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Growth, Yield and Elemental Status of *Lycopersicum esculantum* L. Grown in Fly ash with Azosprillum amended Soil

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ABSTRACT

Fly ash (FA) from NALCO, Odisha (India) was used for amending soil at levels equivalent to 0, 5, 10, 20 40 and 80 T/H in which, tomato was grown and elemental residues of amended soil and plant were enumerated. In the present experiment Azosprillum mixed with graded levels of FA (5, 10, 20 40 and 80 T/H) to observe the role of Azosprillum in improving soil quality and reducing metal toxicity. FA amendments caused significant improvement in soil quality and germination percentage of tomato plants. Growth (seedling height, Shoot length, leaf number) and yield (number of fruits, fruit weight and fruits per plant) of tomato increased with an increase in FA amendments. In the present study fly ash neutralize the pH imbalance, increased EC, CEC, OC, P and some essential and nonessential micro elements i.e. Fe, Mn, Pb, Co and K. Further Azosprillum supplementations caused invariably increments in each growth parameters. The levels of 20 and 40 T/H FA were ideal for fruit yield. FA+ Azosprillum reduced heavy metal concentrations in both soil and plant. Hence, addition of bacterial species to FA may help in reducing the possible heavy metal toxicity of crop plants and can be used for solid waste management in Agro ecosystem.

INTRODUCTION

Coal-fired power plants generate fly ash (FA) whose elemental composition (both nutrient and toxic elements) varies due to types and source of used coal (Camberato *et al*., 1997). In most instances FA consists of macro-nutrients, Na, K, P, and Fe and micronutrients, Co, B, Zn, Cu, and Mn. Heavy metals like Pb, Ni, Cr, Cd and a few more, also occur abundantly and have the potential to cause contamination/toxicity (Fytianos *et al*., 2001). Further, plant micro-nutrients at high concentrations can cause metal toxicity (Miller *et al*., 2000). Although mobilized elements from dumped FA masses are potential sources of nutrients for plants there is a universal concern regarding heavy metal contaminations of terrestrial and aquatic ecosystems may also occur (Miller *et al*., 2000).

In India, about 80-million metric tons of FA is generated annually from thermal power stations with only a minor part used now for preparing bricks, ceramics and cements. Fly ash pond occupies an additional 100 ha land each year. Over flooding of fly ash water in rainy season to adjacent areas, like rice fields and other crop fields inevitably become contaminated, thus potentiating grave problems. Utilization of fly ash in agriculture is one of the option to reduce solid waste pollution. FA and other coal combustion byproducts have been used as nutrients supplements to crop soil in India and several countries (Miller *et al*., 2000; Mishra *et al*., 2009). Lower amendment levels of FA caused enhancements of both growth and yield while adverse effects at higher levels were observed for several crops including maize, soybean, barley, cabbage, apple, alfalfa, beet (Korcak, 1995; Miller *et al*., 2000). Further, higher levels of macro and micro-nutrients in FA have been shown to affect growth and yield of several crops in USA, Europe and India adversely, i.e., Maize and soybean (Mishra and Shukla, 1986), barley and cabbage (Koracak, 1995), apples (Fail and Wochok, 1977) and soybean (Allen *et al*., 1974). The present study aims to show the effect of FA alone and FA with Azosprillum on growth, yield and elemental status of *Lycopersicum esculantum* L. in coasted lands of south Odisha, India.

MATERIALS AND METHODS

Fly ash

Electro-statically precipitated FA in an unweathered condition (Sample-lots less than 30 days old) obtained from NALCO power plant (Odisha) consists of the following (%) by weight: sand 15.5, silt 72.5 and clay 13, with pH 7.4 and the following elements (mg per kg): Na 800, K 840, Fe 425, P 68, Ni 190, Co 670, Pb 200, Zn 340, Mn 450, Cu 700, Cr 505 and Cd 131, by analysis with an absorption spectrophotometer (Model AA 1475 at RRL, Bhubaneswar).

Field preparation and Fly ash treatment

The experimental fields were repeatedly ploughed to completely remove the rhizomes, roots of perennial grasses and shrubs. Then the field was left to be dried under sun for a week and then ploughed again. After 2-3 times thoroughly ploughed, experimental plots of $1\times1m^2$ sizes were prepared. The experimental plots were uniformly spaced by 8 inch high and 1 feet wide ridge throughout. Soil samples were collected at a depth of 5-10cms, air dried and stored for further analysis. All the experimental plots were mixed thoroughly with cow dung compost @ of 7.5T/H. Then the plots were amended with fly ash @ 5, 10, 20, 40, 80 TH 1kg of Azosprillum and mixed thoroughly by a spade. The fields were watered by sprinkling lightly so as to leave the soil with enough moisture for germination.

Disease free healthy tomato seeds were procured from the agriculture office, Jeypore (District: Koraput), Odisha, India. Five replicates of 100 seeds each were soaked overnight and next day sown in the fields. Sprouting was observed six days after sowing. Germination counts were recorded on each alternative day. 100 healthy seeds were selected from the soaked seeds. These seedlings were sown in the respective experimental plots with uniform spacing as per agronomic practice. All the experimental plots as well as the control plots were maintained alike.

Soil analysis

Soil pH: Soil of experimental plots was sandy loam, and pH of soil samples (without and with FA) was measured with a digital pH meter (Digison model, D1-707) in a soil/water mixture at the ratio of 1: 2.5 (Magdoff and Bartlett, 1985; Mishra *et al*., 2009).

Electrical conductivity (EC): Electrical conductivity (EC) expressed in µMho/cm of soil samples (FA/soil water at ratio of 1/5 suspension) was determined following 30 min equilibration in a mechanical shaker, by a digital conductivity meter (Digison model, D1-909) (Khan and Khan, 1996).

Cation exchange capacity (CEC): Cation exchange capacity (CEC) of soil was determined by the methylene blue method; a lot of 2 g soil sample was equilibrated with 50ml of 1% $NaCO_3$, for titration against methylene blue as an indicator. The end point was noted by a light blue hallow circle a dark blue centre from a drop of solution on a Whatman no.1 filter paper; CEC value was determined by multiplying the titration factor with 0.535 and expressed as C mol. per kg (Sumner and Miller, 1996).

Organic Carbonic: Organic Carbonic values of 30-days-old-soil samples were determined by oxidation with potassium dichromate in acid medium (Walkly and

Black, 1934) to lots of 5g of air-dried and sieved soil/FA samples, aliquots of 10 ml of 1N $K_2Cr_2O_7$ solution, 20ml of 12 NH_2SO_4 and 1.25% $AgSO_4$ were added with constant stirring. After incubation for 30 min to each sample a volume of 200 ml distilled water was added followed by addition of 10ml phosphoric acid (85%) and 1 ml (0.42%). The indicator phenyl amine and titrated against 1N ferrous ammonium Sulphate (Bremner and Jenkinson. 1960; Mishra *et al.*, 2009).

Phosphorus 003A: The soil sample is treated with concentrated sulphuric acid and hydrogen peroxide to dissolve phosphorus in organic and non-silicate inorganic forms. Phosphorus in the silicate lattice is released by hydrofluoric acid treatment (Alef and Nannipieri, 1995).

Nitrogen: Discrete samples were made and pressed using washed sea sand and bentonite clay as a soil like matrix. Scotts Super Turf Builder (36% N) was added to the soil matrix for nitrogen samples. Measuring a total Nitrogen in soil was estimated by Using Laser-Induced Breakdown Spectroscopy (LIBS) (Harris *et al.*, 2004).

Exchangeable Cations (Na^+, K^+): Exchangeable cations are extracted from the soil using an extracting solution (1 N NH4OAc) at pH 7.0. The extracted solution is then analyzed by AA (atomic absorption) for the soil cations (Thomas *et al.*, 1982).

Elemental analysis

Detailed methods of study of soil characteristics have been described previously (Harper *et al.*, 1989). Digestion of soil samples were done in 20 ml of mixed acids (10N HNO_3, 12N H_2SO_4, 60% $HClO_4$ in the ratio of (5:0.5:1) (Shaw, 1992). Harvested leaves were thoroughly washed and oven-dried at 110^{0}C for 40h, and the dried leaves ground to powders. Lots of the powders were digested with 10 N HNO_3 (Koracak, 1995) and subjected to elemental analysis using an atomic absorption spectrophotometer (Model AA1475, at Regional Research laboratory, Bhubaneswar), whereas Na and K contents were analyzed by flame photometry.

RESULTS AND DISCUSSION

Ex-situ germination patterns of tomato seeds were found to be better at 5 to 40 T/H and the Azosprillum supplementations induced better germination pattern in 11 days study. Plant growth measured used as average seedling height, shoot height, leaf number, leaf area, flower number, number of fruits, fruit weight, and root length and plant dry weight. Clearly indicate that FA amendment significantly supported the growth of tomato (Table-1). The average seedling height increased from 3.7cm (Control) to 3.8cm (80T/H FA); the average shoot height increased from 30.37cm (control) to 38.77cm (80T/H FA); the average leaf number increased from 8.1 (Control) to 10.0 (80T/H FA); the average number of flower increased from 11 (control) to 31 (80T/H FA); the average number of fruits increased from 7.2 (control) to 12.2 (80T/H FA); the average fruit weight increased from 312.47gm/m^2 (control) to 429.12 gm/m^2 (40 T/H FA); the average root length increased from 17.25cm (control) to 22.11 (10 T/H FA); the average plant dry weight increased from 16.88 gm/m^2 (control) to 25.27 gm/m^2 (10 T/H FA). Azosprillum supplemented flyash perform better in all growth parameters (Table-1-9). The statistic analysis of data supported this conclusion. For levels of significance 2 types of comparisons are made, 1) between control and FA treatment (a), 2) between FA and FA+ Azosprillum (b). Levels of significance are indicated in respective tables.

Table 1: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on percentage of germination in *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Days after sowing											
	6		7		8		9		10		11	
	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+
Cont.	35	26	39	41	40	47	40	45	40	47	41	47
5	15	14	21	32	35	45	45	54	46	57	56	64
10	29	13	30	57	41	61	49	64	57	64	61	65
20	19	21	30	35	41	48	50	59	54	59	62	69
40	20	17	32	44	40	49	46	49	58	61	63	73
80	16	11	26	28	31	33	40	46	54	56	66	77

FA: Flyash, T/H: Tones per hectare

Table 2: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on seedling height (in cm) of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	MEAN ± SEM Height (c.m.)	FA+ Treatment (T/H)	MEAN ± SEM Height (c.m.)
Cont.	3.7 ± 0.1 ***(a)	Cont	3.19 ± 0.8 ***(b) NS (a+)
5	2.60 ± 0.1 ***(a)	5+	2.60 ± 0.1 ***(a+) NS (b)
10	2.50 ± 0.2 ***(a)	10+	2.50 ± 0.2 ***(a+) NS (b)
20	2.50 ± 0.7 ***(a)	20+	2.50 ± 0.7 ***(a+) NS (b)
40	3.07 ± 0.1 NS(a)	40+	3.07 ± 0.1 ***(a+) NS (b)
80	3.80 ± 0.1 NS(a)	80+	3.80 ± 0.1 ***(a+) NS (b)

Probability level:*p<0.05, **p<0.01, ***p<0.001, NS: Not Significant, T/H: Tones per hectare
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 3: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on shoot length of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Height (cm)							
	21DAS		31DAS		41DAS		51DAS	
	FA	FA+	FA	FA+	FA	FA+	FA	FA+
Cont.	5.95±0.15 NS(a)	5.5±0.25 **(b) ** (a+)	9.82±0.28 NS(a)	11.59±0.33 **(b)** (a+)	16.25±0.43 NS(a)	17.08±0.4 NS(b)*** (a+)	30.37±0.63 *(a)	32.94±0.52 ***(b)NS(a+)
5	5.9±0.13 ***(a)	6.87±0.23 **(b) ** (a+)	9.78±0.27 NS(a)	13.39±0.29 *(b)NS(a+)	16.69±0.04 NS(a)	21.24±0.4 **(b)NS(a+)	32.05±0.57 **(a)	33.61±1.20 **(b)NS(a+)
10	7.49±0.25 ***(a)	6.9±0.14 NS(b)*** (a+)	10.27±0.43 NS(a)	11.53±0.19 NS(b)***(a+)	16.39±0.32 NS(a)	17.9±0.33 **(b) NS(a+)	33.72±0.92 NS(a)	34.10±2.03 NS(b) **(a+)
20	7.93±0.47 ***(a)	7.73±0.27 NS(b)*** (a+)	11.39±0.59 ***(a)	12.39±0.24 NS(b)***(a+)	17.01±0.04 NS(a)	18.06±0.32 NS(b)NS(a+)	34.28±1.7 ***(a)	36.36±0.73 NS(b)***(a+)
40	7.09 ±0.13 ***(a)	7.05 0.12 NS(b)*** (a+)	13.32±0.38 ***(a)	13.32±0.38 **(b) ***(a+)	17.23±0.42 ***(a)	17.39±0.31 ***(b) ***(a+)	36.5±1.2 ***(a)	36.84±0.93 ***(b)***(a+)
80	7.09 ±0.13	8.17±0.26	13.24±0.16	14.2±0.29	20.25±0.43	21.50±0.47	38.77±0.44	42.05±0.72

Probability level:*p<0.05, **p<0.01, ***p<0.001, NS: Not significant, a: Significant test between flyash and control soil
T/H: Tones per hectare, DAS: Days after sowing
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 4: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on number of leaves of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Number of leaves (DAS)					
	23 DAS		33 DAS		43 DAS	
	FA	FA+	FA	FA+	FA	FA+
Cont.	4.6±0.16 **(a)	5.8±0.19 ***(b) *(a+)	7.6 ±0.16 ***(a)	8.6 ±0.16 **(b)**(a+)	8.1 ±0.31 **(a)	9.7 ±0.15 NS(b)NS(a+)
5	5.5±0.22 ***(a)	6.4±0.16 ***(b)***(a+)	8.7 ±0.21 *(a)	7.9 ±0.17 **(b)**(a+)	10.0 ±0.51 *(a)	9.7 ±0.26 *(b)NS(a+)
10	5.7±0.21 ***(a)	7.4±0.16 ***(b)***(a+)	8.3 ±0.21 NS(a)	9.2 ±0.12 NS(b)***(a+)	9.7 ±0.63 NS(a)	9.3 ±0.15 NS(b)NS(a+)
20	5.6±0.16 ***(a)	7.1±0.23 ***(b)**(a+)	7.9 ±0.37 NS(a)	7.3 ±0.15 **(b)NS(a+)	9.3 ±0.71 *(a)	9.9 ±0.17 **(b)*(a+)
40	5.6±0.16 NS(a)	7.5±0.42 ***(b)NS(a+)	7.4 ±0.22 ***(a)	8.7 ±0.26 NS(b)***(a+)	9.2 ± 0.29 ***(a)	10.4±0.22 NS(b)**(a+)
80	4.7 ± 0.15	5.9 ±0.27	6.6 ±0.16	6.5 ±0.16	10.0 ±0.25	10.6±0.22

Probability level:*p<0.05, **p<0.01, ***p<0.001, NS: Not significant, a: Significant test between flyash and control soil
T/H: Tones per hectare, DAS: Days after sowing
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 5: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on number of flowers of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	NUMBER OF FLOWERS (DAS)															
	48		50		52		54		56		58		60		62	
	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+
Cont.	0	0	0	0	0	0	0	0	0	0	0	0	0	7	11	29
5	0	0	0	0	1	0	3	0	8	4	18	21	27	30	17	34
10	1	0	0	3	2	4	2	3	5	10	16	23	22	33	23	31
20	2	2	3	5	8	7	13	16	20	28	36	47	41	45	32	44
40	0	6	1	7	3	12	10	24	25	30	42	51	43	62	47	50
80	0	0	1	0	2	1	4	2	10	12	24	30	26	39	31	51

FA: Flyash, T/H: Tones per hectare, DAS: Days after sowing
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 6: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on number of fruits of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Number of Fruits (DAS)					
	60		70		80	
	FA	FA+	FA	FA+	FA	FA+
Cont.	2.7±0.26 NS(a)	2.7±0.33 NS(b) ***(a)	5.7 ±0.85 *(a)	7.2 ±0.80 NS(b) NS(a+)	7.2 ±0.59 NS(a)	8.1 ±0.67 ***(b) ***(a+)
5	5.0±1.3 NS(a)	5.3±0.51 NS(b) **(a+)	10.0 ±0.14 NS(a)	8.6 ±0.40 NS(b) NS(a+)	8.2 ±0.48 NS(a)	13.4 ±0.03 *(b) NS(a+)
10	4.0±0.76 ***(a)	5.6±0.68 NS(b) ***(a+)	7.5 ±0.93 *(a)	9.6 ±1.0 NS(b) *(a+)	7.4 ±0.47 NS(a)	9.4 ±0.71 ***(b) ***(a+)
20	8.7±1.5 ***(a)	8.9±0.9 *(b) ***(a+)	9.2 ± 1.2 ***(a)	9.8 ±0.22 NS(b) *(a+)	6.9 ±0.43 **(a)	11.9 ±0.7 NS(b) ***(a+)
40	7.8±0.94 ***(a)	10.9±1.1 NS(b) ***(a+)	10.4 ± 0.52 ***(a)	10.3 ±1.1 NS(b) *(a+)	10.72 ± 0.69 ***(a)	12.18±0.51 NS(b)***(a+)
80	6.3±1.0	7.9±0.75	9.9 ± 1.0	9.8±0.62	12.2 ± 0.4	13.94±0.64

Probability level:*p<0.05, **p<0.01, ***p<0.001, NS: Not significant, a: Significant test between flyash and control soil
T/H: Tones per hectare, FA: Flyash
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 7: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on Fruit Weight/Plant (gm/m^2) of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Fruit Weight/Plant (gm/m^2)	FA+ Treatment (T/H)	Fruit Weight/Plant (gm/m^2)
Cont.	312.47	Cont.+	368.012
5	418.29	5+	433.7
10	426.3	10+	448.59
20	429.12	20+	458.63
40	419.85	40+	421.95
80	362.16	80+	384.33

FA: Flyash, T/H: Tones per hectare, DAS: Days after sowing
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 8: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on Root length of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Root length(cm)	FA+ Treatment (T/H)	Root length(cm)
Cont.	17.25 ± 1.8 NS(a)	Cont.+	21.3 ± 0.87 NS(b) NS(a)
5	22.11 ± 2.3 *(a)	5+	24.62 ± 1.8***(b) ***(a)
10	22.11 ± 0.92NS(a)	10+	33.52 ± 2.8 NS(b) ***(a+)
20	17.27 ± 1.7 NS(a)	20+	17.41 ± 0.38 NS(b) ***(a+)
40	15.69 ± 1.6 NS(a)	40+	17.25 ± 0.47 NS(b) ***(a+)
80	15.89 ± 1.1	80+	15.89 ± 0.40

Probability level:*p<0.05, **p<0.01, ***p<0.001 NS: Not significant, a: Significant test between flyash and control soil T/H: Tones per hectare, FA: Flyash, DAS: Days after sowing
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

Table 9: Effect of different concentrations of fly ash emended (without and with Azosprillum) on Plant Dry Weight of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Dry Weight/Plant (gm/m^2)	FA+ Treatment (T/H)	Dry Weight/Plant (gm/m^2)
Cont.	16.88±1.0 NS(a)	Cont.+	19.36±1.4 NS(b) *(a+)
5	20.79±1.7***(a)	5+	23.52±1.5 NS(b) **(a+)
10	25.27±1.5**(a)	10+	25.16±1.9 NS(b)NS(a+)
20	21.26 1.0 *(a)	20+	22.46±1.2 *(b) *(a+)
40	19.95±0.99 NS(a)	40+	23.09±0.98 *(b)NS(a+)
80	16.15±0.57	80+	18.55±0.63

Probability level:*p<0.05, **p<0.01, ***p<0.001 NS: Not significant, a: Significant test between flyash and control soil T/H: Tones per hectare, FA: Flyash, DAS: Days after sowing
a= Significant test between control and FA
a+= Significant test between control and FA+
b= Significant test between FA and FA+

FA amendment in soil caused a gradual increase in pH from 5.7 (control) to 6.6 (80 T/H FA), however addition of Azosprillum didn't show any significant effects on pH level. Similarly CEC changed from 3.67(Control) to 5.8 (10 T/H FA and FA+). The EC changed from 0.32 (control) to 0.47 (80 T/H FA) and 0.39(control) to 0.53(80

T/H FA+); Organic Carbon changed from 0.80(control) to 0.89 (80 T/H FA) and 0.84(control) to 0.90 (80 T/H FA+); Nitrogen Content changed to 0.080(control) to 0.089 (80 T/H FA) and 0.084 (control) to 0.090 (80 T/H FA+);Phosphate content changed to 70.02 (control) to 98.35 (80 T/H FA) and 84.53 (control) to 99.02 (80 T/H FA+); Potassium Content changed from 398 (control) to 697 (80 T/H FA) and 502 (control) to 540 (80 T/H FA+). Azosprillum supplemented flyash perform better in all soil properties. Results are presented in Table-10 to 16.

Table 10: pH of fly ash (without and with Azosprillum) amended on Tomato field

Cont. FA	5T/H	10T/H	20T/H	40T/H	80T/H
B.C.(5.6-5.7)	(5.6-5.7)	(5.6-5.7)	(5.6-5.7)	(5.6-5.7)	(5.6-5.7)
A.C.(5.7-5.8)	(5.7-5.8)	(5.8-6.1)	(6.0-6.2)	(6.2-6.6)	(6.2-6.6)
Cont+. FA+	**5+ T/H**	**10+ T/H**	**20+ T/H**	**40+ T/H**	**80+ T/H**
B.C.(5.8-5.9)	(5.8-5.9)	(5.8-5.9)	(5.8-5.9)	(5.8-5.9)	(5.8-5.9)
A.C.(5.8-5.9)	(5.9-6.0)	(6.0-6.2)	(6.1-6.3)	(6.2-6.4)	(6.3-6.7)

B.C.: Before cropping, A.C.: After cropping

Table 11: Cation exchange capacity of fly ash (without and with Azosprillum) amended on Tomato field

FA Treatment (T/H)	Cation exchange capacity	FA + Treatment (T/H)	Cation exchange capacity
Cont.	3.67	Cont.+	3.7
5	5.45	5+	5.55
10	5.8	10+	5.81
20	3.67	20+	4.81
40	3.14	40+	4.67
80	3.8	80+	4.21

FA: Flyash, T/H: Tones per hectare, DAS: Days after sowing

Table 12: Electrical Conductivity of fly ash (without and with Azosprillum) amended on Tomato field

Cont. FA	5T/H	10T/H	20T/H	40T/H	80 T/H
B.C.(0.28-0.32)	(0.28-0.32)	(0.28-0.32)	(0.28-0.32)	(0.28-0.32)	(0.28-0.32)
A.C.(0.35-0.38)	(0.35-0.38)	(0.39-0.40)	(0.40-0.42)	(0.38-0.46)	(0.41-0.47)
Cont+. FA+	**5+ T/H**	**10+ T/H**	**20+ T/H**	**40+ T/H**	**80+ T/H**
B.C.(0.34-0.39)	(0.34-0.39)	(0.34-0.39)	(0.34-0.39)	(0.34-0.39)	(0.34-0.39)
A.C. (0.36-0.40)	(0.40-0.42)	(0.39-0.41)	(0.42-0.48)	(0.44-0.49)	(0.47-0.53)

B.C.: Before cropping, A.C.: After cropping

Table 13: Organic Carbon content (lb/acre) of fly ash (without and with Azosprillum) amended Tomato field

Organic Carbon content (lb/acre)					
Cont.FA	**5T/H**	**10T/H**	**20T/H**	**40T/H**	**80 T/H**
B.C.(0.79-0.80)	(0.79-0.80)	(0.79-0.80)	(0.79-0.80)	(0.79-0.80)	(0.79-0.80)
A.C.(0.81-0.82)	(0.82-0.83)	(0.86-0.85)	(0.85-0.87)	(0.86-0.88)	(0.87-0.89)
Cont+.FA+	**5+ T/H**	**10+ T/H**	**20+ T/H**	**40+ T/H**	**80+ T/H**
B.C.(0.82-0.84)	(0.82-0.84)	(0.82-0.84)	(0.82-0.84)	(0.82-0.84)	(0.82-0.84)
A.C. (0.85-0.87)	(0.86-0.87)	(0.86-0.88)	(0.87-0.89)	(0.85-0.87)	(0.88-0.90)

B.C.: Before cropping, A.C.: After croppin

Table 14: Nitrogen content of fly ash (without and with Azosprillum) amended on Tomato field

Nitrogen content (lb/acre)					
Cont.FA	**5T/H**	**10T/H**	**20T/H**	**40T/H**	**80T/H**
B.C.(0.079-0.080)	(0.079-0.080)	(0.079-0.080)	(0.079-0.080)	(0.079-0.080)	(0.079-0.080)
A.C.(0.081-0.082)	(0.082-0.083)	(0.086-0.085)	(0.085-0.087)	(0.086-0.088)	(0.087-0.089)
Cont+.FA+	**5+ T/H**	**10+ T/H**	**20+ T/H**	**40+ T/H**	**80+ T/H**
B.C.(0.082-0.084)	(0.082-0.084)	(0.082-0.084)	(0.082-0.084)	(0.082-0.084)	(0.082-0.084)
A.C.(0.085-0.087)	(0.086-0.087)	(0.086-0.088)	(0.087-0.089)	(0.085-0.087)	(0.088-0.090)

B.C.: Before cropping, A.C.: After cropping

Table 15: Phosphate content of fly ash (without and with Azosprillum) amended on Tomato field

Phosphate content (lb/acre)					
Cont. FA	**5T/H**	**10T/H**	**20T/H**	**40T/H**	**80 T/H**
B.C.(63.83-70.02)	(63.83-70.02)	(63.83-70.02)	(63.83-70.02)	(63.83-70.02)	(63.83-70.02)
A.C.(83.95-84.62)	(89.7-90.98)	(89.88-91.63)	(90.98-92.89)	(97.05-98.08)	(97.55-98.35)
Cont+. FA+	**5+ T/H**	**10+ T/H**	**20+ T/H**	**40+ T/H**	**80+ T/H**
B.C.(82.52-84.53)	(82.52-84.53)	(82.52-84.53)	(82.52-84.53)	(82.52-84.53)	(82.52-84.53)
A.C.(83.12-86.49)	(86.35-87.15)	(89.70-90.80)	(96.60-98.20)	(96.35-98.40)	(97.42-99.02)

B.C.: Before cropping, A.C.: After cropping

Table 16: Effect Influence of FA on soil elemental (in ppm) status (without and with Azosprillum).

FA Treatment (T/H)	**Fe**		**Mn**		**Pb**		**Co**		**Na**		**K**		**P**	
	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+	FA	FA+
Cont.	650	600	18.8	12.4	2.8	2.0	1.4	1.0	1180	1200	3900	3600	45.5	45.5
5	720	703	45	36.0	8.8	8.0	3.2	2.4	1215	1005	4280	4600	36.9	45.5
10	686	662	42.4	25.8	5.4	5.2	1.8	1.6	1180	1215	6500	5890	46.0	68.2
20	795	722	31.6	19.8	5.8	4.4	1.6	1.0	900	950	7050	7700	50.3	90.9
40	811	692	20.8	15.6	1.8	1.6	1.2	0.8	850	1005	8290	8000	46.8	68.0
80	664	633	19.4	14.2	1.6	1.4	1.1	0.8	1050	1050	10150	9650	70.0	82.0

Table 17: Potassium content of flyash (without and with Azosprillum) amended on Tomato field

Potassium content (lb/acre)					
Cont. FA	**5T/H**	**10T/H**	**20T/H**	**40T/H**	**80 T/H**
B.C.(388-398)	(388-398)	(388-398)	(388-398)	(388-398)	(388-398)
A.C.(390-400)	(390-420)	(410-448)	(423-456)	(490-560)	(618-697)
Cont+. FA+	**5+ T/H**	**10+ T/H**	**20+ T/H**	**40+ T/H**	**80+ T/H**
B.C.(410-428)	(458-469)	(444-480)	(462-458)	(481-499)	(457-502)
A.C.(423-440)	(468-478)	(456-480)	(469-500)	(511-532)	(510-540)

B.C.: Before cropping, A.C.: After cropping

Table 18: Effect of different concentrations of fly ash emended soil (without and with Azosprillum) on heavy metal uptake of leaves of *Lycopersium esculentum* C.V. S-28

FA Treatment (T/H)	Heavy metal uptake (ppm)							
	Fe		Mn		Pb		Co	
	FA	FA+	FA	FA+	FA	FA+	FA	FA+
Cont.	650	600	18.8	12.4	2.8	2.0	1.4	1.0
5	720	703	45	36.0	8.8	8.0	3.2	2.4
10	686	662	42.4	25.8	5.4	5.2	1.8	1.6
20	795	722	31.6	19.8	5.8	4.4	1.6	1.0
40	811	692	20.8	15.6	1.8	1.6	1.2	0.8
80	664	633	19.4	14.2	1.6	1.4	1.1	0.8

FA: Flyash, T/H: Tones per hectare

The Fe contents of soil remain almost unchanged due to FA amendments. Microelements Mn, Pb, Co had progressively increased due to increasing FA amendment (Table-17). Azosprillum supplementations caused lowering of the concentrations in soils. Elemental analysis of *Lycopersicum esculantum* L. leaves revealed significant changes in different levels in different metals. Fe accumulates from 650 (Control) to 811ppm at 40 T/H FA; Mn accumulates from 18.80 (Control) to 45.0 ppm at 5 T/H FA; Pb accumulates from 2.80 (Control) to 8.8 ppm at 5 T/H FA; Co accumulates from 1.4 (Control) to 3.2ppm at 5 T/H FA due to FA amendments. Azosprillum supplementations caused an invariable decrease of each value. Surprisingly toxic elements accumulate at lower concentration of FA.

Field experiments, carried out with *Lycopersicum esculantum* L. grown in FA amendments, clearly indicated that growth of tomato crop was significantly increased by FA, particularly around 40 T/H FA for *Lycopersicum esculantum* L. Similarly results of growth enhancements by FA have been recorded for several crops, grown in other countries (Koracak, 1995; Allen *et al*., 1974). Ecological studies in effects of FA contaminating terrestrial and aquatic habitats have also been well documented (Twardowska, 1990; Mishuntinand and Shilinikova, 1971). Similarly increase in growth and yield of numerous crops and vegetables like *Medicago sativa, Hordeum vulgare, Zea mays, Sorghum bicolor,Echinochola crusgalli, Dacus carota, Allium cepa, Phaseolus vulgaris, Brassica oleracea* (Aggarwal *et al*., 2009; Siddiqui and Singh, 2005) have been observed by various researchers. The presence of essential plant nutrients such as K, Mg, S and micronutrients make FA a source of important plant nutrients which influences the plant growth (Muduli *et al*., 2014). All these reports recorded heavy metal pollutions due to FA and accumulations of such recalcitrant ions in all the crops observed. In addition to plant growth there are improvements of soil physical properties, EC, CEC due to FA amendment. Increase of EC values due to FA could suggest that the binding of metal ions occurred readily to soil particles, causing the eventual availability/ entry of metal nutrients to growing plants. Increase in growth and yield of *Lycopersicum esculantum* in FA amended soil was due to ready supply of some excess plant nutrients without any interference of the higher pH range to soil plant relationship, as exemplified by Calmano *et al*. (1993). Moreover, Calmona *et al*. (1993) had shown the binding forms of heavy metals (Zn, Pb, Cu and Cd) change significantly by periodic redox changes in a low-buffered sediment. Further, within limits of 10 T/H FA, an amendment of tropical tomato soil in the water logging condition should be a boon. This finding is encouraging for an agro-friendly disposal of this potential multiple pollutants in tomato cultivation and soil fertilization as well. Comparative increase in K, P and Fe contents in soil by FA was found to have additive effect on growth and yield of tomato.

The observed decline in yield at higher FA levels may be linked to metal toxicity caused by accumulation of Mn, Pb, Co, Fe in plant tissues as in other crops (Korcak, 1995). The toxic elements were in concentration of low level in the presently used FA level. In the present study reported heavy metal level in the leaves of tomato plant was not about threshold concentrations determined to that of crucifers (Davies, 1992).

Based on the data obtained it could be concluded that the soil amended at 20 to 40 T/H not only improved the physical properties of the soil but also contributed to the better growth and yield of tomato. Simultaneously contamination of heavy metal ions was found progressive with doses of FA remaining below the threshold levels. Azosprillum supplementations at the FA level used in soil had additive effects concerning all growth parameters and deductive effects on accumulation of toxic elements in soil and plant were recorded. Keeping in view of the heavy metal toxicity FA should be used with biological reagents for better yield and lesser toxicity.

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