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PHYSICO-CHEMICAL PROPERTIES OF BRICK KILN DUST AMENDED SOILS AND THEIR EFFECT ON *SOLANUM TUBEROSUM*

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ABSTRACT

The study was conducted to analyze the physico-chemical properties of various levels of brick kiln dust in soil application (0, 5, 10, 15, 20, 25, 30, 40 and 50%), before planting and after harvesting of potato (*Solanum tuberosum*) crop and to observe their impact on various parameters of potato plant. The pH, EC, CEC, WHC, pore space, sulphate, chloride, phosphorus, magnesium, zinc, manganese and boron increased at all the levels of brick kiln dust, while, nitrogen and potassium decreased at all the levels before planting of potato crop. After harvesting of potato crop all physico-chemical properties were still greater than control but less than pre-planting of potato, except P and Mg which decreased gradually upto 30%; and K as well as Mn upto 40%, and then they increased in subsequent levels. While N was recorded only in control and at 50% treatment. Application of brick kiln dust in soil from 5% to 40% was found beneficial for plant growth, yield, biomass, photosynthetic pigments, carbohydrate contents, and phosphorus and potassium concentrations of plants and the highest increase in above parameters was recorded at 25% level. At 50% level, there was marked reduction in all these parameters. However, nitrogen concentration of plants and protein content in tubers decreased gradually as levels of kiln dust were increased.

Key words: Amendment, brick kiln dust, potato.

INTRODUCTION

In India, particulate air pollutants *viz*. fly ash, cement dust, brick kiln dust, coal dust, soil dust and textile dust are major problem. These particulate materials are the result of uncontrolled mechanization of industries. Brick is a common construction material widely used all over the country. Generally, brick making industries are established near the agricultural lands in rural areas. For firing the bricks, wood and coal are used as fuel. Large number of brick industries are running throughout the country. In Aligarh district, about 250 brick kilns are in operation. In one round, about 6,00,000 bricks are prepared. The consumption of coal and wood is about 12-18 t for preparing 100,000 bricks (Upadhyay 2004). Complete combustion of fuel in brick kilns leads to the formation of fluoride, carbon dioxide, water molecules, oxides of nitrogen, sulphur dioxide, sulphur trioxide and large amount of brick kiln dust.

Particulates as brick kiln dust are dumped in pits or kept as stock piles. Particulate pollutants after moving far away from their source of origin fall and get deposited on the plant parts and soil surface. After settling and mixing with soil, they influence the growth and yield of crops (Heck *et al.* 1970). The beneficial effects of fly ash on biomass and other plant growth parameters have been noticed in onion, potato and garlic (Khan *et al.* 2006), soybean and maize (Mishra and Shukla, 1986), mustard (Upadhyay *et al.* 2008). Recently Rizvi and Khan (2009) observed improvement in plant growth and yield of eggplant when fly ash and brick kiln dust were applied to soil at 20% and 30% levels, respectively. The particulates actually change the physico-chemical properties of soil. Recently use of some particulates as a fertilizer has been advocated by some workers (Mishra and Shukla 1986, Khan 1989, Wong and Wong 1989, Khan and Singh 1996, Raghav and Khan 2002). Therefore, potato was evaluated against different levels of brick kiln dust as soil application.

MATERIALS AND METHODS

Application of brick kiln dust with soil

For the experiment, brick kiln dust was obtained from the brick kiln situated at Manzoor Garhi, Aligarh. Soil was collected from agricultural fields up to 20 cm depth after scrapping of the surface litters present, if any. The soil was sandy loam. It was autoclaved before incorporation.

The brick kiln dust was mixed with soil in the following proportions.

Control = 0 g brick kiln dust + 3000 g soil
5% = 150 g brick kiln dust + 2850 g soil
10% = 300 g brick kiln dust + 2700 g soil
15% = 450 g brick kiln dust + 2550 g soil
20% = 600 g brick kiln dust + 2400 g soil
25% = 750 g brick kiln dust + 2250 g soil
30% = 900 g brick kiln dust + 2100 g soil
40% = 1200 g brick kiln dust + 1800 g soil
50% = 1500 g brick kiln dust + 1500 g soil

After proper mixing, clay pots of 30 cm height (25 cm diameter) closed at bottom were filled with 3 kg of each type of mixture. Each treatment was replicated five times. Total 45 pots including control set were prepared for the experiments (9 treatments × 5 replicates). Analysis of soil from each treatment was done before planting and after harvesting of potato following the standard methods. The physico- chemical parameters: water holding capacity (WHC), pore space, sulphate, chloride, magnesium, zinc, manganese and boron were determined by the standard methods (Gupta 2002), nitrogen as described by Subbiah and Asija (1956), phosphorus by Olsen *et al.* (1956) and potassium by Flame photometer; while pH, EC (Electrical conductivity), CEC (Cation exchange capacity) by Conductivity meter. The characteristics of soil, brick kiln dust and tap water used in the experiment are given in Table 1.

Table 1. Characteristics of soil, brick kiln dust and tap water (values are mean, n = 5)**.**

Parameter		Soil	Brick kiln dust	Tap water
pH		6.79	9.5	7.2
Electrical conductivity	(mmhos cm^{-1})	0.05	0.180	
Cation exchange capacity	(mEq/ 100g)	3.00	7.10	
Water holding capacity	(%)	42	90	
Pore space	(%)	40.12	80.7	
Sulphate	(mg/l)	15	27.3	6.0
Chloride	(mg/l)	49	85	22
Nitrogen	(mg/kg)	95.0	65.0	
Phosphorus	(mg/kg)	11.5	18.5	0.13 (mg/l)
Potassium	(mg/kg)	51.7	35.4	5.75 (mg/l)
Magnesium	(mg/kg)	37.0	41.2	5.12 (mg/l)
Zinc	(mg/kg)	1.5	2.3	
Manganese	(mg/kg)	5.7	5.9	
Boron	(mg/kg)	0.47	1.5	

Plant culture and setting of experiment

Potato (*Solanum tuberosum* L.) var. Kufri Alankar, commonly grown in India, was selected as test crop. Small square pieces (size 2.5-3.0 cm^2) of potato tubers were cut in such a way that each piece had at least one eye. The pieces were surface sterilized (dipped in 0.01% $HgCl_2$ for 15 min) before planting. A small pit (5 cm deep) was made in the centre of each pot already prepared with different concentrations of brick kiln dust amended soil. One potato piece was placed into the pit of each pot in such a way that eye was always towards upper side. Pots were arranged in randomized block design on glasshouse benches at 27/23°C day/night temperature. Photosynthetic active radiation was PAR>750 μmol m^{-2} s^{-1} between 1100 and 1200 h, and humidity in the green house was 67±5%. Pots were irrigated on alternate days with limited amount (200-250 ml) of tap water just to moist the soil and surface flow was avoided. Approximately 10-12 l of water per pot was used till the harvesting of plant. Plants were uprooted carefully after 90 days. Roots and potato tubers were thoroughly washed under tap water to avoid soil particles and debris. Plant growth and yield were determined. The photosynthetic pigments, NPK concentrations of plants, protein and carbohydrate contents of potato were estimated through standard methods presented by Mac Lachan and Zalik (1963), Gupta (2002), Lowery *et al.* (1951) and Yih (1965), respectively. Data were analyzed statistically for significance.

RESULTS

Physico-chemical properties of amended soils before planting

Data comprised in Table 2 show that there was a significant ($p<0.05$ and $p<0.01$) and gradual increase in pH, EC, CEC, WHC and pore space with increase in the level of brick kiln dust in soil. Five percent treatment, however, these were non-significant either at $p<0.05$ or $p<0.01$ level. Sulphate and chloride were increased significantly ($p<0.05$ and $p<0.01$) with the increase in the levels, except at 5% treatment, where these parameters were at par with control.

In NPK concentrations, N and K were decreased gradually and significantly with the increment in the levels, except at 5% level of brick kiln dust, where K was non-significant. However, P increased significantly as compared to control, except at 5 and 10% treatments (Table 2).

Mg, Zn and B increased significantly ($p<0.05$ and $p<0.01$) with the increasing level of brick kiln dust, except Mg at 5% level and Zn from 5 to 15% treatments, where these parameters were similar to control. However, the increase in Mn was significant (Table 2).

Physico-chemical properties of amended soils after harvesting

Data summarized in Table 3 shows that there was gradual and significant increment in pH, EC, CEC, WHC and pore space with the increase in brick kiln dust level, except EC, CEC and WHC which were non-significant ($p<0.01$) at 5% treatment. This table also shows that there was gradual and significant increase in sulphate and chloride contents in all the levels except at 5% treatment, where these were non-significant.

In NPK concentrations, N was recorded only in control (1.5 mg/kg) and at 50% level (3.5 mg/kg). However, P and K were first decreased significantly upto 25% level and then increased slowly in subsequent levels, except K at 5% treatment (Table 3).

Similarly, Mg and Mn were also decreased gradually upto 25% level then increased gradually in subsequent levels. The increase were non-significant at 5, 10, 30 and 40% levels for Mg; and at 5 and 40% for Mn. However, Zn and B increased significantly at all the treatments when compared to control, except Zn which was non-significant at 5, 10 and 15% levels, while B at 5% level (Table 3).

Table 2. **Physico-chemical properties of brick kiln dust amended soil before planting of *S. tuberosum* var. Kufri Alankar (**values are mean, n = 5**).**

Treatment (%)	pH	Electrical conductivity (mmhos cm^{-1})	Cation exchange capacity (mEq/100 g)	Water holding capacity (%)	Pore space (%)	Sulphate content (mg/l)	Chloride content (mg/l)
0	6.79	0.050	3.00	42.00	40.12	15.0	49.0
5	6.92	0.053	3.20	43.12	43.60	15.4	49.8
10	7.11	0.057	3.46	47.01	46.12	16.0	51.3
15	7.31	0.061	3.71	50.10	49.47	16.5	53.3
20	7.52	0.065	3.95	53.21	52.50	17.2	55.1
25	7.75	0.070	4.24	57.60	55.31	17.8	57.0
30	7.96	0.075	4.50	60.27	57.73	18.5	59.1
40	8.25	0.084	5.00	64.50	60.28	19.7	62.2
50	8.67	0.095	5.52	68.25	63.75	20.8	65.7
LSD (P<0.05)	0.134	0.003	0.157	2.349	2.761	0.35	0.75
LSD (P<0.01)	0.181	0.005	0.212	3.167	3.721	0.47	1.01
Treatment (%)	**Nitrogen (mg/kg)**	**Phosphorus (mg/kg)**	**Potassium (mg/kg)**	**Magnesium (mg/kg)**	**Zinc (mg/kg)**	**Manganese (mg/kg)**	**Boron (mg/kg)**
0	95	11.5	51.7	37.0	1.50	5.70	0.47
5	93	11.6	50.7	37.1	1.52	5.65	0.50
10	91	12.0	50.0	37.3	1.59	5.67	0.56
15	89	12.3	49.1	37.5	1.60	5.71	0.61
20	88	12.7	48.3	37.7	1.65	5.72	0.65
25	87	13.0	47.5	38.0	1.68	5.73	0.71
30	85	13.4	46.7	38.1	1.73	5.74	0.76
40	82	14.3	45.0	38.5	1.80	5.75	0.85
50	79	15.0	43.4	39.0	1.91	5.77	0.96
LSD (P<0.05)	1.4	0.53	0.97	0.17	0.075	0.251	0.021
LSD (P<0.01)	1.9	0.71	1.31	0.23	0.101	0.338	0.028

Plant growth and yield

Data presented in Table 4 reveal that potato crop showed variable growth responses to different levels of brick kiln dust in soil. At 25% level treatment, plant growth in terms of length, fresh wt and dry wt of root and shoot was much better than other levels, however, a significant increase ($p<0.05$ and $p<0.01$) in growth parameters was observed from 10% to 30% levels of treatment. At 50% level, there were marked reductions in all these parameters. Highest increase in length, fresh wt and dry wt of shoot and root were recorded at 25% level.

The yield in terms of tuber fresh weight and tuber dry weight was also affected by soil application of brick kiln dust. The significant increase ($p<0.05$ and $p<0.01$) in these parameters was observed from 10 to 30% levels. Highest increase in tuber fresh weight and tuber dry weight was recorded at 25% level. At 50% level, these parameters decreased significantly. Similar result was also observed for biomass.

Photosynthetic pigments and NPK

Table 5 shows that photosynthetic pigments of leaves gradually increased with the increase in the levels of treatment. Significant increase in chlorophyll a, chlorophyll b, total chlorophyll and carotenoids was recorded from 10 to 30% levels, highest being at 25% level. At 50% level, there was marked reduction in chlorophyll b and total chlorophyll as compared to control.

In NPK concentrations of plants, N was gradually decreased ($p<0.05$ and $p<0.01$) with respect to the increasing levels, however, at 5% level it was non-significant as compared to control. P and K were significantly increased ($p<0.05$ and $p<0.01$) from 10 to 30% levels, highest being at 25% level. At 50% level, these parameters were significantly reduced as compared to control (Table 5).

Protein and carbohydrate

Table 6 shows that soluble, insoluble and total protein were decreased gradually as the levels of brick kiln dust were increased. Highest reduction in these parameters was recorded in the range between 15 to 50% application. However, soluble, insoluble and total carbohydrate were increased significantly from 15 to 30% levels, highest being at 25% level. In rest of the treatments all these parameters were non-significant as compared to control.

Table 3. Physico-chemical properties of brick kiln dust amended soil after harvesting of *S. tuberosum* var. Kufri Alankar (values are mean, n = 5**).**

Treatment (%)	pH	Electrical conductivity (mmhos cm^{-1})	Cation exchange capacity (mEq/100 g)	Water holding capacity (%)	Pore space (%)	Sulphate content (mg/l)	Chloride content (mg/l)
0	7.20	0.027	1.61	39.00	20.21	22.7	119.5
5	7.43	0.032	1.72	41.12	23.75	22.0	121.1
10	7.65	0.037	1.84	43.46	26.81	21.2	122.7
15	7.86	0.042	1.95	45.75	30.02	20.7	124.6
20	8.07	0.048	2.12	48.36	34.55	20.5	126.4
25	8.24	0.052	2.32	51.12	38.87	19.9	128.1
30	8.49	0.057	2.55	54.20	42.30	21.7	130.3
40	8.72	0.064	2.77	57.25	47.16	26.1	133.5
50	8.95	0.071	3.05	60.45	52.29	31.0	137.2
LSD (P<0.05)	0.152	0.004	0.093	2.052	2.295	0.67	1.27
LSD (P<0.01)	0.203	0.006	0.125	2.766	3.093	0.90	1.71

Treatment (%)	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Magnesium (mg/kg)	Zinc (mg/kg)	Manganese (mg/kg)	Boron (mg/kg)
0	1.5	6.6	27.5	49.5	1.27	5.12	0.31
5	-	6.1	26.1	48.6	1.28	5.00	0.33
10	-	5.8	20.2	48.4	1.29	4.95	0.36
15	-	5.6	16.5	48.2	1.30	4.91	0.39
20	-	5.5	13.0	48.0	1.32	4.85	0.43
25	-	5.3	8.1	47.3	1.33	4.56	0.47
30	-	6.2	11.0	48.6	1.40	4.87	0.54
40	-	8.7	22.5	50.2	1.55	5.10	0.69
50	3.5	11.0	32.2	52.1	1.70	5.29	0.84
LSD (P<0.05)	-	0.11	1.31	0.89	0.026	0.092	0.032
LSD (P<0.01)	-	0.15	1.77	1.19	0.035	0.124	0.043

Table 4. Effect of different levels of brick kiln dust as soil application on plant growth and yield of *S.tuberosum* var. Kufri Alankar (values are mean, n = 5).

Treatment (%)	Plant growth						*Yield*		Plant biomass (g)
	Length (cm)		Fresh wt. (g)		Dry wt. (g)		Tuber fresh wt. (g)	Tuber dry wt. (g)	
	Root	Shoot	Root	Shoot	Root	Shoot			
0	20.92	29.35	5.95	34.51	0.75	4.31	104.23	17.38	22.44
5	23.07	32.34	6.72	39.38	0.83	4.98	116.21	20.05	25.86
10	25.16	35.12	7.42	45.09	0.94	5.57	129.09	22.26	28.77
15	27.85	38.12	8.35	50.21	1.03	6.28	142.02	23.68	30.99
20	31.34	41.17	9.00	55.26	1.15	6.74	151.90	24.91	32.80
25	34.21	44.06	9.75	60.66	1.19	7.49	165.07	26.63	35.31
30	29.61	37.47	8.35	54.25	1.03	6.87	149.75	24.97	32.87
40	21.15	31.65	6.00	35.61	0.77	4.52	118.25	20.05	25.34
50	17.30	24.19	4.82	28.35	0.60	3.49	82.41	14.22	18.31
LSD (P<0.05)	2.524	3.612	0.925	5.635	0.094	0.726	14.921	3.134	3.576
LSD (P<0.01)	3.402	4.869	1.247	7.596	0.127	0.979	20.114	4.225	4.821

Table 5. Effect of different levels of brick kiln dust as soil application on photosynthetic pigments and NPK uptake of *S.tuberosum* var. Kufri Alankar (values are mean, n = 5).

Treatment (%)	Photosynthetic pigments (per g fresh weight)				NPK amount by plant (dry weight)		
	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)	Carotenoids (mg/g)	Nitrogen (mg/plant)	Phosphorus (mg/plant)	Potassium (mg/plant)
0	0.79	0.37	1.16	0.0042	280	15.7	127
5	0.83	0.41	1.24	0.0044	278	18.0	130
10	0.88	0.45	1.33	0.0047	272	20.1	146
15	0.91	0.48	1.39	0.0049	266	21.6	154
20	0.95	0.57	1.52	0.0052	263	22.8	163
25	1.03	0.61	1.64	0.0055	260	24.6	175
30	0.96	0.53	1.49	0.0050	254	22.9	164
40	0.83	0.40	1.23	0.0044	245	17.5	125
50	0.75	0.26	1.01	0.0041	227	12.7	91
LSD (P<0.05)	0.064	0.041	0.110	0.0003	5.4	2.12	4.5
LSD (P<0.01)	0.086	0.055	0.148	0.0004	7.3	2.86	6.1

Table 6. Effect of different levels of brick kiln dust as soil application on protein and carbohydrate contents of *S. tuberosum* var. Kufri Alankar (values are mean, n = 5).

Treatment (%)	Protein content			Carbohydrate content		
	Soluble protein (%)	Insoluble protein (%)	Total protein (%)	Soluble carbohydrate (%)	Insoluble carbohydrate (%)	Total carbohydrate (%)
0	2.57	5.05	7.62	7.15	10.37	17.52
5	2.31	4.34	6.65	7.41	10.61	18.02
10	2.01	3.86	5.87	7.63	10.94	18.57
15	1.85	3.46	5.31	8.09	11.23	19.32
20	1.73	3.21	4.94	8.47	11.51	19.98
25	1.62	2.95	4.57	8.81	11.85	20.66
30	1.67	2.98	4.65	8.00	11.33	19.33
40	1.72	3.22	4.94	7.37	10.62	17.99
50	1.86	3.46	5.32	6.91	9.89	16.80
LSD (P<0.05)	0.351	0.752	1.022	0.352	0.424	0.753
LSD (P<0.01)	0.473	1.013	1.377	0.475	0.572	1.015

DISCUSSION

Brick kiln dust is a second major particulate air pollutant after fly ash in India (Upadhyay 2004). It contains mixture of ashes (coal + wood) and dust particles (soil + sand). The pH, EC, CEC, WHC and pore space were increased gradually with respect to brick kiln dust level in soil. Because the elements present in ashes enriched the soils, and dust particles increased the pore spaces, as dust contains mostly sand particles, which are used during the preparation of raw bricks and are detached during combustion. Upadhyay (2004) has also observed the similar results in these parameters of brick kiln dust. The increment in the elemental composition, due to the ashes of coal and wood has also been observed by Upadhyay (2004) and Upadhyay *et al.* (2008).

After harvesting of *S. tuberosum*, all the physico-chemical properties of brick kiln dust amended soil were less in respective parameters as compared to before planting, except pH, sulphate, chloride and magnesium because their concentration were greater than before planting. The increment in these parameters was due to addition of water (irrigation), which contains all theses elements. Concentration of nitrogen was nil in all the levels of amended soil, except at 50% level and in control. The reductions in the concentrations of the elements were due to the absorption of these elements by potato. When concentrations of elements in the available form were calculated, it was observed that the sum of amount before planting and amount present in water were equal to the sum of amount after harvesting + amount taken up by plants. These results also collaborate with Upadhyay (2004).

In the soil application of brick kiln dust, the length, fresh and dry weights of root and shoot, fresh and dry weights of tubers, plant biomass, photosynthetic pigments, P and K concentrations of plants and carbohydrate contents of potato tubers were increased upto 40% brick kiln dust levels, however, all parameters were highest at 25% level. While, Raghav and Khan (2002) observed that 15% level of brick kiln dust was best for tomato plant. Upadhyay (2004) reported that the growth of *Brassica juncea* and *Linum usitatissimum* were best at 45% level of brick kiln dust. These studies indicate that different plant species require the macro and micro nutrients at a particular limit, beyond that the elements become harmful. This may be due to their different genetic make-up. Addition of brick kiln dust increased the physico-chemical properties, which had favourable effect on plants. Elseewi *et al.* (1981) suggested that EC is positively correlated with pH that affects the concentration of soluble cations and anions, which are available to plants at certain level. The physical and chemical properties of brick kiln dust at 25% level were found best for increasing the plant growth, yield, photosynthetic pigments, biomass and carbohydrate contents of potato in the present study.

After 25% level, the above parameters declined gradually with respect to levels. This might be due to more absorption of elements, which acted, as phytotoxic in subsequent levels. Gradual decline in plant growth, yield and other parameters was also attributed probably to increased alkalinity and salinity, caused by higher levels of sulphate and chloride in amended soils. Possibly higher amount of Mn, Zn and B became phytotoxic to potato crop. Similar trends in reduction at higher levels have also been observed in *B. juncea* and *L. usitatissimum* by Upadhyay (2004). Brick kiln dust also caused deficiency of nitrogen in soils. Deficiency of nitrogen at higher level of dust application might have adversely affected the protein content, because it is a component of protein synthesis (Devlin and Witham 2000).

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