WITH THE NAME OF

ALLAH

THE MOST BENEFICIENT AND THE MOST MERCIFUL

INVESTIGATION INTO THE

EFFECTS OF AUTOMOBILE POLLUTANTS ON GROWTH AND METAL CONTENTS OF SOME ROADSIDE PLANTS

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INVESTIGATION INTO THE

EFFECTS OF AUTOMOBILE POLLUTANTS ON GROWTH AND METAL CONTENTS OF SOME ROADSIDE PLANTS

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Dedicated to
my supervisor
Prof. Dr. M. Zafar Iqbal,
my parents and family
for
inspiration and
encouragement

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خلاصہ

کراچی کی آلودہ فضا میں *السٹونیا اسکالرس*، *بوگیمیا پینیٹا*، *کیشیا سمیا* اور *پیلٹوفورم ٹیروکارپم* کی نشو ونما واضح طور پر متاثر ہوئی ہے۔ جامعہ کراچی کے مقابلے میں دہ پودے جو گلشن اقبال، ناظم آباد، شاہراہِ فیصل اور محمد علی جناح روڈ پر اُگے ہوئے تھے آلودگی سے زیادہ متاثر ہوئے۔ *السٹونیا اسکالرس* پتیوں کی لمبائی موسم گرما میں محمد علی جناح روڈ پر شاہراہِ فیصل، ناظم آباد، گلشن اقبال اور جامعہ کراچی کی نسبت سب سے کم پائی گئی۔ *بوگیمیا پینیٹا* اور *کیشیا سمیا* پودوں کے پتوں کی چوڑائی اور جسامت موسم خزاں میں، محمد علی جناح روڈ پر جامعہ کراچی کے مقابلے میں متاثر کن ($p < 0.05$) طور پر کم ہوئی۔ اس ہی طرح *پیلٹوفورم ٹیروکارپم* کے پتوں کی جسامت موسم سرما میں محمد علی جناح روڈ پر دیگر کم آلودہ علاقوں کے مقابلے میں نمایاں طور پر کم ہوئی۔

گاڑیوں سے نکلنے والے دھوئیں نے *پیلٹوفورم ٹیروکارپم* اور *کیشیا سمیا* کے بیجوں کی تنبت اور نوخیز پودوں کی بالیدگی پر مضر اثرات مرتب کئے۔ *پیلٹوفورم ٹیروکارپم* اور *کیشیا سمیا* کے بیجوں کو شہر کی مصروف شاہراؤں پر اُگنے والے درختوں سے حاصل کرنے کے بعد جب اُگایا گیا تو ان کے اُگنے کی فیصد شرح میں نمایاں طور پر کمی واقع ہوئی اور اِن آلودہ بیجوں سے حاصل نوخیز پودوں کا خشک وزن بھی کم پایا گیا۔ *کیشیا سمیا* کے بیجوں کو جو کہ آلودہ علاقوں سے حاصل کئے گئے تھے کو جب گملوں میں اگایا گیا تو ان کی تنبت اور نوخیز پودوں کی بالیدگی جامعہ کراچی میں اگنے والے پودوں سے حاصل کردہ بیجوں کے مقابلے میں بُری طرح متاثر پائی گئی۔

پیلٹوفورم ٹیروکارپم، *کیشیا سمیا* اور *لیوسینیا لیوکوسیفیلا* کے بیجوں پر سیسہ اور کیڈمیم کی ٹریٹمنٹ سے مضر اثرات مرتب ہوئے۔ سیسہ کی ۵۰ پی پی ایم ٹریٹمنٹ نے *پیلٹوفورم ٹیروکارپم* اور *کیشیا سمیا* کے بیجوں سے اُگنے والی جڑوں کی لمبائی کو واضح ($p < 0.05$) متاثر کیا۔ اس ہی طرح ۲۵ پی پی ایم سیسہ کی ٹریٹمنٹ سے *پیلٹوفورم ٹیروکارپم* کے نوخیز پودوں کا خشک وزن واضح طور ($p < 0.05$) پر کم ہوا۔

کیڈمیم کے ۵۰ پی پی ایم ٹریٹمنٹ سے *لیوسینیا لیوکوسیفیلا* اور *پیلٹوفورم ٹیروکارپم* کے بیجوں کی تنبت کنٹرول کے مقابلہ میں موثر طور ($p < 0.05$) پر کم ہوئی۔ ۵۰ پی پی ایم کیڈمیم کی ٹریٹمنٹ سے *کیشیا سمیا* کے بیجوں کی نمو سے حاصل شدہ نوخیز پودوں کی جڑوں کی لمبائی اور خشک وزن بمقابلہ کنٹرول کے واضح طور پر ($p < 0.05$) پر کم ہوئی۔

وہ تمام پودے (*السٹونیا اسکالرس*، *پونگیمیا پنیٹا*، *کیشیا سمیا* اور *پیلٹوفورم ٹیروکارپم*) جو شہر کی مصروف سڑکوں کے ساتھ اُگ رہے تھے اُن میں سیسہ اور کیڈمیم کی مقدار واضح طور پر زیادہ پائی گئی۔ اُن تمام درختوں کی پتیوں میں جو کہ محمد علی جناح روڈ پر اُگ رہے تھے ان میں سیسہ اور کیڈمیم کی مقدار شاہراہِ فیصل، ناظم آباد، گلشن اقبال اور جامعہ کراچی کے مقابلے میں زیادہ پائی گئی۔ سیسہ اور کیڈمیم کا *السٹونیا اسکالرس* اور *پونگیمیا پنیٹا* میں زیادہ مقدار میں پایا جانا غالباً اس کی پتیوں کے بڑے رقبہ کی وجہ سے ہے۔

موجودہ تحقیق سے یہ بات واضح ہوئی کہ *پیلٹوفورم ٹیروکارپم* پودے پر آلودگی کے اثرات دیگر تحقیق کردہ پودوں کے مقابلے میں کم ہوئے۔ لہٰذا یہ مناسب ہوگا کہ مستقبل میں شہر کی مصروف سڑکوں پر اس پودے کو ترجیحاً اگایا جائے۔

ABSTRACT

ABSRACT

The phenology of *Alstonia scholaris*, *Pongamia pinnata*, *Cassia siamea* and *Peltophorum pterocarpum* was significantly ($p<0.05$) affected in the Karachi city polluted environment. Plants were more affected to pollutants at Gulshan-e-Iqbal, Nazimabad, Shahrah-e-Faisal and M.A. Jinnah Road as compared to Karachi University Campus. Leaf length, width and area of *A. scholaris* were found lowest in summer at M.A. Jinnah Road as compared to Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus, respectively. Leaf length and area of *P. pinnata* were significantly ($p<0.05$) reduced in autumn at the highly polluted sites of M.A. Jinnah Road as compared to Karachi University Campus. Leaf width and area of *C. siamea* were significantly ($p<0.05$) reduced in autumn at the highly polluted sites of M.A. Jinnah Road as compared to Karachi University Campus. Leaflet length of *P. pterocarpum* was also found significantly ($p<0.05$) reduced at M.A. Jinnah road in winter as compared to other less polluted sites of the city.

Autoemission showed toxic effect on seed germination and seedling growth of plants. The seeds of *P. pterocarpum* and *C. siamea* collected from the trees growing along the busy roads of the city showed low percentage of germination. Seedling dry weight of the plants also decreased significantly ($p<0.05$). In pot experiments, the seed germination and seedling growth of *C. siamea* was badly affected in seeds collected from the polluted areas of the city as compared to Karachi University Campus.

Lead and cadmium treatment produced toxic effects on seed germination and seedling growth of *Peltophorum pterocarpum* and *Leucaena leucocephala*. Root length of *L. leucocephala* and *P. pterocarpum* was significantly ($p<0.05$) reduced at 50 ppm treatment of lead. The treatment of Pb at 25 ppm suppressed the seedling dry weight of *P. pterocarpum*. Cadmium treatment of 50 ppm produced significant ($p<0.05$) effects on seed germination of *L. leucocephala* as compared to control. The seed germination, seedling length and dry weight of *C. siamea* were significantly affected by 25 ppm cadmium treatments as compared to control.

The trees of all species (*A. scholaris*, *P. pinnata*, *C. siamea* and *P. pterocarpum)* growing along the busy roads of the city showed significantly higher concentration of Pb and Cd. The concentration of Pb and Cd in leaves of all the species was quite high at M.A. Jinnah road as compared to Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus. Higher level of Pb and Cd in leaves of *A. scholaris* and *P. pinnata* might be due to the large surface area that is available for exposure to any pollutant as compared to *C. siamea* and *P. pterocarpum*. Low vehicular traffic activities at the campus showed lowest Pb and Cd contents for all the tree species investigated.

In this study, *Peltophorum pterocarpum* was found less affected to automobile pollution of the city as compared to other species. It is therefore suggested that *P. pterocarpum* should be given more preference for future plantation in the city areas, particularly along the roads.

INTRODUCTION

INTRODUCTION

Karachi city, the 25th largest city of the world, with a population of 10 million people demands a large transport system to serve as the means for carrying people and goods from one place to another. The buses and minibuses are the primary modes of conveyance, which carry an estimated 70% of the passenger traffic. According to Karachi Traffic Engineering Bureau, the total number of all types of motor vehicles on the road of Karachi were estimated to be 930,000 in 1997, which amounts to over 30% of all the vehicles in the country (Ghauri *et. al.*, 1999). The traffic system in the city is not only noisy but also producing hazardous environmental effects on plants. Most of the automobiles emit black smoke due to incomplete combustion of fuel. These toxic materials such as carbon particles, unburned and partially burned hydrocarbons, fuels, tar materials, lead compounds and other elements which are the constituents of petrol and lubricating oils deposit on the surface of plants. These pollutants in combinations cause greater or synergistic effects to plants (Qadir & Iqbal, 1991).

Trees in cities face a severe limitation of plantable space and an exceptionally stressful growing environment such as air pollution, environmental degradation, pressure for land space, traffic congestion, destruction of trees and green areas to accommodate urban development which suppresses performance and shorten life span (Gilbertson &

Bradshaw, 1985; Jehan & Iqbal, 1992; Sawidis, *et al.*, 1995; Jim, 1996,1997,1998; Webb, 1998). The phenological observation for woody ornamentals plants in urban environment of Athens city, showed reduction in the shoot diameter and total leaf area upto 60% due to high burden of lead pollution (Chronopoulos *et al.*, 1996). The pollutants emitted from the autoexhaust not only adversely affect the metabolic processes in growing plants, but also the germinability of seeds (Guderian, 1977; Wong *et al.*, 1984; Türkan, 1988; Mehmood & Iqbal, 1989; Qadir & Iqbal, 1991).

There are about 50 metals that are of special interest with respect to the toxicological importance to human health, plants and animals (Burhan *et al.*, 2001). Metals exert toxic effects on plants if they enter into biochemical reactions. Unlike many organic chemicals, metals can not be broken down into less toxic components. Lead and cadmium are the toxic elements of primary importance in ecotoxicology (Breckle & Kahile, 1992).

Lead is one of the best known heavy trace elements, with a long history of toxicity. Its exposure is becoming a great concern because of its toxic nature, wide spread occurrence and long life in biological system. It is the metallic element of group IV elements. Its Latin name is plumbum. The atomic number of lead is 82. Pure lead is a soft, low melting metal which, when freshly cut, has a silvery luster that rapidly dulls and turns blue grey on exposure to air. The major sources of lead available to plants has been the soil usually derived from weathered bedrock, parents material from lead mine, smelting operations, use of lead arsenate, use of tetraethyl and tetramethyl lead as antiknocks additive to petrol (Foy *et al.*, 1978).

Lead is a toxic element that human economic activity has been releasing into the atmosphere for the last 70 years (Antosiewicz & Wierzbicka, 1999). Inhibition to germination and retardation of plant growth are commonly reported effects due to lead toxicity (Morzeck & Funicelli, 1982; Wierzbicka & Obidzinska, 1998; Iqbal & Siddiqui, 1992). Kalimuthu & Siva (1990) found reduction in seed germination in *Zea mays* (Maize) when treated with heavy metals (lead acetate and mercuric chloride 20, 50, 100 and 200 μg^{-ml}). Foliar application of lead nitrate solution resulted in a reduction in various growth indices and yield parameters of wheat (Rashid & Mukherji, 1993).

Cadmium is a transitional metal and an element of II-B group in periodic table. Its atomic number is 48. Cadmium is a relatively volatile element and reacts readily with non-oxidizing acids, releasing hydrogen and giving the divalent ions. It reacts readily when heated with oxygen, to produce the oxides. Cadmium in the form of cadmium sulfate is available in the environment and geochemically is quite mobile in soil, water and thus freely taken up by plants. Cadmium is also one of the metals highly dispersed by human activities (Kabata-Pendias & Dudka, 1990).

Many research workers have drawn their attention on the toxic effects of cadmium on plant growth. Seedling length of *Dalbergia sissoo* Roxb., showed a significant reduction with increase in concentration of cadmium (Iqbal & Mehmood, 1991). Cadmium chloride at 2 mM significantly ($p<0.05$) reduced the seed germination of rice (*Oryza sativa* L. cv-Al-Ahssa) (Al-Helal, 1995). Cadmium chloride treatment at 400 ppm has induced extremely severe effects on seed germination and seedling growth of *Parkinsonia aculeata L.*, and *Pennisetum americanum* (L.) Schumann (Shaukat *et al.*, 1999).

Uptake and accumulation of elements in plants may follow two different paths, i.e., the root system and the foliar surface (Sawidis, *et al.*, 2001). Contamination of vegetation by airborne lead, cadmium, copper and nickel in urban areas is mainly by aerial deposition from motor vehicle exhaust (Burton & John, 1977). High level of lead was found in sweet corn plants (Ward *et al.*, 1975), roadside plants and crops (Albasel & Cottenie, 1985) along the highways. Increased fallout of different types of metals from vehicles in Karachi city is increasing day by day. Considerable higher levels of Pb, Cu and Zn have been recorded in some of the stands, where *Suaeda fruticosa* (L.) Forssk., and *Salsola baryosma* (R. & S.) Dandy, have been associated with *Prosopis juliflora* Swartz, along the super highways (Iqbal *et al.*, 1998).

The aim of the present research was to investigate the effects of automobile pollutants on plant growth and seed germination. Effects of lead and cadmium on seed germination were also studied alongwith the analysis of lead and cadmium in the foliage of some important plants growing in different areas of the city of Karachi, Pakistan.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Effects of autoemission on growth of plants

Bhatti & Iqbal, (1988) have found that the phenology and productivity of *Ficus bengalensis* L., and *Eucalyptus* sp., was highly affected due to automobile exhausts. They have also concluded that the automobile emission significantly reduced the productivity, leaf area and leaf dry weight of *Guaiacum officinale* L., *F. bengalensis* and *Eucalyptus* sp., at the polluted sites of the city of Karachi as compared to control. Abdullah & Iqbal, (1991) found stomatal clogging in relation to automobile particulate matters and found 81% clogged stomata in *Polyalthia longifolia* Bth. & Hk. f., at Gruminder site in Karachi city. A significant ($p<0.05$) decline in leaf area, fresh and dry weight and moisture content of the roadside plant, *Bougainvillea spectibilis* Willd, was observed by Hussain *et al.*, (1997).

Alam & Ahmad, (1998) investigated the effect of environmental pollution on the phenological behavior of *Croton bonplandianuum* populations. The vegetative, flowering and fruiting period of the two populations was studied and it was observed that the periodic life cycles of the railway yard population at Patna junction (India) were shorter than the field population. The plants were growing in adverse biotic conditions and the environmental factors played a major role in disturbing the phenolgical behavior of both the populations.

Effects of autoemission on seed germination and seedling growth

The seeds of *Albizia lebbeck* (L.) Bth., and *Dalbergia sissoo* Roxb., collected from different polluted areas of the city showed significant reduction in germination as compared to seeds collected from the less polluted areas (Mehmood & Iqbal, 1989).

Growth of *Pongamia pinnata* (L.) Merrill and *Albizia lebbeck* (L.) Bth., was significantly decreased in seedlings raised from the polluted seeds as compared to control (Qadir & Iqbal, 1991). Significant reduction was also observed in shoot height of the polluted seedlings of *P. pinnata* (49.16%) and *A. lebbeck* (23.27%).

Siddiqui & Iqbal (1994) investigated the effect of automobile pollution on seedling growth of some roadside species (*Cassia surattensis* Burm F., *Leucaena leucocephala* (Lam.) de-Wit, *Parkinsonia aculeata* L., *Sesbania sesban* (L.) Merill. The seeds of most of the species collected from the polluted areas showed significant reduction in germination as compared to control. The percentage reduction in dry biomass for *C. surattensis*, *P. aculeata* and *S. sesban* was decreased significantly in seedlings raised from the polluted seeds as compared to control. The significant reduction was observed in shoot height, number of leaves and circumference of polluted seedlings. In growth experiment, *L. leucocephala* was found less affected by automobile pollution as compared to other species.

Effects of lead and cadmium on seed germination and growth of plants

Mathur *et al.*, (1987) have found that higher concentration of Cd and Cr (100-250 ppm) affected germination and early growth performance of *Allium cepa*. Seed germination of red spruce (*Picea rubens* Sarg.), balsam fir (*Abies balsamea* L.), yellow birch (*Betula alleghaniensis* Britt.) and paper birch (*Betula papyrifera* Marsh) was evaluated under laboratory conditions at pH 3,4 and 5 with and without phytotoxic metal ions (Al at 10 and 100 mg/l, Cd at 1 mg/l, Cu at 5 and 10 mg/l, Pb at 5 and 20 mg/l or Zn at 5 and 10 mg/l). Germination of the tested species was not affected by acidity and metal treatment (Scherbatskoy *et al.*, 1987).

Seedling lengths of *Leucaenea leucocephala* (Lam.) de-wit and *Dalbergia sissoo* Roxb., was significantly reduced with increase in concentration of cadmium solution (Iqbal & Mehmood, 1991). *D. sissoo* showed most dismal germination as compared to other species. Seedling length of *D. sissoo* showed gradual decrease with an increase in concentration of cadmium. The dry biomass of the above species also showed significant reduction with increasing concentration of cadmium.

The influence of different concentrations of heavy metals viz., cadmium, cobalt, copper, iron, mercury, manganese and zinc on pollen germination and tube growth of *Lilium longiflorum* (Thunb.) was investigated by using light microscopy (Sawidis & Reiss, 1995). Heavy metals were added as chloride salts to the medium. Cd^{+2} was the only metal, which produced toxic effects at the intracellular level: organelle distribution within the tip region appeared disorganized. Cadmium treatment with 3 μM showed swelling and reduction of the pollen tuble length at tip region. Therefore it was concluded, that at least in regions of high pollution, pollen tubes which are exposed to higher concentrations of heavy metals might influence higher plant reproduction.

The effects of Zn, Cd, Cu and Hg on the soluble protein bands and growth of the plumule and radicle during germination in lentil seeds, *Lens esculenta* L. (Fabaceae) were investigated (Ayaz & Kadioglu, 1997). The percentage of seed germinating and the lengths of plumule gradually decreased with higher concentration of 50 mg/l Cd $(NO3)_{2.}$

The effect of cadmium on the growth of Cauliflower (*Brassica oleracea* var. botrytis was examined (Hasegawa *et al.*, 1997). Cauliflower showed tolerance with 25 mM $CdCl_2$ treatment for eight days, but killed by 50 mM concentrations. Seedlings of tomato plants grown in soil in pots, treated with lead nitrate solution at 500 and 1000 ppm showed pronounced effect in the root system as compared to leaves and stem (Jaffer *et al.*, 1999). The roots were considerably short and brown at 1000 ppm treatment.

Toxic effects of heavy metals viz., lead, chromium and cadmium on germination, seedling growth, dry biomass accumulation and phenolic contents of *Pennisetum americanum* (L.) Schumann, and *Parkinsonia aculeata* L., have been reported (Shaukat *et al.*, 1999). Final germination percentage was greatly reduced by cadmium, chromium and lead salts of 50 ppm concentration or more. *P. aculeata* was less affected in terms of germination, root and shoot growth and dry matter accumulation as compared to *P. americanum*, exhibiting some degree of tolerance to heavy metals.

Heavy metal accumulation in plants, soil and atmosphere

Page and Ganje, (1970) demonstrated that lead accumulations in and on plants next to highways in Southern California were caused mainly by aerial deposition. Hampp (1974) found *Acer platanoides* as an indicator of the traffic caused lead pollution in the city limits of Munich, when the air borne lead on the leaves of trees and hedges in an urban environment increased with high traffic densities.

It has been known for many years that dust and soils may contain high concentrations of lead. Lead concentrations up to several thousands parts per million in street dirt and soils are frequently found in urban areas or near certain types of industry (Barltrop *et al.*, 1974). Lepow *et al.*, (1974) reported that urban household dust from a group of homes in Hartford, Connecticut, contained 11 000 ppm lead. The contamination of plants by air borne lead residue from motor car exhausts depends on the density of traffic, the distance from road and the season (Horak *et al.*, 1976). Lead levels of the vegetation showed a decrease in early spring, remained fairly constant from May to July and began to increase again in August. Highest lead contents were in the plant samples collected during the winter months.

Presence of lead and cadmium in the needles of *Picea excelsa* were determined by atomic absorption spectrophotometer (Mankovska, 1978).

The contents of Pb were 10-100 times higher than that of Cd and 11-17 times higher as compared to localities without air pollution. A survey was made for the accumulation of Pb from motor vehicle exhaust on soils and trees growing along a busy area of Baroda city, India. Plant and soils near the roadside had a higher concentration of Pb than at a distance of 4-6 meters. A good correlation existed between traffic volume, total and extractable soil Pb and Pb content of roots and shoots of the grass *Cynodon dactylon* in roadside of Delhi (Dutta & Mookerjee, 1981). An enhancement of lead in the levels was found in roadside soil and vegetation due to combustion of leaded petrol by automobile exhaust in Baghdad city (Khalid *et al.*, 1981). Kovacs *et al.*, (1981) monitored the heavy metal content, including Pb, Cu and Zn, in leaves of three tree species in urban and rural environments in Budapest. They reported that the leaves accumulate various heavy metals in quantities 1.2 to 9 times higher in an urban than a rural environment. A survey for lead pollution was carried out in Baghdad city (Hanna & Al-Bassam, 1983). Palm leaves, which were collected from 25 different sites of the city, showed a relative increase of Pb deposition due to vehicles using leaded petrol.

Concentration of airborne Cd, Pb and Zn were determined at one urban site and two rural sites in northwestern England over 24 Hours and 7 days sampling period (Harrison & Williams, 1982). At all sites, Cd originated entirely from regional pollutant transport, but Pb, and to a lesser extent Zn arose from local vehicular sources at the urban sites and regional transport at the rural sites.

In the New Jersey Agricultural experiment Station laboratory there has been a continuing interest in the heavy metal content of roadside trees. In support of the hypothesis that trees might serve as an effective sink for undesirable pollutants, measurements have been made of the heavy metal content of foliage in eight tree species growing adjacent to roadways where traffic volume ranged from <25 to 60,000 vehicles/24h (Kazmir *et al.*, 1982). Research projects concerned with levels of lead in city soils and vegetables were carried out in the greater London area (Davies & Peters, 1983). The probability of finding land uncontaminated by lead decreased towards Central London, and that 40% of land in central or inner London was found unsuitable for vegetable cultivation.

A survey of the contribution of city buses to the total emission of gases and particulate pollutants in Jerusalem showed that buses are one of the main sources of NO_X and particulate matter (Luria *et al.*, 1984).

A systematic study carried out on vegetables and other agricultural products used as food suggests a tentative classification of products exposed to roadside Pb pollution from automobile exhausts (Favretto, 1984). It was found that Pb contents decreased with distance from the source. Similarly, the distribution pattern of lead in the leaves of Banyan tree (*Ficus bengalensis*) L. from different traffic density regions of Calcutta was carried out (Datta & Ghosh, 1985). In high and medium traffic density regions, Pb content of leaves was high in winter than in summer months. Such changes due to seasonal variations were not marked in low and zero traffic density areas.

An ecological survey was conducted on the roadside vegetation at three different sites, Tai Po, a commercial and residential area, and Shek O and Wu Kai Sha, recreational areas (Wong & Lau, 1985). *Cynodon dactylon* (L.) Pers. and *Eleusine indica* (L.) Gaertn., were the two most dominant species. The Tai Po site had higher Pb contents in both soil and plant followed by Shek and than Wu Kai Sha.

Nasralla & Ali (1985) found accumulation of Pb in different parts of vegetables growing around six Egyptian traffic roads. Leafy vegetables such as lettuce and cabbage accumulated lead up to 78.4 ppm in their edible portions, with lowest Pb accumulation in carrot and radish. These findings suggested that Pb was accumulated in plants through both foliage and root systems, but lead absorption though foliage was more pronounced at locations close to the emissions source of Pb vapor and fine particles.

Tam *et al.,* (1987) studied metal contamination of *Bahunia variegata* leaves, surface soil and dust collected in urban park, near roadside in Hong Kong: results of their comparisons for unwashed and washed leaves suggested that main source of Pb pollutants was aerial deposition from the vehicles.

Yousafzai (1991) found the level of Pb (810-4527 ppm) and Cd (0.2-4.5 ppm) in the street dust of metropolitan city of Karachi and concluded that Pb in roadside dust of Karachi city was mostly attributed by leaded gasoline from vehicular traffic. Kartal *et al.,* (1992) studied Pb, Ni, Cd and Zn pollution of traffic in Kayseri (Turkey). A good correlation between the number of cars and the heavy metal contents was found.

Al-Saleh & Taylor, (1994) determined the concentration of lead in the atmosphere and soil at 13 locations in the city of Riyadh during the working days (Saturday and Wednesday) and found that lead concentration in the atmosphere and soil was significantly higher in areas where the traffic density was consistently high than non residential areas. There was a significant relationship between the concentrations of airborne and soil lead.

A survey of 136 topsoil and plant samples were taken in urban and suburban areas to determined the levels and sources of soil and plant contamination by Cd, Cu, Cr, Ni, Pb, Zn, metal contents and polycyclic aromatic hydrocarbons (Sànka *et al.,* 1995). Significant difference was found between the level of pollution in urban and suburban areas particularly, for Pb, Cr and Ni in plants. Traffic was found to be the major source of Pb, Zn and Cu in the urban areas.

The main pollution sources in Thessaloniki (Greece) was characterized due to automobile exhausts, central heating installations and petrochemical and other heavy and light industries (Sawidis *et al.*, 1995a). Concentrations of heavy metals (Pb and Cd) in lichens species were found quite high in the above city. A comparison of the sampling sites from the city centre showed that in the city of Thessaloniki, the lichens accumulate much greater amounts of heavy metals than in the other regions. Concentrations of lead (144.3 μg^{-g}) and cadmium (1.4 μg^{-g}) was found quite high in *Lecanora muralis* and *Neophyscelia pulla,* respectively. These results showed that lichens are more reliable indicators in ecological monitoring of the environment.

The air pollution of the city of Thessaloniki (Greece) was studied, using park trees as biomonitors (Sawidis, *et al.*, 1995b). 14.5 mg^{-kg} Pb was found in the leaves of *Populus alba* L. (white poplar) collected from near the railway station.

The lead levels in washed leaf samples of *Phoenix dactylifera* (L.) showed slight differences between urban, urban roadside, urban park, suburban sites, but Pb content was higher than that found in the rural area (Aksoy & Öztürk, 1996). The concentrations of Pb, Cu, Fe and Mn were analyzed in the surface deposit and tissue of Holly Oak (*Quercus ilex* L.) leaves from several sites of the urban area of Naples exposed to different degrees of air pollution (Alfani *et al.*, 1996). These included some major roads with heavy traffic loads, squares and three urban parks. The soil from the trunk base area of *Q. ilex* trees in the same sites was also analyzed for total and available metal contents. The Pb content was higher in the leaf surface deposit than in the leaf tissue. Total Pb contents in soil was in the range of 80-757 μg^{-g} dry weight

High level of heavy metals were investigated in the leaves of *Ficus bengalensis* L., *Guaiacum officinale* L., *Eucalyptus* sp., *Ficus religiosa* L., and soil samples from various polluted areas of Karachi city (Ara *et al.,* 1996; Khalid *et al.,* 1996). Date palm (*Phoenix dactylifera* L.) was tested as a possible biomonitor of heavy metal pollution at Antalya, Turkey (Aksoy & Öztürk, 1996). Concentrations of Pb, Cd, Zn and Cu have been determined for unwashed and washed leaflets and soils. The leaflet of *P. dactylifera* collected from the urban roadside of the city showed high levels of Pb (24.37 μg^{-g}) and Cd (0.699 μg^{-g}). *P. dactylifera* has been confirmed as a useful biomonitor of these heavy metals investigated.

The effect of high lead level on datepalm (*Phoenix dactylifera*) and tomato (*Lycopersicon esculentum*) Mill, in an area near a major highway showed that the contamination by lead decreases rapidly with increasing distance from the highway (Jaffer *et al.,* 1999). Atmospheric depositions appeared to be the main contributor to plant contamination by lead. Lead levels in the soil of study area varied from 0.0 to 0.14 ppm. This low level of lead could be due to low population and the relatively limited number of vehicles on the street.

Concentrations of five metals (Cd, Cu, Mn, Fe, Zn) were determined in tree leaves collected from an area with large coal-fired plants in

Ptolemais, Macedonia, Greece (Swaidis, *et. al.,* 2001). Cadmium concentrations in tree leaves ranged from 0.23 to 1.98 ppm. In the leaves of *Ulmus minor* Mill. (Ulmaceae), significantly ($p<0.05$) higher concentration of cadmium (1.98 ppm) was recorded.

MATERIALS AND METHODS

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Site description

Karachi is situated on the coast along the Arabian Sea at a latitude of 24° 48' N and longitude of 66° 55' E. The soil is calcareous, marine in origin and belong to upper tertiary period. Moving away from the coast, the ground rises gently forming a large plain to the north and east on which the city is built. The city is between 1.5 and 37 M above sea level. Chaudhry (1961) has characterized the climate of Karachi as subtropical maritime desert. Whereas, the bioclimate of Karachi, determined by Holdrige (1947) comes in the category of "Tropical desert bush formation". Average wind velocity is 12 M Sec^{-1} during June and July and 3.5 M Sec^{-1} from January to March. During the southwest monsoon season winds blow from the sea towards the coast, whereas during the northeast monsoon their direction is reversed. Therefore, pollutants are pushed inland during the southwest monsoon season and are blown out to sea during the northeast monsoons (UNEP, *1*992).

The hot and humid rainy season, which is variable, lasts from June to September (Table 1). Minimum rainfall is 1 mm in the month of October whereas, the maximum rainfall (85 mm) occurs in the month of July. The winter season is very short lasting from middle of November to middle of February. The rest of the months constitute the summer, autumn and spring seasons. Temperature is mild with no frost. Dew formation is quite common, the relative humidity is high and the differences in day and night temperatures are great. The climatic conditions at the control site (Karachi University Campus) are not different from other sites of the city.

Selection of sites

The site in urban area is disturbed mainly by autovehicular activities, includes all main traffic network (Gulshan-e-Iqbal, Nazimabad, Shahrah-e-Faisal and M.A. Jinnah Road) whereas, Karachi University is relatively a clean area (Fig. 1). Brief description of the study area is given below: -

A. Karachi University Campus: Karachi University Campus is situated at the outskirts of the city. This site is relatively free from the autovehicular activities as compared to other sites of the city. Karachi University Campus is clean and 20 Km away from Quaid-e-Azam tomb.

B. Gulshan-e-Iqbal: Gulshan-e-Iqbal is located about 8 Km North East of the Quaid-e-Azam tomb. This place is comparatively open with low traffic. However, traffic congestion in the morning hours is common due to trade activities at old vegetable and fruit market.

C. Nazimabad: Nazimabad handles a large traffic volume, moving from north to west of the city. This site is about 10 Km away from the North of Quaid-e-Azam tomb.

D. Shahrah-e-Faisal: Shahrah-e-Faisal has many multistoryed buildings. This site is 15 Km from the eastern site of the Quaid-e-Azam tomb and heavily influenced by traffic activities.

E. M.A. Jinnah Road: This site is the most congested site along the Quaid-e-Azam tomb. The density of traffic from Gulshan-e-Iqbal, Nazimabad, Liaquatabad and Shahrah-e-Faisal passes through this road. Multistoryed buildings are common at this site. The slow movement of traffic starts building up toxic pollutants in the area.

Collection of seeds and leaf samples

Alstonia scholaris (commonly known as Dita bark tree) is a beautiful evergreen tree with a tall stem and dark green leaves in whorls of 4 to 10 (Figs. 2, 9, 13 & 17). It exudes milky juice on cutting. It is found in tropical Australia, Africa, India to Indonesia and cultivated in Pakistan for ornamental purposes.

Pongamia pinnata (Charr) is a medium sized, almost evergreen tree and spreading shady crown (Figs. 3, 6, 10, 14 & 18). It is indigenous to the foothills of the Himalayas, but cultivated in plains for its ornamental value.

Cassia siamea (Kassod tree) is a moderate sized, well-shaped evergreen tree with a dense crown (Figs. 4, 7, 11, 15 & 19). It is native to South India. This tree is largely planted for ornamental purposes. The tree grows fairly rapidly, and is easy to cultivate.

Peltophorum pterocarpum is a native to Ceylon and North Australia, commonly cultivated as roadside tree in gardens and in plains of Pakistan (Figs. 5, 8, 12, 16 & 20).

Nomenclature of all the plant species was followed according to Stewart (1972).

The healthy seeds of *P. pterocarpum* and *C. siamea* were collected from the polluted sites of the city as well as from a comparatively clean area of the Karachi University Campus.

The common roadside trees like *Alstonia scholaris* R. Br., *Pongamia pinnata* (L.) Merrill, *Cassia siamea* Lamk., and *Peltophorum pterocarpum* D.C. Backer ex K. Heyne, having uniform growth and D.B.H (Diameter Breast Height) were chosen from each site. The samples influenced by traffic were obtained from road edge at a distance of 1 M at the beginning of each season. Twenty-five fresh leaf samples from each individual of a species were randomly collected from each area at two-meter height throughout the plant canopy to give representative average sample. Quantitative characters of the leaves such as, leaf length, width, area and dry weights were recorded during four consecutive seasons (Summer, Winter, Autumn, Spring). All measurements were based on three replicates. The leaves samples were kept in the oven at 80° C for 48 hours and the dry weight of leaves were taken at Precisa Junior 500 Swiss Quality electric balance.

Seed germination studies

Healthy seeds of *P. pterocarpum* and *C. siamea* were rubbed by sand paper to break the seed dormancy. All the seeds were soaked in one percent bleach solution for one minute and later on wash with double distilled water to avoid any type of fungal contamination during germination. Ten seeds of each species were kept in well-sterilized Petri dishes (90-mm diameter) on Whatman filter paper No. 42 at room temperature (28° C± 2). Four 40-Watt tube lights were used as a continuous light source. There were three replicates and the experiment was completely randomized. The seed germination was regularly checked. The root length and seedling lengths were measured after ten days and their oven dry weights were obtained.

Similar types of experiments were also conducted in pots. The seed dormancy of *P. pterocarpum* and *C. siamea* was removed and other treatments carried out, as explained earlier. The seedlings of all these species raised both from the control and polluted seeds in large container filled with natural manure and fine sand in a ratio of 1:2, were transplanted to the plastic cup of 130-mm diameter. These pots were also filled with natural manure and fine sand in a ratio of 1:2. There were three replicates and the experiment was completely randomized. After six weeks growth period in the natural environmental conditions during september-october (atmospheric temperature Day 32°C±2, Night 24°C±2, atmospheric humidity 73%), all the plants were removed from the pots and washed with tap water.

The root length and seedling lengths were measured and their oven dry weights were determined.

Effects of lead and cadmium on seed germination

The healthy seeds of *P. pterocarpum*, *C. siamea* and *L. leucocephala* were collected randomly from the Karachi University Campus. Pretreatment of all seeds was carried out as described earlier. The seeds were placed in Petri dishes (90-mm diameter) on filter paper (Whatman No. 42) and were treated with 2 ml of 25, 50, 75 and 100 ppm lead nitrate and cadmium sulfate solutions. In control, no treatment was given except double distilled water. There were three replicates for each treatment and the Petri dishes were kept at room temperature (28±2° C) under four 40-Watt tube lights. The experiment was completely randomized and lasted for 10 days. The seed germination, root and seedling lengths were measured and their oven dry weight were obtained.

Indices of tolerance was determined by the following formula as given by Iqbal and Rahmati (1992):

$$\text{Tolerance Index} \quad \frac{\text{Mean root length in metal solution}}{\text{Mean root length in double distilled water}} \times 100$$

The data collected for various parameters from different experiments was statistically analyzed by analysis of variance techniques (ANOVA) and Duncan's Multiple Range Test (DMRT) on personnel computer software package, Co-Stat version 3.

Analysis of lead and cadmium in leaf samples

The contents of lead and cadmium in the foliage of different roadside plants collected from different areas of the city were analyzed. Unwashed leaf samples were oven dried at 80° C for 24 hours and made in powdered form. 0.5 gram powdered leaf sample was taken in 100 ml Pyrex beaker and 10 ml concentrated nitric acid was added. The beaker was partially covered with watch glass to avoid any loss of acid. Later, the beaker was kept on the hot plate in fume chamber for digestion. The sample was digested till a clear solution obtained. The watch glass was removed from the top of the beaker and heating continued till the volume of content was reduced to 1-2 ml. Evaporation was allowed but not to dryness. Later, the content was cooled down. The digested plant material was filtered by using 0.1N HCl, through Whatman filter paper No. 44 and the volume was made upto 50 ml in volumetric flask. Digested plant material solution was analyzed for metal contents on the atomic absorption spectrophotometer (Perkin Elmer 3100) using appropriate cathode. A series of standard solutions for each element in the range of absorbance noted for unknown samples were simultaneously run on atomic absorption spectrophotometer. The calibration curves obtained for absorbance versus concentration data were statistically analyzed using fitting of straight line by least square method. Three replicates were used in this analysis. Concentration of elements is expressed as μg^{-g} of samples.

All reagents were of Analar grade. A series of standard solution for lead and cadmium were obtained. All glassware's were carefully cleaned with double distilled water and later rinsed with deionized water.

Equipment

Research activities in the mid 1970's increased due to an awareness of the importance of metals as environment pollutants and the availability of atomic absorption spectrophotometer. Atomic absorption spectrophotometer- ers allowed rapid and routine analysis of the concentrations of a wide range of metals in biological samples to be conducted at relatively low cost. The development of multielemental analytical techniques such as atomic absorption spectrophotometer has allowed scientists to examine mineral and biological samples both rapidly and accurately for many of the chemical elements both essential and toxic to life (Thornton, 1990).

Atomic absorption spectrophotometer (Perkin Elmer 3100) was used for the determination of trace elements in the leaves. The analyses of lead and cadmium were performed at wavelengths 283.3 nm and 228.8 nm, respectively. The standards for calibration were prepared in deionized water. To minimize the errors in dilution, serial dilution was performed. Instructions for instrument setting, calibration and assay for specific trace metal was followed as mentioned in the operational manual.

Table 1a. Climatic data of Karachi city (1995-1996)*

Months	Atmospheric Temperature (°C)		Atmospheric Relative Humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
January	26	10	64	43	15
February	27	13	71	46	12
March	29	20	78	55	9
April	31	22	87	60	2
May	33	25	87	65	3
June	34	27	85	70	20
July	33	27	88	70	85
August	32	25	92	72	50
September	32	25	87	71	15
October	32	23	80	55	1
November	30	17	65	48	4
December	26	13	63	45	4

*Data taken from Karachi Meteorological Station

Table 1b. Pollution and traffic density of Karachi city

Pollutants		Max.	Min.	Ave.	Source
SO_2	($\mu g\ m^{-3}$)	134.0	25.0	61.0	Ghauri *et al.*, SPARCO (1988)
NO_2	($\mu g\ m^{-3}$)	544.0	38.0	104.0	Ghauri *et al.*, SPARCO (1988)
O_3	($\mu g\ m^{-3}$)	50.0	36.0	43.0	Ghauri *et al.*, SPARCO (1988)
Sulfur	(ppm)	565.0	91.0	266.0	Iqbal , Tropical Ecology (1988)
Pb	(ppm)	2677.0	4.0	1488.0	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Cd	(ppm)	1.2	0.2	0.8	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Cu	(ppm)	187.0	3.0	134.0	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Zn	(ppm)	638.0	6.0	285.0	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Mn	(ppm)	305.0	4.0	173.0	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
CO	(ppm)	10.0	2.0	6.0	Rehman, Environmental News (1993)
CO_2	(ppm)	350.0	170.0	260.0	Rehman, Environmental News (1993)
HC	(Vol. %)	2.3	0.4	1.3	Rehman, Environmental News (1993)
PM	($\mu g\ cm^{-3}$)	566.0	67.0	316.0	Rehman, Environmental News (1993)
Daily Traffic Density		1,29,675.0	51,628.0	94587.0	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)

Note: SO_2, NO_2, O_3, CO, CO_2, HC, PM were recorded in the air. Other values were of street dust.

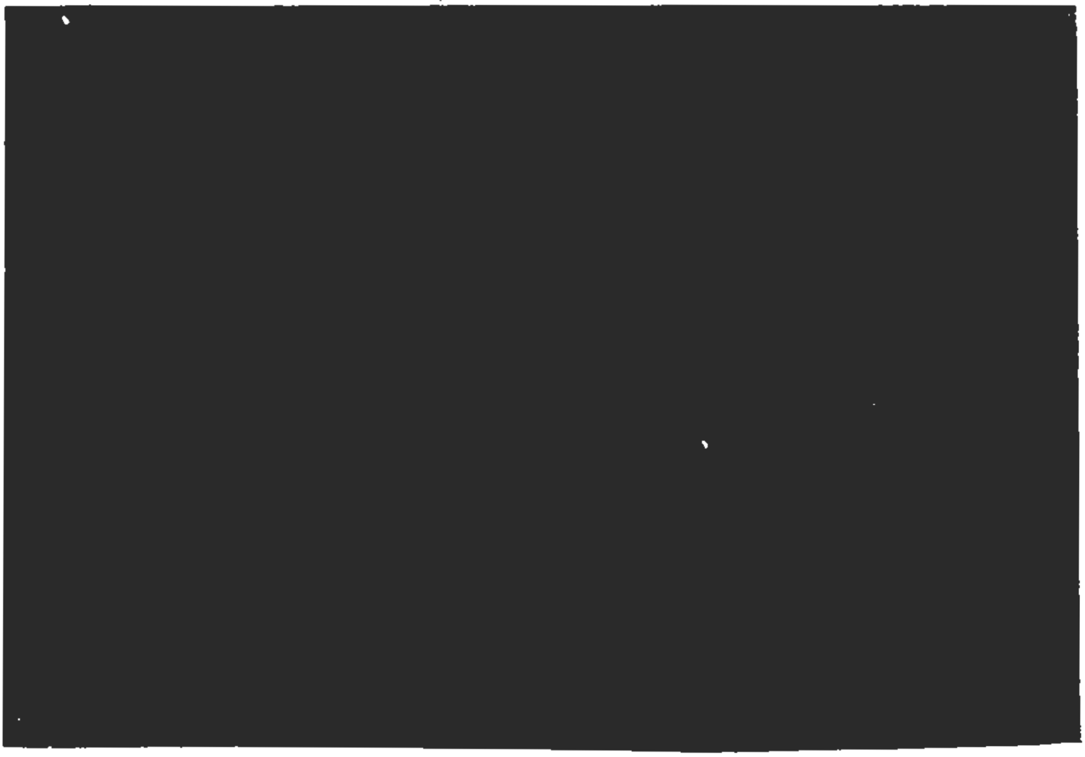


Fig. 1. Map of the study area (A= Karachi University, B= Gulshan-e-Iqbal, C= Nazimabad, D= Shahrah-e-Faisal, E= M.A. Jinnah Road).

Figs. 2 & 3. *Alstonia scholaris* (above) and *Pongamia pinnata* (below) are growing at the Karachi University Campus. 1-meter scale is placed along the tree trunk.

Figs. 4 & 5. *Cassia siamea* (above) and *Peltophorum pterocarpum* (below) are growing at the Karachi University Campus. 1-meter scale is placed along the tree trunk.

Figs. 6 & 7. *Pongamia pinnata* (above) and *Cassia siamea* (below) are growing at Gulshan-e-Iqbal. 1-meter scale is placed along the tree trunk.

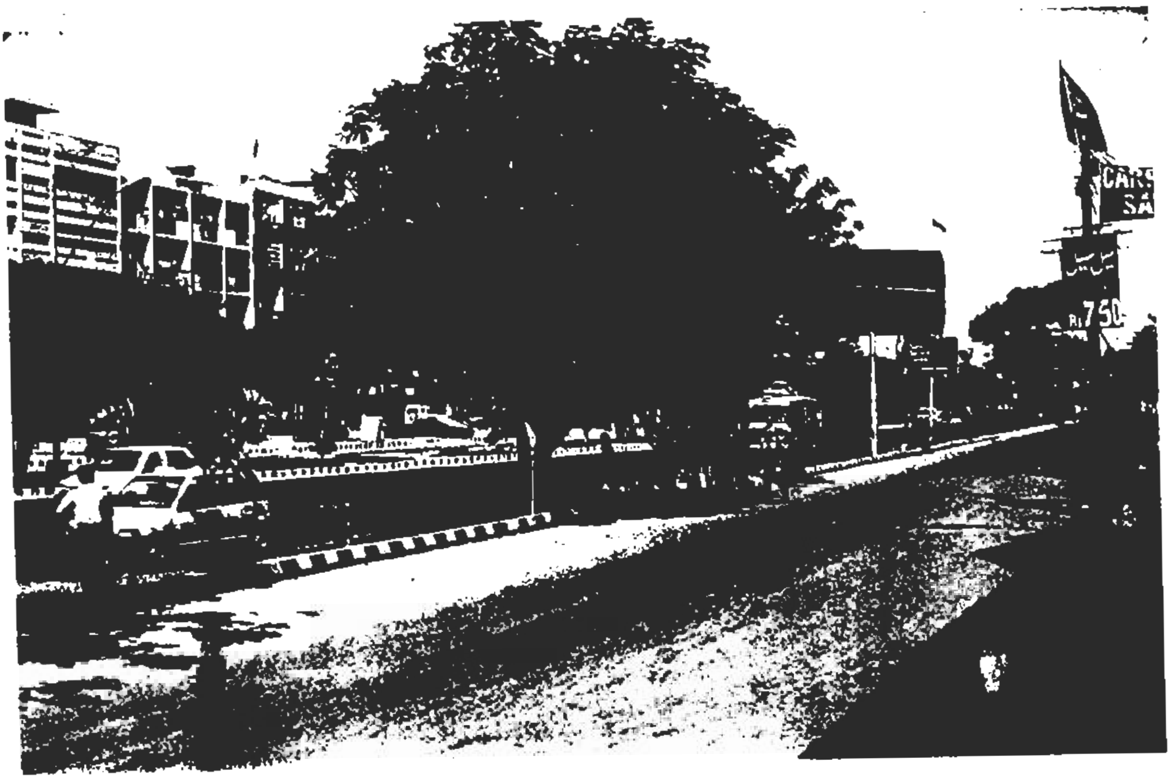


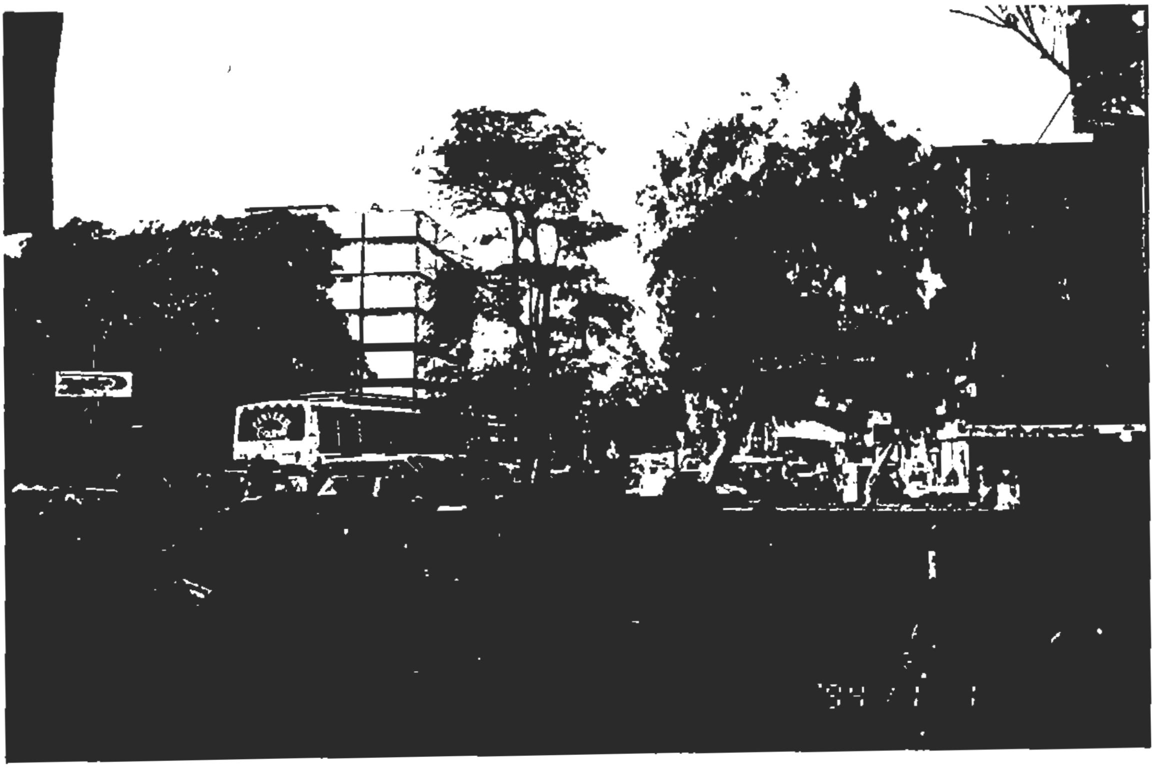
Fig. 8. *Peltophorum pterocarpum* is growing at Gulshan-e-Iqbal. 1-meter scale is placed along the tree trunk.

Figs. 9 & 10. *Alstonia scholaris* (above) and *Pongamia pinnata* (below) are growing at Nazimabad. 1-meter scale is placed along the tree trunk.

Figs. 11 & 12. *Cassia siamea* (above) and *Peltophorum pterocarpum* (below) are growing at Nazimabad. 1-meter scale is placed along the tree trunk.

Figs. 13 & 14. *Alstonia scholaris* (above) and *Pongamia pinnata* (below) are growing at Shahrah-e-Faisal. 1-meter scale is placed along the tree trunk.

Figs. 15 & 16. *Cassia siamea* (above) and *Peltophorum pterocarpum* (below) are growing at Shahrah-e-Faisal. 1-meter scale is placed along the tree trunk.



Figs. 17 & 18. *Alstonia scholaris* (above) and *Pongamia pinnata* (below) are growing at M.A. Jinnah Road. 1-meter scale is placed along the tree trunk.

Figs. 19 & 20. *Cassia siamea* (above) and *Peltophorum pterocarpum* (below) are growing at M.A. Jinnah Road. 1-meter scale is placed along the tree trunk.

RESULTS

RESULTS

Effects of autoemission on leaves of plants

The leaf size of *Alstonia scholaris*, *Pongamia pinnata*, *Cassia siamea* and *Peltophorum pterocarpum* was affected in the polluted environment as compared to plants growing at Karachi University Campus (Table 2-5). Plants were found more affected to pollutants at M.A. Jinnah Road as compared to other polluted areas of the city.

The effects of autoemission on leaves of *A. scholaris* varied from site to site (Table 2). The periodical study indicated that the leaf length and width were significantly ($p<0.05$) affected in summer at M.A. Jinnah Road as compared to Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus. The lowest leaf area of *A. scholaris* was also found in summer at M.A. Jinnah Road followed by Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus.

A reduction in leaf size of *P. pinnata* was observed in autumn at M.A. Jinnah Road as compared to Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus (Table 3). The leaf length of this species was significantly ($p<0.05$) affected in autumn at highly polluted sites of M.A. Jinnah Road as compared to Karachi University Campus.

The present study reveals that *C. siamea* growing in the polluted site of the city showed reduction in all the leaf parameters as compared to Karachi University Campus (Table 4). Leaflet length of *C. siamea* was not significantly affected in winter at all the sites of the city except M.A. Jinnah Road. The leaflet width of *C. siamea* was highly affected in autumn at M.A. Jinnah Road as compared to Karachi University Campus. *C. siamea* showed lowest leaflet area in autumn at M.A. Jinnah Road as compared to other less polluted sites of the city. This species showed maximum leaflet dry weight at Karachi University Campus in summer followed by Gulshan-e-Iqbal, Nazimabad, Shahrah-e-Faisal and M.A. Jinnah Road.

The periodical study indicated that leaf sample of *P. pterocarpum* collected from the polluted sites of the city showed reduction in leaflet length, width, area and dry weight as compared to Karachi University Campus (Table 5). The leaflet length of *P. pterocarpum* was significantly less in winter at M.A. Jinnah Road as compared to other less polluted sites of the city. *P. pterocarpum* showed maximum leaflet width and area in autumn at Karachi University Campus as compared to Gulshan-e-Iqbal, Nazimabad, Shahrah-e-Faisal and M.A. Jinnah Road. This species also showed lowest leaflet dry weight in summer at M.A. Jinnah Road followed by Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and University Campus.

Table 2. Effects of autoemission on leaf length, width, area and dry weight of *Alstonia scholaris*

Parameters	Sites	Summer	Winter	Autumn	Spring
Leaf length (mm)	A	*128± 6 a	126±2 a	117± 8 a	113±3 a
	B	126±14 a	125±3 a	114± 7 ab	100±3 b
	C	101± 3 b	123±2 a	107±13 abc	97±1 bc
	D	99± 9 b	104±1 b	100± 5 bc	96±4 bc
	E	83± 1 c	97±2 c	95± 6 c	94±3 c
L.S.D. p<0.05		15	5	16	6
Leaf width (mm)	A	40±1 a	37±2 a	33±2 a	35±1 a
	B	31±2 b	36±1 a	31±1 ab	31±7 ab
	C	30±1 bc	35±2 a	30±5 ab	29±2 ab
	D	28±1 b	30±1 b	28±2 ab	28±1 ab
	E	24±1 d	27±2 c	27±2 a	26±2 b
L.S.D. p<0.05		2	3	5	7
Leaf area (sq. mm)	A	3421±148 a	3115±106 a	2598±179 a	2694±78 a
	B	2545±227 b	2973± 66 a	2366± 46 ab	2145±90 b
	C	2008± 45 c	2808± 78 a	2114± 87 bc	1959±83 bc
	D	1847±117 c	1974±132 b	1871±117 c	1831±42 cd
	E	1324± 15 d	1729± 92 b	1718±142 c	1663±89 d
L.S.D. p<0.05		422	312	388	225
Leaf dry weight (g)	A	0.22±0.01 a	0.21±0.02 a	0.21±0.01 a	0.17±0.01 a
	B	0.21±0.01 a	0.20±0.01 ab	0.17±0.01 bc	0.10±0.01 b
	C	0.18±0.01 b	0.19±0.01 ab	0.15±0.01 c	0.10±0.01 bc
	D	0.16±0.01 b	0.18±0.01 b	0.14±0.01 d	0.09±0.01 cd
	E	0.15±0.01 b	0.15±0.03 b	0.10±0.01 e	0.07±0.01 d
L.S.D. p<0.05		0.028	0.050	0.034	0.047

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly (p<0.05) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Table 3. Effects of autoemission on leaf length, width, area and dry weight of *Pongamia pinnata*

Parameters	Sites	Summer	Winter	Autumn	Spring
Leaf length (mm)	A	*84±3 a	100±2 a	93±4 a	93±1 a
	B	76±2 ab	87±3 b	82±4 bc	84±3 b
	C	66±4 b	86±6 b	80±3 bc	79±2 bc
	D	65±4 b	78±2 bc	72±1 bc	76±1 c
	E	65±4 b	69±3 c	61±5 c	69±2 d
L.S.D. p<0.05		11	13	11	6
Leaf width (mm)	A	48±1 a	54±2 a	56±3 a	56±2 a
	B	45±1 ab	52±2 a	51±1 a	52±2 a
	C	42±4 ab	51±2 a	45±2 b	47±1 b
	D	41±2 ab	50±1 ab	41±1 bc	44±1 b
	E	40±1 b	44±1 b	37±1 c	37±1 c
L.S.D. p<0.05		6	7	6	5
Leaf area (sq. mm)	A	2706± 72 a	3643±184 a	3497±355 a	3462±152 a
	B	2304± 43 ab	3040±131 ab	2783±259 bc	2678±184 b
	C	1832± 292 b	2948±294 ab	2397±153 bc	2583±136 b
	D	1831± 154 b	2595±145 bc	1958± 66 cd	2258± 54 b
	E	1776± 125 b	2039±104 c	1476± 74 d	1685± 55 c
L.S.D. p<0.05		512	692	614	403
Leaf dry weight (g)	A	0.230±0.03 a	0.326±0.02 a	0.243±0.01 a	0.236±0.01 a
	B	0.186±0.01 ab	0.306±0.02 a	0.236±0.01 a	0.223±0.01 a
	C	0.153±0.02 b	0.233±0.01 b	0.206±0.01 ab	0.173±0.01 b
	D	0.127±0.02 b	0.216±0.01 bc	0.183±0.02 b	0.163±0.02 b
	E	0.124±0.02 b	0.193±0.01 c	0.138±0.01 c	0.160±0.01 b
L.S.D. p<0.05		0.06	0.023	0.041	0.03

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Table 4. Effects of autoemission on leaflet length, width, area and dry weight of *Cassia siamea*

Parameters	Sites	Summer	Winter	Autumn	Spring
Leaflet length (mm)	A	*56±1 a	46±1 a	63±2 a	52± 1 a
	B	53±1 a	45±1 a	57±1 bc	44± 2 b
	C	57±1 ab	42±2 a	43±2 c	40± 1 c
	D	46±1 bc	28±3 a	38±1 c	37±1 cd
	E	46±1 c	28±3 b	32±3 d	34± 1 d
L.S.D. $p<0.05$		4.4	7.2	5	4
Leaflet width (mm)	A	18±1 a	18±1 a	21±1 a	17±1 a
	B	18±1 a	17±1 ab	16±1 bc	15±1 b
	C	18±1 a	16±1 b	13±1 c	14±1 b
	D	15±1 b	14±1 c	12±1 c	12±1 c
	E	15±1 b	11±1 d	9±1 d	11±1 c
L.S.D. $p<0.05$		1.7	1.6	1.5	1.6
Leaflet area (sq.mm)	A	701±24 a	558± 1 a	855±28 a	576±42 a
	B	629±38 ab	517±18 ab	608±31 bc	422±20 b
	C	570± 5 bc	439±34 bc	378±15 c	362±16 bc
	D	521±10 cd	401±26 c	306±17 c	291± 5 cd
	E	462±33 d	223±23 d	204±16 d	252± 6 d
L.S.D. $p<0.05$		80	108	73	71
Leaflet dry weight (g)	A	0.08±0.001 a	0.07±0.004 a	0.05±0.009 a	0.04±0.002 a
	B	0.07±0.003 ab	0.06±0.002 a	0.03±0.004 ab	0.03±0.007 ab
	C	0.07±0.005 ab	0.06±0.002 ab	0.02±0.001 b	0.03±0.003 bc
	D	0.06±0.005 bc	0.05±0.004 b	0.02±0.002 b	0.02±0.004 cd
	E	0.05±0.001 c	0.04±0.001 c	0.02±0.004 b	0.02±0.003 d
L.S.D. $p<0.05$		0.017	0.001	0.008	0.008

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Table 5. Effects of autoemission on leaflet length, width, area and dry weight of *Peltophorum pterocarpum*

Parameters	Sites	Summer	Winter	Autumn	Spring
Leaflet	A	*17±1 a	16±1 a	18±1 a	17±1 a
length (mm)	B	14±1 ab	14±1 b	15±1 bc	14±1 b
	C	13±1 bc	13±1 bc	11±1 c	13±1 b
	D	12±1 c	12±1 c	10±1 cd	12±1 c
	E	8±1 d	7±1 d	8±1 d	8±1 d
L.S.D. $p<0.05$		2	2	3	2
Leaflet	A	7±1 a	7±1 a	8±1 a	7±1 a
width (mm)	B	6±1 ab	6±1 ab	7±1 bc	6±1 a
	C	6±1 ab	6±1 ab	6±1 bc	5±1 b
	D	5±1 bc	5±1 bc	5±1 cd	5±1 c
	E	4±1 c	4±1 c	4±1 d	4±1 d
L.S.D. $p<0.05$		1	1	1	1
Leaflet area	A	74±8 a	76±1 a	99±8 a	82±9 a
(sq.mm)	B	62±5 ab	54±3 b	65±1 bc	58±3 b
	C	51±7 bc	49±5 bc	45±4 c	50±6 bc
	D	43±1 c	41±4 c	37±2 cd	46±2 c
	E	23±1 d	21±4 d	22±2 d	21±1 d
L.S.D. $p<0.05$		16	11	17	8
Leaflet	A	0.007±0.001 a	0.007±0.004 a	0.004±0.001 a	0.005±0.001 a
dry weight	B	0.006±0.004 bc	0.007±0.004 b	0.003±0.002 bc	0.005±0.001 b
(g)	C	0.002±0.002 c	0.006±0.004 c	0.003±0.001 c	0.004±0.002 c
	D	0.002±0.001 c	0.005±0.004 d	0.002±0.001 d	0.003±0.001 d
	E	0.001±0.001 d	0.004±0.001 e	0.002±0.001 e	0.003±0.001 e
L.S.D. $p<0.05$		0.002	0.002	0.001	0.003

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Effects of autoemission on seed germination and seedling growth

Autoemission showed toxic effects on seed germination and seedling growth of *P. pterocarpum* and *C. siamea* (Table 6-7). The seeds of *P. pterocarpum,* collected from the Karachi University Campus, which is considered as control site showed high rate of germination and growth as compared to seeds of the same species collected from the city areas, particularly from M.A. Jinnah Road. The seedling length of *P. pterocarpum* was greatly affected at M.A. Jinnah Road (55 mm) followed by Shahrah-e-Faisal (65 mm), Nazimabad (80 mm) and Gulshan-e-Iqbal (85 mm) as compared to control (93 mm). Similarly, the seedling dry weight of *P. pterocarpum* was also significantly ($p<0.05$) affected at M.A. Jinnah Road (0.023 g), Shahrah-e-Faisal (0.025 g), Nazimabad (0.037 g) and Gulshan-e-Iqbal (0.043 g) as compared to Karachi University Campus (0.060 g). The root length of *P. pterocarpum* was significantly ($p<0.05$) reduced at M.A. Jinnah Road (20 mm) as compared to Karachi University Campus (38 mm).

Seeds of *C. siamea* collected from the polluted areas also showed low percentage of germination, seedling length, root length and seedling dry weight. Germination of *C. siamea* seeds was significantly ($p<0.05$) affected in samples collected from M.A. Jinnah Road, Shahrah-e-Faisal, Nazimabad and Gulshan-e-Iqbal as compared to Karachi University Campus. Seedling length of *C. siamea* was also greatly affected in samples collected from M.A. Jinnah Road (50 mm), Shahrah-e-Faisal (55 mm), Nazimabad (65 mm) and Gulshan-e-Iqbal (73 mm) as compared to Karachi University Campus (75 mm). Similarly, root length of *C. siamea* was significantly ($p<0.05$) reduced in samples collected from M.A. Jinnah Road (19 mm), Shahrah-e-Faisal (27 mm), Nazimabad (36 mm) and Gulshan-e-Iqbal (38 mm) as compared to Karachi University Campus (39 mm). Similarly, the seedling dry weight of *C. siamea* also showed decrease in samples collected from M.A. Jinnah Road (0.017 g), Shahrah-e-Faisal (0.025 g), Nazimabad (0.033 g) and Gulshan-e-Iqbal (0.047 g) as compared to Karachi University Campus (0.059 g).

In pot experiments the seed germination of *P. pterocarpum* and *C. siamea was* greatly reduced in seeds collected from the city area as compared to control (Table 8-9). The growth of *P. pterocarpum* and *C. siamea* seedlings raised from the Karachi University Campus seeds showed better growth as compared to seedling raised from M.A. Jinnah Road samples, which was highly affected by autovehicular emission. The seedlings length, root length and seedling dry weight of *P. pterocarpum* and *C. siamea* were significantly ($p<0.05$) affected in seedlings which were raised from the seeds of M.A. Jinnah Road, Shahrah-e-Faisal, Nazimabad and Gulshan-e-Iqbal as compared to Karachi University Campus.

Table 6. Effects of autoemissions on seed germination, seedling length, root length and seedling dry weight of *Peltophorum pterocarpum*

Parameters	Sites	*Peltophorum pterocarpum*
Seed germination (%)	A	*97.00±3.33 a
	B	85.00±1.30 b
	C	79.00±1.50 c
	D	68.00±1.00 d
	E	59.00±1.33 e
L.S.D. $p<0.05$		6.64
Seedling length (mm)	A	93.00±3.33 a
	B	85.00±2.40 ab
	C	80.00±3.05 b
	D	65.00±3.33 c
	E	55.00±2.64 d
L.S.D. $p<0.05$		9.38
Root length (mm)	A	38.00±3.33 a
	B	35.00±2.40 a
	C	34.00±1.85 ab
	D	27.00±6.66 ab
	E	20.00±1.44 b
L.S.D. $p<0.05$		11.42
Seedling dry weight (g)	A	0.060±0.00050 a
	B	0.043±0.00064 b
	C	0.037±0.00052 bc
	D	0.025±0.00029 c
	E	0.023±0.00033 c
L.S.D. $p<0.05$		0.015

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Table 7. Effects of autoemissions on seed germination, seedling length, root length and seedling dry weight of *Cassia siamea*

Parameters	Sites	*Cassia siamea*
Seed germination (%)	A	*82.00±0.66 a
	B	63.00±3.33 b
	C	55.00±3.33 bc
	D	53.00±2.88 c
	E	52.00±1.66 c
L.S.D. p<0.05		8.46
Seedling length (mm)	A	75.00±2.66 a
	B	73.00±1.44 ab
	C	65.00±4.99 b
	D	55.00±2.88 c
	E	50.00±2.88 c
L.S.D. p<0.05		9.19
Root length (mm)	A	39.00±2.96 a
	B	38.00±0.87 a
	C	36.00±0.99 a
	D	27.00±2.90 b
	E	19.00±2.96 c
L.S.D. p<0.05		7.42
Seedling dry weight (g)	A	0.059±0.00049 a
	B	0.047±0.00033 b
	C	0.033±0.00030 c
	D	0.025±0.00035 cd
	E	0.017±0.00032 d
L.S.D. p<0.05		0.011

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Table 8. Effects of autoemission on seed germination and seedling length, root length and root length and seedling dry weight of *Peltophorum pterocarpum* in pot experiment

Parameters	Sites	*Peltophorum pterocarpum*
Seed germination (%)	A	*80.00±5.77 a
	B	62.00±1.15 b
	C	53.00±1.73 c
	D	50.00±5.77 c
	E	47.00±3.46 c
L.S.D. p<0.05		7.045
Seedling length (mm)	A	95.00±9.33 a
	B	80.00±2.88 b
	C	66.00±8.66 c
	D	65.00±5.77 c
	E	60.00±5.77 c
L.S.D. p<0.05		13.52
Root length (mm)	A	56.00±2.30 a
	B	46.00±2.80 b
	C	44.00±3.40 b
	D	37.00±2.80 c
	E	29.00±0.57 c
L.S.D. p<0.05		8.28
Seedling dry weight (g)	A	0.075±0.005 a
	B	0.045±0.005 b
	C	0.034±0.005 bc
	D	0.033±0.005 bc
	E	0.0270±0.005 c
L.S.D. p<0.05		0.011

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly (p<0.05) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Table 9. Effects of autoemission on seed germination and seedling length, root length and root length and seedling dry weight of *Cassia siamea* in pot experimenrt

Parameters	Sites	*Cassia siamea*
Seed germination (%)	A	*72.00±2.30 a
	B	58.00±4.04 b
	C	47.00±1.73 c
	D	50.00±5.77 c
	E	45.00±2.88 c
L.S.D. p<0.05		7.04
Seedling length (mm)	A	98.00±1.15 a
	B	73.00±4.17 b
	C	64.00±4.17 bc
	D	58.00±3.70 c
	E	54.00±7.50 c
L.S.D. p<0.05		14.4
Root length (mm)	A	50.00±1.73 a
	B	42.00±2.30 b
	C	32.00±1.15 c
	D	30.00±2.80 c
	E	28.00±1.15 c
L.S.D. p<0.05		6.2
Seedling dry weight (g)	A	0.0610±0.001 a
	B	0.0433±0.001 b
	C	0.0400±0.001 b
	D	0.0320±0.001 bc
	E	0.0250±0.001 c
L.S.D. p<0.05		0.016

Symbol used:

Sites A=Karachi University Campus B= Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E=M.A. Jinnah Road. Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly (p<0.05) different, according to Duncan's Multiple Range Test. *Mean ± Standard Error

Effects of lead and cadmium on seed germination and seedling growth

Seeds of *Leucaena leucocephala*, *Peltophorum pterocarpum* and *Cassia siamea* treated with lead and cadmium produced toxic effects on seed germination and seedling growth (Table 10-15). It was observed that 50 ppm lead treatment produced significant ($p<0.05$) effects on seedling and root length of *L. leucocephala* as compared to control (Table 10). The seedling dry weight of *L. leucocephala* was significantly ($p<0.05$) reduced at 25 ppm treatment of lead as compared to control. Similarly, 25 ppm cadmium treatment produced significant ($p<0.05$) effects on seedling length of *L. leucocephala* as compared to control (Table 11). The root length was also greatly decreased at 50 ppm treatment of cadmium. The seedling dry weight of *L. leucocephala* was significantly ($p<0.05$) affected at 25 ppm cadmium treatments as compared to control.

Similarly, seed germination and seedling length of *P. pterocarpum* were significantly ($p<0.05$) reduced at 75 ppm treatment of lead (Table 12). The seedling dry weight of *P. pterocarpum* was significantly ($p<0.05$) reduced at 25 ppm treatment of lead, while 50 ppm Pb suppressed the root length as compared to control. It was observed that 50 ppm cadmium treatment produced toxic effects on root length of *P. pterocarpum* as compared to control (Table 13). Higher concentration of Cd at 75 ppm showed adverse effects on seed germination and seedling growth of *P. pterocarpum* as compared to control. The treatment of Cd at 25 ppm significantly ($p<0.05$) reduced seedling dry weight of *P. pterocarpum* as compared to control.

Similarly, seed germination and root length of *C. siamea* was significantly ($p<0.05$) reduced at 50 ppm treatment of lead as compared to control (Table 14). The treatment of lead at 25 ppm produced significant ($p<0.05$) effects on seedling length and dry weight of same species. The treatment of Cd at 25 ppm decreased seed germination, seedling length and dry weight of *C. siamea* as compared to control (Table 15).

The seedlings of different tree species viz., *L. leucocephala, P. pterocarpum* and *C. siamea* were tested for tolerance to heavy metals, using different concentrations of lead and cadmium (Figs. 21-26). *L. leucocephala* showed high percentage of tolerance at 25 ppm of lead as compared to *P. pterocarpum* and *C. siamea*. Increased in concentration of lead gradually decreased the tolerance of *L. leucocephala*. The treatment of lead at 100 ppm showed the lowest percentage of tolerance in *L. leucocephala* followed by *P. pterocarpum* and *C. siamea*, respectively.

It was also observed that cadmium treatment produced low percentage of tolerance in *L. leucocephala, P. pterocarpum* and *C. siamea*. High percentage of tolerance was found in *P. pterocarpum* as compared to *L. leucocephala* and *C. siamea* at 25 ppm cadmium treatment. Increased in concentration of cadmium treatment reduced the percentage of tolerance for seedlings of different tree species. Low percentage of tolerance was found in *L. leucocephala* as compared to *P. pterocarpum* and *C. siamea* at 100 ppm cadmium treatment.

According to tolerance test it was observed that tolerance in *L. leucocephala* at 100 ppm of lead and cadmium was lower as compared to *C. siamea* and *P. pterocarpum*. Cadmium treatment showed comparatively more effects on tree seedlings as compared to lead.

Table 10. Effects of lead on seed germination, seedling length, root length and seedling dry weight of *Leucaena leucocephala*

Parameters	Treatments	Lead
Seed germination (%)	Control	*97.00±1.15 a
	25 ppm	90.00±5.77 ab
	50 ppm	87.00±1.73 ab
	75 ppm	83.00±4.61 ab
	100 ppm	77.00±5.77 b
L.S.D. $p<0.05$		13.54
Seedling length (mm)	Control	82.66±6.35 a
	25 ppm	73.00±1.15 ab
	50 ppm	64.00±2.30 b
	75 ppm	55.00±8.66 bc
	100 ppm	42.00±5.19 c
L.S.D. $p<0.05$		17.36
Root length (mm)	Control	35.00±8.66 a
	25 ppm	23.00±4.61 ab
	50 ppm	20.00±2.30 b
	75 ppm	15.00±2.30 b
	100 ppm	11.00±2.90 b
L.S.D. $p<0.05$		13.16
Seedling dry weight (g)	Control	0.041±0.003 a
	25 ppm	0.032±0.001 b
	50 ppm	0.031±0.002 b
	75 ppm	0.029±0.001 bc
	100 ppm	0.022±0.002 c
L.S.D. $p<0.05$		0.007

Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test.

* Mean ± Standard Error

Table 11. Effects of cadmium on seed germination, seedling length, root length and seedling dry weight of *Leucaena leucocephala*

Parameters	Treatments	Cadmium
Seed germination (%)	Control	*95.00±2.88 a
	25 ppm	80.00±5.77 ab
	50 ppm	75.00±5.77 b
	75 ppm	73.00±4.61 b
	100 ppm	65.00±5.77 b
L.S.D. $p<0.05$		16.04
Seedling length (mm)	Control	86.00±10.39 a
	25 ppm	65.00± 6.35 b
	50 ppm	55.00± 5.77 bc
	75 ppm	46.00± 3.46 cd
	100 ppm	37.33± 1.73 d
L.S.D. $p<0.05$		14.26
Root length (mm)	Control	35.00±8.66 a
	25 ppm	23.00±4.61 ab
	50 ppm	14.00±2.30 b
	75 ppm	11.00±1.73 b
	100 ppm	8.00±1.73 b
L.S.D. $p<0.05$		14.65
Seedling dry weight (g)	Control	0.041±0.003 a
	25 ppm	0.032±0.001 b
	50 ppm	0.031±0.002 b
	75 ppm	0.030±0.001 b
	100 ppm	0.024±0.002 b
L.S.D. $p<0.05$		0.008

Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test.

* Mean ± Standard Error

Table 12. Effects of lead on seed germination, seedling length, root length and seedling dry weight of *Peltophorum pterocarpum*

Parameters	Treatments	Lead
Seed germination (%)	Control	*100.00± 5.77 a
	25 ppm	93.00± 1.15 ab
	50 ppm	90.00± 2.30 abc
	75 ppm	87.00± 1.73 bc
	100 ppm	80.00± 2.88 c
L.S.D. p<0.05		10.09
Seedling length (mm)	Control	123.00±13.27 a
	25 ppm	119.33± 6.56 ab
	50 ppm	103.00± 7.50 ab
	75 ppm	94.66± 7.68 b
	100 ppm	94.00± 2.30 b
L.S.D. p<0.05		25.99
Root length (mm)	Control	45.00± 2.88 a
	25 ppm	40.00± 2.88 a
	50 ppm	25.00± 3.46 b
	75 ppm	23.00± 2.88 b
	100 ppm	18.00± 1.15 b
L.S.D. p<0.05		8.72
Seedling dry weight (g)	Control	0.073±0.004 a
	25 ppm	0.045±0.003 b
	50 ppm	0.042±0.002 b
	75 ppm	0.040±0.001 b
	100 ppm	0.030±0.001 c
L.S.D. p<0.05		0.008

Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test.
* Mean ± Standard Error.

Table 13. Effects of cadmium on seed germination, seedling length, root length and seedling dry weight of *Peltophorum pterocarpum*

Parameters	Treatments	Cadmium
Seed germination (%)	Control	*93.00±4.04 a
	25 ppm	85.00±2.88 a
	50 ppm	80.00±5.77 ab
	75 ppm	60.00±8.66 bc
	100 ppm	55.00±8.66 c
L.S.D. p<0.05		20.32
Seedling length (mm)	Control	118.00±10.39 a
	25 ppm	106.00± 9.23 ab
	50 ppm	93.00± 7.50 abc
	75 ppm	84.00± 5.19 bc
	100 ppm	37.33± 1.73 c
L.S.D. p<0.05		24.55
Root length (mm)	Control	47.00±9.81 a
	25 ppm	40.00±2.88 a
	50 ppm	24.00±2.30 b
	75 ppm	22.00±2.30 b
	100 ppm	17.00±1.73 b
L.S.D. p<0.05		15.22
Seedling dry weight (g)	Control	0.071±0.001 a
	25 ppm	0.050±0.002 b
	50 ppm	0.043±0.002 c
	75 ppm	0.028±0.001 d
	100 ppm	0.020±0.001 e
L.S.D. p<0.05		0.005

Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test.

* Mean ± Standard Error.

Table 14. Effects of lead on seed germination, seedling length, root length and seedling dry weight of *Cassia siamea*

Parameters	Treatments	Cadmium
Seed germination (%)	Control	*98.00±1.15 a
	25 ppm	93.00±1.15 a
	50 ppm	77.00±1.73 b
	75 ppm	73.00±1.15 b
	100 ppm	63.00±1.15 c
L.S.D. p<0.05		6.14
Seedling length (mm)	Control	97.00±2.88 a
	25 ppm	87.00±2.88 b
	50 ppm	83.00±1.15 bc
	75 ppm	81.00±2.88 bc
	100 ppm	74.00±2.88 c
L.S.D. p<0.05		8.98
Root length (mm)	Control	55.00±2.88 a
	25 ppm	47.00±1.15 ab
	50 ppm	42.00±1.15 bc
	75 ppm	40.00±1.15 bc
	100 ppm	35.00±2.88 c
L.S.D. p<0.05		8.29
Seedling dry weight (g)	Control	0.066±0.006 a
	25 ppm	0.045±0.008 b
	50 ppm	0.042±0.003 b
	75 ppm	0.033±0.002. bc
	100 ppm	0.023±0.001 c
L.S.D. p<0.05		0.015

Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test.

* Mean ± Standard Error

Table 15. Effects of cadmium on seed germination, seedling length, root length and seedling dry weight of *Cassia siamea*

Parameters	Treatments	Cadmium
Seed germination (%)	Control	*97.00±1.73 a
	25 ppm	83.00±4.04 b
	50 ppm	73.00±1.73 bc
	75 ppm	67.00±4.04 cd
	100 ppm	60.00±5.77 d
L.S.D. p<0.05		11.95
Seedling length (mm)	Controi	88.00±4.61 a
	25 ppm	64.00±1.00 b
	50 ppm	57.00±9.81 b
	75 ppm	57.00±9.81 b
	100 ppm	53.00±8.66 b
L.S.D. p<0.05		19.99
Root length (mm)	Control	58.00±1.73 a
	25 ppm	42.00±1.00 ab
	50 ppm	37.00±1.73 b
	75 ppm	35.00±8.66 b
	100 ppm	27.00±6.92 b
L.S.D. p<0.05		16.12
Seedling dry weight (g)	Control	0.043±0.001 a
	25 ppm	0.026±0.001 b
	50 ppm	0.025±0.002 b
	75 ppm	0.021±0.002 b
	100 ppm	0.018±0.001 b
L.S.D. p<0.05		0.009

Statistical significance determined by analysis of variance. Numbers followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test.
* Mean ± Standard Error

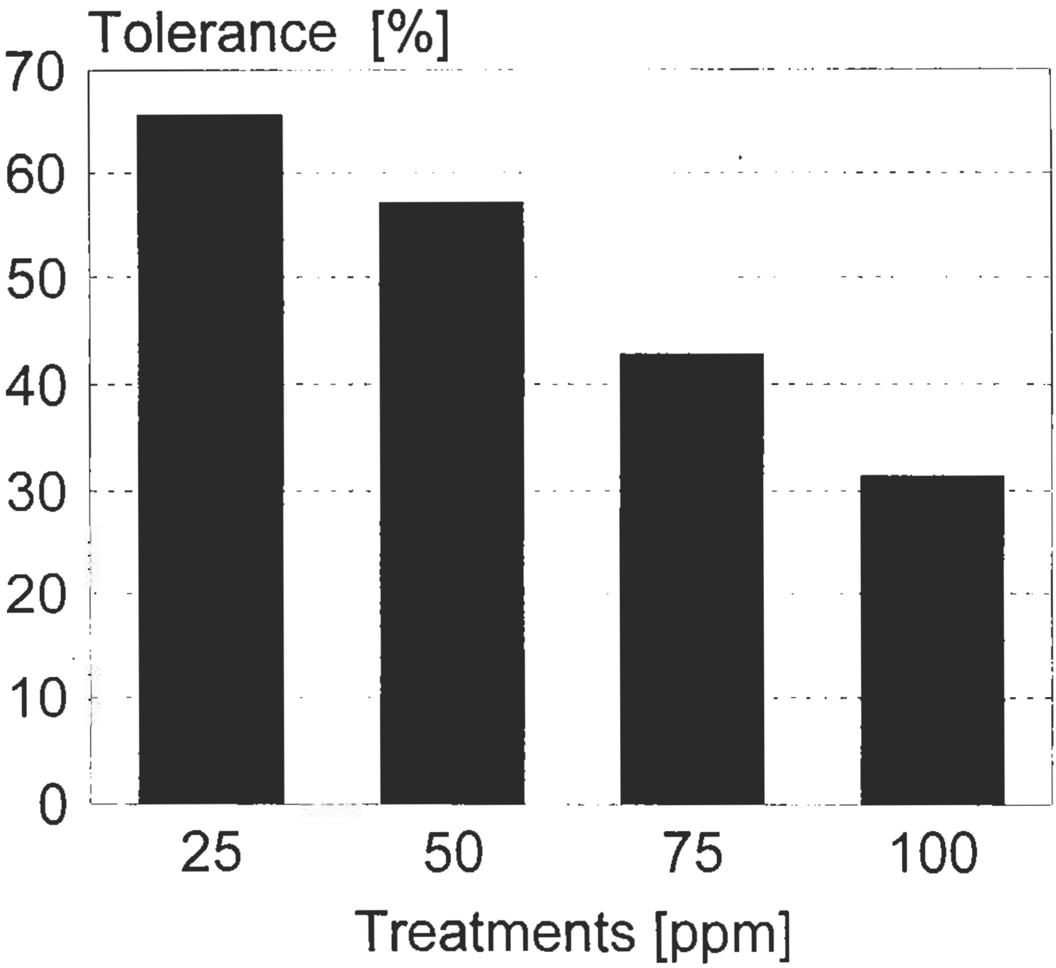


Fig. 21. Tolerance index of *Leucaena leucocephala* at different concentrations of lead

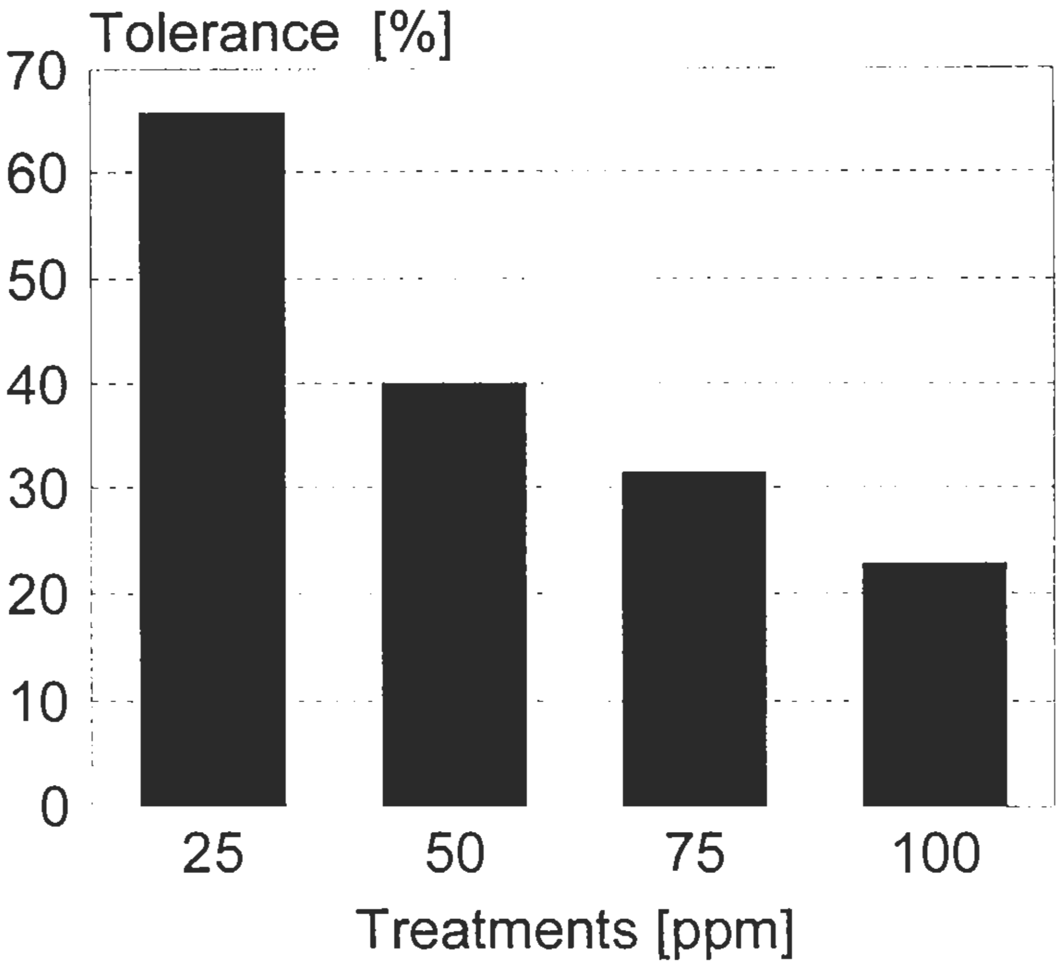


Fig. 22. Tolerance index of *Leucaena leucocephala* at different concentrations of cadmium

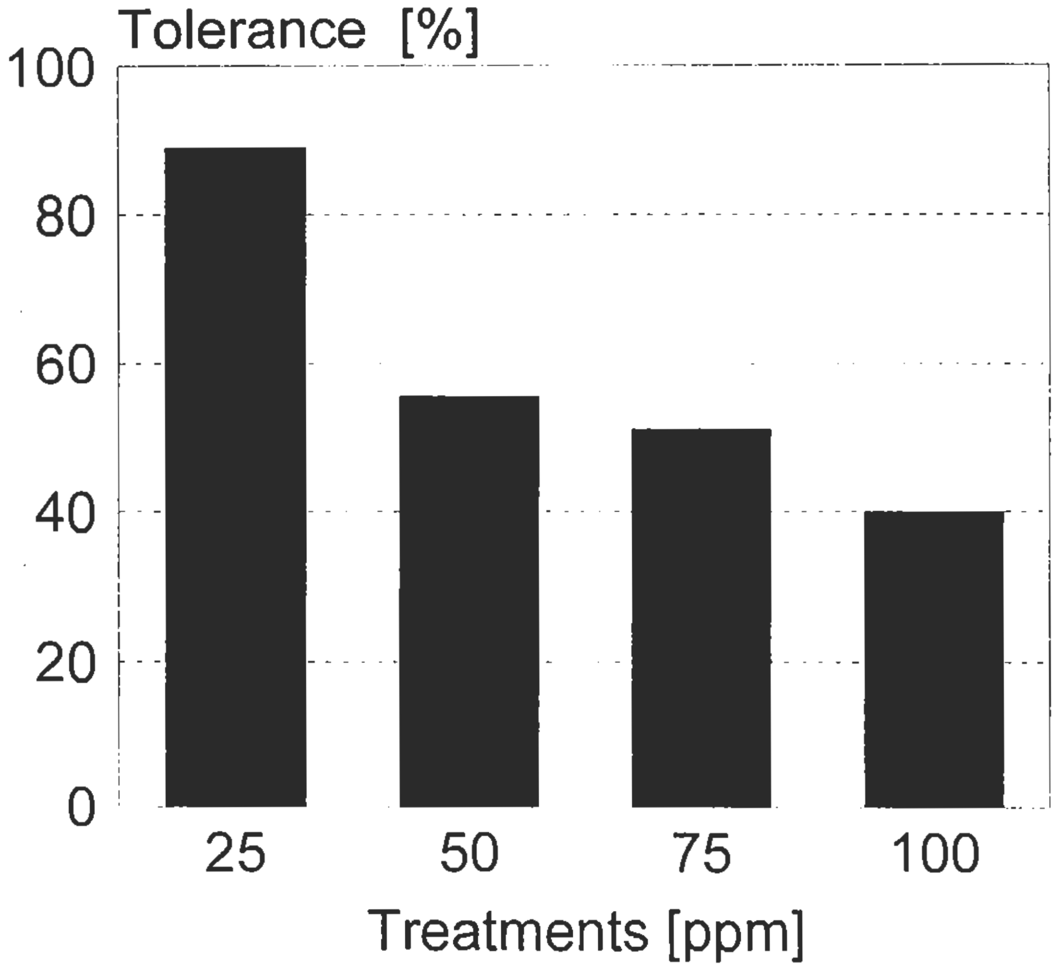


Fig. 23. Tolerance index of *Peltophorum pterocarpum* at different concentrations of lead

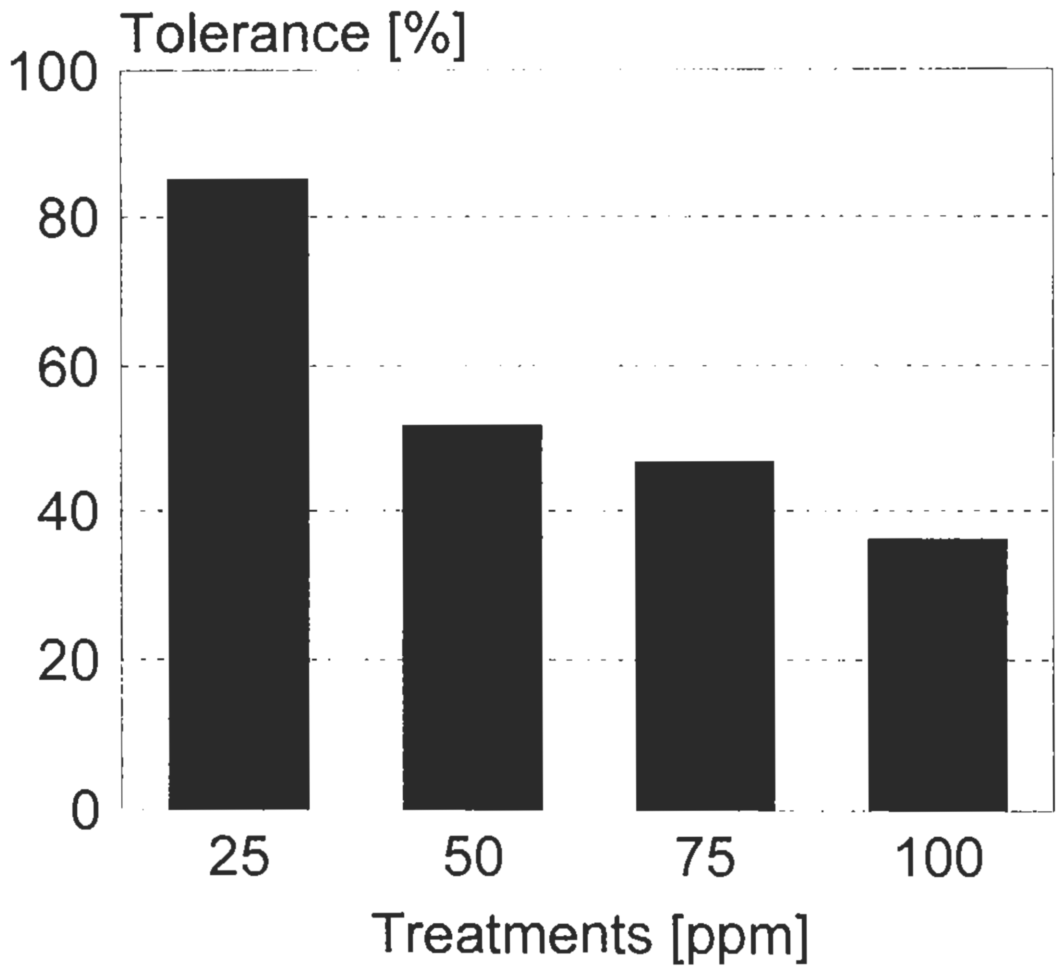


Fig. 24. Tolerance index of *Peltophorum pterocarpum* at different concentrations of cadmium

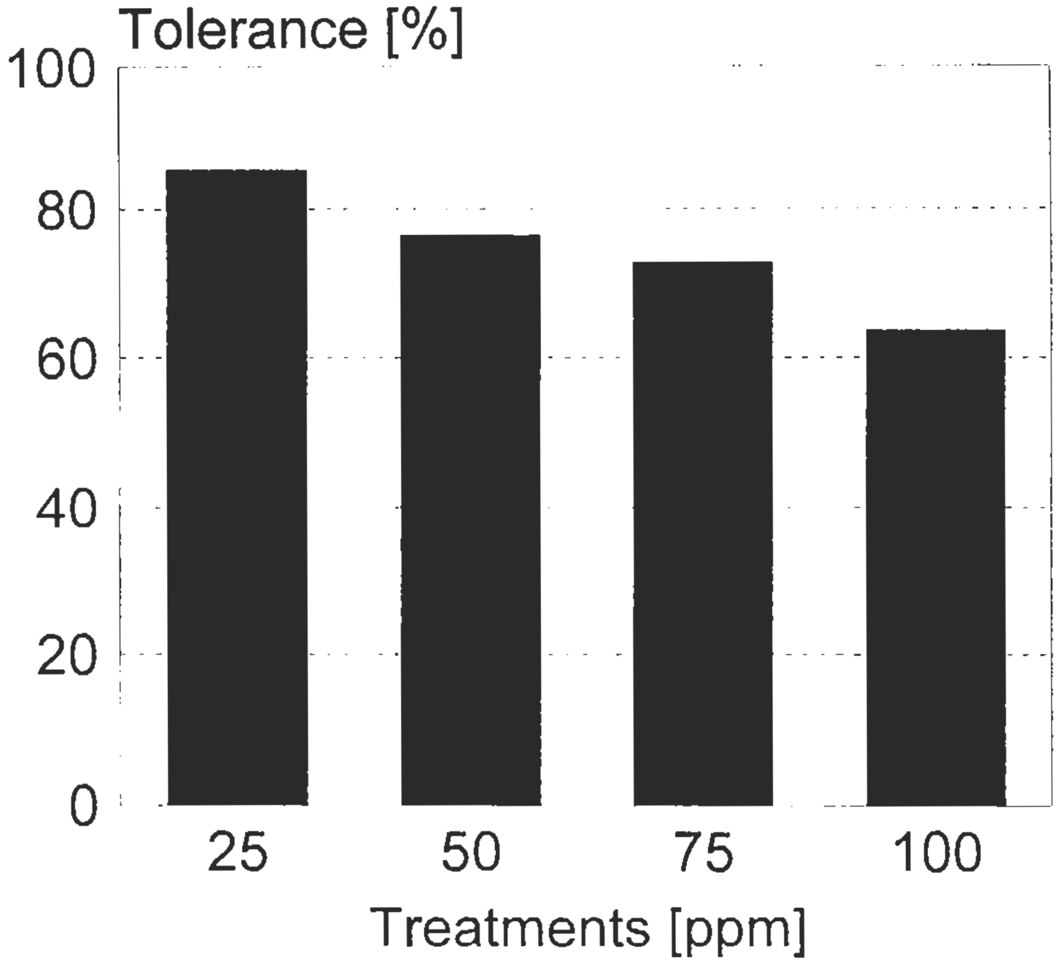


Fig. 25. Tolerance index of *Cassia siamea* at different concentrations of lead

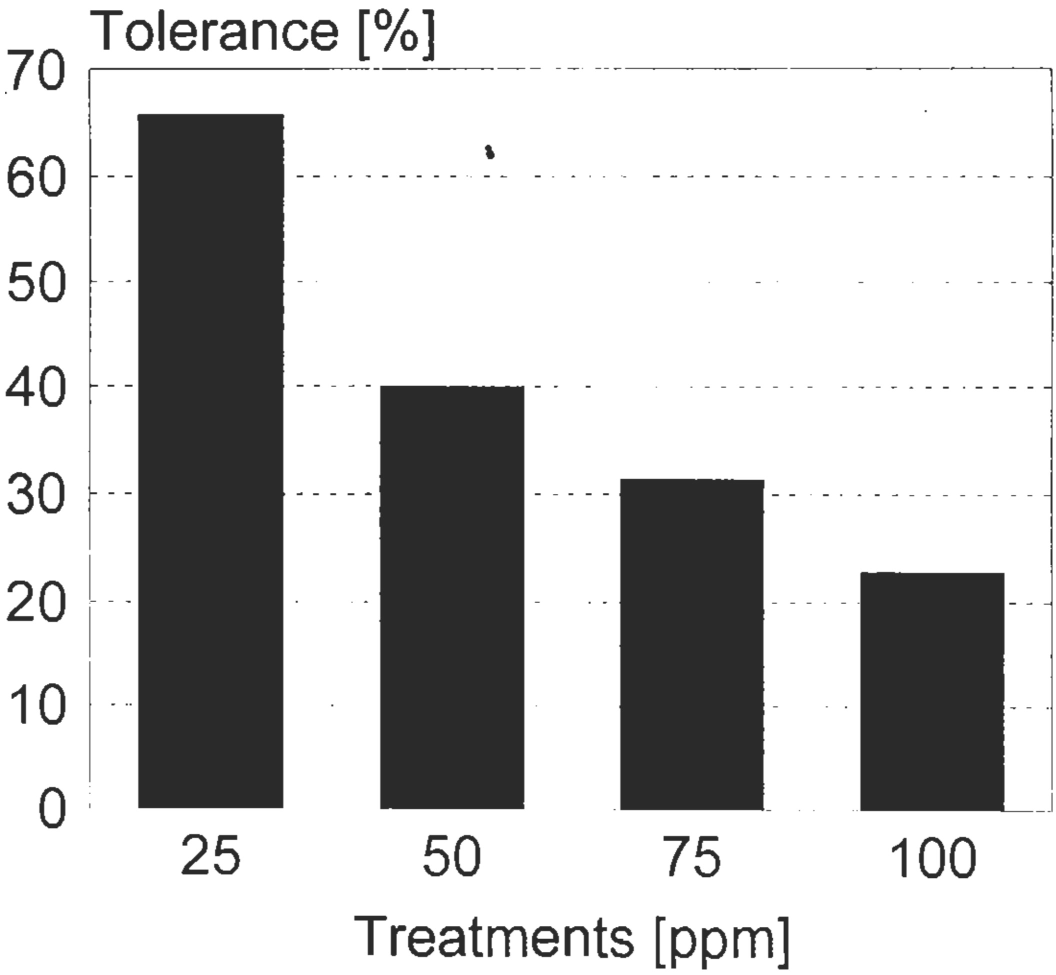


Fig. 26. Tolerance index of *Cassia siamea* at different concentrations of cadmium

Lead and cadmium in the foliage of different plants

The analysis showed high levels of lead and cadmium in the leaves of *Alstonia scholaris*, *Pongamia pinnata*, *Cassia siamea* and *Peltophorum pterocarpum* collected from the polluted as compared to less polluted sites of the city (Table 16-17).

A significant ($p<0.05$) difference was found in Pb content in the leaves collected from the polluted and less polluted areas (Table 16). The values were found higher in the city environment than at Karachi University Campus. Higher lead content (95 μg^{-g}) was found in *A. scholaris* at M.A. Jinnah Road, while the minimum (10 μg^{-g}) was recorded at Karachi University Campus. At Shahrah-e-Faisal, the concentration of lead was significantly ($p<0.05$) higher (75 μg^{-g}) as compared to control. An average level of lead (57 μg^{-g}) content was recorded in the leaves of *A. scholaris* from Nazimabad site, while low concentration of lead (41 μg^{-g}) was found in the leaves of same species collected from Gulshan-e-Iqbal.

Concentration of lead investigated in the leaves of *P. pinnata* was (106 μg^{-g}) at M.A. Jinnah Road, while, the lowest level (18 μg^{-g}) was recorded in leaves collected from Karachi University Campus. At Shahrah-e-Faisal the concentration of lead in *P. pinnata* leaves was 71 μg^{-g}, while, an average level of lead content was recorded from Nazimabad (54 μg^{-g}) and Gulshan-e-Iqbal (43 μg^{-g}).

The level of lead in the leaves of *C. siamea* was found high at M.A. Jinnah Road (87 μg^{-g}), followed by Shahrah-e-Faisal (78 μg^{-g}), Nazimabad (48 μg^{-g}) and Gulshan-e-Iqbal (31 μg^{-g}), respectively. Lowest level of lead (8 μg^{-g}) was recorded in foliage of *C. siamea* growing at Karachi University Campus.

Levels of lead in the leaves of *Peltophorum pterocarpum* ranged between 7-81 μg^{-g} . Lowest level of lead (7 μg^{-g}) was found in leaf samples collected from Karachi University Campus, while highest level of lead (81 μg^{-g}) was recorded at M.A. Jinnah Road. An average level of lead was found in *P. pterocarpum* leaves was found at Shahrah-e-Faisal (57 μg^{-g}) and Nazimabad (36 μg^{-g}) sites, respectively.

Cadmium analysis in leaves of *Alstonia scholaris*, *Pongamia pinnata*, *Cassia siamea* and *Peltophorum pterocarpum* showed low levels as compared to lead (Table 17). The leaves of all the species showed high level of cadmium in samples collected from the city area as compared to Karachi University Campus. Cadmium level in leaves of all the species was found in the range of 0.26-2.96 μg^{-g} . The highest level of Cd (2.96 μg^{-g}) was found in the leaves of *A. scholaris* growing at M.A. Jinnah Road. The level of cadmium in the leaves of *A. scholaris* collected from Shahrah-e-Faisal, Nazimabad and Gulshan-e-Iqbal, were 1.76 μg^{-g} , 1.50 μg^{-g} and 0.86 μg^{-g}, respectively.

High concentration of cadmium (2.10 μg^{-g}) was investigated in the leaves of *P. pinnata* at M.A. Jinnah Road whereas, the lowest level of cadmium (0.26 μg^{-g}) was recorded at Karachi University Campus. Cadmium was found higher at Shahrah-e-Faisal (1.16 μg^{-g}), while, at Nazimbad and Gulshan-e-Iqbal, the concentration of cadmium in leaves of the same species was 0.63 μg^{-g} and 0.43 μg^{-g}, respectively.

High amount of cadmium (1.76 μg^{-g}) was found in the leaves of *C. siamea* at M.A. Jinnah Road, while the lowest cadmium (0.56 μg^{-g}) was recorded at Karachi University Campus. Levels of cadmium in leaves were 1.50, 0.93 and 0.76 μg^{-g} in samples collected from Shahrah-e-Faisal, Nazimabad and Gulshan-e-Iqbal sites, respectively.

Different level of cadmium was observed in the foliage of *P.* pterocarpum collected from both polluted and less polluted sites of the city. The level of cadmium in the leaves of *P. pterocarpum* was in the range of 0.46-1.53 μg^{-g}. High cadmium level (1.53 μg^{-g}) was detected at M.A. Jinnah Road, while the lowest was recorded at Karachi University Campus (0.46 μg^{-g}). Cadmium levels at Shahrah-e-Faisal (1.06 μg^{-g}), Nazimabad (0.70 μg^{-g}) and Gulshan-e-Iqbal (0.60 μg^{-g}) were in between M.A. Jinnah Road and Karachi University Campus.

Table 16. Concentration of lead in the foliage of different plants

Name of Species	Sites	Pb (μg^{-g})	
Alstonia scholaris	E	*95.00±2.88	a
	D	75.00±3.46	b
	C	57.00±4.04	c
	B	41.00±2.88	d
	A	10.00±2.88	e
L.S.D. p<0.05		10.3	
Pongamia pinnata	E	106.00±1.15	a
	D	71.00±1.73	b
	C	54.00±3.47	c
	B	43.00±7.50	c
	A	18.00±1.15	d
L.S.D. p<0.05		12.8	
Cassia siamea	E	87.00±1.52	a
	D	78.00±2.64	b
	C	48.00±1.52	c
	B	31.00±4.61	d
	A	8.00±1.15	e
L.S.D. p<0.05		7.8	
Peltophorum pterocarpum	E	81.00±1.15	a
	D	57.00±2.30	b
	C	36.00±3.46	c
	B	14.00±4.04	d
	A	7.00±6.35	d
L.S.D. p<0.05		12.2	

Symbol used:

Sites A=Karachi University Campus B=Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E= M.A. Jinnah Road. Statistical significance determined by analysis of variance. Number followed by the same letters in the same column are not significantly ($p<0.05$) different, according to Duncan's Multiple Range Test. * Mean ± Standar Error

Table 17. Concentration of cadmium in the foliage of different plants

Name of Species	Sites	Cd (µg^{-g})	
Alstonia scholaris	E	*2.96±0.057	a
	D	1.76±0.057	b
	C	1.50±0.288	c
	B	0.86±0.115	d
	A	0.30±0.230	e
L.S.D. p<0.05		0.600	
Pongamia pinnata	E	2.10±0.092	a
	D	1.16±0.001	b
	C	0.63±0.003	c
	B	0.43±0.051	cd
	A	0.26±0.057	d
L.S.D. p<0.05		0.219	
Cassia siamea	E	1.76±0.057	a
	D	1.50±0.034	ab
	C	0.93±0.132	abc
	B	0.76±0.577	bc
	A	0.56±0.150	c
L.S.D. p<0.05		0.866	
Peltophorum pterocarpum	E	1.53±0.023	a
	D	1.06±0.057	ab
	C	0.70±0.115	bc
	B	0.60±0.034	bc
	A	0.46±0.305	c
L.S.D. p<0.05		0.471	

Symbol used:

Sites A=Karachi University Campus B=Gulshan-e-Iqbal C=Nazimabad D=Shahrah-e-Faisal E= M.A. Jinnah Road. Statistical significance determined by analysis of variance. Number followed by thc same letters in the same column are not significantly (p<0.05) different, according to Duncan's Multiple Range Test. * Mean ± Standar Error

DISCUSSION

DISCUSSION

Emissions from automobile contribute most of air pollution problems. Trees in cities are subjected to a widespread pressure of autovehicular emission. In plant organs, the leaf is the most sensitive part to be affected by air pollutants. The sensitivity rests on the fact that the major portions of important physiological processes are concentrated in the leaf. Therefore, the leaf at its various stages of development, serves as a good indicator to air pollutants. Pollutants derived from the autoemission can directly affect the foliage of plants by entering the leaf, destroying individual cells, and reducing the plant ability to produced food. Reduction in leaf length, width, area and dry weight of roadside plants was the witness of bad effects of the city environment. It is found that the plants growing close to the busy road of the city are highly affected by autoemission. The inhibitory effects on the growth of plants are due to the presence of toxic material in the autoemission.

The results of the present study testify this grave situation facing for trees growing at the polluted sites. Trees are dying as a result of prolonged exposure of exhaust emission especially at M.A. Jinnah Road. The leaf growth of *Alstonia scholaris*, *Pongamia pinnata*, *Cassia siamea* and *Peltophorum pterocarpum* was significantly affected at the polluted environment of city as compared to clean area.

Leaf size of all the species reduced progressively depending on the level of pollution at the city. During the present investigation it was observed that the trees were more sensitive to air pollutants at M.A. Jinnah Road as compared to other less polluted areas of the city. In summer, the leaf length, width and area of *A. scholaris* was significantly affected at M.A. Jinnah Road. Significant reduction in leaf size for *P. pinnata* was also found in autumn at M.A. Jinnah Road as compared to other less polluted sites of the city. The reduction in leaf size of *A. scholaris* and *P. pinnata* might be due to the large surface area of their leaves that is available to exposure to any pollutant. A significant ($p<0.05$) decline in leaf area of a roadside plant, *Bougainvillea spectibilis* Willd, has been observed by Hussain *et al.*, (1997).

The leaf size of *C. siamea* was highly affected in autumn season at M.A. Jiannah Road as compared to other sites of the city. The decrease in leaf parameters could be attributed to high level of automobile pollutants in the environment and excessive fall of autodust on their aerial parts. Excessive quantities of air borne particulate matters cover the leaves, clogg the stomata, thereby both reducing the absorption of carbon dioxide from the atmosphere and the intensity of light reaching the interior of leaf, and suppressing the growth of plants. Bhatti & Iqbal (1988) reported reduction in leaf length of *Ficus bengalensis* L., at the polluted sites. Atmospheric pollutants after making their entry through stomata of leaves cause reduction in leaf size of plants due to damage of photosynthetic tissues. Since plant growth and production depends on phyotosynthetically functional leaves leaf size of all the tested species were found significantly reduced for plants growing at the polluted sites of the city. The automobile pollutants have also significantly reduced the leaf length of *C. siamea* at M.A. Jinnah Road in winter season. This might be that during winter, growth was already slow, therefore the effects of pollutants on plants were more pronounced.

The leaf dry weight of *C. siamea* and *P. pterocarpum* were highly affected at the polluted sites of the city as compared to campus. The presence of various types of pollutants derived from the automobiles might be responsible for the reduction in leaf dry weight of plants. Low leaf dry mass of all the species at polluted sites might be due to carbon exchange becomes limited and hence photosynthesis reduced. Light intensity at the polluted area was low, which could result in less photosynthesis and eventually less growth of plants (Shams & Iqbal, 1986). The productivity of a plant mostly depend on the rate of photosynthesis and reasonable respiration but at the polluted areas all these processes are disturbed which results in reduction of tree growth and biomass production.

The pollutants emitted from the automobile activities also influence on the seed germination ability (Maguire, 1969). Vehicles passing through the busy roads of the city produce different types of pollutants thus affecting seed germination and their viability. In the present study, seeds collected from different sites of the Karachi city responded differently in germination and seedling growth. The seed germination, seedling growth and dry weight of *Peltophorum pterocarpum* and *Cassia siamea* were found low in the city areas. Significant reduction in seed germination and seedling growth was observed in seeds of *P. pterocarpum* and *C. siamea* collected from M.A. Jinnah Road as compared to Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus. The effect of autoemission on seed germination and seedling growth varied from site to site and species to species. The reduction in seed germination of *C. siamea* and *P. pterocarpum* could be due to the development of unhealthy seeds produced by trees growing along the main road of the city. The reduction in seed germination of both the species collected from the polluted areas of M.A. Jinnah Road, Nazimabad, Shahrah-e-Faisal and Gulshan-e-Iqbal as compared to Karachi University Campus agrees with the findings of Iqbal & Siddiqui (1996) who found reduction in seed germination of *Pongamia pinnata* (L.) Merrill and *Sesbania sesban* (L.) Merrill collected from other parts of the polluted areas. Similar observation have been made by Mahmood & Iqbal (1989) and Qadir & Iqbal (1991) who found that seeds of *Dalbergia sissoo* Roxb., collected from different areas of the city showed significant reduction in germination as compared to clean area.

The seed germination of *C. siamea* was greatly affected by autoemission as compared to *P. pterocarpum*. It is interesting to note that the pods of *C. siamea* are not thick, the air pollutants from the roadside might easily enter into seeds which leads to the development of unhealthy seeds. The accumulation of toxic products, excess fall of autodust which contain hydrocarbon and metals are likely to be important in the reduction of seed germination and seedling growth of plants. Low percentage of seed germination, seedling growth and dry weight of *C. siamea* raised from seeds of the polluted environment has proved the loosing viability of the seeds. The deposition of lead and soot particles on the surface of pods from automobile activities could cause low production of healthy seeds. The seed germination of *P. pterocarpum* was found less affected in samples collected from the polluted sites. This demonstrated that the seeds of *P. pterocarpum* are more tolerant than seeds of *C. siamea*. The degree of effectiveness of seeds could be due to their genetic ability.

In pot experiments the seedling length of *P. pterocarpum* and *C. siamea* raised from the seeds of polluted area of M.A. Jinnah Road showed reduction upto 37% and 44%, respectively. Mehmood and Iqbal (1989) concluded that the seed viability was more affected in seed collected from plants growing close to the roadside. *P. pterocarpum* and *C. siamea* also showed a decrease in root growth in seedlings raised from the polluted seeds as compared to control. Wong et al., (1984) have also studied the inhibition in root growth of roadside plants of *Brassica chinesis* and *Brassica parachinensis*. The pollutants emitted from the autoexhaust have greatly influenced the seedling dry weight capability of roadside plants. The seedling dry weight was reduced in the polluted seedlings as compared to control. An inhibition and delay in germination of seeds of *Cucumis sativus*, cv. *Beite alpha* and *Triticum aestivum* cv., cumhuriyet 75 have been also recorded with the application of exhaust gas (Türkan, 1988). The yield of seeds and fruits of *Guiacum officinale* L., and *Azadirachta indica* (L.) A.

Juss., was lessened at the polluted sites (Bhatti & Iqbal, 1988). The present study reveals that seeds from the plants growing close to the busy roads showed more reduction in germination and growth, which might be due to toxicity of autoemissions. In the polluted atmosphere the chlorophyll is disintegrated and CO_2 uptake is reduced followed by a reduction in synthesized assimilates. Marked reduction in seed germination and seedling growth for *C. siamea* was observed, which might be its less resistance to the toxic pollutants. In few cases the resistance might be provided by nature, particularly in *P. pterocarpum*, due to the presence of hard pod and hard seed coat. The tolerance of plants to different pollutants enables them to produce a greater number of viable seeds, as supported by the work of Pell & Puente (1988). In autovehicular pollution, some hidden or physiological changes or metabolic disorders of plants take place, which affect the reproductive capacity of plants and enforce plants to produce low viabile of seeds. The viability of seeds produced by plants growing in the polluted areas was significantly affected as compared to the seeds of clean areas. A comparative study for growth between the polluted and control seedlings of *P. pterocarpum* and *C. siamea* showed a considerable reduction in polluted plants as compared to control under uniform environmental conditions. This decrease in growth of polluted plants was observed in all the parameters and was attributed to the presence of high automobile pollution of the environment at M.A. Jinnah Road from where the seeds of polluted species had been collected.

A chemical balance of inorganic elements in living organisms is a basic conditions for their proper growth and development (Markert, 1990). The plants under stress conditions are most likely to be adversely affected by high concentration of heavy metals. Lead and cadmium toxicity has become important due to their constant increase in the environment. Excessive amount of toxic element usually caused reduction in plant growth (Prodgers & Inskeep, 1981).

In the present investigation, lead and cadmium treatment decreased seed germination and seedling growth of all the tested species viz., *L. leucocephala*, *P. pterocarpum* and *C. siamea*. This decrease in seed germination of *L. leucocephala*, *P. pterocarpum* and *C. siamea* can be attributed to the accelerated breakdown of stored food materials in seed by the application of lead and cadmium. Reduction in seed germination of all these species can also be attributed to alterations of selection permeability properties of cell membrane. The reductions in the seed germination due to metal treatments are similar to the findings of other workers. Kalimuthu & Siva (1990) found reduction in seed germination in maize (*Zea mays*) treated with 20, 50, 100 and 200 μg^{-ml} lead acetate and mercuric chloride. Treatment of wheat with lead at 1, 2, 5, 10 and 20 mM hindered the germination process showing gradual reduction in germination with increase in concentration (Hasnain *et al.*, 1995).

Plants require different elements for growth, but excessive amount can lead to toxicity. The seedling growth of *L. leucocephala*, *P.*

pterocarpum and *C. siamea* also showed reduction with increase in concentration of cadmium solution. Iqbal & Mehmood (1991) had reported gradual decrease in plant growth of *Dalbergia sissoo* Roxb., with the increase of cadmium level. The reason of reduced seedling length in metal treatments could be the reduction in meristematic cells present in this region and some enzymes contained in the cotyledon and endosperm. Cells become active and begin to digest and store food which is converted into soluble form and transported to the radicle and plumule tips for enzyme amylase which, convert starch into sugar and protease act on protein. So when activities of hydrolytic enzyme were affected, the food do not reach to the radicle and plumule and in this way seedling length were affected. The reduction in the seedling growth might be due to accumulation of lead in the substrate. Mathur *et al.*, (1987) found that higher concentration of Cd and Cr (100-250 ppm) affected germination and early growth performance of *Allium cepa*.

Lead and cadmium treatment produced greater toxic effects on root growth of *L. leucocephala*, *P. pterocarpum* and *C. siamea*. The reason of reduced root length in metal treatments could be due to reduction of mitotic cells in meristematic zone of root. Lerda (1992) did same type of study on *Allium cepa* root. These findings confirm that metal treatment reduced the frequency of mitotic cell in meristematic zone and responsible for inhibition in root growth. The reason for different response of seedling and root growth to heavy metals is not known but might be due to rapid accumulation of heavy metals in root than shoot or to faster rate of detoxification in the shoot than root. The growth rate of root, shoot and formation of lateral root were found to be retarded with the increase in concentration of mercuric chloride, cadmium acetate and zinc sulfate in ground nut (Renjini & Janardhanan, 1989). In another investigation, Breckle & Kahile (1992), identified the toxicity of lead and cadmium in young roots of *Fagus silvatica*. A combined treatment of 20 ppm Pb and 1 ppm Cd lead to higher growth depression for *F. silvatica* than in treatment where metals were applied separately.

The effects of toxic substances on plants are dependent on the amount of toxic substance taken up from the given environment. The toxicity of some metals may be so great that plant growth is retarded before large quantities of the element can be translocated (Haghiri, 1973). The seedling of all the tested species also showed gradual decrease in dry weight with increase in concentration of lead and cadmium. The lead and cadmium treatment showed great effects on seedling dry weight, which is evident due to poor growth of roots and aerial parts.

According to tolerance test it could be seen that tolerance to Pb and Cd in *L. leucocephala* was lower than *P. pterocarpum* and *C. siamea*. The reason for low tolerance against both metals might be due to changes in the physiological association of the tolerance mechanism in seed germination and seedling growth of plants. *C. siamea* and *P. pterocarpum* are possessing a better tolerance to lead and cadmium application.

Plant materials such as tree bark, tree rings and leaves of higher plants; have been used to detect the deposition, accumulation and distribution of metal pollution for many years (Aksoy & Sahln, 1999). To study airborne dust particles deposited in the polluted areas, the most suitable method is leaf collection (Freer-Smith *et al.*, 1997). It is logical to conclude that heavy metals, which are discharged into the atmosphere through motor vehicles exhaust, are deposited on and penetrate into leaves. The Pb content in this study was found in the range of 7-106 μg^{-g} with great differences among sites and plant species. In the present study the concentration of lead in leaves sample of *Alstonia scholaris*, *Pongamia pinnata*, *Cassia siamea* and *Peltophorum pterocarpum* was found high at the polluted sites as compared to Karachi University Campus. This high level of lead at polluted site might be due to presence of high lead additive compounds used in petrol. A complete monitoring data on both metals is sparse. However, it should be noted that lead content of petrol are quite high (1.5-2.0 μg^{-1}), which are above the guideline of World Health Organization (0.5-1.0 μg^{-1}) (UNEP, 1992). Air borne Pb is closely associated with the density and congestion of motor vehicle traffic. It is therefore not surprising to see that Pb concentrations in the leaf of trees growing at M.A. Jinnah Road was quite high as compared to leaf samples collected from other less polluted sites (Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal) and Karachi University Campus.

Accumulation and deposition of metals on the surface of leaves can increase the metal concentrations. The higher level of Pb in the leaf of *P.*

pinnata (106 μg^{-g}) and *A. scholaris* (95 μg^{-g}) was recorded at M.A. Jinnah road, which might be due to the large surface area that is available for exposure to any pollutant. Aksoy *et al.,* (2000) found high level of Pb (15.98- 177 μg^{-g}) in unwashed leaves sample of *Robinia pseudo-acacia* L. growing along roadside of Kayseri city (Turkey). High concentration of Pb in leaves sample of *C. siamea* and *P. pterocarpum* were also found at M.A. Jinnah Road, where the traffic density was highest as compared to Karachi University Campus. The flow of traffic at M.A. Jinnah Road near Quaid-e-Azam tomb is quite slow due to presence of traffic signals. The area is rather congested with the result that pollutants emitted from the motor vehicles remained suspended in the atmosphere for some time and ultimately deposited on the surface of leaves. The amount of lead potentially available to plants in any given locality obviously depends on the density of vehicles. Low vehicular traffic activities at the campus showed lowest lead contents for *A. scholaris*, *P. pinnata*, *C. siamea* and *P. pterocarpum.*

The cadmium level in the air is also an important component leading to the problems of environmental pollution. Lagerwerff & Specht (1970) have suggested that cadmium be found in lubricating oils as a part of many additives. The concentration of cadmium in leaf samples of all tree species collected from M.A. Jinnah Road, Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus showed a distribution similar to those obtained for lead. The data emphasized that motor vehicles traffic load is a major cause of high level of Cd content in leaf samples of all tested species viz., *A. scholaris*, *P. pinnata*, *C. siamea* and *P. pterocarpum* collected from the polluted areas of the city. Level of cadmium for all species was found in the range of 0.26-2.96 μg^{-g} . Maximum level of cadmium (2.96 μg^{-g}) was detected in the foliage of *A. scholaris* at M.A. Jinnah road, which is a highly polluted site of the city. The roughness of the outer surfaces leaves contributed to the trapping and retention of air particles (Sawidis *et al.*, 1995). The rough and large surfaces on the leaf of *A. scholaris* could be the reason for high concentration of cadmium as compared to *C. siamea* and *P. pterocarpum* in leaf samples. Similarly, Aksoy & Sahln (1999) investigated high level of cadmium (1.38 μg^{-g}) in unwashed leaves of *Eleagnus angustifolia* L. collected from the crowded parts of city center in Kayseri (Turkey). Ara *et al.*, (1996) had also found high Cd content in the leaves of *Ficus religiosa* L., (0.036 ppm) and *Eucalyptus* sp., (0.033 ppm) from polluted area of the city.

These results indicate that metal aerosols after deposition on the leaf surface of all species are responsible for increase in the level of lead and cadmium in the city area as compared to Karachi University Campus. Moreover, in the present study it was observed that *P. pinnata* and *A. scholaris* leaf samples collected from the polluted sites showed a tendency of higher concentration of lead and cadmium than *C. siamea* and *P. pterocarpum*. In literature, the concentrations of Pb (30-300 μg^{-g}) and Cd (0.03-3.8 μg^{-g}) is considered toxic or contaminated in plants (Ross, 1994). A comparison of the sampling sites from the polluted areas of city centre showed that all the investigated species accumulated much greater amounts of Pb and Cd than the less polluted areas. The concentrations of Pb (7 to 106 μg^{-g}) and Cd (0.26 to 2.96 μg^{-g}) in *Alstonia scholaris, Pongamia pinnata, Cassia siamea* and *Peltophorum pterocarpum* did not exceed the upper limit at any site as suggested by Ross (1994) in his work.

Overall study for phenology, seed germination, seedling growth, lead and cadmium tolerance and their levels in different plant species reveals, that most of the plants growing in the polluted city environment are badly affected by autoemissions. However, *Peltophorum pterocarpum* was found comparatively tolerant species, which could resist the polluted environment of the city to some extent. It is therefore, suggested that *P. pterpcarpum* should be given more preference over other species for future plantation, particularly along the busy roads of the city.

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