA solution; 30 ml of the colouring reagent was added, swirled for few seconds and placed on a bath of boiling water. After 30 minutes the flasks were removed and cooled immediately in cold water (using ice) for 15 minutes. The volume was made to 50 ml with water and mixed thoroughly. The absorbance of red colour developed measured at 527 nm using spectrophotometer. The urea content of the extract was calculated with reference to a calibration graph plotted from the results obtained with standards containing 0, 25, 50, 100, 150 and 200 µg of urea.

### Calculation

The soil urease activity was calculated from the expression  $(B-A) \times t$  where, B is the amount of urea added, A is the amount of urea found after time 't' and 'x' is the oven dry equivalent of the amount (g) of soil taken for incubation. If time is taken in hours then urease activity can be expressed as  $\mu\text{g urea g}^{-1} \text{ soil h}^{-1}$ .

### Results and Discussion

#### Effect of fly ash and soil amendments on soil reaction

The pH of the soil in control (without amendment) increased from 4.6 (initial) to 4.65 at 40 days of sowing and there after decreased to 4.61 at 60<sup>th</sup> day (Fig.1). Application of lime increased the soil pH to 6.85 at 40 day. On the other hand, application of gypsum did not alter the soil pH and behaved like control treatment. In lime treatment, as CaCO<sub>3</sub> dissolves, its reaction raise the pH, thus increases the pH dependent charge on soil colloid, which in turn retained the release Ca<sup>2+</sup>, prevents its downward leaching. Further, the CO<sub>3</sub><sup>2-</sup> ion released by CaCO<sub>3</sub> reaction forms CO<sub>2</sub> gas and water and deprived Ca<sup>2+</sup> cation that could accompany them in leaching process. On the other hand, gypsum being a neutral salt does not raise soil pH or increase CEC. Further, the SO<sub>4</sub><sup>2-</sup> ions released by dissolution of gypsum is available to accompany Ca<sup>2+</sup> cations in leaching. Once the Ca<sup>2+</sup> and SO<sub>4</sub><sup>2-</sup> ions move down ward to sub

soil, the  $\text{Ca}^{2+}$  ions replace  $\text{Al}^{3+}$  ions from the exchange sites and released  $\text{Al}^{3+}$  ions react with  $\text{SO}_4^{2-}$  to form  $\text{AlSO}_4$  which are non phytotoxic. Several researchers have demonstrated that gypsum can ameliorate aluminium toxicity despite the fact that it does not increase soil pH.

Application of FYM with gypsum or lime increased the soil reaction and pH attained a value of 4.97 and 6.12, respectively. Marginal change in soil pH (increase/ decrease) with addition of FYM was resulted due to its buffering effect on soil pH.

Fly ash being neutral in pH (6.7) was better than gypsum. It increased the pH from 4.6 to 5.16 and 5.55 when applied alone or with FYM, respectively. In other words, it can be safely used in acid soils as an amendment to increase soil pH as well as provide several plant nutrients to crop. Further, integrated application of lime+FYM+Flyash was found best treatment combination for acid soils with respect to neutralising capacity associated with availability of other beneficial plant nutrients.

#### **Dehydrogenase activity ( $\mu\text{g TPF/g soil/h}$ )**

Biological oxidation of soil organic compounds is generally a dehydrogenation process carried out by specific dehydrogenases involved in the oxidative energy transfer of microbial cells [15]. The activity is a measure of microbial metabolism and thus of the oxidative microbial activity in soils. The activity of dehydrogenase enzyme in the soil system is very important as it indicates the potential of a soil to support biochemical processes which maintain soil fertility [16]. A good correlation has been reported between microbial biomass and soil dehydrogenase activity by Chander *et al.* [17].

The results of our study indicated that application of lime alone or with FYM significantly increased the dehydrogenase activity over control soil ( $16.54 \mu\text{g TPF/g soil/h}$ ) by 19 and 43%, respectively at 40 DAS of maize crop (Table 2). Application of gypsum or fly ash alone did not affect much and behaved like control soil. But, when FYM was included with these amendments, there was significant increase in dehydrogenase activity (19-47 %). Combined application of fly ash and FYM supersedes the lime+FYM treatment although the pH remained under acidic range. This might have happened due to fly ash supplied several plant nutrients towards dehydrogenase activity. The beneficial effect of FYM enhanced the nutrient availability added through fly ash and creates a conducive environment for dehydrogenase activity. On the other hand, integrated application of lime+fly ash+FYM recorded maximum dehydrogenase activity ( $27.49 \mu\text{g TPF/g soil/h}$ ) which was 66 % higher over control. This might have happened since, lime neutralises soil acidity, FYM act as source of energy and fly

ash supports the supply of major plant nutrients. Similar results were reported by Tejada and Gonzalez [18].

The dehydrogenase activity at latter stage of maize crop (60 day) was drastically reduced in control (61%), lime (57%), gypsum (55%) and fly ash (47%) treatments as compared to that at 40 DAS. However, the intensity of activity was maintained in the treatments when amendments were mixed with FYM.

Several workers studied the effect of organic manure on dehydrogenase activity. Marinari *et al.* [19] reported that a higher dehydrogenase activity was observed in soil treated with vermicompost and manure compare to soil treated with chemical fertilizer. Perucci [20] reported the application of compost caused a significant increase in dehydrogenase activity. The enzyme activity in organic amendment soil increased by an average 2-4 fold compared with the unamended soil [21].

Hinojosa *et al.* [22] observed greater amount of dehydrogenase activities in non-polluted area as  $71.4 \pm 5.2$   $\mu\text{g TPF/g soil/h}$ , average activities were reported in reclaimed area as  $53.0 \pm 0.5$   $\mu\text{g TPF/g soil/h}$  and least value reported in polluted area as  $2.9 \pm 12.1$   $\mu\text{g TPF/g soil/h}$ . Similar findings were reported by Pati and Sahu [23] while studying the  $\text{CO}_2$  evolution and enzyme activities (dehydrogenase, protease, and amylase) and found little or no inhibition of soil respiration and enzyme activities up to 2.5% fly ash amendment.

#### **Urease activity ( $\mu\text{g urea/g soil/h}$ )**

Urea hydrolysis in soils is an enzymatic decomposition process by the enzyme urease. Urease catalyzes the hydrolysis of urea to yield ammonia and carbamate, which spontaneously hydrolyzes to form carbonic acid and a molecule of ammonia. Soil urease is involved in nitrogen mineralization and supplying nitrogen to plants from natural and fertilizer sources. The results of the present study indicated that after 40 days of sowing of maize crop, application of lime or fly ash alone resulted significantly higher urease activity over control but they remained at par with each other. Application of gypsum alone or in combination with FYM remained at par with each other and with control, too. The highest increase in urease activity over control was observed with lime (39.19 %) followed by fly ash (35.80 %) (Table 2). Addition of FYM with lime, fly ash or gypsum did not have much impact on urease activity since the values were lower as compared to their sole application. The micro-organism derived energy and nutrient from fertilizer and amendments and did not much depend on organic manure.

After 60 days of sowing of maize crop, the urease activity was declined by 42.8-55% in lime, gypsum and fly ash treatments. But, the reduction was reduced (7-8%) when FYM was mixed with amendments. Among the treatments, combined application of fly ash + FYM + lime resulted significantly higher urease activity (85.46%) over control. This finding was corroborating with the findings of Lal *et al.*, [24]. They reported that FA added to soil at 16% (w/w) increased urease and cellulose activities. However, acid phosphatase activity was depressed with FA application.

#### **Microbial biomass carbon ( $\mu\text{g C/g soil}$ )**

It is well known that organic matter in soils stimulates soil microbial populations and soil biological activity [25]. The carbon in manure could be easily used as energy source for soil microorganisms, and resulted in increased soil microbial populations and soil biomass. The results of present study revealed that the MBC in control was 294.29 ( $\mu\text{g C/g soil}$ ) and increased by 22.56% with lime (Table3). Application of gypsum alone or in combination with FYM remained at par with each other but had significant effect over control. The highest increase in microbial biomass carbon over control was in lime+flyash+FYM (24.44 %) followed by fly ash+FYM (20.0 %) treatment.

Similarly, after 60 days of sowing of maize crop, The MBC was reduced by 36.3% in control and 41.7-47.8% in amendments over 40DAS. However, the reduction was minimum when FYM was mixed with amendments. This showed that FYM helped to maintain MBC content when fertilizer source was exhausted in the root zone. However combined application of fly ash + FYM ( $T_7$ ) + lime treatment recorded maximum MBC at 60 DAS. These findings are in agreements with the results obtained by Goyal *et al.* [26] and Hassan [27] that addition of organic amendments increased microbial biomass and resulted in a positive correlation between MBC and soil microbial population.

#### **Maize yield**

The maize grain yield data presented in figure 2 revealed that in absolute control, the yield was 35.74, 39.94 and 40 12 q/ha during kharif 2013, rabi 2013-14 and kharif 2014, respectively. Application of lime to each crop significantly increased the pooled yield over control by 27 %. The yield in gypsum treatment was at par with control. On the other hand one time application of fly ash to first crop stabilised the yield up to third season and recorded significantly higher yield(43.12 q/ha) over control and gypsum treatment. Inclusion of FYM with amendments resulted in about 5 q/ha higher yield over their sole application. Integrated use of lime+fly ash+FYM recorded maximum yield as compared to their sole

application or combination with FYM. Inclusion of FYM with amendments enhanced the activity of beneficial microbes, which play an important role in mobilization of nutrients and there by leading to better availability of nutrients facilitating uptake by plants resulting in better growth and dry matter production. The data further indicated that one time application of fly ash with FYM is compared with lime treatment and can be recommended for crops in acid soils.

### **Conclusion**

Overall, the impact of FA on microbial activity is thus inconsistent, but in the presence of organic manure (FYM), the effect is positive and can be compared with lime in acid soils. Integrated use of organic manure (FYM), Fly ash, lime with recommended levels of inorganic fertilizers increased the microbial population, dehydrogenase activity and urease activity, soil organic matter content, resulting in more microbial proliferation and thereby sustained soil health. The results of the present study thereby support the concept of integrated nutrient management practices for improving the soil quality and sustained crop productivity.

### **Bibliography**

- [1] Central Electricity Authority India, 2012-13, Annual Report on Fly-ash utilization.
- [2] Odisha State Pollution Control Board, Annual report, 2013-14.
- [3] Karpagavalli, S. and Ramabadran, R. 1997. Effect of lignite fly ash on the growth and dry matter production (DMP) of soil borne pathogens. In: Souv and abstracts: National Sem on Bio-Utilization of Fly ash, 4–5 April 1997. Khallikote Autonomous College; Berhampur, Orissa, India: p. 11.
- [4] Sen, A. (1997) Microbial population dynamics in fly ash amended acid lateritic soil. B. Tech. Thesis. Kharagpur, India: Indian Institute of Technology.
- [5] Tabatabai, M.A. 1994. Soil enzymes. In: Weaver, R.W., Angle, J.S., Bottomley, P.S. (Eds.), Methods of Soil Analysis: Microbiological and Biochemical Properties. Part 2. SSSA Book Ser. 5. SSSA, Madison, WI, pp. 775–833.
- [6] Kandeler, E., Kampichler, C. and Horak, O. 1996. Influence of heavy metals on the functional diversity of soil microbial communities. *Biol. Fertil. Soils*. **23**: 299–306.
- [7] Tra'sar-Cepeda, C., Leiros, M.C. and Gil-Sotres, F. 2000. Biochemical properties of acid soils under climax vegetation (Atlantic oakwood) in an area of the European temperate-humid zone (Galicia, NW Spain): specific parameters. *Soil Biology and Biochemistry*. **32**: 747–755.

- [8] Ndiaye, E.L., Sandeno, J.M., McGrath, D. and Dick, R.P. 2000. Integrative biological indicators for detecting change in soil quality. *American Journal of Alternative Agriculture*. **15**: 26–36.
- [9] Joergensen, R. and Emmerling, C. 2006. Methods for evaluating human impact on soil microorganisms based on their activity, biomass, and diversity in agricultural soils. *Journal of Plant Nutrition and Soil Science*. **169**:295-309.
- [10] Ros, M., J.A. Pascual, C. García, M.T. Hernández, and H. Insam. 2006. Hydrolases activities, microbial biomass and bacterial community in a soil after long-term amendment with different compost. *Soil Biology and Biochemistry*. **38**:3443-3452.
- [11] Vance, E.D., Brokes, P.C. and Jenkinson, D.S. 1987. An extraction method for measuring soil microbial biomass carbon. *Soil Biology and Biochemistry*. **19**, 703-706.
- [12] Hu, Chang and Cao, Zhiping 2007. Size and activity of the soil microbial biomass and soil enzyme activity in long term field experiments. *World Journal of Agricultural Sciences*. **3**(1):63-70.
- [13] Klein, D.A., Loh, T.C. and Goulding, R.L. 1971. A rapid procedure to evaluate Dehydrogenase activity of soils low in organic matter. *Soil Biology and Biochemistry*. **3**: 385-387.
- [14] Pal, S. and Chhonkar, P.K. 1981. Urease activity in relation to soil characteristics. *Pedobiologia*. **21**: 152-158.
- [15] Burns, R.G. 1978. Enzyme activity in soil: some theoretical and practical considerations. In: Burns RG (ed.) *Soil enzymes*. Academic, London, pp 295–340.
- [16] Joychim, H.J.R., Makoi, P. and Ndakidemini A. 2008. Selected soil enzymes: examples of their potential roles in the ecosystem. *African Journal of Biochemistry*. **7**: 181-191.
- [17] Chander, K., Goyal, S., Mundra, M.C. and Kapoor, K.K. 1977. Organic matter, Microbial biomass and enzyme activity of soils under different crop rotations in the tropics. *Biology and Fertility of Soils*. **24**:306-310.
- [18] Tejada, M. and González J.L. 2009. Application of two vermicomposts on a rice crop: Effects on soil biological properties and rice quality and yield. *Agronomy J*. **101**: 336-344.
- [19] Marinari, S., Masciandaro, G., Ceccanti, B. and Grego, S. 2000. Influence of organic and mineral fertilizers on soil biological and physical properties. *Bioresource Technol*. **72**: 9–17.
- [20] Perucci, P., 1992. Enzyme activity and microbial biomass in a field soil amended with municipal refuse. *Biol. Fert. Soils*. **14**: 54–60.

- [21] Martens, D.A., Johanson, J.B. and Frankenberger Jr., W.T. 1992. Production and persistence of soil enzymes with repeated addition of organic residues. *Soil Sci.* **153**: 53–61.
- [22] Hinojosa, M.B., Carreira, J.A., Rodríguez-Maroto, J.M. and García-Ruíz, R. 2008. Effects of pyrite sludge pollution on soil enzyme activities: Ecological dose-response model. *Science of the total Environment.* **396**: 89-99.
- [23] Pati, S.S. and Sahu, S.K. 2004. CO<sub>2</sub> evaluation and enzyme activities (dehydrogenase, protease and amylase) of fly ash amended soil in presence and absence of earthworms (Under laboratory condition). *Geo Derma.* **118**:289–301.
- [24] Lal, J.K., Mishra, B. and Sarkar, A.K.1996. Effect of fly ash on soil microbial and enzymatic activity. *Journal of the Indian Society of Soil Science.* **44**:77-80.
- [25] Brady, N.C. and Weil, R.R. 1999. Soil organic matter. In: *The Nature and Properties of Soils.* Upper Saddle River, New Jersey, pp. 446–490.
- [26] Goyal, S., Mishra, M.M., Hooda, I.S. and Singh, R. 1992. Organic matter-microbial biomass relationships in field experiments under tropical conditions: effects of inorganic fertilization and organic amendments. *Soil Biol. Biochem.* **24**: 1081–1084.
- [27] Hassan D.H. 1996. Effects of cadmium and sewage sludge on soil microbial biomass and enzyme activities. *Bioresource Technol.* **56**:141–145.

**Table1.** Physical and chemical properties of soil and fly ash used in experiment

Properties	Soil	Fly ash
Particle size distribution		
Sand (%)	69.18	41.2 (0.02- 2 mm)
Silt (%)	22.32	49.6 (0.002-0.02 mm)
Clay (%)	8.49	9.2 (< 0.002 mm)
Texture	Sandy loam	-
BD (Mg m <sup>-3</sup> )	1.63	0.98
WHC (%)	26.48	47.5
pH <sub>(1:2.5)</sub>	4.6	6.7
EC <sub>(1:2.5)</sub> (dS/m)	0.06	0.16
OC (g kg <sup>-1</sup> )	3.82	1.55
ECEC (cmol(+)kg <sup>-1</sup> )	2.93	-
Exchange acidity ((cmol(+)kg <sup>-1</sup> )	0.44	-

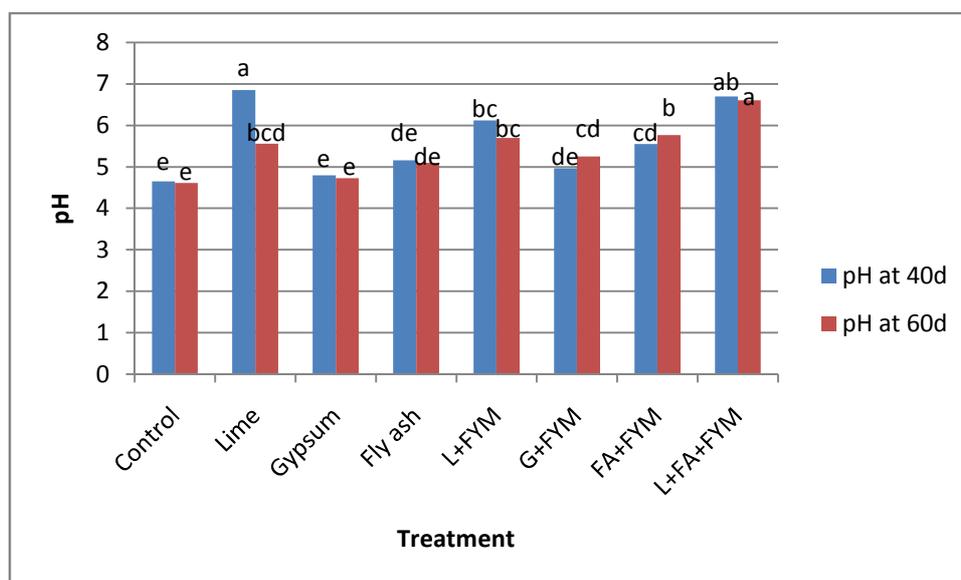
Exchangeable Al <sup>3+</sup> (cmol(+))kg <sup>-1</sup> )	0.33	-
Exchangeable H <sup>+</sup> (cmol(+))kg <sup>-1</sup> )	0.11	-
LR (kg CaCO <sub>3</sub> /ha)	1633.33	-
Available N (mg kg <sup>-1</sup> )	82.1	15.2
Available P (mg kg <sup>-1</sup> )	6.54	12.18
Available K (mg kg <sup>-1</sup> )	58.03	72.8
Available Ca (cmol(+))kg <sup>-1</sup> )	1.35	2.12
Available Mg (cmol(+))kg <sup>-1</sup> )	0.92	1.46
Available S (mg kg <sup>-1</sup> )	10.5	39.26
DTPA Extractable Fe (mg kg <sup>-1</sup> )	51.44	105.94
DTPA Extractable Mn (mg kg <sup>-1</sup> )	37.5	65.73
DTPA Extractable Zn (mg kg <sup>-1</sup> )	0.86	1.92
DTPA Extractable Cu (mg kg <sup>-1</sup> )	1.04	1.14
DTPA Extractable Cd (mg kg <sup>-1</sup> )	0.012	0.04
DTPA Extractable Pb (mg kg <sup>-1</sup> )	0.04	0.4
DTPA Extractable Cr (mg kg <sup>-1</sup> )	0.18	0.2

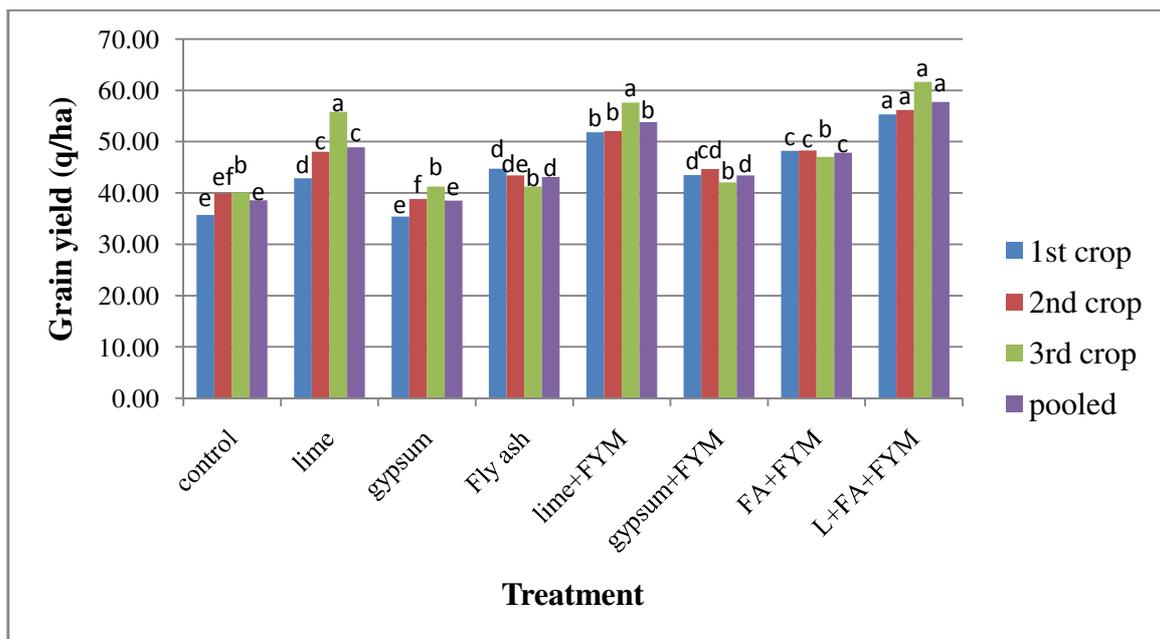
**Table 2.** Effect of fly ash and soil amendments on dehydrogenase and urease activities

Treatment	Dehydrogenase activity (µg TPF/g soil/h)		Urease activity (µg urea/g soil/h)	
	40 DAS	60 DAS	40 DAS	60 DAS
Control	16.54 <sup>c</sup>	6.40 <sup>b</sup>	52.09 <sup>c</sup>	29.78 <sup>d</sup>
Lime (L)	19.76 <sup>bc</sup>	8.44 <sup>b</sup>	72.50 <sup>a</sup>	35.13 <sup>cd</sup>
Gypsum (G)	16.44 <sup>c</sup>	7.33 <sup>b</sup>	65.55 <sup>abc</sup>	29.48 <sup>d</sup>
Fly ash (FA)	15.51 <sup>c</sup>	8.17 <sup>b</sup>	70.74 <sup>a</sup>	39.02 <sup>c</sup>
L+FYM	23.58 <sup>ab</sup>	15.80 <sup>a</sup>	67.84 <sup>ab</sup>	45.88 <sup>b</sup>
G+FYM	19.66 <sup>bc</sup>	16.86 <sup>a</sup>	52.39 <sup>c</sup>	48.19 <sup>b</sup>
FA+FYM	24.28 <sup>ab</sup>	15.28 <sup>a</sup>	56.86 <sup>bc</sup>	51.81 <sup>ab</sup>
L+FA+FYM	27.49 <sup>a</sup>	19.24 <sup>a</sup>	59.55 <sup>abc</sup>	55.23 <sup>a</sup>
CD(0.05)	5.02	4.76	13.59	6.65
CV(%)	14.04	12.30	12.48	9.08

**Table3.** Effect of fly ash and soil amendments on microbial biomass carbon

Treatment	MBC ( $\mu\text{g C/g soil}$ )			
	40 DAS	% increase over control	60 DAS	% increase over control
Control	294.29 <sup>d</sup>	-	187.47 <sup>de</sup>	-
Lime (L)	360.67 <sup>ab</sup>	22.56	210.13 <sup>cd</sup>	12.09
Gypsum (G)	345.16 <sup>bc</sup>	17.28	180.31 <sup>e</sup>	-3.82
Fly ash (FA)	339.90 <sup>c</sup>	15.50	189.98 <sup>de</sup>	1.34
L+FYM	359.04 <sup>abc</sup>	22.00	226.90 <sup>abc</sup>	21.03
G+FYM	347.19 <sup>abc</sup>	17.98	226.18 <sup>bc</sup>	20.65
FA+FYM	353.15 <sup>abc</sup>	20.00	240.03 <sup>ab</sup>	28.04
L+FA+FYM	366.22 <sup>a</sup>	24.44	254.25 <sup>a</sup>	35.62
CD(0.05)	20.68		27.50	
CV(%)	3.42		7.33	

**Figure1.** Effect of fly ash and amendments on soil pH in the root zone of maize crop



**Figure 2.** Effect of amendments on maize grain yield (q/ha) over the years