



**Quantification of growth pattern of tree species  
growing in and around Baroda industrial area and  
their suitability for green belts**

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## S U M M A R Y

Urbanisation and industrialisation has resulted in the impoverishment of the environment. Many industrial processes such as coal and oil combustion, and roasting of some mineral ores produce sulphur dioxide and nitrogen oxides which are released into the environment. Industries sustain a large mass of people which causes their dwelling in congested and 'environmentally unmanaged' projections. In order to gain more, industries often go on widening by ignoring environmental laws. Many times pollution control boards fail to regulate. This results in the air, water, and soil pollution around industrial areas which may prove hazardous to plants, animals and human beings. Due to air pollutants, damage to the plants, is a trite. There is ample literature on plants being used as indicators or studied for air pollution monitoring. It has been studied under field conditions (in agricultural lands, forest stands and ruderals), semifield conditions (in open-top chambers with artificial nutrients and gaseous mixtures) or under fully controlled laboratory regimes. The importance of air pollution in vegetational deterioration is well documented. Plant's differential responses and its air pollutants scavenging is nicely reviewed. Plants as biomonitoring tools, their growth reductions and alterations are also focused. But it is felt that, tropical trees growing around industries in open fields are less studied. Change in growth pattern (phenology) of trees growing in industrial environments too, are less documented/studied.

Though, tree phenology plays major role, no earlier worker had tried to correlate leaf phenology with different biochemical or growth parameters; nor canopy architectural changes (due to air pollution) have been focused. No data exists for a wide range of tree species and localities; similarly, dust scavenging is not quantitatively measured for different species. How a plant with dead apical bud acts on getting favourable conditions or what happens to its phenology and growth? To address these lacunae the present study has been conducted. It is aimed at emphasising the importance of an

appropriate growth parameter study together with concurrent phenological changes under field conditions. To generalise the assumptions for synergistic effects of air pollutants in field conditions - more number of localities were selected. The localities were with different air pollutant concentrations and with different assortments of trees. This study is aimed at augmenting the existing knowledge for tree growth and leaf phenology under the influence of industrial air pollution.

#### **Aims of the study are**

- (1) To study growth patterns of trees under the influence of industrial air pollution, Their comparison between localities and between different tree species.
- (2) Recommendation of suitable species for green belts around industries, based on the growth performances and pollution accumulation capacity.

Geographically the **study area** falls under the Vadodara Urban Development Area (VUDA), which lies at  $73^{\circ} - 74^{\circ}10'$  E longitude,  $21^{\circ} - 23^{\circ}$  N latitude, and 30 m above mean sea level. The general topography of the area is plain with little undulations in the North (N) and North-West (NW) directions with the *Mahisagar* and the *Mini* rivers. The study area is intercepted by two small rivers (i.e., *Mini* and *Vishwamitri*), flowing from the N to NW direction. Water of these two rivers was potable earlier. Presently they are used as industrial effluent canals. The study area is composed of Vadodara district's industrial zone which lies in NW direction of the Baroda city. The study area has a large group of industries ( $\cong 239$ ), running on small to medium scales and polluting heavily (The Nandesari Industrial Estate). Other industrial giants are an oil refinery, a petrochemical complex, a fertilizer company, an alkalis and chemicals unit, a polymer unit, a plastics unit, a glass making unit, a diamines unit and a gas-based power plant. Common pollutants are oxides of nitrogen, sulphur dioxide, hydrocarbons, ethylene, methane, benzene, ammonia, chlorides, fluorides and sulphides of many compounds in gaseous, liquid and solid stages. Ambient air quality monitoring data was procured from Gujarat Pollution Control Board (GPCB), Gujarat

State Fertilizers Company (GSFC) and Indian Petrochemicals Corporation Limited (IPCL). Soil samples were collected twice in a year at 5-10 cm depth from all the sites and were analysed at the Soil Testing Department of the Gujarat State Fertilizers Company Limited

The growth study was done for 12 tree species. It was conducted for eight periods (i.e., April-June, 1994 was the 1st and January-March, 1996 was the 8th) for two years.

*Acacia nilotica* (L.) Del

*sp. indica* (Benth.) Brenan

*Anogeissus latifolia* Wall.

*Azadirachta indica* A. Juss

*Bauhinia racemosa* Linn

*Cordia dichotoma* Forst.

*Holoptelea integrifolia* Planch.

*Mangifera indica* Linn.

*Mimusops hexandra* Roxb.

*Moringa pterygosperma* Goert

*Pithecellobium dulce* Benth.

*Streblus asper* Lour.

*Tamarindus indica* Linn.

At each site, a minimum of 5 to a maximum of 10 individuals for each tree species were selected, based on their approachability for sampling. *Bauhinia* and *Cordia* were less frequent and minimum of 3 individuals for both of them were selected at each site. To attenuate the age differences, trees belonging to similar circumference (CBH) range were selected. It was kept in mind that randomly spread individuals of the selected tree species would present mixed vegetation pattern at a particular site.

Growth pattern of trees cannot be done the way it is normally carried out for crop plants or annuals. In this study emphasis was laid down to observe the relative variations in the growth pattern of trees over a two year period. The **growth measurements** like height (Ht), circumference at breast height (CBH), spread or radius of canopy (Cr), and canopy depth (Cd) were taken for the selected trees. At each site, sampling was done at an interval of 85 ( $\pm 5$ ) days by making it four sampling periods each year for two years. During each sampling three young growing twigs were collected from each individual tree canopy. They were positioned in

different directions of the crown periphery at a height of 6 to 12 feet from the ground depending on the species. Starting from the tip of the branch, the first ten fully expanded leaves were separated and their average leaf area (LA), leaf area damage (LD) were measured by using a dot grid made on a transparent sheet. The first ten fully expanded leaves and the branch holdings them were packed separately and oven dried at 70° C for 48 hrs, and weighed. Twig weight (TWt) was calculated by adding leaf weight (LWt) and branch weight (BWt). During the reproductive phase, number of flowers on each inflorescence (FL/IN), number of inflorescences on the sampled branch (IN/BR) and similarly, number of fruits per branch (FR/BR) were recorded. To monitor leaf phenology and to identify its impact on growth performances, tagging was done on the young, growing branches depending upon easy approachability. Dust deposition of the leaves and sulphur content in the foliage were estimated.

Soil composition for the major plant nutrients was similar at all the sites. Lesser changes in the analysed soil parameters of the present study area indicated that the soil quality of the selected sites did not differ much because of the industrialisation. Hence it was assumed that soil quality *per se* had minimal impact on the growth difference of the trees. Data obtained for major air pollutants in the study area are for sulphur dioxide (SO<sub>2</sub>), oxides of nitrogen (NO<sub>x</sub>) and suspended particulate matter (SPM). These air pollutants indicated higher concentrations as compared to control. The presence of other unmonitored air pollutants with their derivatives and precursors can also act synergistically. Because of the presence of micro-level pollutants, correlation between the available ambient air quality data and tree growth became difficult in this study.

**Damage symptoms** like chlorosis and necrosis were recorded on the foliar surfaces at various localities. Symptoms were more on evergreens as their leaves persist for longer durations. Trees at polluted sites showed reduced vegetative growth after severe defoliation or apical bud mortality. Reductions in flowering and fruiting were more in evergreens as compared to deciduous trees. Height of the trees was reduced

at polluted sites. This has resulted in stunted appearance of the trees. Species like *Anogeissus latifolia*, *Bauhinia racemosa*, *Holoptelea integrifolia*, *Mangifera indica*, *Streblus asper* and *Tamarindus indica* have shown stunted canopies with dried apical buds and altered canopy structures. In *Acacia*, *Azadirachta*, *Cordia*, *Mimusops*, *Moringa* and *Pithecellobium*, the reductions in tree height were negligible. They exhibited lesser reductions in canopy depths and cover. In the **tagging** experiment, apical bud mortality was found both in deciduous and evergreen species at heavily polluted sites. After the death of apical bud further growth occurred by means of lateral branches. This had changed the canopy form. Tagging experiments of this study had shown that there was considerable reduction in shoot length in evergreens as compared to deciduous species. Foliage number reduction was high in *Holoptelea* suggesting decrease in number of internodes. In *Azadirachta* none of the tagged twigs showed dried apical buds suggesting its continued growth.

**Internodal length** and girth were measured to see growth of the sampled twigs which were reduced at polluted sites. As compared to deciduous species, evergreen species showed lesser reductions in this study. Among evergreen trees, reductions in the internodal length were more than the reductions in the girth. This has resulted in compactly arranged leaves. In deciduous species both internodal length and girth were reduced proportionately. Leaf area at the polluted sites was reduced due to lessened leaf size, changes in leaflet number, leaf area damage and reduced leaf longevity. Leaf fall at the polluted sites was dependent on wind flow pattern. It was heavy in the sites falling in the western direction of the industrial belt. Heavy leaf fall observed was compensated soon after monsoon and/or due to change in wind direction. This showed that trees can recover under favourable conditions.

**Biomass** accumulation was hampered at all the polluted sites. It was indicated by reduced biomass of leaves and stems. Leaf fall had remarkably reduced leaf weight. There were two trends found in biomass accumulation. Both leaf weight and branch weight were less during Aug at sites falling in north-east of the industrial belt. While

other sites (falling in the west), had reduced biomass during Feb. This was irrespective to tree's phenology indicating influence of air pollution loads. Trees' **reproductiveness** at polluted sites were affected. Reduced number of flower per inflorescence (FL/IN), inflorescences per branch (IN/BR) and fruits per branch (FR/BR) were observed. Reductions were more in evergreens because of their preference for vegetative growth. Reduced biomass production could be responsible for altered partitioning of biomass and subsequent reduction in reproductive growth. Altered timing for reproductive cycle might be responsible for lessening damages in *Anogeissus*, *Azadirachta* and *Pithecellobium*. Fruiting was affected heavily in *Mangifera*, *Bauhinia*, *Holoptelea* and *Tamarindus*. It is important to note that plants with inherent capabilities of longer periods for reproductive cycle could get adjusted by altering their timing for flowering and fruiting. This was seen among *Moringa*, and *Pithecellobium*. In *Bauhinia*, *Mangifera*, *Tamarindus* and *Holoptelea* fruiting was reduced heavily as they have comparatively short time for flowering.

The present study revealed that *Anogeissus*, *Azadirachta*, *Cordia*, *Holoptelea*, *Mimusops* and *Streblus* are tolerant trees. *Acacia*, *Bauhinia* and *Pithecellobium* are moderate ones and *Mangifera*, *Moringa* and *Tamarindus* are sensitive trees.

In spite of growth reductions and reduced leaf longevity in the present study trees at polluted sites had higher sulphur accumulation. Few of them have shown good sulphur accumulation revealing their suitability for plantation in sulphur-rich environment. Dust deposition on foliar surfaces was more during summer at control as well as at polluted sites. Dust capturing capacity can be linearly correlated with leaf area, study revealed that mature, fully expanded leaves were capable of holding maximum dust. Among the selected species, trees with simple, hairy and broad leaf habit had maximum dust capturing.

These studies indicate that **green belt** plantation should be based on stack height, wind flow (Meteorology), type of pollutants etc. Based on two types of stack heights, two separate plantation strategies can be adopted. Those are (1) for high level source/s and (2) for low/ground level source/s. As there will be less deposition in wake region of high level sources, plantation of moderate and sensitive species can be mixed near the source. With an increase in concentration down-wind upto its maximum, there should be gradual increase in the number of tolerant species in combination with moderate ones. At the point of maximum concentration/deposition, only tolerant species should be planted. Again in the periphery a combination of moderate and sensitive ones can be planted. Near the ground level sources, only tolerant species should be planted. They can be surrounded by a mixture of tolerant and moderate trees. Green belts for both the patterns of pollutant settlement usually should be in circular-form around the source/s. For greater efficiency, circular green belts can be widened in prevailing wind flow direction. It is also advisable to keep fast growing tolerant species in close vicinity to the source and thorny species out side the green belt for protection. Literature shows that seedlings and saplings of trees are more sensitive to air pollution. Hence plantation should be done well before the actual industrial functioning. This will give an established and functional green belt. Green belt should not be developed only as an air purifier but it should be allowed to develop as a major component of the industrial ecosystem by increasing number of species and their interactions.