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RESEARCH PAPER

Effect of flyash on the physiochemical properties of soil health and mustard crop

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Abstract : The study was conducted at the Soil Science and Agriculture Chemistry Research Farm, School of Forestry and Environment, Sam Higginbottom Institute of Agriculture, Technology and Sciences (Formerly Allahabad Agricultural Institute Deemed University), Allahabad during the years 2008 and 2009 in the *Rabi* season to study the effect of flyash on the physiochemical properties of soil health and mustard crop. The best treatment combination for growth and yield attributes during both years was observed in S_2F_2 (Flyash @ 10 t ha^{-1}+ $N_{80}P_{60}K_{40}$ + S_{10} kg ha^{-1}). Maximum concentration of heavy metals was observed in T_4 (Flyash @ 15 t ha^{-1}) but was under the permissible limit (Ar 3.9, Cd 37, Cr 300, Pb 400, Mn 1800, Ni 1600). T_{11} (Flyash @ 10 t ha^{-1}+ $N_{80}P_{60}K_{40}$ + S_{10} kg ha^{-1}) showed the best treatment combination in terms of cost benefit ratio. Therefore it can be concluded that there is an ample scope for safe utilization of industrial waste *i.e.* flyash in combination with chemical fertilizers for improving soil fertility, growth and yield of mustard.

Key Words : *F*

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INTRODUCTION

Every year Indian thermal power plants produce more than 100 million tons of flyash, which is expected to reach 175 million tons in near future. Disposal of this huge quantity of ash is a great problem due to its limited utilization in manufacturing of bricks, cements, ceiling and other civil construction activities which contribute to land and atmospheric degradation. Flyash is either disposed in wet process in a slurry form to a nearby ash pond site in which the ash settles and clear water is allowed to overflow from the ash pond or in dry disposal which is often stored in the large area assigned for the disposal of waste material. In either cases flyash is dumped in open land which degrades the soil and enhances air pollution leading to severe health effects of human beings. Flyash has been considered hazardous for living organisms because of its minute particle size and presence of potentially toxic elements like arsenic, chromium, boron, vanadium and antimony (Snigdha and Batra, 2006).

Today, about 100 million tones of flyash are generated per year from the 82 thermal power station in the country. Flyash imparts the demand of an inexpensive products management technology for its fruitful utilization due to its good source of nutrients, abundant availability and amelioration property. It has also been reported that flyash can be advantageously used in agriculture as soil conditioner improving some important physico-chemical property of soil and as a source for essential plant nutrient.

Fly ash is an amorphous mixture of ferroaluminosilicate minerals generated from combustion of ground or powdered coal at temperature ranging from 400-1500^{0}C. The physical, chemical and mineralogical characteristics of fly ash depend on a variety of factors such as composition of parent coal, combustion conditions, the efficiency and type of emission

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control devices and the disposal methods used. The chemical constituents of fly ash may benefit plant growth and the addition alters physical properties of soil (Jala, 2005).

Sulphur is one of the secondary nutrient in crop production which is very much essential for the synthesis of amino acids and activity of proteolytic enzymes. Sulphur fertilization improves both yield and quality of crops. Sulphur plays an important role in the chemical composition of seed and also increases the percentage of oil content of the seed. Insufficient concentration of sulphur reduces the production of plants. However, excessive amount of sulphur can be toxic to plants, soil and water.

According to recent estimates, production of mustard is 3.84 million tonnes and the cultivated area is 4.42 million hectares in India. In Uttar Pradesh 7.81 lakh hectares area is under mustard with the production of 7.87 lakh tonnes. However, the productivity is quite high (1008 kg/ha) in comparison to average productivity of India (869 kg/ha) (Damodaran and Hegde, 2005).

MATERIAL AND METHODS

The experiment was conducted at the Soil Science and Agriculture Chemistry Research farm School of Forestry and Environment, Sam Higginbottom Institute of Agriculture, Technology and Sciences (Formerly Allahabad Agricultural Institute Deemed University), Allahabad. The area is situated on the right bank adjacent to Yamuna river in the south of Allahabad city, which is located at $25^{0}24'$ 08.71 N latitude and $81^{0}50'16.95''$ E longitude and 98 meter above the sea level. All the facilities necessary for experimentation were made available from the department.

Details of experiment:

The field experiment was conducted at the Research Farm of Department of Environmental Science School of Forestry and Environment, Sam Higginbottom Institute of Agriculture, Technology and Sciences (Formerly Allahabad Agricultural Institute Deemed University), Allahabad in order to find out the effect of different levels of flyash and sulphur on growth, yield, nutrient and accumulation of uptake of heavy metals *viz*., Cd, Cr, Pb and in soil and mustard.

Plan of layout:

The experiment was laid out in a 4 x 4 Factorial Design with four levels of flyash and four levels of fertilizers and their combinations. The treatment was replicate three times and were allocated randomly in each replication.

Details of layout:

Number of treatments	=	16
Number of replications	=	3
Total number of plots	=	48
Area of individual plot (2x1)	=	2 m^2
Width of main irrigation channel	=	1 m
Width of sub irrigation channel	=	50 cm
Width of bund	=	30 cm
Net cultivated area	=	96 m^2
Gross experimental area	=	197.12m^2
Length of experimental plot	=	22.40 m^2
Width of experimental plot	=	8.8 m^2
Length of each plot	=	1m^2
Width of each plot	=	2m^2

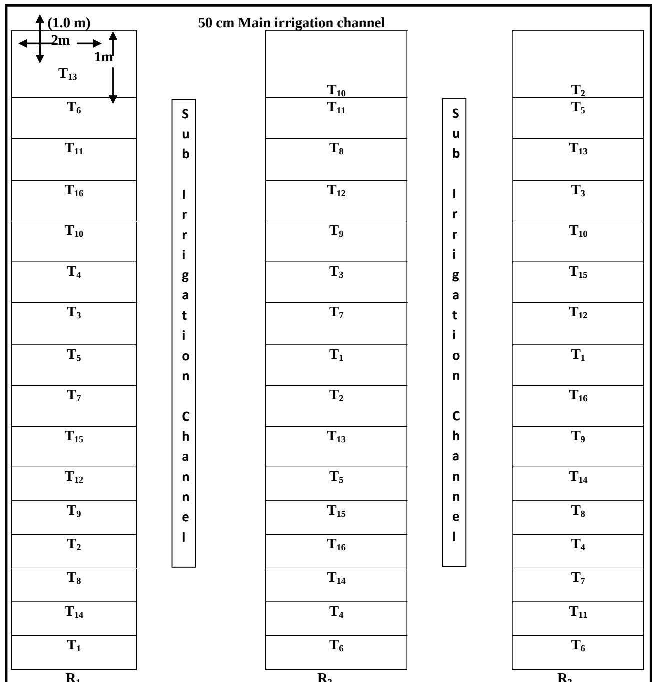

Fig. A : Layout of main experimental plot

Source of nitrogen:

Nitrogen requirement of crops was met with the help of urea, which contains 46% of nitrogen and the urea was applied at the rate of 80 kg ha^{-1}.

Source of phosphorous:

Phosphorous requirement was met with application of DAP which contains 46%of P_2O_5. Crop requirement of phosphorus is 60 kg ha^{-1}.

Source of potassium:

Potassium requirement was met with application of MOP which contains 60% of K_2O. Crop requirement of potassium is 40 kg ha^{-1}.

Details of treatment :

The details of the treatment with the notation used under each of them are given below:

Characteristic properties of soil:

The soil of the experimental field is alluvial under the

Table A : Details of treatment with the notation

Factors	Treatment	Notation
I Levels of Flyash	Control	F_0
	5 t ha^{-1}	F_1
	10 t ha^{-1}	F_2
	15 t ha^{-1}	F_3
II levels of fertilizers	Control	S_0
	$N_{80}P_{60}K_{40}$ + S_5 kg ha^{-1}	S_1
	$N_{80}P_{60}K_{40}$ + S_{10} kg ha^{-1}	S_2
	$N_{80}P_{60}K_{40}$ + S_{15} kg ha^{-1}	S_3

soil order inseptisol and suborder fluvents. The mechanical and chemical analysis of soil was done before start of the experiment in order to characterize the various soil properties.

Table B : Details of treatment combination

Treatments	Combination	Description
T_1	S_0F_0	Flyash @ 0 t ha^{-1}
T_2	S_0F_1	Flyash @ 5 t ha^{-1}
T_3	S_0F_2	Flyash @ 10 t ha^{-1}
T_4	S_0F_3	Flyash @ 15 t ha^{-1}
T_5	S_1F_0	Flyash @ 0 t ha^{-1}+$N_{80}P_{60}K_{40}$+S_5 kg ha^{-1}
T_6	S_1F_1	Flyash @ 5 t ha^{-1}+ $N_{80}P_{60}K_{40}$+S_5 kg ha^{-1}
T_7	S_1F_2	Flyash @ 10 t ha^{-1}+$N_{80}P_{60}K_{400}$+S_5 kg ha^{-1}
T_8	S_1F_3	Flyash @ 015t ha^{-1}+$N_{80}P_{60}K_{40}$+S_5 kg ha^{-1}
T_9	S_2F_0	Flyash @ 0 t ha^{-1}+ $N_{80}P_{60}K_{40}$ + S_{10} kg ha^{-1}
T_{10}	S_2F_1	Flyash @ 5 t ha^{-1}+ $N_{80}P_{60}K_{40}$ + S_{10} kg ha^{-1}
T_{11}	S_2F_2	Flyash @ 10 t ha^{-1}+ $N_{80}P_{60}K_{40}$+S_{10} kg ha^{-1}
T_{12}	S_2F_3	Flyash @ 15 t ha^{-1}+ $N_{80}P_{60}K_{40}$+S_{10} kg ha^{-1}
T_{13}	S_3F_0	Flyash @ 0 t ha^{-1}+ $N_{80}P_{60}K_{40}$+S_{15} kg ha^{-1}
T_{14}	S_3F_1	Flyash @ 5 t ha^{-1}+ $N_{80}P_{60}K_{40}$ +S_{15} kg ha^{-1}
T_{15}	S_3F_2	Flyash @ 10 t ha^{-1}+ $N_{80}P_{60}K_{40}$+S_{15} kg ha^{-1}
T_{16}	S_3F_3	Flyash @ 15 t ha^{-1}+ $N_{80}P_{60}K_{40}$+S_{15} kg ha^{-1}

RESULTS AND DISCUSSION

A series of experiments were conducted on the effect of flyash on the physiochemical properties of soil health and mustard crop. The results obtained were based on the data collected during the experimental investigation of the study, and are presented through subjective analysis and tables.

Plant height (cm):

Maximum plant height (177.52 cm) was observed in S_2F_2which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Increased in plant due to increasing levels of flyash, similar results reported by Dubey *et al.* (1982).

Number of leaves:

Maximum number of leaves (26.30) was observed in S_2F_2whereas, rest of the interaction were statistically different from each other. Similar results were also reported by Tripathi and Sahu (1997).

Table C : Physicochemical analysis of Flyash

Analysis	Parameters	Unit	Result
Physical characteristics			
Mechanical	Sand	%	78.45
Analysis	Silt	%	19.47
	Clay	%	2.83
	Soil Texture		Sandy
	Bulk Density	g/c.c.	0.86
	Hydraulic conductivity	m/day	11.21
	Porosity	%	35.58
Chemical characteristics			
Chemical	pH (1:2)		7.83
Analysis	EC	dSm^{-1}	0.43
	Organic carbon	%	0.65
	Total Nitrogen	%	0.20
	Total Phosphorus	%	0.43
	Total Potassium	%	2.15
	Total Sulphur	%	0.05
	Copper	ppm	44.17
	Zinc	ppm	33.42
	Manganese	ppm	282.5
	Iron	ppm	34.21

Numbers of siliqua/plant:

Perusal of the pooled data appended revealed that maximum 198.00 Number of Siliqua/plant was recored in S_2F_2 which was statistically at par with all the treatment combination. Similarly trend was observed in year 2009 and 2010. However minimum was recorded 87.89 in S_0F_0 that is control.

Grain yield (q ha $^{-1}$):

Perusal of the pooled datea appended revealed that maximum grian yield 55.00 was recored in S_2F_2 which was statistically at par with all the treatment combination. Similarly trend was observed in year 2009 and 2010. However minimum was recorded 15.17 in S_0F_0 that is control.

Bulk density of the post harvest soil:

Bulk density at a depth of 0-15 cm revealed that maximum bulk density (1.39 mg/m^3) was observed in S_0F_0 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum bulk density (1.34 g/m^3) was found in S_3F_0 has reveals at par with the treatment of S_0F_2. At a depth of 15-30 cm revealed that maximum bulk density (1.41 mg/m^3) was observed in S_1F_0 (0 t ha^{-1} Flyash + RDF + 5 kg ha $^{-1}$ Sulphur) which was statistically at par with S_3F_2 whereas, rest of the interaction were statistically different from each other. Similarly minimum bulk density (1.33 mg/m^3) was found in S_3F_0. At the depth of 30-45 cm results indicated that the maximum bulk density (1.41 mg/m^3) was observed in S_1F_0

which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum bulk density (1.33 mg/m^3) was found in S_3F_0. Similar findings were earlier reported by Rautary *et al.* (2002).

Table 1 : Effect of flyash on the growth parameters of mustard crop

Treatment combinations		Plant height (cm)	Number of leaves	Numbers of siliqua/ plant	Grain yield (q ha $^{-1}$)
T_1	S_0F_0	159.55	9.44	87.89	18.68
T_2	S_0F_1	162.52	14.50	88.39	19.67
T_3	S_0F_2	159.81	10.34	96.78	20.92
T_4	S_0F_3	164.81	10.75	114.94	21.94
T_5	S_1F_0	165.87	12.47	123.00	21.97
T_6	S_1F_1	166.49	17.42	134.28	23.12
T_7	S_1F_2	167.93	18.52	140.33	23.57
T_8	S_1F_3	172.03	19.21	132.11	24.64
T_9	S_2F_0	170.40	16.84	130.67	22.10
T_{10}	S_2F_1	173.10	23.60	185.78	25.87
T_{11}	S_2F_2	177.52	26.30	198.00	27.84
T_{12}	S_2F_3	173.93	23.61	194.22	26.81
T_{13}	S_3F_0	170.04	15.87	133.17	22.38
T_{14}	S_3F_1	175.31	20.35	161.33	25.49
T_{15}	S_3F_2	173.22	22.27	179.28	25.92
T_{16}	S_3F_3	166.15	18.83	153.44	25.34

Particle density of the post harvest soil:

At the depth of 0-15 cm revealed that maximum particle density (2.72 mg/m^3) was observed in S_0F_2.(10 t ha^{-1} Flyash + 0 kg ha $^{-1}$ Sulphur) which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum particle density (2.15 mg/m^3) was found. At the depth of 15-30 cm maximum particle density (2.69 mg/m^3) was observed in S_0F_1 which was statistically at par with S_3F_2 whereas, rest of the interaction were statistically different from each other. Minimum particle density (2.11 mg/m^3) was found in S_3F_1. Maximum particle density at the depth of 30-45 cm (2.62 mg/m^3) was observed in S_0F_1, which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum bulk density (2.06 mg/m^3) was found in S_3F_1

pH of the post harvest soil:

Soil pH at the depth of 0-15 cm revealed that maximum pH (7.92) was observed in S_0F_2 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum pH (7.38) was found in S_3F_1. The findings are also indicating that the maximum pH (7.55) was observed in S_2F_3. At the depth of 15-30 cm which was statistically at par with S_3F_2 whereasn rest of the interaction were statistically different from each other and minimum pH (7.38) was found in S_1F_1. Similar result was also found at the depth of 30-45 cm that maximum pH (7.71) was observed in S_2F_3 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum pH (7.15) was found in S_1F_0. This may be due to the liming potential of the flyash. Similar findings were also reported by Tiwari *et al.* (1992) ; Khandkar *et al.* (1996) and also Naveen *et al.* (2000) as pH of soil decreased with ash content in sandy loam soil.

EC of the post harvested soil:

Soil EC revealed that maximum EC (0.21) was observed in S_3F_0. at the depth of 0-15 cm which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum EC (0.13) was found in S_0F_2. The findings also indiating that the maximum EC (0.63) was observed in S_2F_2. At the depth of 15-30 cm (10 t ha^{-1} Flyash + RDF + 10 kg ha^{-1} sulphur) which was statistically at par with S_3F_2 whereas, rest of the interaction were statistically different from each other. Minimum EC (0.12) was found in S_0F_2.similar trend was also found in at the depth of 30-45 cm maximum EC (0.18) was observed in S_3F_0 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum EC (0.12) was found in $S_1F_{0.}$ One possible reason for this bethat salts might have leached down with water and resulting in lower EC of the soil. These observation corroborate with the earlier work reported by Anjali *et al.* (2000).

Organic carbon of the post harvest soil:

Maximum organic carbon (0.48) was observed at the depth of 0-15 cm in S_0F_3 whereas, rest of the interaction were statistically different from each other. Minimum organic carbon (0.23) was found in S_3F_0. Maximum organic carbon (0.46) was observed in S_0F_3, rests of the interaction were statistically different from each other. Minimum organic carbon (0.22) was found in S_3F_0. At the depth of 30-45 cm maximum organic carbon (0.42) was observed in S_0F_3 whereas, rest of the interaction were statistically different from each other and minimum organic carbon (0.16) was found in S_1F_0. Similarly results are also corroborated by Naveen *et al.* (2000) organic carbon content of soil increased with the application of flyash.

Available nitrogen (kg ha^{-1}) of the post harvest soil:

Maximum available nitrogen (219.65 kg ha^{-1}) at the depth of 0-15 cm was observed in S_2F_2 whereas, rest of the interaction were statistically different from each other. Minimum available nitrogen (110.47 kg ha^{-1}) was found in S_0F_0. Maximum available Nitrogen (216.35 kg ha^{-1}) was observed in S_2F_2 at the depth of 15-30 cm whereas, rest of the interaction was statistically different from each other and minimum available Nitrogen (107.97 kg ha^{-1}) was found in S_0F_0. At the depth of 30-45 cm maximum available nitrogen (212.82 kg ha^{-1}) was observed in S_2F_2 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other and minimum available

Table 2 : Effect of flyash on the physic-chemical properties of soil health

Treatment combinations		Depth in cm	Bulk Density (Mg/m^3)	Particle Density (Mg/m^3)	Soil pH ($dS\ m^{-1}$)	Soil EC	Organic Carbon	Available Nitrogen ($kg\ ha^{-1}$)	Available Phosphorus ($kg\ ha^{-1}$)	Available Potassium ($kg\ ha^{-1}$)	Available Sulphur ($kg\ ha^{-1}$)
T_1	S_0F_0	0-15	1.39	2.63	7.65 7.83	0.16	0.20	110.47	11.29	231.34	8.33
		15-30	1.37	2.59	7.92	0.16	0.32	139.15	12.45	228.31	7.52
		30-45	1.34	2.63		0.13	0.34	148.46	12.94	230.11	6.80
T_2	S_0F_1	0-15	1.38	2.67	7.65 7.54	0.13	0.48	161.38	13.17	236.00	8.43
		15-30	1.39	2.69	7.48	0.13	0.24	164.61	13.99	229.24	7.71
		30-45	1.38	2.59		0.14	0.34	180.63	14.57	227.95	6.81
T_3	S_0F_2	0-15	1.37	2.72	7.65	0.14	0.36	182.00	14.26	276.33	8.79
		15-30	1.36	2.59	7.81	0.14	0.45	181.68	15.04	257.34	8.34
		30-45	1.35	2.60	7.63	0.13	0.23	174.74	13.54	254.65	7.80
T_4	S_0F_3	0-15	1.35	2.63	7.69	0.17	0.26	206.46	19.11	296.17	8.81
		15-30	1.37	2.60	7.70	0.14	0.30	219.65	23.46	299.29	8.27
		30-45	1.35	2.60	7.84	0.13	0.31	212.68	23.21	297.21	8.09
T_5	S_1F_0	0-15	1.34	2.64	7.46	0.21	0.23	177.22	13.97	312.17	10.33
		15-30	1.38	2.61	7.38	0.14	0.30	192.22	16.66	304.30	10.07
		30-45	1.35	2.64	7.72	0.14	0.32	198.06	18.29	302.26	9.80
T_6	S_1F_1	0-15	1.35	2.65	7.78	0.14	0.35	184.90	15.98	337.00	10.46
		15-30	1.40	2.61	7.55	0.16	0.19	107.97	9.97	238.67	10.20
		30-45	1.39	2.61	7.74	0.15	0.31	136.97	11.07	236.62	9.81
T_7	S_1F_2	0-15	1.35	2.64	7.72	0.12	0.32	142.84	11.22	345.00	10.50
		15-30	1.39	2.59	7.60	0.12	0.46	156.01	11.80	341.59	10.27
		30-45	1.41	2.11	7.18	0.12	0.23	161.46	11.80	339.21	10.01
T_8	S_1F_3	0-15	1.39	2.65	7.38	0.13	0.33	179.42	12.98	352.17	11.18
		15-30	1.38	2.38	7.53	0.13	0.35	175.10	12.91	343.75	10.80
		30-45	1.37	2.43	7.72	0.13	0.44	178.28	13.84	341.17	10.35
T_9	S_2F_0	0-15	1.36	2.66	7.57	0.12	0.22	167.97	11.69	320.34	13.34
		15-30	1.36	2.55	7.62	0.15	0.25	202.73	17.03	312.15	12.67
		30-45	1.37	2.58	7.65	0.63	0.29	216.35	21.36	310.10	12.16
T_{10}	S_2F_1	0-15	1.36	2.68	7.75	0.11	0.30	209.20	20.80	372.00	13.60
		15-30	1.33	2.62	7.40	0.18	0.22	173.18	12.31	370.70	13.24
		30-45	1.37	2.53	7.27	0.14	0.30	187.46	14.25	368.28	12.72
T_{11}	S_2F_2	0-15	1.34	2.66	7.63	0.13	0.31	178.80	16.24	386.67	13.62
		15-30	1.35	2.54	7.64	0.13	0.34	181.91	14.31	380.12	13.20
		30-45	1.41	2.56	7.46	0.15	0.19	126.22	8.79	378.09	12.87
T_{12}	S_2F_3	0-15	1.39	2.65	7.66	0.14	0.30	134.42	10.12	385.67	13.85
		15-30	1.35	2.55	7.62	0.12	0.28	140.33	9.74	377.27	13.44
		30-45	1.40	2.57	7.50	0.12	0.42	154.07	10.63	375.65	13.06
T_{13}	S_3F_0	0-15	1.41	2.62	7.15	0.12	0.16	157.68	10.64	314.33	18.13
		15-30	1.40	2.56	7.32	0.13	0.29	177.64	11.53	325.98	17.64
		30-45	1.38	2.59	7.48	0.12	0.31	172.24	10.77	322.16	17.12
T_{14}	S_3F_1	0-15	1.38	2.15	7.67	0.13	0.41	174.63	12.37	359.33	18.16
		15-30	1.37	2.57	7.54	0.11	0.22	165.22	10.65	352.06	17.82
		30-45	1.36	2.55	7.59	0.14	0.21	199.13	14.86	349.69	17.42
T_{15}	S_3F_2	0-15	1.38	2.45	7.60	0.12	0.25	212.82	20.21	363.50	18.30
		15-30	1.37	2.49	7.71	0.11	0.26	206.11	19.26	357.51	18.00
		30-45	1.33	2.06	7.31	0.18	0.18	170.10	11.26	354.17	17.81
T_{16}	S_3F_3	0-15	1.37	2.47	7.27	0.12	0.25	184.76	12.75	350.67	18.37
		15-30	1.33	2.29	7.56	0.12	0.27	176.12	14.77	300.99	18.12
		30-45	1.34	2.37	7.55	0.12	0.30	180.49	12.35	296.66	17.91

nitrogen (126.22 kg ha^{-1}) was found in S_0F_0. Koter *et al.* (1984) also observed increase in available P status and they attributed it to the P content of flyash.

Available phosphorus (kg ha^{-1}) of the post harvest soil:

Maximum available Phosphorus (23.46 kg ha^{-1}) at the depth of 0-15 cm was observed in S_2F_2 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum available phosphorus (11.29 kg ha^{-1}) was found in S_0F_0. Similarly maximum available Phosphorus (21.36 kg ha^{-1}) was observed in S_2F_2 at the depth of 15-30 cm which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other and minimum available Phosphorus (9.97 kg ha^{-1}) was found in S_0F_0 (0 t ha^{-1} Flyash + 0 kg ha $^{-1}$ Sulphur). At the depth of 30-45 cm maximum available Phosphorus (20.21 kg ha^{-1}) was observed in S_2F_2 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other and minimum available Phosphorus (8.79 kg ha^{-1}) was found in S_0F_0. Anjali *et al.* (2000) reported similar increase in available P contene of soil. Koter *et al.* (1984) also observed increase in available P status and they attributed it to the P content of flyash.

Available potassium (kg ha^{-1}) of the post harvest soil:

Available Potassium (386.67 kg ha^{-1}) at the depth of 0-15 cm was observed in S_2F_2 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other and minimum available Phosphorus (231.34 kg ha^{-1}) was found in S_0F_0. Maximum available Potassium (380.12 kg ha^{-1}) was observed in S_2F_2 at the depth of 15-30 cm which was statistically at par with S_2F_3 whereas, rests of the interaction were statistically different from each other and minimum available Potassium (228.31 kg ha^{-1}) was found in S_0F_0. At the depth of 30-45 cm maximum available Potassium (378.09 kg ha^{-1}) was observed in S_2F_2 which was statistically at par with S_2F_3 whereas, rest of the interaction were statistically different from each other. Minimum available Potassium (230.11 kg ha^{-1}) was found in S_0F_0. Positive effect of flyash addition on available K content of soil was also reported by Warambhe *et al.* (1992) also Anjali *et al.* (2000) and Selvakumari *et al.* (2000) reported that application of flyash increased K content in soil.

Available sulphur (kg ha^{-1}) of the post harvest soil:

Maximum Sulphur (18.37 kg ha^{-1}) was observed in S_3F_3 at the depth of 0-15 cm which was statistically at par with S_3F_2 whereas, rest of the interaction were statistically different from each other and minimum Sulphur (8.33 kg ha^{-1}) was found in S_0F_0. Similarly maximum Sulphur (18.12 kg ha^{-1}) was observed in S_3F_3 at the depth of 15-30 cm whereas, rest of the interaction were statistically different from each other and inimum Sulphur (7.52 kg ha^{-1}) was found in S_0F_0. At the depth of 30-45 cm maximum Sulphur (17.91 kg ha^{-1}) was observed in S_3F_3 which was statistically at par with S_3F_2 whereas, rest of the interaction were statistically different from each other and minimum Sulphur (6.80 kg ha^{-1}) was found in I_0F_0. Anjali *et al.* (2000) and Selvakumari *et al.* (2000) reported that application of flyash increased S content in soil.

Conclusion:

The best treatment combination for growth and yield attributes during both years was observed in S_2F_2 (Flyash @ 10 t ha^{-1}+ $N_{80}P_{60}K_{40}$ + S_{10} kg ha^{-1}). Hence, it is found that the application of fly ash could be alternative source of plant nutrient with fertilizer for sustaining soil fertility status vis-à-vis crop productivity. Therefore it can be concluded that there is an ample scope for safe utilization of industrial waste that is flyash in combination with chemical fertilizers for improving soil fertility, growth and yield of mustard.

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