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EFFECT OF FLY ASH, LIME AND CHEMICAL FERTILIZERS ON SOIL PHYSICO-CHEMICAL PROPERTIES AND GROWTH OF LENTIL

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ABSTRACT

Fly ash (FA), a byproduct of coal combustion in thermal power plants, has been considered as a problematic solid waste and its safe disposal is a cause of concern. Several studies proposed that FA can be used as a soil additive; however, its effect on physico chemical properties of soil and growth of lentil (cv. Malviya Viswanath) to fly ash (FA) application in conjunction with lime and chemical fertilizers was studied in a pot experiment during winter 2020 in acid soil of Rajgarh block. Application of fly ash at higher dose in combination with lime amended the acidic condition of soil, whereas increased the salt concentration in soil. At higher level, when fly ash was applied to soil, it improved the physical properties of soil but declined the organic carbon content in soil. The application of fly ash @ 80% FD in conjunction with lime @ 20%LD and 100% RDF was more beneficial for the growth performance of lentil than the unamended soil.

KEY WORDS: Fly ash, Fly ash dose (FD), Lime dose (LD), Recommendation dose of fertilizer (RDF)

INTRODUCTION

The proper disposal of fly ash (FA), a byproduct of coal burning in thermal power plants, has been regarded as a problematic solid waste. Being a byproduct of coal combustion, FA exhibits a wide range of physico-chemical and mineralogical characteristics depending on the parent coal's composition, combustion conditions, the kind of emission control systems, and handling and storage procedures (Jala and Goyal, 2006). In recent era, agriculture is heavily dependent on chemical fertilizers to produce more and more food per unit area. The injudicious use of chemical fertilizers has a severe influence on soil productivity as well as soil health. The FA amendment is becoming more important in agriculture for enhancing soil health and sustaining productivity as it contains SiO_2, Al_2O_3 and Fe_2O_3, CaO as principal components and mineral nutrients as minor components (Singh *et al.*, 2011). The use of FA in agriculture is limited due to its low N and P contents, low soil microbial activity, and high concentration of toxic heavy metals. However, some reports mention the potential use of FA as a soil ameliorant for improving the physical properties of soil (Shen *et al.*, 2008) and a source of available plant micronutrients and macronutrients (Rautaray *et al.*, 2003). Fly ash is a potentially advantageous amendment for soil reclamation due to its fine sized particles, low bulk density (BD), higher water holding capacity, alkaline pH, and essential plant nutrient contents (Ram and Masto, 2010). The crop production in acid soil is very low. The limiting factors to crop growth associated with soil acidity are mainly due to concentrations of H^+, Al^{3+} ions in the soil solution. The usage of lime for acid soil amelioration is steadily declining due to its expensive cost. Therefore, fly ash is used as an alternative source for the reclamation of acid soil due to its liming potential, and it is an excellent step to reduce the input cost in agriculture (Mittra *et al.*, 2005). Pulses are a crucial component of the vegetarian diet and the least expensive source of protein for poor farmers of the Indian subcontinent. The lentil grain has a full complement of amino acids and comprises 57–60% carbohydrates, 24–26% protein, 3.2% fibre, and only 1.3% fat. Its protein has a high protein efficiency ratio, excellent biological value, and is readily digested. The newly harvested lentil grains are rich in phosphate, iron, vitamin A, and vitamin C. In acid soil, the crops like mustard (Rautaray *et al.*, 2003), and peanut (Basu *et al.*, 2007) have performed better with the application of fly ash. The research about the effect of fly ash on the growth performance of lentil in acid soil is very limited. Therefore, my investigation focused on the possibility of using fly ash as an amendment, either alone or in conjunction with lime in acid soil, to see its effect on soil health and the growth of lentil.

MATERIALS AND METHODS

Experimental setup

A pot culture experiment was conducted in the winter 2020 with lentil (cv. Malviya Viswanath) in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. For this experiment, soil was collected from Rajgarh block, which was acidic. Collected soil sample was air-dried in shade, ground and sieved through a 2 mm sieve. The fly ash was collected from the Singrauli Super Thermal Power Station, U.P, India. The fly ash sample was oven dried at 105^0C for 24 hours to remove moisture from fly ash sample and kill off any pathogens followed by drying at room temperature for one week. After drying of fly ash samples, they were ground and sieved. The physico chemical properties of fly ash and initial soil sample were presented in the Table 1. The earthen pots are filled with 10 kg soil, calculated amount of fly ash, lime and NPK fertilizers according to treatments. The calcium carbonate equivalent value of fly ash was 7.75% and the lime requirement of soil to raise pH 6.5 was 5.4 t ha^{-1}. The fly ash amount which was

Table 1. The physico chemical properties of initial soil and fly ash sample

Physico chemical properties	Soil	Fly ash
pH	5.62	8.76
EC (dS m^{-1})	0.11	0.52
Organic carbon (g kg^{-1})	4.0	
Bulk density (Mg m^{-3})	1.38	0.96
Water holding capacity (%)	33.62	54.46

equivalent to full lime requirement (5.4 t ha^{-1}) was calculated by using CCE value and lime requirement value. The lime requirement value and fly ash requirement value were designated as fly ash dose (FD) and lime dose (LD) respectively. The recommended dose of fertilizer (RDF) for lentil crop is 40:60:20 N, P_2O_5 and K_2O kg ha^{-1}. The nitrogen, phosphorus and potassium will be added to the soil of each pot through Urea, Diammonium Phosphate (DAP) and Muriate of potash (MOP), respectively. The treatment details are presented in the Table 2. Each treatment was replicated for three times. Finally, six plants were kept in the pot and with the help of a meter scale, plant height of lentil was measured at 30, 60 and 90 days after sowing (DAS).

Analysis of physico-chemical properties of soil

After harvesting of lentil crop, the soil samples were collected from each pot, ground and sieved through a 2 mm sieve. Thereafter soil samples were stored in polythene bags for analysis of physical and chemical properties of soil. Soil pH was carried out using glass electrode pH meter and the ratio of soil and water was 1:2.5 (Jackson, 1973), electrical conductivity (EC) of soil was measured by using EC meter. Particle size analysis was performed using Bouyoucos hydrometer method (Bouyoucos, 1962), bulk density (BD) by using pycnometer, water holding capacity by Keen Raczkowski box method. Soil organic carbon was determined by using the method proposed by Walkley and Black (1934), available nitrogen content by alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus by using BrayP1 extractant (0.03N NH_4F+ 0.025N HCl) as proposed by Bray and Kurtz, 1945.

Statistical analysis

Experimental data were obtained in triplicate and were compared by one way analysis of variance (ANOVA) and comparison of significance difference of treatment means at $P \leq 0.05$ was done by Duncan's multiple range test.

Table 2. Treatment details of the experiment

Treatments	Treatment details
T_1	Control
T_2	100% RDF
T_3	100% FD
T_4	100% LD
T_5	100% RDF + 100% LD
T_6	100% RDF + 80%LD+ 20% FD
T_7	100% RDF + 50% LD + 50% FD
T_8	100% RDF + 20% LD + 80% FD
T_9	100% RDF + 100% FD
T_{10}	75% RDF + 100% LD
T_{11}	75% RDF + 80%LD+ 20% FD
T_{12}	75% RDF + 50% LD + 50% FD
T_{13}	75% RDF + 20% LD + 80% FD
T_{14}	75% RDF + 100% FD
T_{15}	50% RDF + 100% LD
T_{16}	50% RDF + 80%LD+ 20% FD
T_{17}	50% RDF + 50% LD + 50% FD
T_{18}	50% RDF + 20% LD + 80% FD
T_{19}	50% RDF + 100% FD

Where RDF: recommendation dose of fertilizer, FD: fly ash dose, LD: lime dose

RESULTS AND DISCUSSION

Impact of fly ash, lime and chemical fertilizers on the height of lentil crop

The results of the growth of lentil in term of plant height as influenced by fly ash, lime and chemical fertilizers are presented in Table 3. Application fly ash, lime and different levels of fertilizers had significant effect on plant height change at 30 days after sowing (DAS), 60 DAS and 90 DAS. The application of RDF @ 100% in T_2 at 30 DAS had a substantial influence on the growth in plant height over the control. At 30 DAS, the plant height in T_3 (100%FD) and T_4 (100%LD) was comparable to the control, however the application of fly ash @100% with RDF @100% in T_9 significantly increased the plant height over the control. Similarly, when lime @ 100% was applied in conjunction with RDF @ 100% in T_5, the plant height rose considerably over the control at 30 DAS. At 60 DAS the plant height was significantly higher in T_2 (100%RDF) than the control. Application of fly ash @ 100% in T3 had no significant effect on the increase in plant height over control, whereas the application of fly ash with fertilizers in T_9 (100% RDF + 100% FD), T_{14} (75% RDF + 100% FD), and T_{19} (50% RDF + 100% FD) had a significant effect on the increase in plant height over control. The plant height in T_4 (100%LD) was at par with the control, whereas the application of lime with fertilizers in T_5 (100% RDF + 100% LD), T_{10} (75% RDF + 100% LD), and T_{15} (50% RDF + 100% LD) had a significant effect on the increase in plant height over control. The highest plant height was found in T_8 (100%RDF + 20%LD+80%FD) with a value of 23.77 cm among treatments at 60 DAS. At 90 DAS, plant height in fly ash-amended treatment (T_3: 100%FD) and lime-amended treatment (T_4: 100%LD) was at par with control. The application of RDF @ 100% in T_2 had a significant effect on the increase in plant height over control. In the treatments, T_6 (100% RDF + 80%LD+ 20% FD) to T_8 (100% RDF + 20% LD + 80% FD), an increment in plant height was observed over control. Similarly in the treatments T_{11} (75% RDF + 80%LD+ 20% FD) to T_{13} (75% RDF + 20% LD + 80% FD), with an increase in fly ash doses plant height increased over control. In the treatments T_{16} (50% RDF + 80%LD+ 20% FD) to T_{19} (50% RDF + 100% FD), an increasing trend in plant height was also observed. The highest plant height was observed in T_8 (100%RDF + 20%LD + 80%FD) among treatments, which was at par with T_2 (100%RDF) at 90 DAS. Initially, the plant height significantly increased in the treatment which received NPK fertilizers. This might be due to the availability of primary nutrients through applied fertilizers which helped in the growth and development of the crop. Singh *et al.* (2004) also found the results of increasing the growth of lentil with application of nitrogenous fertilizer. At 60 DAS and 90 DAS the highest plant height was observed in T_8 (100%RDF + 20%LD+80%FD). This might be due to the supply of more nutrients from fly ash in addition to fertilizers for better growth and development of the crop. The soil pH was higher in T_8 as compared to the control which enhanced the availability of the nutrients. Another possible reason for better growth in fly ash-amended soil might be due to better microbial activity and enzymatic activity which in turn created a better supply of nutrients. The better growth of red gram was achieved with the addition of fly ash has been reported (Pandey *et al.*, 2008).

Impact of fly ash, lime and chemical fertilizers on the physico chemical properties of post-harvest soil

Results of Table 4 revealed that lime, fly ash and different doses of fertilizers had a significant effect on soil pH. The highest pH was observed in T_4: 100%LD (6.30) followed by T_3: 100%FD (6.23) > T_{14}: 75%RDF +100%FD (6.22) > T_{13}: 75%RDF +

20%LD+80%FD (6.20) = T_{15}: 50%RDF + 100%LD (6.20) > T_{19}: 50%RDF +100%FD (6.19) > T_{18}: 50%RDF + 20%LD+80%FD (6.17) > T_{17}: 50%RDF + 50%LD+50%FD (6.16) > T_{11}: 75%RDF + 80%LD+20%FD (6.15) > T_{12}: 75%RDF + 50%LD+50%FD (6.14) = T_{16}: 50%RDF + 80%LD+20%FD (6.14) > T_9: 100%RDF + 100%FD (6.09) > T_{10}: 75%RDF + 100%LD (6.08) > T_8: 100%RDF + 20%LD+80%FD (6.07) > T_5: 100%RDF + 100%LD (6.05) > T_6: 100%RDF + 80%LD+20%FD (6.01) > T_7: 100%RDF + 50%LD+50%FD (5.98) > T_1: control (5.60) > T_2: 100%RDF (5.55). The treatment T_4 (100%LD) was statistically at par with T_3 (100% FD). The soil pH was higher in T_5 (100%RDF + 100%LD) than in T_2 (100%RDF) which indicated lime had a significant effect on the increase in soil pH. Among the treatments T_5 (100%RDF + 100%LD), T_{10} (75%RDF + 100%LD), and T_{15} (50%RDF + 100%LD) the highest soil pH was observed in T_{15}. The soil pH in T_5 (100%RDF + 100%LD) was statistically at par with T_{10} (75%RDF + 100%LD). Application of fly ash alone (T_3: 100%FD) had a significant effect on the increase in soil pH than fly ash applied in conjunction with RDF (T_9: 100%RDF + 100%FD). In fly ash and lime applied treatments (T_5: 100%RDF + 100%LD - T_{10}: 75%RDF + 100%LD) it was observed by decreasing lime doses and increasing fly ash doses had no significant effect on the change in soil pH except in T_7 (100%RDF + 50%LD+50%FD). The soil pH was significantly lower in T_7 (100%RDF + 50%LD+50%FD) than T_5(100%RDF + 100%LD). By decreasing lime doses and increasing fly ash doses in treatments from T_{10} (75%RDF + 100%LD) to T_{12} (75%RDF + 50%LD+50%FD) there was no significant change in soil pH, whereas T_{13} (75%RDF + 20%LD+80%FD) and T_{14} (75%RDF +100%FD) had significantly higher soil pH than T_5 (100%RDF + 100%LD). Similarly in treatments from T_{15} (50%RDF + 100%LD) to T_{19} (50%RDF +100%FD), decreasing lime doses and increasing fly ash doses had no significant effect on the change in soil pH. The highest pH in lime-amended soil might be attributed to the acid neutralizing capacity of lime. The lime ($CaCO_3$) reacts with H^+ ions and forms Ca^{2+}, CO_2, and H_2O which caused an increase in soil pH (Holland *et al.*, 2017). There were significant differences in the electrical conductivity (EC) of soil found among treatments (Table 4). Application fly ash @100% had a significant effect in the increase in EC of soil over control. The EC was significantly lower in lime treated soil (T4) than in soil treated with fly ash (T3). With an increase in fly ash doses,

Table 3. Impact of fly ash, lime and chemical fertilizers on the height of lentil crop

Treatments	Treatment details	Plant height (cm)		
		30 DAS	60 DAS	90 DAS
T_1	Control	6.70h	12.87g	17.63h
T_2	100%RDF	12.23a	20.13bcd	31.63abcd
T_3	100%FD	7.00h	13.43g	18.53h
T_4	100%LD	7.17gh	13.20g	18.03h
T_5	100%RDF + 100%LD	10.80abc	18.53cde	29.77def
T_6	100%RDF + 80%LD+20%FD	11.67a	20.87b	32.17abc
T_7	100%RDF + 50%LD+50%FD	11.77a	22.83a	32.97a
T_8	100%RDF + 20%LD+80%FD	11.90a	23.77a	33.17ab
T_9	100%RDF + 100%FD	10.97ab	19.13bcde	30.97abcde
T_{10}	75%RDF + 100%LD	9.37cde	16.27f	27.97fg
T_{11}	75%RDF + 80%LD+20%FD	9.47cde	19.00cde	30.87abcd
T_{12}	75%RDF + 50%LD+50%FD	9.73bcd	19.77bcd	31.37abcd
T_{13}	75%RDF + 20%LD+80%FD	10.23bc	20.37bc	31.97bcde
T_{14}	75%RDF +100%FD	9.97bcd	17.27ef	28.77efg
T_{15}	50%RDF + 100%LD	8.60defg	15.90f	27.20g
T_{16}	50%RDF + 80%LD+20%FD	7.67fgh	15.97f	27.37g
T_{17}	50%RDF + 50%LD+50%FD	7.83fgh	18.37de	29.17efg
T_{18}	50%RDF + 20%LD+80%FD	8.03efgh	18.87cde	30.20cde
T_{19}	50%RDF +100%FD	8.73def	15.80f	26.97g
SEm±		0.46	0.58	0.69
CD ($P \leq 0.05$)		1.32	1.65	1.98

Mean values with the same lower-case letter are not significantly different in a column for each parameter at $p < 0.05$ by Duncan's multiple range test an increasing trend in the EC of soil was observed in treatments varied from T_6 (100%RDF + 80% LD+20%FD) to T_9 (100%RDF + 100%FD). The highest EC (dSm^{-1}) of soil was found in T_3: 100%FD (0.24) and followed by T_{14}: 75%RDF +100%FD (0.23) = T_{19}: 50%RDF +100%FD (0.23) > T_9: 100% RDF+100% FD (0.22) > T_8: 100% RDF+20% LD+80% FD (0.21) = T_{18}: 50% RDF+ 20% LD+80%FD (0.21) > T_{13}: 75%RDF+20%LD+80%FD (0.20) > T_{12}: 75% RDF+ 50%LD+50%FD (0.19) > T_7: 100% RDF+50% LD+50%FD (0.18) = T_{17}: 50% RDF+50% LD+50%FD (0.18) > T_6: 100%RDF + 80% LD+20%FD (0.16) = T_{16}: 50%RDF + 80%LD+20%FD (0.16) > T_5: 100%RDF + 100%LD (0.15) = T_{15} : 50%RDF + 100%LD (0.15) > T_4: 100%LD (0.14) = T10: 75%RDF + 100%LD (0.14) > T2: 100% RDF (0.13) > T1: control (0.11). The highest EC value found in T3 might be ascribed to the presence of cations like Na, K, Ca, Mg, etc. in fly ash which increased the electrical conductivity of the soil. There were significant differences in soil organic carbon (SOC) content among treatments. The SOC content in T_2 (100%RDF) was significantly lower than control as the application of chemical fertilizers did not able to build up organic carbon in the soil. Application of fly ash @ 100% in T3 reduced the organic carbon content in soil over control and the SOC in 3 (100%FD) was statistically at par with T_1(control). The lowest organic carbon content in T_8 (100%RDF + 20%LD+80%FD) might be ascribed to the high mineralization of soil organic matter without the addition of organic substances to the soil. Fly ash had low total organic carbon and lime does not contain organic carbon. Therefore, the addition of lime and fly ash and fertilizers might not able to build up soil organic carbon in the soil. It was reported that the addition of fly ash at higher doses increased the carbon mineralization rate of agricultural soil (Nayak *et al.*, 2013). The application of soil amendments with fertilizer had a significant impact on the bulk density (BD) of the soil (Table 4). The lowest bulk density value of soil was observed in T_3 with the application of fly ash @100% and the same value was also found in treatments T_9, T_{14}, T_{18}, and T_{19}. Application of fly ash @100% in T_3 had a significant effect in lowering the BD of soil than the application of lime @100% in T_4. The BD of soil in T_4 (100%LD) was statistically at par with T_2 (100%RDF) and T_1(control). In the treatments T_9, T_{14}, and T_{19}, different doses of fertilizers had no significant effect on change in the BD of soil. Soil bulk density indicates the ability of soil to function for water and solute movement, aeration, etc. The lower the BD value better is the soil function for aeration and water movement. Application of fly ash at higher

Table 4. Impact of fly ash, lime and chemical fertilizers on the physico chemical properties of post-harvest soil

Treatments	pH	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	BD ($Mg\ m^{-3}$)	WHC (%)
T_1: Control	5.60j	0.11i	3.98a	1.38a	33.64j
T_2: 100%RDF	5.55j	0.13hi	3.90de	1.37ab	33.70ij
T_3: 100%FD	6.23ab	0.24a	3.95abc	1.34e	34.82ab
T_4: 100%LD	6.30a	0.14gh	3.96ab	1.37ab	33.66j
T_5: 100%RDF + 100%LD	6.05gh	0.15fgh	3.91cde	1.36abcd	33.74hij
T_6: 100%RDF + 80%LD+20%FD	6.01gh	0.16efg	3.90de	1.36abc	33.82h
T_7: 100%RDF + 50%LD+50%FD	5.98i	0.18def	3.65j	1.36abc	34.12f
T_8: 100%RDF + 20%LD+80%FD	6.07fg	0.21abc	3.60k	1.35cde	34.64cd
T_9: 100%RDF + 100%FD	6.09defg	0.22ab	3.92bcde	1.34de	34.84a
T_{10}: 75%RDF + 100%LD	6.08efg	0.14gh	3.75fgh	1.37ab	33.68j
T_{11}: 75%RDF + 80%LD+20%FD	6.15bcde	0.15gh	3.74fghi	1.37ab	33.76hij
T_{12}: 75%RDF + 50%LD+50%FD	6.14bcdef	0.19cde	3.71hi	1.35cde	34.18f
T_{13}: 75%RDF + 20%LD+80%FD	6.20bc	0.20cd	3.70i	1.35cde	34.14f
T_{14}: 75%RDF +100%FD	6.22bc	0.23ab	3.94abcd	1.34de	34.56d
T_{15}: 50%RDF + 100%LD	6.20bc	0.15gh	3.78f	1.36abcd	33.80hi
T_{16}: 50%RDF + 80%LD+20%FD	6.14cdef	0.16efg	3.77fg	1.35cde	33.94g
T_{17}: 50%RDF + 50%LD+50%FD	6.16bcd	0.18def	3.73ghi	1.36 abcd	34.22f
T_{18}: 50%RDF + 20%LD+80%FD	6.17bc	0.21bc	3.71hi	1.34e	34.44e
T_{19}: 50%RDF +100%FD	6.19bc	0.23ab	3.88e	1.34e	34.72bc
SEm±	0.03	0.01	0.01	0.01	0.04
CD ($P \leq 0.05$)	0.07	0.02	0.04	0.02	0.11

Mean values with the same lower-case letter are not significantly different in a column for each parameter at $p < 0.05$ by Duncan's multiple range test doses caused a decrease in BD of soil as fly ash has lower bulk density than soil. Another possible reason might be due to changes in packing patterns as a result of the mixing of particles of different size classes. A decrease in BD of soil with the application of fly ash has also been reported (*Jala et al.,* 2006). The application of fly ash, lime, and different levels of fertilizers had a significant impact on the WHC of soil. The application of fly ash @100% in T_3 significantly increased the WHC of soil over control. Similarly, lime @100 % applied treatment (T_4) had significantly more WHC of soil than the control. The highest WHC of soil was recorded in T9 (100%RDF + 100%FD) which was at par with T_3 (100%FD). In the treatments, T_6 to T_8, with the increase in fly ash doses the WHC of soil was significantly increased. The water holding capacity of a soil depends upon the surface area and pore space volume of soil. Fly ash has low bulk density and it contains more fine particles. Fine particles present in fly ash form a hydrophilic surface to retain more water molecules. So, the treatment containing higher doses of fly ash exhibited more water holding capacity of the soil. (Sarkar and Rano, 2006).

CONCLUSION

Use of fly ash as a soil amendment is a great concern to reduce the amount of industrial waste and cost burden of lime. Application of fly ash at higher dose in combination with lime amended the acidic condition of soil, whereas increased the salt concentration in soil. At higher level, when fly ash was applied to soil, it improved the physical properties of soil but declined the organic carbon content in soil. Pot experiment concluded that fly ash @ 80% FD in conjunction with lime @ 20%LD and 100% RDF is more beneficial for the growth performance of lentil than the unamended soil. This study suggests lentil is safe and suitable for cultivation in soil amended with fly ash in combination with lime and chemical fertilizers.

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