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Influence of Coal Fly-Ash on Soil Properties and Productivity of Chickpea Crop In Semi-Arid Region of Bundelkhand

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Abstract

Fly ash changes the soil properties which may cause disastrous influence on microbial activity and growth of the plant. However, the scientific studies on the influence of fly ash in various combination with an organic fertilizers on soil properties and microbial response at semi-arid region of Bundelkhand soil is scanty in India. The main objective of this study was to assess the impact of lower or higher doses of fly ash on the soil physico-chemical characteristic, microbial population and growth of leguminous plant chickpea (*cicer arietinum L*), an important crop of Bundelkhand. The field experiment was conducted during winter, different treatment were made such as control with no amendment of fly ash (T1), amendment of fly ash at the rate of 10tha^{-1}(T2), 20tha^{-1} (T3), 30tha^{-1} (T4), 40tha^{-1} (T5), 50tha^{-1} (T6) in combination with vermi-compost (2tha^{-1} in soil) and Nitrogen, potassium and phosphorus (20kgN h^{-1}+20kg k_2O ha^{-1} + 50 kgP_2O_5 ha^{-1} in soil) with three replications. In the present study, it was seen that fly ash, increased water holding capacity (WHC), moisture content, pH, soil porosity, organic carbon and electrical conductivity values of the soil. An increasing trend was also seen in P, K, S, and Mn, concentration from 9.87 to 12.21kg ha^{-1}, 121 to 124 kg ha^{-1}, 9.36 to 12.14mg/kg and 9.27 to 87 mg/kg, respectively whereas bulk density and total nitrogen decreased from 1.29 to 1.24 g/cm^3 and 247 to 205 kg ha^{-1}, respectively in the fly ash applied soil. The application of fly ash at 20tha^{-1} (T3) was found optimum for bacterial population though the fly ash level exceeding 20tha^{-1}, resulted decline microbial population.

Article History

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Introduction

Indian power generation is in majority dependent on coal-based thermal power station. The coal combustion products produced every year is around 112MT (million tons) in India and it exceeds 225 MT by 2017[Singh, 2012]. Impact assessment of fly ash on environmental are very complex and detailed research is important and analysis of the side-effects on plants and soil is need of the hour. Sustainable agriculture needs careful use of any organic amendments to improve the fertility of soil while minimizing any harmful effect on the environment [Ram and Masto, 2014]. The fly ash application on agricultural land has been widely evaluated, it affects the soil environment, contains many non-essential as well as essential elements but characteristically poor in nitrogen and phosphorus. The studies on the influence of fly ash amendment in different combinations on soil biological properties is very minimal [Schutter *et al.,* 2001]. Therefore, management of fly ash would remain a great concern today. Due to its high cost of environmental management and disposal, utilization of fly ash in forestry, horticulture, floriculture and agriculture sectors could be a viable option.

Fly ash is generally alkaline due to the low content of sulphur and the presence of hydroxides of magnesium carbonate and calcium carbonates [Vimlesh and Giri, 2011]. Though fly ash utilization in agriculture is rare because of its high pH, low N and P including minmal soil microbial activity [Wong and Wong, 1989]. Fly ash helps in improving the soil nutrient [Rautaray *et al.,* 2003]. Some reports mentioned apllication of fly ash as a soil ameliorant to improve soil physical properties [Shen *et al.,* 2008], alkaline pH of fly ash also helps to enhance organic mineralization and promotes nutrient supply to the plants [Mittra *et al.,* 2005]. It constitute various elements such as Si, Na, Ca, Mg, K, Cd, Pb, Cu, Co, Fe, Mn, Mo, Ni, B, Zn, and Al, lack of nitrogen and phosphorus. Various heavy metals namely Cu, Ni, Fe, Pb, Cr, Cd etc that may exhibit metal toxicity in plants. Fly ash utilization in soil systems has been tested so far for *Brassica juncea, Helianthus annus* [Pandey *et al.,* 1994], *Cassia siamea* [Tripathi *et al.,* 2005], *Triticum aestivum* [Kumar *et al.,* 2010], rice [Bisoi *et al.,* 2017]. The presence of nutrients allows the use of fly ash for agricultural purposes to fortify crops with nutrients, such as Se, Fe, and Zn. It is reported that leguminous crops can tolerate too many heavy metals. Chickpea is an important source of amino acids and protein. In the semi-arid region of India, it is cultivated on a large scale [Pandey *et al.,* 2010].

Soil of Bundelkhand region in India fall into two categories the Red soil and Black soil. The red soil locally known as rakar, exhibits very low retention of water and large permeability [Biswas *et al.,* 2012]. They are poorly rich in organic matter, nitrogen and phosphorus. It is hypothesized that the addition of organics could be beneficial in improving the soil Physico-chemical characteristics and sustain productivity [Biswas *et al.,* 2012]. In this study Chickpea is used as test crop because it is an important leguminous food grain in India. In Uttar Pradesh, Jhansi district is one of the major producers of chickpea fall under the Bundelkhand region. The main objective of this study was to assess the effect of different doses of fly ash on the Bundelkhand soil which is semiarid region and suffers from water stress and exposed to increasingly variable and extreme conditions of weather. The field experiment was conducted during winter ,different treatment were made such as control with no amendment of fly ash (T1), amendment of fly ash at the rate of 10tha^{-1}(T2), 20tha^{-1}(T3), 30tha^{-1} (T4), 40tha^{-1} (T5),50tha^{-1} (T6) in combination with vermicompost (2tha^{-1} in soil) and Nitrogen, phosphorus and potassium (20kg N + 50 kgP_2O_5/ha + 20kg k_2O/ ha in soil) with three replications.

Methodology

Experimental Site and Climate

In the present experiment fly ash was collected from Parichha TPP, Jhansi, Uttar Pradesh, India. Jhansi district is situated 24^0 11'N to 25^0 57'N latitude and 78^0 10'E to 79^0 23' E longitude in the semi-arid region of the country. The field experiment was conducted at the agricultural field of Bundelkhand University, Jhansi, India during November 2018-March 2019.

Experimental Set –up

In the present experiment Chickpea plant (*Cicer arietinum* L.) of variety, Awrodhi was used. The fly ash samples were taken from the Parichha thermal power plant, Jhansi. The experimental plots (each 2x2m size) were arranged in a completely RBD manner in triplicates. The various treatment were vermicompost + NPK(T1) (control), fly ash (10 tha^{-1}) + NPK + vermicompost (T2), fly ash (20 tha^{-1}) + NPK + vermicompost (T3), fly ash (30tha^{-1}) + NPK + vermicompost (T4), fly ash (40 tha^{-1}) + NPK + vermicompost (T5), fly ash (50 tha^{-1}) + NPK + vermicompost (T6). Divide each experimental plot to minimize the possibility of nutrient and microbial exchange among the treatments. In each of treatment fly ash, NPK and vermicompost combination were given. The vermicompost and NPK were added at a fixed rate. The common dose of NPK was applied 20kg N ha^{-1} + 50 kgP_2O_5 ha^{-1} + 20kg k_2O ha^{-1} and 2 t ha^{-1} vermicompost was applied.

Soil Analysis

Composite soil samples were taken from the 10-20cm horizon near the root of the plants growing under different treatments and immediately transferred in the laboratory.

The pH of fly ash and soil samples were measured in the 1:5(w/v) suspension of with the help of pH meter. EC was measured by conductivity meters [Piper CS, 1966], moisture content was measured by gravimetric method, porosity [Brgowski *et al.,* 2014], water holding capacity (WHC) and bulk density (BD) by Black method [Black GR, 1965], Organic carbon (OC) determined by Walkey and Black's rapid titration method [Allison FA, 1973], total nitrogen (N) was determined by Kjeldhal's method, phosphorus determined by Olsen and Sommers [Olsen and Sommer, 1982]. Potassium measured by Flame photometer method [Jackson ML, 1967], Sulphur was determined by turbidimetric method [Tandon HLS, 1995], Zinc, Boron, Iron, Mangenese, Cadmium, Molybdenum, Arsenic and Copper in control, fly ash and amended soil were measured from 1g dried sample in 20 ml of tri acid mixtures (HNO_3:H_2SO_4:HClO4:5:1:1) at 80^0 C for 8 h [Allen *et al.,* 1986]. Then, the samples were filtered and used of heavy metal analysis using AAS.

Plant Sampling and Analysis

The chickpea seeds were dipped in 0.01% mercuric chloride to sterilized surface. Each line was sown in 6 rows with 30 cm inter-row spacing at 3cm deep furrow. The plant height, number of branches per plant, the dry matter weight, number of root nodules were measured by randomly selected sample of ten plants from each plot at 30 days, 45 days, 60 days, 75days and at harvest days after sowing (DAS). The number of pod/ plant, number of seed/pod recorded from random plants samples at the time of harvest. Seed Index (g), seed yield/plant, seed yield from the net plot was recorded after drying under the standard moisture conditions. The seed yield of crop/plot were then changed in to yield/ hectare (Kg/ha).

Estimation of Microbial Population

For estimation of microbial population the soil were isolated from rhizosphere of control and fly ash amended soil treatment by serial dilution and spread plate technique. For isolation of *phosphate solubilizing bacteria* and N_2 fixing bacteria, *Rhizobium leguminosarum*, 0.5ml of aliquot of appropriate dilutions were plated in sterilized Petri plates containing Pikovskaya's Medium and Yeast extract Mannitol Agar plates respectively. Three replicates were taken for each sample. After incubation at 30-32^{0}C upto 48-72 hours colony count was recorded. Microbial density were expressed in the form of CFU /g of soil.

Results

Physico Chemical characterization of Soil, Fly Ash and Fly ash Amended Soil

The Physico chemical properties of unamended soil and fly ash amended soil are summarized in table 1 and characterization of fly ash is presented in table 2. The value of pH, Electricity conductivity (EC), porosity, Moisture content and water holding capacity (WHC) of soil were increased significantly with increases doses of fly ash. pH was 7.6 recorded in unamended soil (T1, control) whereas fly ash amended soil become more alkaline with 8.3 in T6 treatment. EC, porosity, Moisture content and water holding capacity were recorded 1.66 dsm-1, 33.26%, 4.4, 56.81% respectively higher in T6 plot as compared to unamended soil. Value of Bulk density and total nitrogen were 1.24g/cm^3, 205kg/ha respectively found in T6 treatment lower than unamended soil, as the dose of fly ash increases they decrease continuously. Total phosphorus, Organic carbon, potassium, sulphur were recorded higher in T6 treatment 12.21kg/ ha, 1.85%, 124kg/ha, 12.14mg/kg respectively as compared to the experimental plot (T1) as given in table. Fly ash used was little alkaline with pH 7.4 and EC was 0.32dsm^{-1} recorded. Total nitrogen, total phosphorus, total potassium were recorded 0.30%, 0.20%, 0.57% respectively.

Table 1: Physico- chemical properties of unamended soil and Fly ash treated soil (Mean±SD)

Parameter	T1(control)	T2(10tha^{-1} fly ash)	T3(20tha^{-1} fly ash)	T4(30tha^{-1} fly ash)	T5(40tha^{-1} fly ash)	T6(50tha^{-1} fly ash)
pH	7.6±0.05	7.8±0.11	7.9±0.05	7.10±0.30	8.1±0.05	8.3±0.05
Electricity conductivity(dsm^{-1})	0.77±0.11	0.79± 0.05	1.24±0.24	1.34±0.06	1.40±0.08	1.66±0.28
Porosity (%)	30.06±0.03	30.37±0.05	30.78±0.01	31.11±0.05	31.90±0.04	33.26±0.06
Moisture content	2.3±0.11	2.7±0.05	3.8±0.05	3.9±0.11	4.2±0.05	4.4±0.17
Bulk density(g/cm^3)	1.29±0.11	1.27±0.05	1.28±0.11	1.26±0.01	1.25±0.01	1.24±0.01
Water holding capacity (%)	37.11±0.61	38.12±0.57	39.89±0.21	39.96±0.014	40.11±0.52	56.81±0.46
Total phosphorus (kg/ha)	9.87±0.02	10.10±0.46	10.14±0.01	10.51±0.02	11.06±0.55	12.21±0.02
Total nitrogen (kg/ha)	247±0.57	245±0.57	239±0.57	220±0.57	215±0.57	205±0.57
Total organic carbon (%)	0.67±0.03	0.69±0.07	0.81±0	0.96±0.13	1.23±0.07	1.85±0.08
Total potassium (kg/ha)	121±0.57	122.11±0.66	123±0.80	123.20±0.61	123.52±0.90	124±0.57
Total sulphur (mg/kg)	9.36±0.72	10.14±0.023	10.60±0.09	11.05±0.11	11.84±0.07	12.14±0.08

Table 2: Characterization of Fly ash ((Mean±SD)

Parameter	Fly ash
pH(1:2)	7.4±0.02
ECH_2O (1:2) (dS/m)	0.32±0.78(dS/m)
Bulk density(g/cc)	0.97±0.48(g/cc)
Water holding capacity(%)	56.75±0.23(%)
Porosity (%)	48±0.34(%)
Organic carbon (%)	0.80±0.12(%)
Texture	Silt loam
Total N (%)	0.30±0.11(%)
Total P (%)	0.20±0.19(%)
Total K (%)	0.57±0.03(%)

Growth/ Yield Attributes

All yield/growth attributes was recorded at different time interval of 30DAS, 45DAS, 60DAS, 75DAS and at harvest. The number of branches, plant height, root nodules/ plant, dry matter weight, number of pod/ plant, number of seed/ pod, seed yield/ plant and seed index increased up to T3 later reduced significantly at higher dose of fly ash amended soil as compared to control (T1) as given in Figure 1 and Figure 2 respectively. All the growth parameter of chickpea crop was higher at 20tha^{-1} fly ash amended soil along with fertilizer and vermicompost whereas at higher dose of fly ash i.e. 30tha^{-1}, 40tha^{-1} and 50tha^{-1} recorded significantly lower yield.

Effect of Fly Ash on Soil Microbial Density

The rhizospheric zone contains huge microorganism which helps the plant to survive in stress condition, the population of Phosphate solubilizing bacteria and N_2 fixing bacteria was recorded maximum at 20 tha^{-1} fly ash (T3) application beyond this population completely ceased as given in table 3.

The pH of the soil in this study is around neutral and fly ash amendment makes the soil more alkaline which cause negative effects to microorganism.

A significant reduction in the microbial population was observed in fly ash 50 t ha^{-1} (T6).

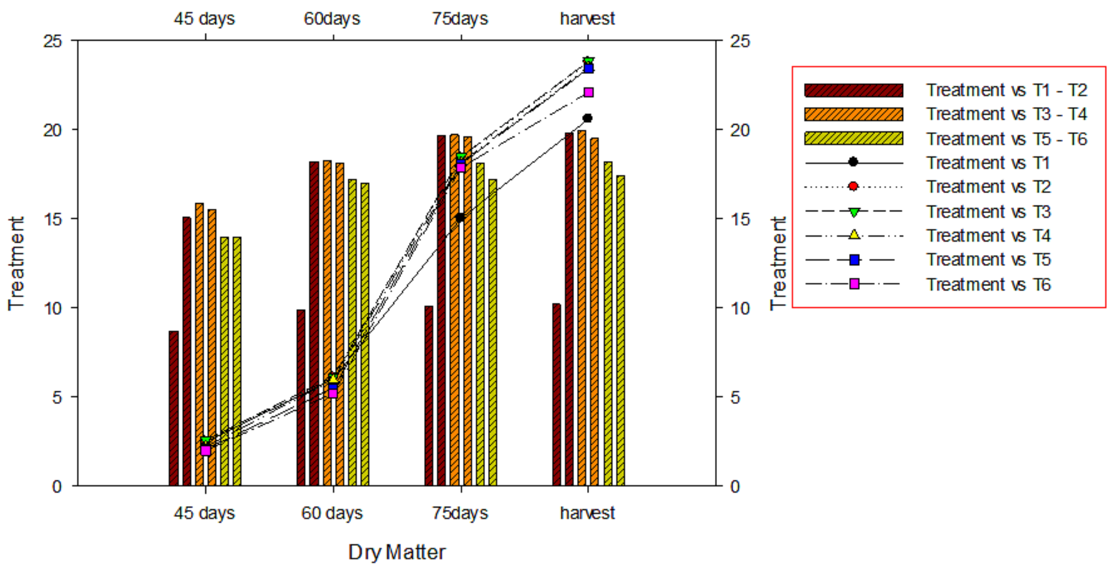


Fig. 1: Impact of Treatments on Root Nodule and Dry matter of selected plant (Chick Pea) on different time interval

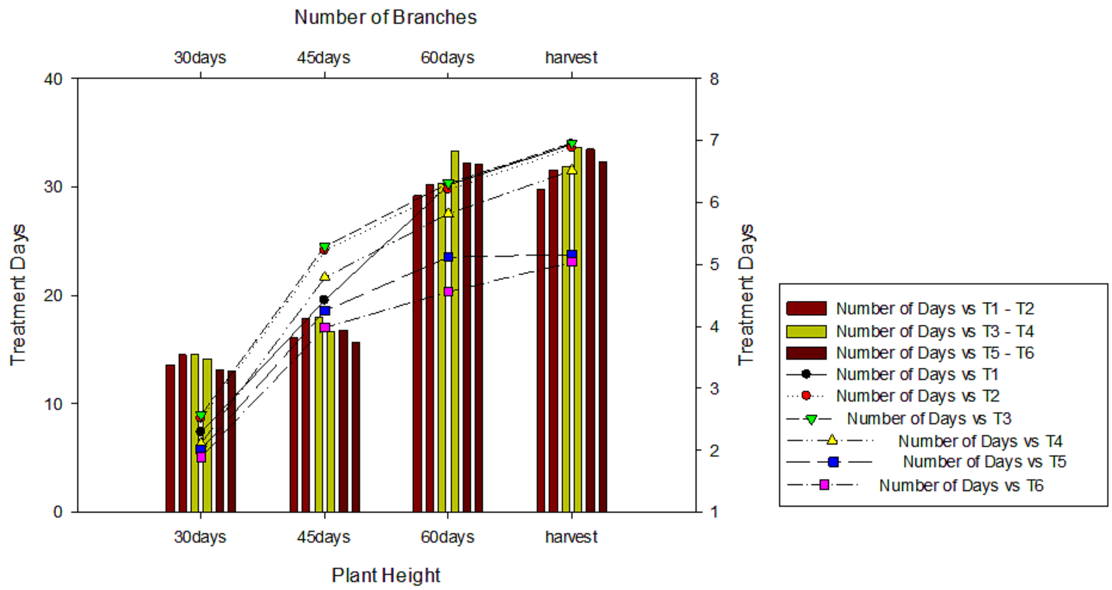


Fig. 2: Impact of Treatments on Branches Numbers and Plant Height of selected plant (Chick Pea) on different time interval

Table 3: Microbial population in unamended soil and coal fly ash amended soil grow under chickpea crop (x 10^2 CFU) (Mean±SD)

Treatment	Phosphate solublizing bacteria (x10^4)	N_2fixing bacteria (x10^4)
T1(No amendement, control)	36±0.16	38±0.08
T2(FA10tha^{-1}+NPK+vermicompost)	70±0.58	66±0.27
T3(FA20tha^{-1} +NPK+vermicompost)	76±0.44	75±0.27
T4(FA40tha^{-1} +NPK+vermicompost)	66±0.23	67±0.61
T5(FA50tha^{-1} +NPK+vermicompost)	64±0.78	60±0.63
T6 (FA60tha^{-1} +NPK+vermicompost)	51±0.90	48±0.20

Heavy Metal Contents In Fly Ash and Fly Ash Amended Soil

The result of heavy metal analysis of fly ash and fly ash added soil increased as compared to control shown in table 4. Upto 20tha^{-1} fly ash no significant increment in the concentration of Co, Cr, Fe, Mn, Ni, Cu, Pb, Zn and As were recorded. However, beyond 30tha^{-1} fly ash there was an increase in concentration of all the metals. Cd was recorded nil in both fly ash and fly ash applied soil. The fly ash was found alkaline hence at higher dose of fly ash application heavy metal increased due to their inherent concentration in fly ash.

Table 4: Concentration of heavy metal (mg/ kg) in unamended soil, fly ash amended soil and coal fly ash (Mean±SD)

Heavy metals	T1	T2	T3	T4	T5	T6	Fly ash
Cd	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Co	0.07±0.02	1.07±0.03	1.49±0.08	2.01±0.08	2.14±0.05	4.12±0.04	5.06±0.05
Cr	3.32±0.05	4.03±0.64	6.01±0.29	7.92±0.08	10±0.03	16±0.06	18.39±0.04
Cu	6.34±0.04	6.39±0.34	7.01±0.12	9.12±0.30	10.68±0.04	11.01±0.03	12.49±0.05
Fe	11201±1.12	11204±1.13	11207±1.15	11208±1.09	11208±1.78	11209±1.67	489± 0.03
Mn	9.27±0.48	20.33±0.23	28.45±0.02	32.01±0.05	41±0.03	50.83±0.07	87±0.40
Ni	0.03±0.02	1.78±0.07	2.47±0.04	3.30±0.03	4.67±0.02	5.34±0.02	12±0.03
Pb	0.40±0.03	0.57±0.02	0.63±0.03	0.92±0.07	1.12±0.08	2.01±0.05	4.04±0.02
Zn	0.80±0.15	1.28±0.08	2.12±0.04	2.61±0.04	3.12±0.02	3.29±0.03	5.19±0.4
As	0.02	0.03	0.03	0.04	0.05	0.05	0.09

Discussion

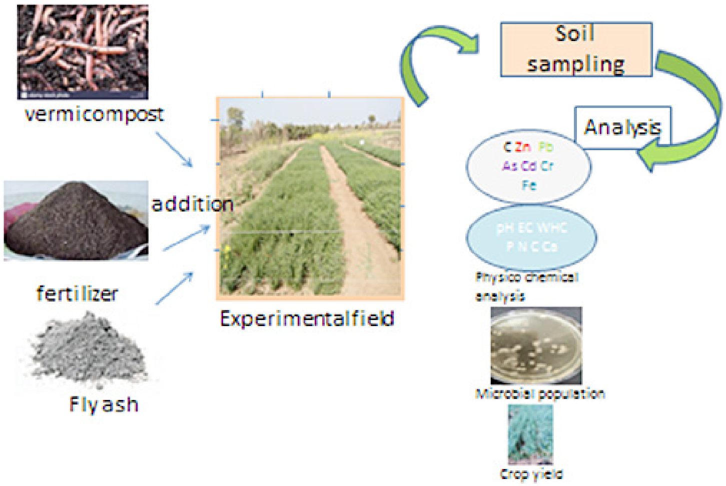
In this experiment, various parameters were characterized such as Physico-chemical, biological with different concentration of fly ash along with NPK and vermicompost. The objective of this study was to evaluate the impact of the use of fly ash aided in low nutrient content soil in Bundelkhand where drought is a common problem. To reach this objective different concentration of fly ash was used to evaluate the suitable level of fly ash for the growth of crop and microbial response. After setting up an experimental field, it appears that fly ash amended soil had a different effect on soil than that of control soil. Indeed, all the plots in this experiment showed different values for Physico-chemical parameters, as the concentration of fly ash increased the value of pH, EC, porosity, moisture content, WHC, P, N, OC, K, S, B, Fe, Mn, and Co also increased as given in table 1. Same has been observed by Tejasvi and Kumar [Tejasvi and Kumar, 2012], according to them the fly ash changed the soil texture, increased water holding capacity, soil porosity, pH, electrical conductivity and organic carbon , decreased bulk density values, N. The nitrogen content decreased as fly ash level increased the same [Dash *et al.,* 2015]. According to Sharma and Singh, 2016 in chickpea leaves the nitrogen content was decreased as the level of fly ash increases. Gradual reduction of nitrogen in chickpea leaf with an increasing proportion of fly ash can be correlated to the nitrogen in fly ash [Mishra and Shukla, 1986]. All concerned growth and yield parameters were suffered due to poor availability of nitrogen in the soil amendments with fly ash. Fly ash amendment at higher doses caused high deficiency of nitrogen in the soil, which caused suppressed growth and crop yield. The decline in growth of plant and yield from 50 to 100% fly ash amended soil was possibly due high levels of chloride, sulphate, carbonate, and bicarbonate salts leading to increase in salinity in fly ash amended soil [Singh and Siddiqui,2003].

The lower bulk density was observed in T2, T3, T4, and T5 as compared to T1 (control), the bulk density decreased due to the presence of ashes [Dransart *et al.,* 2019]. Fly ash was found an excellent amendment for soil which reduces soil bulk density causing dispersed aggregate fine particles, increase water holding capacity and reduce saturated hydraulic conductivity.

It changed environmental factors like pH, organic carbon, total nitrogen determine and influence the soil microbial population distribution [Mazinani *et al.,* 2012]. Surridge AKJ, 2009 have reported that the addition of fly neutralizes the pH which leads to increased ion mobility causing increase in bacterial species richness. Our results indicated that the addition of fly ash to soil would influence microbial activity in the soil the result could be explained by the application of different concentration of fly ash to soil. In terms of microbial population, this suggests that at higher application rate results in to the insufficient substrate C, N and high levels of heavy metals content [Nayak *et al.,*2014]. A similar observation was found by some authors that the most limiting factors for microbial activity are usually due a insufficient substrate C and N supply [Klubek *et al.,* 1992]. However, fly ash contains high toxic heavy metals which can ultimately hinder the normal metabolic process of soil inhabitant microorganisms [Jala and Goyal, 2006].

In fly ash amended soil rhizosphere creates an aerobic environment in the soil that enhances the microbial activity which stimulates oxidation of organic matter [James *et al.,* 2016]. The optimum growth of the bacterial population was observed in T3 therefore, significant reduction in microbial population was observed beyond T3 as given in table 6. Similar result reported by Kohli and Goyal, 2010 that fly ash application at the 10t ha^{-1} was good for population of bacteria, dehydrogenase enzyme activity and microbial biomass. According to Nayak *et al.,* 2014, the population of both actinomycetes and fungi decreased in fly ash amended the and beyond fly ash at 20 tha^{-1} the actinomycetes growth completely ceased. There was a slight decrease in NO_2 oxidizer microbes in fly ash amended soil whereas denitrifiers showed an increase up to fly ash at 40 tha^{-1}. Pichtel and Hayes, 1990 reported that with 20% fly ash, the population of bacteria, fungi, and actinomycetes reduced by 57%, 86% and 80%, respectively.

Fly ash contains Ca, Mg, Fe, Cu, Mn, S, B, P and Zn which are beneficial for the growth of the plant, as well as it contains some metals such as Pb, Hg, Ba, Cr, and As [Panda *et al.,* 2015]. The presence of Iron, Zinc, Copper in T6 plot is higher which decreases the growth of chickpea crop decreases may be due to accumulation of higher concentration of heavy metals Fly Ash containing 10 % ash which had a positive effect on soil microorganism in term of N and P cycling, enzyme activity and reducing the availability of heavy metals [James *et al.,* 2016]. In the present study, the application of fly ash up to 20 tha^{-1} increased the growth parameters of crop such as plant height, dry matter weight, root nodules and a number of branches, beyond 20 tha^{-1} the growth was found to be ceased. Previous studies have depicted that fly ash affects the crop yield [Singh *et al.,* 2011]. According to Panda *et al.,* 2015, application of fly ash in soil improved the rice and maize growth up to certain treatments and after that, fly ash caused deleterious effects on the growth of the plant. Similarly, [Dransart *et al.,* 2019] found that 40% of fly ash was found most suitable for growth and yield of test crop.



Graphical Abstract

Conclusion

This study suggests that application of fly ash, fertilizer and vermicompost had a significant impact on soil properties, microbial population, and growth of the crop. The result indicates the higher dose of fly ash contain heavy metal may increase toxicity which leads to decrease microbial population. The alteration in soil properties after the amendment of different doses of fly ash which in turn affect the nutrient status of soil and crop yield. The short term experiment indicates an ample scope of fly ash utilization in combination with fertilizer and organic manure to improve the fertility of the soil, microbial population and crop productivity in dry Bundelkhand region.

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Conflict of Interest

The authors do not have any conflict of interest.

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