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EFFECT OF INDUSTRIAL POLLUTION ON GERMINATION AND GROWTH OF *ZEA MAYS* L. AND *CYAMOPSIS TETRAGONOLOBA* L.

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ABSTRACT

Soil from Javedan Cement factory site and University of Karachi campus were collected to identify their role on the germination and growth of *Zea mays* L. and *Cyamopsis tetragonoloba* L. Soils from Cement factory site is considered as polluted while campus soil considered as control. Different concentrations (25, 50, 75 and 100%) are prepared for polluted soil and applied on selected plant species for determining their effects. Experiments were conducted on Petri dishes and pots and recorded their results separately. In Petri dishes experiments germination and seedling parameters of *Cyamopsis tetragonoloba* (guar) was increased as increasing the concentrations of treatment (25, 50 and 75%) but decreased at 100% concentration of cement containing soil. On the other hand *Zea mays* showed maximum germination and growth parameters on 50%. The results of pot experiments showed that *Cyamopsis* showed high rate of germination and seedling parameters on 25% concentration while on 100% concentrations it showed no growth. Almost similar results exhibited by *Zea mays* with some variation. Number of leaflets, Leaf dry weight (g), Leaf fresh weight (g) and Leaf area ratio of *Zea mays* (maize) showed high rate of germination and seedling length on 75% concentration of treatment. As contrast to *Cymopsis* this species (maize) showed poor growth and germination on 100% treatment concentration. Relationship between the control and different grades of polluted soils were sought to determine their effects on germination and seedling growth of two species.

KEYWORDS: Industrial pollution, Seed germination, Seedling growth, Polluted soil.

INTRODUCTION

Environmental contamination due to dust particle coming from Cement Industries, Coal Mining, Quarrying, Stone Crushing, Thermal Power Plant etc., has drawn attention of the environmental scientists as they pose threat to the ecosystem. According to Stern, (1976) cement industry plays a vital role in the imbalances the environment and produces air pollution hazards. The effects of cement factory kiln dust on natural vegetation as well as on cultivated plants have been investigated by Sheikh *et al*. (1976) and Iqbal and Shafiq, (2001). The problem of environmental pollutions have existed since long time and increasing rapidly as a result of unplanned industrialization, particularly in developing countries (Naheed *et al.,* 1986). The hazard of fast industrial growth is causing an enormous environmental pollution problem, affecting vegetation composition and soil characteristics of the area. Industrial pollution is caused by the discharges of varieties of industrial pollutants in the forms of gases, liquids and solids which affect the physical, chemical and biological conditions of the environment and are detrimental to human health, fauna, flora and soil properties (Dueck and Endenijk, 1987). The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, and nonpoint sources such as soluble salts (natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizers (Nriagu and Pacyna, 1988; McGrath *et al.,* 2001; Schalscha and Ahumada, 1998). The effect of such deposition affects the growth and biochemical characteristics of field crops has also been widely studied (Prasad and Inamadar, 1990). Due to polluted water, terrestrial and aquatic plants may absorb pollutants from water (as their main nutrients source) and pass them to the food chain (consumer animals and humans). Similarly plants may absorb soil contaminants and pass them to the food chain. Various kinds of industrial pollutants affecting the plants have been reported (Habib and Iqbal, 1996; Iqbal and Khalid, 1997). Soil contamination with heavy metals may also cause changes in the composition of soil microbial community, adversely affecting soil characteristics (Giller *et al.*, 1998; Kozdrój and van Elsas, 2001; Kurek and Bollag, 2004).

The chemical and physical analysis of the soil collected from the vicinity of the Javedan Cement Factory in Karachi was carried out and determine its effects on germination and seedling growth of two plants species and compare it with other two soils.

MATERIALS AND METHODS

Collection of soil samples: In this study, soils from Javedan cement factory site at Manghopir Road, Karachi and Campus soil (Control) was collected from the backside of Pharmacy Department, University of Karachi.

Soil concentrations preparation: We prepared different concentrations of polluted soil. For the preparation of 25% concentration, we use 25 g cement soil and add into 75 g control soil. For 50% concentration, we use 50 g cement soil and add into 50 g control soil and on similar manner prepare 75% concentration. For 100% concentration; we use only cement soil that means we did not add control soil in it.

Soil analysis: Following edaphic properties of all soils were analysed.

1. Soil pH: Soil pH was determined by direct pH meter (Model Adwa 1000, Hungary). Take 10 g of soil sample and dissolve in 50mL distilled water. Stir the solution for 10 minutes and filter it into a beaker and note the pH by using the pH meter.

2. Maximum water holding capacity (MWHC): Maximum water holding capacity was determined by the method of Keen (1931). Weight of empty tin cane was taken along with filter paper. Soil (100g) was added in tin cane and placed it in water bath. When soil became saturated then placed the tin cane on blotting paper in order to remove excessive water. Then weight of tin along with saturated soil was taken and placed it in oven at 80 ºC for 24 hours. After 24 hours, weight of dried soil was recorded.

$$\text{M.W.H.C}\ (\%) = \frac{\text{Weight of saturated soil} - \text{weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

3. Soil organic matter: Soil organic matter was determined following the method of Jackson (1958). Ten gram soil was taken in pre-weighted beaker. Hydrogen peroxide was added until the reaction stop and then placed the beaker on hot plate at 80^{o}C for 24 hours. After 24 hours the weight of the soil was taken.

$$\text{Organic matter}\ (\%) = \frac{\text{Weight of soil before heating} - \text{weight of soil after heating}}{\text{Weight of soil before heating}} \times 100$$

4. Electrical conductivity: Electrical conductivity (EC) of the soil samples was determined by digital conductivity meter (Model Adwa 1000, Hungary). 10g of sieve soil was dissolved in 50mL of distilled water and EC of suspension was measured.

5. Calcium carbonates: Calcium carbonate was determined by acid neutralization method (Qadir *et al.*, 1966).

$$\text{Calcium carbonate}\ (\%) = \frac{\text{weight of soil} - \text{weight of oven dried soil}}{\text{weight of soil}} \times 100$$

6. Bulk density: Bulk density of soil was estimated following the method described by Birkeland (1984); Cresswell and Hamilton (2002). The weight of empty specific gravity bottle (25mL) was taken. Filled the bottle with sieved soil and the weight was taken. Then soil was removed from bottle and water was added in it and cleaned the water from bottle's surface. Then weight of bottle along with water was taken.

$$\text{Bulk density}\ (\text{g/cm}^3) = \frac{\text{Dry soil weight (g)}}{\text{Soil volume (cm}^3)}$$

Seed germination and seedling growth in Petri dishes: Different solutions of cement soil samples were prepared i.e. 25, 50, 75 and 100% in Petri dishes. Add distilled water and 5mL of each dilution in each Petri dish and respective replicates of seeds of *C. tetragonoloba* (guar) and *Z. mays* (maize) sown in these Petri dishes. This diluted solution was changed after every 3 days and continued this process for at least 10 days. Then after 10 days, germination was recorded. Root length, shoot length and seedling length were also measured. For the estimation of biomass, root and shoot of all seeds were placed in an oven at 80^{o}C for 24 hours. After 24 hours, their oven dried weights were recorded.

Pot culture experiment: Similar dilutions (25, 50, 75 and 100%) of soils were also prepared in pots. Seeds of *C. tetragonoloba* and *Z. mays* were sown in these soil dilutions along with three replicates of each. After a month, the plants were harvested and leaflets quantity and leaf area were recorded. Lengths of roots, shoots and seedlings were measured. For the measurement of dry weight root, shoot and leaves of all plants placed in an oven at 80^{o}C for 24 hours. After 24 hours, the root, shoot, leaves and total plant dry weight were recorded. Root/shoot ratio and specific leaf area were calculated following the method described by Tony (1990), Westoby *et al.* (2000) and Khan (2008).

RESULTS

Cement containing soil showed greater values of all soil parameters except soil organic matter. Maximum water holding capacity (MWHC) of cement containing soil was 26.05% while 21.12% was exhibited by control (Table 1). Control showed high percentage of organic matter than cement factory site soil. The pH of control soil was slightly acidic (6.7) while polluted soil exhibited alkaline pH (9.5). Cement factory site soil showed grater values of bulk density, electrical conductivity and $CaCO_3$ than control (Table 1).

Table 1. Edaphic variables of cement factory site and control.

Samples	Maximum water holding capacity	Organic matter (%)	pH	Bulk density (g/cm^3)	Electrical conductivity (µS/cm)	Total dissolved solids	Calcium carbonate (%)
Cement soil	26.05 ± 0.14	0.63 ± 0.88	9.5 ± 0.01	1.31 ± 0.01	8.84 ± 0.07	0.442 ±	21.33 ± 0.33
Control	21.12 ± 0.11	1.30 ± 0.06	6.7 ± 0.00	0.82 ± 0.20	5.00 ± 0.01	0.25 ±	19.66 ± 0.33

Table 2. Effect of soils extract (cement factory site and control) on the germination and seedling growth (mean (%) ± SE) of the seeds of *C. tetragonoloba* and *Zea mays* in Petri dishes.

	Parameters	Control	25%	50%	75%	100%
Cyamopsis tetragonoloba				**Cement factory site soil**		
1.	Germination (%)	100 ± 0.0	88.88 ± 11.1	100 ± 0.0	100.00 ± 0.0	86.88 ± 11.1
2.	Root length (cm)	5.94 ± 1.38	17.33 ± 2.12	21.55 ± 1.75	23.61 ± 0.45	17.49 ± 3.83
3.	Shoot length (cm)	9.07 ± 1.44	7.05 ± 0.61	8.57 ± 0.04	7.86a ± 0.60	7.14 ± 0.93
4.	Seedling length (cm)	15.01 ± 2.57	24.38 ± 2.6	32.12 ± 1.79	31.47 ± 1.01	24.63 ± 4.75
5.	Oven dried weight (g)	0.07 ± 0.02	1.24 ± 0.00	1.31 ± 0.13	1.22 ± 0.03	1.15 ± 0.07
Zea mays				**Cement factory site soil**		
1.	Germination (%)	88.88 ± 11.11	86.88 ±19.24	100 ± 0.0	77.77 ± 38.49	73.77 ± 38.49
2.	Root length (cm)	7.77 ± 2.36	2.79 ± 0.98	7.37 ± 1.06	2.44 ± 1.69	5.55 ±4.8
3.	Shoot length (cm)	7.27 ± 2.03	6.77 ±1.18	12.39 ± 0.04	15.22 ± 1.08	8.91 ± 5.11
4.	Seedling length (cm)	15.05 ± 3.77	9.57 ± 1.37	19.77 ± 0.94	17.66 ± 16.16	14.46 ± 9.86
5.	Oven dried weight (g)	0.84 ± 0.25	0.03 ± 0.02	0.06 ± 0.05	0.05 ± 0.01	0.03 ± 0.04

Germination and seedling growth of *C. tetragonoloba* showed significant difference of all treatments (25, 50, 75 and 100%) on cement site soil extract when compared with control (Table 2). Root length was simultaneously increased from 25% to 75% and decreased at 100% treatments when compared with control. Whereas, shoot length, seedling length and oven dried weight was increased in 25 and 50% while decreased in 75 and 100% when compared with control. In *Z. mays*, there was also significant difference was observed in germination, root length, shoot length, seedling length and oven dried weight when compared with control (Table 2). On 50% concentration germination showed 100% output while on other concentration it showed lesser growth as compared to control. Root length found to be lesser growth as compare to control. Root length increased from 25 to 75% while decreased at 100% concentration of soil containing soil. Oven dried weight was significantly lesser as compare to control. Seedling length was increased from 25 to 50% while decreased on 75% and 100% when compared with control.

Cyamopsis tetragonoloba showed significant difference in all treatments (25, 50, 75 and 100%) of cement containing soil extract when compared with control (Table 3). Root length, shoot length, seedling length, number of leaflets, leaf area, root dry weight, shoot dry weight, leaf dry weight and total plant dry weight was decreased from 25 to 75% and on 100% it showed zero growth and germination when compared with control. Root shoots ratio, leaf fresh weight, leaf area ratio and specific leaf area increased from 25 to 50% while decreased at 75%.

Z. mays also showed significant differences in all growth parameters and even on 100% concentration of cement containing soil showed some growth. Shoot length of *Z. mays* showed particular trend of decrease from 25 to 100% concentration of cement soil extract when compared with control (Table 3) while other parameters did not show such type of trend. Most of the growth parameters showed highest value on 25 and 75% concentration of cement soil extracts. The growth and germination drastically lower on 50% concentration of cement containing soil extracts. All the growth parameters are lesser on 100% when compare with control.

DISCUSSION

Different parameters of polluted soil and control soil were recorded which are maximum water holding capacity, organic matter, pH, bulk density, electrical conductivity and calcium carbonates. High values of all parameters were recorded in polluted soils except organic matter value than control soil. Soil having high maximum water holding capacity, alkaline pH, bulk density, electrical conductivity and calcium carbonates reduce the growth of plants and do not promote or supports their growth. Cement industry plays a vital role in the imbalances of the environment by producing toxic substances (Sakalauskaite *et al*., 2009). High concentration of cement containing soil is not favourable for the growth of *Cyamopsis tetragonoloba*, may be this species could not grow on basic soil and could be grow on neutral medium. On this toxic concentration *Z. mays* showed some growth, could be due to its tolerance power. It is evident that some plant species showed susceptibility to cement dust and could not grow better while some exhibited tolerance and grow in proper way. Cement manufacturing plants produce toxic compounds such as Cu, beryllium, fluoride, Mg, H_2SO_4, lead, zinc, and HCl (Andrzej, 1987). Dust ranging from 1 to 48 g/m^2 day $^{-1}$ falling on the soil caused a shift in pH to the alkaline side (Ellis, 1966). The pH of soil was high because of high calcium carbonates which turn the pH of soil towards the alkalinity, the pH gradually increased due to the effects of cement when compared to control soil.

The alkalinity of cement soil reduces the absorption of mineral substances from the soil and it causes changes in the plant's morphology and physiology. The ability of plants to absorb nutrients will be decreased when alkaline soil have high amount of Calcium content (Mandre, 1995). Studies of the effects of cement-kiln dust deposited on the soils also raised questions. Some investigators reported no harmful effects of cement at levels from 1.5 to 7.5 g/m^2 /day, while others reported that concentrations from 1.0 to 48 g/m^2 /day caused shifts in the soil alkalinity which may be favourable to one crop but harmful to others (Lerman and Darley, 1975) as proved in the current study.

The growth of *C. tetragonoloba* was highly decreased in cement soil which might be due to the presence of high amount of calcium in alkaline pH because it is more sensitive to grow than *Z. mays*. It grown at both soils i.e. cement factory soil and campus soil. It might be due to that, cement soil was reported to release some essential plant nutrients and improve soil aggregation and soil water retention (Ahuja and Swatzendraber, 1972) when incorporated to the control soil. So, *Z. mays* are less sensitive to high amount of calcium carbonate in alkaline pH than *C. tetragonoloba.* Salts in soil can also decreased the productivity of plants. Excess soluble salts in the root zone restrict plant roots from withdrawing water from the surrounding soil, reducing the plant available water (Bauder and Brock, 2001).

Current study revealed that plants growth was found to be affected by cement dust, which might be due to the presence of different toxic pollutants in cement dust. The growth of *C. tetragonoloba* was found to be highly affected as compared to *Z.mays*. Shah *et al.* (1989) and Oyedele *et al.* (1991) suggested that cement dust pollution is an operative ecological factor causing hazardous effects in our environment. The results give a particular effect of polluted soils on the germination and seedlings growth of both the species and showed variable response.

Table 3. Effect of soils extracts (cement factory site and control) on the germination and seedling growth (mean (%) ± SE) of *Cyamopsis tetragonoloba* and *Zea mays* in pots.

S. No.	Treatments	Control	25%	50%	75%	100%
			Cement factory site soil			
	Cyamopsis tetragonoloba					
1.	Root length (cm)	12.16 ± 3.08	12.9 ±1.32	7.03 ± 2.25	5.10 ± 2.69	0.00 ± 0.00
2.	Shoot length (cm)	13.98 ± 0.91	18.98 ± 0.54	12.69 ± 2.50	8.04 ± 4.02	0.00 ± 0.00
3.	Seedling length (cm)	26.16 ± 3.95	31.87 ± 1.79	19.73 ± 4.63	13.15 ± 6.62	0.00 ± 0.00
4.	No of leaflets	8.00 ± 0.57	11.33 ± 1.20	6.66 ± 0.88	6.33 ± 3.48a	0.00 ± 0.00
5.	Leaf area (cm^2)	1.59 ± 0.14	3.20 ± 0.51	2.41 ± 1.21	1.36 ± 0.70	0.00 ± 0.00
6.	Root dry weight (g)	0.04 ± 0.01	0.03 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.00 ± 0.00
7.	Shoot dry weight (g)	0.22 ± 0.17	0.07 ± 0.01	0.07 ± 0.01	0.02 ± 0.01	0.00 ± 0.00
8.	Leaf dry weight (g)	0.48 ± 0.04	0.06 ± 0.00	0.03 ± 0.01	0.03 ± 0.01	0.00 ± 0.00
9.	Total plant dry weight (g)	0.7 ± 0.21	0.16 ± 0.01	0.07 ± 0.03	0.07 ± 0.03	0.00 ± 0.00
10.	Root shoot ratio	0.49 ± 0.32	0.44 ± 0.16	0.26 ± 0.14	0.46 ± 0.29	0.00 ± 0.00
11.	Leaf fresh weight (g)	0.70 ± 0.12	0.39 ± 0.04	0.43 ± 0.03	0.33 ± 0.17	0.00 ± 0.00
12.	Leaf area ratio	2.45 ± 0.60	19.91 ± 3.94	35.00 ± 2.51	13.10 ± 7.50	0.00 ± 0.00
13.	Specific leaf area (cm^2/g)	3.36 ± 0.43	41.42± 19.36	80.83 ±0.83b	25.26 ± 13.63	0.00 ± 0.00
	Zea mays					
1.	Root length (cm)	22.45 ± 0.99	38.26 ± 3.58	18.33 ± 9.19	22.13 ± 3.28	5.20 ± 5.20
2.	Shoot length (cm)	10.51 ± 0.47	10.75 ± 0.35	7.50 ± 3.78	7.50 ± 3.78	3.10 ± 3.10
3.	Seedling length (cm)	32.96 ± 1.4b	49.01 ± 3.93	25.88 ± 12.98	33.61 ± 3.58	8.30 ± 8.30
4.	No of leaflets	7.00 ± 0.00	6.33 ± 0.66	7.00 ± 3.60	7.33 ± 1.20	2.33 ± 2.33
5.	Leaf area (cm^2)	15.98 ± 0.86	22.37 ± 1.33	12.39 ± 6.19	22.85 ± 2.88	3.99 ± 3.99
6.	Root dry weight (g)	0.31 ± 0.04	0.44 ± 0.07	0.13 ± 0.06	0.18 ± 0.01	0.05 ± 0.05
7.	Shoot dry weight (g)	0.14 ± 0.02	0.15 ± 0.01	0.10 ± 0.05	0.14 ± 0.00	0.02 ± 0.02
8.	Leaf dry weight (g)	0.22 ± 0.01	0.26 ± 0.03	0.22 ± 0.11	0.27 ± 0.01	0.08 ± 0.08
9.	Total plant dry weight (g)	0.65 ± 0.10	0.85 ± 0.04	0.45 ± 0.22	0.60 ± 0.03	0.16 ± 0.16
10.	Root shoot ratio	2.21 ± 0.34	3.05 ± 0.68	0.92 ± 0.52	1.26 ± 0.06	0.70 ± 0.70
11.	Leaf fresh weight (g)	0.35 ± 0.04	0.30 ± 0.04	0.32 ± 0.16	0.44 ± 0.00	0.16 ± 0.16
12.	Leaf area ratio	25.48 ± 4.19	26.31 ± 1.6a	18.56 ± 9.46	38.07 ± 5.79	7.99 ± 7.99
13.	Specific leaf area (cm^2/g)	70.80 ± 3.56	90.14 ± 17.6	38.37 ± 20.17	84.41 ± 12.96	15.98 ± 15.98

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