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Yield and trace metal levels in colocasia (*Colocasia esculenta* L.)-potato (*Solanum tuberosum* L.) cropping sequence as influence by fly ash and fertilizer application

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Abstract

Experiments were conducted to see the effect of fly ash on growth, yield and quality of two tuber crops cropping sequence Colocasia and potato in red and lateritic soil of Chotanagpur Plateau. Result revealed a positive and significant effect of 4, 8 and 16 percent fly ash (w/w) incorporation in acidic soil (pH 5.9) on crop yield and on all growth attributes of both the tested vegetable crops. Tuber yield of Colocasia was recorded as 4.96, 5.66 and 6.95 t ha^{-1}, respectively due to application of 4, 8 and 16% fly ash alone. Yield of Colocasia drastically increased over control and found higher (11.92 t ha^{-1}) at 16% FA+NPK followed by 10.25 t ha^{-1} yield of Colocasia with 8% FA+NPK. Potato yield (22.39 t ha^{-1}) was higher in 16% FA+NPK treatment followed by yield 20.63 t ha^{-1} at 8% FA+NPK applied treatment when grown on residual fly ash application. In control plot Pb, Co and Ni content were found 13.9, 15.2 and 5.0 mg kg^{-1}, while at 16% fly ash application level, Pb, Co and Ni content were found 28.7, 35.6 and 15.7 mg kg^{-1}, respectively in edible part of Colocasia (cormel). Fe (310 mg kg^{-1}), Mn (28 mg kg^{-1}), Zn (46.7 mg kg^{-1}), Cu (35.8 mg kg^{-1}), Pb (22.0 mg kg^{-1}), Ni (20.9 mg kg^{-1}) and Co (27.0 mg kg^{-1}) content were higher in potato tuber, when grown on 16% residual fly ash in Colocasia-potato cropping sequence.

Keywords Colocasia-potato cropping sequence, fly ash, lateritic soil, trace metal

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Introduction

Fly ash is the waste obtained from the combustion of pulverized bituminous or sub-bituminous coal (lignite) in thermal power plants and comprises of unburnt mineral constituents of coal. Fine minute particles of ash that is fly ash are carried away with flue gases in electrostatic precipitators or cyclone separators and are collected by wet (slurry form) or dry scrubbing method, which requires large volumes of land, water and energy. Use of high ash containing 30-50% bituminous or sub-bituminous coal in thermal power stations, in addition to several captive power plants, contributes to indiscriminate disposal of this industrial waste every year [1, 2].

In India, presently, coal combustion product is around 170 MT and is likely to exceed with increasing need of energy in future [3]. Besides the present use of fly ash in making bricks and cement refractory products, fly ash disposal in agricultural land is a viable alternative. Addition of fly ash in agricultural soil can be beneficial for its amendment and nutrient supply and can partly solve the problem of its disposal. Present study was undertaken with fly ash (Bokaro Steel Plant fly ash) and fertilizer

application in Colocasia- potato cropping sequence that is most popular among tribal farmers of Chotanagpur Plateau. Detailed characterization of fly ash from different sources has been already presented by Kumar et al. [4].

Methodology

Field experiments were conducted at experimental area of Department of Horticulture, Ranchi University with Colocasia (*Colocasia esculenta* L.) - potato (*Solanum tuberosum* L.) cropping sequence on typical red loam with kadma local and kufri lalima cultivars respectively for two consecutive years (1997-98 and 1998-1999). Fly ash was evaluated at four rates of application viz., 0, 4, 8, 16, percent (w/w) corresponding to 0, 90, 180 and 360 t ha^{-1} in combination with 50 and 100 percent recommended fertilizer dosage in each crop (Table 1). The treatments were conducted in 3 replications in randomized block design and fly ash was mixed with the upper 15 cm (plough layer) soil. After harvest of Colocasia, potato were grown on residual soil without disturbing the layout. Recommended management practices for crops were followed. After harvesting of Colocasia and potato, edible part were processed with following steps of washing, drying and grinding. Ground edible part (0.5g) was taken in a conical flask and 10 ml of tri-acid mixture (HNO_3: $HClO_4$: H_2SO_4 in 10: 4: 1) was added. Further, it was heated on a hot plate until complete digestion [5]. The residue was dissolved in double-distilled water and after filtration (what man filter paper No. 42), its final volume was made to 50 ml. Total Zn, Cu, Fe, Mn, Pb, Ni and Co were determined in the aliquot with the help of Atomic Absorption Spectrophotometer (GBC 902). The initial soil and fly ash samples were chemically analyzed. Fly ash of Bokaro Steel Plant was characterized as slightly acidic in reaction (pH 6.5) and rich in total and available plant nutrients except nitrogen. Observations of growth, yield and quality parameters (pooled mean of 1997 and 1998) were recorded and trace and heavy metals content (Zn, Cu, Fe, Mn, Pb, Ni and Co) in edible parts were also monitored.

Table 1. Growth and yield attributes of *Colocasia* crop in fly ash amended soil (Average value of two years experiment)

Treatments	Plant height (cm)	No. of leave/ plant	Leaf length (cm)	Leaf width (cm)	No. of tubers/plant	Tuber weight/ plant (g)	Tuber yield/ plot (kg)	Tuber Yield (t ha^{1})	Percent increase in yield over control
Control	52.14	6.00	26.04	15.39	9.93	111.98	3.04	3.75	0
Rec.NPK	66.97	6.13	35.98	19.80	15.68	234.83	6.7	8.27	120.53
4 percent FA	56.67	6.10	30.77	18.17	12.70	145.33	4.01	4.96	32.27
8 percent FA	63.70	6.03	31.10	18.38	11.91	155.17	4.58	5.66	50.93
16 percent FA	66.13	6.07	32.07	19.18	17.00	221.83	5.63	6.95	85.33
4 percent FA + NPK	68.46	6.23	34.34	20.47	14.10	231.33	6.38	7.88	110.13
4 percent FA +1/2NPK	67.73	6.47	35.08	20.82	18.18	262.83	6.55	8.08	115.47
8 percent FA + NPK	73.66	6.50	35.22	20.52	17.62	294.83	8.32	10.25	173.33
8 percent FA +1/2NPK	71.34	6.20	36.46	21.33	15.90	229.67	6.64	8.19	118.40
16 percent FA+ NPK	77.62	6.27	36.97	24.12	17.73	308.00	9.66	11.92	217.87
16 percent FA + 1/2NPK	72.03	6.27	36.05	21.92	16.55	249.66	7.67	9.47	152.53
C.D. at 5 percent	9.68	NS	5.62	1.98	2.56	66.58	1.96	2.17	
Corr. Coeff. for 0,4,8 & 16 percent FA	0.9415	0.3995	0.8177	0.8496	0.9381	0.9875*	0.9886*	0.9879*	

* Values significant at 5 percent, FA –Fly ash (from Bokaro Steel Plant); Rec. NPK - Recommended dose of NPK fertilizers

Results and Discussion

Growth and yield attributes of Colocasia and potato

All the growth attributes of Colocasia were significantly affected due to application of fly ash and fertilizer. Cormel yield of Colocasia was recorded as 4.96, 5.66 and 6.95 t ha^{-1}, respectively due to application of 4, 8 and 16% fly ash w/w. In control treatment (without fly ash and fertilizer application), Colocasia tuber yield was recorded as 3.76 t ha^{-1} (lowest among all treatment), while at recommended NPK level observed yield was 120 per cent (8.27 t ha^{-1}) higher than control. Percent increase in yield over control was recorded from 32.27% to 85.33% with application of 4 and 16% fly ash, respectively (Table 1). Colocasia yield drastically increased over control and found higher (11.92 t ha^{-1}) on 16% fly ash application with recommended NPK followed by 10.25 t ha^{-1} yield with 8% FA+NPK.

When potato was grown on residual fly ash with 50 and 100% recommended NPK application, significant impact of fly ash was observed on growth attributes and yield. Similar to the Colocasia cormel yield (direct application of fly ash), higher potato yield (22.39 t ha^{-1}) was observed at 16% FA+NPK treatment followed by 20.63 t ha^{-1} yield in 8% FA+NPK treatment. Percent increase in yield was found 194.22 and 171.09% over control yield, respectively, when 8 and 16% fly ash were applied with recommended NPK. When 4, 8 and 16% fly ash w/w was applied, it showed a significant residual impact on succeeding crop in Colocasia-potato cropping sequence (Table 2). Potato yield was 10.10, 11.85 and 13.54 t ha^{-1} at the level of 4, 8 and 16% fly ash application, while potato tuber yield was 7.61 and 17.18 t ha^{-1} respectively in control and recommended NPK application level. The results were in accordance with the finding of Elssewi et al. [6] and Kumar et al. [7]. Their results indicated better response in most of the vegetables and agronomic species on 8 percent fly ash addition to soil, while under certain condition better response was also up to 16 percent supply.

Trace and heavy metals content in edible part of Colocasia and potato

Higher content of all trace metals in Colocasia cormel was observed at 16% fly ash application without NPK and with NPK, followed by 8 and 4% fly ash application respectively.

Table 2. Growth and yield attributes of Potato crop in fly ash amended soil (Average value of two years experiment)

Treatments	Plant height (cm)	No. of leaves/ plant	No. of branches/ plant	No. of tubers/ plant	Tuber weight/ plant (g)	Tuber yield/ plot (kg)	Tuber Yield (t ha^{1})	Percent increase in yield over control
Control	14.64	22.41	3.70	9.77	119.67	6.17	7.61	
Rec.NPK	25.31	41.16	5.20	17.81	316.67	13.92	17.18	125.76
4 percent FA	17.61	22.55	3.20	12.57	133.33	8.18	10.10	32.72
8 percent FA	16.21	24.61	4.00	13.64	163.70	9.60	11.85	55.72
16 percent FA	17.42	24.91	3.80	11.94	164.43	11.01	13.59	78.58
4 percent FA + NPK	25.75	34.78	5.00	13.56	252.66	14.84	18.32	140.74
4 percent FA +1/2NPK	28.05	33.16	4.20	13.48	248.66	14.10	17.42	128.91
8 percent FA + NPK	27.47	29.66	4.00	15.23	259.25	16.72	20.63	171.09
8 percent FA +1/2NPK	26.51	33.58	3.90	14.98	270.16	14.70	18.15	138.5
16 percent FA+ NPK	31.14	40.16	5.00	14.77	340.88	18.00	22.39	194.22
16 percent FA + 1/2NPK	30.19	36.04	4.50	13.87	270.66	15.86	19.59	157.42
C.D. at 5 percent	7.21	4.68	0.92	3.12	52.48	2.57	2.84	
Corr. Coeff. for 0,4,8 & 16 percent FA	0.6299	0.8953	0.3871	0.4485	0.8573	0.9672*	0.9669*	

* Values significant at 5 percent; FA - Fly ash (from Bokaro Steel Plant); Rec. NPK - Recommended dose of NPK fertilizers

Table 3. Trace metal concentration on dry matter basis in Colocasia cormel as affected by different levels of fly ash and fertilizer addition (Average value of two years)

Treatments	Trace metal content (mg kg^{-1})						
	Fe	Mn	Zn	Cu	Pb	Co	Ni
Control	228	39	27.6	14.3	13.9	15.2	5.0
Rec.NPK	222	41	31.5	14.1	13.1	15.8	5.5
4 percent FA	247	63	44.6	21.4	19.1	20.7	8.7
8 percent FA	296	68	54.3	30.3	23.7	28.4	13.2
16 percent FA	332	91	61.5	34.9	28.7	35.6	15.7
4 percent FA + NPK	218	51	45.6	25.9	21.1	17.6	7.6
4 percent FA +1/2NPK	246	47	47.3	26.6	19.7	19.9	7.1
8 percent FA + NPK	281	78	58.1	29.2	25.2	25.7	13.4
8 percent FA +1/2NPK	294	78	58.1	30.6	24.1	27.5	13.1
16 percent FA+ NPK	314	86	62.9	34.5	29.7	34.3	16.5
16 percent FA + 1/2NPK	329	87	64.6	36.0	29.9	33.5	16.7
C.D. at 5 percent	47	13	6.9	6.3	3.0	5.5	2.4
Corr. Coeff. for 0,4,8 & 16 percent FA	0.9792*	0.9723*	0.9340	0.9563*	0.9825*	0.9868*	0.9592*
Corr. Coeff. (yield) at 0,4,8,16 percent FA	0.9926*	0.9765*	0.9788*	0.9885*	0.9753*	0.9709*	0.9957*

*Values significant at 5 percent; FA - Fly ash; Rec. NPK - Recommended dose of NPK fertilizer

In control plot of the experiment, 13.9, 15.2 and 5.0 mg kg^{-1} Pb, Co and Ni content were found, respectively in edible part of Colocasia, while at 16% fly ash application level 28.7, 35.6 and 15.7 mg kg^{-1} Pb, Co and Ni content were found in edible part, respectively, which was about 2 to 3 times more as compared to control treatment (Table 3).

Due to residual impact of fly ash, accumulation of trace metal in potato tubers was significantly affected in red and lateritic soil conditions. Similar to sole crop in Colocasia-potato cropping sequence, Fe (310 mg kg^{-1}), Mn (28 mg kg^{-1}), Zn (46.7 mg kg^{-1}), Cu (35.8 mg kg^{-1}), Pb (22.0 mg kg^{-1}), Ni (20.9 mg kg^{-1}) and Co (27.0 mg kg^{-1}) content were found higher in potato tuber, when grown on 16% residual fly ash (Table 4).

Table 4. Residual effect of fly ash and fertilizer application on content of trace metals in Potato tubers (Average of two years)

Treatments	Trace metal content (mg kg^{-1})						
	Fe	Mn	Zn	Cu	Pb	Co	Ni
Control	187	16	19.4	13.3	8.0	6.2	9.3
Rec.NPK	191	20	20.7	16.0	7.9	7.5	9.6
4 percent FA	297	30	30.4	25.8	11.1	11.5	14.1
8 percent FA	293	27	38.8	31.7	15.2	18.7	21.1
16 percent FA	310	28	46.7	35.8	22.0	20.9	27.0
4 percent FA + NPK	285	27	28.1	25.2	10.6	11.3	12.4
4 percent FA +1/2NPK	307	27	26.1	26.4	11.5	12.0	13.5
8 percent FA + NPK	290	28	37.3	31.1	15.9	14.1	20.6
8 percent FA +1/2NPK	305	26	37.8	31.9	14.4	15.3	21.7
16 percent FA+ NPK	301	26	46.2	34.9	22.3	17.7	28.2
16 percent FA + 1/2NPK	309	28	46.2	35.0	22.1	18.8	27.9
C.D. at 5 percent	0.9	4	4.5	3.2	3.7	2.9	2.9
Corr. Coeff. for 0,4,8 & 16 percent FA	0.7564	0.5972	0.9684*	0.9131	0.9992*	0.9329	0.9832*
Corr. Coeff. (yield) at 0,4,8,16 percent FA	0.8785	0.7455	0.9997*	0.9876*	0.9630*	0.9853*	0.9867*

* Values significant at 5 percent ; FA - Fly ash; Rec. NPK - Recommended dose of NPK fertilizer

Application of fertilizer did not show significant effect on increase of trace metals accumulation in potato tuber, when it was grown on residual fly ash. Pb, Ni and Co content in potato tuber were 11.1, 11.5, 14.1 mg kg^{-1} at 4% fly ash, while 15.2, 18.7 and 21.1 mg kg^{-1} content were found at 8% fly ash application level when grown in Colocasia-potato cropping sequence. Kumar et al. [7,8] earlier reported higher content of Pb, Ni and Co in soybean, rice and residual impact on wheat with increasing level of fly ash incorporation in soil.

Conclusion

Direct and residual impact of fly ash certainly increased the Colocasia and potato yield, when grown in red lateritic soil of Chotanagpur Plateau. Content of trace metals (Zn, Cu, Fe, Mn, Pb, Ni and Co) in edible part of Colocasia and potato were also increased when grown in fly ash incorporated soil.

The study pointed out the need to monitor the level of trace metals, particularly heavy metals viz. Pb, Ni and Co before their use by farmers in agricultural fields. This is a matter of concern and there can be potential health hazards on continuous use of fly ash in such soil.

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