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Addition of fly ash for enhancing the soil microbial activity under the vermicompost and RDF amendment on Bundelkhand soil, Uttar Pradesh, India

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ABSTRACT

The field experiment was carried out with eight experimental treatments containing varying degree of fly ash (FA) and uniform amendment of vermicompost (VC) and RDF (recommended dose of fertilizer) for monitoring the effect of FA. Hence, an experiment was conducted to assess the soil CO_2 evolution, microbial population, heavy metal accumulation in soil and yield of chickpea crop at different doses of FA, to control the toxic effect of metal was studied in semi-arid region of Bundelkhand. The treatments designed as: (T1) control, (T2) Recommended of fertilizer (RDF) only, (T3) (VC) only, (T4) FA 10t ha^{-1} + VC + RDF, (T5) FA 20 t ha^{-1} + VC+ RDF, (T6) FA 30 t ha^{-1} + VC + RDF, (T7) FA 40 t ha^{-1} + VC + RDF, (T8) FA 50 t ha^{-1} + VC + RDF. It was observed that FA application improved the soil physico-chemical properties. Statistical analysis revealed that, Pearson correlation analysis showed a significant correlation between pH, EC, WHC, porosity, moisture content, bulk density, P, N, OC, K, S, Co, Cr, Cu and As. A positive correlation exist between microbial population and soil CO_2 evolution with R^2 =0.895. The experimental studies confirmed that lower dose of FA (20 t ha^{-1}) offer a potential amendments to improve soil activities and crop yield and safe FA utilization practices.

Figures : 02 References : 19 Tables : 02
KEY WORDS : CO_2, Fertilizer, Fly ash, Heavy metal, Vermicompost.

Introduction

The waste and residual soil amendments such as sludge, ashes and manures released from industrial processes are being used in agriculture to meet two objectives: to solve problem of disposal and provide economically attractive alternative to farmers at the same time, knowledge about their effects on soil quality is also very important. The constitute of FA suggest that ash can be used as both an agent capable of improving physical and chemical parameters of degraded soils and as a fertilizer in cropland [12].

FA consists of several elements such as Co, Mn, Fe, Mo, Ca, Si, Na, Cd, Mg, K, Pb, Cu, Ni, B, Zn, and Al although it lacks nitrogen and phosphorus. This indicates that FA contains several elements which are required for growth of plant as well as metabolism. FA also contains some non-essential toxic elements for plants[18]. Toxic effect of FA is insignificant as toxic elements concentration at low doses is under the permissible limits in some plantation work[13]. Various experiments revealed that unweathered FA application to soil decreased N cycling processes, enzymatic activity and microbial respiration [14]. To study more about microbial status in the soil, carbon mineralisation is a reliable method, which assesses changes in carbon mineralization rate and it used as a criterion for assessing toxicity of any pollutant[19]. During the biodegradation of carbonaceous compounds by microorganism, changes the rate of CO_2 evolution from soil indicates changes in levels of ecosystem, especially carbon cycling.

Leguminous crops can fix nitrogen by symbiotic bacteria in their root nodules. The crop yield increases by using plant growth promoting organism- based biofertilizer (*Rhizobium* with *Phosphobacteria*), they not only fix atmospheric nitrogen but also improve the phosphorus availability in leguminous crops[16]. In Bundelkhand region, it is cultivated on a large scale, whereas the soil is poorly consisted of nitrogen, organic matter and phosphorus and it is hypothesized that the addition of organic matter is not only beneficial in improving the soil physico-chemical properties but also sustain productivity[4]. Keeping this in view, the present study was

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TABLE-1: Different combination of fly ash, vermicompost (VC) and Recommended dose of fertilizer (RDF)

Treatments	Doses
T_1	No amendment (Control)
T_2	RDF
T_3	2 t ha^{-1} VC
T_4	2 t ha^{-1} VC + RDF + 10 t ha^{-1} fly ash
T_5	2 t ha^{-1}VC + RDF + 20 t ha^{-1} fly ash
T_6	2 t ha^{-1} VC + RDF + 30 t ha^{-1} fly ash
T_7	2 t ha^{-1} VC + RDF + 40 t ha^{-1} fly ash
T_8	2 t ha^{-1} VC + RDF + 50 t ha^{-1} fly ash

carried out to use FA as a soil conditioner in a field condition with combination of vermicompost and RDF for its sustainable utilization and to evaluate its impact on soil CO_2 evolution and enzymatic activity as well as the crop yield.

Materials and Methods

Soils sampling

The impact of FA, vermicompost and RDF on soil physico-chemical properties and soil microbial activity was assessed in Bundelkhand soil. The rhizospheric soil samples were collected from the 10-20 cm horizon near the root of the plants growing in vicinity of different treatments. Soil samples were collected from each treatment and immediately transferred to the laboratory and sieved them properly.

Experiment set up

The field experiment was carried out during winter season with eight experimental treatments at the agricultural farm of Bundelkhand University, Jhansi, India. The Chickpea plant was used as a test crop. The completely randomized block design (RBD) method used to arrange the experimental plots with three replicates. The treatments designed as: (T_1) control, (T_2) Recommended of fertilizer (RDF) only, (T_3) (VC) only, (T_4) FA 10t ha^{-1} + VC + RDF, (T_5) FA 20 t ha^{-1} + VC+ RDF, (T_6) FA 30 t ha^{-1} + VC + RDF, (T_7) FA 40 t ha^{-1} + VC + RDF, (T_8) FA 50 t ha^{-1} + VC + RDF. (Table-1). The experimental plot separated with a strip of 25cm to avoid the interchange of nutrient and microbes among the treatments. The common dose of 20kg Nha^{-1} + 50 Kg P_2O_5 ha^{-1} + 20 kg k_2O ha^{-1} through DAP was applied and vermicompost was amended at the rate 2 t ha^{-1}.

Plant sampling and analysis

The chickpea seeds were dipped in 0.01% mercuric chloride for sterilization of surface. Each line was sown in 6 rows with 30cm inter-row spacing at 3cm deep furrow. For plant samples, intact roots of five plants were carefully dugout randomly from control and treated plots at 75 day after sowing seed for analysis. The plants were thoroughly washed after placing them under tap to remove soil particles binding with the root surfaces. Yield was determined as the number of pod per plant, number of seed per pod and seed yield per plant was measured.

Physico-chemical analysis of soil

The physico-chemical analysis of FA, unamended soil was measured such as pH, Electrical conductivity (EC), moisture content, Water holding capacity (WHC), porosity, bulk density (BD), Total nitrogen (N), Organic carbon (OC), Sulphur (S), Potassium (K), Phosphorus (P) were determined by using standard methods whereas micronutrients such as, Co, Cr, Cu and As were measured by the method of Allen[2], 1 g air-dried sample added in 20 ml of tri acid mixtures (HNO_3:H_2SO_4:$HClO_4$:5:1:1) for 8 h at 80^0 C. After digestion, the samples were filtered and kept aside for determination of heavy metals. Exchangeable nutrients and heavy metals were further analyzed using model- Shimadzu AA-6880 Atomic absorption spectrophotometer.

TABLE-2 : Yield attributing characters of chickpea as affected by different treatments

Treatment	No of pod per plant	No of seed per pod	Seed yield per plant (g)
T_1	22.42	1.2	6.24
T_2	22.87	1.6	7.94
T_3	24.88	1.6	8.12
T_4	28.32	1.6	9.02
T_5	30.04	1.8	9.11
T_6	29.87	1.7	8.64
T_7	24.11	1.4	7.45
T_8	22.45	1.2	7.80

Estimation of microbial population

For estimation of microbial population, the soil was isolated from rhizosphere of control and FA amended soil treatment by serial dilution and spread plate technique. For isolation of *phosphate solubilizing bacteria* and, 0.5ml of aliquot of appropriate dilutions were plated in sterilized Petri plates containing King's pseudomonas for *Pseudomonas* bacteria. Three replications were taken for each sample. After incubation for bacteria at 30-32^{0}C upto 48-72 hours, colony count was recorded. Data of microbial density are expressed as CFU /g of soil.

Estimation of CO_2 evolution in different treatments

Soil respiration (CO_2 evolution) was measured[9]. Placed the inverted glass jar in the experimental field using 20 ml of 0.1N of KOH solution and was poured in a small glass beaker and placed it inside the jar for 24 hr. After 24hr, the CO_2 fixed by KOH was estimated by titrating the same with 0.1 N HCl solution using phenolphthalein as an indicator. A control was maintained by sterilized sand instead of soil samples. Soil respiration was expressed as µg of CO_2 /g soil on dry weight basis.

Statistical analysis

The experiment was conducted in RBD design with each treatment replicated three times. Regression analysis was performed between microbial population and soil CO_2 evolution. Pearson's correlation analysis was used to assess the significance of interrelationship between physico-chemical parameters. All statistical analyses were conducted using Ms-Excel.

Observation and Result

In present study, the addition of different doses of FA have revealed that FA increased CO_2 evolution in treatment T_5 that received 20t ha^{-1} FA with RDF and vermicompost (18.4 µg of CO_2/g soil) followed by T_6 that received 30t ha^{-1} FA with RDF and vermicompost (18.1 µg of CO_2/g soil) as compared to control T_1 (10.1µg of CO_2 /g soil) at 60th of the experiment. The overall regression was significant, F (1,6)= 51.40, $p<0.001$, R^2 = 0.89. A positive relationship of soil CO_2 evolution was observed with the soil microbial density (i.e *Pseudomonas* bacteria). Indicating that addition of FA at lower dose has a limiting effect on soil leading to increased soil microbial density, ultimately causing an increase in CO_2 evolution (Fig. 1).

Pearson correlation analysis indicated that pH of soil was positively correlated with EC (r = 0.963, p<0.01), porosity (r = 0.792, p< 0.01), moisture content (r = 0.978, p< 0.01) WHC (r = 0.935, p< 0.01), total S (r = 0.927, p<0.01). The EC shows positive correlation with porosity (r = 0.826, p< 0.01), moisture content (r = 0.975, p< 0.01), WHC (r = 0.803, p< 0.01) and total S (r = 0.968, p< 0.01). Bulk density is positively correlated with total N (r = 0.388, p< 0.01). Total P is correlated with total N (r = 0.728, p< 0.01), OC (r = 0.848, p < 0.01) and K (r = 0.810, p< 0.01). All growth attributes were recorded at different amendments of FA at 75DAS. Number of pod per plant, number of seed per pod and seed yield per

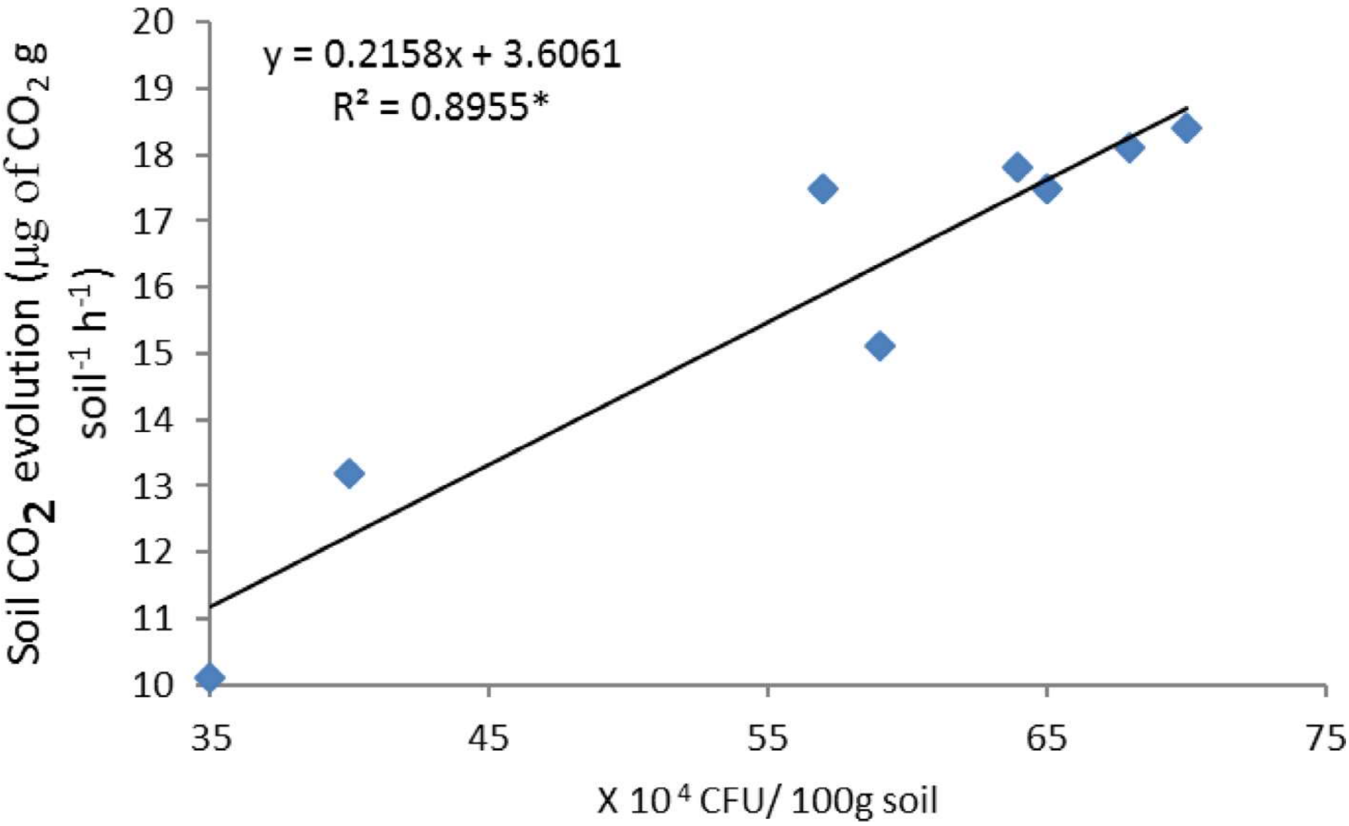

Fig. 1 : Regression analysis between microbial density (CFU) and soil CO_2 evolution. Total sample used in this regression analysis was N=24 (8 treatments x 3 replicates) *p<0.05.

plant measured, increased upto T_5, later reduced significantly at higher concentration of FA applied to soil as compared to control (T_1) (Table-2).

Discussion

Effect of fly ash on microbial activity of soil

The CO_2 evolutions (a measure of metabolic activity) in various chemical transformations are commonly used as indices for assessment of effect of contaminants on microbial activity and soil fertility status[7]. Evolution of CO_2 maximum at 20 t ha^{-1} (T5) FA amendment, further addition of FA decreased CO_2 evolution. The FA addition to the soil increased the pH, EC and plant nutrients and various nonessential heavy metals. The combustion of by-product of coal contain few amount of CaO and MgO[1]. The soil limiting ability of FA may be due to these oxides which may influence soil respiration and other microbial activity in soil due to their ability to affect soil pH, because there is always a characteristics optimum pH for each microbial activity[10]. Not only pH but some other properties of FA particularly EC and heavy metals might have substantial effect on the status of microbial activities [5]. In most cases, pollution of heavy metals had no effect on CO_2 evolution at low concentration but at higher concentration the soil respiration decreases[3,7].

Heavy metals are positively correlated with pH, EC, porosity, moisture content, WHC and total S significantly with p<0.01 (Figure 2). Therefore, it is noticed that as the doses of FA increase that leads to increase the concentration of heavy metal in soil. The FA contains heavy metals[12], and also have various macro and micro nutrients that can enhance soil health and crop productivity and could be used as soil amendements/ conditioner. FA helps in improving the soil nutrient status[15]. Various researchers mentioned that the FA can be utilized as a soil ameliorant to improve physical properties of soil as well as alkaline pH of FA also helps to enhance the organic mineralization and promotes nutrient supply to the plants. The amendment of FA in higher dose may cause detrimental effects to the soil, plants and harmful for environment due to pozzolanic effect[8].

Effect of fly ash on chickpea yield

All the growth parameters of chickpea crop were higher in treatment that received 20t ha^{-1} FA along with fertilizer and vermicompost whereas at higher dose of FA it reduced significantly. Similar observations were found

	pH	EC	Porosity	isture con	BD	WHC	Total P	Total N	Total OC	Total K	Total S	Co	Cr	Cu	As
EC	0.896**	1.000**													
Porosity	0.791**	0.821**	1.000**												
Moisture content	0.930**	0.975**	0.820**	1.000**											
BD	-0.942	-0.985	-0.824	-0.976	1.000**										
WHC	0.883**	0.973**	0.797**	0.953**	-0.939	1.000**									
Total P	0.026	0.251	-0.23	0.153	-0.233	0.141	1.000**								
Total N	-0.436	-0.359	-0.71	-0.482	0.358*	-0.407	0.689**	1.000**							
Total OC	-0.194	-0.159	-0.58	-0.268	0.144	-0.199	0.771**	0.948**	1.000**						
Total K	0.910**	0.972**	0.792**	0.935**	-0.986	0.916**	0.288*	-0.249	-0.06	1.000**					
Total S	0.932**	0.968**	0.749**	0.935**	-0.971	0.955**	0.247	-0.239	-0.028	0.978**	1.000**				
Co	0.900**	0.983**	0.783**	0.977**	-0.963	0.982**	0.235	-0.389	-0.155	0.928**	0.949**	1.000**			
Cr	0.922**	0.980**	0.761**	0.992**	-0.974	0.965**	0.232	-0.39	-0.167	0.942**	0.955**	0.986**	1.000**		
Cu	0.929**	0.947**	0.689**	0.938**	-0.97	0.899**	0.329*	-0.199	0.01	0.974**	0.975**	0.921**	0.954**	1.000**	
As	0.964**	0.920**	0.838**	0.917**	-0.94	0.917**	-0.005	-0.424	-0.229	0.932**	0.956**	0.895**	0.908**	0.927**	1.000**
Fe	0.919**	0.947**	0.903**	0.977**	-0.947	0.938**	0	-0.618	-0.407	0.893**	0.889**	0.955**	0.953**	0.865**	0.906**

Correlation is significant at *p<0.05 and **p<0.01 (2 tailed)

Fig 2 : Pearson correlation matrix between physico-chemical properties and heavy metal during RDF, vermicompost and FA amendment in soil

earlier[11], where noticed the negative effect of increased dose of FA in chickpea. Previous studies revealed that FA affects the yield of crop[17]. FA contains traces of N and no organic carbon [18], therefore at higher level when added to soil, cause dilution, moreover increases the content of heavy metal which leads to decline crop yield. It was also reported that higher level of FA (above 50%) reduces the chlorophyll content and yield due to higher concentration of metalloids and heavy metals causing nutritional imbalance[6].

Conclusion

The finding conclusively propose that soil amended with FA, RDF and vermicompost proved to be suitable for soil microbial activity and for maintaining soil fertility which ultimately improved the yield of chickpea in Bundelkhand soil. Thus, in present study 20 t ha^{-1} FA along with RDF and vermicompost proved a better amendment for being utilized in chickpea cultivation that provide a promising method for ecological engineering of Bundelkhand soil. Simultaneously, it provide a good practice for FA management.

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