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Tree Size Comparison of Some Important Street Trees Growing at Different Sites of Karachi City, Pakistan

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ABSTRACT: The importance of trees in urban environment is now widely recognized as they cleanse the particulate air pollution and help to make cities and towns more agreeable places to dwell upon. A detailed survey was conducted to study the size of *Alstonia scholaris, Azadirachta indica, Bombax ceiba, Cassia fistula, Eucalyptus* sp., *Ficus benghalensis, Ficus religiosa* and *Guaiacum officinale* trees in the urban environment of Karachi, Pakistan. Results showed a wide range of variation in tree diameter breast height (17.12-65.50 cm) at M. A. Jinnah Road, University Road (near Hassan Square), North Nazimabad and Karachi University Campus, respectively. *A. indica, Eucalyptus* sp., and *F. benghalensis* showed less dbh (tree diameter breast height) at M. A. Jinnah Road as compared to University Road (near Hassan Square), North Nazimabad and Karachi University Campus, respectively. *G. officinale* growing at University Road (near Hassan Square) showed less tree dbh as compared to M. A. Jinnah Road and Karachi University campus. Similarly, the tree size of *B. ceiba* and *A. scholaris* was recorded less at Nazimabad as compared to M. A. Jinnah Road, University Road (near Hassan Square) and Karachi University Campus, respectively. *C. fistula* growing at North Nazimabad site showed low tree dbh as compared to University Road (near Hassan Square) site. *A. scholaris* growing at Karachi University Campus site showed highest dbh value as compared to all studied sites. The tree size of *G. officinale* was recorded highest at M. A. Jinnah Road as compared to North Nazimabad, University Road (near Hassan Square) and Karachi University Campus, respectively. Whereas, *Eucalyptus* sp. and *F. benghalensis* recorded highest dbh at North Nazimabad site as compared to M. A. Jinnah Road, University Road (near Hassan Square) and Karachi University Campus, respectively. More research is needed on these trees for healthy environment of city. The present study recommends for the complete documentation of tree species growing in city. Such information will be useful to identify characteristics that can be used to select tree species that are better suited for planting on other areas of the city. These findings can be helpful for arboriculturists, environmental scientists and town planners when working on plantation in the selected area.

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Keywords: Circumference, diameter at breast height, size, roadside tree, urban environment, Pakistan.

Introduction

It is well known that urban trees produce various types of benefits and costs (Soares et al., 2011) and most of the environmental benefits associated with urban trees (Semenzato et al., 2011). The importance of tree in urban environment can not be ignored. Street trees are important in the attractiveness of residential streets (Schroeder and Cannon, 1983). Trees help in maintaining the ecological balance. There are numerous other advantages that trees hold water runoff reductions, pollution reduction and climate amelioration (Akbari, 2002; Akbari et al., 2001; Nowak et al., 2002). For every ton of new wood that grows, about 1.5 tons of CO_2 are removed from the air and 1.07 tons of life giving oxygen is produced (Whitaker, 2010). Trees also assist in lessening air pollution levels by absorbing pollutants, intercepting particulate matter, and releasing oxygen (Escobedo et al., 2006; Nowak and Crane, 2002). Trees found in the urban environment prevent solar radiation from heating buildings, cool the area through their evapotranspiration, reduce wind speed and reduce the need to use air-conditioning systems (Dimoudi and Nikolopoulou, 2003). Urban conditions are known to affect tree growth. As the ecology of urban systems has been increasing studied, many physical,

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mechanical, chemical, and human stresses upon urban street trees have been enumerated (Qigley, 2004). Trees typically increase in size by three to four orders of magnitude from the seedling to adult stage (Meinzer et al., 2005). Tree size distributions are changing in many natural forests around the world, and it is important to understand the underlying processes that are causing these changes (Coomes and Allen, 2007).

Measurement of tree size, diameter, circumferences, frequencies, health assessment phenology, age, thickness and growth performances observed by researchers (Alméras et al., 2005; Baker, 1997; Bertram, 1989; Cannell et al., 1988; Cao et al., 2010; Iqbal et al., 1994; Lie et al., 2009; Shafiq and Iqbal, 1999, 2003; Shafiq et al., 2009; William et al., 2007). Comparisons of current and historical tree species composition and size structure along natural productivity gradients are useful for inferring effects of disturbance regimes and productivity on patterns of succession (Surrette et al., 2008). Proper selection of tree size is essential to maximize the efficiency of canopy restoration efforts. Municipal and landscape ordinances often specify the use of large caliper trees, 7.6 cm (2.5 in) or larger, to provide a more substantial impact (Paul, 2008). From tree survey all the valuable information like age, size and kind of trees can be determined. There is important information that must be included in tree survey. This includes reference number of tree, name of the tree either common or specific, height of trees, stem of diameter, age of the trees, structural condition of the trees, management recommendation for the trees, safe useful life expectance of the trees, color coding and categorizing of the trees by letter, removal of trees and also retention of the trees on the base of above data (Jackston, 2010).

Trees commonly suffer under a chronically stressful regime in terms of harsh microclimate and soil conditions and improper care (Jim, 2005). Trees in urban settings play an important role in improving urban life by reducing runoff, air pollution and energy use, and improving human health and emotional well being (Wu et al., 2008). Furthermore, city trees increase the attractiveness of communities, reduce noise, and improve wildlife habitat, while the spaces in which they grow provide many recreational opportunities (Chen and Jim, 2008). Today the many benefits of vegetation within cities are beginning to receive attention in public (Grimm et al., 2008; Manning, 2008). Tree diameters are normally measured at DBH (diameter at breast height), which is 4.5 feet (1.37 m) above the ground. The measurement of tree size as dbh is a very precise measure. Measurement of tree dbh helps in selection of trees having better growth form. The diameter growth of trees may vary depending on the tree size, species and other tree related factors (Nabeshima et al., 2010). Tree diameter at breast height (dbh) has traditionally been the "sweet spot" on a tree where measurements are taken and a multitude of calculations are made to determine things like growth, volume, yield and forest potential. Tree dbh is outside bark diameter at breast height. Breast height is defined as 4.5 feet (1.37 m) above the forest floor on the uphill side of the tree and is the most frequent measurement made by a forester using either a diameter tape or tree caliper (Nix, 2011).

Karachi is the largest industrial city of Pakistan. Trees in cities have an important positive effect on people's lives. One such positive effect is the amelioration of microclimate (Georgi and Zafiriadis, 2006). In addition to tolerance classifications, tree size (typically reported using diameter at breast height or basal area as a proxy measurement) is commonly used to predict tree growth. The expected growth rate of a tree changes with age and size (Wyckoff and Clark, 2005). The role of the street tree has transitioned from one of beautification and ornamentation to one of environmental service provision over the course of the last 30 years (Seamans, 2013). The urban ecosystem is under increasing scrutiny as society strives to manage the environment in a sustainable way. Urban trees play a critical role in the urban environment on many levels. As we increase our understanding of the complex processes at play in the rhizosphere, we will not only be able to better manage landscape trees, but also more fully benefit from their role in urban ecosystem processes (Day et al., 2010). Height and diameter measurements were taken for silver, sugar and Norway Maple Street trees in Rochester and Syracuse, New York (Nowak, 1990). From the farthest reach of the woody roots to the tips of the twigs, trees expand in girth. This annual growth increment allows trees to respond to changing environmental conditions (Coder, 1996). Tree size is often a necessary piece of information in studies of forest management. It is not only related to age, fire susceptibility, harvest potential, and silvicultural treatment of tree stands, but also to biodiversity and ecological health of the forest environment. It can often be related to specific ecological environments and the biological maturity of those environments (Haynes et al., 2011). The importance of sustainable land use is increasingly emphasized (Gotmark et al., 2009). Human beings are almost fully dependent on flora of the region for their social, economic, ecological and environmental needs.

A comparison of tree sizes with in other studies confirmed the need to extend the knowledge to the

behavior of more species and more site specific conditions. The size of trees at maturity and their growth rate have also a considerable importance in guiding planning and design decisions during management practices and helpful for working on the applications to the protection and plantation of tree at these sites. Tree size is an important measure for productivity as well as growth performance of plants in any environment. The determination of tree size with the help of dbh is a common way to get information about tree size. These values often show variation and can be useful for long term studies. There is no information available regarding tree size growing at different sites of Karachi city. Therefore a detailed survey was conducted to study the size of some important street trees (*Alstonia scholaris, Azadirachta indica, Bombax ceiba, Cassia fistula, Eucalyptus* sp., *Ficus benghalensis, Ficus religiosa* and *Guaiacum officinale*) growing in urban site of Karachi city.

MATERIALS AND METHODS

Study sites: Karachi is the largest industrial city of Pakistan and is spread over 3,530 km^2 (1,360 sq mi) in area. It is situated on the coast of the Arabian sea with a geographic coordinates 24°51′ N 67°02′ E. Chaudhry (1961) has characterized the climate of Karachi as subtropical maritime desert. Average wind velocity is 12 meter sec^{-1} during June and July and 3.5 meter sec^{-1} from January to March. During southwest monsoon season wind blows from the sea towards the coast, whereas during the northeast monsoon their direction is reversed. The hot and humid rainy season, which is variable, lasts from June to September. The winter season is 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 study area included main road net work of the city and covered an area of 25 x 25 sq km. Four different sites were selected for the present study in which climatic conditions are not much variable. The sites A, B, C and D included all main traffic networks as M. A. Jinnah Road, University Road (near Hassan Square), North Nazimabad and Karachi University Campus, respectively.

Fig. 1. *Alstonia scholaris*

Fig.2. *Azadirachta indica*

Fig. 4. *Cassia fi*

Fig. 5. *Ficus bengalensis*

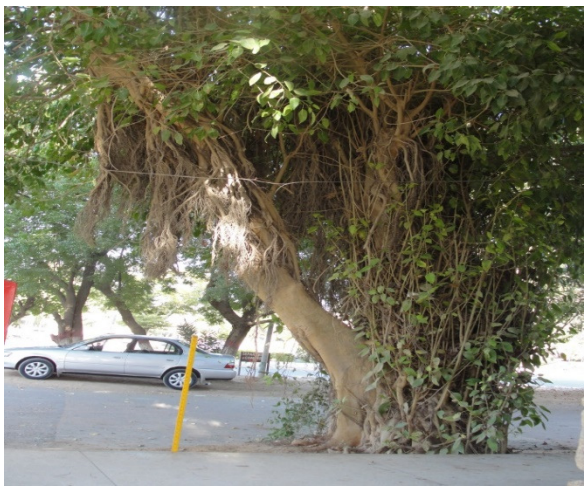

Fig. 6. *Ficus religiosa*

*Species description***:** *Alstonia scholaris* (Linn.) R. Br. (family Apocyanaceae) is a tall evergreen tree up to 20 m or more (Figure 1). The inner bark is of medicinal value and is used as a source of anti-malarial drug. It is cultivated in Pakistan as an ornamental. *Azadirachta indica* Adr. Juss. (family Meliacaea), vern Neem is a tree, up to 15 m tall (Figure 2). The tree is cultivated in the warmer parts of the country. It yields good timber. All parts of the plant are medicinal. A native of India and China, it is cultivated and naturalized through-out India, Malaysia and Pakistan. *Bombax ceiba* Linn., (family Malvaceae), vern. Simbal, Simal, is commonly cultivated as a roadside and garden tree in Pakistan (Figure 3). *Cassia fistula* Linn. (family Fabaceae), vern. Amaltas tree is up to 20 m tall (Figure 4). The bark in young tree is smooth and ash colored becoming rough and dark brown in old. This species is commonly planted in gardens. An ornamental tree, the bark is used as tanning material and wood ash is used as mordant in dyeing. Various parts of the plant are also reputed to have medicinal properties. *Eucalyptus* sp. (family Myrtaceae) (Figure 5) and *Ficus benghalensis* Linn, (family Moraceae) vern. Bargad or Bohar are large, evergreen to deciduous trees and up to 20 m tall (Figure 6). *Ficus religiosa* Linn. vern. Pipal, Pipli, Doguri is a large or medium sized, evergreen or deciduous tree, 6-15 m tall (Figure 7). It is planted as an avenue or roadside tree and is held sacred by Hindus and commonly planted near Hindu temples in India. The fruits are commonly eaten by birds and in times of famine by human beings. The leaves and

twigs are lopped for cattle and goats. The wood is used for packing cases
and in sacrificial fires by Hindus. Leaves and tender shoots are used as purgative and in skin diseases. The fruit is laxative, alterative and also has cooling effect (Efloras, 2013). *Guiacum officinale* L. (family Zygophyllacea) and is a beautiful, small to medium sized tree (Figure 8) of dry tropical forests (Francis, 1993).

Fig. 8. *Eycalyptus* sp. *ale*

Measurement of tree size: Eight tree species (*Alstonia scholaris, Azadirachta indica, Bombax ceiba, Cassia fistula, Eucalyptus* sp., *Ficus benghalensis, Ficus religiosa*, *Guaiacum officinale*) growing different sites of Karachi city were selected for the present studies. The tree circumference for all the tree species in terms of dbh was measured. The circumference from 10 individual of each tree species was measured at each site. The minimum, maximum, mean values and standard error were calculated. The data were analyzed by standard statistical technique.

RESULTS AND DISCUSSION

The variation in dbh was found in all tree species growing at different sites of Karachi city (Table 1). The mean dbh value for *A. scholaris, A. indica, B. ceiba, C. fistula, Eucalyptus* sp., *F. benghalensis, F. religiosa* and *G. officinale* at Karachi University Campus site was recorded as 42.19, 42.17, 33.15, 25.73, 28.91, 28.15, 31.94 and 33.86 cm, respectively. The mean dbh value of *A. scholaris, A. indica, B. ceba, Eucalyptus* sp. *F. benghalensis, F. religiosa* and *G. officinale* at North Nazimabad site was recorded as 24.79, 49.90, 29.45, 65.50 and 41.40 cm, respectively. *A. scholaris, B. ceiba, C. fistula, Eucalyptus* sp., *F. benghalensis, F. religiosa, Eucalyptus* sp. and *G. officinale* registered dbh value in the following order at University Road (near Hassan Square) 24.87, 35.06, 27.00, 21.91, 38.81, 37.69 and 25.90 cm, respectively. *A. scholaris, A. indica, B. ceiba, C. fistula, F. benghalensis, F. religiosa, Eucalyptus* sp. and *G. officinale* showed similar trend in dbh values 32.72, 34.55, 20.90, 17.12, 44.10 and 34.16 cm at M. A. Jiunnah Road site, respectively. *Eucalyptus* sp., *F. benghalensis* and *A. indica* attained lowest dbh values at M. A. Jinnah Road as compared to University Road (near Hassan Square), North Nazimabad and Karachi University Campus, respectively. The dbh of *G. officinale* (34.16 cm) and *F. religiosa* (44.10 cm) was recorded highest at M. A. Jinnah Road as compared to University Road (near Hassan Square) and Karachi University Campus site. Whereas, *Eucalyptus* sp. and *F. benghalensis* recorded highest dbh at North Nazimabad site as compared to M. A. Jinnah Road, University Road (near Hassan Square) Essa Nagri and Karachi University campus, respectively. *Eucalyptus* sp. and *A. scholaris* also recorded highest dbh values at Karachi University Campus as compared to all studied sites.

From this study, average tree size of *A. scholaris* ranged between 24.79 and 42.19 cm, and *A. indica* ranged between 32.72 and 49.90 cm. Tree size measurements were taken for eight street trees in Karachi city. *Eucalyptus* sp. proved to be having highest dbh value. Individual tree heights can vary due to differences in climatic, edaphic, and biotic factors such as genetics, age and competition (Kozlowski, 1971). Population viability is determined by vital demographic factors, such as birth, growth and death processes (Schemske et al., 1994). The demographic patterns are important in determining the most crucial stages in the life cycle of a tree species (Ng et al., 2009). An increment in tree size dbh represents more biomass in larger than in small trees, and because large trees generally grew more biomass in absolute terms, average dbh increment is often similar for a large range of tree sizes (Prior et al., 2004; Nouvellon et al., 2010). In urban areas, tree height is an important consideration in deciding what species to plant and/or where to plant them. Considering that many urban tree

inventories measure tree diameter (Nowak, 1990). *Eucalyptus* sp., *F. bengalensis, F. religiosa* and *B. ceiba* trees are rated as the most common trees in the urban site of the city. This is preliminary data, which can be used to monitor tree size changes with changing patterns of human disturbance to develop effective management plans for the plantation of tree species in future. The present findings may be helpful for the construction of tree inventory data base. The characteristics and variability of tree diameter distributions were studied in natural and managed old *Pinus sylvestris* L. dominated forests in the middle boreal vegetation zone of eastern Fennoscandia located in Hame in Southwestern, Finland and the natural stands were located in the Vienansalo wilderness area in northwestern Russia (Rouvinena and Kuuluvainenb, 2005). In natural stands, the mean tree density (tree height > 1.3 m) was found significantly higher compared to managed stands. High variability of tree sizes and stand structures considered as an important diversity feature of naturally dynamic *Pinus* dominated forests in Fennoscandia (Rouvinena and Kuuluvainenb, 2005), Individuals of plant populations typically vary in size, thus exhibiting various size hierarchies (Weiner, 1985). The next research step in this area should be to carry out periodical measurement of tree size. The publication of tree size data and inventory can be helpful at the time of plantation of such species in the selected area. The data and the ultimate expected dbh of each tree species can be used to create a list of suitable trees. It is important to understand that the species have high dbh value are proving suitable for plantation in other site of the city due to better adaptation to available environmental conditions prevailing in the area. For example, both species of *Ficus* found ideal conditions for growth at all studied sites. Such studies can be very useful in helping to identify characteristics that can be used to select tree species that are better suited for the plantation on other site of the city. The importance of trees in urban environment is now widely recognized that they too cleanse the particulate air pollution and help to make cities and towns more agreeable places to dwell upon. In urban areas, plantation is ensured in parks, residential localities, street and road avenues and industrial sites as shelter-belts plantation. (Chakre, 2006). A variation in trees size growing in natural populations observed. Understanding this variation in growth is central to forest ecology because of its significance to forest structure and biomass (Coomes and Allen, 2007). The Metropolitan Municipality City of Karachi and other civic agencies are working on a strategy to plant more trees for cleaner and healthier environment. However, only little is known about the relative importance of tree size. In our present findings the variation in tree size of *A. scholaris, A. indica, B. ceiba, C. fistula, Eucalyptus* sp., *F. benghalensis, F. religiosa,* and *G. officinale* was observed. Such variation is an interesting while estimating the tree size of different tree species from different sites of the city. The variation in tree size of all tree species recorded from different sites might be due to underlying edaphic factors. The tree size of *A. indica, Eucalyptus* sp. and *F. benghalensis* was markedly less at M. A. Jinnah Road site. The tree size of *A. scholaris* and *G. officinale* was recorded less at University Road (near Hassan Square). Similarly, the tree size of *B. ceiba* was found less at North Nazimabad Road. The tree size of *F. religosa* and *C. fistula* was also less at Karachi University Campus. Tree height and trunk diameter are both characteristic dimensions of individual tree size. Tree height is related to ability to intercept light in crowded stands, whereas tree trunk is related to the supporting and absorbing capacity of an individual tree, and is easily measured on site (Kohyama et al., 1990). Literature on the comparison of tree size growing at roadside for Karachi is scanty. The largest and smallest trees size in terms of dbh with in all species and sites were recorded. Tree size thickness can be varying considerably with changes in stem diameter. The size of tree gets thicker as the tree grows. Tree stems generally increase in girth as the plants get older, and diameters are therefore the most appropriate measure for grouping plants into size classes. *A. indica, Eucalyptus* sp. and *F. benghalensis* at North Nazimabad site showed large tree size. *B. ceiba* and *C. fistula* recorded large dbh at University Road (near Hassan Square). *F. religiosa* and *G. officinale* showed large tree size at M. A. Jinnah Road. *A. scholaris* attained the highest tree size at Karachi University Campus. The performance of urban trees depends upon the ability of their root systems to acquire resources and provide anchorage. However, conditions prevalent in the built environment, such as compacted soils, underground infrastructure, chemical contamination, and excessive heat, create a unique and often unaccommodating environment that may impair root growth and development (Day et al., 2010). Tree height, crown height, crown diameter and stem diameter for 282 trees of the indigenous species *Combretum erythrophyllum*, *Searsia lancea* and *S. pendulina* were measured in the urban forest of the City of Tshwane, South Africa and suggested that the obtained results can be used in forecasting the physical dimensions of these species as a function of time, air pollution uptake, rainfall interception, carbon sequestration and microclimate modification of urban forests (Stoffberg et al., 2009).

*Conclusion***:** The present paper recommends for the complete documentation of tree species growing in city. The findings can be helpful for arboriculturists, environmental scientists, and town planners when working on plantation in the selected area. Much more research on these trees is needed for healthy environment of city. It is, therefore, important not only to record the variations in size of tree within cities, but also need to be carried out periodical studies on the variation in the phonological characteristics of trees of the area. An inventory of all trees growing in the city and especially along the roadside is also suggested.

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Table 1: Size of urban trees (dbh cm) measured at different sites

	SITES			
Name of Plant species	**A**	**B**	**C**	**D**
Alstonia scholaris (Linn.) R.Br	N / A	24.87 ± 7.87 (*4.37–42.17)	24.79 ± 7.84 (*5.95–44.34)	42.19 ± 13.35 (*16.71–30.24)
Azadirachta indica L.	32.72 ± 10.35 (*21.64–54.11)	N / A	49.90 ± 14.21 (*21.32–58.88)	42.17 ± 13.34 (*16.71–30.24)
Bombax ceiba L.	34.55 ± 10.93 (*23.87–39.79)	35.06 ± 11.09 (*23.87–44.70)	29.45 ± 9.32 (*5.72–53.47)	33.15 ± 10.49 (*16.71–30.24)
Cassia fistula L.	N / A	27.00 ± 8.54 (*12.73–32.14)	N / A	25.73 ± 8.15 (*16.71–30.24)
Eucalyptus sp.	20.90 ± 6.62 (*16.71–30.24)	21.91 ± 6.93 (*9.50–28.32)	65.50 ± 20.74 (*12.57–31.76)	28.91 ± 9.15 (*16.71–30.24)
Ficus benghalensis L.	17.12 ± 5.41 (*38.99–74.79)	38.81 ± 12.28 (*15.51–51.07)	41.40 ± 13.10 (*13.52–60.79)	28.15 ± 8.91 (*16.71–30.24)
Ficus religiosa L.	44.10 ± 13.95	37.69 ± 11.92	42.70 ± 1.49	31.94 ± 10.10

	(*16.71–77.98)	(*7.79–63.66)	(*15.97–68.43)	(*16.71–30.24)
Guaiacum officinale L.	34.16 ± 10.84 (*13.52–46.95)	25.90 ± 8.19 (*9.50–35.49)	N / A	33.86 ± 10.71 (*16.71–30.24)
Symbol used: Standard Error ± (S.E.), N / A = not available, *Range of tree samples dbh (cm) **SITES**: **A**: M. A. Jinnah Road, **B**: University Road (Near Hassan Square): **C**: North Nazimabad, **D**: Karachi University Campus (Control site)				