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Effect of Coal Fly Ash on Crop Yield and Soil Health under Cotton-Wheat Cropping Sequence

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Abstract

The potential of fly ash use in light textured soil was evaluated in cotton-wheat cropping sequence to explore its utility in agriculture. Pond fly ash was applied at 0, 0, 20, 40 and 80 t/ha to cotton crop before sowing for three years. The application of fly ash during the first year increased the seed cotton yield up to 20 t/ha of fly ash, whereas the residual beneficial effect on subsequent wheat was only up to 10 t/ha. The beneficial effects of fly ash during second and third year were higher. The highest yield increase of 30% in seed cotton yield and of 45% in wheat grain yield were observed at 80 and 40 t/ha, respectively, during third year of cropping. Yields when pooled over three years, the average yield increase in cotton was 3, 8, 13 and 19% at 10, 20, 40 and 80 t/ha of fly ash, respectively, whereas the corresponding increase in wheat was 11, 13, 15 and 1%. After three years of experiments, the application of fly ash resulted in significant increase in organic carbon, calcium carbonate, Fe, B and Mo content in soils which are beneficial for crop production. The build up of heavy metals was not significant. The beneficial effects of fly ash in cotton-wheat cropping sequence demonstrated its potential for use in agriculture, thus, safe disposal of huge amounts of fly ash will help in maintaining clean environment.
Key words : Cotton, Cotton-wheat rotation, Fly ash, Soil health, Wheat.

Energy is the most important for economic development of a country and improvement in the quality of life of its people. Recent developments in the field of science and technology have revolutionized the industrial growth of the country due to which the energy requirement has increased manifold. But these developments also generate a huge quantity of undesirable but unavoidable wastes which are regularly thrown in the rivers, ponds, soil and open places, and ultimately endangering their fragile ecosystems. Waste products from thermal power plant, mainly fly ash, are one of such wastes which have drawn the attention of the scientists, academicians, engineers and professionals. Fly ash is generated during the combustion of coal in coal fired thermal power plants. Disposal of this huge quantity of fly ash is thus a great problem which would aggravate owing to erection of more thermal power plants. Being fine in particle size, fly ash can readily escape to the atmosphere along with fuel gases and become a source of atmospheric pollution. It may get deposited in pulmonary tissue of the respiratory tract and gain entry into the blood stream. Deposition of fly ash particles on crop canopies reduces the yield of crops due to impaired photosynthetic activities. Moreover, fly ash deposited on the fodder crops makes it unfit for cattle feeding. Potentially toxic elements leached from fly ash can contaminate soil (1), groundwater (2) and surface water (3). In a serial batch leaching study on Indian fly ash, it was found that total cumulative concentrations of As, Mn and Mo were found to be higher than the World Health Organization (WHO) recommended values for drinking water (4).

Efforts are being made to device strategies on purposeful use and safe disposal of huge amounts of fly ash produced. It can find application in road construction as lime, bricks, fly ash concrete, cement, land fill and mine storing activities. Unfortunately, these activities have not gained popularity due to relatively higher cost benefit ratio. However, its application in agriculture as a potential supplier of nutrients and in ameliorating soil related constraints is widely reported (5—7). The essential nutrients present in it are P, K, Ca, Mg and S besides micronutrients like Zn, B, Mo, Si, Na and Al (8). It has alkaline pH and when mixed in soil, tends to neutralize acidity (9). Fly ash is an amendment to correct nutritional deficiency of B, Mo, Mg and Zn (10). A significant

Table 1. Physico-chemical characteristics of surface soil of experimental site.

Soil characteristics	Value
Soil texture	Loamy sand
pH	8.8
Electrical conductivity (ds/m)	0.19
Organic carbon (%)	0.18
Available P (kg/ha)	14.1
Available K (kg/ha)	289

Table 2. Seed cotton and wheat grain yield (q/ha) during three years of experimentation as influenced by various rates of fly ash.

Year	Rate of fly ash applied (t/ha) 0	10	20	40	80	CD (5%)
Seed Cotton Yield						
1	12.4	12.7	14.4	14	12.7	NS
2	25.9	26.2	27.1	27.9	30.2	NS
3	24	25.4	25.6	28.7	31.2	4.3
Mean	20.8	21.4	22.4	23.5	24.7	
Wheat Grain Yield						
1	21.5	24.1	21.8	19.8	17.5	NS
2	22.8	23.2	24.0	24.4	24.2	NS
3	21.2	25.0	28.1	30.8	24.5	6.6
Mean	21.8	24.1	24.6	25.0	22.1	

rice yield increase was observed when fly ash was applied in a mixture with gypsum (3:1) in silicate and Ca deficient soils (11). Tiwari et al. (12) reported improvement in rice (*Oryza sativa* L.) yield and Ramesh and Chhonkar (13) found yield increase in rice and lettuce with fly ash in acid sulfate soil. Kalra et al. (6) observed the beneficial effects of fly ash application on yield of yellow sarson (*Brassica rapa* var *glauca*)-rice (*Oryza sativa*)-yellow sarson cropping sequence. Recently, Singh et al. (14) observed beneficial effects of 2.5 cm layer of fly ash on soil surface in terms of root density (61%), grain yield (31%), straw yield (38%) and water use efficiency (39%) in wheat. The application of fly ash retarded the NO^-_3, NH_4^+ and P leaching in sandy soil (15) and may therefore be a useful tool for improvement of nutrient management in sandy soils. The beneficial effects of fly ash have also been reported in forest trees and fruit crops (16). These studies indicated that fly ash has the potential to be used as a source of nutrients and amendments for improving the physical and chemical characteristics of soils. However, the information so far generated is largely on the use of fly ash in individual crop with one time application but information is meager on its use in a cropping sequence over a period of time and its subsequent effects on soil health. So the present investigation was undertaken with the following objectives : To evaluate the effects of various rates of fly ash application on yield of crops in cotton-wheat cropping sequence over a period of three years; to know the effects of fly ash on soil health after three years of application.

Methods

Three year field study was conducted at research farm of Punjab Agricultural University Regional Station at Bathinda. This research station is located at an altitude of 211 m above sea level and is intersected by 30^{0}9′ N latitude and 74^{0}56′ E longitudes. Geologically the farm area forms a part of the Indo-Gangetic alluvial plains. The area was characterized as arid (dry) and mean rainfall is 401 mm. The rainfall being monsoonal in nature, approximately 70—75% is received during July, August and September. In this region the soils are light textured and underground water is brackish. The soil of the experimental field was loamy sand and belongs to Gahri Bhagi series (mixed, Hyperthermic, Ustochreptic Camborthid). Some physical and chemical properties of the soil are presented in Table 1. Cotton (*Gossypium hirsutum* cv LH 1556) and wheat (*Triticum aestivum* cv PBW 343) were grown in sequence for three years on the same site. The pond fly ash obtained from Thermal Plant, Bathinda (pH 6.7, EC 0.12 ds/m, OC 0.22%, bulk density 0.78 g/cm^3, WHC 45% at 1/3 bar) was applied annually at 0, 10, 20, 40 and 80 t/ha to cotton only. The experiment was laid in randomized block design with four replications. The cotton was sown between 9—17 April during all three years. The recommended fertilizers for cotton applied were 75 kg N and 30 kg P_2O_5/ha. The half N was applied after first irrigation and the second half at flowering. Whole of phosphorus was basal applied (before sowing) in all the treatments. The wheat was sown during first week of November during all the three years. The fertilizer to

Table 3. Chemical properties of soil after three years of fly ash application.

	Rate of fly ash applied (t/ha)					CD (5%)
Soil property	0	10	20	40	80	
pH	8.6	8.9	8.9	8.9	8.8	NS
Electrical conductivity (ds/m)	0.10	0.13	0.14	0.15	0.17	0.03
Organic carbon (%)	0.14	0.32	0.43	0.51	0.94	0.13
$CaCO_3$ (%)	0.67	3.86	2.88	1.28	1.97	0.55
Available N (kg/ha)	45	59	48	45	45	NS

wheat was 125 kg N and 62.5 kg P_2O_5 kg/ha. Half N and whole of phosphorus were applied before sowing of wheat and second half of N was applied after first irrigation. All other recommended package of practices for cotton and wheat relating to water, weed and plant protection measures were followed. After each crop harvest, seed cotton and wheat grain yield was recorded for all the treatments and all the replications. After three years of experimentation, surface (15 cm) soil sample were collected from all the plots. These soil samples were air dried and sieved through 2 mm sieve and were analyzed for AB-DTPA extractable essential nutrients and trace elements using inductively coupled argon plasma atomic absorption spectrophotometer.

Results and Discussion

Crop Yield

The application of fly ash during the first year increased the seed cotton yield up to 20 t/ha of fly ash, however, the residual beneficial effects on subsequent wheat was only up to 10 t/ha (Table 2). The beneficial effect during second and third years were higher which were highest at highest rates of fly ash (80 t/ha) in cotton but in wheat highest beneficial effects were observed at 40 t/ha of fly ash addition. The highest yield increase of 30% in cotton and 45% in wheat was observed at 80 and 40 t/ha, respectively, during third year of growth. When pooled over three years, the average yield increase in cotton was 3, 8, 13 and 19% at 10, 20, 40, and 80 t/ha of fly ash, respectively, whereas the corresponding increases for wheat was 11, 13, 15 and 1%. These beneficial effects are over and above the yields obtained with recommended rates of N and P for this crop sequence. Similar to these results, an increase of 17% was observed when

Table 4. Effect of fly ash on AB-DTPA extractable essential nutrient status (ppm) of soil after three years of application.

	Rate of fly ash application (t/ha)					CD (5%)
Nutrient	0	10	20	40	80	
P	7.7	6.7	11.1	10.5	10.9	NS
K	57	75	64	77	77	NS
Ca	334	471	398	379	387	NS
Mg	47	85	76	49	52	NS
S	21	64	41	42	44	8.79
Zn	1.46	2.79	2.17	1.44	1.51	NS
Cu	0.97	3.18	2.09	1.15	1.21	NS
Fe	12.3	69.0	41.0	14.3	11.8	6.68
Mn	12.2	11.3	15.4	15.4	16.2	NS
B	1.33	1.00	1.05	2.04	3.82	1.89
Mo	0.63	0.42	0.28	2.81	4.36	2.51
Co	0.14	0.07	0.12	0.15	0.16	NS

30 t/ha of fly ash was applied in conjunction with the recommended dose of fertilizer to sarson-rice cropping sequence (17).

Changes in Soil Chemical Properties

The data on chemical properties of soil after harvest of three crop rotations revealed that the soil pH was not affected significantly with the applied levels of fly ash (Table 3). However, the EC of soil increased progressively and significantly with increasing rates of fly ash. The organic carbon content of soil increased significantly over control at each level of applied fly ash. Organic carbon content of soil varied from 0.14 to 0.94% which is more than six time increase with the highest level (80 t/ha) of fly ash application. Similar increase in organic carbon content has been reported by Lee et al. (11). The content of calcium carbonate increased significantly over control with each level of fly ash application. The content of available N in soil was not significantly affected and the findings are similar to the previous results obtained by Rautaray et al. (17).

AB-DTPA Extractable Nutrients in Soil

The amount of essential nutrients in soil increased over control with the application of fly ash at various rates (Table 4). The content of S in soil was significantly higher than control at all the levels of applied fly ash. The contents of B and Mo increased

Table 5. Effect of fly ash on AB-DTPA extractable trace element status (ppm) of soil after three years of application. * nd = Not detected.

Nutrient	Rate of fly ash applied (t/ha) 0	10	20	40	80	CD (5%)
Al	4.79	7.25	13.3	4.47	2.27	7.06
Cd	0.25	0.55	0.41	0.58	0.52	NS
Cr	1.72	1.63	1.86	1.71	1.82	NS
Pb	0.64	1.50	1.54	0.80	0.78	NS
Hg	nd*	nd	nd	nd	nd	
As	nd	nd	nd	nd	nd	

significantly over control with the highest level of fly ash (80 t/ha) whereas the content of Fe increased significantly only with the application of 10 and 20 t/ha.However, the increase in the content of other elements was not found to be significant. The spectacular increase in essential elements seems to be responsible for improving the yield owing to the application of fly ash (17). The build up of essential nutrients over the years might have resulted in higher yield during the third year of this experimentation. Among the various trace metals, As and Hg were not detected in these soils (Table 5). But Al increased significantly when fly ash was applied at 20 t/ha. The contents of Cd, Cr, Ni and Pb also increased with fly ash additions for three years, but the increase was not statistically significant. Similar build up of these elements have been reported earlier (11).

In conclusion, the present study demonstrated that addition of fly ash has beneficial effects for improving the yield potential of cotton-wheat cropping sequence in light textured soils. The yield increase was over and above the yield obtained with the recommended fertilizers, indicating that the supply of essential nutrients, other than applied through inorganic fertilizers, were responsible for yield increase. The build up of essential nutrients will improve the production of subsequent crops grown on the same fields. This shows that fly ash use in agriculture has the potential for safe disposal of huge amounts of fly ash produced, thus, will help in maintaining clean environment.

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