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Adaptation in *Atriplex griffithii* and *Prosopis juliflora* plants in response to cement dust pollution

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ABSTRACT: In the present study, we attempted to determine the effects of cement dust on the adaptations of plants growing in polluted area and to compare it with a leeward site (control) of the cement factory that was unpolluted. The emphasis was also given to observe the effects of cement dust on the soil characteristics of the factory area. The introduction of cement dust from a cement factory produced negative effects on the morphological traits of both plant species (*Atriplex griffithii* and *Prosopis juliflora*) growing at the polluted as compared to unpolluted area. Low seedling height and plant circumference for *A. griffithii* and *P. juliflora* were observed at the polluted site of the cement factory. *A. griffithii* showed significant reduction in leaf area growing at the polluted site as compared to control site. Similarly, a significant ($p<0.05$) reduction in leaf area was also recorded for *P. juliflora* at the polluted sites. The growth pattern of *A. griffithii* and *P. juliflora* looked more greener, better in plant height and healthier as observed at unpolluted sites. No significant difference in vegetative growth for both plant species for plant height and circumference was seen at the polluted sites of the factory. We believe that the underlying edaphic factor and genotypic ability of both species helped to some extent in adaptation to the extreme habitat conditions at the polluted sites. The significance differences in soil pH level and organic matter contents were recorded from polluted area as compared to control site. © JASEM

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Introduction: All compartments of the biosphere are polluted by a variety of inorganic and organic pollutants as a result of anthropogenic and industrial activities (Prasad and Freitas, 2003). The addition of pollutants in the environment normally results brought up changes in physico-chemical properties of soil. Plants can be affected directly by air pollutants, as well as indirect through the contamination of soil and water. At the same time, plants are part of food chain and may create a risk for man and animals through contamination of food supplies (Fargašová, 1994). The introduction of various types of toxic materials such as particulate matter, dust particles, unburned and partially burned hydrocarbons, fuels, tar materials, heavy metals from the industries without any treatment affected local environment. The pollutants when combined together produced additive or synergistic effects on plants growth. Pollution complexes emitted into the atmosphere as a result of industrial activities are known to affect the physiological and biochemical conditions of plants, depending on the chemical composition and concentrations of pollutants (Lu et al., 2008; Mandre, 2000; Mandre and Ots, 1999; Mandre et al., 1992, 1994, 1999; Parn and Mandre, 2011).

Cement industrial units are an important source of environmental pollution and produced negative effects on plant growth. During the process of cement manufacturing considerable amount of dust is emitted at different stages of handling, spillages, leakages, starting with the quarrying of the major raw material limestone and ending with the packing and dispatch of cement from the plant (Abdul-Wahab, 2006). Concentrations of dust released from cement plant vary from plant to plant, from one area to another depending on the nature and intensity of local sources, and on other factors such as topography, general weather conditions and liability to temperature inversions (Abdul-Wahab, 2003; Trindade et al., 1981).

High concentrations of particles emitted from cement plant affect the vegetative growth characteristics of plants growing adjacent to the cement factories. There are numerous studies about the impact of cement dust on living organism, extinction of plant

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species, growth retardation and biomass production (Brandt and Rhoades, 1973; Gigauri et al., 1992; Grill and Golob, 1983; Haapala et al., 1996 a, b; Hirano et al., 1995; Kupcinskiene and Huttunen, 2005; Kupcinskiene et al., 2008; Lerman and Darley, 1975; Ots et al., 2011). Large amount of dust emitted in the course of years has caused notable alkalization of precipitation in the town of Kunda (Estonia) and its vicinity (Tuulmets, 1995). Shafiq and Iqbal (1987) and Iqbal and Shafiq (1995) found reduction in number of species around the heavily polluted industrial units of the cement in Karachi.

Prosopis juliflora (Sw.) DC. (Family: Leguminosae) and *Atriplex grifithii* Moq (Family: Amaranthaceae) are the important wild species of the study area. *P. juliflora* is an exotic species and found either in a wild or cultivated state in the drier regions. It is evergreen spiny tree with drooping branches. Its fast growth and hardy nature are suitable for its use in green belt designing and development in various industrial sectors (Rai et al., 2004). The use of *Atriplex* spp. has long been considered suitable for the restoration of degraded lands. Genus *Atriplex* has several plant species that are capable to complete their life cycles under very harmful environmental conditions such as drought, high temperature and high salinity (Ramos, et al., 2004; Silveira et al., 2009). Several species belonging to the genus *Atriplex* are adapted to harsh environmental conditions and therefore constitute a useful material for the identification of physiological mechanisms and genes involved in abiotic stress resistance (Cabello-Hurtado and Ramos, 2004; Hassine et al., 2008; Wang and Showalter, 2004).

To improve the understanding of the effects of environmental pollutant on plant growth, development and adaptation it is important to study the response of plant to pollutants. The aim of the present study was to study the effects of cement dust on the growth performance of *P. juliflora* and *A. griffithii*. The growth performance of both plant species was compared between polluted and unpolluted sites of an old cement factory. The study also focused in relation to physical and chemical soil properties of the area.

MATERIALS AND METHODS

Karachi is the largest industrial city of Pakistan. The study site was located in the vicinity of one of the huge cement manufacturing units situated in Manghopir near Latifabad, Karachi. Actual name of the industrial unit was deliberately omitted to protect the privacy of the industry. Vegetation and soil characteristics were determined from two different sites different sites, (1) outside the cement factory in the direction of the wind ward and (2) on against the wind direction, leeward) some distance away from the cement factory. Twenty five leaves sample of each species (*P. juliflora* and *A. griffthii*) were collected for the determination of leaf area. Leaf area was calculated for both species by multiplying leaf length with breadth and with 2/3 correction factor as leaves are not rectangular. A cm scale was used for measuring length and breadths. Whole compound leaves were used for measuring length and breadth. The coverage and plant height was calculated based on average value of ten readings. Measuring tape was used to take coverage and height of plant species. The average of ten individual of each species was counted. In case where the same species occurred in both the polluted and unpolluted sites an attempt was made to use plants of similar heights as among plants, height is a better measure than age and more important as well. No rainfall was witnessed throughout the year.

The climate of Karachi is subtropical and the area classified as semi arid due to less than 225 mm rainfall annually. Soil is geologically young, calcareous and alkaline in nature (Qadir et al., 1966). Dew fall is common. Strong winds blow throughout moon soon season from seaside. Soil samples were collected outside the cement factory leeward and windward at 30 cm depth and were brought to the laboratory in polythene bags. Soil samples were air dried and then sieved through 2 mm sieve. There were three replicates for each soil sample. The soil samples were collected from polluted and unpolluted sites. Mechanical analysis of soil was carried out in order to determine soil texture by pipette method. Alkaline earth carbonate percentage was analyzed. Soil pH was determined by direct pH reading meter (MP-220, Mettler, Toledo). The electrode was first standardized with two buffer solutions and then dipped into the sample solutions made in a 1:5 ratio of soil weight and distilled water. Soil samples were air dried to determine the physical and chemical characteristic. Five grams of soil mixed with 25 ml of distilled water were shaken and filtered using Whatman no. 1 filter paper and soil pH was measured with pH meter. Estimation of organic matter in percentage was done according to Jackson (1958). The data obtained were statistically analyzed on personnel computer using COSTAT 3.

RESULTS

The effects of cement dust on the vegetative characteristics such as plant height, plant circumference and leaf area of *A. griffithii* and *P. juliflora* were observed from the polluted and unpolluted site of the cement factory (Table 1). The growth parameters of *A. griffithii* and *P. juliflora* were higher in unpolluted sites. Aggregate results of the study showed low plant height (5.80 cm) and circumference (22.60 cm) of *A. griffithii* from the polluted sites. The study showed similar trend of low vegetative growth characteristics such as plant height (58.50 cm) and plant circumference (522.00 cm) of *P. juliflora* from the polluted sites. A significant ($p<0.05$) decrease in leaf area (81.75 sq. mm) was observed from the polluted sites for *A. griffithii*. The decrease in leaf area (540.80 sq. mm) was also significant ($p<0.01$) for *P. juliflora* from the polluted sites as compared to unpolluted sites. The plant size (8.10 cm), circumference (36.50 cm) and leaf area (90.16 sq. mm) for *A. griffithii* was found high at unpolluted sites. Plant height (61.50 cm), circumference (558.00 cm) and leaf area (587.43 sq. mm) of *P. juliflora* was also found high at unpolluted sites.

The effects of cement dust on the physical and chemical soil characteristics were observed in polluted and unpolluted site soil (Table 1). The soil textures of polluted and unpolluted area were sandy loam. A significant ($p<0.05$) variation in chemical properties of soil for soil pH and organic matter (%) at polluted site was observed. The soil of polluted area was alkaline in nature. A high level of soil pH (8.55 ± 0.05) was found at the polluted site as compared to unpolluted site soil pH (7.38 ± 0.09). A significant ($p<0.05$) effect on organic matter (%) at polluted sites was also observed. High percentage of organic matter (3.33 ± 0.27) was observed at unpolluted area soil sample as compared to polluted areas (2.01 ± 0.47) soil sample. Chemical properties of soil for alkaline earth carbonate (%) were slightly greater (2.40 ± 0.01) at polluted site with a little difference (2.27 ± 0.02) at polluted sites of cement factory.

DISCUSSION

In present investigation significant changes in the morphological characteristics of two important wild plant species viz., *A. griffithii* and *P. juliflora*, and physico-chemical properties of soil were observed due to cement dust pollution released from the cement factory as compared to unpolluted site. In visual observation the color of leaves of both the plant species was lighter than the plants growing at control site. The effects of cement dust on morphological traits such as plant height, plant coverage and leaf area for both the plant species were more pronounced at the polluted sites of the factory. *A. griffithii* and *P. juliflora* showed low seedling height and circumference at polluted sites. However, significant reduction in leaf area of *A. griffithii* and *P. juliflora* is probably due to underlying edaphic factors of the polluted site. Abdullah and Iqbal (1991) described the effect of cement and stone dust on the stomatal clogging of *Innula grantioides* leaves. The better seedling growth performances in terms of plant height and plant circumference of *A. griffithii* and *P. juliflora* indicated well adaptation capabilities beside introduction of cement dust pollution. We believe that no significant changes in plant height and circumference in *A. griffithii* and *P. juliflora* might have genotypic origin. A significant decrease in leaf area of *A. griffithii* and *P. juliflora* under pollutants stress was an indication of depressing effect of cement dust toxicity having high levels of metals which were responsible for disturbances on vital metabolic process. Extreme environmental conditions that induce functional changes in plants to such an extent that stress of the organism develops and results in inhibited growth, reduced bio production of due to these changes. Sensitivities of individual species in a population have been associated with changes in the structure and function of natural ecosystems (Ots et al., 2011). Ogunbileje et al. (2013) determined relative abundance of heavy metals (Hg, Cu, Cr, Cd, Ni, Mn, Pb, Fe and Cr (VI)) in cement dust from different cement factories in Nigeria and US in order to predict their possible roles in the severity of cement dust toxicity and concluded that the concentrations of heavy metals and Cr (VI) are known human carcinogens. Additional their study revealed that metal content concentrations are factory dependent. Leaf size can be considered as an important indictor of adaptational mechanism. Toxicity may result from the binding of metals to sulphydryl groups in proteins, leading to an inhibition of activity or disruption of structure, or from the displacing of an essential element resulting in deficiency effects (Van Assche and Clijsters, 1990). In addition, heavy metal excess may stimulate the formation of free radicals and reactive oxygen species, perhaps resulting in oxidative stress (Dietz et al., 1999). Some plants species, however, have evolved tolerant races that can survive and thrive on such metalliferous soils, presumably by adapting mechanisms that may also be involved in the general homeostasis of, and constitutive tolerance to, essential metal ions as found in all plants. This information can be considered a contributing step in exploring and finding some level of adaptation of *A. griffithii* and *P. juliflora* recorded from the polluted site and compared with the unpolluted site. Results of the findings can be used as a useful indicator of cement dust pollutant stress adaptation to some extent.

Under pollution load the dimensions of conifer needles and their average age as well as the length growth of shoots diminish, and necrosis of needles often can also be observed (Braniewski and Chrzanowska, 1988). Growth performance of *A. grifithii* and *P. juliflora* decreased in the polluted environment which can be due to addition of alkalisation of the soil. Significant damage of vegetation is observed in the immediate vicinity of emission sources (Grantz et al., 2003; Kozlov and Niemelä, 1999). In our previous findings the alkalisation of the environment, resulting from the large amounts of pollutants emitted in the course of many years largely influenced on the vegetation of the area (Abdullah and Iqbal, 1991; Iqbal and shafiq, 1995; Shafiq and Iqbal, 1987). The soil texture, water holding capacity, organic matter, calcium carbonate, pH and available sulfate and heavy metals were affected the plant growth. Soil of industrial areas has been analyzed by many workers to investigate effects of soils on plants. Soil texture, $CaCO_3$, organic matter, pH were analyzed in the vicinity of various industries of Karachi city (Mehmood and Iqbal, 1995; Shafiq and Iqbal, 1987). Data from the present studies showed that increase in soil pH of polluted site is responsible for decreased in leaf size of *A. grifithii* and *P. juliflora*. In the present study, possibly the high soil pH and alkaline earth carbonate percentage due to addition of cement dust affected leaf area of both species and this agrees with the findings of Annuka and Mandre (1995) and Mandre et al. (2002). Soil of an area had a great impact on plants hence plants and soil were strongly influenced by each other (Kim et al., 1995). Depending on the dust load, duration and tolerance of the plants, particulates may cause negative changes in the leaf surface ultra structures, inhibit growth of the plants, reduce the area of leaves and hence, reduce the total biomass (Shukla et al., 1990). Atmospheric pollution produced by cement works is known to include high levels of calcium carbonate and oxides of potassium, silicon and Na_2SO_4 the particles of which become airborne (Bačić, et al., 1999).

Conclusions: This information from the present studies can be considered a contributing step in exploring and finding of the some level of adaptation of *A. grifithii* and *P. juliflora* recorded from the polluted site and compared with the unpolluted site. Results of the findings can be useful indicator of cement dust pollutant stress adaptation to some extent. It is concluded that the seedlings growth performance of *A. grifithii* and *P. juliflora* showed negative differences in morphology due to cement dust pollution. The study suggests that the cement dust also influenced the edaphic characteristics of the study site. The seedlings of *P. juliflora* showed better adaptability than *A. grifithii* in the unpolluted area. In present studies *P. juliflora* was found well adapted at the polluted site of the factory. This might be due to well adaptative nature to harsh environment. *P. juliflora* is considered to have more tolerant characteristics to toxic metals when grown on fly ash contaminate landfill as compared to other leguminous plants (Rai et al., 2002). It is concluded that the vegetative growth characteristics such as height and coverage of *A. grifithii* was highly affected as compared to *P. juliflora*. The better growth performance of *P. juliflora* than *A. grifithii* at the polluted sites suggests that the seedlings of *P. juliflora* have the better genetic ability to some extent. This study can be useful for the non-governmental organizations, regulatory agencies, research organizations, consultants and all those concerned in planning for plantation of such species around cement industrial units.

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Table: 1. Vegetation and soil characteristic of polluted and unpolluted sites of cement factory

Site	Plant Species	Vegetation characteristic Height (cm)	Circumference (cm)	Leaf area (sq mm)	Soil characteristics Soil texture	pH	AEC (%)	OM (%)
Polluted	*Atriplex grifithii*	5.80	22.60	81.75** ± 5.07	Sandy Loam	8.55*± 0.05	2.4± 0.01	2.01 *±0.47
	Prosopis juliflora	58.50	522.0	540.80* ± 25.07	Sandy Loam	8.55*± 0.05	2.4± 0.01	2.01 *±0.47
Unpolluted	*Atriplex grifithii*	8.10	36.50	90.16 ± 4.94	Sandy Loam	7.38±0.09	2.27 ±0.02	3.33 ±027
	_*Prosopis juliflora*	61.50	558.0	587.43 ±28.10	Sandy Loam	7.38±0.09	2.27 ±0.02	3.33 ±0.27

Symbol used: ± Standard Error. AEC = Alkaline earth carbonate, OM= Organic matter
All values are mean of triplicates. *t*-test (two-tailed) of cement effluent polluted compared to unpolluted soil (**P*<0.05, ***P*<0.01).

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