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Effects of Coke on Soil and Seedling Growth of different *Vigna* species (Fabaceae)

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Coke production is one of the important source of pollution from steel industries. This paper describes the effects of coke treatment on soil and seedling growth performance of three different Vigna species viz. *Vigna radiata, Vigna mungo* and *Vigna unguiculata*. A statistically significant $p<0.05$ effects of coke treatment at 20% affected seedling and root length *V. radiata* as compared to control. The coke treatment gradually decreased root, seedling length, leaf area, leaf dry weight, root dry weight, specific leaf area and leaf area ratio of *V. mungo* as compared to control. The treatment of coke at higher concentration significantly ($p<0.05$) decreased shoot length, shoot, total seedling dry weight, root / shoot ratio and leaf weight ratio as compared to control. The coke treatment at 20, 60 and 80% had a stimulating effect on root length of *V. unguiculata* as compared to control. An increase in coke concentration treatment at 20-80% significantly ($p<0.05$) decreased leaf and root dry weight of *V. unguiculata* as compared to control. The seedling tolerance index for *V. unguiculata* (111.71%), *V. radiata* (105.35%) and *V. mungo* (80.36%) with the increase in concentration of coke at 80% was recorded. A pronounced variation in garden and coke treated soil characteristics was recorded. Soil pH was significantly ($p<0.05$) increased in coke treated soil (9.82, 9.79, 9.72 and 9.69). Electrical conductivity significantly increased in 80%. Water content significantly increases in 20% (11.56%) as compared to control (0.39). Bulk density showed significant decline towards higher concentration. Water holding capacity significantly increased from 40 to 80% (36.42%), (39.48%) and (47.30%) as compared to control (26.96%). Organic matter and chloride significantly increased from 20% to 80% coke treated soil. Calcium carbonate significantly reduced in 80% coke treated soil. Exchangeable potassium and sodium showed no significant differences among treatment.

Keywords: Coke, Eco toxicity, seedling vigor index, tolerance, Vigna spp

INTRODUCTION

Naturally found coal is converted to coke (Ghose, 2002) for metallurgies industries. Significant quantities of sludge and slag are generated as byproduct from steel industries. The considerable quantities of metals from steel industries released (Das et al., 2007) in the environment. Steel is one of the most utilized and recycled materials within the global economy (Zhang et al., 2009). The iron and steel industry has generated significant amounts of hazardous waste and has emitted vast quantities of toxic pollutants into the atmosphere. Metal dusts, slag, carbon monoxide, nitrogen oxides, and ozone are examples of substances generated during the steel making process and coke oven emissions contain harmful substances like polycyclic aromatic hydrocarbons, volatile organic compounds, benzene, particulate matter, and dioxins (Rosenfeld and Feng, 2011).

The production of coke is an integral component of the steel manufacturing process (Walsh and Thornley, 2012). Industrial activities, including iron steel metallurgy, are major source of atmospheric heavy metals emissions like copper (Cu), zinc (Zn), nickel (Ni), lead (Pb), chromium (Cr) and cadmium (Cd) (Boloniaz and Bulinski, 1984; Gritsan and Babiy, 2000; Kaminski and Landsberger, 2000; Adamo et al., 2002; Salemaa et al., 2001; Venditti et al., 2000). These toxic airborne metals settle on soil surfaces and vegetation canopies (Kadem, et al., 2004) can affect plant growth and physical and chemical properties of soil. The effects of coke emission on the physiological response to plants growth and human health observed (Prasad and Rao, 1981; Charles et al, 2011; Nakata et al., 2011; Zhai et al., 2012; Liu et al., 2014).

The coke productions play an important role in steel industries. Coke release high concentration of toxic pollutants in the environment and can inhibit or decrease the germination and growth of plants. Many researchers have drawn their attention on the effects of coke on plant growth. Therefore, the objective of this study was to investigate the effects of coke on seed germination and seedling growth of plant by using the different concentrations of coke and compared it with control.

MATERIALS AND METHODS

The coke sample was collected from Pakistan Steel Mill, Karachi, Pakistan. Pakistan steel mill is one of the enormous and gigantically expanded industrial complex in the country that is located at a distance of 40 km Southeast of Karachi at Bin Qasim near Port Muhammad Bin Qasim. It is one of the largest industrial complex in Pakistan as well as in South Asia.

The composition of coke is:

High Fixed Carbon (80-85%)

Low Ash (10-15% ash)

Low Volatile Matter (2% maximum)

Low Phosphorous (0.3% maximum)

The seeds of *Vigna radiata* L. Wilezek, *Vigna mungo* L. Hepper and *Vigna unguiculata* L. Walp) were obtained locally. The uniform sized and healthy seeds were imbibed in water for half an hour to break the dormancy of seed. 10 g coke was added in 100 ml distilled water and that mixture was kept for 24 hours and then filtered. This filtered solution was assumed to be the standard solution which was 100%. From this standard solution further dilution 20%, 40%, 60% and 80% were made in distilled water. The garden soil was sieved wit 2 mm sieve. The fraction of garden soil was one part manure and two parts find sand. The seeds of all the three species were sown in medium sized clay pots with two parts find sand and one part manure. When the seedling reached a suitable height only one seedling was transferred to each pot of 7 cm in diameter and 9.6 cm in depth. The pots containing treated soil and the treatments were 20, 40, 60 and 80%. Garden soil was used as control with each treatment has five replicates. The pots were placed in green house at the department of Botany, University of Karachi. The atmospheric temperature was 22-35ºC and relative humidity was 41-48% during the whole period of experiments. All the pots were watered daily with tap water. Every week, reshuffling of pots was also done to avoid light, shade or any other climatic effects. Experiment was completely randomized and lasted seven weeks. After seven weeks, all the plants were carefully removed from the pots. Growth parameter in terms of root, shoot and seedling length was measured. Root, shoot and leaves were separated for drying in an oven at 80º C. The seedlings were dried in an oven at 80° C for 24 hours until the seedlings were completely oven dried. Seedling tolerance indices were also determined according to Iqbal and Rehmati (1992).

Root / shoot ratio, Leaf weight ratio, Specific leaf area (cm^2g^{-1}) and Leaf area ratio (cm^2g^{-1}) was determined by the following formulae.

Root / shoot ratio = Root dry weight / shoot dry weight

Leaf weight ratio = Leaf dry weight / Total plant dry weight

Specific leaf area (cm^2g^{-1}) = leaf area/ leaf dry weight

Leaf area ratio (cm^2g^{-1}) = leaf area/ total plant dry weight

Soil analysis

Soil was collected after harvesting from each pot containing coke treated and garden soil. Soil samples were air dried, and passed through a 2.0 mm sieve and kept in the laboratory.

Physical analysis of soil:

Maximum water holding capacity (M.W.H.C.) of soil was calculated by the method of Keen (1931). Bulk density of soil was determined in g/cc according to Birkeland (1984).

Water content

Water content was evaluated by the following formulae.

$$\text{Water content} = \frac{\text{Weight of soil} - \text{Weight of oven dried soil}}{\text{Weight of oven dried soil}} \times 100$$

Chemical analysis of soil:
5 g soil was dissolved in 50 ml distilled water; shake highly for half an hour and then filter. Soil pH was recorded by direct pH reading meter (AD 1000 pH/mv and temperature meter). Soil electrical conductivity (E.C. ms cm^{-1}) was determined by 4510 conductivity reading meter. Calcium carbonate percentage was determined by a method of acid neutralization (Qadir, et al., 1966). Chlorides (meq L^{-1}) were evaluated through Mohr's titration method. Soil organic matter (%) was done according to Jackson (1958). Exchangeable sodium and potassium in soil was determined according to Richards (1954).

Statistical analysis
The data collected from various growth indices were statistically analyzed by standard statistical technique on personal computer. Experimental data were analyzed by using statistical analysis software COSTAT version 3.03 on personnel computer. All the data was statistically analysed by ANOVA. Duncan's Multiple Range Test was used where appropriate for mean separations at $p<0.05$ probability level.

RESULTS
The effects of different concentration (0, 20, 40, 60 and 80%) of coke on seedling growth of three different bean crops (green gram, cow pea and Urd bean) were observed (Table 1-2, Fig. 1). The result of the present studies showed difference in seedling growth and biomass production of three different Vigna species (Fabaceae) viz. *Vigna radiata, Vigna mungo* and *Vigna unguiculata* (Table 1). The significant $p<0.05$ effects of coke treatment at 40% affected seedling length of *V. radiata* as compared to control. The coke treatment did not produce any significant effect on root, shoot, leaf area, leaf, shoot, root, total seedling dry weight, root / shoot ratio, leaf weight ratio, specific leaf area and leaf area ratio of *V. radiata* as compared to control. Seedling height, shoot length and leaf area of *V. radiata* did not show any significant change when treated with different concentration of coke as compared to control. Coke treatment at 20% significantly ($p<0.05$) increased root length (18.50 cm) of *V. radiata* as compared to control (15.70 cm). Coke treatment at 20 and 40% showed gradual increase in seedling length 43.50 cm and 50.84 cm of *V. radiata* as compared to control (39.14 cm). The coke treatment at 20, 40, 60, and 80% showed sign of phytotoxicity with the decrease in leaf dry weight 0.072, 0.066, 0.058, and 0.056 g as compared to control 0.074 g, respectively. Coke treatment at all level showed changes in shoot and seedling length and seedling dry weight of *V. radiata* as compared to control. Similar to shoot dry weight, root/shoot ratio, specific leaf area and leaf area ratio was low as compared to control.

The coke treatment gradually decreased root, seedling length, leaf area, leaf dry weight, root dry weight, specific leaf area and leaf area ratio of *V. mungo* as compared to control. The treatment of coke at high concentration significantly ($p<0.05$) decreased shoot length, shoot dry weight, total seedling dry weight, root / shoot ratio and leaf weight ratio as compared to control. A pronounced significant ($p<0.05$) effects on shoot length of *V. mungo* was found in response to different concentration (20, 40, 60, 80%) of coke treatment as compared to control. There was decreased in root, shoot and seedling length of *V. mungo* with increasing level of coke treatment. Leaf area of *V. mungo* was decreased 4.48, 4.16, 3.89 and 3.63 cm^2 by coke treatment 20, 40, 60, 80%, respectively as compared to control (5.14 cm^2). Coke extract treatment at all concentration showed significant ($p<0.05$) effects on shoot and total seedling dry weight as compared to control. Leaf weight ratio of *V. mungo* was found significantly ($p<0.05$) decreased 0.42, 0.45, 0.37 with coke treatment at 20, 60 and 80% respectively, as compared to control (0.49).

The coke treatment at 20% significantly decreased leaf dry weight of *V. unguiculata* as compared to control treatment. However, coke treatment at 20, 60 and 80% had a stimulating effect on root length of *V. unguiculata* as compared to control. Coke treatment decreased shoot, seedling growth, leaf area, shoot dry weight, total plant dry weight, leaf weight ratio and leaf area ratio of *V. unguiculata* as compared to control. An increase in coke concentration at 20-80% significantly ($p<0.05$) decreased leaf and root dry weight of *V. unguiculata* as compared to control. Results indicated a decreasing trend in shoot and seedling length of *V. unguiculata* when treated with 20, 40, 60 and 80% of coke treatment as compared with control. It was found that the coke treatment gradually decreased leaf area of *V. unguiculata* as compared to control.

Table 1. Effects of different concentration (0, 20, 40, 60 and 80%) of coke on growth of *Vigna radiata Vigna mungo and Vigna unguiculata*

	Coke concentration (%)				
Growth parameter	**0**	**20**	**40**	**60**	**80**
Root length (cm)	^{VR}15.70a±2.42 ^{VM}16.30a±2.56 ^{VU}16.56a±2.48	^{VR}18.50ab±1.92 ^{VM} 15.84a±1.53 ^{VU}22.30a±2.57	^{VR} 24.32b±1.98 ^{VM}13.66a±2.09 ^{VU}15.30a±2.49	^{VR} 17.10a± 2.47 ^{VM}20.62a± 2.90 ^{VU}18.14a± 2.28	^{VR}16.54a±1.82 ^{VM} 13.10a±3.06 ^{VM} 18.50a±2.74
Shoot length (cm)	^{VR}23.44a±0.69 ^{VM}23.70b±0.96 ^{VU}27.06a±1.05	^{VR} 25.00a±1.55 ^{VM} 23.30b±0.77 ^{VU}23.04a±3.30	^{VR}26.50a±1.49 ^{VM} 21.34ab±0.90 ^{VU}26.60a±1.86	^{VR}25.60a±1.13 ^{VM} 19.26a±1.84 ^{VU}23.80a±2.0	^{VR}24.60a±0.85 ^{VM} 20.70ab±0.48 ^{VU}25.10a±0.92
Seedling length (cm)	^{VR}39.14a± 2.13 ^{VM}39.96a± 2.19 ^{VU}43.62a± 2.37	^{VR}43.50a± 1.82 ^{VM}39.14a± 1.49 ^{VU}45.34a± 1.96	^{VR}50.84a± 0.82 ^{VM}35.00a± 2.71 ^{VU}41.90a± 2.96	^{VR}42.70a± 3.31 ^{VM}39.88a± 2.83 ^{VU}41.94a± 3.83	^{VR}41.14a±0.85 ^{VM}33.80a±3.14 ^{VU}43.60a±2.50
Leaf area (cm^2)	^{VR}6.21a± 0.66 ^{VM}5.14a± 0.79 ^{VU}8.62a± 1.10	^{VR}6.74a± 0.59 ^{VM}4.48a± 0.55 ^{VU}6.72a± 1.46	^{VR}8.27a± 1.47 ^{VM}4.16a± 0.27 ^{VU}8.82a± 1.12	^{VR}6.60a± 0.74 ^{VM}3.89a± 0.35 ^{VU}7.18a± 1.13	^{VR}6.12a± 0.40 ^{VM}3.63a± 0.47 ^{VU}5.81a± 1.05
Leaf dry weight (g)	^{VR}0.074a± 0.01 ^{VM}0.068a± 0.00 ^{VU}0.148ab± 0.01	^{VR}0.072a± 0.01 ^{VM}0.056a± 0.01 ^{VU}0.154b± 0.03	^{VR}0.066a± 0.01 ^{VM}0.066a± 0.01 ^{VU}0.128ab± 0.01	^{VR}0.058a± 0.01 ^{VM}0.044a± 0.00 ^{VU}0.110ab± 0.01	^{VR}0.056a± 0.01 ^{VM}0.036a± 0.01 ^{VU}0.086a± 0.01
Shoot dry weight (g)	^{VR}0.070a± 0.01 ^{VM}0.056c± 0.00 ^{VU}0.116a± 0.02	^{VR}0.074a± 0.00 ^{VM}0.050bc± 0.00 ^{VU}0.112a± 0.02	^{VR}0.078ab± 0.01 ^{VM}0.034ab± 0.00 ^{VU}0.144a± 0.01	^{VR}0.070ab± 0.01 ^{VM}0.042abc± 0.01 ^{VU}0.120a± 0.02	^{VR}0.078a± 0.01 ^{VM}0.028a± 0.0 ^{VU}0.086a± 0.00
Root dry weight (g)	^{VR}0.020a± 0.0 ^{VM}0.012a± 0.00 ^{VU}0.050ab± 0.01	^{VR}0.020a± 0.0 ^{VM}0.020a± 0.00 ^{VU}0.070b± 0.01	^{VR}0.028a± 0.0 ^{VM}0.014a± 0.00 ^{VU}0.048ab± 0.0	^{VR}0.026a± 0.00 ^{VM}0.012a± 0.00 ^{VU}0.046ab± 0.01	^{VR}0.026a± 0.00 ^{VM}0.020a± 0.00 ^{VU}0.030a± 0.00
Total seedling dry weight (g)	^{VR} 0.164a± 0.01 ^{VM} 0.136b± 0.01 ^{VU} 0.314a± 0.03	^{VR}0.126ab± 0.01 ^{VM}0.166a± 0.03 ^{VU}0.336a± 0.06	^{VR}0.114ab± 0.01 ^{VM}0.172a± 0.02 ^{VU}0.320a± 0.02	^{VR}0.098ab± 0.00 ^{VM}0.154a± 0.02 ^{VU}0.276a± 0.04	^{VR}0.084a± 0.01 ^{VM}0.160a± 0.02 ^{VU}0.202a± 0.02
Root / shoot ratio	^{VR} 0.33a± 0.10 ^{VM} 0.22a± 0.04 ^{VU} 0.47a± 0.10	^{VR}0.26a± 0.03 ^{VM}0.40a± 0.06 ^{VU}0.65a± 0.10	^{VR}0.36a± 0.09 ^{VM}0.48ab± 0.14 ^{VU}0.35a± 0.07	^{VR}0.36a± 0.10 ^{VM}0.31a± 0.06 ^{VU}0.42a± 0.10	^{VR}0.33a± 0.06 ^{VM}0.71b± 0.08 ^{VU}0.36a± 0.08
Leaf weight ratio	^{VR} 0.43a± 0.02 ^{VM} 0.49ab± 0.02 ^{VU} 0.47a± 0.01	^{VR}0.42a± 0.03 ^{VM}0.42a± 0.05 ^{VU}0.44a± 0.03	^{VR}0.38a± 0.01 ^{VM}0.57b± 0.01 ^{VU}0.38a± 0.01	^{VR}0.36a± 0.03 ^{VM}0.456ab± 0.03 ^{VU}0.40a± 0.02	^{VR}0.34a± 0.05 ^{VM}0.37a± 0.07 ^{VU}0.40a± 0.04
Specific leaf area (cm^2g^{-1})	^{VR} 87.46a± 8.34 ^{VM} 83.01a± 20.76 ^{VU}60.75a± 11.11	^{VR}124.15a± 37.6 ^{VM}107.51a± 41.29 ^{VU}44.12a± 1.84	^{VR}128.96a±18.89 ^{VM}70.79a±10.97 ^{VU}74.04a±12.51	^{VR}120.24a± 10.39 ^{VM}90.54a± 6.99 ^{VU}66.42a± 9.42	^{VR}148.62a± 54.0 ^{VM}170.85a± 56.1 ^{VU}74.26a± 11.94
Leaf area ratio (cm^2g^{-1})	^{VR} 38.16a± 2.31 ^{VM} 40.24a± 8.21 ^{VU}29.57a± 6.25	^{VR}49.67a± 12.11 ^{VM}37.40a± 6.43 ^{VU}19.72a± 0.63	^{VR}49.23a± 7.09 ^{VM}41.04a± 6.53 ^{VU}28.51a± 4.30	^{VR}44.01a± 4.49 ^{VM}40.88a± 3.91 ^{VU}27.22a± 3.65	^{VR}42.92a± 7.45 ^{VM}48.72a± 6.93 ^{VU}28.72a± 3.45

Number followed by the same letters in the same row are not significantly different according to Duncan Multiple Range Test at <0.05 level. ± Standard Error. VR=*Vigna radiate*, VM=*Vigna mugo,* VU= *Vigna unguiculata,*

Table 2. Effects of different concentration (0, 20, 40, 60 and 80%) of coke on physical and chemical properties of soil

	Coke concentration (%)				
Soil parameter	0	20	40	60	80
pH	7.40a±0.35	9.82b±0.02	9.79b±0.01	9.72b±0.01	9.69b±0.01
Electrical conductivity ($mScm^{-1}$)	0.46a±0.00	0.69b±0.00	0.72c±0.00	0.70b±0.00	0.73c±0.00
Water content (%)	0.39a±0.17	11.56b±4.91	2.85a±0.44	3.56ab±0.46	4.22ab±0.91
Bulk density (g/cm^3)	1.34d±0.01	1.19c±0.04	1.08bc±0.04	1.05b±0.03	0.87a±0.03
Water holding capacity (%)	26.98a±0.04	32.50ab±0.88	36.42b±0.28	39.48c±3.34	47.30d±0.32
Organic matter (%)	0.85a±0.15	2.09b±0.05	3.04c±0.16	3.57c±0.16	3.73c±0.33
Chloride(meq/L)	7.10a±0.10	25.00b±1.0	28.50bc±0.50	35.50cd±4.5	40.50d±0.50
Calcium carbonate (%)	34.21bc±0.08	34.54c±0.08	34.05bc±0.08	33.73b±0.08	32.26a±0.40
Exchangeable sodium (µg/g)	4.91a±0.66	14.65a±1.35	14.45a±8.54	13.77a±0.48	6.99a±1.33
Exchangeable potassium (µg/g)	7.06a±1.40	6.04a±1.33	5.66a±2.66	2.98a±0.27	1.37a±0.66

Number followed by the same letters in the same row are not significantly different according to Duncan Multiple Range Test at <0.05 level. ± Standard Error.

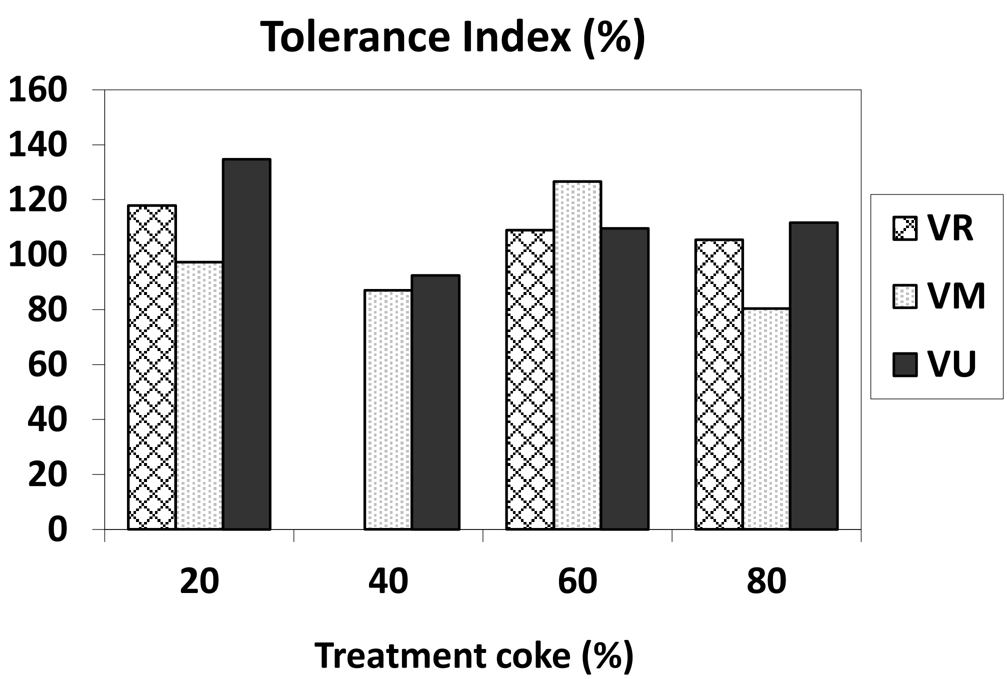

Figure. 1. Seedling tolerance index for seedlings of VR (*Vigna radiata*), VM (*Vigna mungo*) and VU (*Vigna unguiculata*) in response to different level (20, 40, 60 and 80%) of coke treatment.

Maximum seedling dry weight, leaf dry weight, shoot dry weight, and root dry weight was found highest in control seedlings of *V. unguiculata.* The seedling tolerance index for *V. radiata* (105.35%), *V. mungo* (80.36%) and *V. unguiculata* (111.71%) with the increase in concentration of coke at 80% as compared to control was recorded (Fig. 1).

A significant ($p<0.05$) variation in physical and chemical of coke and treated soil and control soil (garden loam soil) was recorded (Table 2). Soil pH was significantly ($p<0.05$) increased in coke treated soil, 9.82, 9.79, 9.72 and 9.69 at 20, 40, 60 80% as compared to control (7.40). The highest electrical conductivity (0.73 $mScm^{-1}$) was significantly ($p<0.05$) high in 80% treated soil as compared to control. Water content significantly increased in 20% coke treated soil (11.56%) as compared to control (0.39%). Bulk density of coke treated soil showed significant decline 1.34, 1.19, 1.08, 1.05, 0.87 g/cm^3 towards higher concentration 0, 20, 40, 60 and 80% of coke treated soil. Water holding capacity percentage of coke treated soil in 40, 60, and 80% treated soil was significantly high (36.42%), (39.48%) and (47.30%) as compared to control (26.96%). The lowest organic matter (0.85%) content in garden soil was recorded. The coke treated soil 20, 40, 60, 80% showed increase in organic content 2.0, 3.04, 3.57 and 3.70%, respectively. A significant ($p<0.05$) variation (25.00 - 40.50 meq/L) in chloride level in coke treated soil 20-80% was recorded as compared to control (7.10 meq/L). The calcium carbonate (%) concentration in coke treated soil (20-80%) showed low variation among treatment. Exchangeable potassium and sodium showed no significant differences in all treated soil as compared to control.

DISCUSSION

Coke is an important raw material in the iron and steel industry (Bond et al., 2013). In the present study, the effects of coke on seedling growth performance of some bean crops species viz. *V. radiata, V. mungo* and *V. unguiculata* to different level of coke treatment (20, 40, 60, and 80%) as compared to control was observed. Comparative analysis of the obtained data using different growth parameters (root, shoot and seedling length, root / shoot ratio, leaf area, and seedling dry weight and tolerance indices) of *V. radiata, V. mungo* and *V. unguiculta* allowed the validation on understanding the toxic nature of coke as a pollutant. Germination and early seedling growth have been regarded as critical phases, which are greatly influenced by stressful conditions (Shah and Dubey, 1995). Concerning the impact of coke pollution on root, shoot and seedling length of *V. radiata*, the same trend detected in the decrease in seedling length of *V. mungo.* Whereas, coke treatment at all concentration increased the seed germination percentage of *V. unguiculata* which might be due to its tolerance to coke to some extent as compared to control. Reduction in the plant height of *V. mungo* and *V. unguiculata* showed that the losses generally can be attributed to the coke treatment which contained toxic metals. Coke concentration added at higher concentrations (80%) produced significant ($p<0.05$) impact on seedling growth performance of *V. unguiculta* as compared to control. Cokes wastewater is one of the most toxic industrial effluents since it contains high concentrations of toxic materials such as phenols, cyanides and thiocyanate (Kim et al., 2008). In the present studies for all bean crop showed variation in seedling tolerance indices value as compared to control. The study reported here in reveals that the reductions in seedling dry weight of *V. radiate, V. mungo* and *V. unguiculata* was due to reduction in root and shoot growth as the concentration of coke treatment increased in substrate as compared to control. Growth characteristics such as root shoot and seedling length decreased and treated seedlings of bean crops. This effect was dose dependent, and was more significant at higher concentration as compared to control and agrees with the finding of other researcher. The effect of steel factory effluent on seed germination and seedling, growth of *Phaseolus mungo* cv. T-9, showed that increasing concentration of effluent induced a gradual decrease in germination percentage. The maximum seedling growth occurred in 25% concentration of effluent and minimum at 100% (Suresh, 2006).

CONCLUSION

Overall results showed that growth of different *Vigna* species viz. *V. radiata, V. mungo* and *V. unguiculata* was differently affected by all level of coke pollution as compared to control. Coke treatment was found most toxic for *V. unguiculata* seedlings than *V. radiata* and *V. mungo* which might be due to the presence of different toxic pollutants in coke. The study of plant behavior in coke pollution allows the identification and selection of pollution indicating species.

Furthermore, this study can be helpful in building a baseline data for future long term field studies essential for developing coke management guidelines. A significant ($p<0.05$) variation in physical and chemical of coke and treated soil and control soil (garden loam soil) was recorded.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

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AUTHOR CONTRIBUTIONS

The authors contributed as follows.
RJ performed the experiment and collected the data. MZI designed and supervised the experiment, MS statistically analysed the experimental data and draft the manuscript. MK and ZF reviewed the manuscript.

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