Pak. J. Bot., 46(5): 1829-1835, 2014.

IMPACT OF AUTOVEHICULAR DENSITY AND BIOCLIMATIC CONDITIONS ON THE QUALITATIVE AND QUANTITATIVE CHARACTERS OF *AZADIRACHTA INDICA* A. JUSS.

M. KABIR*, M. ZAFAR IQBAL, M. SHAFIQ AND ZIA-UR-REHMAN FAROOQI

Department of Botany, University of Karachi, Karachi, 75270, Pakistan.
**Corresponding author e-mail: kabir_botany82@yahoo.com; shafiqeco@yahoo.com*

Abstract

The impact of auto-vehicular pollution on the qualitative and quantitative characteristics of *Azadirachta indica* A. Juss. growing along different polluted roads of Karachi was evaluated. Reductions in leaves parameters such as leaf area, leaf fresh and dry weight of *A. indica* were observed at University Campus, University Road, Board Office Road, Shaheed-e-Millat Road and Shahrah-e-Faisal during different seasons of the years from, 2008-2009. Some visual observations as leaf color, fruit and seed production were also recorded periodically, which showed variation at different sites. Results indicated that *A. indica* at control site were growing as fast as they were given the favorable resources such as bio-climatic factors which include heat index, chill, humidity, temperature and wind speed naturally available to them but road-side pollution stressed the growth. Climatic conditions were comparatively different on the city roads as compared to the University Campus. The automobiles density has significantly ($p<0.05$) reduced the leaf area of *A. indica* at Shahrah-e-Faisal in summer season (July, 2008). The soil of the studied area showed a high percentage of $CaCO_3$, slightly alkaline pH, electrical conductivity (E.C.), total dissolved salts (T.D.S.) in city roads as compared to University Campus soil. These findings demonstrated that traffic density and harsh bio-climatic conditions showed poor appearance and reduction in the qualitative characters and biomass of *A. indica*.

Key words: Autovehicular density, *Azadirachta indica*, Bioclimate, Qualitative and Quantative cjaracteristics.

Introduction

Pakistan is a developing country with an estimated population of 187,343,000 in 2011. It is the world's sixth most populated country. The urban centers of the country are experiencing environment related problem. Karachi is the widely populated city of the world, having an estimated population of census 2013 was 12, 991, 000 (Anon., 2013) and is the Pakistan's largest industrial and commercial center handling much of Pakistan's international trade and leading manufacturing industries include food processing, shipbuilding, and the making of textiles, chemicals, and machinery. Karachi city is situated at 64^o longitudes and 27^o latitude on the shore of Arabian Sea near the Indus River delta. The capital of Sindh province, it is Pakistan's main seaport and industrial center. The city covers an area of approximately 3,530 km^2 with 18 towns and 6 cantonment boards. It comprised largely of flat or rolling plains, with hills on the western and Manora Island and the Oyster Rocks. The Arabian Sea beach lines the southern coastline of Karachi. Karachi city is facing many challenges that are central to many developing metropolises, including traffic congestion and pollution related problems. Karachi is tormented by a series of environmental problems due to increase in population growth, automobiles activities, solid refuse burning, domestic fuel burning and industrial activities. Transport system consists on buses, minibuses, rickshaws, cars, trucks and locomotive train are the primary modes of city conveyance and most of the badly maintained automobiles producing hazardous pollutants in the environment and producing toxic effects on plants. 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 and responsible for decrease in plants growth. These pollutants in combinations cause greater or synergistic effects to plants (Qadir & Iqbal, 1991). Air quality crisis in cities is mainly due to vehicular emissions. Transportation systems are increasing everywhere and the improvements in technology are insufficient to counteract the growth (Ghose *et al*., 2004).

Vehicular traffic has become a major source of air pollution in urban areas (Sivcoumar & Thanasekaran, 1999). Automobile pollution can have a wide range of negative consequences for plant health and productivity. Many organisms morphologically responded different to environmental factors. Reduced yield of flowers, fruits and seeds have been also demonstrated by Heagle *et al*., (1976). Air pollution is a major part of overall atmospheric pollution and motor vehicles usually constitute the most significant source of ultra fine particles in an urban environment (Zhu *et al*., 2002). The changes in foliar and cambial behavior in *Azadirachta indica* (Neem tree) due to coal smoke pollution, has revealed inhibitory effects of pollution stress on leaf pigments concentrations, nitrate reductase activity and the contents of reducing sugars and total N content, whereas stimulatory effects were recorded on stomatal index, nitrate and sulphur contents (Iqbal *et al.,* 2010).

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; Jim, 1996, 1997, 1998). The problem of environmental pollution can be related to poor quality of fuel available in the market and as a result vehicles emit particulate matter and oxides of carbon, nitrogen and sulfur in the atmosphere. Carbon monoxide, hydrocarbons and benzene emissions are high in gasoline vehicles compared to diesel vehicles. The age of the vehicles contribute more pollutants. Important chemical pollutants emitted by land vehicles are Carbon monoxide (CO), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and Total suspended particles (TSP) (Najeeba & Saleem, 1997). Street dust and neem tree samples (*Azadirachta indica*) from Maiduguri Metropolis, Borno State, Nigeria were collected for the determination of trace elements. The concentrations of all the metals in plant samples were reported significantly highest in the leaves of *A. indica*, while the stem bark showed the least values. Levels of chromium (Cr), lead (Pb), nickel (Ni), cobalt (Co), cadmium (Cd) and arsenic (As) in plant samples exceeded the world health organization standard limits for medicinal plants and concluded that the traffic situation in the area of study might be regarded as a source of heavy metal contents in the roadside dust and plant samples (Akan *et al.,* 2013).

Seasonal changes include variations in the duration of sunlight, precipitation, temperature and other life controlling factors. Blooming of flowers and falling of leaves in a year are considered a part of the cycles of life. The environmental impacts are particularly severe in cities of about 10 million or more inhabitants also known as megacities (Gurjar & Lelievel, 2005). Low light intensity at the polluted area could be resulted in less photosynthesis and eventually less growth of plants. The productivity of a plant mostly depends on the rate of photosynthesis and respiration but at the polluted areas, all these vital processes were disturbed which result in reduction of tree growth and biomass production. The reduction in leaf parameters could be attributed to high level of automobile pollutants in the environment and excessive fall of auto dust on their aerial parts. Excessive quantities of air borne particulate matters cover the leaves, clog 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 (Shams & Iqbal, 1986). The flowering in plants growing at polluted site is delayed and there was a marked reduction in flowering density, flowering period, size of floral parts, pollen fertility, fruit and seed set. These changes were found to be closely associated with the extent of air pollution caused mainly by significant in the number of automobiles (Chauhan *et al.,* 2004).

Azadirachta indica A. Juss. Azadirachta belongs to family Meliaceeae. Numerous species have been described in the genus but only two are currently recognized, *A. excelsa* (Jack) Jacobs, and the economically important neem tree, *A. indica* (Pennington & Styles, 1975). Both species are native to the Indomalaysian region, and *A. indica* is also widely cultivated and naturalized outside its native range. Earliest reference of Neem is found in Sanskrit writings that are over 4,000 years old (Larson, 1990). Parts of this tree have been used for medicine, shade, building materials, fuel, lubrication, and most of all as pesticides. The use of this tree as an insecticide has now drawn interest from industrialized countries. It is seen as an environmentally safe alternative to synthetic pesticides. To date over 195 species of insects are affected by this tree extracts at concentrations ranging from 0.1 to 1,000 ppm, and insects that have become resistant to synthetic pesticides are controllable with these extracts (Menn, 1990). The neem tree is believed to have originated in Assam and Burma of South Asia and is also found in Pakistan, Sri Lanka, Thailand, Malaysia, and Indonesia (Anon., 1992). *A. indica* also grows well in tropical and subtropical areas around the world (Verkerk *et al*., 1993).

The aim of the present study is to investigate the effects of traffic density, auto exhaust emission and climatic condition on vegetative and reproductive characteristics of *A. indica* at different roads of Karachi during different seasons of the year 2008-2009.

Materials and Methods

A periodical survey was conducted for traffic density, climatic data and vehicular emission effects on growth of *Azadirachta indica* A. Juss. on different roads in Karachi. The study sites selected were University Campus as Control while Board Office Road, University Road, Shaheed-e-Millat Road and Shahrah-e-Faisal as polluted roads. Traffic density of each road was recorded during three different seasons. A number of different types of vehicles were recorded in the morning (9:00 to 11:00 am), after noon (2:00 to 4:00 pm) and evening (5:00 to 7:00 pm) hours. Similarly climatic data of different roads for same duration was also recorded using the Kestrel 4000 NV Pocket Weather Tracker. Later on the total number of vehicles per hour was calculated for different roads.

The plant materials influenced by the traffic emission were obtained from the road edge at a distance of 1-3 meters at the beginning of each season. Twenty five fresh leaf samples of *A. indica* were collected randomly from each area at 2-5 meters height through out the plant canopy to give respective average sample. Quantitative characters of the leaves such as leaf length, breadth, area and leaf fresh and dry weights were recorded during different months (July& November, 2008 and February, 2009). The fresh weight of leaves was taken and the samples were kept in an oven at 80 ^{0}C for 24 hours and oven dried weight of leaves was obtained by electrical balance.

Soil samples were obtained from different roads near the stem roadside trees. These samples were brought to the laboratory in polythene bags and were kept in air for drying. The soil samples were passed through 2 mm sieve after drying and were subjected to chemical analysis for calcium carbonate, pH, Electrical Conductivity (E.C.) and Total Dissolved Salts (T.D.S.). Calcium carbonate was determined by a method of acid neutralization, as described by Qadir *et al.,* (1966). Soil pH was determined by direct pH reading meter (Mettler Toledo, MP 220). Soil Electrical Conductivity (E.C.) and Total Dissolved Salt (T.D.S.) were determined by AGB 1000 (England) conductivity reading meter.

ANOVA was applied to the data to determine the significance of differences between sample means of different study sites. The data obtained were also statistically analyzed by Duncan's Multiple Range Test using SPSS software version 13.0 on a personnel computer at $p<0.05$ level.

Results

Motor vehicle emission showed toxic effects on seedling growth of *Azadirachta indica* A. Juss. Number of vehicles causing pollution were recorded per hour on some selected roads include trucks, tankers, buses, mini buses, cars/pickups, rickshaws and motorcycles. Traffic density data was determined which gave the estimate about the number of vehicles passing through the road (Table 1).

Different types of vehicles also vary on roads of the city. Data had shown that significantly ($p<0.05$) more number of trucks/tankers were recorded at Board Office, Shaheed-e-Millat Roads and Shahrah-e-Faisal as compared to other roads (University Road and Karachi University Campus). Number of buses were more on the University road and Board Office Road while minibuses, cars/pickups were comparatively high on the Shahrah-e-Faisal, which is considered as one of the largest and busiest road of the city. University road was found as very much polluted road as it carries high traffic load due to its central location in the city. On this road, the number of truck and tankers were less while buses, minibuses, cars/pick ups, rickshaws and motorcycles were recorded more during peak hours of the day. Similarly, the number of vehicles recorded per hour was low on the Board Office and Shaheed-e-Millat Roads of the city which were denoted as polluted and less polluted roads, respectively. Results indicated that high traffic density liberated more pollutants into the environment which are badly affecting climatic factors, water, air and soil characteristics resulting in a direct reduction of plant growth and their development.

Table 1. Traffic density per hour at different roads of Karachi recorded during different seasons of the year 2008-2009.

Sites	Trucks /Tankers	Buses	Mini-buses	Cars/pick ups	Rickshaws	Motorcycles	Total
A	1.50±0.50a	13.67±0.88ab	21.00±7.63a	360.33±18.65a	36.33±9.84a	326.00±75.69a	758.33±109.22a
B	4.66±1.20ab	32.67±4.66bc	512.67±68.48c	1043.00±70.94c	482.67±75.84c	174.67±44.77d	3816.33±85.67d
C	8.67±1.45bc	50.33±13.64c	542.33±65.58c	995.67±22.80c	434.67±40.54c	1439.33±16.67c	3471.00±80.78c
D	12.00±2.51c	3.33±1.85a	336.00±31.75b	779.67±18.28b	188.00±30.61b	1002.67±108.91b	2321.67±167.48b
E	7.33±0.88bc	18.33±3.17ab	645.00±7.00c	184.33±38.86d	176.33±26.44b	1357.33±32.71c	4045.67±63.61d

Table 2. Climatic data in the morning, afternoon and evening hours along the roads of Karachi recorded during 2008.

Time	Sites	Heat index °C	Atmospheric humidity %	Chill °C	Atmospheric temperature °C	Wind speed m/s
Morning (9:00-11:00am)	A	33.33±0.39a	67.56±6.04a	29.40±0.62a	29.83±1.29a	1.27±0.33a
	B	35.37±1.58a	62.60±4.39a	31.17±0.63ab	39.90±1.39ab	1.27±0.26a
	C	33.30±2.35a	51.90±11.30a	30.27±0.51ab	30.17±0.51a	1.13±0.18a
	D	35.63±0.38a	60.70±3.62a	30.87±0.32ab	31.00±0.40ab	1.27±0.03a
	E	37.47±2.48a	59.97±0.81a	31.86±0.89b	34.27±1.82b	1.33±0.20a
Afternoon (2:00-4:00pm)	A	35.86±1.15a	58.23±4.39a	31.63±0.09a	32.03±0.39a	1.63±0.49a
	B	36.20±3.28a	60.83±3.87a	31.03±1.62a	31.07±1.63a	1.93±0.43a
	C	34.47±2.77a	50.60±9.65a	30.76±0.89a	31.03±0.79a	2.03±0.20a
	D	36.20±1.89a	47.30±6.72a	32.67±0.63a	32.73±0.62a	1.50±0.26a
	E	37.60±1.72a	59.37±1.51a	31.97±0.46a	33.63±0.64a	1.63±0.29a
Evening (5:00-7:00pm)	A	34.76±1.90a	60.53±4.93a	30.43±0.22a	30.33±0.27a	1.60±0.40a
	B	33.53±2.72a	61.76±2.87a	29.87±1.41a	29.53±1.64a	1.60±0.26a
	C	32.13±2.31a	52.93±9.49a	29.63±0.71a	29.63±0.77a	1.53±0.12a
	D	35.63±0.46a	54.10±7.33a	31.67±0.52a	31.63±0.50a	1.20±0.26a
	E	35.50±1.75a	62.80±1.30a	30.57±0.64a	31.00±0.75a	1.80±0.15a
Average	A	34.65±0.75ab	61.11±2.74a	30.49±0.37ab	30.73±0.52a	1.50±0.21a
	B	35.03±1.37ab	61.73±1.90a	30.69±0.68ab	30.83±0.85a	1.60±0.19a
	C	33.30±1.29a	51.81±5.10a	30.22±0.39a	30.28±0.41a	1.57±0.16a
	D	35.82±0.58ab	54.03±3.61a	31.73±0.36b	31.79±0.36ab	1.32±0.12a
	E	36.85±1.06b	60.71±0.82a	31.47±0.41ab	32.97±0.78b	1.59±0.13a

Number followed by the same letters in the same column are not significantly different according to Duncan Multiple Range Test at $p<0.05$ level
± Standard Error; Sites: A = University Campus, B = University Road, C = Board Office Road, D = Shaheed-e-Millat Road, E = Shahrah-e-Faisal

Bio-climatic factors which include heat index, atmospheric humidity, chill, atmospheric temperature and wind speed were recorded during different seasons of the year showed that these parameters were higher for the Afternoon hours as compared to when they were recorded for the morning and evening time for the 2008 and 2009. The chill and atmospheric temperature showed significant difference ($p<0.05$) between morning and evening hours but this relation was non-significant for the afternoon. Similarly, heat index, atmospheric humidity and wind speed revealed no significant relation during morning, afternoon and evening hours. City roads showed higher values for these climatic parameters as compared to that which was recorded at the University Campus (Table 2).

The qualitative and quantitative characteristics of *A. indica* recorded during different seasons of the years (2008-2009) on different roads showed diverse effects on seedling growth. Different parameters which include leaf area, leaf fresh and dry weight of plant species were affected greatly by auto emission on Shahrah-e-Faisal as compared to other city roads and University Campus. During the first investigation carried in July 2008, this specie was found in flowering, fruiting and seed formation stages at the University Campus (Table 3). No seed formation occurred in *A. indica* during second and third investigations recorded in November, 2008 and February, 2009.

In the first investigation leaf area of *A. indica* was significantly ($p<0.05$) less at Shahrah-e-Faisal, which was 6.57 cm^2 along with other city roads as compared to University Campus with leaf area of 14.39 cm^2 and at other polluted roads (Table 4). On Shaheed-e-Millat Road leaf area was recorded as 8.21 cm^2 which was highest out of all the polluted roads. Leaf weight, which included leaf fresh and dry weights determined during first and second observations (July and November, 2008) showed that fresh and dry weights were found significantly ($p<0.05$) low at polluted roads as compared to the University Campus. For Shahrah-e-Faisal, the values were 151 mg and 33.17 mg while, for University Campus these values for leaf fresh and dry weights were 230 and 112.52 mg, respectively. At all other polluted roads species also showed significant ($p<0.05$) reduction in their leaf fresh and dry weights as compared to the University Campus.

Months	Sites	Leaf color	Flowers
	A	Dark green	
	B	Dusty green	
July, 2008	C	Dusty green	-
	D	Dark green	
	E	Dusty green	
	A	Dark green	
	B	Dark green	
November, 2008	C	Dusty green	-
	D	Dark green	
	E	Dusty green	
	A	Old leaves greenish yellow and new leaves were formed	Initial flowering
	B	New leaves formation	Initial flowering
February, 2009	C	New leaves formation	Initial flowering
	D	New leaves formation	Initial flowering
	E	New leaves formation	Flowers were absent

Table 4. Effects of auto emission on leaf area, leaf fresh and dry weights of *Azadirachta indica* at different roads of Karachi during July, November, 2008 and February, 2009.

Sites	July, 2008			November, 2008			February, 2009		
	Leaf area (sq cm)	Leaf fresh weight (mg)	Leaf dry weight (mg)	Leaf area (sq cm)	Leaf fresh wt. (mg)	Leaf dry weight (mg)	Leaf area (sq cm)	Leaf fresh weight (mg)	Leaf dry weight (mg)
A	14.39±0.89a	230±7.21a	112.52±6.30a	17.23±0.82a	230±13.07a	125.94±9.29a	11.83±0.71a	220±6.92a	108.66±3.75a
B	7.32±0.54b	152±9.38b	37.65±5.49b	7.95±0.18b	153±9.33b	45.16±4.25b	7.26±0.56b	140±11.46b	62.66±8.35b
C	7.99±0.12b	167±10.86b	39.25±6.14b	8.57±1.79b	165±12.17b	47.48±5.92b	7.84±0.70b	160±4.05b	69.66±1.20b
D	8.21±0.46b	173±9.38b	43.31±6.08b	8.69±1.46b	167±8.18b	52.16±12.10b	8.15±0.41b	164±18.9b	74.33±5.92b
E	6.57±0.78b	151±7.63b	33.17±3.55b	7.50±0.27b	148±12.52b	41.84±5.30b	6.96±0.78b	126±19.36b	61.33±1.20b

Table 5. Analysis of soil collected around the vicinity of *Azadirachta indica* from different roads of Karachi.

Sites	% of $CaCO_3$	pH	EC (dS^{-cm})	TDS (mg^{-L})
A	18.37 ± 4.06a	7.23 ± 0.12abc	14.76 ± 11.97b	10.57 ± 8.62 b
B	21.83 ± 1.01ab	7.68 ± 0.09bc	4.97 ± 0.73ab	3.53 ± 0.55ab
C	21.97 ± 0.85ab	7.42 ± 0.13abc	9.40 ± 2.05ab	6.67 ± 1.44ab
D	23.50 ± 0.60b	7.42 ± 0.13a	3.46 ± 0.83b	2.43 ± 0.60ab
E	23.83 ± 0.39b	7.11 ± 0.06ab	6.93 ± 1.32ab	4.90 ± 0.87ab

Number followed by the same letters in the same column are not significantly different according to Duncan Multiple Range Test at $p<0.05$ level
± Standard Error; Sites: A = University Campus, B = University Road, C = Board Office Road, D = Shaheed-e-Millat Road, E = Shahrah-e- Faisal
Symbol used: $CaCO_3$ = Calcium carbonate, pH = Power of hydrogen ion, E.C. = Electrical conductivity, T.D.S. = Total dissolved salt

In last observation leaf area, leaf fresh and dry weights recorded during February, 2009 showed significant ($p<0.05$) reductions on polluted sites of the city as compared to those which were recorded at the University Campus. Leaf area for Shahrah-e-Faisal was 6.96 cm^2 while at the University Campus the leaf area was 11.83 cm^2. Leaf fresh weight for Shahrah-e-Faisal was recorded as 126 mg and dry weight was 61.33 mg which was less as compared to University Campus which was 220 and 108 mg for fresh and dry weights, respectively.

Low percentage of $CaCO_3$ (18.37%) was recorded in the soil of University Campus while, it increased significantly ($p<0.05$) in soil of polluted areas obtaining high value in soil sample collected from Shahrah-e-Faisal (23.83%) (Table 5). For University Campus, pH value was 7.23 which increased up to 7.42 both at Board Office and at Shaheed-e-Millat Roads while, pH 7.68 in soil of University Road and pH 7.11 was recorded in the soil of Shahrah-e-Faisal. Electrical conductivity (E.C.) was high in soil of University Campus which was 14.76 dS^{-cm} and decreased to 9.40 dS^{-cm}, 6.93 dS^{-cm}, 4.97dS^{-cm}, 3.46 dS^{-cm} in soil of Board Office Road, Shahrah-e-Faisal, University Road and Shaheed-e-Millat Road, respectively. Total dissolved salt measured showed a direct relation to E.C. which indicated that soil with high E.C. attained a higher value of T.D.S. For University Campus T.D.S. was 10.57 mg^{-L} and decreased to 6.67 mg^{-L}, 4.90 mg^{-L}, 3.53 mg^{-L} and 2.43 mg^{-L} in soil of the Board Office Road, Shahrah-e-Faisal, University Road and Shaheed-e-Millat Road, respectively.

Discussion

The results of the present study showed that increased in number of vehicles at the polluted sites of the city affected the plants growth more seriously as compared to the area with less number of vehicles recorded. Increased numbers of vehicles had more profound effects on the morphology and growth of *Azadirachta indica* A. Juss. with varying seasons on the busy roads of the city. As increasing demand for fossil fuels due to the luxurious lifestyle, significant growth of population, transportation and the basic industry sectors has caused serious environmental problems (Fattah *et al.,* 2013). During November increased numbers of vehicles were recorded on Shahrah-e-Faisal which resulted in more reduction in all the growth variables of *A. indica*. Heat index, chill and atmospheric temperature were recorded high on the city roads as compared to University Campus while atmospheric relative humidity was comparatively low on the roads. These variations of climatic factors and number of vehicle affected the growth performance of *A. indica*.

The effects of vehicular emission on different plant species varied from site to site depending on traffic density, distance from the source and type of pollutants released from automobiles. Emissions from auto exhaust have a detrimental effect on plants growing in the polluted area. The study suggested that increased in global temperature as a result of climate change may worsen the harmful effects of pollution on plant growth at polluted sites of city. Overall, pollution had a significant impact on species richness of plants found in a specific area: increased levels of pollutants caused a decline in species richness. However, the effects are also depending on the type of polluters and the plant group i.e. trees, shrubs, grasses and herbs. The present findings are supported by Hussain *et al*., (1989) and Shah *et al.,* (1991), who observed that roadside plants generally grow unhealthy. Biomass allocation among morphological structures is considered a trait that characterizes life history strategies in plants. In addition, warmer and more humid climate conditions may intensify the mobility and toxicity of the pollutants. An increase in temperature is likely to have a significant impact on tree growth and development as reported for *A. indica*. One of fundamental effects may be changed in plant phenology which indicated by interactions between temperature and photoperiod (Bale *et al*., 2002).

Urban air quality is generally poor at traffic intersections due to variations in vehicles speeds as they approach and leave. Most studies have found that vehicular exhaust emissions near the traffic intersections are largely dependent on fleet speed, deceleration speed, queuing time in idle mode with a red signal time, acceleration speed, queue length, traffic-flow rate and ambient conditions. The vehicular composition also affects emissions (Pandian *et al.,* 2009).

Assessing the impacts of polluted climate on plants is a vital task. In both developed and developing countries, the influence of climate on crops persists despite irrigation, improved plant and animal hybrids and the growing use of chemical fertilizers (Nasir *et al*., 2012a,b). An increase in temperature could allow plants to start growing earlier in the season and advanced flowering dates and early onset of bud break has already been reported for numerous species in the northern hemisphere (Walther, 2003). The continued dependence of agricultural production on light, heat, water and other climatic factors, the dependence of much of the world's population on agricultural activities and the significant magnitude and rapid rates of possible climate changes all combine to create the need for a comprehensive consideration of the potential impacts of polluted environment on global agriculture.

Effects of environmental contamination on plant seasonal developments have rarely been documented (Kozlov *et al.,* 2007). The rates of most biophysical processes are highly dependent on climate variables such as radiation, temperature and moisture that vary regionally. For example, rates of plant photosynthesis depend on the amount of photosynthetically active radiation and levels of atmospheric carbon dioxide (CO_2). Temperature is an important determinant of the rate at which a plant progresses through various phenological stages towards maturity. The accumulation of biomass is constrained by the availability of moisture and nutrients to a growing plant. Increases in temperature raise the rate of many physiological processes such as photosynthesis in plants, to an upper limit with accumulation of different pollutants.

Visual characteristics such as flowering, fruits and seeds formations were observed during different seasons of the year, 2008-2009. These characteristics of plants were greatly affected by different types of pollutants released by vehicular emission which not only disguise the visual characteristics of roadside plants, but productivity and mass reduction also occurred depending on distance of plants from a source and its tolerance for automobile pollutants. *A. indica* on Shahrah-e-Faisal have high dusty leaves as compared to leaves collected from other less polluted roads as well as from University Campus.

Phenological studies have received considerable attention during the past decades as possible indicators of global changes and effects on biota (Iqbal & Shafiq, 1999; Hughes, 2000; Menzel & Estrella, 2001, Walter *et al.,* 2002). Similarly, Bhatti & Iqbal (1988) have found that the phenology of *Ficus bengalensis* L., and *Eucalyptus* sp., was highly affected due to automobile exhausts in Karachi city. They have also showed that the automobile emissions significantly ($p<0.05$) reduced the leaf area of *Guaiacum officinale* L., *F. bengalensis* and *Eucalyptus* sp., at the polluted sites of the city, as compared to less polluted areas. All these investigations are strongly supported to our findings that the visual characteristics of *A. indicia* showed variations on polluted city roads as compared to University Campus during different seasons of the years 2008-2009. Similarly, according to Brun *et al.,* (2003) delayed phenological development was detected in herbaceous plants grown on metal contaminated soils. They have also found the foliar surface configuration and biochemical changes in two plant species, namely *Ficus religiosa* L. and *Thevetia nerifolia* L., growing at highly polluted sites, moderately polluted site and low polluted site. The geographical pattern detected by analysis suggests that in the future, plant species in the warmer and polluted environment may be more severely affected by pollution. Even in areas where pollutant emissions are within the limits set by legislation, the study suggests that these contaminants could become more harmful to plant communities as the environment warms and changes by different types of pollutants.

It was concluded from our results that auto vehicular density and bio-climatic conditions showed marked alterations in leaf area, leaf fresh and dry weight and foliar surface architecture of *A. indicia* growing at the highly polluted site as compared to low polluted and comparatively unpolluted sites.

Acknowledgement

We are highly grateful to Higher Education Commission (H.E.C.) of Pakistan for funding this study, which is a part of project No. 20-1073/07. We are also thankful to the chairperson, Department of Botany and the University authorities for providing us space and facilities for conducting the research.

References

Akan, J.C., L.B. Inuwa., Z.M. Chellube and B. Lawan. 2013. Heavy metals in leaf, stem bark of neem tree (*Azadirachta indica*) and roadside dust in Maiduguri Metropolis, Borno State, Nigeria. *Environment and Pollution*, 2(1): 88-95.

Anonymous. 1992 (National Research Council). 1992. Neem: a tree for solving global problems. National Academy Press, Washington, D.C.

Anonymous. 2013. MPCW (Most Populous Cities of the World) 2013. http://www.infoplease.com/ipa/A0762524. html. Visited on 18-12-2013.

Bale, J.S., G.J. Masters, I.D. Hodkinson, C. Awmack, T.M. Bezemer, V.K. Brown, J. Butterfield, A. Buse, C. Coulson, J. Farrar, J.E.G. Good, R. Harrington, S. Hartley, T. Hefin Jones, R.L. Lindroth, M.C. Press, I. Symrnioudies, A.D. Watt and J.B. Whittaker. 2002. Herbivory in global climate change research: direct effect of rising temperature on insect herbivores. *Global Change Biology*, 8: 1-16.

Bhatti, G.H. and M.Z. Iqbal. 1988. Investigations into the effect of automobile exhausts on the phenology, periodicity and productivity of some roadside trees. *Acta Societatis Botanicorum Poloniae,* 57: 395-399.

Brun, L.A., J.L. Corff, and J. Maillet. 2003. Effects of elevated soil copper on phenology, growth and reproduction of five ruderal plant species. *Environmental Pollution,* 122: 361-368.

Chauhan, S.V.S., C. Bharati and R. Anita. 2004. Impact of air pollution on floral morphology of *Cassia siamea* Lamk. *J. Environ. Biol.*, 25(3): 291-297.

Fattah, I.M.R., H.H. Masjuki., A.M. Liaquat., R. Ramli., M.A. Kalam and V.N. Riazuddin. 2013. Impact of various biodiesel fuels obtained from edible and non-edible oils on engine exhaust gas and noise emissions. *Renewable and Sustainable Energy Reviews,* 18: 552-567.

Ghose, M.K., R. Paul and S.K. Banerjee. 2004. Assessment of the impacts of vehicular emissions on urban air quality and its management in Indian context: the case of Kolkata (Calcutta). *Environmental Science & Policy*, 7(4): 345-351.

Gilbertson, P. and A.D. Bradshaw. 1985. Tree survival in cities; the extent and nature of the problem. *Arboricultural Journal*, 9: 131-142.

Gurjar, B.R. and J. Lelievel. 2005. New directions: megacities and global change. *Atmospheric Environment,* 39: 391-393.

Heagle, A.S., R.B. Philbeck and W.M. Knott. 1976. Threshold for injury, growth, yield and loss caused by Ozone on field corn hybrids. *Phytopathology*, 69: 21-26.

Hughes, L. 2000. Biological consequences of global warming: is the signal already apparent?, *Trends Ecological Evolution,* 15: 56- 61.

Hussain, F., I. Illahi and A. Rashid. 1989. Effect of cement dust on the chlorophyll contents, stomatal clogging and biomass of some selected plants. *Pak. J. Sci. & Ind. Res.*, 32: 542-545.

Iqbal, M., J. Jura-Morawiec., W. WŁoch and Mahmooduzzafar. 2010. Foliar characteristics, cambial activity and wood formation in *Azadirachta indica* A. Juss. as affected by coal–smoke pollution. *Flora - Morphology, Distribution, Functional Ecology of Plants*, 205(1): 61-71.

Iqbal, M.Z. and M. Shafiq. 1999. Impact of vehicular emission on germination and growth of Neem (*Azadirachta indica*) tree. *Hamdard Medicus XLII,* 4: 65-69.

Jehan, S. and M.Z. Iqbal. 1992. Morphological and anatomical studies of leaves of different plants affected by motor vehicular exhaust. *Journal of Islamic Academy of Science,* 5: 21-23.

Jim, C.Y. 1996. Roadside trees in urban Hong Kong: Part II species composition. *Arboricultural Journal*, 20: 279-298.

Jim, C.Y. 1997. Roadside trees in urban Hong Kong: Part IV tree growth and environmental condition. *Arboricultural Journal*, 21: 89-99.

Jim, C.Y. 1998. Pressure on urban trees in Hong Kong: Pervasive problem and possible amelioration. *Arboricultural Journal*, 22: 37-60.

Kozlov, M.V., J.K. Eranen and V.E. Zverev. 2007. Budburst phenology of white birch in industrially polluted areas. *Environmental Pollution*, 148(1): 125-131.

Larson, R.O. 1990. Commercialization of the neem extract Margosan-O in a USDA collaboration. In: (Eds.): Locke, J.C. and Lawson, R.H. Proceedings of a workshop on neem's potential in pest management programs. USDA-ARS, Beltsville, MD. ARS-86, pp. 23-28.

Menn, J.J. 1990. USDA interest in neem research. In: *Proceedings of a workshop on neem's potential in pest management programs*. (Eds.): Locke, J.C. and Lawson, R.H. USDA-ARS, Beltsville, MD. ARS-86, pp. 1-3.

Menzel, A. and N. Estrella. 2001. Plant phenological changes. In: *Fingerprints' of Climate Change – Adapted Behaviour and Shifting Species Ranges*, (Eds.): Walther, G.-R., C.A. Burga and P.J. Edwards. Kluwer Academic Publishers, New York and London pp. 123-138.

Najeeba, S. and M. Saleem. 1997. Air pollution by motor vehicle emission at Murree Highway. *Journal of Rawalpindi Medical College*, 1(2): 75-77.

Nasir, A., C. Arslan, A. Sattar and M.A. Khan. 2012a. Physical analysis of groundwater at thickly populated area of Faisalabad by using GIS. *Pak. J. Agri. Sci*., 49: 541-547.

Nasir, A., M.U. Khalid, S. Anwar, Ch. Arslan, M.J. Akhtar and M. Sultan. 2012b. Evaluation of bio-fertilizer application to ameliorate the environment and crop production. *Pak. J. Agri. Sci*., 49:527-531.

Pandian, S., S. Gokhale and A.K. Ghoshal. 2009. Evaluating effects of traffic and vehicle characteristics on vehicular emissions near traffic intersections. Transportation Research Part D: *Transport and Environment,* 14(3): 180-196.

Pennington, T.D. and B.T. Styles. 1975. A generic monograph of the Meliaceae. *Blumea,* 22: 419-540.

Qadir, N. and M.Z. Iqbal. 1991. Growth of some plants raised from polluted and unpolluted seeds. *Int. J. Environ. Studies*, 39: 95-99.

Qadir, S.A., S.Z. Qureshi and M.A. Ahmed. 1966. A phytosociological survey of the Karachi University Campus. *Vegetatio*, 13: 339-362.

Shah, Z., F. Hussain and Z. Sher. 1991. Determination of size and density of air born particulates along Jamrud – University road, Peshawar (NWFP Pakistan). *J. Sci. & Tech.*, 15:67-68.

Shams, Z.I. and M.Z. Iqbal. 1986. Study of some important climatic and bioclimatic parameters of Karachi city centre. *Pakistan Journal of Scientific and Industrial Research,* 29: 23-29.

Sivacoumar, R. and K. Thanasekaran. 1999. Line source model for vehicular pollution prediction near roadways and model evaluation through statistical analysis. *Environmental Pollution*, 104(3): 389-395.

Verkerk, R.H.J. and D.J. Wright 1993. Biological activity of neem seed kernel extracts and synthetic *Azadirachta* in against larvae of *Plutella xylostella* L. *Pesticide Science*, 37: 83-91.

Walter, G.R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J.M. Fromentin, O. Hoegh-Guldberg and F. Bairlein. 2002. Ecological responses to recent climate change. *Nature,* 416(6879): 389-395.

Walther, G.R. 2003. Plants in a warmer world. *Perspectives in Plant Ecology, Evolution and Systematics*, 6(3): 169-185.

Zhu, Y., W.C. Hinds, S. Kim and C. Sioutas. 2002. Concentration and size distribution of ultra fine particles near a major highway. *J. Air Waste Manag. Assoc.*, 52(9): 1032-1042.

(Received for publication 30 May 2013)