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Effect of Fly Ash on Yield and Heavy Metal Content of Maize *(Zea mays)* Grown in an *Alfisol*

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A field experiment was conducted for three consecutive seasons during 2013 and 2014 in order to study the effect of fly ash with lime and gypsum with and without FYM on heavy metal content of maize as well as its yield in an *Alfisol*. The experiment was laid out in a randomized block design (RBD) with eight treatments namely, T_1-control (received no amendments), T_2-lime @ 0.2 LR, T_3-gypsum @ 2.5 q/ha, T_4-FA @ 40 t ha^{-1}, T_5-lime @ 0.2 LR + FYM @ 10 t ha^{-1}, T_6-gypsum @ 2.5 q ha^{-1}+ FYM @ 10 t ha^{-1}, T_7-FA @ 40 t ha^{-1} + FYM @ 10 t ha^{-1} and T_8-lime @ 0.2 LR+FA @ 40 t ha^{-1} + FYM @ 10 t ha^{-1}. The Fe and Cu accumulation in fly ash treatment was comparable with that under lime treatment and observed lower in Mn and Zn content. The accumulation of Fe, Mn and Cu due to combined application of lime or fly ash with FYM was at par with their sole application. Combined application of FYM with fly ash significantly lowered the Pb accumulation as compared to fly ash alone, whereas Cd and Cr accumulation was at par in both the treatments. Similar trend was observed for Cd, Cr and Pb uptake. Grain yield of maize was increased due to lime application (48.89 q ha^{-1}) over control (38.6 q ha^{-1}) by 27 %. Inclusion of FYM enhanced the use efficiency of lime, gypsum or fly ash. Combined application of fly ash with FYM was as effective as lime treatment. Conjunctive application of lime + flyash + FYM recorded the maximum grain yield of 57.72 q ha^{-1} among all treatment combinations. One time application of fly ash to first crop stabilized maize yield up to third season. Heavy metal (Pb, Cd, Cr) accumulation in flyash treatments were below toxic level and could be used in acidic soils without affecting the soil health.

*(**Key words**: Flyash, FYM, Lime, Gypsum, Heavy metals, Maize yield, Alsfisol)*

Acid soils of Odisha (India) comprising 75% of the state (Mandal, 1997) are characterized with low pH, low availability of Ca, Mg, P, etc. which indirectly affect the crop yield and total production. Of various amendment options to neutralize soil acidity, application of paper mill sludge (a byproduct of paper mills) was used extensively to correct soil acidity. It enhanced the yield of several crops by 15-20 % in the state of Odisha (Jena, 2011). Fly ash (a byproduct of coal combustion electric power plant), phospho-gypsum (byproduct of fertilizer plant) can be effectively utilized in acid soils as it provides calcium and sulphur (Sarkar, 2013). Recycling of alkaline fly ash can be considered for pH adjustment and partial nutrient supplementation (McCarty *et al.,* 1994; Adriano *et al.,* 1980). Fly ash can be used to correct plant nutritional deficiencies of B (Randsome and Dowdy, 1987; Marten, 1971), Mg (Hill and Camp, 1984), Mo (Elseewi *et al.,* 1980), S (Hill and Camp, 1984), and Zn (Schnappinger *et al.*, 1975).

Fly ash contains many trace elements including As, B, Co, Mo, Se and Sr that are concentrated in smaller ash particles (Adriano *et al.,* 1980; Page *et al.,* 1979). In fact fly ash contains all the elements present in soil except organic carbon and nitrogen (Kumar *et al.,* 2000). Barman *et al.,* (1999) reported that there was accumulation of heavy metals in vegetables, pulses and wheat grown in fly ash amended soils. The metal contents (Cd, Ni, Cr and Pb) in soil samples were higher than control soil. But, in the edible parts of the plant, Pb concentration was within the permissible limits, whereas Cd, Cr and Ni concentrations were sometimes higher.

The organic materials with different C:N ratios and biochemical compositions not only release nutrients at different space (Azmal *et al.*, 1996), but also provides specific metal binding sites from which metals are difficult to exchange (Stewart *et al.*, 1998). So there is a great need to create awareness for the use of the organic materials like different organic wastes in combinations with fertilizers and fly ash to explore their potentialities, and complexities, to evaluate their behaviour and to assess the benefits as well as adaptability for greater profit and sustainable crop production (Dar *et al.,* 2009). Keeping this in knowledge the present experiment was conducted to study the impact of flyash along with lime and FYM on micronutrient, heavy metal contents and yield of maize crop grown in an *Alfisol.*

MATERIALS AND METHODS

A field experiment was carried out in upland site of Central Research Station, Orissa University of

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Agriculture and Technology, Bhubaneswar during the k*harif* seasons of 2013 and 2014 and *rabi* season of 2013-14. The soil of the experimental site was sandy loam, acidic (pH 4.6), low in available N, P and K. The fly ash (FA) collected from Indian Metals Ferrro Alloys Corporation (IMFA), Chaudar, Cuttack (Odisha) was used for the study. The initial characteristics of soil at the experimental site and the properties of fly ash are furnished in Table 1. The experiment consisted of eight treatments and each replicated thrice in a randomized block design (RBD). The treatments were: T_1-control (received no amendments), T_2-lime @ 0.2 LR, T_3-gypsum @ 2.5 q ha^{-1}, T_4-FA @ 40 t ha^{-1}, T_5-lime @ 0.2 LR + FYM @ 10 t ha^{-1}, T_6-gypsum @ 2.5 q ha^{-1}+ FYM @ 10 t ha^{-1}, T_7-FA @ 40 t ha^{-1} + FYM @ 10 t ha^{-1} and T_8-lime @ 0.2 LR+FA @ 40 t ha^{-1} + FYM @ 10 t ha^{-1}. Each crop, received the recommended dose of fertilizers @ 120:60:60 kg N: P_2O_5: K_2O per hectare through DAP, urea and MOP and amendments ($CaCO_3$ as lime and $CaSO_4$ as gypsum) as per the treatment respectively. But FA @ 40 t ha^{-1} and FYM @ 10 t ha^{-1} were applied to the first crop only. The crops were harvested at maturity. The maize (*var.* P 3570) grains and stovers were air dried and weighed plot wise. Two plants from each plot were collected randomly for detailed chemical analysis. The grains and stovers were kept separately in envelopes, labeled properly and dried in hot air oven at 60ºC. Each sample was ground separately with the help of a Willy

Table 1. *Physical and chemical properties of soil and fly ash used in experiment*

Properties	Soil			Fly ash
	0-15 cm	15-30 cm	30-45 cm	
Sand (%)	69.18	63.50	58.30	41.2 (0.02- 2 mm)
Silt (%)	22.32	26.40	28.60	49.6(0.002-0.02mm)
Clay (%)	8.49	11.2	15.8	9.2 (< 0.002 mm)
Texture (USDA)	Sandy loam	Sandy loam	Sandy loam	–
BD (Mg m^{-3})	1.63	1.68	1.74	0.98
WHC (%)	26.48	35.60	39.2	47.5
$pH_{(1:2.5)}$	4.60	4.57	4.53	6.70
$EC_{(1:2.5)}$ (dS m^{-1})	0.06	0.04	0.04	0.16
OC (g kg^{-1})	3.82	2.98	2.25	1.55
CEC [cmol(+)kg^{-1}]	2.93	3.04	3.54	–
Exchange acidity [cmol(+)kg^{-1}]	0.44	0.82	1.32	–
Exchangeable Al^{3+}[cmol(+)kg^{-1}]	0.33	0.65	0.99	–
Exchangeable H^+[cmol(+)kg^{-1}]	0.11	0.17	0.33	–
LR (kg $CaCO_3$ ha^{-1})	1633.33	–	–	–
Available N (mg kg^{-1})	82.10	78.50	72.30	15.20
Available P (mg kg^{-1})	6.54	5.91	4.78	12.18
Available K (mg kg^{-1})	58.03	38.52	36.36	72.80
Available Ca [cmol(+)kg^{-1}]	1.35	1.26	1.28	2.12
Available Mg [cmol(+)kg^{-1}]	0.92	0.86	0.84	1.46
Available S (mg kg^{-1})	10.50	9.11	10.71	39.26
DTPA Extractable Fe (mg kg^{-1})	51.44	63.85	76.46	105.94
DTPA Extractable Mn (mg kg^{-1})	37.50	42.80	45.40	65.73
DTPA Extractable Zn (mg kg^{-1})	0.86	0.80	0.72	1.92
DTPA Extractable Cu (mg kg^{-1})	1.04	1.62	1.58	1.14
DTPA Extractable Cd (mg kg^{-1})	0.01	0.01	0.01	0.04
DTPA Extractable Pb (mg kg^{-1})	0.04	0.32	0.34	0.40
DTPA Extractable Cr (mg kg^{-1})	0.18	0.19	0.19	0.20

mill to pass through 20 mesh sieve and was used for analysis of different elements. As per the method outlined by Piper (1950), 1 g of ground plant sample was predigested with 20 ml of concentrated HNO_3 followed by digestion with 10 ml of diacid [HNO_3 : $HClO_3$= 3:2(volume ratio)] on hot plate. The content was then filtered and preserved for further analysis. After suitable dilution of the aliquot, the samples were analyzed by Atomic Absorption Spectrophotometer (ANALYST 200 of Perkin ELMER) to determine the iron, copper, zinc, manganese and other heavy metal contents of different plant parts using respective hallow cathode lamps (HCL) at desired wavelengths. Similarly, the aliquot was taken directly to determine the heavy metals contents in Atomic Absorption Spectrophotometer as described by Jackson (1973). Crop yield and nutrients analysis data recorded were compiled and analyzed statistically by using DSAASTAT software.

RESULTS AND DISCUSSIONS

Heavy metal content and uptake by maize

Application of lime did not alter significantly the Fe and Cu concentration in maize grain, it however decreased numerically as compared to control since, higher pH depressed the uptake of Fe, Mn and Cu (Table 2). Brun *et al.,* (2001) observed that accumulation of Cu in maize was same in acidic and calcareous soils, while the accumulation of Zn was quite reverse. On the other hand, accumulation of Fe and Mn in gypsum treated plots was higher than that with lime treatment which might be due to lowering of pH. The Fe and Cu accumulation in fly ash treated plots was comparable with lime treated plots. When lime or fly ash was applied along with FYM, the Fe, Mn and Cu accumulation were at par with their sole application. Application of lime recorded 13.6, 10.4, 11.0 and 31.1 percent higher in Fe, Mn, Cu and Zn uptake over control respectively and was at par with gypsum or fly ash alone or with FYM (Table 4). But, combined application of lime and FYM resulted in significantly higher Fe, Mn and Zn uptake. Integrated use of fly ash @ 10 t ha^{-1} with organic wastes and chemical fertilizers was reported to result in higher uptake of N, P, K, Fe, Mn, Zn, Cu, Ca, Mg, S in rice grain than application of only chemical fertilizers (Rautaray *et al.,* 2003; Sarangi *et al.,* 1997; Sajwan 1995). Similar results of significant increase in uptake of nutrients were observed in okra (Yeledhalli and Ravi, 2008), sudan grass and oats (Srivastava and Chhonkar, 2000).

Accumulation of metals in plants vary from species to species and also within the different parts of a plant. However, Rautaray *et al.,* (2003) reported less concentration of Cd and Ni in rice grain but, high Cd content in residual mustard. Similar results were reported by Singh *et al.* (2008). The results of a field experiment in acidic sandy loam soil with groundnut as the test crop over four seasons indicated that application of fly ash @ 40 t ha^{-1} recorded higher Cr concentration in kernel (5.73 mg kg^{-1}) during first season but decreased during subsequent seasons. Accumulation of Cd decreased over years and the values were within the permissible limit (Jena *et al.,* 2013).

The results of the present study indicated that application of lime significantly decreased Pb, Cd and Cr concentration in maize grain by 13.95, 20.0 and 13.04 % over control, respectively (Table 3). Application of

Table 2. *Effect of fly ash and amendments on micronutrient concentration (mg kg^{-1}) in maize (pooled over 3 consecutive seasons)*

Treatments	Fe		Mn		Zn		Cu	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Control	55.16^{bc}	67.83^{ab}	33.82^{c}	42.57^{b}	13.18^{d}	22.90^{bc}	4.67^{ab}	9.69^{ab}
Lime (L)	51.52^{cd}	64.03^{b}	29.00^{d}	40.98^{bc}	17.97^{a}	20.82^{c}	4.69^{ab}	8.58^{bc}
Gypsum (G)	63.03^{a}	70.33^{a}	36.90^{ab}	43.53^{ab}	16.63^{ab}	25.26^{ab}	4.69^{ab}	8.74^{bc}
Fly ash (FA)	49.42^{d}	65.47^{b}	33.40^{c}	39.61^{c}	13.60^{d}	22.59^{bc}	4.83^{ab}	9.99^{b}
L+FYM	52.33^{cd}	67.68^{ab}	31.34^{cd}	42.58^{b}	17.43^{a}	22.32^{c}	3.99^{b}	9.40^{ab}
G+FYM	58.84^{ab}	70.99^{a}	37.27^{a}	44.69^{a}	14.02^{cd}	26.28^{a}	4.28^{b}	9.43^{ab}
FA+FYM	53.41^{bcd}	67.66^{ab}	34.16^{bc}	41.67^{bc}	16.27^{abc}	23.06^{bc}	5.20^{ab}	10.29^{a}
L+FA+FYM	54.25^{bcd}	69.43^{a}	31.91^{cd}	42.20^{b}	14.96^{bcd}	23.11^{bc}	5.69^{a}	9.88^{a}
CD (0.05)	5.47	5.41	3.08	2.83	2.47	2.82	1.21	1.01
CV (%)	5.70	4.55	5.25	3.82	9.09	6.91	14.53	8.19

(Means with at least one letter common are not statistically significant using DMRT)

Table 3. *Effect of fly ash and amendments on heavy metals concentration (mg kg^{-1}) in maize (pooled over 3 consecutive seasons)*

Treatments	Pb		Cd		Cr	
	Grain	Stover	Grain	Stover	Grain	Stover
Control	0.43^{cd}	1.44^{abc}	0.10^{bc}	0.35^{b}	0.23^{cd}	0.79^{bcd}
Lime (L)	0.37^{e}	1.39^{c}	0.08^{e}	0.29^{c}	0.20^{d}	0.78^{cd}
Gypsum (G)	0.49^{ab}	1.50^{a}	0.12^{a}	0.38^{ab}	0.25^{bc}	0.86^{a}
Fly ash (FA)	0.51^{a}	1.48^{ab}	0.10^{bc}	0.36^{ab}	0.28^{ab}	0.86^{ab}
L+FYM	0.39^{de}	1.40^{c}	0.08^{de}	0.31^{c}	0.25^{bc}	0.76^{d}
G+FYM	0.45^{bc}	1.48^{ab}	0.11^{ab}	0.3^{a}	0.25^{bc}	0.84^{abc}
FA+FYM	0.45^{c}	1.49^{a}	0.11^{ab}	0.37^{ab}	0.30^{a}	0.85^{ab}
L+FA+FYM	0.45^{c}	1.43^{bc}	0.09^{cd}	0.35^{b}	0.28^{ab}	0.80^{abcd}
CD (0.05)	0.04	0.05	0.01	0.03	0.04	0.06
CV (%)	5.57	2.22	6.95	5.63	9.72	4.44

(Means with at least one letter common are not statistically significant using DMRT)

Table 4. *Effect of fly ash and amendments on total uptake of micronutrient and heavy metal (g ha^{-1}) in maize (pooled over 3 consecutive seasons)*

Treatments	Fe	Mn	Zn	Cu	Pb	Cd	Cr
Control	465.91^{e}	288.19^{c}	136.11^{e}	54.09^{d}	7.01^{d}	1.68^{e}	3.84^{e}
Lime (L)	529.60^{cd}	318.30^{c}	178.52^{bc}	60.05^{cd}	7.82^{cd}	1.65^{e}	4.33^{de}
Gypsum (G)	519.70^{cde}	313.02^{c}	163.35^{cd}	52.76^{d}	7.77^{cd}	1.93^{cde}	4.34^{de}
Fly ash (FA)	476.82^{de}	303.95^{c}	149.96^{de}	61.11^{cd}	8.15^{c}	1.90^{de}	4.65^{cd}
L+FYM	620.89^{b}	381.54^{ab}	205.53^{a}	68.90^{bc}	9.13^{ab}	2.00^{bcd}	5.13^{bc}
G+FYM	566.86^{bc}	358.46^{b}	177.41^{bc}	60.00^{cd}	8.51^{bc}	2.20^{abc}	4.82^{bcd}
FA+FYM	573.38^{bc}	358.88^{b}	185.49^{b}	73.34^{ab}	9.09^{b}	2.23^{ab}	5.40^{ab}
L+FA+FYM	676.04^{a}	405.93^{a}	207.58^{a}	85.00^{a}	10.05^{a}	2.36^{a}	5.82^{a}
CD (0.05)	54.17	35.93	19.10	12.13	0.94	0.29	0.64
CV (%)	5.59	6.02	6.22	10.75	6.34	8.27	7.95

(Means with at least one letter common are not statistically significant using DMRT)

gypsum significantly increased Pb, Cd and Cr content in maize grain over lime by 32.4, 50.0 and 25.0%, respectively. Application of fly ash significantly increased the Pb and Cr content by 18.6 and 21.7% over control, respectively. Inclusion of FYM with lime or gypsum did not have much effect on Pb and Cd accumulation, whereas FYM with fly ash significantly lowered the Pb accumulation as compared to fly ash alone. However, Cd and Cr contents were at par. Integration of lime with fly ash and FYM behaved similar to fly ash with FYM treatment. Similar trend was observed for Cd, Cr and Pb uptake (Table 4).

Maize yield

The maize grain yield data presented in Figure 1 revealed that in absolute control, the yield was 35.74, 39.94 and 40.12 q ha^{-1} during *Kharif* 2013, *Rabi* 2013-14 and *Kharif* 2014, respectively. Application of lime to each crop significantly increased the pooled yield over control by 27 %. The yield due to gypsum treatment was at par with control. On the other hand one time

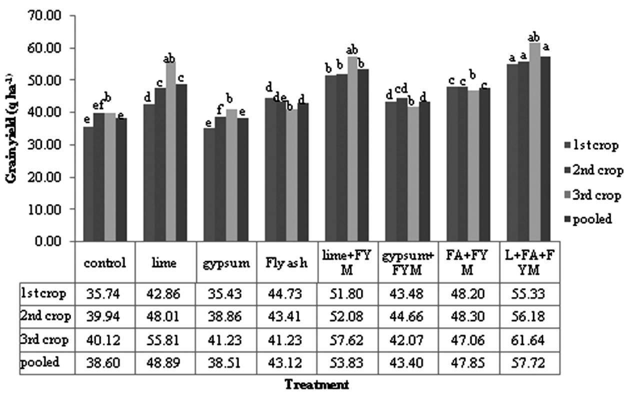

Fig. 1. *Effect of amendments on maize grain yield (q ha^{-1}) over the years*

application of fly ash to first crop stabilised the yield up to third season and recorded significantly higher pooled yield (43.12 q ha^{-1}) over control and gypsum treatment. Inclusion of FYM with amendments resulted in significantly higher pooled yield over their sole application. Integrated use of lime with fly ash and FYM recorded maximum yield as compared to their sole application or combination with FYM. Inclusion of FYM with amendments enhanced the activity of beneficial microbes (Srivastava and Chhonkar, 2000), which play an important role in mobilization of nutrients and there by leading to better availability of nutrients facilitating uptake by plants resulting in better growth and dry matter production. The data further indicated that one time application of fly ash with FYM is comparable with lime treatment and can be recommended for crops in acid soils.

From the present investigation it was concluded the Fe and Cu accumulation by maize grain in fly ash treatment was comparable with lime treatment but had lower Mn and Zn content. Application of fly ash significantly increased the Pb and Cr, however inclusion of FYM with fly ash significantly lowered the Pb accumulation. One time application of fly ash to first crop stabilised the maize yield up to third season. Inclusion of FYM with fly ash resulted in higher yield over their sole application. Considering heavy metal accumulation and maize yield, fly ash could be effectively utilized in acid soil of Chaudar, Cuttak, Odisha, for higher crop production without affecting the soil health.

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