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EFFECT OF AIR POLLUTION ON THE LEAF MORPHOLOGY OF COMMON PLANT SPECIES OF QUETTA CITY

SAADULLAH KHAN LEGHARI AND MUDASSIR ASRAR ZAIDI

Department of Botany University of Balochistan Quetta, Pakistan
**Corresponding author's e-mail: saadbotany@yahoo.com*

Abstract

The urban air pollution is a major environmental concern, particularly in the developing countries and in their major cities. Therefore, the present study was mainly aimed to study the effect of air pollution on the morphological characteristics of leaf of 13 common plant species *viz., Elaeagnus angustifolia* L., *Eucalyptus tereticornis* L., *Ficus carica* L., *Fraxinus excelsior* L., *Melia azadirach* L., *Morus alba* L., *Morus nigra* L., *Pistacia vera* L., *Prunus armeniaca* L., *Punica granatum* L., *Robinia pseudo acacia* L., *Rosa indica* L. *and Vitis vinifera* L. grown in the urban (polluted site) and peri-urban (non-polluted) sites of Quetta. Results showed that all plant species exhibited significant ($p<0.05$) reduction at polluted site in their leaf length, width, area and petiole length when compared with the same plant species of non-polluted site. These plant species also showed significant variation in the growth of morphological parameters from season to season. Results also showed that the overall reduction % in leaf length, width, area and length of petiole during different seasons at polluted sites with respect to those of non-polluted sites were found maximum during summer (33.91, 36.61, 37.08 and 46.17 %), followed by autumn and lowest was recorded during spring season (28.39, 23.50. 32.49 and 26.34 %), respectively. Results also deciphered that minimum decrease in leaf length (19.86%), leaf width (17.81%), leaf area (22.66%) and petiole length (02.56%) was observed in *Vitis vinefera* L., *Pistacia vera* L., *Ficus carica* L. and *Pistacia vera* L. Whereas, maximum decrease 72.59, 50.58, 57.98 and 65.48% for the same attributes were noted in *Punica granatum* L., *Elaeagnus angustifolia* L., *Rosa indica* L. and *Eucalyptus tereticornis* L., respectively. Results further indicated that as the plants get ages, the reduction % of various leaf attributes of polluted plants also increased as compared with non-polluted plant species. This could be mainly due to maximum exposure of plants to air pollutants come from various auto emission sources.

Introduction

Leaf is the most sensitive part to be affected by air pollutants instead of all other plant parts such as stem and roots. The sensitivity rests on the fact that the major portions of the important physiological processes are concerned with leaf. Therefore, the leaf at its various stages of development, serves as a good indicator to air pollutants. Pollutants came from the auto emission can directly affect the plant by entering in to the leaf, destroying individual cells, and reducing the plant ability to produce food. Urban air pollution is a major environmental problem, mainly in the developing countries (Mage *et al*., 1996). Heavy metals released from automobiles are extremely toxic metal and reduces plant growth and morphological parameters. Therefore, study conducted by Ahmad *et al*., (2012) is agreement that the Cadmium had toxicity at 5 mg L^{-1} in case of root and shoot growth. Air pollution due to vehicular emission mostly arises from cars, buses, minibuses, wagons, rickshaws, motorcycles and trucks. These resources introduces varieties of pollutants (oxides of nitrogen and sulphur, hydrocarbon, ozone, particulate matters, hydrogen fluoride, peroxyacyl nitrates, etc.) into the environment which not only put adverse effect on the health of human beings, and animals, but seriously threating the trees and crops of such areas. Research studies revealed that plants growing in the urban areas are affected greatly by these pollutants (Uaboi-Egbenni *et al*., 2009). The car pollutants have long term effects on plants by influencing CO_2 contents, light intensity, temperature and precipitation. Plants need special protection because they are not only a source of food but are also helpful in cleaning the environment. Most of the authors (Bhatti & Iqbal, 1988; Gupta & Ghouse, 1988) have reported the effects of air pollution on the morphology and anatomy of different plants species grown in different regions, but very little is known about the plants of Quetta city. Researchers also reported that plants which are sensitive to air pollutants had showed changes in their morphology, anatomy, physiology and biochemistry (Reig-Armiñana *et al*., 2004; Silva *et al*., 2005). Various authors investigated the effects of pollution on different plant species. A strong correlation between the degree of contamination and concentrations in all plant leaves assessed displayed that plants like *Robinia pseudoacacia* reflect the environmental changes accurately, and that they appear as an effective biomonitor of environmental quality (Celik ***et al.,*** 2005).

Quetta is the provincial capital of Balochistan province. It is situated at an elevation of 1676-1900 meters above sea level. The climate of the area is generally dry and cold. Maximum rainfall and snowfall occurs in January and February. Summer season is moderate, while June and July is the hottest month with maximum temperature of 30 and 20 ^{0}C respectively. January is the coldest month with mean maximum and minimum temperature of about 11 ^{0}C and -3 ^{0}C, respectively (Anonymous, 1998). Air pollution in Quetta city is rising to an alarming state rapidly since the last few decades due to heavy automobile activities. Rapid increase in automobile activities and traffic congestion contributes most of air pollution problems, resulting in damage to the plants growth. Therefore, the present work was mainly designed to analyze the effects of air pollution, dominantly presented by automobile, industrial pollution and microclimate, on morphology of different plant species, growing near the roads of the city. The investigated plants are very common and widespread in the investigated area and these can be cultivated and also grows spontaneously. They have a wide distribution, which indicates a high ecologically plasticity and adaptability to different environmental conditions. Therefore, the main object of this study was to explore the morphological features of plants as adaptability indicator. The goal was to prove the statement that the plants answer on environmental stress, from different anthropogenic and non-anthropogenic sites/ locations, by changing morphology of leaves.

Materials and Methods

Sample collection: The study was carried out during spring, summer and autumn of the year 2011. Leaf samples of 13 different plant species of trees, shrubs and climbers *Elaeagnus angustifolia* L., *Eucalyptus tereticornis* L., *Ficus carica* L., *Fraxinus excelsior* L., *Melia azadirach* L., *Morus alba* L., *Morus nigra* L., *Pistacia vera* L., *Prunus armeniaca* L., *Punica granatum* L., *Robinia pseudo acacia* L., *Rosa indica* L. *and Vitis vinifera* L. of Quetta city (polluted site) and peri-urban area (non-polluted) i.e., Botanical garden University of Balochistan, Quetta (control site) were collected from iso-ecological conditions (light, water and soil) following the standardized methods of Ara *et al*., (1996). About 30 leaf samples were taken from each individual of a species from three different height positions on the plant (10 leaves from each position), representing three discrete leaf age classes, i.e. a young, expanding leaf on the upper portion of the plant; a mature, fully developed leaf near the middle portion of the plant; and an older, mature to senescing leaf on the lower portion of the plant throughout the plant canopy to give representative average sample.

Leaf morphological characteristics: Quantitative characters of the leaves such as, leaf length, width, area and length of petiole were recorded periodically at regular interval of three months *viz.,* March-May, Jun-August, and September-November. All the measurements were based on three replicates. Leaf length (cm), breadth (cm), area (cm^2) and petiole length (cm) were determined by using leaf area meter (CI-202, USA) and graph paper method, while petiole length was recorded by scale in centimeter. Leaf morphological characteristics including leaf abnormalities of both young and mature leaves were also observed on the plants of both sites (polluted and non-polluted), with the following criteria *viz.,* change in color (chlorosis, browning, yellowing, spotting or change in the leaf's normal pigment) and shape (normal shape or deformed/modified).

Statistical analyses: The standard deviation values of the means were calculated for a comparison of site categories. To determine the significance of the samples a paired t-test was performed (Steel & Torrie, 1980).

Percentage increasing & decreasing: Percentage increasing & decreasing of leaf length, width, area and length of petioles during different seasons was calculated according to the formula used by Syed & Iqbal (2008).

Results and Discussion

Results described in Table 1-6, and Figs. 1-4 revealed that there was significantly ($p<0.05$) slow growth in all the investigated parameters in all the plants species at polluted site with respect to non-polluted site, which might be due to severe air pollution in the city center. Similar observations were also reported by many other researchers of the globe (Reig-Armiñana *et al*., 2004; Silva *et al*., 2005; Bhatia, 2006; Rao, 2006; Stevovic *et al.,* 2010). They all are agreed that air pollutants affect the plant growth and morphological characters adversely. Of all the plant parts, leaf is the most sensitive part to be affected by air pollutants and reduction in leaf length, width and area of roadside plants was the witness of bad effects of the city environment. Similarly the reduction in leaf area growing in the vicinity of heavy pollutants was also observed in many plants by other researchers (Bhatti & Iqbal, 1988). The observation made by Keskin & Ili, (2012), Gielwanowska *et al*., (2005) and Makbul *et al*., (2006) also supported these views. They found that the plants growing close to the busy road of the city are highly affected by auto-emission. The inhibitory effects on the growth of plants are due to the presence of toxic material in the auto-emission. Results pertaining to the study of different morphological attributes of various plant species are described and discussed as under:-

Table 1. Effect of air pollution on average length (cm) and width (cm) of leaf of different plant species growing at polluted and non-polluted sites of Quetta during the whole growing seasons.

Plants name	Average length of leaf			Average width of leaf		
	PS S.D.	NPS S.D.	t	PS S.D.	NPS S.D.	t
Elaeagnus angustifolia L.	4.87 (0.95)	7.06 (1.59)	2.75*	2.24 (0.59)	3.37 (0.77)	2.72*
Eucalyptus tereticornis L.	11.2 (1.20)	14.2 (2.83)	2.48*	3.11 (0.49)	3.89 (0.86)	2.47*
Ficus carica L.	12.5 (1.59)	16.0 (2.66)	2.68*	10.1 (0.59)	13.0 (1.34)	3.01*
Fraxinus excelsior L.	6.97 (1.54)	8.97 (2.36)	2.23*	2.99 (0.57)	3.67 (0.94)	2.09*
Pistacia vera L.	8.59 (2.14)	11.8 (3.29)	2.41*	5.35 (0.80)	6.31 (1.04)	2.23*
Prunus armeniaca L.	5.51 (1.23)	7.17 (1.78)	2.29*	5.39 (0.98)	7.97 (1.92)	2.83*
Punica granatum L.	3.98 (0.85)	6.86 (2.03)	2.70*	5.85 (0.72)	7.43 (1.52)	2.69*
Melia azadirach L.	3.16 (0.57)	4.86 (1.02)	2.89*	1.79 (0.34)	2.40 (0.61)	2.87*
Morus alba L.	6.72 (1.03)	9.26 (1.78)	2.81*	5.58 (0.87)	7.30 (1.64)	2.56*
Morus nigra L.	6.38 (1.19)	9.59 (2.20)	2.79*	5.91 (0.80)	7.44 (1.53)	2.51*
Robinia pseudoacacia L.	4.82 (1.17)	7.07 (2.24)	2.59*	2.39 (0.31)	3.25 (0.49)	2.99*
Rosa indica L.	2.14 (0.41)	3.56 (0.87)	2.98*	1.69 (0.11)	2.43 (0.26)	3.16*
Vitis vinifera L.	9.67 (1.20)	11.6 (1.81)	2.45*	10.0 (0.48)	12.5 (1.26)	2.96*

Each mean value consist of thirty readings, PS= polluted site, NPS= non-polluted site, S.D. = standard deviation, *= slightly significant at $p<0.05$, and t = calculated values in t-test

Table 2. Effect of air pollution on the average leaf area (cm^2) and length of petiole (cm) in different plant species growing at polluted and non-polluted sites of Quetta during the whole growing seasons.

Plants name	Average area of leaf			Average length of petiole		
	PS S.D.	NPS S.D.	t	PS S.D.	NPS S.D.	t
Elaeagnus angustifolia L.	03.14 (0.72)	04.77 (1.19)	2.37*	0.60 (0.15)	0.89 (0.25)	2.59*
Eucalyptus tereticornis L.	14.30 (1.82)	17.57 (2.81)	2.61*	1.31 (0.39)	2.17 (0.72)	2.66*
Ficus carica L.	60.94 (8.52)	74.74 (9.60)	2.59*	2.59 (0.32)	3.71 (0.57)	2.96*
Fraxinus excelsior L.	10.35 (1.87)	16.24 (3.39)	2.97*	0.53 (0.13)	0.86 (0.24)	2.82*
Pistacia vera L.	48.53 (8.46)	59.72 (9.09)	1.98ns	1.33 (0.35)	1.49 (0.45)	1.15ns
Prunus armeniaca L.	24.24 (3.62)	35.99 (7.47)	2.95*	2.59 (0.19)	3.51 (0.32)	3.16*
Punica granatum L.	03.25 (0.66)	04.85 (1.20)	2.82*	0.51 (0.08)	0.78 (0.28)	2.66*
Melia azadirach L.	03.35 (0.95)	05.23 (1.78)	2.62*	0.32 (0.05)	0.44 (0.14)	2.37*
Morus alba L.	43.78 (6.28)	58.54 (9.81)	2.81*	2.74 (0.41)	3.34 (0.77)	2.18*
Morus nigra L.	34.69 (7.03)	49.48 (8.31)	2.68*	2.71 (0.27)	3.24 (0.53)	2.49*
Robinia pseudoacacia L.	12.50 (3.33)	17.42 (5.53)	2.36*	0.36 (0.09)	0.44 (0.15)	1.74*
Rosa indica L.	02.97 (0.76)	04.27 (1.35)	2.76*	0.30 (0.08)	0.47 (0.15)	2.57*
Vitis vinifera L.	54.75 (8.26)	74.36 (9.47)	2.85*	5.71 (0.27)	6.28 (0.50)	2.70*

Each mean value consist of thirty, readings, PS= Polluted site, NPS= non-polluted site, S.D. = standard deviation, *= slightly significant at $p<0.05$, ns = non-significant and t = calculated values in t-test

Table 3. Increasing % of leaf length between season to season in different plant species growing at polluted and non-polluted sites of Quetta.

Plants name	Inc % of leaf length				Inc % of leaf width			
	Spring to summer,		summer to autumn		Spring to summer,		summer to autumn	
	PS	NPS	PS	NPS	PS	NPS	PS	NPS
Elaeagnus angustifolia L.	29.93	33.38	1.28	3.09	30.98	34.22	1.92	2.18
Eucalyptus tereticornis L.	17.14	30.48	0.50	1.19	22.73	29.90	4.90	8.54
Ficus carica L.	20.24	25.68	0.52	1.53	08.47	15.32	2.47	3.22
Fraxinus excelsior L.	33.76	39.02	0.25	1.73	24.60	33.50	9.80	11.5
Pistacia vera L.	37.23	40.19	1.61	4.08	21.38	23.09	4.87	6.32
Prunus armeniaca L.	34.03	37.18	0.64	1.21	21.80	29.92	11.8	13.1
Punica granatum L.	32.43	43.29	1.11	1.60	18.37	27.96	3.45	8.00
Melia azadirach L.	26.90	30.45	3.66	4.49	23.24	25.42	11.9	20.0
Morus alba L.	24.04	28.61	1.09	3.53	22.03	31.14	5.45	7.60
Morus nigra L.	28.67	33.96	1.54	3.17	18.37	27.95	6.39	8.21
Robinia pseudoacacia L.	35.98	43.50	2.69	8.05	18.73	20.82	4.20	6.06
Rosa indica L.	28.33	33.93	3.72	8.04	10.34	15.75	1.69	3.05
Vitis vinifera L.	19.51	24.12	1.15	1.80	04.29	13.25	4.94	5.76

Each value is mean which consist of thee, readings, PS = polluted site, NPS = non-polluted site, S.D. = standard deviation

Table 4. Increasing % of foliage length between season to season in different plant species growing at polluted and non-polluted sites of Quetta.

Plants name	Inc % of leaf area				Inc % of petiole length			
	Spring to summer,		summer to autumn		Spring to summer,		summer to autumn	
	PS	NPS	PS	NPS	PS	NPS	PS	NPS
Elaeagnus angustifolia L.	34.00	40.33	2.77	3.76	35.82	39.39	5.63	7.47
Eucalyptus tereticornis L.	20.00	24.00	1.29	3.23	43.05	46.00	3.82	6.38
Ficus carica L.	21.70	24.49	1.67	4.88	19.57	23.56	1.43	2.21
Fraxinus excelsior L.	25.65	28.83	5.79	7.47	33.90	38.95	4.84	8.65
Pistacia vera L.	35.63	38.87	1.10	4.36	39.07	42.35	2.58	5.56
Prunus armeniaca L.	22.09	28.79	3.80	7.31	11.19	13.97	1.47	2.14
Punica granatum L.	28.57	33.21	6.67	9.66	22.22	47.13	5.26	13.0
Melia azadirach L.	41.41	46.67	2.78	7.69	23.53	44.00	5.55	7.41
Morus alba L.	22.34	25.26	1.47	2.90	23.31	34.49	1.33	2.35
Morus nigra L.	30.71	35.81	1.94	5.02	15.49	24.86	1.38	2.78
Robinia pseudoacacia L.	39.14	44.57	2.53	5.71	37.50	46.00	4.76	7.41
Rosa indica L.	36.36	39.23	5.71	8.77	38.24	45.45	2.85	3.51
Vitis vinifera L.	23.19	27.68	2.03	5.90	7.216	11.61	1.36	3.15

Each mean value consist of thee, readings, PS = polluted site, NPS = non-polluted site, Inc% = increasing %

Table 5. Seasonal reducing % of morphological characteristics in all the plant species of polluted site with respect to non-polluted site of Quetta.

Parameters	Spring Rd % S.D.	Summer Rd % S.D.	Autumn Rd % S.D.
Leaf length (cm)	28.39 (12.34)	33.91 (08.57)	33.82 (08.35)
Leaf width (cm)	23.50 (19.66)	36.61 (13.21)	35.90 (13.57)
Leaf area (cm^2)	32.49 (21.62)	37.08 (13.95)	35.79 (13.78)
Petiole length (cm)	26.34 (23.55)	46.17 (23.58)	43.51 (21.66)

Table 6. Gross leaf morphological changes of the different plant species and growth stages growing two different sites (polluted and unpolluted).

Plants name	Growth stage	Color		Shape	
		Polluted	Non-polluted	Polluted	Non-polluted
Elaeagnus angustifolia L.	Young	Whitish	Light Green	Deformed	Typical
	Mature	Whitish	Light Green	Deformed	Typical
Eucalyptus tereticornis L.	Young	Light Green	Dark Green	Deformed	Typical
	Mature	Browning	Dark Green	Deformed	Typical
Ficus carica L.	Young	Light Green	Dark Green	Deformed	Typical
	Mature	Light Green	Dark Green	Deformed	Typical
Fraxinus excelsior L.	Young	Light Green	Light Green	Typical	Typical
	Mature	Yellowish	Dark Green	Deformed	Typical
Pistacia vera L.	Young	Light Green	Light Green	Deformed	Typical
	Mature	Light Green	Dark Green	Deformed	Typical
Prunus armeniaca L.	Young	Light Green	Light Green	Deformed	Typical
	Mature	Yellowish	Dark Green	Deformed	Typical
Punica granatum L.	Young	Dark Green	Dark Green	Deformed	Typical
	Mature	Dark Green	Dark Green	Deformed	Typical
Melia azadirach L.	Young	Light Green	Dark Green	Typical	Typical
	Mature	Light Green	Dark Green	Deformed	Typical
Morus alba L.	Young	Light Green	Dark Green	Deformed	Typical
	Mature	Light Green	Dark Green	Deformed	Typical
Morus nigra L.	Young	Light Green	Light Green	Deformed	Typical
	Mature	Browning	Light Green	Deformed	Typical
Robinia pseudoacacia L.	Young	Light Green	Light Green	Typical	Typical
	Mature	Light Green	Dark Green	Deformed	Typical
Rosa indica L.	Young	Light Green	Light Green	Deformed	Typical
	Mature	Browning	Dark Green	Deformed	Typical
Vitis vinifera L.	Young	Light Green	Light Green	Deformed	Typical
	Mature	Yellowish	Dark Green	Deformed	Typical

1. Leaf length: Results presented in Table 1 revealed that the overall average leaf length during the whole growing season was found 2.14-12.5 cm at polluted site and 3.56-16.0 cm lowest to highest at non polluted site in *Rosa indica* L. and *Ficus carica* L., respectively. Statistical t-test indicated that there was slightly a significant ($p<0.05$) variation in the values of leaf length between two sites. The increasing % of leaf length from spring to summer and summer to autumn was in the range of 17.14-37.23% in *Eucalyptus tereticornis* (L.) and *Pistacia vera* L., and 0.25-3.72% in *Fraxinus excelsior* L. and *Rosa indica* L. at polluted site, while at non-polluted site it was 24.12-43.50% in *Vitis vinifera* L. and *Robinia pseudoacacia* L. and 1.19-8.05% in *Eucalyptus tereticornis* L. and *Robinia pseudoacacia* L., lowest to highest, respectively (Table 3). The overall average decreasing % of leaf length at polluted site with respect to non-polluted site was found in the range of 19.86-72.59% lowest to highest in the leaf of *Vitis vinifera* L. and *Punica granatum* L., respectively (Fig. 1). Seasonally maximum reducing % in all the investigated plant species at polluted site with respect to non-polluted site was found during summer (33.91%), followed by autumn and lowest was during spring (28.39%) (Table 5). Slow increasing percentage of leaf length at polluted site as compared to non-polluted site might be due to effect of air pollution at that site which reduces the gases exchange for photosynthesis and productivity of leaf. Similar observation was also made by Bhatti & Iqbal (1988). They found significant decline in leaf length of *Ficus bengalensis* at the polluted sites. More over other workers (Iqbal & Shafiq, 1999; Shafiq & Iqbal, 2003; 2005) also reported that plants growing adjacent to roadsides of Karachi city exhibited considerable damage in response to automobile exhaust emission. They also reported that atmospheric pollutants after making their entry through stomata of leaf causes reduction in leaf size of plants due to damage of photosynthetic tissues. Since plant growth and production depend on phyotosynthetically functional leaf size of the species. Preeti (2000) also observed that leaves of *Thevetia nerifolia* and *Cassia siamea* growing in the polluted environment showed significant reduction in their growth.

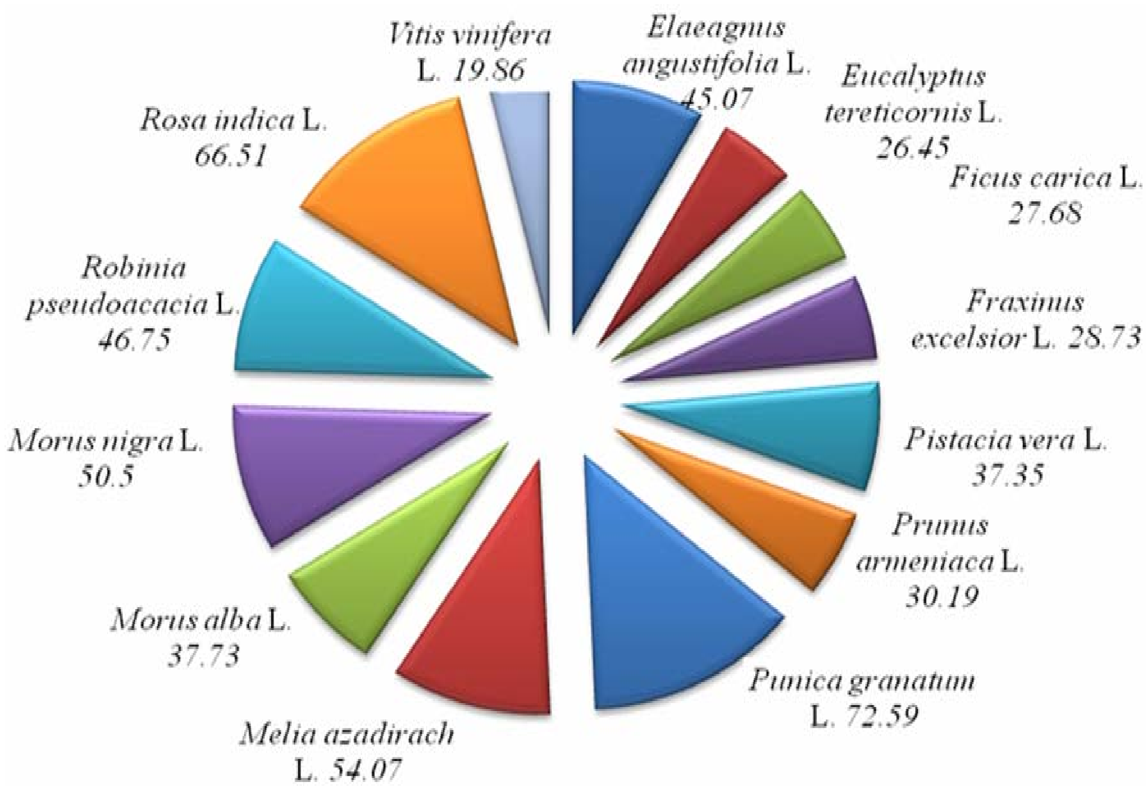

Fig. 1. Over all average decreasing % of foliage length of different plant species of polluted site with respect to non-polluted site of Quetta city during through out the growing period.

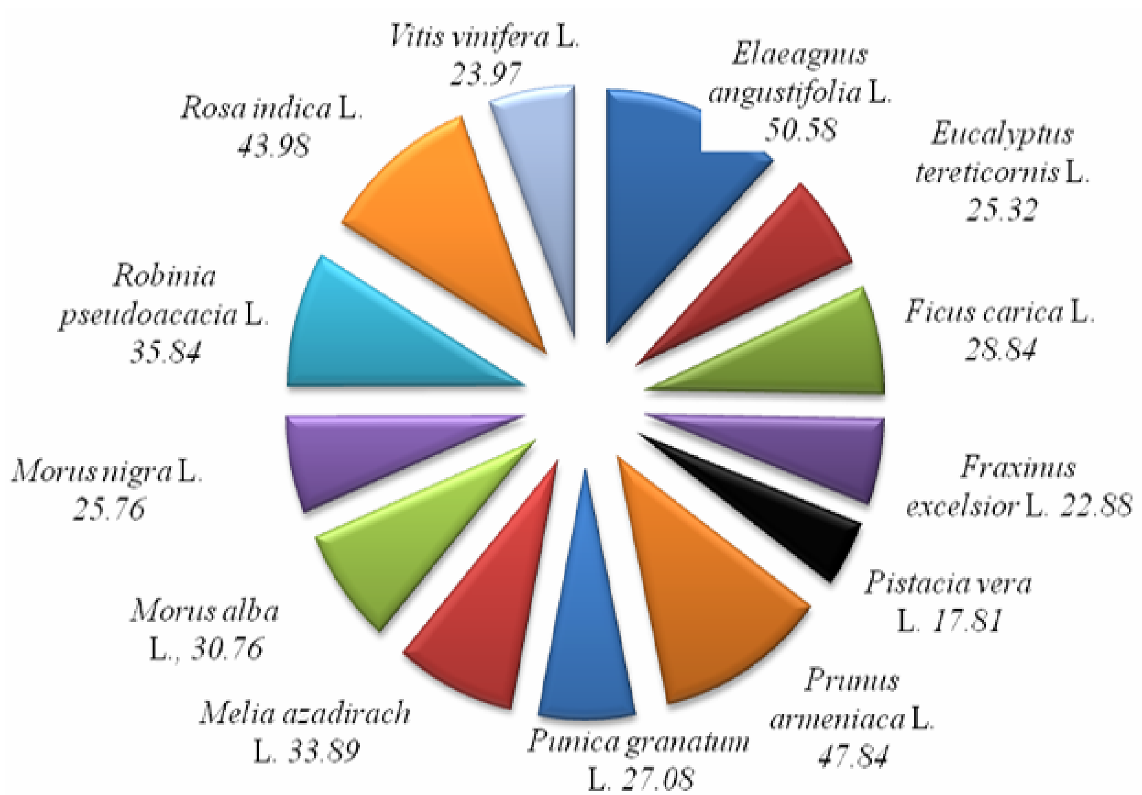

Fig. 2. Over all average decreasing % of foliage width of different plant species of polluted site with respect to non-polluted site of Quetta city during through out the growing period.

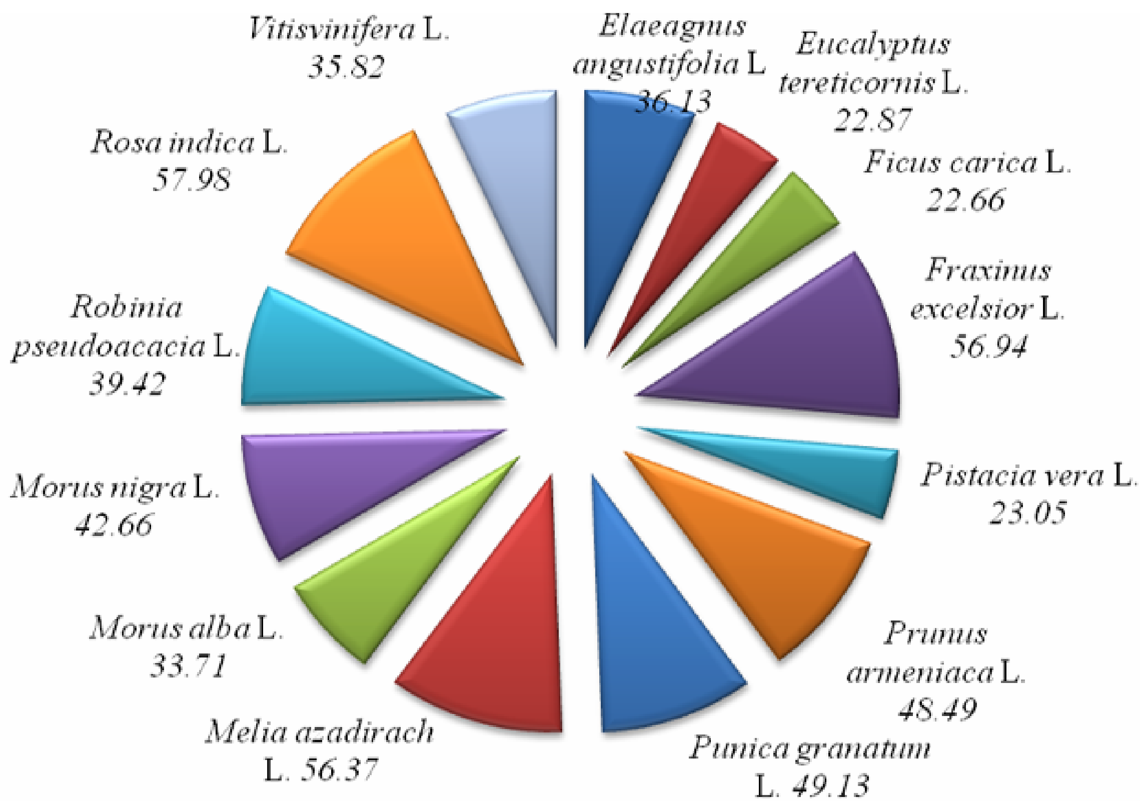

Fig. 3. Over all average decreasing % of foliage area of different plant species of polluted site with respect to non-polluted site of Quetta city during through out the growing period.

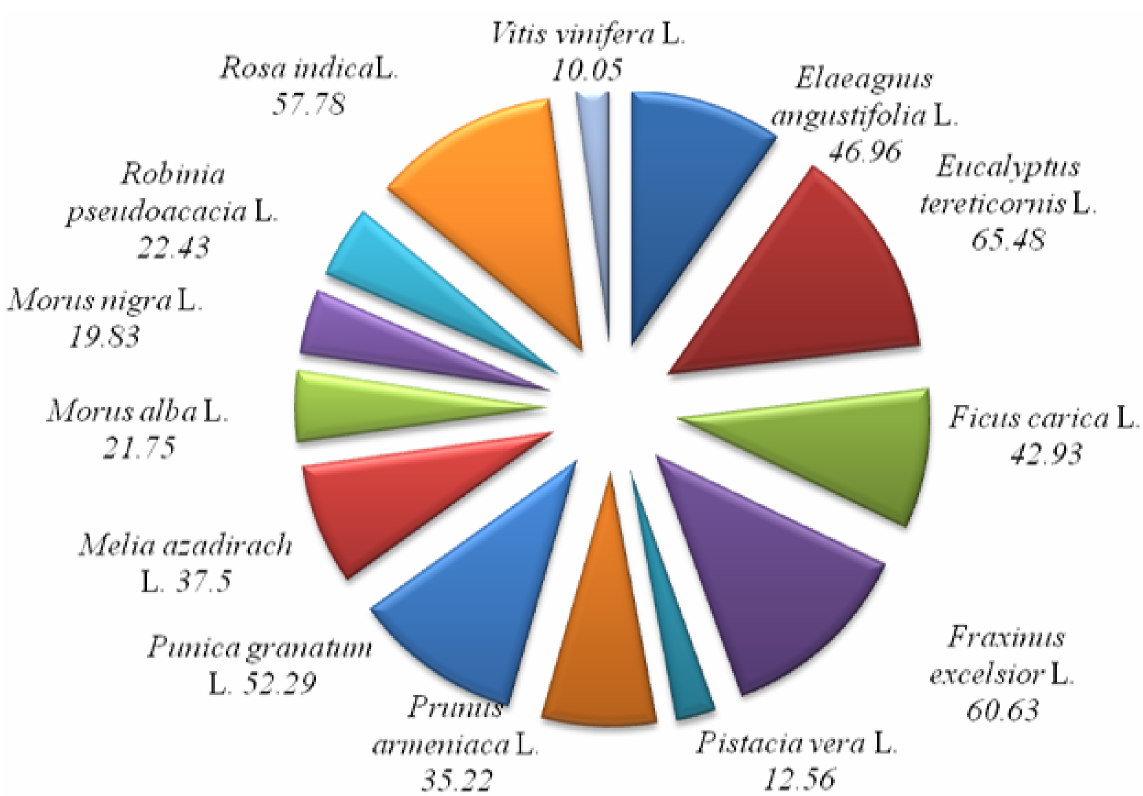

Fig. 4. Over all average decreasing % of petiole length of different plant species of polluted site with respect to non-polluted site of Quetta city during throughout the growing period.

2. Leaf width: Data regarding to overall average width of leaf (Table 1) indicated that minimum leaf width at polluted and non-polluted site (1.69 & 1.79 and 2.43 & 2.40cm) was found in *Rosa indica* L. and, *Melia azadirach* L., while maximum (10.10 & 13.0 and 10.00 & 12.50cm) was recorded in *Ficus carica* L. and *Vitis vinifera* L., respectively. Statistical t-test also indicated that there was a slightly significant ($p<0.05$) difference in the leaf width of all the plant species of both sites. The increasing % of leaf width from spring to summer was 4.29-30.98% at polluted site in *Vitis vinifera* L. and *Elaeagnus angustifolia* L. while at non-polluted site it was 13.25-34.22% again in *Vitis vinifera* L. and *Elaeagnus angustifolia* L. However, from summer to autumn it was 1.69-11.90% in the *Rosa indica* L. and *Melia azadirach* L. at polluted site, whereas at non-polluted site it ranges between 2.18-20.00% i.e., lowest to highest in *Elaeagnus angustifolia* L. and *Melia azadirach* L., respectively (Table 3). Similar observations were also recorded by Shafiq *et al*., (2009). They found that the leaves taken from the polluted sites showed decline in length, width and area. The overall decreasing % of leaf width at polluted site with respect to non-polluted site during the whole growing season was found 50.58% in *Elaeagnus angustifolia* L. as a highest and 17.81% in *Pistacia vera* L., as a lowest, while in remaining 11 plant species it was in the range of 22.88-47.84% (Fig. 2). However, seasonally maximum reducing % in all the investigated plant species at polluted site with respect to non-polluted site was found during summer 36.61%, followed by autumn 35.90%, and lowest was during spring 23.50% (Table 5). These results are also in line with those reported by Preeti (2000). He observed that leaves of *Thevetia nerifolia* and *Cassia siamea* growing in the polluted environment showed significant reduction in growth. He also found that compound leaves showed greater damage than narrow simple leaves and the portion of injured area was 15.57% in *T. nerifolia* and 22.33% in *C. siamea.*

3. Leaf area: The average minimum and maximum of leaf area in 13 different plant species was noted 02.97 and 60.94 cm^2 in *Rosa indica* L. *and Ficus carica* L. at polluted site, while at non polluted site it was 04.27 & 74.74 cm^2 also in *Rosa indica* L. *and Ficus carica* L., respectively. Statistical analysis using t-test indicated that except of one plant species i.e., *Pistacia vera* L. all other 12 plant species showed slightly significant ($P<0.05$) variation in their values of leaf area between two sites (Table 2). Data regarding to increasing % of leaf area from spring to summer and summer to autumn in 13 different plant species growing at polluted and non-polluted site is illustrated in Table 4. Results revealed that highest increasing % from spring to summer at polluted site was 41.41% in *Melia azadirach* L., and lowest was 20.00% in *Eucalyptus tereticornis* L., while at non-polluted site it was 46.67% as a highest and 24.00% as a lowest are also noted for the same 2 plant species. However, during summer to autumn highest increasing % at polluted site was 6.67% in *Punica granatum* L. and at non-polluted site was 9.66% are also in *Punica granatum* L. at both sites, whereas the lowest were 1.10% in *Pistaci avera* L. at polluted site and 2.90 % in *Morus alba* L., at non-polluted site. Therefore, it has been proved from the above results that the leaf surface were badly affected by air pollutant, as its area remain small at polluted site with respect to non-polluted site. The observation recorded by Qadir & Iqbal (1991) also reported that the constituents of petrol and lubricating oils deposit on the aerial parts of plants and these pollutants in combinations cause greater or synergistic effects to plants. Observations shown recorded in Fig. 3 revealed that the overall maximum decreasing percentage was 57.98% in *Rosa indica* L. and minimum 22.66% in *Ficus carica* L. at polluted site with respect to non-polluted site. However, other remaining plant species showed reduction in the range of 23.05-56.94% low to high, respectively. Seasonally maximum reducing % of leaf area in all the investigated plant species at polluted site with respect to non-polluted site was found during summer (37.08%), followed by autumn (35.79%) and lowest was during spring i.e., 32.49% (Table 5). Similar reduction in leaf area growing in the vicinity of heavy pollutants was also observed in many other plant species by Bhatti & Iqbal (1988).

4. Petiole length: Results about the growth of leaf petiole length at polluted site revealed that the average length of petiole was found in the range of 0.30-5.71 cm in *Rosa indica* L. and *Vitis vinifera* L., while at non-polluted sites it was 0.44-6.28 cm in *Robinia pseudoacacia* L., *Melia azadirach* (L.) as a lowest and *Vitis vinifera* L. as highest, respectively. The statistical t-test results showed that there was slightly a significant ($p<0.05$) variation in the values of petiole length of polluted and non-polluted sites in all the plant species except *Pistacia vera* L. (Table 2). The increasing % at polluted site from spring to summer was in the range of 7.22-43.05% in *Vitis vinifera* L. and *Eucalyptus tereticornis* L., while at non-polluted site it was 11.61-47.13% lowest to highest, also in *Vitis vinifera* L. and *Punica granatum* L., respectively. However, from summer to autumn it increased by 1.33-5.63% in *Morus alba* L. and *Elaeagnus angustifolia* L. at polluted site and 2.14-13.00% at non- polluted site in *Prunus armeniaca* L. and *Punica granatum* L. lowest to highest, respectively (Table 4). The overall average decreasing % of petiole length at polluted site with respect to non-polluted site was 2.56-65.48% in *Pistacia vera* L. and *Eucalyptus tereticornis* L., respectively. While other remaining 11 plant species showed reduction in the range of 10.05-60.63% (Fig. 4). Seasonally maximum reducing % in all the investigated plant species at polluted site with respect to non-polluted site was found during summer (33.91%), followed by autumn and lowest was recorded during spring (26.34%) season (Table 6.) Similar observation was also reported in the leaves of *G. officinale* which showed significant reduction in petiole length, leaf length and leaflet area (Iqbal, 2006). Other workers also showed previously significant reduction in different leaf variables in the polluted environment with respect to clean atmosphere. Jahan & Iqbal (1992) in their study on *Platanus acerifolia* showed changes in leaf blade and petiole size of polluted site. Leaf growth (Leaf length, width and length of petiole) of *C. siamea* and *P. pterocarpum* was significantly affected at the polluted environment of the city as compared to clean area. Leaf size of both tree species reduced progressively depending on the level of pollutant in the city (Zaidi and Leghari, 2004: Shafiq *et al*., 2009).

5. Leaf color and shape: The plants growing in urban area of Quetta are continuously exposed to different air pollutants (carbon monoxide, oxides of nitrogen and sulphur, particulate matter, lead and other heavy metals etc.), which are released into the environment as a consequence of incomplete combustion in the automobile engines. This study reveals that all the plant species investigated showed some morphological changes (color and shapes), and hidden injury or physiological disturbance (Table 6), which caused reduction in morphological attributes (like leaf length, width, area and length of petiole) of all investigated plant species. Some morphological, anatomical and phonological changes in *Lilium candidum* L. (Liliaceae) were also reported by Özen1 *et al.,* (2012) in natural environment.

Conclusions

It is difficult to estimate the effects of air pollutants because the organisms are exposed to a wide range of uncontrolled variables (parasites, weather conditions, complex mixture of pollutants). On the morphological point of view, the plants from polluted sites present important changes especially regarding their colors, shapes, leaf length, width, area and petiole length. However, despite of these changes, plants were survived well at the polluted environment of Quetta city. These results showed the importance of morphological data for precocious diagnosis injury and to determine the sensitivity of different plant species to the action of air pollutants. After this study, we can consider that there is still a serious lack of knowledge of the impact of air quality on vegetation in the urban areas. Overall, the study reveals that all the plant species growing in the polluted environment of the city are badly affected by auto-emission. There is a need to set limits on how much of a pollutant is allowed in the air. The exchange of experience and information from the developed countries on this aspect of pollution impact on plants might be useful. Our goal must be to have clean air for flora and fauna. We should take necessary steps to get rid of the ever increasing pollution.

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