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Effect of fly ash, lime and vermicompost application on Physico-chemical properties of soil

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Abstract
A study was conducted during *Kharif* 2020 to asses the "Effect of fly ash, lime and vermicompost application on Physico-chemical properties of soil" in an *Inceptisol* at KVK, Katghora, Korba, (Chhattisgarh). The treatments were different doses of fly ash with lime, vermicompost and RDF besides absolute control. The treatments were laid out in Randomized Block Design (RBD) with three replications. The results showed that the application of fly ash with lime and vermicompost could be a viable option for enhancing the production of crops under acidic soil conditions. The conjoint application of fly ash lime and vermicompost with RDF i.e. 75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost was found to decreased bulk density of surface soil (0-15 cm) from 1.61 Mg m^{-3} to 1.50 Mg m^{-3}. It retain higher moisture content in soil after harvest of crop and increases the soil pH, available NPK status significantly with the application of fly ash, lime and vermicompost**,** while no effect on electrical conductivity, particle density and organic carbon was recorded.

Keywords: Fly ash, lime, vermicompost, soil Physico-chemical properties

Introduction

Electricity is the backbone of modern world and particularly the machinery which acts as a driving force for economies globally has direct or indirect dependence on electricity. Since 1920, coal is being used as a basic fuel for power generation and billions of tons of fly ash and other by-products have been created till now and the improper disposal of these by-products has had a considerable negative influence on the environment (Yousuf *et al.*, 2020) [26].

There are 197 major Thermal Power Plants in India. The total fly ash production in India is expected to reach about 226.13 million tones in the year 2019-2020. The fly ash utilization in the country is estimated to be about 187.81 million tones (83.05 %) only. Since it has a huge amount of coal reserves, Chhattisgarh is a major fly-ash-generating state in India. There are 29 main Chhattisgarh Thermal Power Plants. A total of 34.822 million tons of ash are produced by the state in 2019-2020 and a meager 26.85 million tons (77.12%) are used annually (Annonomous-1).

The majority of fly-ash minerals contain comparatively large quantities of Si, Al, Ca, and Fe, mostly in the oxide phase, and the smaller the fly ash particle size, the higher the Pb, Ti, Sb, Se, As, Ni, Cr, and Zn concentrations (Davidson *at al.*, 1974) [6]. Some soluble components are removed by fly ash weathering (Shannon and Fine, 1974) [20].

Lime can effectively raise soil pH and precipitate active Al and Fe as insoluble hydroxy-Al and hydroxy-Fe (Haling *et al.*, 2010) [8]. Improved Calcium nutrition, improved soil structure and neutralization of soil pH value, contributing to an improvement in Phosphorus supply, can also be due to the beneficial functions of lime for crop growth (Curtin and Syers 2001) [4].

Vermicomposting is an environmentally-friendly, low-technology method used for handling agricultural waste. It has been shown that the resulting vermicompost has many beneficial effects on plant growth and health. This organic fertilizer is also increasingly used as a promising alternative to inorganic fertilizers and/or peat in greenhouse potting media in agriculture and horticulture (Lazcano and Domínguez, 2011) [12]

Materials and Methods

The study was conducted in an *Inceptisol* at KVK, Katghora, Korba, (Chhattisgarh) during *kharif* 2020 with rice variety (Indira aerobic-1) in a Randomized Block Design. The treatments details having various combinations of fly ash, lime, vermicompost along with RDF are given in table 1. The experimental soil falls under clay loam textural class, acidic in reaction, medium in organic carbon and available potassium while available nitrogen and phosphorus was low. The details of soil under study are given in table 2. Fly ash has silty texture, low in bulk density, alkaline in reaction, low in total carbon, nitrogen, phosphorus and potassium, however micronutrients viz. Fe & Mn was higher and Zn & Cu was sufficient (table 3).

Table 1: Treatment details

Treatment No.	Treatment name
T_1	Control
T_2	100% RDF (100:60:40:: $N:P_2O_5:K_20$)
T_3	75% RDF + 2 t/ha Lime
T_4	75% RDF + 2 t/ha Vermicompost
T_5	75% RDF + 20 t/ha Fly ash
T_6	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime
T_7	75% RDF + 20 t/ha Fly ash + 2 t/ha Vermicompost
T_8	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost
T_9	75% RDF + 40 t/ha Fly ash
T_{10}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime
T_{11}	75% RDF + 40 t/ha Fly ash + 2 t/ha Vermicompost
T_{12}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost

Table 2: Important initial Physico-chemical properties of the soil under study

S. No.	Properties	Values	Status
01.	Mechanical compositions		
	Sand (%)	29	
	Silt (%)	41	
	Clay (%)	30	
	Soil textural class		Clay loam
02.	pH	5.1	Acidic
03.	EC (dSm-1 at 25^0C)	0.06	Normal
04.	Organic carbon (%)	0.51	Medium
05.	Bulk density (Mg m^{-3})	1.61	
06.	Particle density (Mg m^{-3})	2.22	
07.	Available N (kg ha^{-1})	135.32 kg/ha	Low
08.	Available P (kg ha^{-1})	7.53	Low
09.	Available K (kg ha^{-1})	270.23	Medium

Table 3: Physico-chemical properties of fly-ash

S. No.	Particulars	value
01.	Mechanical compositions	
	a) Sand	23%
	b) Silt	69%
	c) Clay	8%
02.	Bulk density (Mg m_{-3})	0.88
	pH	8.3
03.	EC (mS/cm)	0.37
04.	Total carbon	0.18
05.	N (%)	0.12
06.	P (%)	0.049
07.	K (%)	0.022
08.	Total Fe (mg kg^{-1})	3313
09.	Total Mn (mg kg^{-1})	310
10.	Total Zn (mg kg^{-1})	32
11.	Total Cu (mg kg^{-1})	12

Soil pH was determined in 2.5:1 water-soil suspension (by Piper, 1966) [16] than samples were allow to settled down for recording electrical conductivity (Black, 1965) [2]. The organic carbon was determined by Walkley and Black rapid titration method (1934). Available nitrogen was estimate by alkaline potassium permanganate method (Subbiah and Asija. 1956) [23], available phosphorus by Bry and Kurtz P-1 method and available potassium was determined by neutral normal ammonium acetate extractant and detected by Flame photometer.

For determining the bulk density, core samples for 0-15 cm depth were drawn and oven dried to a steady weight at 105 ^{0}C. Bulk density was calculated by.

$$\text{B.D. } (\text{Mg/m}^3) = \frac{\text{Weight of oven dry soil}}{\text{Volume of core sampler}}$$

Pycnometer method was used to determined particle density and Particle density was calculate by using formula-

$$\text{P.D. } (\text{Mg/m}^{-3}) = \frac{\text{Mass of dry soil}}{\text{Volume of soil solid}}$$

Soil moisture content was determined by weighing moist samples then dried to a constant weight in an oven at 105°C (for about 24 hours) and weighed.

$$\text{Soil moisture content } (\%) = \frac{(\text{wt. of wet soil}) - (\text{wt. of dry soil})}{(\text{wt. of dry soil})} \times 100$$

Results and Discussion

Bulk Density

The data presented in table 4, shows that the highest bulk density (1.61 Mg m^{-3}) was recorded in treatment T_1 (control) whereas lowest bulk density (1.50 Mg m^{-3}) was recorded in the treatment T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost). The application of graded levels of fly ash (@ 20 and 40 ton/ha) with lime and vermicompost significantly decreased the bulk density as compared to control and 100% RDF in an *Inceptisol*.

The decrease in bulk density of soil may be attributed to an increase in coarse and fine sand sized particles due to application of fly ash and lime, which might have altered the configuration and arrangement of the soil particles due to which the soil was loosened and the total porosity of soil was increased. Addition of vermicompost might have helped in development of aggregation in soil which resulted in increased porosity and ultimately lowered the bulk density as also reported by Sharma and Kalra (2006) [21], Deshmukh *et al.*, (2000) [7] and Patel (2015) [15] who found a decrease in soil bulk density as fly ash levels were increased.

Particle Density

The results of particle density are presented in Table 4 revealed that particle density varies from 2.22 Mg m^{-3} to 2.34 Mg m^{-3}. The highest particle density was found in treatment T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) while lowest 2.22 Mg m^{-3} in T_1 (control). The data evidenced that no significant difference was found in soil particle density due to imposition of different treatments. Similar results were reported by Patel (2015) [15] and Lal (2014) [11].

The increase in particle density of soil may be due to mineral composition of fly ash which contains various heavy minerals- mullite, quartz, lime, anhydrite, and gehlenite (Zhao *et al.*, 2010) [27] and also contained heavy metals like nickel, vanadium, cadmium, barium, chromium, copper, molybdenum, zinc and lead (Ismail *et al.*, 2007) [9].

Table 4: Impact of application of fly ash with lime and vermicompost on bulk density and particle density at 0-15 cm in an *Inceptisol* at harvest.

S. No.	Treatments	Bulk Density (Mg m^{-3})	Particle Density (Mg m^{-3})
T_1	Control	1.61[a]	2.22
T_2	100% RDF	1.60[a]	2.23
T_3	75% RDF + 2 t/ha Lime	1.58[a]	2.23
T_4	75% RDF + 2 t/ha Vermicompost	1.57[a]	2.29
T_5	75% RDF + 20 t/ha Fly ash	1.56[ab]	2.24
T_6	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime	1.55[b]	2.27
T_7	75% RDF + 20 t/ha Fly ash + 2 t/ha Vermicompost	1.54[b]	2.32
T_8	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost	1.51[bc]	2.34
T_9	75% RDF + 40 t/ha Fly ash	1.56[ab]	2.25
T_{10}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime	1.55[b]	2.28
T_{11}	75% RDF + 40 t/ha Fly ash + 2 t/ha Vermicompost	1.52[b]	2.33
T_{12}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost	1.50[c]	2.34
	SEm±	0.02	0.03
	CD (P=0.05)	0.05	NS

Soil moisture content

It is evident from the data represented in table 5 that treatment T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) recorded comparatively highest soil moisture content after 7th days of harvesting followed by T_8 (75% RDF + 20 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) and T_{11} (75% RDF + 40 t/ha Fly ash + 2 t/ha Vermicompost) while, the minimum in T_1 (control). The results shows that the loss in moisture content is lower when fly ash is incorporated in soil with lime and vermicompost.

Table 5: impact of fly ash with lime and vermicompost on drying pattern in *Inceptisol* at harvest.

Treatments	Moisture content						
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
T_1 (Control)	8.33	7.98	7.56	7.14	6.52	6.03	5.21
T_2 (100% RDF)	8.69	8.19	7.78	7.23	6.64	6.11	5.17
T_3 (75% RDF + 2 t/ha Lime)	9.13	8.77	8.26	7.73	7.32	6.87	6.55
T_4 (75% RDF + 2 t/ha VC)	10.11	9.82	9.09	8.64	8.01	7.38	6.89
T_5 (75% RDF + 20 t/ha FA)	8.95	8.26	7.75	7.22	6.72	6.13	5.76
T_6 (75% RDF + 20 t/ha FA + 2 t/ha Lime)	10.46	10.01	9.51	8.97	8.39	7.89	7.38
T_7 (75% RDF + 20 t/ha FA + 2 t/ha VC)	11.52	11.02	10.49	9.96	9.35	8.84	8.43
T_8 (75% RDF + 20 t/ha FA + 2 t/ha Lime + 2 t/ha VC)	12.53	12.04	11.53	11.00	10.47	9.94	9.45
T_9 (75% RDF + 40 t/ha FA)	9.63	9.05	8.43	7.98	7.46	6.98	6.45
T_{10} (75% RDF + 40 t/ha FA + 2 t/ha Lime)	10.98	10.49	9.93	9.37	8.86	8.25	7.89
T_{11} (75% RDF + 40 t/ha FA + 2 t/ha VC)	12.10	11.56	11.02	10.56	9.99	9.53	9.01
T_{12} (75% RDF + 40 t/ha FA + 2 t/ha Lime + 2 t/ha VC)	13.58	13.14	12.77	12.21	11.78	11.33	11.01

Soil Reaction (pH)

Table 6 shows that soil pH was significantly improved from initial value (5.09) due to addition of fly ash and lime in *Inceptisol*. The pH value varies from 5.09 to 6.32. The highest value of soil pH (6.32) was found in treatment T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) while minimum (5.09) in T_1 (control). It was at par within treatments T_6, T_8 and T_{10}.

The application of different doses fly ash with lime and vermicompost had significantly enhanced soil reaction (pH). The enhanced in pH of soil may be due to addition of lime that can greatly improve soil pH and precipitate active Al and Fe as insoluble hydroxy-Al and hydroxy-Fe and also release Ca^{2+} ions that can replace H^+ ions from exchange complex in soil system. Rahman *et al.*, (2002) [17] and Rautaray *et al.*, (2003) [19] also reported that lime increased soil test pH and Ca & Mg content in soil.

Electrical conductivity

Table 6 shows that no significant difference in the value of electrical conductivity of soil was found between the treatments. The EC varies from 0.08 dSm^{-1} (T_1-control) to 0.13 dSm^{-1} (T_{12}-75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost). There was no significant change in EC. Similar results were also reported earlier by Matte and Kene (1994) [13], Das *et al.*, (2013) [5] and Patel (2015) [15].

Organic carbon

The data presented in Table 6 revealed that no significant difference in the status of organic carbon in soil was found between the treatments due to application of fly ash with lime and vermicompost. The organic carbon varies from 0.47% (T_1-control) to 0.54% (T_{12}-75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost).

Table 6: impact of fly ash with lime and vermicompost on chemical properties of soil after harvest of rice crop.

S. No.	Treatments	Soil pH	Electrical conductivity (dS m^{-1})	Organic carbon (%)
T_1	Control	5.09[c]	0.08	0.47
T_2	100% RDF	5.12[c]	0.09	0.48
T_3	75% RDF + 2 t/ha Lime	5.30[bc]	0.10	0.49
T_4	75% RDF + 2 t/ha Vermicompost	5.15[c]	0.09	0.50
T_5	75% RDF + 20 t/ha Fly ash	5.23[c]	0.10	0.49

T_6	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime	6.12[a]	0.12	0.50
T_7	75% RDF + 20 t/ha Fly ash + 2 t/ha Vermicompost	5.40[b]	0.11	0.52
T_8	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost	6.29[a]	0.12	0.53
T_9	75% RDF + 40 t/ha Fly ash	5.36[b]	0.11	0.49
T_{10}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime	6.25[a]	0.12	0.51
T_{11}	75% RDF + 40 t/ha Fly ash + 2 t/ha Vermicompost	5.60[b]	0.11	0.52
T_{12}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost	6.32[a]	0.13	0.54
	SEm±	0.11	0.01	0.02
	CD (P=0.05)	0.34	NS	NS

Available Nitrogen
Table 7 shows that available nitrogen ranged from 130.46 kg ha^{-1} to 207.37 kg ha^{-1}. The treatment T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) recorded highest available nitrogen in soil (207.37 kg ha^{-1}) while, T_1 (control) had the lowest (130.46 kg ha^{-1}). It was at par with treatments T_8 and T_{11}. Availability of nitrogen was significantly increased due to addition of fly ash with lime and vermicompost in *Inceptisol*.

The addition of fly ash along-with chemical fertilizers, lime and vermicompost increased the nitrogen supply due to mineralization of organic nitrogen from vermicompost and fly ash, which is a slow process occurs during the crop growth period and resulted in increased soil N status under different treatments as also reported by Das *et al.*, (2013) [5], Yadav (2006) [25], Jala (2005) [10] Patel (2015) [15] and Ramteke (2016) [18].

Available Phosphorus
Table 7 shows that the maximum available P in soil (12.99 kg ha^{-1}) was recorded in treatment of T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) while, the minimum under T_1 (control) 7.16 kg ha^{-1}. It was at par with treatments T_7, T_8 and T_{11}. Availability of phosphorus in soil was significantly increased due to addition of fly ash with lime and vermicompost in *Inceptisol*.

The increases in available phosphorus status of soil with application of fly ash with lime and vermicompost may be attributed to silica content of fly ash, which played a major role in releasing the P from the insoluble source to available pool as well as from P fertilizer. Also hydrolysis of Fe^{2+}, Al^{3+}, and Mg^{2+} compounds in fly ash, as well as the release of inorganic acids may have contributed to increased available P in soil. Since organic matter in the soil has a buffering capability, the liberated acids may have aided in the release of available phosphate from the unavailable form without disrupting the pH.

Yadav (2006) [25], Onwuka (2011) [14], Singh and Verma (2003) [22] Patel (2015) [15] and Ramteke (2016) [18] also reported similar findings.

Available Potassium
Table 7 shows that the maximum available K in soil (325.55 kg ha^{-1}) was recorded in treatment of T_{12} (75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost) while, the minimum under T_1 (control) 255.94 kg ha^{-1}. It was at par with treatments T_7, T_8, and T_{11}. Availability of potassium in soil was significantly enhanced due to addition of fly ash with lime and vermicompost in *Inceptisol* that may be attributed to higher content of exchangeable potassium in fly ash which led to the rise of exchangeable and available potassium with its application. The positive effect of fly ash on potash content was also reported by Das *et al.*, (2013) [5], Patel (2015) [15] and Ramteke (2016) [18].

Table 6: Impact of fly ash with lime and vermicompost on available macronutrients of soil in *Inceptisol* at harvest.

S. No.	Treatments	Available N of Soil (kg ha^{-1})	Available P of Soil (kg ha^{-1})	Available K of Soil (kg ha^{-1})
T_1	Control	130.46[f]	7.16[d]	255.94[d]
T_2	100% RDF	173.68[c]	10.72[b]	311.93[b]
T_3	75% RDF + 2 t/ha Lime	147.39[e]	9.73[c]	296.82[c]
T_4	75% RDF + 2 t/ha Vermicompost	155.53[de]	10.60[bc]	302.72[c]
T_5	75% RDF + 20 t/ha Fly ash	153.77[e]	9.91[c]	298.72[c]
T_6	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime	182.17[c]	10.75[b]	314.54[b]
T_7	75% RDF + 20 t/ha Fly ash + 2 t/ha Vermicompost	195.05[b]	11.67[ab]	315.82[ab]
T_8	75% RDF + 20 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost	201.32[a]	12.78[a]	321.04[a]
T_9	75% RDF + 40 t/ha Fly ash	163.73[d]	10.69[b]	310.33[b]
T_{10}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime	183.45[c]	10.84[b]	314.78[b]
T_{11}	75% RDF + 40 t/ha Fly ash + 2 t/ha Vermicompost	198.43[ab]	11.79[a]	316.11[a]
T_{12}	75% RDF + 40 t/ha Fly ash + 2 t/ha Lime + 2 t/ha Vermicompost	207.37[a]	12.99[a]	325.55[a]
	SEm±	3.35	0.46	3.63
	CD (P=0.05)	9.90	1.37	10.72

Conclusions
Integration of fly ash is an amendment with lime and vermicompost may proved beneficial for improving soil chemical environment especially soil pH, which also favours to increasing the availability of macronutrients viz. N, P & K in soils, having low pH. The application of fly ash with lime and vermicompost have shown significant improvement in Physico-chemical properties of soil viz. soil moisture content, bulk density, pH and available NPK. The application of 75% RDF + 40 t/ha FA + 2 t/ha Lime +2t/ha Vermicompost shows higher moisture retention after harvest of crop, also bulk density of soil reduced as compared to initial status. Improvement in pH, available major nutrient (N, P and K) over the initial status was recorded due to the application of 75% RDF + 40 t/ha FA + 2 t/ha Lime +2t/ha vermicompost as compared to sole application of 100% RDF alone.

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References

1. Annonomous-1 Central Electricity Authority Thermal Civil Design Division New Delhi 2020.
2. Black CA. Methods of Soil Analysis. Amer. Soc.of Agro. Inc. Publ. Madison, Wisconsin, USA 1965.
3. Bray RH, Kurtz LT. Determination of total, organic and available forms of phosphorousin soils. Soil Sci. 1945;59:39-45.
4. Curtin D, Syers J. Lime-induced changes in indices of soil phosphate availability. *Soil Sci Soc Am J* 2001;65:147-152.
5. Das BK, Choudhury BH, Das KN. Effect of Integration of Fly Ash with Fertilizers and FYM on Nutrient Availability, Yield and Nutrient Uptake of Rice inInceptisols of Assam, India. International Journal of Advancements in Researchand Technology, 2013;2(11):190-208.
6. Davidson RL, Natusch DFS, Wallace JR, Evans CA Jr. Trace elements in fly ash: Dependence of concentration on particle size. Environ. Sci. Technol 1974;8:1107-1113.
7. Deshmukh A, Matte DB, Kene DR, Bhaisare, Bharti. Soil properties influenced by fly ash application. J Soil Crops. 2000;10(1):69-71.
8. Haling RE, Simpson RJ, Delhaize E, Hocking PJ, Richardson AE. Effect of lime on root growth, morphology and the rhizosheath of cereal seedlings growing in an acid soil. *Plant Soil* 2010;327:199-212.
9. Ismail KN, Hussin K, Idris MS. Physical, chemical & mineralogical properties of fly ash. Journal of Nuclear and Related Technology Special Edition 2007;4:47-51.
10. Jala S. Fly ash as an amendment agent for soil fertility. PhD. Thesis, Thapar Institute of Engineering and Technology, Patiala (Punjab) 2005.
11. Lal B, Nayak V, Sharma P, Tedia K. Effect of Combined Application of FYM, Fly Ash and Fertilizers on Soil Properties and Paddy Grown on Degraded Land. Curr. World Environ 2014;9(2):531-535.
12. Lazcanoa C, Domínguez J. The use of vermicompost in sustainable agriculture: impact on plant growth and soil fertility. *In: Soil Nutrients* ISBN 978-1-61324-785-3. 2011.
13. Matte DB, Kene DR. Effect of fly ash application on yield performance of *Kharif* and Rabi crops. J. Soils Crops 1994;5(2):133-136.
14. Onwuka MI. The chemical composition of different sources of liming materials and their effect on soil chemical properties. J. of Environmental Sciences and Resource Management 2011;3:57-67.
15. Patel K. Influence of Integrated Effect of Inorganic and Organic Fertilizers with Fly Ash on Rice Grown In Acid Soil of Northern Hills Zone (C.G.) M.Sc. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (Chhattisgarh) 2015.
16. Piper CS. Soil and plant analysis.,(Hans Publishers: Bombay. India) 1966.
17. Rahman MA, Meisner CA, Duxbury JM, Lauren J, Hossain ABS. Yield response and change in soil nutrient availability by application of lime, fertilizer and micronutrients in an acidic soil in a rice-wheat cropping system. Symposium no. 05 Paper no. 773 Presentation: poster 2002.
18. Ramteke LK. Effect of fly ash, organic manure and fertilizers on soil health and productivity of rice-wheat cropping system in alfisols and vertisols 2016.
19. Rautaray SK, Ghosh BC, Mittra BN. Effect of fly ash, organic wastes and chemical fertilizers on yield, nutrient uptake, heavy metal content and residual fertility in a rice-mustard cropping sequence under acid lateritic soils. Bioresource Technology 2003;90:275 283.
20. Shannon DG, Fine LO. Cation solubilities of lignite fly ashes. Environ. Sci. Technol 1974;12:10-26.
21. Sharma SK, Kalra N. Effect of fly ash incorporation on soil properties and productivity of crops: a review. J. of Scientific and Industrial Research 2006;65:383-390.
22. Singh KK, Verma G. Influence of fly ash on physic-chemical properties and fertility status of soil. Research on Crops 2003;4(1):63-68.
23. Subbaiah BV, Asija GL. A rapid method for estimation of available N in soil. Current Science 1956;25:259-260.
24. Walkley A, Black IA. An examination of the Digestion method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science 1934;37(1):29-38.
25. Yadav VK. Effect of different doses of fly ash on soil physico–chemical properties and yield of paddy. M.Sc. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 2006.
26. Yousuf A, Manzoor SO, Youssouf M, Malik ZA, Khawaja KS. Fly Ash: Production and Utilization in India - An Overview. Journal of Materials and Environmental Science., 2020;11(6):911-921.
27. Zhao Y, Zhang J, Tian C, Li H, Shao X, Zheng C. Mineralogy and Chemical Composition of High-Calcium Fly Ashes and Density Fractions from a Coal-Fired Power Plant in China Energy Fuels 2010;24(2):834-843.