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Phytoremediation potential of native plant species for gaseous pollution from brick kiln

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Abstract

In developing countries, brick kilns are not well regulated by government agencies. As a result most of the time they are installed near to the cities to reduce transport cost. They use coal, waste plastic, scrap tires, etc as fuel. Brick kiln produces number of toxic pollutant like CO_2, SO_x, NO_x, HF, etc. They produce tons of gaseous pollution which effect near and far settled human population. Phytoremediation is considered the most suitable option for developing countries because of low cost, eco-friendliness and easily manageable. In current study, the purpose was to identify tolerant plant species near the brick kilns by measuring air pollution tolerance index (APTI). Species of trees including *Mangifera indica, Morus alba, Acacia nilotica, Eucalyptus globulus, Dalbergia sissoo* and *Moringa oleifera* were selected for sampling. Samples were collected during July and December at 100m, 300m, 500m and 700m distance around the brick kilns from two selected sampling sites. *Moringa oleifera* (APTI=17.60) was identified as tolerant and a sink of hydrogen fluoride (HF). Whereas, *Eucalyptus globules* (APTI=9.91) was found sensitive, so it can be used as bio-indicator of HF. This study recommends the plantation of *Moringa oleifera* around brick kiln for HF phytoremediation.

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Introduction

Environmental pollution is a growing concern worldwide due to industrialization, urbanization, and unplanned human activities. Among different pollutants, hydrogen fluoride is playing a critical role (Co *et al.,* 2009). Fertilizers companies and brick kilns are major sources of hydrogen fluoride and concentration of fluorine may reach up to 500ppm. Photosynthetic reduction is very prominent due to high fluorine concentration. Fluorine even become more dangerous when mixed up with other pollutants. Many brick kilns in South East Asian countries are using low quality automobile tires as fuel (Achakzai *et al.,* 2017). These emissions create disturbance in ambient air and leads to serious damage to crops, vegetation and humans (Jahan *et al.,* 2016; Adrees *et al.,* 2016). The Plants are considered as skin of pollution in ecosystem (Jha *et al.,* 2008). Toxic metals like Pb, Hg and Hf are absorbed by pants. Many plant species are used as pollution indicators on green belts so purpose of study was to sort out tolerant and sensitive species in vicinities of brick kilns (Ahmad *et al.,* 2012). In this way we can sort out sink of pollutants around bricks (Khan and Khan 2010).

Plants have vital role in maintaining balance of ecosystem and used to lessen air pollution by captivating gaseous pollutants and capturing particulates matter (Hamraz *et al.,* 2014). Due to wide surface area, leaves are considered as sink of pollutants (Kim *et al.,* 2015). HF and heavy metals (Pb and Hg) can be removed by plants because they have high capability to capture pollutants from air (SHANNIGRAHI* *et al.,* 2004). Biochemical adjustments like chlorophyll content, indole acetic acid, pH and relative water content of leaf are very significant for environmental adaptations (Kuddus *et al.,* 2011). Such biochemical parameters are helpful for determination of APTI values of plants (Liu and Ding 2008, Nayak *et al.,* 2015). Sensitive species may serve as bio-indicator, whereas tolerant species as sink. Tolerant species can be used in creating green belts around the brick kilns (Kousar *et al.,* 2014, Rai and Panda 2014). So the objectives of the study were to assess sensitive and tolerant species of plants for HF around the brick kilns by calculating their APTI values. On the basis of the results of the study, we will be able to identify species (locally available) which can be use around brick kiln as sink of the pollutant.

Materials and methods

Site selection

Two areas around Kotaddu and Muzaffargarh cities (Southern Punjab, Pakistan) were selected as there were a lot of brick kilns. The site chosen from the surroundings of the Kot adu city named as site 1, while the site in the vicinity of the Muzaffargarh city was named as site 2. Here in these sites, only the brick kilns are the sources of pollution because these areas are far away from urban areas and surrounded with agricultural land.

Plant sampling

For the study, six plant species were selected and samples were taken at 100m, 300m, 500m and 700m in each direction. Sampling of leaves was conducted in triplicate. These trees were selected on the basis of clear morphological impact of pollution and air flow trend. At site 1, sampling was withdrawn in winter (December), while at site 2; sampling was done in summer season (July). Fluoride absorption behavior was monitored in the leaves under different climatic conditions like humidity and temperature by acid digestion method. These samples were transported to laboratory in container with dry ice for analysis. Sampling was done at same day to avoid changes in climatic conditions. Fresh weight of these samples was measured and leaves were then stored in refrigerator.

Biochemical analysis

Following formula was used to determined relative water content of leaf (Liu and Ding 2008).

$$\mathrm{RWC} = \frac{\mathrm{FW} - \mathrm{DW}}{\mathrm{TW} - \mathrm{DW}}$$

Where, FW is fresh weight

DW is dry weight (after drying at 115°C for 2 hours in oven) of leaves.

TW is turgid weight (mg) after immersion in water.

Chlorophyll a ($C_{55}H_{72}O_5N_4Mg$) and chlorophyll b ($C_{55}H_{70}O_6N_4Mg$) were measured to investigate HF impact on plant. One gram of fresh leaves was crushed in acetone. Homogenate was filtrated, poured in flask and final volume was made 50ml by adding acetone. Absorbance of the filtrate was noted at wavelength range of 645nm to 663nm. By spectrophotometer, Ascorbic acid was measured with the help of formula of Keller (Keller and Schwager 1977). The pH of leaf extract was also measured as per method of Dwivedi (Dwivedi and Gopal 2010).

$$\text{Air pollution tolerance index (APTI)} = \frac{A(T+P)+R}{10}$$

Where A, T, P and R stands for Ascorbic acid content, total chlorophyll, pH and relative water content respectively. If the calculated values range from 1 to 7 the plant will be considered as sensitive, if values range from 8-9 the plants will be considered as intermediate and if the value of APTI calculation greater than or equal to 10 such plants will be considered as tolerant.

Result and discussion

Chlorophyll Contents

The results of chlorophyll contents revealed that chlorophyll a, chlorophyll b and total chlorophyll increase with distance (Table 1). Chlorophyll a significantly increases from 100m to 700m. At the distance of 100m the maximum chlorophyll a (2.45) was found in *Morus alba*, while minimum was in *Mangifera indica* (0.68). chlorophyll b and total chlorophyll also show same trends. Chlorophyll content of any plant determines its productivity, health and biomass. It dependent on number of biotic and abiotic factors like, type of pollutant, concentration of pollutant, age of plant, plant species, etc. (Katiyar and Dubey 2001). Statistical analysis exposed significant difference between species and distance. At some points this trend was inconsistent which may be due to the wind direction and pollutant deposition. Increasing deposition of soot and particulate matter results in the closing of stomata. This further leads to the disturbance in gaseous exchange and biosynthesis pathway (Leghari and Zaidi 2013). These results are inconsistent with finding of previous researchers (Chauhan 2010, Adrees *et al.,* 2016). Brick kilns are the major contributor of pollution like SO_2, soot and particulate matter. These pollutants create serious damage to chlorophyll content due to chlorophyll acidification. Acidification also leads to the deformation of chloroplast and derivatives of chlorophyll i.e. phaeophytin (Agbaire and Esiefarienrhe 2009). The results of this study confirmed that plant species differ in resistance and sensitivity. Resistant species do not undergo much physiological and anatomical change (Nanos and Ilias 2007). Fig. 1, 2, 3 and 4 showing chlorosis in leaves of *Dalber giasissoo, Moringa oleifera, Abelmoschus esculentus* and *Morus alba.*

Ascorbic Acid

When air pollution tolerance is identified in plants, one factor is very important and that is ascorbic acid. It is a strong detoxicant which initiates defense mechanism in plants against many stresses. Studies have reported that when the amount of ascorbic acid is increased in plants, tolerance also increased and vice versa (Aghajanzadeh *et al.,* 2016, Achakzai *et al.,* 2017). Results of the current study showed increase in concentration of ascorbic acid with the distance from pollution source. Plants which were at 100m from source had less ascorbic acid that the plants which were at 500m or 700m (Table 2). This difference in ascorbic acid reveals the tolerance of plant. Same species is more tolerant at 700m and is less to tolerant at 300m. At 100m *Acacia nilotica* shows maximum ascorbic acid (2.87) compared to other species. At the distance of 700m from source the same specie (*Acacia nilotica*) also showed maximum ascorbic acid (4.88) compared to other species. The result indicates that high amount of ascorbic acid near source indicates its tolerance against SO_2 (Laghari *et al.,* 2015, Aghajanzadeh *et al.,* 2016, Aguiar-Silva *et al.,* 2016).

Relative H_2O content

Water is an important ingredient for plants; it regulates many biological and chemical functions during stress conditions. Relative water content is a widely studied parameter, based on its relative importance (Agrawal and Tiwari 1997, Nayak *et al.,* 2015). Results of this study show inconsistency between relative water content and distance from pollution source (Table 3). Maximum water concentration at 100m distance was calculated in *Moringa oleifera* (84.41). Water content in *Dalbergia sissoo* was 75.86 at a distance of 100m. The order of relative water concentration at 700m (site 2) was as follows:

Mangifera indica (105.4) < Morus alba (98.9) < Acacia nilotica (88.1) < Moringa oleifera (87.43) < Eucalyptus globules (74.02) < *Dalbergia sissoo* (65.19)

Table 1. Concentration of chlorophyll contents at different distances from the source.

Species		100m			300m			500m			700m		
		Chl a	Chl b	Total chl	Chl a	Chl b	Total chl	Chl a	Chl b	Total chl	Chl a	Chl b	Total chl
Mangifera indica	Site 1	0.68 ±0.04	0.62 ±0.21	0.32 ±0.31	1.15 ±0.20	0.70 ±0.12	0.45 ±0.12	1.74 ±0.28	0.84 ±0.07	0.55 ±0.11	2.05 ±0.19	0.95 ±0.23	0.71 ±0.05
	Site 2	0.81 ±0.12	0.45 ±0.08	0.13 ±0.02	1.82 ±0.24	0.85 ±0.24	0.28 ±0.11	2.22 ±0.35	1.13 ±0.31	0.43 ±0.31	2.78 ±0.13	0.63 ±0.75	0.35 ±0.52
Morus alba	Site 1	2.45 ±0.82	2.53 ±0.05	1.34 ±0.12	0.98 ±0.88	1.54 ±0.45	0.82 ±0.04	0.74 ±0.97	0.74 ±0.57	0.65 ±0.02	1.18 ±0.65	1.47 ±0.35	1.02 ±0.23
	Site 2	1.12 ±0.87	0.27 ±0.72	0.81 ±0.29	1.34 ±0.94	0.47 ±0.15	1.05 ±0.42	1.43 ±1.00	0.82 ±0.42	1.61 ±0.69	1.60 ±0.81	0.63 ±0.91	1.32 ±0.41
Acacia nilotica	Site 1	1.13 ±0.15	0. 13 ±0.04	0.57 ±0.02	2.08 ±0.41	0.27 ±0.07	1.35 ±0.27	2.41 ±0.61	0.53 ±0.71	1.58 ±0.41	0.91 ±0.05	0.38 ±0.03	1.00 ±0.41
	Site 2	2.79 ±0.09	1.31 ±0.05	0.19 ±0.03	1.21 ±0.67	0.67 ±0.31	0.79 ±0.23	0.98 ±0.76	0.35 ±0.36	1.05 ±0.41	2.12 ±0.43	0.63 ±0.41	1.03 ±0.45
Eucalyptus globules	Site 1	1.67 ±0.81	0.69 ±0.58	0.43 ±0.01	1.25 ±0.57	1.03 ±0.45	0.57 ±0.11	1.00 ±0.54	1.23 ±0.37	1.05 ±0.23	1.18 ±0.34	1.35 ±0.40	0.97 ±0.15
	Site 2	1.82 ±0.79	0.57 ±0.51	0.37 ±0.29	2.05 ±0.65	0.79 ±0.36	0.56 ±0.20	2.17 ±0.43	0.91 ±0.21	0.68 ±0.13	1.93 ±0.57	0.73 ±0.05	0.49 ±0.22
Dalbergiasi ssoo	Site 1	1.62 ±0.52	0.59 ±0.33	0.35 ±0.23	1.87 ±0.32	0.77 ±0.23	0.60 ±0.30	2.01 ±0.22	0.93 ±0.15	0.71 ±0.37	2.30 ±0.05	1.15 ±0.37	1.03 ±0.39
	Site 2	2.31 ±0.73	0.57 ±0.42	0.78 ±0.13	2.00 ±0.61	2.03 ±0.57	0.61 ±0.26	1.80 ±0.43	1.71 ±0.41	0.42 ±0.34	1.92 ±0.26	1.91 ±0.51	0.47 ±0.44
Moringaolei fera	Site 1	1.76 ±0.05	1.06 ±0.24	0.39 ±0.19	2.11 ±0.14	1.41 ±0.30	0.67 ±0.27	2.41 ±0.31	1.72 ±0.47	1.01 ±0.35	2.03 ±0.29	1.37 ±0.34	0.87 ±0.77
	Site 2	1.21 ±0.07	0.35 ±0.21	0.23 ±0.37	1.30 ±0.16	2.11 ±0.37	0.34 ±0.43	1.67 ±0.25	2.89 ±0.45	0.62 ±0.49	1.26 ±0.24	1.72 ±0.30	0.19 ±0.21

Fig. 1. *Dalbergia sissoo* leaves with Chlorosis near the brick kiln. **Fig. 2.** *Moringa oleifera* leaves with Chlorosis near the brick kiln.

Fig. 3. *Abelmoschus esculentus* leaves with necrosis near the brick kiln. **Fig. 4.** *Morus alba* leaves with necrosis near the brick kiln.

Table 2. Impact of source distance and species on AA concentration.

Species	100 m		300 m		500 m		700 m	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Mangifera indica	1.05 ±0.58	2.11 ±1.21	1.73 ±0.87	3.06 ±1.37	2.04 ±1.02	3.61 ±1.52	2.37 ±1.21	4.21 ±1.81
Morus alba	1.98 ±1.03	2.31 ±1.23	1.51 ±0.81	2.54 ±1.41	1.27 ±0.61	2.70 ±1.58	1.77 ±0.91	3.01 ±1.13
Acacia nilotica	2.87 ±1.23	2.41 ±1.33	3.98 ±2.11	2.03 ±1.13	4.77 ±2.89	1.73 ±0.74	4.88 ±1.56	2.12 ±1.73
Eucalyptus globulus	1.32 ±0.51	2.78 ±1.14	1.71 ±0.69	2.72 ±1.04	2.01 ±1.00	2.51 ±0.97	2.21 ±1.19	2.92 ±1.32
Dalbergia sissoo	2.56 ±1.21	2.16 ±1.17	3.37 ±1.57	3.45 ±1.88	3.83 ±1.82	3.77 ±1.96	4.00 ±2.11	3.96 ±1.39
Moringa oleifera	2.03 ±0.54	1.13 ±0.32	2.33 ±0.77	1.38 ±0.44	2.65 ±0.91	1.72 ±0.67	2.80 ±0.60	1.98 ±0.31

Table 3. RWC with reference to distance from the brick kilns.

Species	100 m		300 m		500 m		700 m	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Mangifera indica	54.4 ±0.35	86.0 ±0.33	45.2 ±0.61	93.6 ±0.48	38.6 ±0.85	100.2 ±0.78	65.3 ±1.11	105.4 ±0.97
Morus alba	47.3 ±3.73	74.5 ±12.4	60.3 ±3.11	86.7 ±7.4	64.2 ±2.76	92.6 ±5.8	81.7 ±4.35	98.9 ±10.6
Acacia nilotica	41.8 ±3.21	57.4 ±5.45	56.9 ±5.32	66.3 ±3.11	65.8 ±7.23	75.8 ±2.53	77.3 ±4.33	88.1 ±8.75
Eucalyptus globulus	58.70 ±6.37	62.34 ±3.31	43.30 ±13.74	65.11 ±8.32	35.21 ±18.31	71.21 ±10.21	52.12±11.31	74.02±13.81
Dalbergia sissoo	65.05 ±3.04	75.86 ±.4.03	78.21 ±15.33	68.21 ±9.07	81.01 ±17.20	56.11 ±12.30	86.00±10.11	65.19 ±9.11
Moringa oleifera	69.11 ±12.23	84.41 ±7.19	73.27 ±2.43	78.23 ±2.03	77.20 ± 1.48	72.10 ±1.34	80.12 ±0.23	87.43 ±6.39

Variations water content may be due to tolerance among various plants. Many authors have indicated that the early leaf senescence is due to increase in plants cell permeability that is the result of pollutants. So the high relative water content is also the indication of tolerance against air pollution (Paulsamy *et al.,* 2000, Kuddus *et al.,* 2011, Adrees *et al.,* 2016).

pH of leaf extract

In present study, the pH of leaf extract showed significant variations in same species at different sites and different distance. Plant species also differ significantly from one another (Table 4). The pH of leaf extract in *Mangifera indica*, *Morus alba* and *Acacia nilotica* varies from neutral to acidic. In Eucalyptus globulus the pH varies from 6.68 to 8.32. The sharp change in pH was observed in *Moringa oleifera*, where pH ranged from 3.67 (at 100m) to 9.32 (at 700m). pH of the cell cytoplasm plays significant role as it control biochemical reaction through enzymes. Most importantly, hexose to ascorbic acid conversion is also regulated with enzymes (Escobedo *et al.,* 2008) and It was also reported that low pH reduced the photosynthesis (Yan-Ju and Hui 2008). Due to acidic pollutants, the pH move to acidic (Chouhan *et al.,* 2012). pH variation in present study may also because of tolerance difference in plants against different pollutants.

Table 4. pH concentration with reference to HF and plant species.

Species	100 m		300 m		500 m		700 m	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Mangifera indica	5.32 ±0.13	4.98 ±0.85	6.61 ±0.29	5.76 ±0.64	7.05 ±0.50	6.12 ±0.40	6.97 ±0.81	5.10 ±1.04
Morus alba	6.30 ±0.55	7.21 ±0.34	7.13 ±0.71	7.98 ±0.25	8.64 ±0.45	8.28 ±0.15	9.05 ±0.33	6.16 ±0.05
Acacia nilotica	4.81 ±0.15	3.78 ±0.31	5.31 ±0.28	3.32 ±2.43	6.19 ±0.42	2.67 ±2.52	7.77 ±0.63	4.12 ±2.93
Eucalyptus globulus	8.32 ±0.46	6.73 ±0.63	7.17 ± ±0.35	6.73 ±0.34	6.79 ±0.28	6.68 ±0.33	8.00 ±0.40	8.11 ±0.26
Dalbergia sissoo	4.58 ±0.36	7.43 ±0.27	5.39 ±0.27	8.33 ±0.42	6.21 ±0.13	8.69 ±0.67	8.78 ±0.40	6.44 ±0.31
Moringa oleifera	3.67 ±0.23	8.07 ±0.65	4.00 ±0.15	7.47 ±0.83	4.83 ±0.08	6.73 ±1.23	5.17 ±0.32	9.32 ±1.65

Air Pollution tolerance Index (APTI)

The findings of this study indicated that all the six selected plant species under investigation are significantly differ from each other in 'air pollution tolerance index. APTI ranges from 6.03- 17.60 (Table 5). These variations in trends may be due to distance from source, species and pollutant types. The order of APTI at site 2 with in 100m distance was as follows:

Acacia nilotica (6.69) < *Eucalyptus globules* (8.20) < *Mangifera indica* (9.67) < *Morus alba* (9.03) < *Moringaoleifera* (9.35) < *Dalbergiasissoo* (9.37)

The order of APTI at site 2 within 700m distance was as follows:

Dalbergia sissoo (8.42) < *Acacia nilotica* (9.90) < *Eucalyptus globules* (9.91) < *Morus alba* (12.11) *Mangifera indica* (12.83) < *Moringa oleifera* (17.60)

Usually plants are of 2 types, resistant and sensitive. Species with APTI value less that 16 are considered sensitive and species having APTI value more than 16 are generally resistant (Agrawal *et al.,* 1991). Results of the curent study, *Moringa oleifera* (APTI = 17.6) is resistant against air pollution while other 5 species are sensitive (Table 5). The findings of this study are also supported by other studies (data given in table 6).

Table 5. Calculated values of APTI to findout tolerant and sensitive species.

Species	100m		300m		500m		700m	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Mangifera indica	6.03 ±0.74	9.67±1.21	5.74±0.87	11.2 ±0.75	5.41 ±0.65	12.38 ±0.95	8.35 ±1.17	12.83 ±1.05
Morus alba	6.24 ±1.34	9.30 ±1.47	7.23 ±0.78	10.96 ±0.34	7.59 ±1.04	11.93 ±0.97	9.95 ±1.23	12.11 ±1.41
Acacia nilotica	5.72 ±0.48	6.69 ± 0.34	8.34 ±1.31	7.46 ±1.17	10.28 ±1.13	8.22 ±0.97	10.69 ±1.54	9.90 ±1.31
Eucalyptus globulus	7.02 ±0.35	8.20 ±018	5.65 ± 0.44	8.49 ±0.79	5.09 ±1.13	8.96 ±1.34	7.19 ±1.84	9.91 ±1.95
Dalbergia sissoo	7.76 ±1.41	9.35 ±0.57	9.83 ±1.22	9.90 ±1.44	10.75 ±1.01	9.04 ±1.10	12.52 ±0.88	8.42 ±0.75
Moringa oleifera	7.73 ±1,13	9.37 ±1.26	8.41 ±1.26	8.90 ±0.47	9.26 ±1.58	8.47 ±1.62	11.13 ±1.71	17.60 ±1.91

Table 6. Comparison of different plant species against air pollution resistance.

Species	APTI	Classification	Reference
Malcolmia Africana	21.30	Resistant	(Khalid 2019)
Medicago sativa	17.59	Resistant	
Chenopodium album	10.38	Sensitive	
Vitis vinifera	7.58	Sensitive	
Calotrophis procera	19.48	Resistant	(Achakzai *et al.,* 2017)
Triticum aestirium	18.49	Resistant	
Altenenthera pungen	18.20	Resistant	
Malva neglecta	10.05	Sensitive	
Croton bonplandianum	9.77	Sensitive	
Euphobria heiscopia	9.24	Sensitive	
Datura inoxia	9.03	Sensitive	
Parathenium hysterophorus	8.81	Sensitive	
Brassica compestris	8.8	Sensitive	
Mangifera indica	12.83	Sensitive	This study
Morus alba	12.11	Sensitive	
Acacia nilotica	10.28	Sensitive	
Eucalyptus globules	9.91	Sensitive	
Dalbergia sissoo	12.52	Sensitive	
Moringa oleifera	17.60	Resistant	

Conclusion

It was concluded that APTI values of plant species increase or decreases with reference to distance from pollution source, and its good procedure to identify sensitive or tolerant species. Among the six plant species under study *Moringa oleifera* was found most tolerant plant whereas *Acacia nilotica* was as most sensitive plant in vicinities of brick kilns. Similarly, land degradation is usually due to increased urbanization and pollution from brick kilns. APTI is a good parameter to investigate potential sensitive and tolerant species. These tolerant species may be used as sink and scavengers of air pollution.

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