PHYTOREMEDIATION OF PARTICULATE MATTER FROM AMBIENT ENVIRONMENT THROUGH DUST CAPTURING PLANT SPECIES

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CHAPTER - I

INTRODUCTION

1.1 BACKGROUND

Ambient Air constitutes various size ranges of solid particles commonly recognized as Particulates or Dust, which are continuously agglomerated and deposited, on various surfaces. The deposited particulate matter is a conglomerate of chemically heterogeneous substances of many different types, which act on plants in a variety of ways.

The biological activity of the particles at various locations necessarily vary because of differing pollutant source profiles. These variations are expressions of both quantitative and qualitative differences such as relative presence of sulfuric acid mist, sulfates, or other reactive substances in the particulate mix or the relative amounts of specific carcinogenic compounds in the organic fraction of airborne particulate. It therefore can be seen that the evaluation of biological activity ascribable to “particulate” is extremely complex and depends not only on the total quantity, size range and intrinsic physical or chemical properties, but also on their chance for interaction in the polluted air.

Research has shown that plant leaves can act as biological filters, removing large quantities of particles from the urban atmosphere. Stomata are microscopic pores on the underside (abaxial) of the leaf. These allow air into and out of the leaf through which the plant takes in CO_2 and lets out O_2, and allows water vapor out in the process of transpiration. As air passes through the stomata, most of the airborne particles will not pass through the stomata but will rather eliminated on the leaf’s outer surface due to available moisture.

There is a certain amount of force needed for particles to stick to surface. This amount is greater depending on the size of the particle. Because the airflow through the stomata is not very powerful, only the smaller particles will stick to the bottom surface. The particles on the top surface of the leaves will mainly be from the settling of dust. Because particles settled on upper surface of leave are both coarse and fine particles captured by leave surface because of favourable morphological features of leaves. These particulates remain adhered to plant leaves till these are washed down through rain or artificially.

Because the particles deposited on the leaves are from the air, analysis of the particles also provide information about the source of particulate air pollution in the area. The higher the concentration of particulate matter in the area, the higher the concentration of particles on the leaf surface will be. The sizes and chemical compositions of the particles on the leaf surface are the representative of the airborne particles in the sampled area.

Different types of leaves tend to have differences in several aspects of their surfaces. Some types of leaves have greater surface rigidity or roughness than other leaves, which affect their stickiness or particle solubility. Stickier leaves would be better for collecting particles because more particles would stick to their surface and once the deposited particles are washed away, the leaves will be ready for dust capture again. Therefore, certain morphological features of leaves are more favourable for particulate capture from the surrounding environment.

The particles in the air are derived from innumerable natural and man made sources, each contributing different physical and chemical properties. While portions of the particulate milieu consists of relatively non-reactive substances such as carbon or calcium, they differ in their biological activity by virtue of the presence of adsorbed chemicals that may be added through condensation of volatile chemicals in the stack as the flue gases cool, or through interactions with other pollutants in the atmosphere. Therefore, the potential for biological activity of given particle is governed by its opportunistic ability to interact with other environmental pollutant substances capable of chemical or physical interaction.

The biological activities of particles at various locations necessarily vary because of differing pollutant source profiles. These variations are expressions of both quantitative and qualitative differences in the relative amount of sulfuric acid mist, sulfates, or other reactive substances in the particulate mix or the relative amounts of specific carcinogenic compounds in the organic fraction of airborne particulate.

It therefore can be seen that the evaluation of biological activity ascribable to "particulate" is complex and depends not only on the total quantity, size range and intrinsic physical or chemical properties, but also on their chance for interaction in the polluted air. The opportunity for variation in biological activity is enormous, and at this time it would seem unwise to attempt to relate health effects to the total amount of respirable particulate material in the atmosphere without regard for their qualitative differences.

Particulate Matter (10 μm Size) and Human Health

There has been extensive interest in the health implications of fine particles in the atmosphere. Particulate matter having an aerodynamic diameter of less than 10 μm (PM_{10}) has become the standard measure of particulate pollution, since high concentrations of PM_{10} have been linked with increased incidence and severity of respiratory illnesses. The fine particles ($PM_{2.5}$) (size range 2.5 μm aerodynamic diameter) are considered as the most damaging to health, since these could penetrate deep into the respiratory tract more easily.

The PM_{10} mass is contributed by both natural and anthropogenic sources, but in the finer $PM_{2.5}$ component, almost all particles derived from anthropogenic sources. In the urban environment, as much as 80% of emissions of these health-damaging particles originate from road traffic.

Air improving Qualities of Plants

Researches have shown that Plants (including trees) can act as biological filters, removing large quantities of particles from the urban atmosphere. This is predominately due to their large leaf areas relative to the ground on which they stand, and the physiological properties of their surfaces i.e. the presence of trichomes or waxy cuticles on the leaves of some species.

Interception of particles by vegetation has been shown to be much greater for street trees due to their proximity to high intensities of road traffic.

Dust Capturing Mechanism By Plants

Stomata are microscopic pores on the underside (abaxial side) of the leaf. These allow air into and out of the leaf, which is how the plant takes in CO_2 and lets out O_2, and allows water vapor out in the process of transpiration. As air diffuses through the stomata, most of the airborne particles will not pass through the stomata but will

rather land on the leaf's outer surface. This is similar to a filter, where air is pulled through the filter by an air pump and the airborne particles deposit on the filter surface. This air flow could not be the major cause of particles depositing on the leaf. The concentration of particles on abaxial surface of the leaf normally do not observed higher than that of the top surface of the leaf (adaxial surface).

There is a certain amount of force needed for particles to adhere to a surface. This amount is greater depending on the size of the particle. Because the airflow through the stomata is only passive diffusion the fine particles could stick to the bottom surface. The particles on the top surface of the leaves will mainly be from the settling of coarse particles and dust facilitated by sticky surface texture presence of fine veins on leaf surface. Because settled particles are mostly larger ones, those found on the top surface will be mostly larger.

The particles deposited on the plant leaves are from the ambient air, analysis of the particles will provide information about the particulate air pollution in the area sampled. The higher the concentration of particulate matter in the area, higher the concentration of particles on the leaf surface. The sizes and chemical compositions of the particles on the leaf surface mass indicate the source of airborne particles. Urban areas tend to have the highest concentrations of airborne particulate matter, because of traffic related activities and other human activity. This is followed by suburban areas, and then rural areas, with decreasing amounts of particulate matter (Abraham, M.E., 1998). Therefore, if leaf sampling is accurate, particle concentrations on leaves collected from sampled areas will decrease from urban to suburban and from suburban to rural.

Different types of leaves tend to have differences in morphological features of leaf surfaces. Some types of leaves have greater surface rigidity or roughness than other leaves, which may affect their stickiness or particle solubility. Based on this concept, the study has been undertaken to identify the plant species, which have higher potential of dust capturing from environment while sustaining their well being. The dust capture by plant is a unique combination of concentration and exposure period to the pollutant (or pollutants), of plant species, plant age and of environmental conditions. The guidelines evolved based on the study will enable the user to determine simply and directly the factors involved in dust capturing capacity of the plant species, which if used in practice will not only increase the green cover but also simultaneously provide natural filters for reducing the particulate level in ambient air from the dense urban areas with prevailing particulate pollution problems through their dust capturing capacity.

1.2 OBJECTIVES OF STUDY

The present studies have been conducted with following major objectives:

- To study relative exposure vs. dust capturing capacity of various identified plant species through natural and controlled exposure.
- To evaluate the rate of dust deposition/capture capacity of different plants species (Herbs, Shrubs & Trees)
- To identify the Plant species with high potential for Control of Dust/Suspended Particulate Matter in Ambient Air.
- To prepare checklist of Plant species for Phytoremediation of particulate matter from ambient environment.

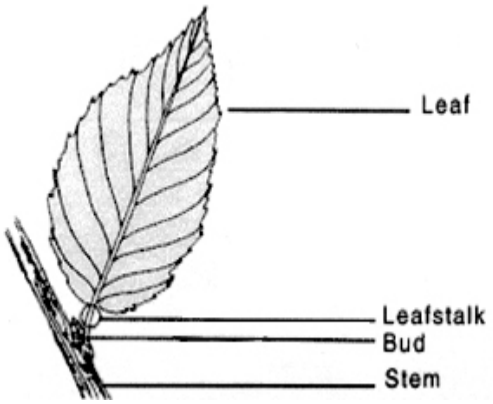
CHAPTER - II

MORPHOLOGICAL, ANATOMICAL, PHYSIOLOGICAL FEATURES OF PLANT SPECIES & ENVIRONMENTAL FACTORS FACILITATIVE FOR DUST CAPTURING EFFICIENCY

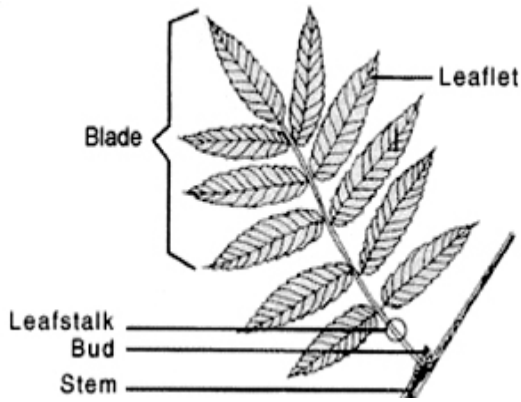
2.1 MORPHOLOGICAL FEATURE OF PLANT LEAVES FOR DUST CAPTURE EFFICIENCY

Different types of leaves tend to have differences in several aspects of their surfaces. Some types of leaves have greater surface rigidity or roughness than other leaves, which may affect their stickiness or particle solubility. Stickier leaves are better for collecting particles because more particles would stick to their surface. Therefore, certain plant leaves may be more useful for efficient dust capturing than other plants. The various morphological features are also major factors for dust capturing by leaves. The crown area of plants is depending upon the morphological features of the leaf. The various types of Morphological features viz. shape, size, surface texture of leaf are discussed below:

Leaves can be of many different shapes. Primarily, leaves are divided into simple - a single leaf blade with a bud at the base of the leaf stems; or compound leaf - a leaf with more than one blade. All blades are attached to a single leaf stem. Where the leaf stems attaches to the twig with an axial bud.



Simple Leaf

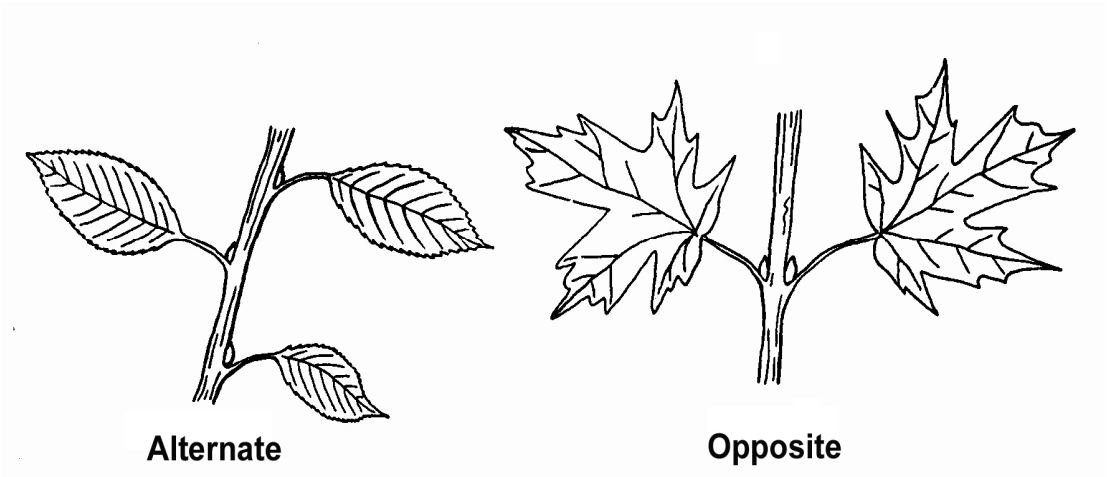


Compound leaf

There are three main parts to a leaf:

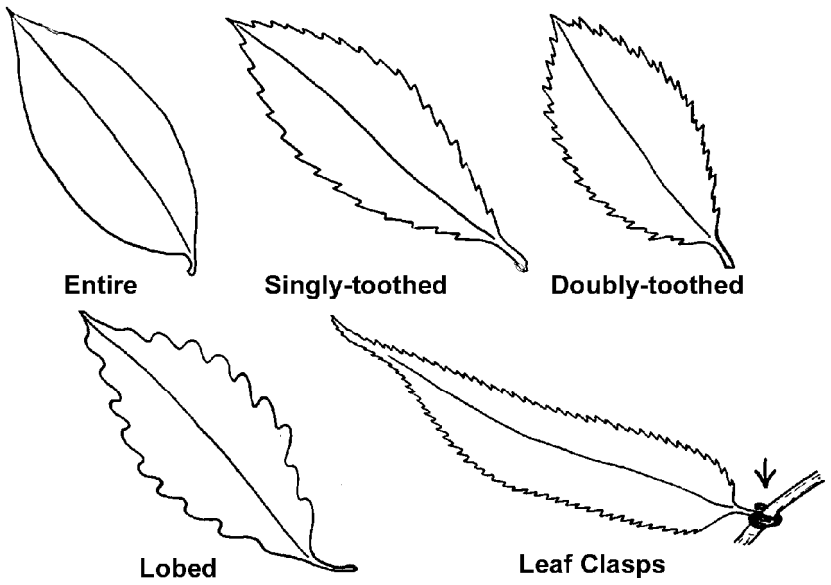
- The **base**, which is the point at which the leaf is joined to the stem.
- The **stalk** or **petiole** is the thin section joining the base to the lamina - it is generally cylindrical or semicircular in form.
- The **lamina** or **leaf blade** is the wide part of the leaf.

Leaves may be arranged on the stem either in an **alternate** arrangement - leaves that are staggered or not placed directly across from each other on the twig; or in an **opposite** arrangement - 2 or 3 leaves that are directly across from each other on the same twig



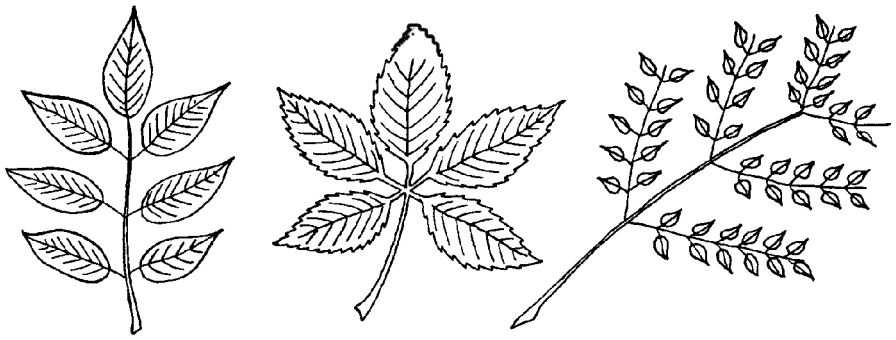
LEAF ARRANGEMENT

The lamina or leaf blade (the edge of a leaf) may be entire, singly-toothed, doubly-toothed, or lobed.



SIMPLE LEAVES - MARGIN STRUCTURE

Compound leaves may be **palmate** - having the leaflets arranged round a single point like fingers on the palm of a hand; or **pinnate** - when the leaves are joined on the two sides of the stalk, like the vanes of a feather.



Pinnate Compound Palmate Compound Doubly-Compound

COMPOUND LEAVES

The form of leaves is related with all their functions and their environment. In addition to photosynthesis, the leaf also carries out other exchanges with the atmosphere. It is through the leaf that the plant "breathes" (absorbs oxygen and releases carbon dioxide and generate energy) and transpires. Epidermic tissues in the leaf contain **stomata** - microscopic openings like valves which regulate opening or closing, permitting or preventing transpiration, through which the plant loses the major part of the water it absorbs so as to allow further absorption by the roots. In most plants the stomata are located on the underside of the leaves. Their function is regulated so that plants living in dry climates have a substantially smaller number of stomata than those in humid climates, where stomata are numerous and prominent. Where humidity is low the stomata may actually be recessed or partly protected by soft hairs which can prevent excessive transpiration.

2.2 ANATOMICAL FEATURES OF PLANT LEAF FOR EFFICIENT DUST CAPTURE

The anatomical features of leafs are different from plant to plant. The general anatomical features of a leaf are given below:

Origin of leaves

- Leaves originate as primordia in the buds. Leaf primordia resemble apical meristems.
- Mature leaves are then formed by the coordinated efforts of several meristems in specific positions.
- Continued growth of a leaf involves cellular expansion and division o Vascular tissue differentiates acropetally (i.e., from the base into the tip of the leaf).
- Other tissues differentiate basipetally (i.e., from the tip toward the base).
- Leaves are the most diverse of all plant organs (shape, size, texture, color, etc.)

Phyllotaxis

It is the arrangement of leaves on a stem. It is determined at the shoot apex and is species-specific. The arrangement may be three types:

- Alternate or spiral (one leaf per node, example - Poplar, Pea)
- Opposite (two leaves per node, example - Maple, Coleus)
- Whorled (three or more leaves per node; oleander, horsetail)

External Structure of Leaves

Most leaves consist of:

- Blade or lamina (flattened, expanded part). It has a network of veins (vascular bundles)
- Petiole (stalk that connects the blade to the stem; collenchyma and sclerenchyma fibers), which is absent in sessile leaves (*Zinnia*)
- Stipules (pair of appendages of varying size, shape, and texture present at the base of the leaves of some plants)

Kinds of leaves

- Simple (undivided blade, may be lobed; maple)
- Compound (blade divided into leaflets in various ways)
  - Pinnately compound (leaflets in pairs along a central, stalklike rachis; rose, walnut)
    Bipinnately compound (subdivided leaflets)
  - Palmately compound (leaflets attached at the same point at the end of the petiole; trifoliate shamrock, lupine)
  - Peltate (petiole attaches to the middle of the blade; tubular leaves of carnivorous plants)
  - Perfoliate (sessile leaves that surround and are pierced by stems)

Venation (arrangement of veins in a leaf or leaflet blade)

- Netted (one or a few prominent mid-veins from which smaller minor veins branch into a meshed network - dicots and some non-flowering plants)
  * Pinnate (main vein -midrib- with secondary veins branching from it)
  * Palmate (several main veins fan out from the base of the blade)

- Parallel (several prominent and parallel veins interconnect with smaller, inconspicuous veins - monocots)
- Dichotomous (no midrib or other large veins; veins fork evenly and progressively from the base of the blade to the opposite margin - *Ginkgo*)

ANATOMICAL INTERNAL STRUCTURE OF LEAVES

- Leaves consist of epidermis, mesophyll and vascular tissues

  a. Epidermis (usually a single layer of cells covering the entire surface of the leaf).

  b. Mesophyll (mainly parenchymatic [photosynthetic] tissue between the two epidermal layers)

  c. Vascular tissues or Veins (vascular bundles scattered throughout the mesophyll)

Epidermis

- *Cell types*
  - Parenchyma (flat, tile like cells, transparent, lacking chloroplasts) Specialized cells (guard cells, trichomes, bulliform cells; some cells modified as glands)
  - Sclerenchyma
- *Cuticle*
  - Protective layer, on outer walls of epidermal cells, made of a fatty substance called cutin often covered by epicuticular wax
  - Functions: protection from desiccation, microbes, abrasion, wind
- *Stomata*
  - pores or openings in the epidermis, each flanked by two specialized guard cells
  - Variable frequency and distribution in different species
  - Guard cells Contain chloroplasts, lack plasmodesmata, distinctly thickened cell Walls. These are Kidney-shaped (dicots), dumbbells (monocots), Surrounded by subsidiary cells (distinctively shaped).
  - Function: regulate exchange of gases (e.g., CO_2, H_2O, O_2) by opening and closing the stomata pore

Mesophyll

- Several cell types (chlorenchyma, storage parenchyma, sclerenchyma)
- Main function is Photosynthesis
- Horizontally oriented leaves (e.g., bean, pumpkin) may have either Palisade mesophyll (columnar chlorenchyma cells, densely packed, usually in two rows, photosynthesis).
- Spongy mesophyll (irregularly shaped cells, loosely arranged with abundant intercellular spaces, gas exchange).
- Vertically oriented leaves (e.g., corn) have uniform mesophyll cells and uniform chlorenchyma surrounds a photosynthetic bundle sheath (some grasses)

Vascular tissues

- Single or several closely associated vascular bundles form the veins, which are scattered throughout the mesophyll
- Xylem forms on the upper side of a vein (next to the stem) and phloem forms on the lower side (away from the stem)
- Veins are supported by fibers and usually surrounded by a layer of parenchyma cells called the bundle sheath
- The veins, in addition to their conducting function, give the leaf its "skeleton" (support)

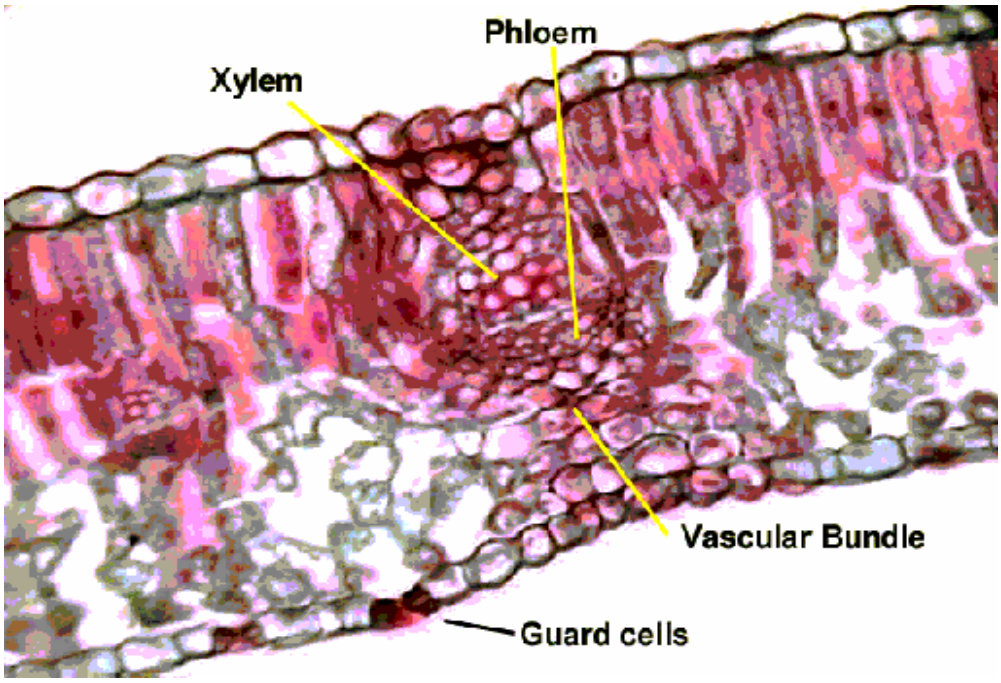


Fig. 2.1: Transverse Section of Typical Leaf Showing Vascular Bundle

2.3 PHYSIOLOGICAL FEATURES OF PLANT LEAF FOR EFFICIENT DUST CAPTURE

The following Leaf functions are directly or indirectly help in efficient dust capture by plants

- Photosynthesis (production of carbohydrates from CO_2 and H_2O using light energy)
- Transpiration (water absorbed by the roots and transported throughout the plant evaporates into the atmosphere)
- Water movement and Cooling
- Abscission (seasonal shedding of leaves in deciduous plants) Nutrient recycling and waste elimination

There are two physiological Features, which are controlled by Leaf morphology & anatomical feature, help in dust capturing efficiency of leaf as well as plants. These are - Photosynthesis Process; and Transpiration Process.

2.3.1 Photosynthesis Process

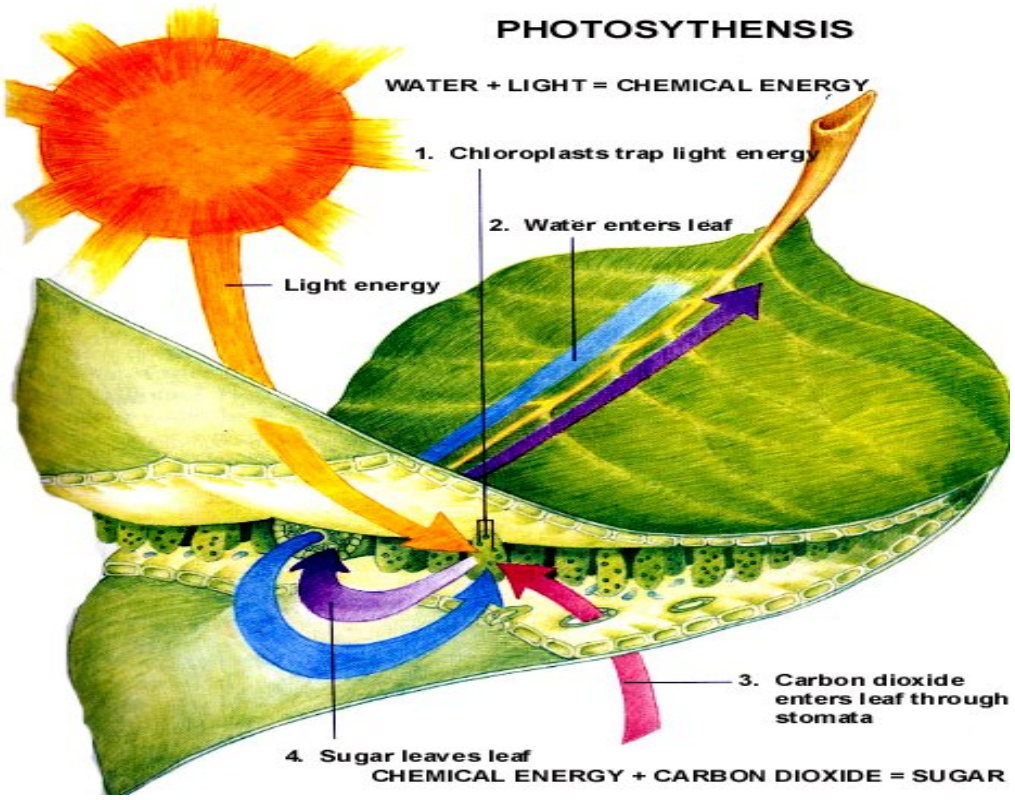


Fig. 2.2 : Graphical representation of Photosynthesis Process on a Leaf

Leaves provide plants with all their food through conversion of sunlight into food energy. **Chlorophyll** makes this energy transformation possible. **Chlorophyll** is a pigment found in the cells of leaves, which is formed only in the presence of light and is the substance that colors plants green. Chlorophyll is contained in chloroplasts and has the property of capturing light energy. The **Photosynthesis** is the process by which plants make sugar from sunlight, water, and carbon dioxide) and releases much needed oxygen during the process.

Sunlight shines through the top of the leaf and reaches the next layer of cells. The light energy is trapped by the chlorophyll in the **chloroplasts**. In the chloroplasts, a process that uses water changes the light energy into a kind of chemical energy. This chemical energy is stored in the chloroplasts.

Stomata – Structure & Function

The chloroplasts use the chemical energy to make food. Air enters the leaf through the **stomata** and moves into tiny spaces around the food-making cells in the leaf. Carbon dioxide from the air passes through the cell walls and membranes of the cells. Carbon dioxide enters the chloroplasts where the previously stored chemical energy converts the carbon dioxide into sugar. Tubes in the plant carry sugar from the leaf cells to other parts of the plant, such as roots, stems, and fruits. Cells in these parts of the plants store some of the sugar.

Stomata are openings in the epidermis of leaves and stems that allow gas change. ***Guard cells*** surround the opening and function to open or close it. Guard cells that contain chloroplasts, other epidermal cells do not contain chloroplasts.

Stomata are pores perforating the epidermis of the leaves and stem. They are usually most numerous in the lower epidermis of the leaf where there may be as many as 400 per mm, there are generally fewer in the upper epidermis and fewer in the stem. Their functions are:

- To allow exchange of carbon dioxide and oxygen between the inside of a leaf and the surrounding atmosphere.
- To permit the escape of water vapor from the leaf

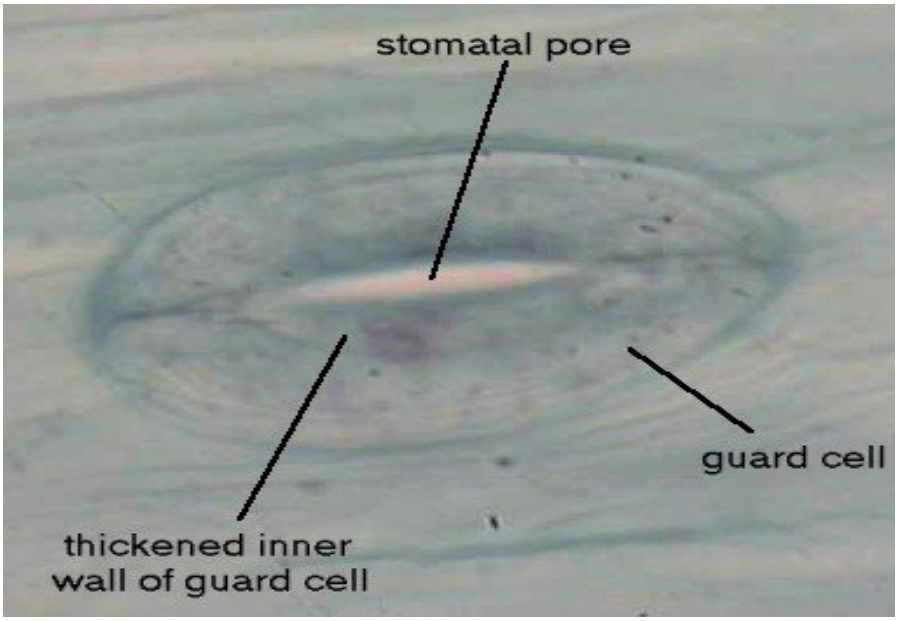


Fig. 2.3 : Microscopically enlarged view of Stomata

Stomata are important in several physiological processes, not just photosynthesis, but they also represent a hazard through excessive evaporation from the leaf. If the leaf opens its stomata, it runs the risk of losing excessive water, particularly if it lives in a dry habitat. On the other hand if it closes these, the leaf may run short of carbon dioxide or oxygen. Plants resolve this problem by not opening these for longer period than is necessary. This does not mean that a plant never loses more water than it can replace from the soil. The observation that plants frequently wilt in hot weather bears witness to the fact that they often do lose excessive water. However wilting is not disastrous so long as the plant is given an opportunity to recover later. The controlled opening and closing of the stomata resolve the conflicting needs of the plant.

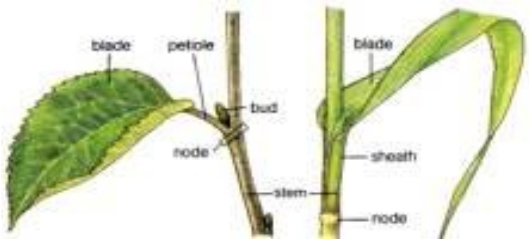
The stomata have controlled mechanism by which they open and close. A pair of guard cells borders the stomata pore (Fig. 2.3). These are sausage-shaped and, unlike other epidermal cells, contain chloroplasts. There is a sap vacuole and, a point of great importance; the inner cellulose wall (i.e. the wall lining the pore itself) is thicker and less elastic than the thinner outer wall.

Stomata opening and closure depends on changes in turgor of the guard cells. If water is drawn into the guard cells by osmosis the cells expand and their turgidity is increased. But they do not expand uniformly in all directions. The thick, inelastic inner wall makes them bend. The result is that the inner walls of the two guard cells draw apart from each other and the pore opens. In normal circumstances when a stoma opens the turgidity of the guard cells is increased by their taking up water from the surrounding epidermal cells. Isolated stomata will open when immersed in water, but if placed in a hypertonic solution, they close. The stomata remain open during the day but closes during night.

Leaves with Different Stomata

One of the functions of stems is to serve as the attachment site for leaves. Leaves are attached to stems at nodes. The space between leaves along the stem is the internode. Leaves exhibit far more variation in shape (morphology) than stems and roots. Leaf shape, size, venation pattern, margins, tips and bases are normally used in identification of plant species.

Most leaves, however, have two common features: the **blade** (or sometimes lamina), the flattened portion of the leaf and the **petiole**, or leaf stalk, which attaches the leaf to the stem. Leaves that do not have a petiole are **sessile**. **Stipules**, small leaf-like growths near the base of the petiole, may or may not be present. Buds are located in the axil of a leaf with the stem.



Dicot Leaf e.g. Gurhal Monocot Leaf e.g. Rice, Wheat, Bamboo

Leaves have a vascular connection to the stem through the petiole. Vascular tissue in leaves comprises the veins. In early development, a procambium strand from the shoot meristem branches out into each leaf primordium. This is the **leaf trace**. Similar strands of procambium branch out into buds, the **bud traces**. They leave a procambium gap in the stem tissue called the leaf trace gap and bud trace gap. The traces and gaps can often be seen in the shoot meristem.

Table 2.1: Prominent Anatomical Features of some High Dust Capturing Herbs, Shrubs & Trees Plant Species

S. No.	Common name	Botanical name	Family	Leaf Epidermis	Leaf Mesophyll	Vascular Tissue in Leaves (Veins)
HERBS						
1.	Elephant's Ear	*Colocasia antiquorum*	Araceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
2.	Cock Scumb	*Celosia argentea*	Amaranthaceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
3.	Genda	*Tagetes patula*	Asteraceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
SHRUBS						
4.	Copper leaf	*Acalypha hispida*	Euphorbiaceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
5.	Beshram	*Ipomea nil*	Convovulaceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
6.	Chandani	*Tabernaemontana divaricata*	Apocyanaceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
7.	Bougainvillea	*Bougainvillea glavara*	Nyctaginaceae	Both upper & lower epidermis cells are present	Mesophyll is present between upper & lower epidermis	Vascular tissues are present thought the leaf in parallel.
TREES						
8.	Poplar	*Populus*	Siliaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
9.	Bottle Brush	*Callistemon citrinus*	Myrtaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
10.	Jack Fruit	*Artocarpus integrifolia*	Moraceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
11.	Arjun	*Terminalia arjuna*	Combretaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series

S. No.	Common name	Botanical name	Family	Leaf Epidermis	Leaf Mesophyll	Vascular Tissue in Leaves (Veins)
12.	Jangal Badam	*Termanilia catappal*	Combrataceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
13.	Blue gum	*Eucalyptus globulus*	Myrtaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
14.	Indian Rubber	*Ficus elastica*	Moraceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
15.	Peepal	*Ficus religiosa*	Moraceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
16.	Banyan Tree	*Ficus bengalensis*	Moraceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
17.	Satni	*Alstonia scholaris*	Apocyanaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
18.	Kadam	*Anthosephalus cadamba*	Rubiaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
19.	Neem	*Azardirachta indica*	Meliaceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series
20.	Amaltas	*Cassia fistula*	Caesalpiniceae	Well distinct thick at both the layer	Well distinct in Palisade & Spongy parenchyma. Spongy parenchyma is present at lower epidermis	Many vascular bundles arranged almost parallel series

2.3.2 Transpiration Process

The Dust capture by leaf/plant depends on the moisture conditions on & around Leaf Surface. The moisture condition on leaf surface is depending upon the rate of transpiration of plant. The transpiration processes plants is diagrammatically represented in Fig. 2.4.

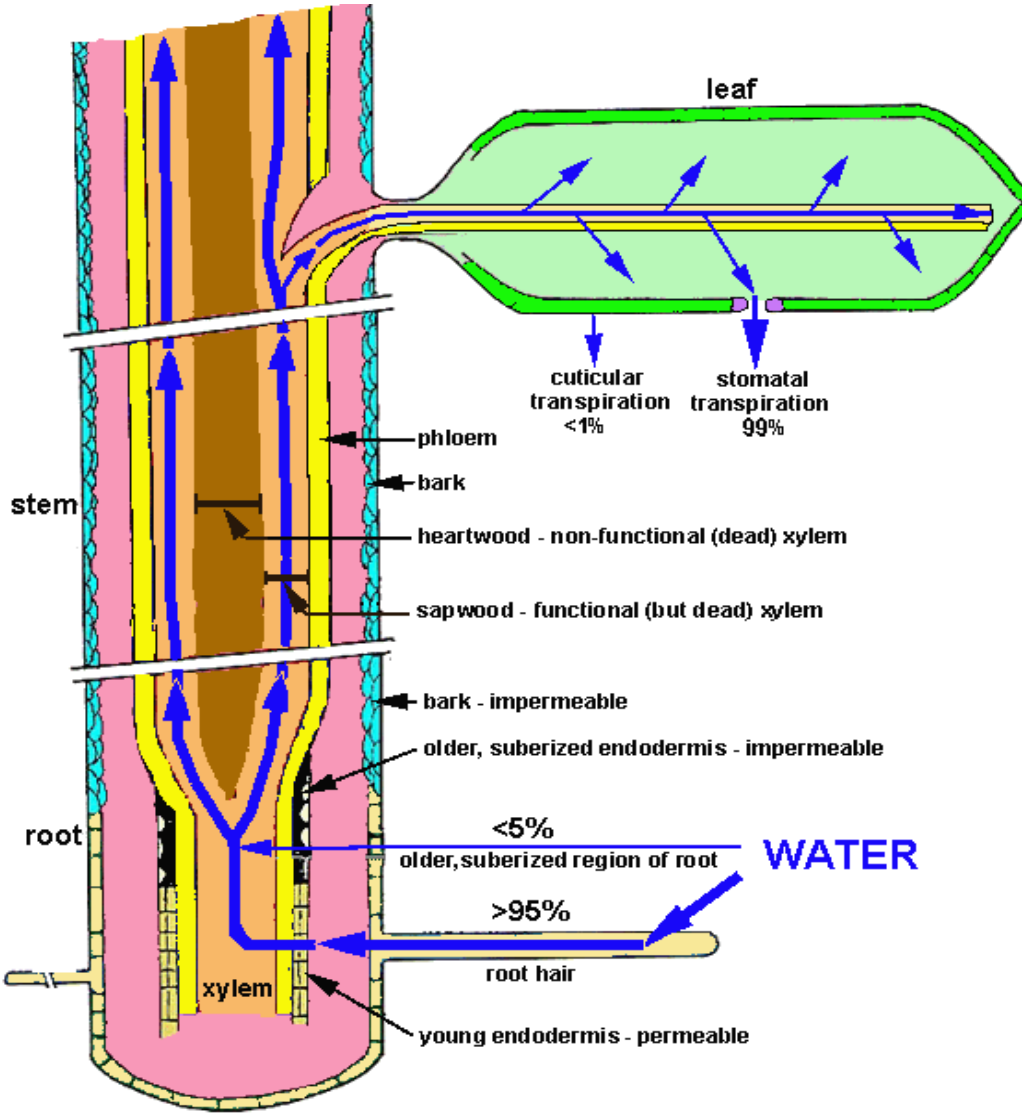


Fig. 2.4: Diagrammatic representation of moisture condition development on & around Leaf Surface

There is a certain amount of force needed for particles to stick to a surface. This amount is greater depending on the size of the particle. The airflow through the stomata is not very powerful, only the smaller particles will stick to the bottom surface. The particles on the top surface of the leaves will mainly be from the settling of dust, which are mostly coarse particles.

2.4. ENVIRONMENTAL FACTORS FOR EFFICIENT DUST CAPTURE BY PLANTS

The following environmental Factors influence the dust capturing efficiency of plants:

- **Light Intensity**

  The photosynthesis & Transpiration process of plants are depending on the light intensity. The leaves may be categorized into two based on light intensity.

  - Sun leaves (smaller, thicker; with smaller and more numerous chloroplasts)
  - Shade leaves (larger, thinner; with fewer chloroplasts and fewer well defined mesophyll layers)

- **Moisture**

  Mesophytes (grow in environments with intermediate amounts of water) and have extensive role in Dust Capture from environment.

  Xerophytes (grow in habitats characterized by seasonal or persistent drought)
  * Small, thick leaves with well-developed spongy and palisade layers
  * Thick cuticle, often sunken stomata overlaid with trichomes (hairy coverings)
  * Some species with multi seriate epidermis or hypodermis
  * Some species with succulent or no leaves

  Hydrophytes (grow in habitually wet, aquatic environments)
  * Large, thin leaves with poorly developed spongy and palisade layer (large aerenchyma)
  * Thin cuticle, stomata on upper surface of floating leaves
  * relatively little xylem and supporting tissue

- **Wind Velocity**:

  The wind velocity is also influence the dust deposition & dust capture by the leaves/plants.

2.5 EFFECTS OF VEGETATION ON URBAN AIR QUALITY

There are following main mechanisms by which urban plantation influence the local air quality:

- intercept particulate pollution and absorb gaseous pollutants,
- lower air temperatures; and
- alter pollutant emissions from power plants.

2.5.1 Interception and Absorption of Pollution

During daylight when plant leaves are transpiring water and taking up carbon dioxide, other gases including pollutants are also simultaneously taken up by the plant leaves. Once inside the leaf, these gases are absorbed and removed from the atmosphere. Some pollution removal can also occur on the plant surfaces. Particles can be deposited on plant surfaces through sedimentation under the influence of gravity or through impaction under the influence of wind. Particles hitting the plant surfaces may be retained on the surface, may rebound off the surface, or may be temporarily retained and subsequently removed (re-suspended into air or transported to soil or other surface). Thus, vegetation acts as temporary retention site for atmospheric particles as many particles can be re-suspended to the atmosphere, be washed off by rain, or drop to the ground through leaf and twig fall. However, trees can store various trace metals (e.g., lead) in their tissue.

Pollutant uptake by plants is highly variable as it is regulated by numerous plants, pollutant and environmental forces (e.g., plant water deficit, light intensity, wind speed, gas solubility in water, leaf size and geometry, etc.). Pollution removal by vegetation is dependent on local meteorological conditions, the plant's inherent ability to remove the pollutant and the concentration of pollution in the atmosphere. In general, the more pollution in the air, the more the plant can remove, up to a point where the plant becomes affected by the pollutant and stomata shut, limiting the removal of gaseous pollutants. The majority of pollution removal by plants occurs inside the leaves during day time conditions, as this is the time when leaf surfaces are actively transpiring and pollution concentration can be absorbed to their maximum Individual plant size affects total removal of pollutants per tree.

2.5.2 Temperature Effects

As water vapor is moved out of open leaf stomata (transpiration), it changes from a liquid to a gas. This change requires a large amount of energy and reduces air temperatures mainly within and near the plant canopy. This mechanism lower air temperatures and can significantly affect local air pollution. By lowering air temperatures, the plants may also affect ozone photochemistry and ozone precursor emission rates, thus influencing ozone formation.

2.5.3 Impact on Energy Use

The trees and plants can increase or decrease building energy use by shading buildings, altering air flows, and lowering air temperatures through transpiration. Lower air temperatures will reduce summer air conditioning needs of residences. However, shading of residences can have effect on building energy use. Summer shade can reduce air conditioning use and reduce energy consumption.

2.6 URBAN AIR QUALITY IMPROVEMENT THROUGH DUST CAPTURING PLANT SPECIES

The urban environment in the country have moderate to high particulate levels. In certain residential areas the SPM levels are in critical level. The particulate emission from industrial areas may be controlled through various pollution control devices, however, in residential area as there are no cost effective control technology for controlling particulates/dust built up except Green Belt development. The SPM level may reach to critical levels, may be due to High Traffic Movement, Vehicular Emissions and other anthropogenic activities.

Despite concerted efforts for controlling air pollution at sources the particulate problem still persisting in urban areas. The pace of population increase, vehicles increase and development of industries further enhancing the particulate pollution problems. Public awareness, proper industrial sitting, land use planning, and other combat measures such as proper traffic and transportation planning etc. are still needed in this direction.

The Green Belt development with dense plantation of Effective Dust capturing plant species such as Medium & High dust capturing efficient plants, may augment the particulate problem around residential areas / industrial area. The green belt with efficient dust capturing plants plants can act as efficient biological filters, removing significant amounts of particulates from urban atmosphere and may prove not only as cost effective technology, but also enhance aesthetic value at urban agglomerations.

CHAPTER - III

METHODOLOGY

3.1 SITES SELECTION

The sites for observation of plant species were selected at identified locations and the following site selection criteria have been followed:

- Climatic Conditions at different latitude & Longitude in Northern Part of the Country specially Rain Fall, Temperature, Humidity
- National Ambient Quality Monitoring Stations.
- High Traffic Zone
- High Dust Producing Industries (Thermal Power Station, Stone Crusher, Coal Mines & Cement Plant).
- Species diversity of Herbs, Shrubs & Trees Plants.

Based on the above criteria, the following sites were selected for the studies:

1. **Metro-cities – Mumbai, Delhi & Kolkata** – High Traffic Zones, Traffic Islands, Residential and Industrial Areas with existing AAQ monitoring Stations.

2. **Stone Crusher –** Five sampling sites in about 1 Km radius around stone crusher at Haridwar.

3. **Coal Mine –** Five sampling sites in about 1 Km radius around Coal Mine Area at Dhanbad.

4. **Cement Plant –** Five sampling sites in about 1 Km radius around Cement Plant at Paonta Sahib.

5. **Thermal Power Station -** Five sites stations in about 1 km radius around Thermal Power Station at Hardwar.

3.2 AMBIENT AIR QUALITY AT SELECTED SITES

Ambient Quality Monitoring stations are located at most of the sites selected for the studies to facilitate particulate pollution status in surrounding areas. The data on Suspended Particulate Matter & Respirable Particulate matter were collected from these stations for Summer & Winter Season.

Identification of Sampling Station has been undertaken on the basis of prevailing High SPM level (Based on air quality data recorded at NAAQM stations at Metro cities and for other areas these were also identified in consultation with State Pollution Control Boards and Municipal Corporation). The ambient suspended particulate matter data in the form of SPM Maps, Reports, literature have also been collected during the survey

3.3 PLANT SAMPLE COLLECTION

The leaf samples from the available plants species were collected twice in two-year project duration, one during summer and other during the winter, to assess the dust capturing capacity of plants during worst & calm periods of season.

3.4 MORPHOMETRIC MEASUREMENT OF PLANT SPECIES

1. The dominant and most commonly available plant species have been identified at each site and leaf samples have been collected in triplicate from each site and each plant. Leaf samples were also simultaneously collected to assess the maximum dust capture based on deposited SPM level., for identification purpose & Herbarium and for Anatomical studies.

2. Morphometric measurements of leaf area by graphic method as well as with leaf area meter were undertaken to assess dust capture area available.

3. Controlled development of plant species in nursery and exposure at identified heavy dust particulate sites.

4. Relative assessment of level of Suspended Particulate matter and relative dust capture by plant species (Herbs/ Shrubs) during the exposure period using Dust Fall Jar as per IS : 5182 : 1969.

5. The Plant height was measured with the help of Sextant and the Average Crown Area occupied by mature plant was computed. The following method was followed for calculation of Crown Area of Plants as described in “A Text Book of Surveying & Leveling For Engineering Students and Practicing Engineers” Part -1 by Kanetkar & Kulkarni.

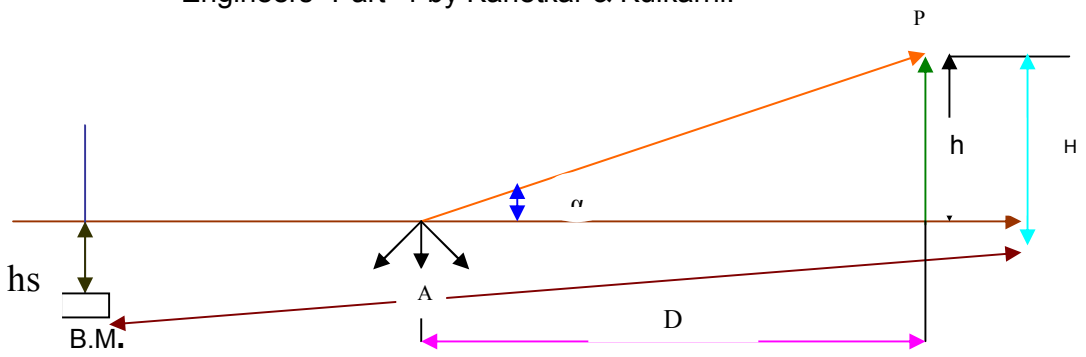


Fig. 3.1 : Crown Area calculation of Plant Species

When Base of the object is accessible, the distance from instrument (Sextant) to the base of the Tree can be measured or obtained by calculation e.g. Top of the Tree as presented in Fig. 3.1

Notations:

H	height of the object above the bench mark (B.M.)
h	height of the object above the instrument axis
hs	staff reading on the bench mark
α	vertical angle observed at the Sextant station
D	distance in meter measured from instrument station to the base of the tree

Then

$$h = D \tan \alpha$$

$$H = D \tan \alpha + h1$$

And R.L. of the tree = R.L. of Bench Mark (BM) + H
= R.L. of B.M. + D tan α + h

When the distance D is large the correction for curvature and refraction viz;

$$\{ 0.0673 \left(\frac{D}{1000}\right)^2 \}$$ may be applied

Therefore R.L. of the object = R.L. of B.M. + D tan α + h

$$+ 0.0673 \left(\frac{D}{1000}\right) 2$$

The method was used for the determination of Plant height. Total diameter of tree crown at the base was also measured. This diameter and plant height was used for the calculation of crown area considering the crown of the tree as conical in shape as:

$$\pi (D/2) l$$

Where, D is the diameter of the crown at base
l is the slanting crown length.

This has been calculated with the help of plant height and crown base.

3.5 LEAF AREA MEASUREMENT

Leaf Area was measured using Graphical Method as well as with Leaf Area Measurement Meter, LI-COr Model No.3000 was used.

Graphical Method

The typical leaf sample outline was drawn on a Graph and the Numbers of square were counted in cm^2 to obtain the leaf area.

LI-Cor Meter

The Leaf area meter i-or odel no 3000, was calibrated by a given standard Plate of definite size. After calibration of instrument the leaf was passed through the photocell. The Leaf area passes through the photocell was recorded by the digital counter.

3.6 IDENTIFICATION OF MAJOR DUST ARRESTING PLANT INDICATOR SPECIES

The identification of the plant species was undertaken at respective sites, which have very high natural capacity to capture particulates from ambient air near Thermal Power Stations, Coal Mines, Lime Kilns/Cement Factory and at metropolitan cities with high automobile movement because of their morphological and anatomical features.

The identification of plants were undertaken with the help of Literature, Monographs & Taxonomical Books. Botanical Survey of India, Regional office, Dehradun assisted for the identification of some species. The "Pictorial Guide to Plants" by Ramesh K. Aima (2003) was also consulted for identification of plant species.The experimental studies for two different environmental conditions were conducted in order to determine dust retention capacity of plant species. On the basis of field observations 20 number of plant species consisting of Herb, Shrubs & Trees were developed in Earthen Pots either by Seeds, Cutting or Plantlets. On the starting date of experiment the plant heights were recorded. Two high dust producing sites were selected for these experiments - One in vicinity of Stone Crusher & otherin vicinity of Thermal Power Station at Haridwar.

Dust fall jars were also installed at these experimental sites, as per standard procedures & major Species of Plants were exposed adjacent. The Plants were washed before exposure. The weekly observations on Dust deposition in Dust Fall Jar & on plant leaves were recorded without changing any environmental conditions. Dust Quantity on Dust Fall Jars & Leaf was measured along with the Leaf Area Measured Graphically as well as with Leaf Area Meter. The dust retention capacity was calculated.

On the basis of compiled information uring the period of study, indexing of dust resistant species of plants have been identified, which will also help in Air Quality Assessment in the region.

3.7 EXPERIMENTAL ANATOMICAL STUDIES

To understand the dust capturing factors, anatomical studies were also undertaken. The Transverse Section of leaf of major species of plants were cut down, Stained and compared the Structure of Leaf Surface & Stomata. The method as detailed in "A Text Book of Practical Botany II" by Ashok Bendre & Ashok Kumar 7th Edition 2003-2004, Rastogi Publication was adopted. Following steps were followed for leaf section anatomical studies:

- Soft, thin and small leaf was placed in pith either by piercing a hole with a needle or by splitting it longitudinally with a blade. The piths used include potato tubers, carrot and radish roots etc.

- A razor has been held keeping the handle and the blade of the razor at right angles to one another. The handle has been kept free while the index finger is placed on the hooked end of the razor; 1st, 2nd and 3rd fingers pressed against the thick back edge of the razor and thumb against the milled surface of the thick shank of blade.

- The embedded leaf material in pith was held between the thumb and the fingers of the left hand. The material in the left hand and the razor's edge kept at right angle.

- The razor was moved quickly over the material and the stroke is completed in one action only.

- More and more uniform strokes were used till the desired quality and numbers of sections were obtained. Care was taken to keep the material and the razor flooded with water.

- Sections float in water on the razor's edge. These were carefully lifted by a fine camel hair brush and then transferred to a watch glass containing water. The sections which float on water in the watch glass were considered to be thin.

- The leaf sections were lifted by hair brush, placed on a slide in a drop of water and observed through microscope. A thin and uniform leaf section was selected for detailed anatomical observations under the microscope.

3.8 DATA INTERPRETATION AND FINDINGS

The findings obtained during the study were technically interpreted and compared with the standards wherever applicable. On the basis of various findings, Low, Medium & High Dust Capturing plant species have been identified and recommended.

The repeated visual observations, quantitative analysis of dust deposits on Herbs, Shrubs & Trees plant species have been undertaken during the present studies. The percentage efficiency of dust capture of plant species have been calculated as below

$$\text{Percentage of Dust Capture} = \frac{\text{Crown Area of Plant Species}}{\text{Quantity of Dust Deposits on Canopy Area of Plant}} \times 100$$

The plant species have been classified based on percentage dust capture into three frequency classes:

Low	-	< 10% dust capture
Medium	-	11 – 20% dust capture
High	-	> 21 % dust capture

CHAPTER – IV

SUSPENDED PARTICULATE MATTER IN AMBIENT AIR AT STUDIED LOCATIONS

Particulate Matter is recognized as solids or liquids that are distributed in ambient air. The term particulate refers to the particles, dust, mist, fumes and smoke that become airborne in surrounding air. Based on the generation mechanism, the air borne particles can be categorized into two broad categories.

a. Dispersion Originated

The particulate originated from wind generated movement in nature as well as man made or from the breakdown from liquid or solid bulk materials, i.e. by grinding, atomization, natural dispersion, wind erosion etc.

b. Condensation Originated

Build up from molecular dimension after heating and cooling.

Dust (Dispersion Originated)

Dust is produced by subdivision of solid material through mechanical actions or in nature. Anthropogenic emissions are generated during grinding or milling of materials, during transfer of finely divided material as well as from agriculture, forestry and construction activities. The larger the particle diameter, they tend to settle faster. The rate of settling also depends on density and shape of particles. Particles larger than 50 µm settle rapidly.

Fumes (Condensation Originated)

Produced from hot solid substances by vaporization and condensation usually industrial process originated, combustion originated or from metallurgical processes.

Mist (Dispersion & Condensation Originated)

Generated from liquid by mechanical actions, evaporation and/or condensation of vapors generated from Industrial processes, spraying, electroplating etc.

Smoke

Smoke is formed of very fine solid and liquid particles generated from purging of carbonaceous material and recognized as serious health hazard.

The behaviour of particles in air is dependent on their physical and chemical properties. The particles have several physico-chemical proportion viz, mass, size, volume, settling velocity, chemical aerodynamic and optical properties, which are important for their role in atmospheric process. Their life span in atmosphere may vary from few seconds to several months. The size, density and shape of the particles are of prime importance because; these factors influence not only their cleansing rate from environment but also their penetration and deposition in respiratory system. The harmful effects, if any, of the particles therefore depend on their chemical and mineralogical composition, solubility and biological activity.

Particle size is regarded as the most important physical characteristic of air borne particulate matter, which control the residence time of particle in ambient air. The emitted particles have certain falling velocity (depending on size of the particle) due to downward force of gravity, which is opposed by aerodynamic drag of atmosphere. The balance between these forces is readily attained and the particle remains suspended in air for long time. The size of particulate matter can vary from 0.002 µm to 500 µm and particles larger than 50 µm can be seen with unaided eyes.

The particles in the 0.005 – 0.05 µm range are produced either by high temperature combustion or by chemical process or by condensation of vapor. Particles in 0.005 – 2.0 µm range are usually formed by coagulation of smaller particles or from particles through vapor condensation. Coarse particles are formed due to mechanical process, such a grinding, wind action, soil erosion and also agglomeration of smaller particles.

The particles having falling speed less than about $3x10^{-3}$ m/s, which is equivalent to that of about 7µm diameter are susceptible to be penetrated into human respiratory system, while the particles with aerodynamic diameter above 10 µm do not usually penetrate beyond the nasal passage, while particles above 50 µm could not be breathed with low suction pressure generated at mouth and nose during action of breathing, therefore do not pose much health hazard and also settles faster in the form of dry deposited matter or dust.

The solubility of particulate matter in aqueous media or in lipids is of great biological significance because it influences the rate of depositing in the body. The chemical composition of particulate matter has direct bearing on the resulting health effect and is generally related with the process from which it is derived. Particulate matter may be classified according to their size as detailed ahead:

Suspended Particulate Matter (SPM)

SPM are the particulate having particle diameter less than 100 µm that tend to remain suspended in the atmosphere for a long period of time. Sea salt, soil dust, volcanic particles and smoke from forest fires are the natural sources of total suspended particulate. Anthropogenic emissions of the total suspended particulates are from fossil fuel burning and industrial processes. Secondary sources of total suspended particulates include conversion of various gaseous substances like H_2S, SO_2, NO_x, NH_3 and hydrocarbons. Hydrocarbons react to form products that condense to form particles at atmospheric temperatures. The atmospheric suspended particulate affect the environment by lowering the visibility, producing hazy condition, participating in secondary reactions in atmosphere and affecting biotic population directly or indirectly.

Respirable Suspended Particulate Matter (RSPM-PM_{10})

Respirable Suspended Particulate matter or PM_{10} are the particulates having diameter less than 10 µm and they are small enough to be inhaled and may enter deep into respiratory tract and pulmonary system of human beings. These particles are responsible for most of the airborne particle threat to human health because of their small size range and pose health hazard due to their inhalation and deep penetration in respiratory system during breathing. The fine particulates generally arise due to agglomeration of aerosols, gas particles, conversion from gas to particles and these are mostly combustion originated. The sources of PM_{10} include road dust, wind blown dust, agriculture, construction and fireplaces. PM_{10} may also be formed from incomplete combustion of any fuel and from other pollutants viz. SO_x, NO_x , Organic etc.

Fine Particulate Matter (RSPM - $PM_{2.5}$)

Fine Particulate Matter or $PM_{2.5}$ is the aerosols having diameter less than 2.5 µm. Particle in the 0.005 – 0.05 µm ranges are usually formed by condensation of vapors produced either by high temperature or by chemical processes. Particles in the 0.05 – 2 µm range are usually formed by coagulation of smaller particles or from smaller particles through vapor condensation. The fine particulates are small enough to bypass the screening of the nose and can penetrate alveoli and get deposited in the upper respiratory tract. $PM_{2.5}$ are emitted from fuel combustion in motor vehicles, process combustion and from industrial sources; residential and agricultural burning. $PM_{2.5}$ is also formed from reactions of other pollutants.

The residence time, which is the average time for which the particulate remains in the atmosphere before settling on surfaces is several days for primary particulate matter. Smaller particles are removed from atmosphere by adhesion to water droplets, which grow in size until they are large enough to precipitate and settle. Larger particles are removed by dry deposition or by direct washout by falling raindrops or wet deposition.

STATUS OF SUSPENDED PARTICULATE MATTER

To assess the particulate problem at studied locations during the present studies the status of Suspended Particulate Matter was assessed through data collected from NAAQM Stations being operated by CPCB.

4.1 MUMBAI

The average level of Suspended Particulate Matter in ambient air at Mumbai during Summer & Winter is presented in Table 4.1:

Table 4.1: Status of Suspended Particulate Matter in ambient air at Mumbai

S. No	Sampling Station	Suspended Particulate Matter (SPM) , µg m^3													
		Summer							Winter						
		March		April		May		Ave.	Dec.		Jan.		Feb		Ave
		2002	2003	2002	2003	2002	2003		2002	2003	2002	2003	2002	2003	
1.	Sion Traffic Island - Hospital	80.74	327.12	97.80	433	83.12	-	204.36	134.07	140	159.97	97.35	200.0	92.29	137.28
2.	Muland Jhonson & Jhonson Factory	112.37	293	113.41	213	79.38	-	162.23	314.12	316.0	280.71	187	-	-	274.46
3.	Wadela Traffic Island	202	215	243	133	146	-	187.80	176	274	273	161	300	183	227.83
4.	Khar – Police Station	264	370	226		208	-	267.0	350	355	343	-	344	348	348.0
5.	Andheri – Ghokhela Bridge	420	403	428	238	408	-	379.40	323.0	325.0	582	300	306	335	361.83
6.	Mahim opposite Church	222	226	227	189	192	-	211.20	204	303.0	429	195	430	291	308.67
7.	Worli Dr. Annie Besent oad	220	367	158	160	113	-	203.60	209.0	212.0	311	237	307	256	255.33
8.	Parel Near Neorappa Municipal School	236	354	236	231	136	235	238.0	358	350	282	276	353	260	313.17
9.	Kalaba Devi – Central Mumbai	232	242	144	148	152	150	178.0	323	320	319	321	368	284	322.50

Table 4.2 : Average Distribution of SPM at different locations in Mumbai

S. No.	Sampling Stations	Average Suspended Particulate Matter ($\mu g/m^3$)	
		Summer	Winter
1.	Sion Traffic Island - Hospital	204	137
2.	Muland Jhonson & Jhonson Factory	162	274
3.	Wadela Traffic Island	187	227
4.	Khar – Police Station	267	348
5.	Andheri – Ghokhela Bridge	379	361
6.	Mahim Opposite Church	211	308
7.	Worli Dr. Annie Besant Road	203	255
8.	Parel Near Neorappa Municipal School	238	313
9.	Kalaba Devi – Central Mumbai	178	322

It is observed from the Table 4.2 and Fig 4.1 that the average Suspended Particulate matter ranged from 178 to 379 $\mu g/m^3$ during summer and 137 to 361 $\mu g/m^3$ during winter at Mumbai. The maximum SPM level was observed at Andheri while the Minimum during summer at Kalbadevi & during winter at Sion Chowk.

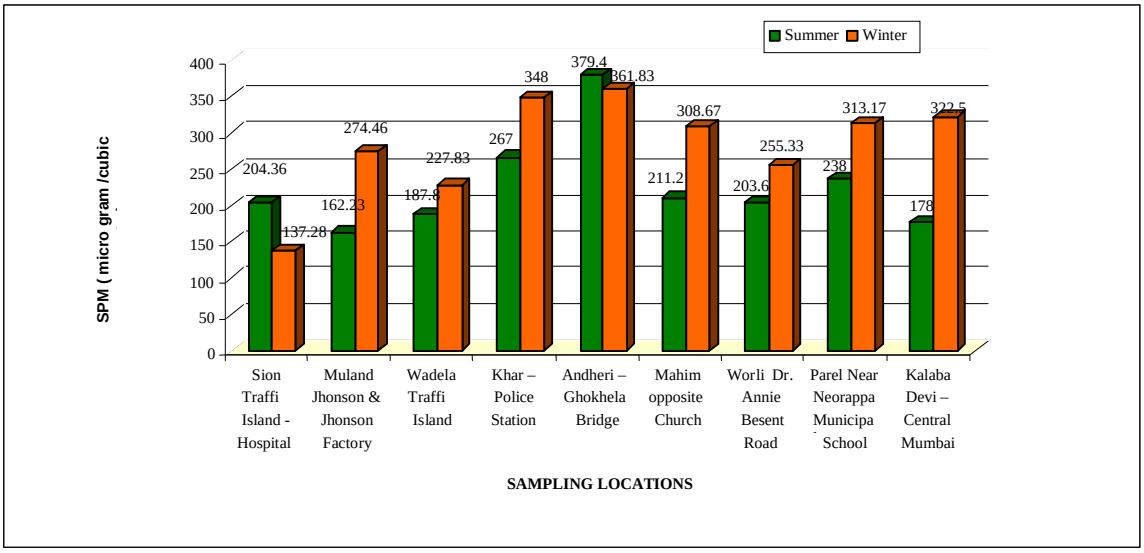


Fig. 4.1: Average Status of Suspended Particulate Matter at Mumbai During Summer & Winter

4.2 DELHI

The average level of Suspended Particulate Matter in ambient air at Delhi during Summer & Winter is presented in Table 4.3 and Fig. 4.2:

Table 4.3: Average Concentration of Suspended Particulate Matter at Delhi

Locations	Average SPM Concentration (microgram/m3)					
	Winter			Summer		
	Dec.02	Jan-03	Feb-03	Mar-03	Apr-03	May-03
Ashok Vihar (R)	724	376	344	336	-	495
Siri Fort (R)	583	290	208	300	291	457
Janakpuri (R)	-	-	-	210	221	-
Nizamuddin (R)	493	314	259	242	303	441
Shahzada Bagh (I)	777	318	306	236	284	529
Shahdara (I)	430	371	337	262	365	524
I.T.O. (Traffic Intersection)	706	543	479	479	598	711
Average	165	107	97	85	131	146

The average Suspended Particulate matter ranged from 97 to 164 µg/m^3 during winter and 85 to 146 µg/m^3 during Summer at Delhi. The maximum SPM level was observed at ITO during summer while the Minimum during winter at Sir Fort.

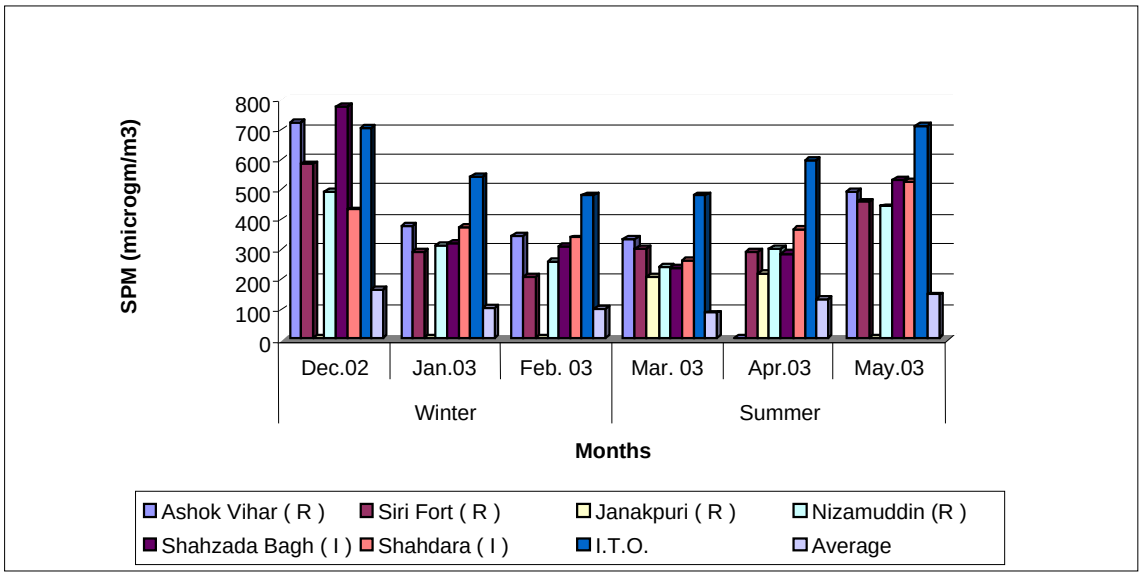


Fig. 4.2: Average Concentration of SPM at Delhi during Summer & Winter

Table 4.4: Average Status of Suspended Particulate Matter in Ambient air at Delhi During 2002 to 2004

Year 2002

PARAMETERS / LOCATIONS	Jun-02		Jul-02		Aug. 2002		Sep-02		Oct-02		Nov-02		Dec-02	
	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Ashok Vihar (R)	409	116	-	-	322	100	228	63	360	139	442	196	724	275
Siri Fort (R)	453	141	479	113	196	74	294	58	355	-	409	152	583	263
Janakpuri (R)	383	99	480	145	325	115	339	75	485	121	273	134	-	170
Nizamuddin (R)	296	108	409	126	156	87	183	82	334	153	345	171	493	232
Shahzada Bagh (I)	527	-	311	-	328	74	272	112	532	205	558	215	777	344
Shahdara (I)	-	-	964	299	234	67	257	83	399	149	379	151	430	203
I.T.O. (R)	441	205	598	276	309	161	332	165	521	249	642	316	706	335

Year 2003

PARAMETERS /LOCATIONS	Jan-03		Feb-03		Mar-03		Apr-03		May-03		Jun-03		Jul-03		Aug-03		Sep-03	
	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$	SPM	$PM_{2.5}$
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Ashok Vihar (R)	376	166	344	111	336	110	-	148	495	170	332	171	200	74	276	85	297	76
Siri Fort (R)	290	132	208	75	300	107	291	100	457	135	346	152	137	58	136	38	201	65
Janakpuri (R)	-	141	-	116	210	123	221	133	-	-	464	236	249	138	287	93	205	78
Nizamuddin (R)	314	170	259	164	242	123	303	115	441	149	423	179	144	64	180	53	215	74
Shahzada Bagh (I)	318	166	306	151	236	80	284	137	529	206	430	-	229	91	323	153	294	110
Shahdara (I)	371	169	337	101	262	104	365	125	524	172	399	130	273	118	233	101	186	53
I.T.O. (R)	543	274	479	191	479	191	598	256	711	380	587	307	299	159	352	156	364	139

2003 – 2004

PARAMETERS /LOCATIONS	Oct-03		Nov-03		Dec-03		Jan-04		Feb-04		Mar-04		Apr-04		May-04	
	SPM	PM25	SPM	PM25	SPM	PM25	SPM	PM25	SPM	PM25	SPM	PM25	SPM	PM25	SPM	PM25
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Ashok Vihar (R)	478	135	433	163	355	174	330	170	309	130	449	274	451	127	352	167
Siri Fort (R)	367	135	330	157	311	130	241	105	241	99	365	136	397	119	428	138
Janakpuri (R)	351	206	386	172	358	162	268	112	302	86	370	185	505	249	343	118
Nizamuddin (R)	446	116	436	133	355	159	294	127	241	96	336	133	472	142	508	230
Shahzada Bagh (I)	461	165	459	177	386	185	270	125	297	126	392	149	411	154	483	108
Shahdara (I)	408	138	496	233	-	141	324	161	290	138	376	130	424	134	507	165
I.T.O. (R)	574	325	571	288	526	255	501	266	461	252	463	186	565	210	629	190

4.3 KOLKATA

The average level of Suspended Particulate Matter in ambient air at Kolkata during Summer & Winter is presented at Table 4.5:

It is observed that the average Suspended Particulate matter ranged from 141 to 289 µg/m^3 during summer and 312 to 663 µg/m^3 during winter at Kolkota. The maximum SPM level was observed at Cassipore while the Minimum at Bator Table 4.6).

Table 4.5: Status of Suspended Particulate Matter in ambient air at Kolkata

S. No.	Sampling Station	Suspended Particulate Matter (SPM), µg m^3													
		Summer							Winter						
		March		April		May		Ave.	Dec.		Jan.		Feb		Ave
		2002	2003	2002	2003	2002	2003		2002	2003	2002	2003	2002	2003	
01	Lal Bazar (Dalhousi Square, Lal Bazar Police Station, Kolkata	397	275	236	232	255	199	268	676	396	367	612	368	431	**475**
02	Gariahat (NEERI Zonal Office, Kasba 1-8,Sector C, Kolkata	149	187	173	203	117	149	163	435	398	401	805	390	413	**473**
03	Cassipore (Cassipore Police Station,BT Road, Kolkata	379	344	268	258	313	169	289	689	434	851	789	614	599	**663**
04	Municipal Corporation Building	290	287	215	205	236	118	225	317	407	540	420	450	389	**421**
05	Bandhaghat Howrah	250	267	N.A.	N.A	90.0	92.0	175	275	363	325	352	300	323	**323**
06	Naskarpora (Ghuseri)														
07	Bator (Bhataur More	210	213	100	108	110	104	141	269	358	300	304	315	324	**312**
08	Ultadanga near Maniktala Fire Station Branch, Bagmari Road, Kolkata	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
09	Salt Lake Near CK Market, Salt Lake, Kolkata	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.6 : Distribution of SPM on different locations at Kolkata

S. No.	Sampling Locations	Average SPM (µg/m^3)	
		Summer	Winter
01	Lal Bazar (Dalhousi Square, Lal Bazar Police Station, Kolkata	268	475
02	Gariahat (NEERI Zonal Office, Kasba 1-8,Sector C, Kolkata	163	473
03	Cassipore (Cassipore Police Station, BT Road, Kolkata	289	663
04	Municipal Corporation Building	225	421
05	Bandhaghat Howrah	175	323
06	Naskarpora (Ghuseri)	NA	NA
07	Bator (Bhataur More)	141	312
08	Ultadanga near Maniktala Fire Station Branch, Bagmari Road, Kolkata	NA	NA
09	Salt Lake Near CK Market, Salt Lake, Kolkata	NA	NA

NA = Not Available

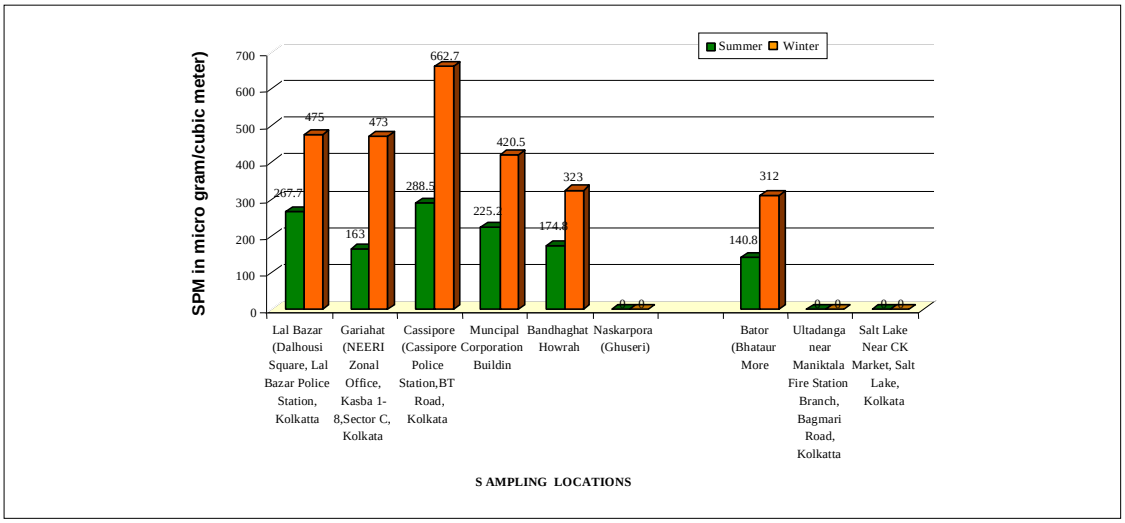


Fig. 4.3: Status of Suspended Particulate matter in Ambient Air during summer & winter at Kolkata

4.4 DHANBAD

The average level of Suspended Particulate Matter in ambient air at Dhanbad during Summer & Winter is presented in Table 4.7. The average Suspended Particulate matter ranged from 304 to 422 µg/m^3 during summer and 429 to 456 µg/m^3 during winter at Dhanbad. The maximum SPM level was observed at Sindri during winter while the Minimum was also observed at Sindri during summer.

Table 4.7: Status of Suspended Particulate Matter in ambient air at Dhanbad

S. No.	Sampling Station	SPM (µg/m^3)													
		Summer							Winter						
		March		April		May		Ave.	Dec.		Jan.		Feb		Ave
		2002	2003	2002	2003	2002	2003		2002	2003	2002	2003	2002	2003	
01	Jharia Coal Mine Area - NAAQM Station near RS College/ Water Tank)	590	440	422	511	294	273	**422**	404	433	546	526	524	664	**429**
02	Sindri Coal Mine Area - NAAQM Station at BIT, Sindri)	152	214	489	393	385	189	**304**	544	247	423	214	942	368	456

Table 4.8 : Distribution of SPM at different locations at Dhanbad

S. No.	SAMPLING STATION	SPM (µg/m^3)	
		Summer	Winter
01	Jharia Coal Mine Area - NAAQM Station near RS College/Water Tank)	422	429
02	Sindri Coal Mine Area - NAAQM Station at BIT, Sindri)	304	456

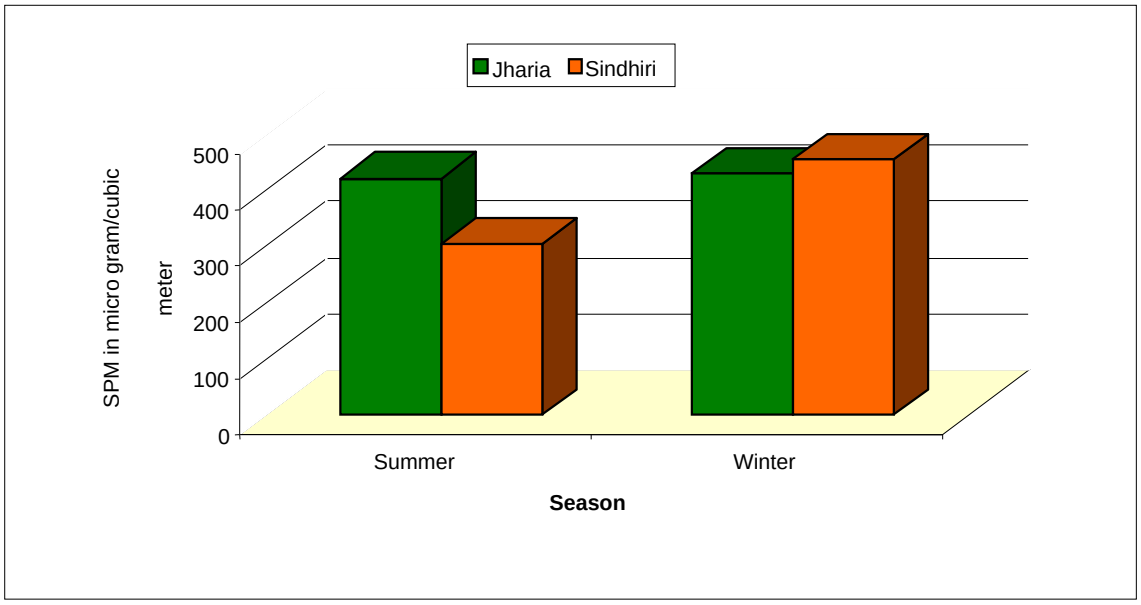


Fig. 4.4: Distribution of Suspended Particulate Matter in Ambient Air during Summer & Winter at Dhanbad

4.5 PAONTA SAHIB, HIMACHAL PRADESH

Ambient air quality of Paonta Sahib is being monitored continuously at two different locations, one at Paonta Sahib town and the other at industrial area Gondpur. Both these locations are classified as **Industrial Area**.

The status of SPM at Paonta Sahib at both the monitored locations (Table 4.9) indicate that air is comparatively poorer at Paonta Sahib Town in comparison to Gondpur because of more industrial and vehicular activities at Gondpur.

Table 4.9 : Status of Suspended Particulate Matter at Paonta Sahib

Month	Paonta Sahib Town (µg/m^3)	Gondpur (µg/m^3)
	Monthly Avg.	Monthly Avg.
April, 03	336	405
May, 03	389	570
June, 03	394	455
July, 03	171	280
August, 03	180	237
Sept., 03	1780	248
October, 03	285	318
Nov., 03	269	310
Dec., 03	352	326

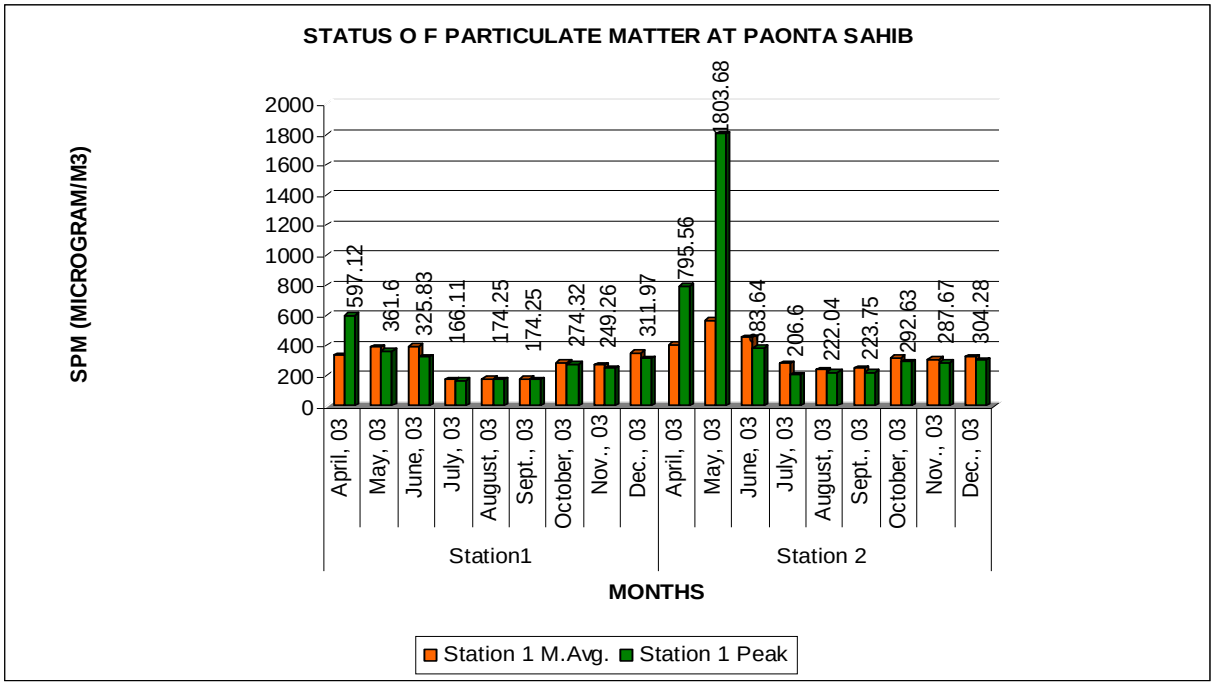


Fig. 4.5 : Status of Suspended Particulate Matter at Paonta Sahib

The average level of Suspended Particulate Matter in ambient air at Paonta Sahib during Summer & Winter is presented in Table 4.10. It is observed that the average Suspended Particulate matter ranged from 325 to 426 µg/m^3 during summer and 235 to 366 µg/m^3 during winter (Table 4.11). The maximum SPM level was observed 396 µg/m^3 during winter while minimum 235 µg/m^3 during summer.

Table 4.10 : Status of Suspended Particulate Matter in ambient air at Paonta Sahib

S. No.	Sampling Station	SPM (µg m^3)													
		Summer							Winter						
		March		April		May		Ave.	Dec.		Jan.		Feb		Ave
		2002	2003	2002	2003	2002	2003		2002	2003	2002	2003	2002	2003	
01	Gaundpur Industrial Area (Industry Office)	204	579	402	405	395	570	426	305	326	271	519	275	497	366
02	Around Cement Factory	206	581	404	407	396	571	427	306	327	272	518	276	498	366
03	High Traffic Zone Cum Residential Area	198	327	287	336	315	389	325	211	352	226	179	187	255	235

Table 4.11 : Distribution of SPM on different locations at Paonta sahib

S. No.	OF Sampling Locations	Average SPM (µg/m^3)	
		Summer	Winter
01	Gaundpur Industrial Area (Industry Office)	426	366
02	Around Cement Factory	427	366
03	High Traffic Zone Cum Residential Area	325	235

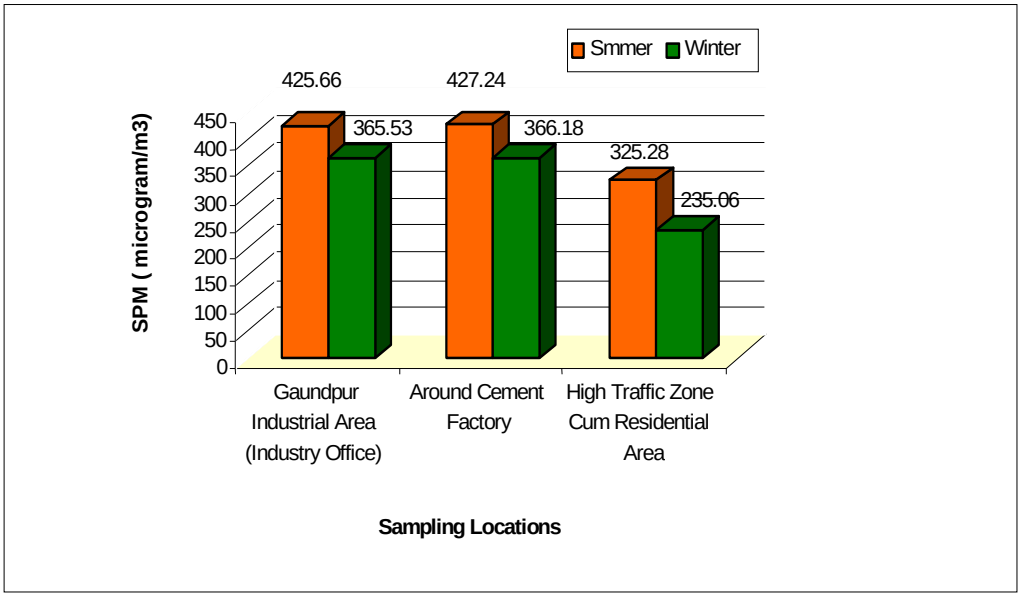


Fig. 4.6 : Average Distribution of SPM on different locations at Paonta Sahib

4.5 HARIDWAR

The average level of Suspended Particulate Matter in ambient air at Hardwar during Summer & Winter is presented in Table 4.12. The average Suspended Particulate matter ranged from 198 to 255 µg/m^3 with an average of 228 µg/m^3 during summer and 165 to 276 µg/m^3 with an average of 221 µg/m^3 during winter at Stone Crusher Site at Hardwar.

The average Suspended Particulate matter ranged from 290 to 320 µg/m^3 with an average of 305 µg/m^3 during summer and 259 to 294 µg/m^3 with an average of 232 µg/m^3 during winter at Thermal Power Station Site at Hardwar.

The average maximum SPM level was observed as 305 µg/m^3 during summer at TPS, Hardwar while Minimum 221 µg/m^3 at Stone Crusher site at Haridwar during winter.

Table 4.12 : Status of Suspended Particulate Matter in ambient air at Haridwar

S. No.	Sampling Station	SPM (µg m^3)													
		Summer							Winter						
		March		April		May		Ave.	Dec.		Jan.		Feb		Ave
		2002	2003	2002	2003	2002	2003		2002	2003	2002	2003	2002	2003	
01	Stone Crusher site	198	229	213	236	234	255	**228**	276	269	165	173	209	236	**221**
02	Thermal Power Station	290	295	300	315	320	310	**305**	275	270	259	294	265	280	**232**

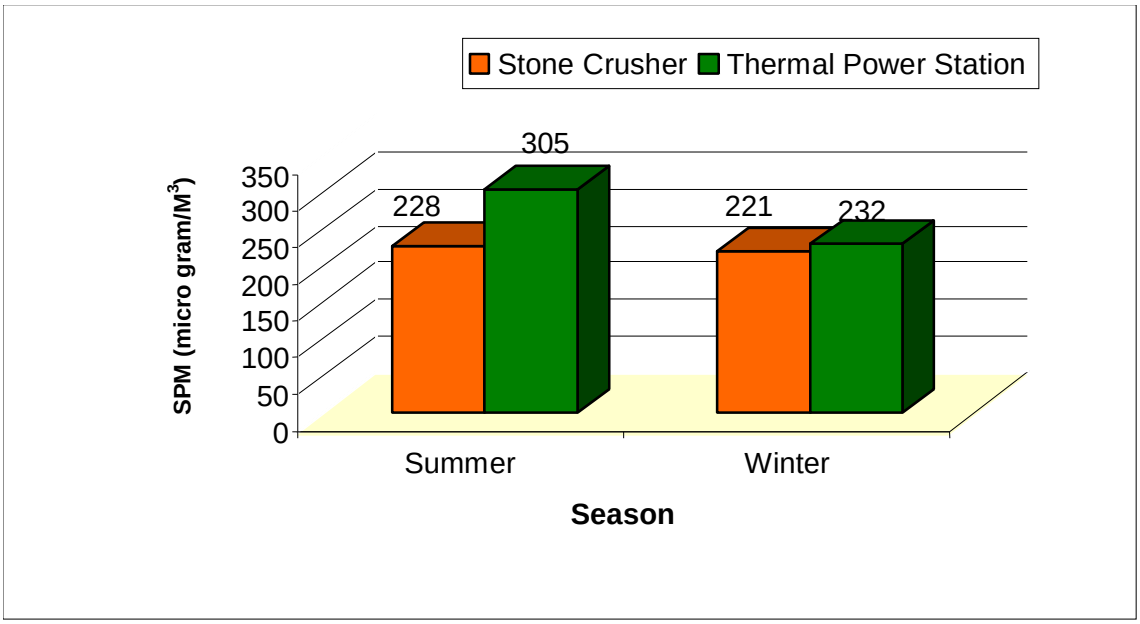


Fig. 4.7 : Average Status of Suspended Particulate Matter in Ambient Air at Haridwar

4.7 OVERVIEW OF STATUS OF SUSPENDED PARTICULATE MATTER AT SELECTED SITES

The observations indicated that the SPM levels at Delhi, Kolkata & Dhanbad in residential areas are in critical level (>210 µg/m^3) whereas in Industrial area it is Moderate to High level (70 to 210 µg/m^3). The increased adoption of pollution control technology in industries the SPM values in industrial areas are keeping up to moderate to high and do not reach up to critical levels but in the residential areas as there are no particulate emission control. The SPM level thus building up to the critical level.

The Green Belt constituting high Dust capturing plant species may be the option for control of particulate matter in environment around residential areas/ industrial area, since Trees can act as efficient biological filters, cost effectively removing significant amounts of particulate pollution from urban atmosphere.

CHAPTER – V

DUST CAPTURING EFFICENCY OF PLANT SPECIES AT URBAN AREAS

The particulate matter discharged to ambient environment is agglomerated to large particles scavenged from environment and tend to deposit on surfaces, ground or other objects. The rate of deposition depends on various factors viz; size of particulates, behavior patterns, wind movement etc. In calm atmosphere the deposition of particles increases as the force acting on particles to keep these particles float, reduces and due to gravitational pull they are deposited on the surfaces. At roadside vegetation the deposition of particles are more on leaves as they spread horizontally while other part of plant grows vertically, therefore deposition is less or negligible. Further the quantum of deposition on plants also depends on the nature of plant leaves, their surface texture, availability of moisture and latex, hairy projections etc.

The residence time, which is the average time for which the particulates remain in the atmosphere before settling on the earth surface, is several days for primary particulate matter. Smaller particles are removed from atmosphere by adhesion to plant leaves because of transpiration moisture. Larger particles are removed by dry deposition or by direct washout by falling raindrops or wet deposition.

The Bad air or dusty conditions at most common locations can be improved by increasing the plants density in urban areas, which may act as natural air filters. Urban forestry has brought attention to air pollution remedies since trees and other plants directly absorb carbon dioxide in their life-dependent process, photosynthesis. By taking in carbon dioxide and converting it to oxygen during photosynthesis, plants naturally remove excess carbon from air. Through photosynthesis and evapotranspiration, air is filtered through the plant, cleaned, cooled and released back into the atmosphere. During photosynthesis, plants also remove other air pollutants from the atmosphere, such as nitrogen oxides, airborne ammonia, some sulphur dioxide, and ozone, which are part of the smog and greenhouse effect problems. Some plant species have higher potential of dust capturing from environment by nature and because of their morphological features, while sustaining their well being. Thus, the dust capturing efficiency varies from plants to plants.

5.1 DUST CAPTURING EFFICIENCY OF PLANT SPECIES DURING SUMMER & WINTER AT MUMBAI

Mumbai is located on the western seacoast of India at 18º53’ N to 19º16’ N latitude and 72ºE to 72º59’E longitude. It occupies an area of 437 km^2. Mumbai experiences tropical savanna climate, it receives heavy southwest monsoon rainfall, measuring 2073.5 mm in the year. On an average, the temperature ranges from 17ºC to 35ºC with marginal difference between summer and winter months, whereas relative humidity ranges from 44% to 86%. Wind are generally moderate, but increase in force during monsoon months. Maximum wind speed recorded was 16.1 kmph in July and minimum was 6.6 kmph in December**.**

Air pollution index comprising three pollutants namely SO_2, NO_2 and SPM ranges from 22% to 160% for ambient air monitoring sites selected for the present studies. The maximum air polluted site at Mumbai is Khar. Andheri traffic junction is highly polluted with respect to SO_2, RSPM & CO while other traffic junctions are polluted with respect to NO_2, RSPM & CO.

The following locations were surveyed for plant species to assess their dust capturing efficiency.

Table 5.1: Sampling locations at Mumbai

S. No.	Sampling Site	Air Quality Monitored by
1.	Sion Traffic Island near Hospital	Maharashtra State Pollution Control Board
2.	Muland Traffic Island at Johnson & Johnson Factory	
3.	Wadela Traffic Island	Municipal Corporation Mumbai
4.	Khar Traffic Island near Police Station	
5.	Andheri Traffic Island at Ghokhela Bridge	
6.	Mahim Traffic Island Opposite Church	
7.	Worli Traffic Island at Dr. Annie Besent Road	NEERI, Zonal Office - Mumbai
8.	Parel Traffic Island Near Neorappa Municipal School	
9.	Kalaba Devi Market Area – Central Mumbai	

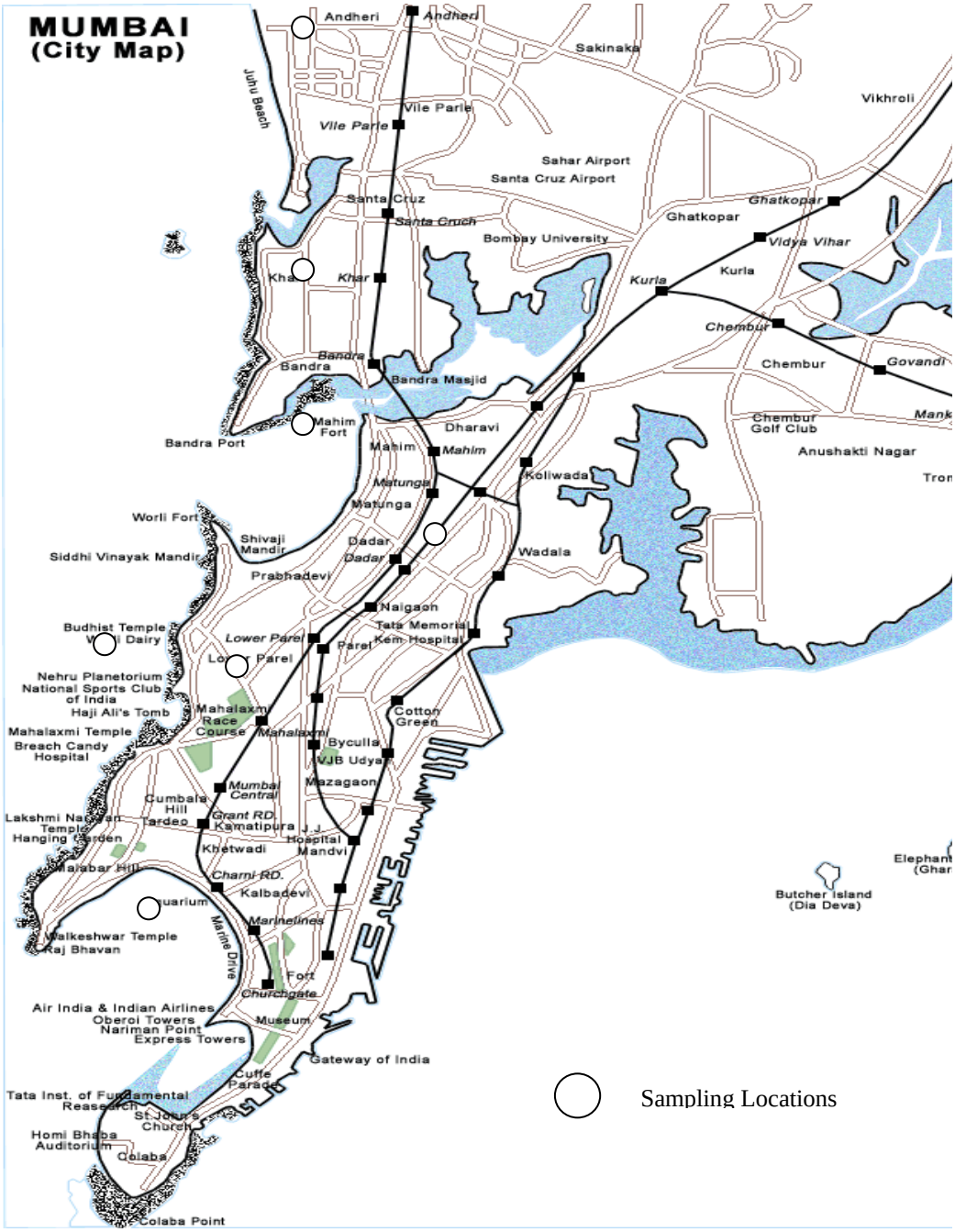


Fig. 5.1: Sampling Locations at Mumbai City

5.1.1 Plant Species Surveyed at Mumbai

The detailed survey of plant species was undertaken at all the sites selected at Mumbai. Based on the Survey the plant species were identified and prominent plant species observed are depicted in Table 5.2.

Table 5.2: Common Plants Species Observed at Mumbai

S. No.	COMMON NAME	PLANT SPECIES	FAMILY
		HERBS	
1.	Elephant's Ear	*Colocasia argentea*	Araceae
2.	Money plant	*Pothus aureus*	Araceae
3.	Dracaena	*Dracaena*	Liliaceae
		SHRUBS	
4.	Yellow Kaner	*Thevetia peruviana*	Apocyanacea
5.	Temple Tree	*Plumaria acuminata*	Apocyanaceae
6.	Chandani	*Tabernaemontana divaricata*	Apocyanaceae
7.	Bougainvallia	*Bouganvillia glavra*	Nyctaginaceae
8.	Acanthus	*Acanthus species*	Acanthaceae
9.	Pink Kaner	*Nerium indicum*	Apocyanceae
10.	Gurhal	*Hibiscus rosa sinensis*	Malvaceae
11.	Crape Myrtle	*Lagerstroemia indica*	Lythraceae
12.	Croton	*Codium variegatus*	Euphorbiaceae
		TREES	
13.	Harsingar	*Nyctanthese arbor tritis*	Oliaceae
14.	Kadam	*Anthosephalus cadamba*	Rubiaceae
15.	Ran Bhindi	*Thespesia populania*	Malvaceae
16.	Amaltas	*Cassia fistula*	Caesalpinaceae
17.	Plums	*Prunus comminis*	Rosaceae
18.	Jack Fruit	*Artocarpus integrifolia*	Moraceae
19.	Mulberry	*Morus alba*	Moraceae
20.	Chilgoja	*Pinus gerardiana*	Pinaceae
21.	Indian Rubber	*Ficus elastica*	Moraceae
22.	Custard apple	*Annona squamosa*	Annanaceae
23.	Jamun	*Syzygium cumini*	Myrtaceae
24.	Samal	*Bombax ceiba*	Bombaceae
25.	Ashoka	*Polyalthia longifolia*	Annoniaceae
26.	Gulmohar	*Delonix regiosa*	Caesalpinaceae
27.	Jangali Jalebi	*Pithocellobium dule*	Mimosacae
28.	Satni	*Alstonia scholaris*	Apocyanaceae
29.	Shesham	*Debergia sissoo*	Papilionaceae
30.	Blue gum	*Eucalyptus globulus*	Myrtaceae
31.	Banyan Tree	*Ficus bangalasis*	Moraceae
32.	Mango	*Magifera indica*	Ancardiaceae
33.	Glorry bower	*Clerodenrum inerme*	Verbinaceae
34.	Kanju, Papadi	*Holiptelia integrifolia*	Ulmaceae
35.	Amrood	*Psidium guava*	Myrtaceae
36.	Wolly Morning Glorry	*Argyreior roxburghira*	Convolvualaceae
37.	Vilayati Kikkar	*Acacia farnesiana*	Mimoseae
38.	Peepal	*Ficus religiosa*	Moraceae

5.1.2 Average Dust Capture by Leaves of Plant Species at Mumbai During Summer & Winter

The leaves sample of Plant species were collected at 0.25, 0.50, 0.75 & 1 km distances around East West North & South direction of Traffic island. The leaf area of each species with respect to quantity of dust captured was calculated. The results of Leaf Area & Quantity of Dust Captured during summer at Mumbai are presented in Table 5.3 and Fig. 5.2, while salient observations are as below:

- The average Dust capturing efficiency of Leaf ranged from 0.0010 gm/cm^2 to 0.5670 gm/cm^2 during summer and 0.008 gm/cm^2 to 0.5386 gm/cm^2 during winter at Mumbai

- Out of 39 Plant species observed, the minimum average dust capture of 0.001 & 0.0008 gm/cm^2 was observed in ***Delonix regiosa*** (Gulmohar) while the maximum average dust capture of 0.5670 & 0.5386 gm/cm^2 was observed in ***Ficus bengalensis*** (Banyan Tree).

- It has been observed that the minimum leaf area (1.87 cm^2) was of ***Delonix regiosa*** (Gulmohar), whereas the average maximum leaf area (266.77 cm^2) was of ***Ficus elastica*** (Indian Rubber).

- It was deduced that the Maximum Dust capturing leaf was of those plants which produce latex and were having moist leaf surface namely ***Ficus bengalensis, Ficus elastica, Thespesia populania, Ficus elastica, Artocarpus integrifolia, Mangifera indica, Anthocephalus cadamba, Argyreia roxburghiria*** & ***Morus alba.***

- The anatomical feature of leaves of high dust capturing plants ***Ficus bengalensis, Ficus elastica, Thespesia populania, Ficus elastica, Artocarpus integrifolia, Mangifera indica, Anthocephalus cadamba, Argyreia roxburghiria*** & ***Morus alba.*** indicated sunken stomata and are having hairy presence which helps in condensation of water vapors taking place during transpiration process. This helps in maintaining moisture condition on leaf surface and increases the capturing of dust by these plants.

- The other plants don't have such anatomical advantages and their dust capture efficiency is low. Some plant leaves have latex but not sunken stomata or having sunken stomata but no latex production. It is derived from the study that both the features are important for the dust capturing capacity of leaf / plant.

Table 5.3: Average Dust capture of Leaf of Plant Species at Mumbai during Summer & Winter

S. No.	Common Name	Botanical Name	Family	Average Dust Capture/ leaf gm/cm^2	
				Summer	Winter
01	Gulmohar	*Delonix regiosa*	Caesalpinaceae	0.0010	0.0008
02	Plums	*Prunus communis*	Rosaceae	0.0129	0.0129
03	Neem	*Azarddirachta indica*	Meliaceae	0.0368	0.0333
04	Vilayeti Kikar	*Acacia farnesiana*	Mimoseae	0.0065	0.0065
05	Jangal jalebi	*Pithecolobium dulce*	Mimosae	0.0083	0.0080
06	Crape Myrtle	*Lagerstroemia indica*	Lythraceae	0.0083	0.0086
07	Temple tree	*Plumaria rubraforma*	Apocyanaceae	0.0083	0.0090
08	Kaner (Pink)	*Nerium indicum*	Apocyanaceae	0.0094	0.0090
09	Kaner	*Thevetia peruviana*	Apocynaceae	0.0097	0.0090
10	Blue Gum	*Eucalyptus globules*	Myrtaceae	0.0239	0.0235
11	Shisham	*Delbergia sissoo*	Papilionaceae	0.0247	0.0239
12	SugarApple	*Annona squamosa*	Annanaceae	0.0220	0.0280

S. No.	Common Name	Botanical Name	Family	Average Dust Capture/ leaf gm/cm^2	
				Summer	Winter
13	Satni	*Alstonia scholaris*	Apocyanaceae	0.0250	0.0250
14	Ashoka	*Polyalthia longifolia*	Annoniaceae	0.0396	0.0287
15	Chandani	*Tabernaemontana divaricata*	Apocyanaceae	0.0350	0.0350
16	Gurhal	*Hibiscus rosa-sinensis*	Malvaceae	0.0349	0.0349
17	Papdi	*Holoptelia integrifolia*	Ulmaceae	0.0384	0.038
18	Chlogoja	*Pinus gerardiana*	Pinaceae	0.0435	0.0430
19	Elephant,s Ear	*Colocasia antiquorum*	Araceae	0.0483	0.0480
20	Croton	*Codium Variegatus*	Euphorbiaceae	0.1851	0.0429
21	Amaltas	*Cassia fistula*	Caesalpiniaceae	0.0435	0.05035
22	Har Singar	*Nyctanthes arbor tritis*	Oliaceae	0.0842	0.0843
23	Bougainvillea	*Bougainvillea glavra*	Nyctagenaceae	0.0723	0.0723
24	Acanthea	*Acanthea*	Acanthaceae	0.0081	0.0742
25	Semal	*Bombax ceiba*	Malvaceae	0.0830	0.0773
26	Amrood (Guava)	*Psidium guyava*	Myrtaceae	0.0809	0.0800
27	Glorry bower	*Clerodenrum inerme*	Verbenaceae	0.0520	0.0866
28	Jamun	*Syzium cumini*	Myrtaceae	0.0836	0.09
29	Money plant	*Pothos aureus*	Araceae	0.1115	0.1112
30	Dracaena	*Dracaena*	Liliaceae	0.6668	0.1246
31	Mulberry	*Morus alba*	Moraceae	0.1794	0.179
32	Wolly Morning Glory	*Argyreia roxburghiria*	Covolvulaceae	0.1998	0.199
33	Kathal	*Artocarpus integrifolia*	Moraceae	0.2802	0.2044
34	Mango	*Mangifera indica*	Ancardiaceae	0.2539	0.2538
35	Kadam	*Anthocephalus cadamba*	Rubiaceae	0.3443	0.3360
36	Peepal	*Ficus religiosa*	Moraceae	0.3236	0.3236
37	Ran Bhindi	*Thespesia populania*	Malvaceae	0.4139	0.4169
38	Indian Rubber Tree	*Ficus elastica*	Malvaceae	0.5293	0.5293
39	Banyan Tree	*Ficus bengalensis*	Moraceae	0.5670	0.5386

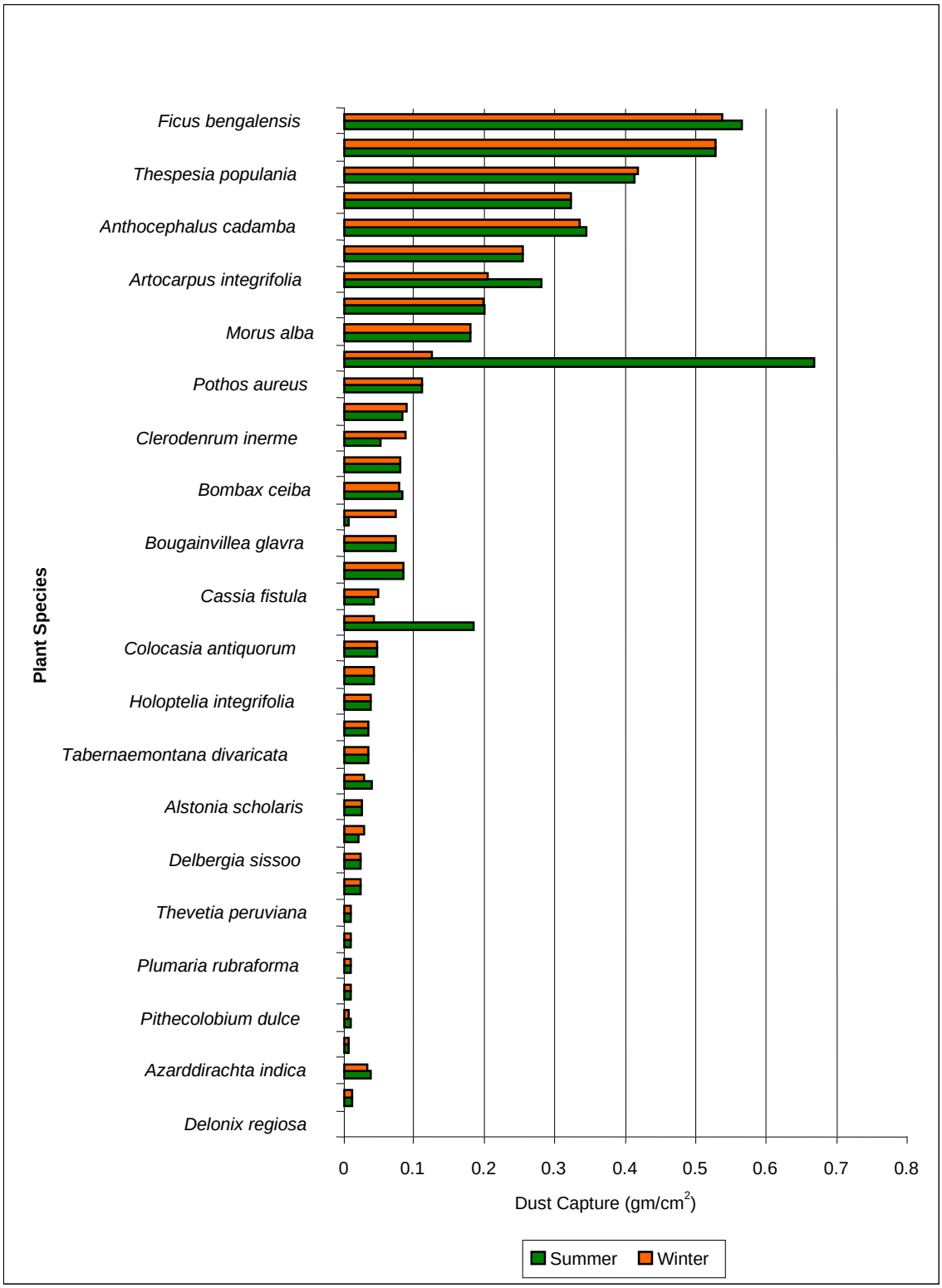


Fig. 5.2: Average Dust capture of Leaf of Plant Species during Summer & Winter at Mumbai

With respect to Canopy area (Crown Area of Plants), the Dust capturing efficiency of plant species were determined and following are the observations:

- The Maximum Dust capturing efficiency of Herb plants ranged between 4.02 gm/m^2 to 11.16 gm/m^2 with an average of 7.59 gm/m^2 to Minimum 0.30 to 0.35 gm/m^2 with an average of 0.325 gm/m^2. The maximum Dust capturing leaf of Herb is *Dracaena sp.* whereas the minimum dust capturing leaf of Herb is *Colocasia antiquorum*

- The Maximum Dust capturing efficiency of Shrub plants ranged from 9744.76 gm/m^2 to 16018.62 gm/m^2 with an average of 12881.69 gm/m^2 to Minimum 29.21 to 38.38 gm/m^{2,} with an average of 33.79 gm/m^2. The maximum Dust capturing leaf of Shrub is *Lagerstomia indica,* whereas the minimum dust capturing leaf of Shrub is *Thevetia peruviana.*

- The Maximum Dust capturing efficiency of Trees ranged from 11425.10 gm/m^2 to 10971.34 gm/m^2 with an average of 11198.22 gm/m^2 to Minimum 242.86 to 243.76 gm/m^2 with an average of 243.31 gm/m^2. The maximum Dust capturing leaf of Tree is *Acacia farnesiana* whereas the minimum dust capturing leaf of Tree is *Nyctanthese arvortritis*.

Table: 5.4: Average Dust Capturing Efficiency Based on Canopy Area of Plant Species at Mumbai

S. No.	Common Name	Plant Species	Family	Summer gm/m^2	Winter gm/m^2	Average (gm/area/m^2 per plant
HERBS						
1	Elephant's Ear	Colocasia antiquorum	Araceae	0.30	0.35	0.325
2	Money plant	Pthos aureus	Aracaceae	3.74	3.7	3.72
3	Dracaena	Dracaena	Liliaceae	11.16	4.02	7.59
SHRUBS						
4	Yellow Kaner	Thevetia peruviana	Apocyanacea	29.21	38.38	33.79
5	Temple Tree	Plumaria acuminata	Apocyanaceae	38.38	73.18	55.78
6	Chandani	Tabernaemontana divaricata	Apocyanaceae	69.32	116.43	92.88
7	Bougainvillea	Baganvillia glavra	Nyctaginaceae	116.43	326.1	221.27
8	Acanthea	Acanthus	Acanthaceae	263.6	263.6	263.6
9	Pink Kaner	Nerium indicum	Apocyanaceae	772.71	29.21	400.96
10	Gurhal	Hibiscus rosa sinensis	Malvaceae	4403.93	263.6	2333.77
11	Croton	Codium variegatus	Euphorbiaceae	16397.22	9352.35	12874.79
12	Crape Myrtle	Lagerstroemia indica	Lythraceae	9744.76	16018.62	12881.69
TREES						
13	Harsingar	Nyctanthese arbor tritis	Oliaceae	242.86	243.76	243.31
14	Plums	Prunus comminis	Rosaceae	252.49	254.45	253.47
15	Chilgoja	Pinus gerardiana	Pinaceae	848.26	848.26	848.26
16	Amaltas	Cassia fistula	Caesalpiniaceae	465.28	1308.77	887.025
17	Jack Fruit	Artocarpus integrifolia	Moraceae	806.44	1009.3	907.87
18	Neem	Azarddirachta indica	Meliaceae	1123.80	1003.85	1063.82

S. No.	Common Name	Plant Species	Family	Summer gm/m^2	Winter gm/m^2	Average (gm/area/m^2 per plant
19	Sugarapple	Annona squamosa	Annanaceae	1816.41	767.25	1291.83
20	Jamun	Syazygium cuminii	Myrtaceae	1981.67	1981.67	1981.67
21	Semal	Bombax ceiba	Bombaceae	2086.48	2086.48	2086.48
22	Ashoka	Polyalthia longifolia	Annoniaceae	2125.28	2125.28	2125.28
23	Shisham	Debergia sissoo	Papilionaceae	4403.93	263.6	2333.77
24	Ran Bhindi	Thespesia populania	Malvaceae	326.06	4436.71	2381.39
25	Jangal jalebi	Pithecolobium dulce	Mimoseae	2396.23	2450.52	2423.38
26	Indian Rubber	Ficus elastica	Moraceae	993.87	5288.53	3141.2
27	Satni	Alstonia scholaris	Apocyanaceae	3074	3381.4	3227.7
28	Wolly Moprning Glorry	Argyreia roxburghira	Convulvaceae	8069.18	706.38	4387.78
29	Mango	Magifera indica	Anacardiaceae	6768.13	2258.88	4513.51
30	Glorry bower	Clerodenrum inerme	Verbinaceae	7357.62	2049.22	4703.42
31	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	7357.62	2049.22	4703.42
32	Mulberry	Morus alba	Moraceae	828.41	7950.93	4389.67
33	Kadam	Anthosephalus cadamba	Rubiaceae	4888.72	4722.12	4805.42
34	Blue gum	Eucalyptus globulus	Myrtaceae	4971.27	4971.27	4971.27
35	Gulmohar	Delonix regiosa	Caesalpiniaceae	2172.64	8066	5119.32
36	Amrood	Psidium guyava	Myrtaceae	7989.17	8809.76	8399.47
37	Peepal	Ficus religiosa	Moraceae	15710.05	2026.99	8868.52
38	Banyan Tree	Ficus bengalensis	Moraceae	5286.51	12768.88	9027.69
39	Vilayati Kikkar	Acacia farnesiana	Mimoseae	11425.1	10971.34	11198.22

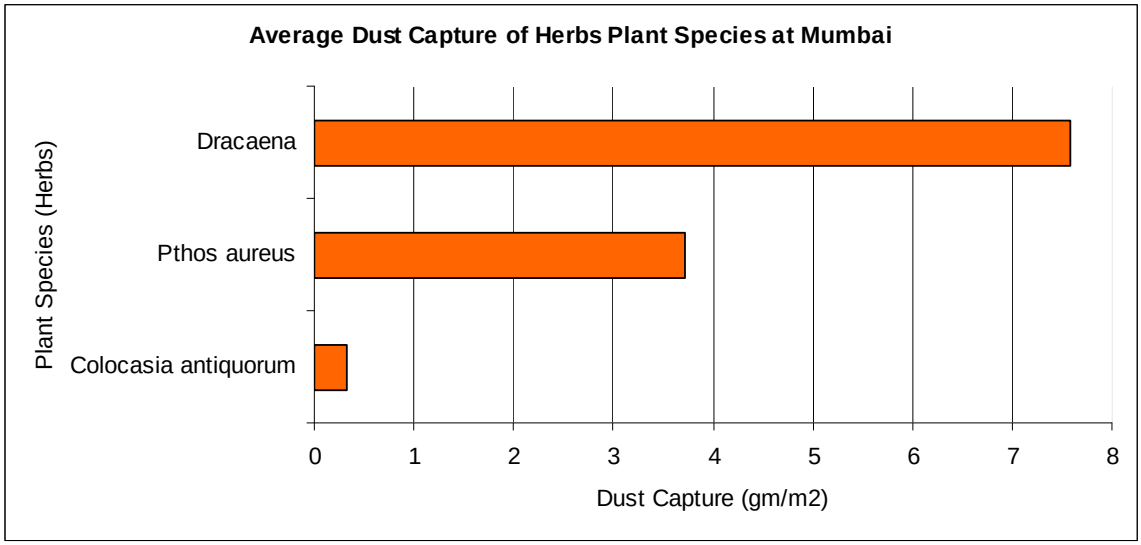


Fig. 5.3: Dust Capture Efficiency of Herbs Plant during Summer & Winter at Mumbai

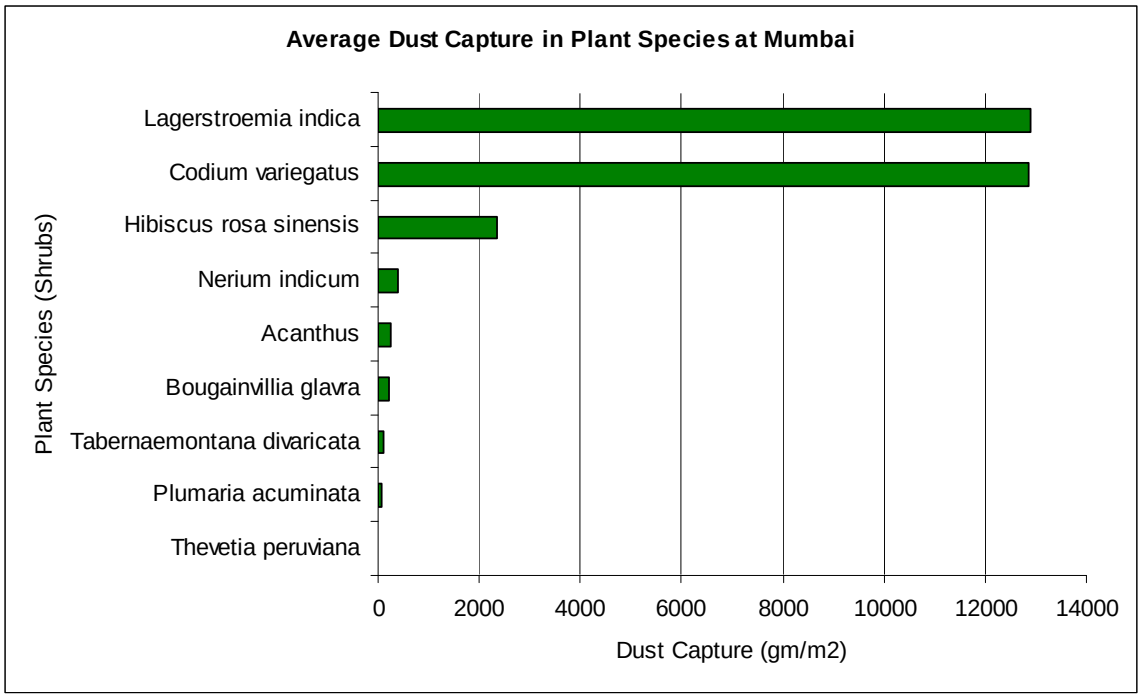


Fig. 5.4: Dust Capture Efficiency of Shrubs Plant during Summer & Winter at Mumbai

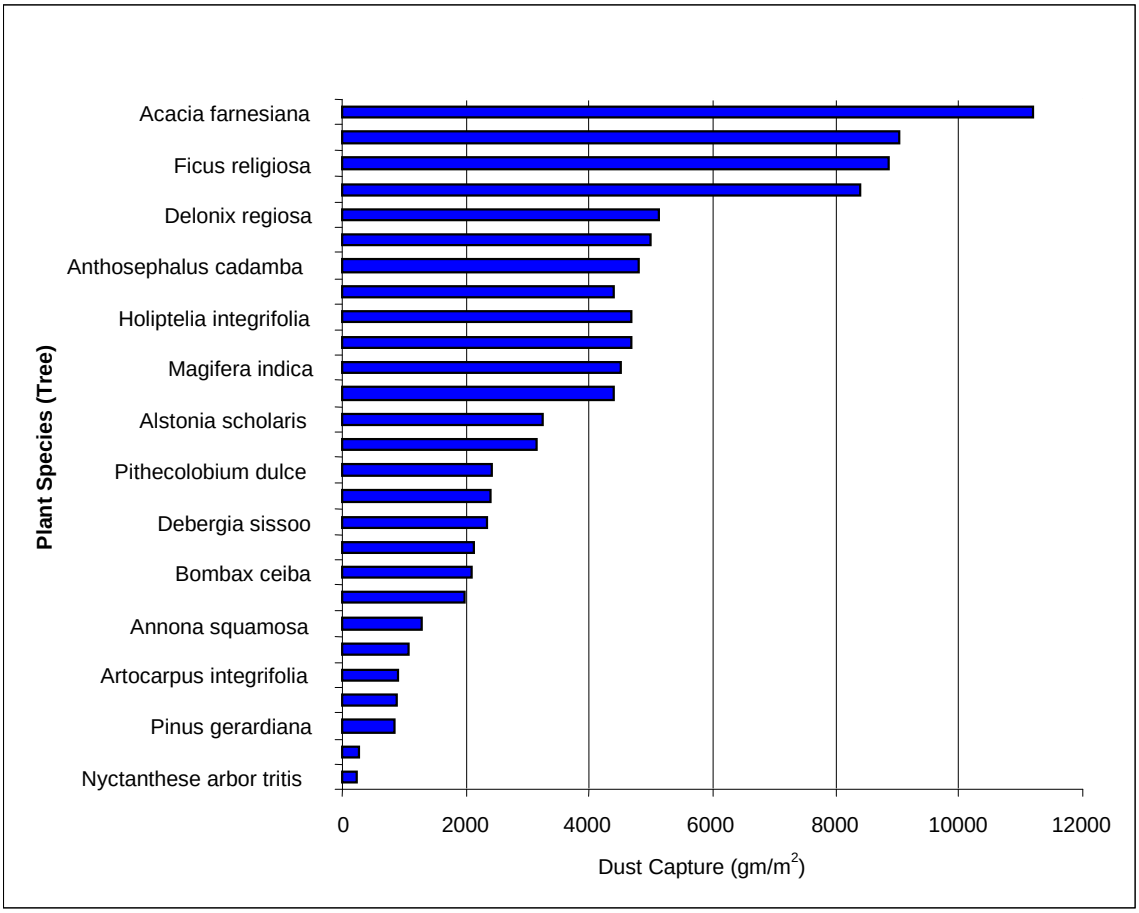


Fig. 5.5: Dust Capture Efficiency of Trees Plant during Summer & Winter at Mumbai

5.2 DUST CAPTURING EFFICIENCY OF PLANT SPECIES DURING SUMMER & WINTER AT NCT - DELHI

Delhi is situated almost in the center of Northern India and forms an enclave inside the Eastern frontiers of Haryana in North India. It is positioned with the Great Indian Desert (Thar Desert`) of Rajasthan to the west and southwest, central hot plains to the south and gangetic plains of Uttar Pradesh/Uttaranchal to the east while cooler hilly regions to the north. It is situated at latitude 28º24'17" and 28º53'00" North; Longitude 76º45'30" and 77º21'30" (East) at about 16 km South of Himalayas at an elevation of 216 m above the mean sea level (msl). Delhi is drained by river Yamuna, a major tributary of Ganges, which traverses through the Delhi metropolitan area entering from Northeast direction and flowing through Southeastern areas. The river Yamuna divides the geographical area of Delhi into smaller, trans-Yamuna area located in east and well developed cis-Yamuna area comprising Old Delhi.

The climate of Delhi region is typical type. The prevalence of continental air from nearby Rajasthan desert region leads to relatively dry conditions with extreme hot summers. The monsoon rains are recurring feature every year and typically extend from last week of June to September. The heavy rains during monsoon months act as "Scrubber" scavenging the atmosphere of air pollution loads. The winter seasons extend from November to January, during which the night temperature is substantially lower than day temperature, thus following diurnal weather cycle. During such cycle, ground based "Temperature Inversion" are regular feature. The air near the ground cools faster than at a height at few hundred meters above, due to low temperature in night creating temperature inversion (an increase in temperature with vertical height in atmosphere). Due to higher vertical temperatures, the emissions are in warmer surroundings and so begin to sink to ground level. The upward motion of the pollutant is restricted within the depth of inversion (mixing height) thrusting the ground level concentration to peak levels. The mixing height is recorded to lowest levels during peak winter months thus linking pollutant dispersion and dispersal.

The prevailing winds in Delhi region are North-West (NW), however during June and July, South-East winds predominate Wind speed is typically higher in summer and monsoon periods while in winter calms are frequent barring few days of moderate winds, due to higher wind speed coupled with low humidity and higher temperatures, dust storms are regular feature during pre-monsoon period. Moreover westerly wind from adjoining Great Indian Desert region of Rajasthan may also have influence of dust storms decreasing the visibility to minimum due to hazy atmosphere. Monthly mean normal temperature range from 14.3ºC in January (minimum 2ºC to 3ºC) to 34.5ºC in June (maximum 47ºC). The annual mean normal temperature is 25.3ºC (WMO, 1971). Delhi region experiences total annual rainfall between 700 mm to 800 mm. Maximum rainfall occurs during monsoon months (maximum in July, more than 200 mm).

Major air pollutant sources at Delhi are Transport (Airways, Railways & Vehicles), Industries (Major industrial units, Industrial estates & Medium industries), and Domestic (Domestic combustion units, Commercial combustion units & Smoking vis-à-vis air pollution.For the present study the, identification of sampling location has been done on the basis of High SPM levels at different traffic junction & residential areas based on prevalence of high to critical SPM levels.

The Ambient Air Quality is monitored by Central Pollution Control Board under National Ambient Air Quality Monitoring Programmme Based on the Ambient Air

Quality, the following 11 sites, covering the entire city (Fig. 5.6), were selected for the studies:

Table 5.5: Sampling Locations at Delhi

S. No.	Sampling Location
01	Traffic Island ITO
02	Traffic Island Dhaula Kuan
03	Traffic Island All India Institute of Medical Sciences (AIIMS)
04	Traffic Island Mohan Bagh
05	Traffic Island Raja Garden
06	Ashok Vihar Colony
07	Traffic Island Nizamuddin
08	Traffic Island Janakpuri
09	Sirifort
10	Traffic Island Shastri Nagar
11	Karkadduma Court Road Side & CPCB Office Shahdara

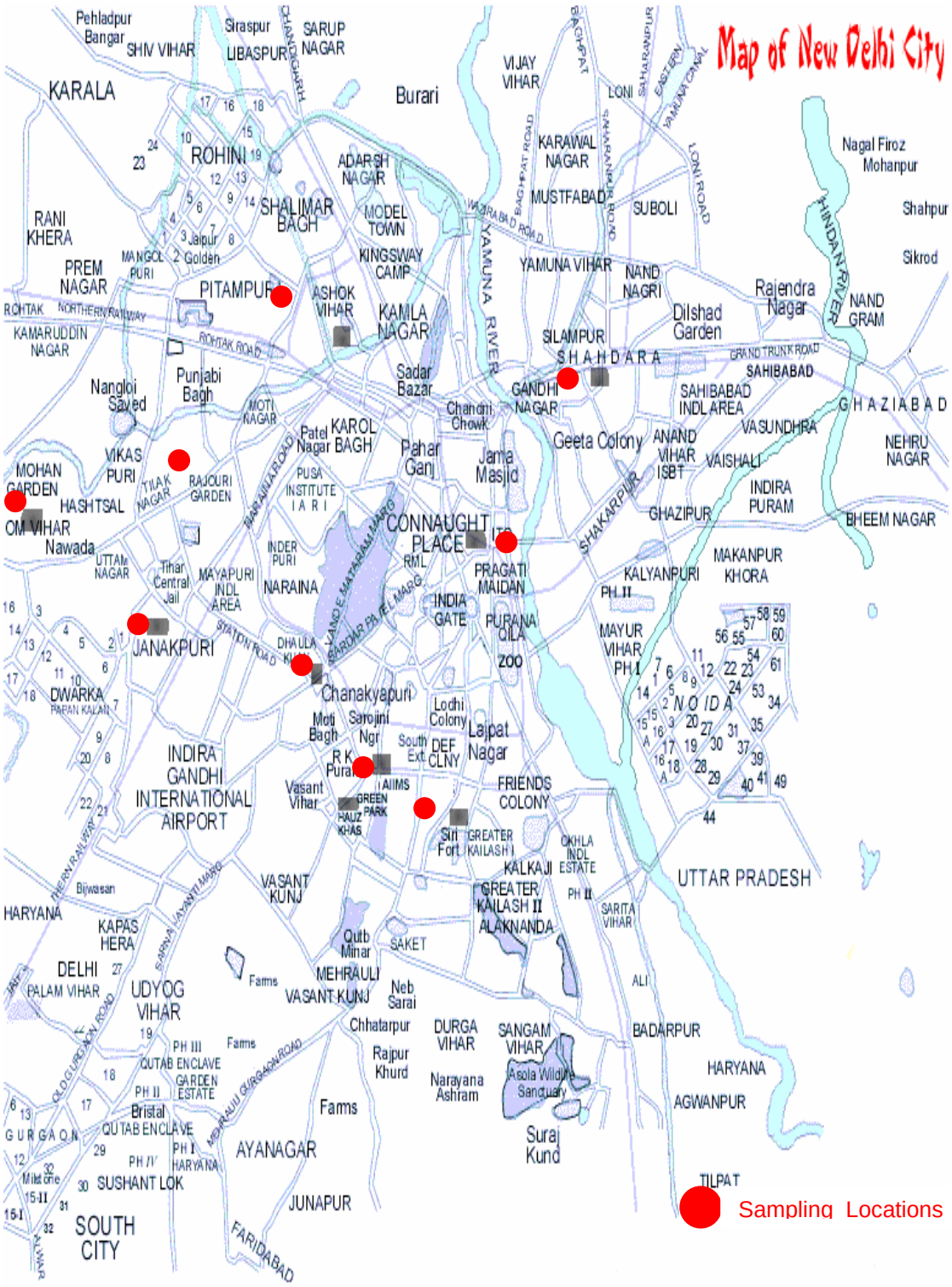


Fig. 5.6: Sampling Locations in NCT - Delhi

5.2.3 Plant Species and Dust capture by Leaf at NCT - Delhi during Summer & Winter

Initially survey of all the sites at Delhi was undertaken. Based on Survey the prominent plant species existing at Delhi have been identified. The leaves samples from these plants were collected for the study: The dominant species of plants encountered during the study are presented in Table 5.6

- The average Dust capturing efficiency of Leaf of Herb ranged from 0.0008 gm/cm^2 to 0. 0792 gm/cm^2 during summer and 0.002 gm/cm^2 to 0.0224 gm/cm^2 during winter at Delhi. The maximum Dust capturing leaf of Herb is *Jasminium sambac* whereas the minimum dust capturing leaf of Herb is Genda *Tagetes patula*.

- The average Dust capturing efficiency of Leaf of Shrub ranged from 0.0028 gm/cm^2 to 0. 0742 gm/cm^2 during summer and 0.035 gm/cm^2 to 0.1008 gm/cm^2 during winter at Delhi. The maxium Dust capturing leaf of Shrub is *Wrightia arboriea* whereas the minimum dust caputing leaf of Shrub is *Rosa indica*.

- The average Dust capturing efficiency of Leaf of Tree ranged from 0.0005 gm/cm^2 to 0.1768 gm/cm^2 during summer and 0.0006 gm/cm^2 to 0.2846 gm/cm^2 during winter at Delhi. The maximum Dust capturing leaf of Tree is *Ficus elastica* whereas the minimum dust capturing leaf of Tree is *Leacena leucophloea*.

Table 5.6: Average Dust capture of Leaf of Plant Species at NCT - Delhi during Summer & Winter

S. No.	Common Name	Botanical Name	Family	Average Dust Capture	
				Summer Dust (gm/cm^2)	Winter Dust (gm/cm^2)
HERBS					
1.	Genda	Tagetes patula	Asteraceae	0.0008	0.0002
2.	Sunflower	Helianthus annuus	Asteraceae	0.0083	0.0087
3.	Dracaena	Dracaena	Liliaceae	0.0513	0.0536
4.	Rat Ki Rani	Cestrum nocturnum	Solanaceae	0.0401	0.0474
5.	Elephant's Ear	Colocasia antiquorum	Araceae	0.0521	0.0559
6.	Crape jasmine	Jasminium sambac	Oliaceae	0.0792	0.0224
SHRUBS					
7.	Rose	Rosa indica	Rosaceae	0.0028	0.0053
8.	Gurhal	Hibiscus rosa sinensis	Malvaceae	0.0062	0.0052
9.	Bougainvillea	Baganvillia glavra	Nyctaginaceae	0.0113	0.0071
10.	Chandani	Tabernaemontana divaricata	Apocyanaceae	0.0267	0.0333
11.	Temple Tree	Plumaria acuminata	Apocyanaceae	0.0046	0.0065
12.	Yellow Kaner	Thevetia peruviana	Apocyanacea	0.0043	0.0062
13	Pink Kaner	Nerium indicum	Apocyanaceae	0.0091	0.0167
14	Dudhi	Wrightia arboriea	Apocyanceae	0.0742	0.1008
15	Crape Myrtle	Lagerstroemia indica	Lythraceae	0.003	0.0035
TREES					
16	Shoe Babool	Leacena leucophloea	Mimoseae	0.0005	0.0006
17	Gulmohar	Delonix regiosa	Caesalpiniaceae	0.0008	0.0003
18	Neem	Azardirachta indica	Meliaceae	0.0016	0.0027
19	Vilayati Kikkar	Acacia farnesiana	Mimoseae	0.0029	0.0023

S. No.	Common Name	Botanical Name	Family	Average Dust Capture	
				Summer Dust (gm/cm^2)	Winter Dust (gm/cm^2)
20	Bankayan	Melia azedarch	Meliaceae	0.0031	0.0027
21	Bottle Brush	Callistemon citrinus	Myrtaceae	0.0045	0.0026
22	Torch Tree	Ixora parviflora	Rubiaceae	0.005	0.0082
23	Chikkoo	Archise sapota	Sapotaceae	0.0053	0.0209
24	Arjun	Terminalia arjuna	Combrataceae	0.0056	0.0107
25	Babool	Accacia nelotica	Mimoseae	0.008	0.0003
26	Shesham	Delbergia sisso	Papilionaceae	0.0086	0.0139
27	Jangal Badam	Termanilia catappal	Combrataceae	0.0093	0.0503
28	Ashoka	Polyalthia longifolia	Annoniaceae	0.0098	0.0197
29	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	0.0124	0.0174
30	Amrood	Psidium guyava	Myrtaceae	0.0151	0.0216
31	Mahua	Madhuca indica	Sapotaceae	0.01787	0.0376
32	Mulberry	Morus alba	Moraceae	0.0197	0.0229
33	Semal	Bombax ceiba	Bombaceae	0.0217	0.0264
34	Popular	Populus trimuloides	Siliaceae	0.025	0.0155
35	Plums	Prunus comminis	Rosaceae	0.0257	0.0281
36	Lemon	Citrus lemon	Rutaceae	0.0278	0.0029
37	Kanchnar	Bauhinia variegata	Caesalpiniaceae	0.0278	0.0203
38	Bel	Aegle marmelos	Rubiaceae	0.0278	0.0174
39	Satni	Alstonia scholaris	Apocyanaceae	0.0444	0.045
40	Mango	Mangifera indica	Anacardiaceae	0.0449	0.1231
41	Blue gum	Eucalyptus globulus	Myrtaceae	0.0473	0.0114
42	Jamun	Syzygium cuminii	Myrtaceae	0.0481	0.0679
43	Peepal	Ficus religiosa	Moraceae	0.0688	0.022
44	Teak	Tectona grandis	Verbenaceae	0.0524	0.0532
45	Kadam	Anthosephalus cadamba	Rubiaceae	0.0529	0.0665
46	Wolly Moprning Glorry	Argyreia roxburghira	Convalvuleceae	0.0541	0.1209
47	Amaltas	Cassia fistula	Caesalpiniaceae	0.0916	0.08
48	Banyan Tree	Ficus bengalensis	Moraceae	0.1331	0.2846
49	Indian Rubber	Ficus elastica	Moraceae	0.1768	0.1768

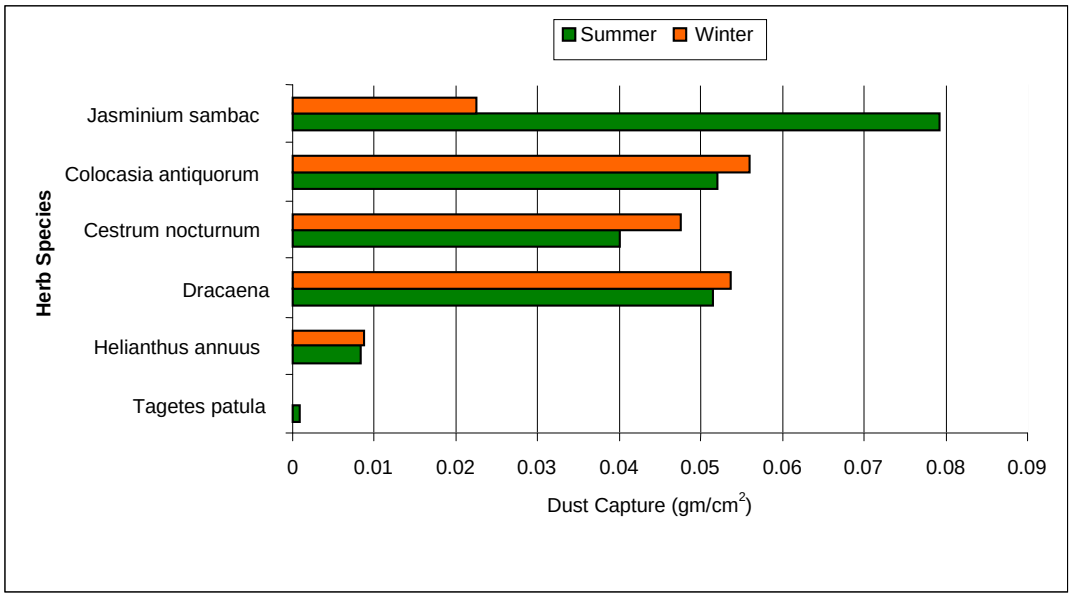


Fig. 5.7: Average Dust capture of Herbs Species during Summer & Winter at NCT - Delhi

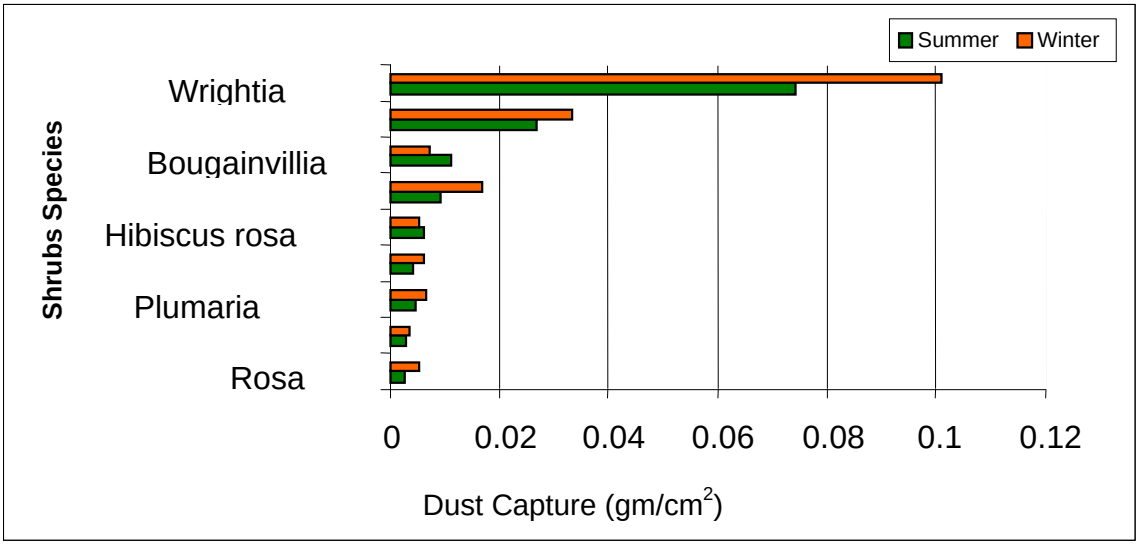


Fig. 5.8: Average Dust capture Efficiency of Shrubs Species during Summer & Winter at NCT - Delhi

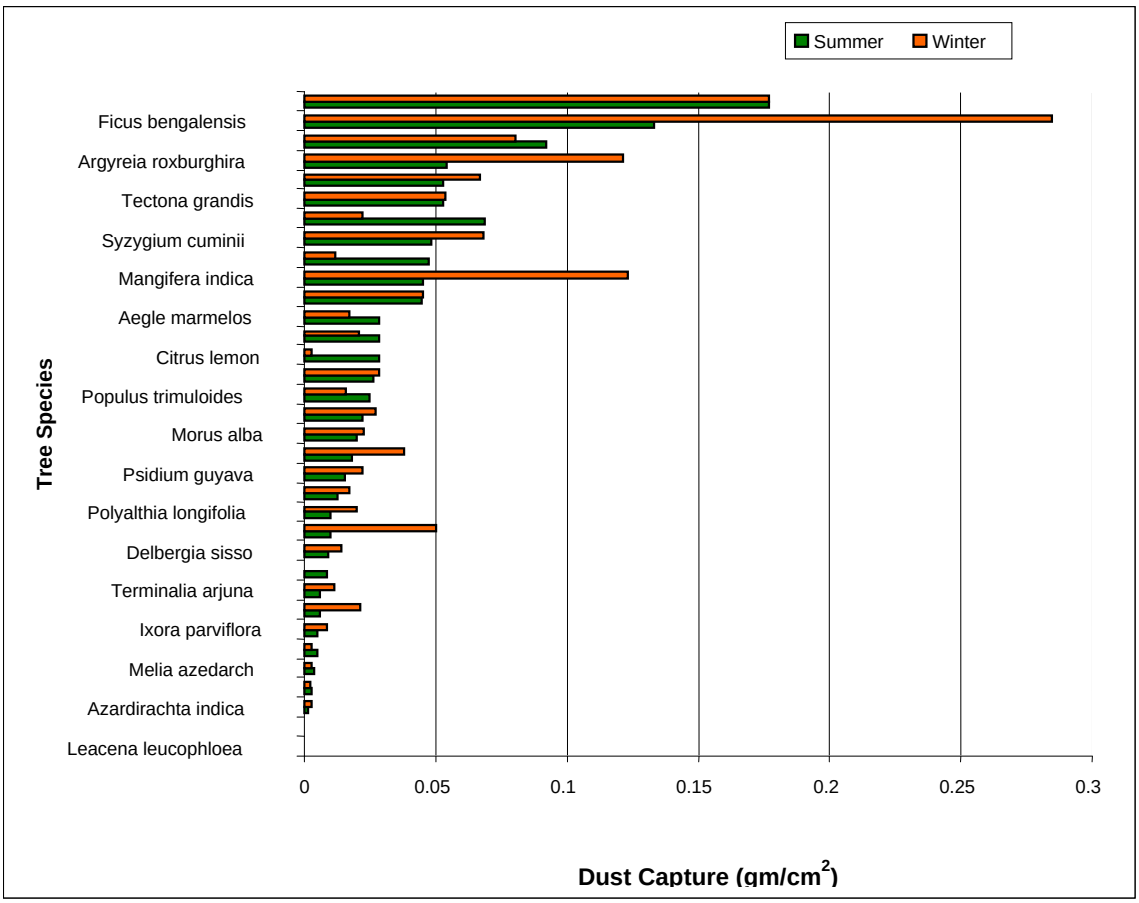


Fig. 5.9: Average Dust Capture Efficiency of Leaf of Trees Species during Summer & Winter at NCT - Delhi

The Dust capturing efficiency of plant species with respect to Canopy area (Crown Area of Plants) is detailed below:

- The Maximum Dust capturing efficiency of Herb ranged from 3.19 gm/m^2 to 9.7 gm/m^2 with an average of 6.445 gm/m^2 to Minimum 0.30 to 0.34gm/m^2 with an average of 0.32 gm/m^2 . The maximum Dust capturing leaf of Herb is *Jasminium sambac* whereas the minimum dust capturing leaf of Herb is *Colocasia antiquorum*.

- The Maximum Dust capturing efficiency of Shrub ranged from 257.91 gm/m^2 to 318.16 gm/m^2 with an average of 288.035 gm/m^2 to Minimum 2.32 to 2.68 gm/m^2 with an average of 2.5 gm/m^2. The maximum Dust capturing leaf of Shrub is *Wrightia arborea* whereas the minimum dust capturing leaf of Shrubs is *Rosa indica*.

- The Maximum Dust capturing efficiency of Tree ranged from 6087.54 gm/m^2 to 8201.54 gm/m^2 with an average of 7144.555 gm/m^2 to Minimum 32.32 to 110.32 gm/m^2 with an average of 71.32 gm/m^2. The maximum Dust capturing leaf of Tree is *Ficus bengalensis* whereas the minimum dust capturing leaf of Herb is *Azardirachta indica*.

Table 5.7: Dust Capture by Plants Species with respect to their Canopy area during Summer & Winter at Delhi

S. No.	Common Name	Botanical Name	Family	Average Dust Capture by Plant Canopy (gm.meter^2)		
				Summer	Winter	Average
HERBS						
1	Elephant's Ear	Colocasia antiquorum	Araceae	0.34	0.3	**0.32**
2	Genda	Tagetes patula	Asteraceae	1.93	0.51	**1.22**
3	Dracaena	Dracaena	Liliaceae	1.44	1.50	**1.47**
4	Sunflower	Helianthus annuus	Asteraceae	1.97	2.08	**2.03**
5	Rat Ki Rani	Cestrum nocturnum	Solanaceae	6.39	6.5	**6.45**
6	Crape jasmine	Jasminium sambac	Oliaceae	9.7	3.19	**6.45**
SHRUBS						
7	Rose	Rosa indica	Rosaceae	2.32	2.68	**2.50**
8	Chandani	Tabernaemontana divaricata	Apocyanaceae	13.84	17.10	**15.55**
9	Gurhal	Hibiscus rosa sinensis	Malvaceae	17.69	20.23	**18.96**
10	Yellow Kaner	Thevetia peruviana	Apocyanacea	18.79	22.59	**20.69**
11	Pink Kaner	Nerium indicum	Apocyanaceae	19.02	46.84	**32.93**
12	Temple Tree	Plumaria acuminata	Apocyanaceae	41.01	43.33	**42.17**
13	Bougainvillea	Baganvillia glavara	Nyctagenaceae	51.07	40.2	**45.64**
14	Crape Myrtle	Lagerstroemia indica	Lythraceae	49.69	44.48	**47.09**
15	Dudhi	Wrightia arboriea	Apocyanceae	318.16	257.91	**288.04**
TREES						
16	Neem	Azardirachta indica	Meliaceae	32.32	110.32	**71.32**
17	Plums	Prunus comminis	Rosaceae	85.87	109.69	**97.78**
18	Amrood	Psidium guyava	Myrtaceae	180.85	229.45	**205.15**
19	Jangal Badam	Termanilia catappal	Combrataceae	90.84	457.96	**274.40**
20	Popular	Populus	Siliaceae	294.09	345.05	**319.57**

S. No.	Common Name	Botanical Name	Family	Average Dust Capture by Plant Canopy (gm.meter^2)		
				Summer	Winter	Average
21	Mahua	Madhuka indica	Sapotaceae	237.04	447.46	**342.25**
22	Shoe Babool	Leacena leucophloea	Mimoseae	236.42	571.24	**403.83**
23	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	380.81	489.41	**435.11**
24	Ashoka	Polyalthia longifolia	Annoniaceae	505.21	426.95	**466.08**
25	Torch Tree	Ixora parviflora	Rubiaceae	449.6	542.48	**496.04**
26	Arjune	Terminalia arjuna	Combrataceae	435.68	593.12	**514.40**
27	Lamon	Citrus lamina	Rutaceae	1141.56	127.62	**634.59**
28	Kadam	Anthosephalus cadamba	Rubiaceae	645.58	691.73	**668.66**
29	Bottle Brush	Callistemon citrinus	Myrtaceae	1119.09	557.98	**838.54**
30	Teak	Tectona grandis	Verbenaceae	906.86	817.9	**862.38**
31	Gulmohar	Delonix regiosa	Caesalpiniaceae	750.92	1013.74	**882.33**
32	Shesham	Delbergia sisso	Papilionaceae	871.76	1018.13	**944.95**
33	Chikkoo	Archise sapota	Sapotaceae	428.67	1512	**970.34**
34	Mulberry	Morus alba	Moraceae	968.07	1050.33	**1009.20**
35	Vilayati Kikkar	Acacia farnesiana	Mimoseae	1229.34	804.37	**1016.86**
36	Beal	Aegle marmelos	Rubiaceae	1482.83	1156.14	**1319.49**
37	Jamun	Syzygium cuminii	Myrtaceae	1156.98	1520.24	**1338.61**
38	Kanchnar	Bauhinia variegata	Caesalpiniaceae	1419.77	1270.59	**1345.18**
39	Bankayan	Melia azedarch	Meliaceae	1803.25	1244.91	**1524.08**
40	Mango	Mangifera indica	Ancardiaceae	1275.63	2346.54	**1811.09**
41	Semal	Bombax ceiba	Bombaceae	1264.01	2384.72	**1824.37**
42	Peepal	Ficus religiosa	Moraceae	3176.21	1018.58	**2097.40**
43	Wolly Moprning Glorry	Argyreia roxburghira	Convulvaceae	1534.53	2733.88	**2134.21**
44	Amaltas	Cassia fistula	Caesalpiniaceae	2446.3	2084.5	**2265.40**
45	Satni	Alstonia scholaris	Apocyanaceae	2992.92	1823.51	**2408.22**
46	Babool	Accacia nelotica	Mimoseae	4176.47	1742.37	**2959.42**
47	Indian Rubber	Ficus elastica	Moraceae	4993.32	5321.67	**5157.50**
48	Blue gum	Eucalyptus globulus	Myrtaceae	8762.64	1668.13	**5215.39**
49	Banyan Tree	Ficus bengalensis	Moraceae	8201.54	6087.57	**7144.56**

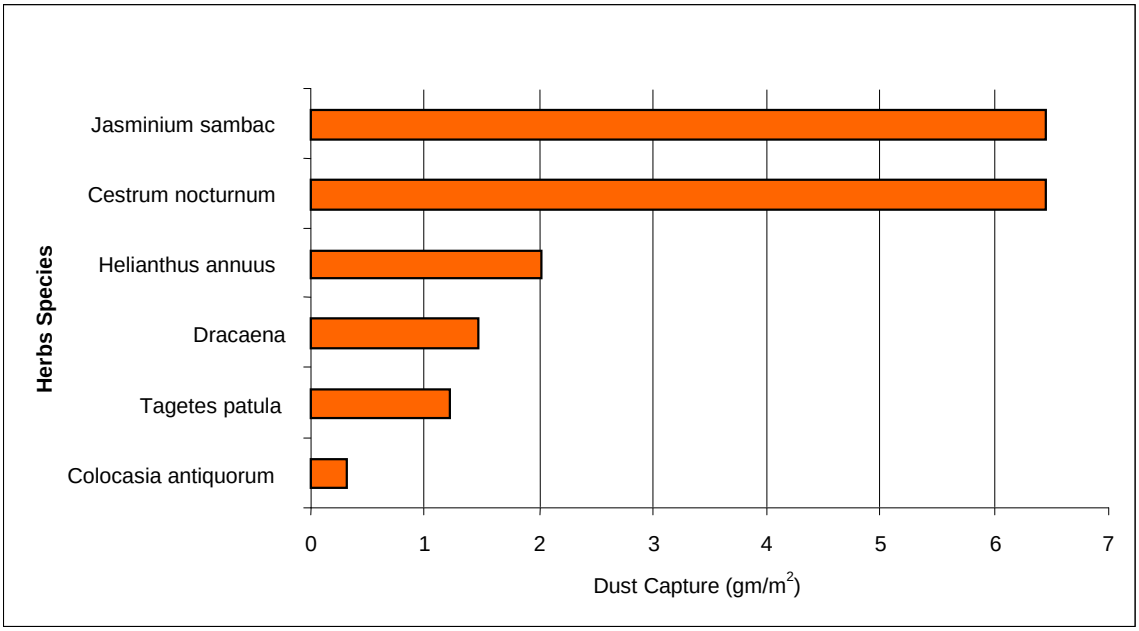


Fig. 5.10: Average Dust Capture Efficiency of Plants Canopy of Herbs at Delhi

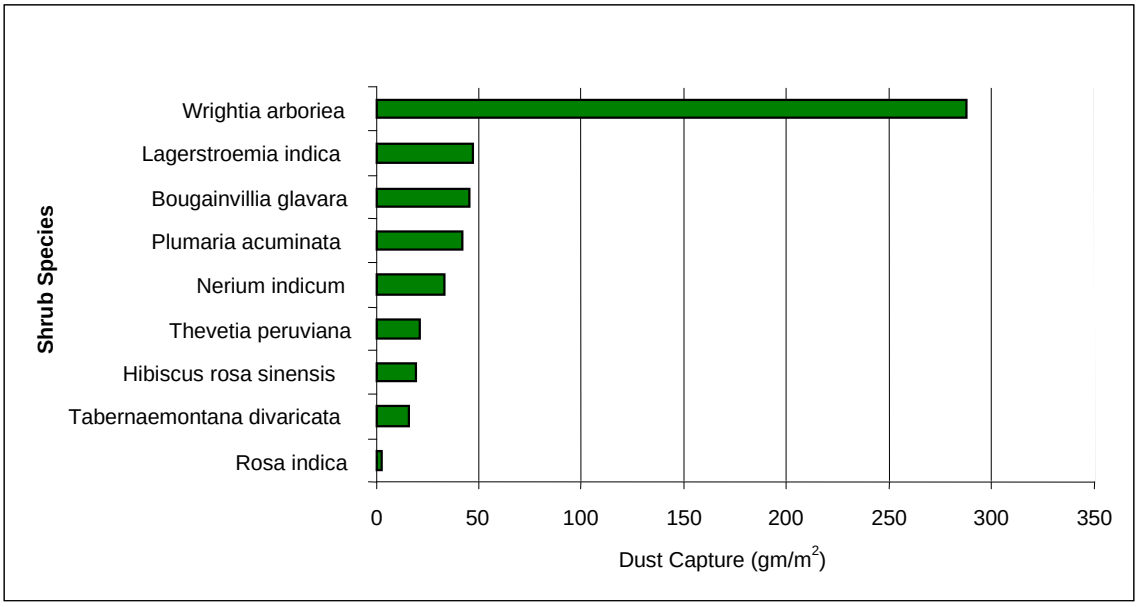


Fig. 5.11: Average Dust Capture Efficiency of Plant Canopy of Shrubs at Delhi

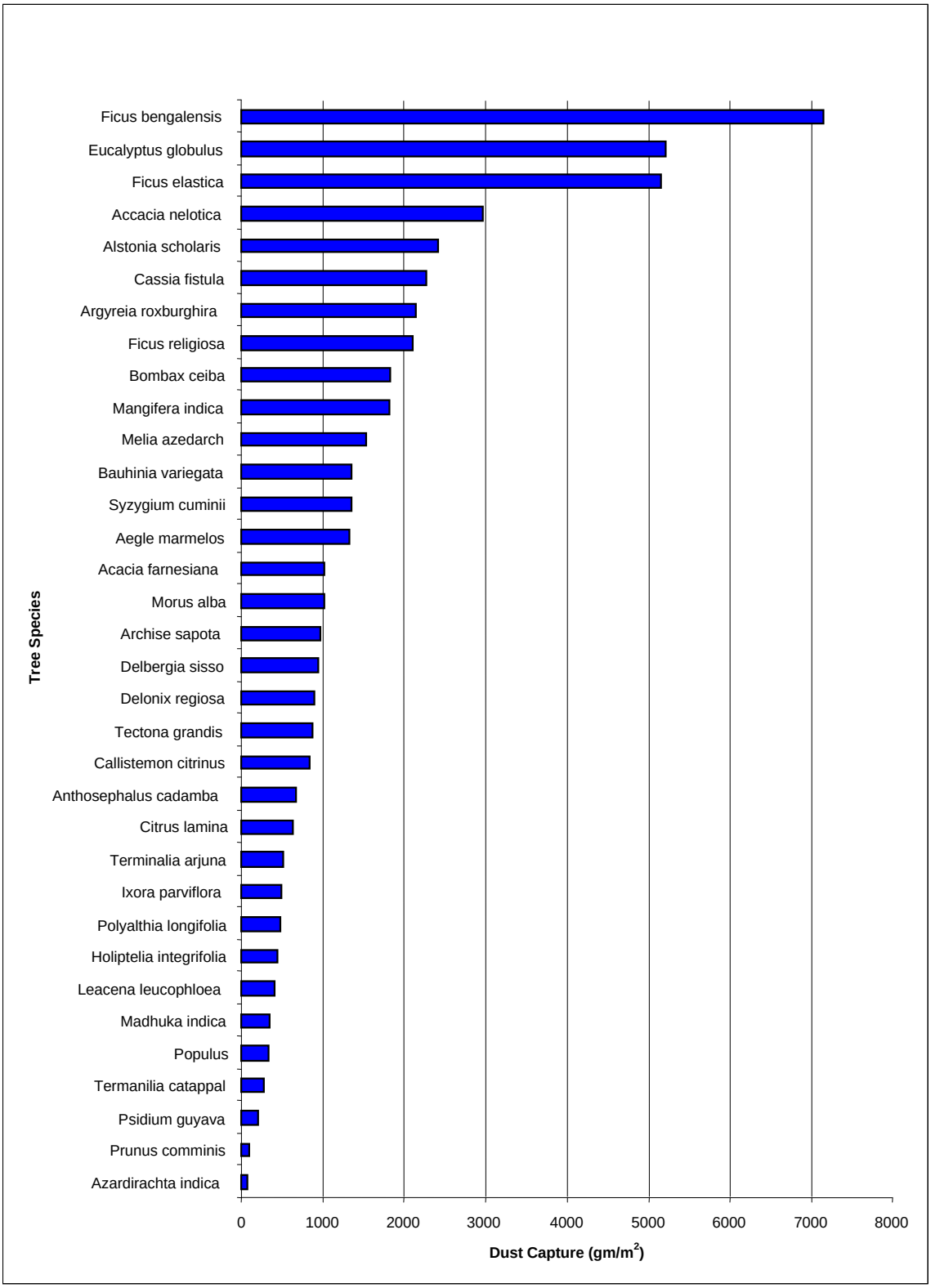


Fig. 5.12: Average Dust Capture Efficiency of Plant Canopy of Trees at Delhi

5.3 DUST CAPTURING EFFICIENCY OF PLANT SPECIES DURING SUMMER & WINTER AT KOLKATA

Kolkata and Howrah, the twin cities situated on the eastern and the western side of the river Hooghly, were established a few hundred years ago. Kolkata was initially the capital of the country during colonial period and later of Bengal. Due to the availability of infrastructural facility which included river fronts, a port and an abundance of water and raw materials for industrial activity such as coal, minerals, jute etc., industrial development took place predominantly in these two cities and in the fringe areas mostly by the side of the river. Whereas Howrah saw a tremendous growth in the industries such as iron foundries, hot rolling mills, metal finishing units etc, a number of thermal power stations and various process industries of different sizes started functioning in Kolkata. As most of these industries were built long before the environmental concern came to the forefront, they generated various forms of emissions in large quantities because of their outdated technology and absence of pollution abatement measures. After the introduction of pollution control legislation, most of these industries have been put on environmental compliance.

Industrial emissions in the city and its suburbs are caused by coal burning in thermal power plants and other industries. Besides, the emissions from rapidly increasing numbers of vehicles are also largely responsible for the high level of air pollution in the city atmosphere. Over the last decade the number of registered automobiles in Kolkata has increased by 52 percent. The effective road area available in Kolkata is less than 5 percent of the total area. In Howrah the pattern is similar or worse. Very high automobile density, disproportionately low percentage of road network, congestion and traffic jams, aging vehicles and unscientific traffic management are the major reasons for high emission of air pollutants. The geographical details & climatic conditions are as below:

Area
City: 102 sq. kms, Metropolitan Area: 1380 sq. km.

Population
City: 4.4 million (1991), Metropolitan Area: 12 million (1991),

Population Density 33000 / sq. km. (1991)

Altitude
About 6 meter above sea level

Topography
Built on flat sedimentary marshy land. The city is dotted with moist deciduous groves and tropical wetlands, most of which have been converted for fish farming.

Geographical Location
Latitude: 22^0 82' North and Longitude: 88^0 20' East

Kolkata is close to Tropic of Cancer and is on the banks of the Hugli River, a branch of the great river Ganges. The Bay of Bengal and the Sunderbans is about 80 -100 km from the city.

Climate
The city enjoys fairly stable, warm and humid climate throughout the year.

Average Temperature
Summer (April - July) 24-38 ^{0}C
Winter (Nov - Feb) 12-27 ^{0}C

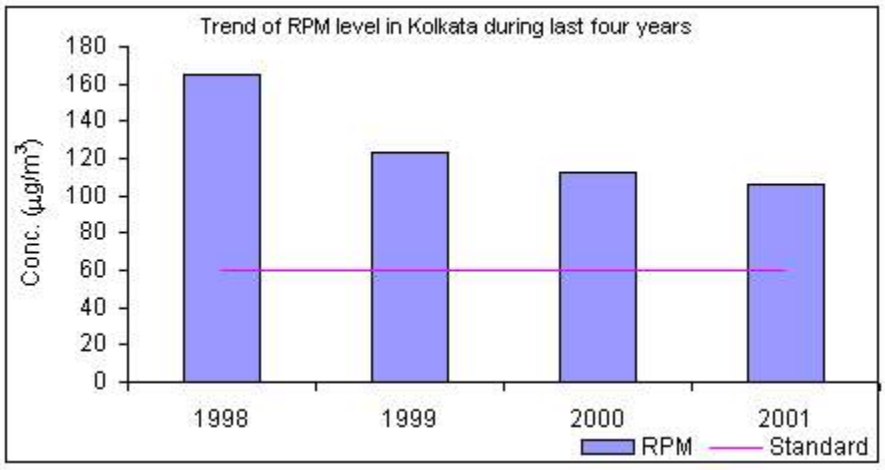
Rainfall
160 cm/year (June - Sept)

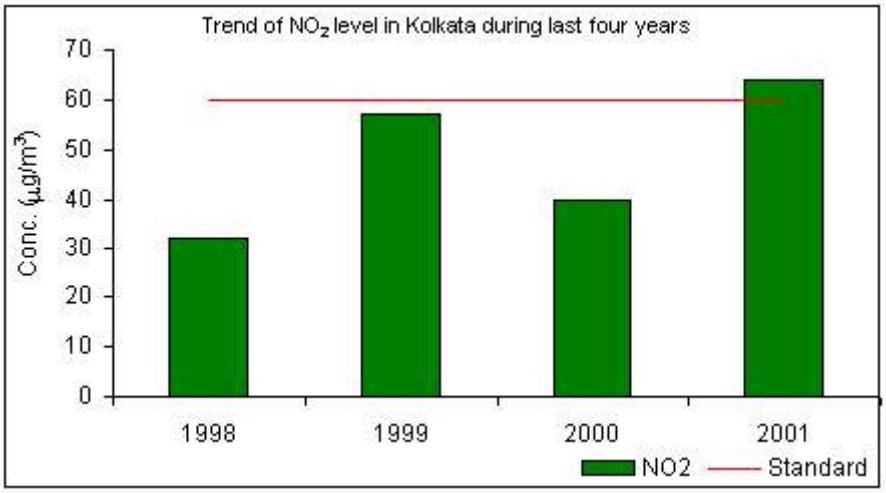
Air quality Monitoring at Kolkata & Howrah

The Central Pollution Control Board, Delhi has been monitoring the ambient air quality of Kolkata and Howrah under the National Ambient Air Quality Monitoring (NAAQM) Programme. Under this programme, the air quality in Kolkata is monitored by the National Environmental Engineering Research Institute at three monitoring stations, whereas by West Bengal Pollution Control Board at Howrah. Besides this programme, the West Bengal Pollution Control Board has been operating a vast air quality monitoring network for Kolkata (25 stations) over the last three years in order to have a much more representative air quality data for taking effective policy decisions for improving the air quality of the city.

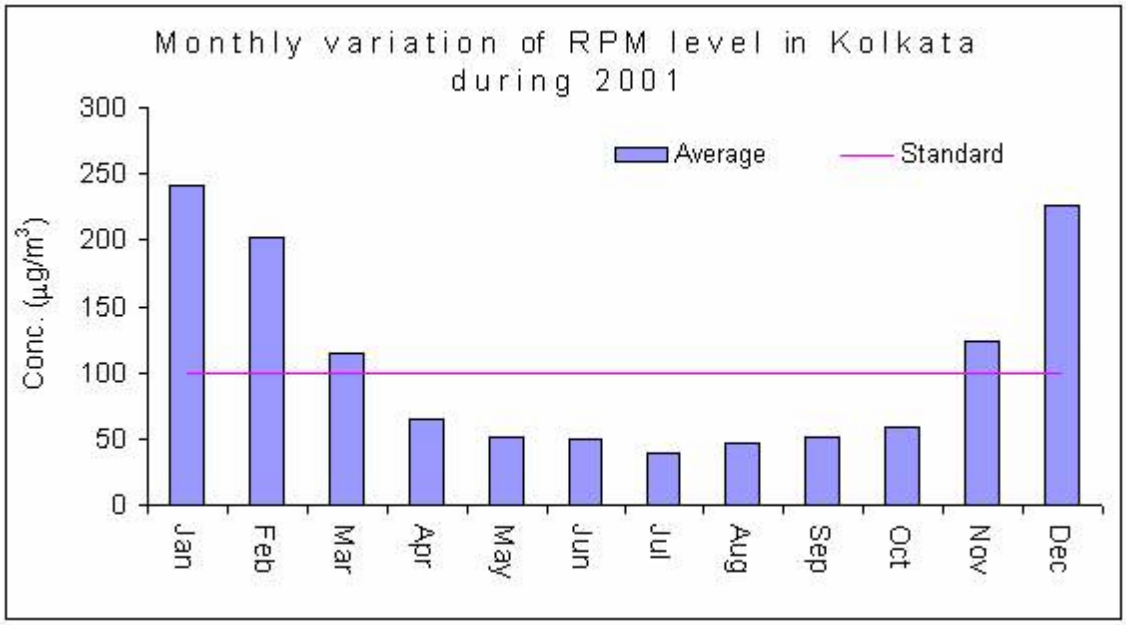
Ambient Air Quality in Kolkata during the Year 2001
(Air quality monitored at 25 stations in Kolkata)

	SPM	RSPM	Lead	SO_2	NO_2
Annual average value	189 μg/m^3	106 μg/m^3	0.4 μg/m^3	10 μg/m^3	64 μg/m^3





The Sulphur Dioxide (SO_2) level in Kolkata is very low.The seasonal (monthly) variations of Respirable Suspended Particulate Matter (RSPM) is presented below:



Ambient Air Quality at Howrah

Air quality monitored at 3 stations in Howrah

Annual average value	**SPM**	**RSPM**	**SO_2**	**NO_2**
	194 µg/m^3	114 µg/m^3	11 µg/m^3	59 µg/m^3

The air quality data reveals that Respirable Suspended Particulate Matter (RSPM) is matter of concern, which remains at a much higher level than the national standard especially during the winter months. The annual mean is also higher than the national permissible limit. The RSPM concentration in Kolkata has declined gradually over the years before steadying during the last two years. Although most of the areas for both Kolkata and Howrah are mixed areas (industrial and residential), the air

quality data are compared only with the national ambient air quality standard for residential areas keeping in view of the possible health impact.

The sampling station has been selected at the following 11 sampling sites, covering the entire city were selected for the studies on the basis of High SPM level at different traffic junction & residential areas.

Table 5.8: Sampling Location at Kolkata

S. No	*Sampling Location*
01	Cassipore Police Station, Kolkata
02	NEERI Station, Kolkata
03	Lal Bazar Police Station, Kolkata
04	Municipal Corporation Building, Kolkata
05	Bandhaghat, Kolkata
06	Naskarpara (Ghuseri), Kolkata
07	Batore More, Kolkata
08	Salt Lake, C. K. Market, Kolkata
09	Manikatala Ultadanga, Kolkata

Dust Capture by Leaves of Plant Species at Kolkata during Summer & Winter

- The average Dust capturing efficiency of Leaves of Herbs ranged from 0.0164 gm/cm^2 to 0.0341 gm/cm^2 during summer and 0.0112 gm/cm^2 to 0.0544 gm/cm^2 during winter at Kolkata. The maximum Dust capturing Herb is *Codium variegatus* whereas the minimum dust capturing Herb is *Celosia argentea*.

- The average Dust capturing efficiency of Shrubs ranged from 0.0068 gm/cm^2 to 0.1348 gm/cm^2 during summer and 0.08 gm/cm^2 to 0.0354 gm/cm^2 during winter at Kolkata. The maximum Dust capturing Shrub is *Hibiscus rosa sinensis whereas* the minimum dust capturing Shrub is *Thevetia* peruviana.

- The average Dust capturing efficiency of Trees ranged from 0.0003 gm/cm^2 to 0.2833 gm/cm^2 during summer and 0.0002 gm/cm^2 to 0.2973 gm/cm^2 during winter at Kolkata. The maximum Dust capturing Tree is *Terminalia catappal* whereas the minimum dust capturing Tree is *Delonix regiosa.*

Table 5.9: Average Dust capture by Plant Species at Kolkata during Summer & Winter

S. No.	Common name	*Botanical Name*	Family	Summer Dust Capture (gm/cm^2)	Winter Dust Capture (gm/cm^2)
HERBS					
1	Cockscomb	*Celosia argentea*	Amaranthaceae	0.0164	0.0112
2	Croton	*Codium variegatus*	Euphorbiaceae	0.0341	0.0544
SHRUBS					
3	Kaner	*Thevetia peruviana*	Apocynaceae	0.0068	0.08
4	Bougainvillea	*Bougainvillea glavra*	Nyctagenaceae	0.0068	0.103
5	Crape Myrtle	*Lagerstroemia indica*	Lythraceae	0.0143	0.0137
6	Temple Tree	*Plumaria rubraforma*	Apocyanaceae	0.0185	0.0152
7	Copper leaf	*Acalpha hispida*	Euphorbiaceae	0.0239	0.0267
8	Chandani	*Tabernaemontana divaricata*	Apocyanaceae	0.0305	0.0354
9	Dudhi	*Wrightia arboriea*	Apocynaceae	0.0543	0.111
10	Gurhal	*Hibiscus rosa sinensis*	Malvaceae	0.1348	0.047
TREES					
11	Gulmohar	*Delonix regiosa*	Ceasalpiniaceae	0.0003	0.0002
12	Bottle Brush	*Callistemon lacceolatus*	Myrtaceae	0.0008	0.001
13	Vilayeti Kikar	*Acacia farnesiana*	Mimoseae	0.0027	0.0037
14	Jangli Jalabi	*Pithecolobium dulce*	Mimoseae	0.0031	0.0021
15	Neem	*Azadirecta indica*	Meliaceae	0.0037	0.0068
16	Plum	*Prunus comminis*	Rosaceae	0.0086	0.0321
17	Torch tree	*Ixora coccineae*	Rubiaceae	0.0105	0.0184
18	Papadi	*Holiptelia integrifolia*	Ulmaceae	0.0142	0.08
19	Chikoo	*Acharis sapota*	Sapotaceae	0.0151	0.0697
20	Sugar Apple	*Annona squamosa*	Annoniaceae	0.0199	0.0199
21	Shesham	*Delbergia sisso*	Papilionaceae	0.0221	0.0133
22	Amrood	*Psidium gujava*	Myrtaceae	0.0328	0.0754
23	Ashoka	*Polyalthia longifolia*	Annoniaceae	0.0381	0.0702
24	Kurchi or Kutaja	*Holarrhena antidysenterica*	Apocynaceae	0.0499	0.1128
25	Wolly Morning Glorry	*Argyreia roxburghiria*	Covolvulaceae	0.0513	0.0703
26	Jamun	*Syzygium cuminii*	Myrtaceae	0.0559	0.0917
27	Peepal	*Ficus religiosa*	Moraceae	0.0573	0.1761
28	Jack Fruit	*Artocarpus integrifolia*	Moraceae	0.0625	0.0374
29	Amaltas	*Cassia fistula*	Caesalpinieae	0.0686	0.0883
30	Rubber Plant	*Ficus elastica*	Moraceae	0.0958	0.0975
31	Satani	*Alstonia scholaris*	Apocyanaceae	0.0995	0.1468
32	Teak	*Tectona grandis*	Verbiniaceae	0.1329	0.1894
33	Mango	*Magnifera indica*	Anacardiaceae	0.1348	0.1014
34	Banyan	*Ficus bengalensis*	Moraceae	0.1381	0.2973
35	Kadam	*Anthocephalus cadamba*	Rubiaceae	0.1716	0.1819
36	Jagali Badam	*Termanilia catappal*	Combrataceae	0.2833	0.0021

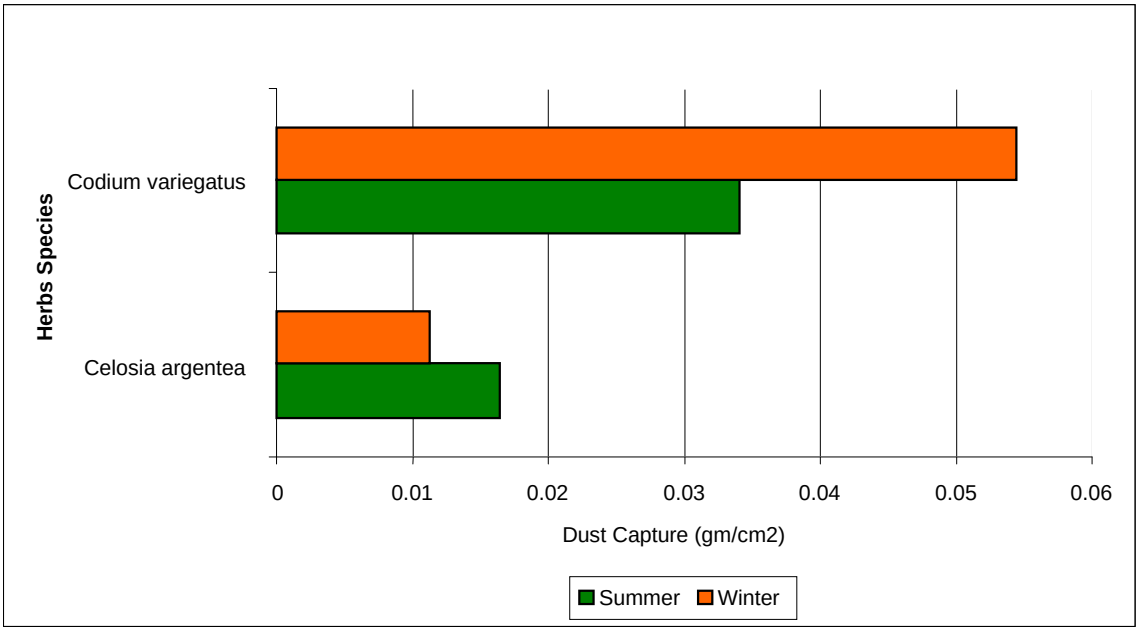


Fig 5.13: Average Dust capture by Herbs Species during Summer & Winter at Kolkata

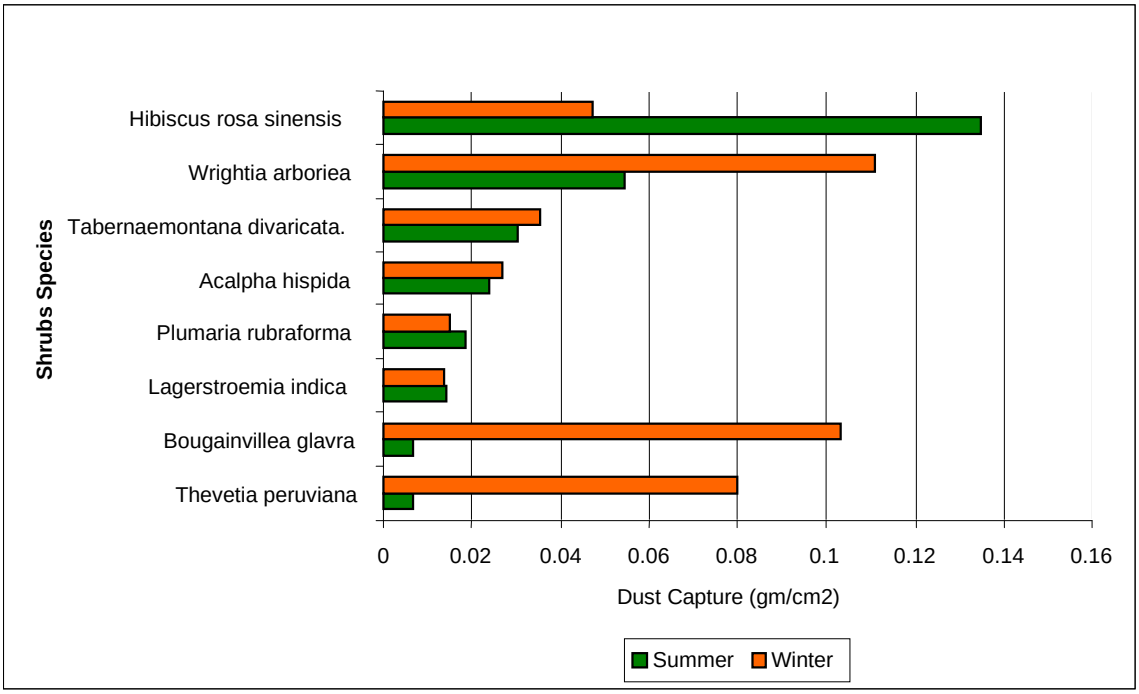


Fig. 5.14: Average Dust capture by Shrubs Species during Summer & Winter at Kolkata

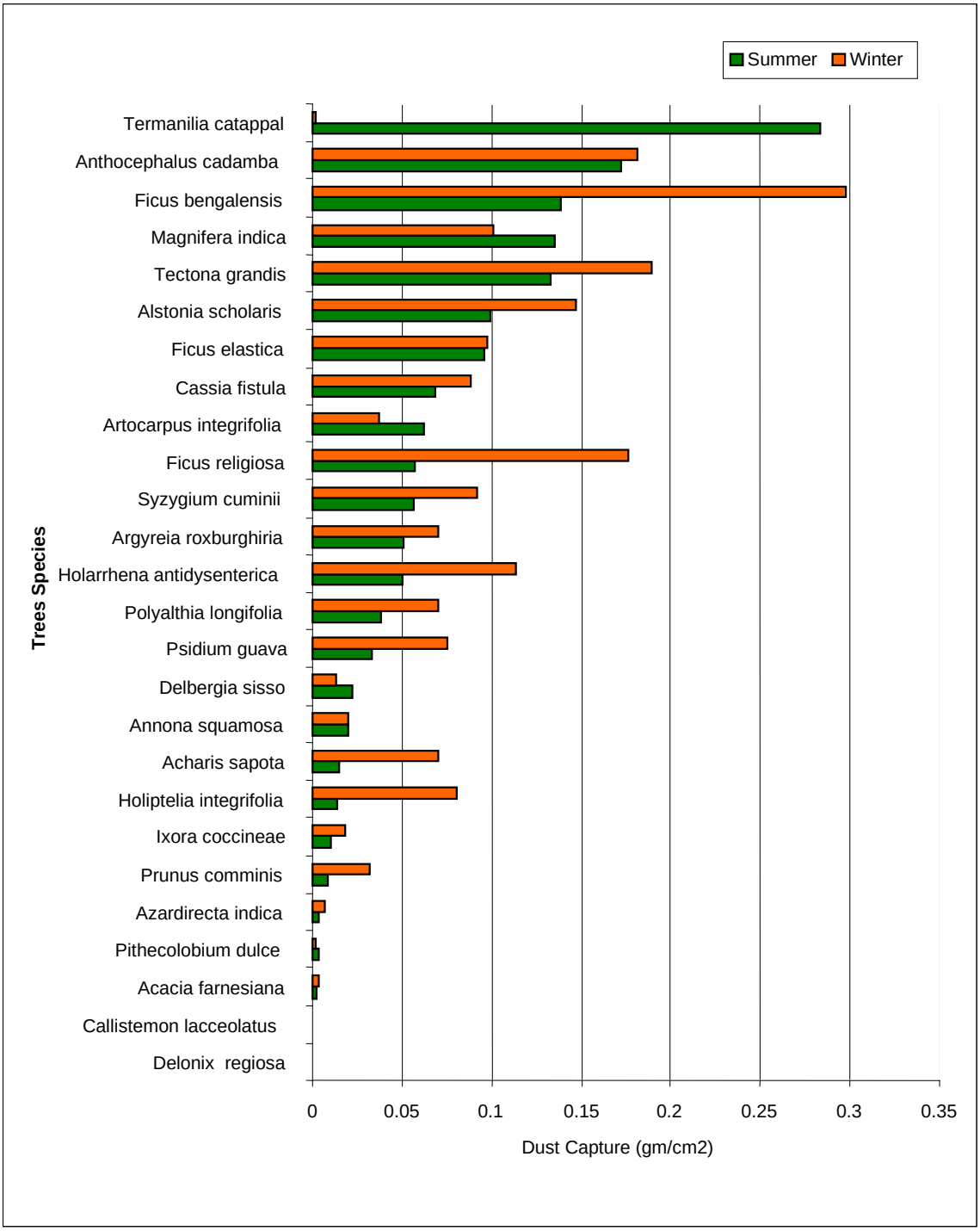


Fig. 5.15: Average Dust capture by Trees Species during Summer & Winter at Kolkata

The Dust capturing efficiency of plant species were determined with respect to the Canopy area (Crown Area of Plants in meter^2) and discussed below::

- The Maximum Dust capturing efficiency of Herbs ranged from 7.5 gm/m^2 to 10.13 gm/m^2 with an average of 8.82 gm/m^2 to Minimum 0.90 to 1.19 gm/m^2 with an average of 1.045 gm/m^2 . The maximum Dust capturing leaf of Herb is *Codium variegates* whereas the minimum dust capturing leaf of Herb is *Celosia argentea*.

- The Maximum Dust capturing efficiency of Shrubs is ranged from 286.52 gm/m^2 to 294.08 gm/m^2 with an average of 185.77 gm/m^2 to Minimum 14.44 to 17.79 gm/m^2 with an average of 16.12 gm/m^2. The maximum Dust capturing leaf of Shrub is ***Wrightia arborea*** whereas the minimum dust capturing leaf of Herb is ***Acalypha hispida***.

- The Maximum Dust capturing efficiency of Trees ranged from 4008.3 gm/m^2 to 17132.9 gm/m^2 with an average of 10570.6 gm/m^2 to Minimum 48.41 to 146.15 gm/m^2 with an average of 97.28 gm/m^2. The maximum Dust capturing leaf of Tree is ***Ficus religiosa*** whereas the minimum dust capturing leaf of Herb is ***Prunus comminis.***

Table 5.10: Dust Capture by Plants Species based on Canopy Area during Summer & Winter at Kolkata

S. No.	Common Name	Botanical Name	Family	Average Dust Capture by Plant (gm/meter^2)		
				Summer	Winter	Average
HERBS						
1	Cock Scumb	Celosia argentea	Amaranthaceae	1.19	0.9	1.05
2	Croton	Codium variegates	Euphorbiaceae	7.5	10.13	8.82
SHRUBS						
3	Copper leaf	Acalypha hispida	Euphorbiaceae	14.44	17.79	16.12
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	57.48	64.98	61.23
5	Gurhal	Hibiscus rosa sinensis	Malvaceae	88.32	67.53	77.93
6	Temple Tree	Plumaria acuminate	Apocyanaceae	90	75.24	82.62
7	Crape Myrtle	Lagerstroemia indica	Lythraceae	70.87	99.35	85.11
8	Yellow Kaner	Thevetia peruviana	Apocyanacea	12.97	204.08	108.53
9	Bougainvillea	Baganvillia	Nyctagenaceae	34.31	337.22	185.77
10	Dudhi	Wrightia arboriea	Apocyanceae	286.52	294.42	290.47
TREES						
11	Plums	Prunus comminis	Rosaceae	48.41	146.15	97.28
12	Neem	Azardirachta indica	Meliaceae	97.72	175.83	136.78
13	Sugar apple	Annona squamosa	Annanaceae	186.82	202.58	194.70
14	Bottle Brush	Callistemon laceolatus	Myrtaceae	376.87	412.41	394.64
15	Kurchi or Kutaja	Holarrhena antidysenterica	Apocyanaceae	311.04	626.66	468.85
16	Amrood	Psidium guyava	Myrtaceae	308.53	751.75	530.14
17	Vilayati Kikkar	Acacia farnesiana	Mimoseae	428.77	941.08	684.93
18	Torch Tree	Ixora parviflora	Rubiaceae	796.95	832.52	814.74
19	Chikkoo	Archise sapota	Sapotaceae	885.82	802.41	844.12
20	Gulmohar	Delonix regiosa	Ceasalpinaceae	1093.25	652.12	872.69
21	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	718.92	1447.31	1083.12
22	Shesham	Delbergia sisso	Papilionaceae	1756.91	904.99	1330.95
23	Amaltas	Cassia fistula	Ceasalpinieae	1279.91	1459.66	1369.79
24	Jamun	Syzygium cuminii	Myrtaceae	1255.71	1614.52	1435.12
25	Jangali Jalabi	Pithecolobium dulce	Mimoseae	2193.59	2033.45	2113.52
26	Ashoka	Polyalthia longifolia	Annoniaceae	1596.32	2221.98	1909.15
27	Jangal Badam	Termanilia catappal	Combrataceae	1648.85	2027.94	1838.40
28	Wolly Moprning Glorry	Argyreia roxburghira	Convulvaceae	2987.8	2315.03	2651.42
29	Kadam	Anthosephalus cadamba	Rubiaceae	2974.44	2291.81	2633.13
30	Teak	Tectona grandis	Verbinaceae	2499.62	3562.28	3030.95
31	Mango	Mangifera indica	Anacardiaceae	3494.19	2896.63	3195.41
32	Indian Rubber	Ficus elastica	Moraceae	2798.84	4820.44	3809.64
33	Jack Fruit	Artocarpus integrifolia	Moraceae	6899.26	2820.95	4860.11
34	Banyan Tree	Ficus bangalasis	Moraceae	5103.19	12584.5	8843.80
35	Satni	Alstonia scholaris	Apocyanaceae	6347.7	12233.6	9290.65
36	Peepal	Ficus religiosa	Moraceae	4008.3	17132.9	10570.60

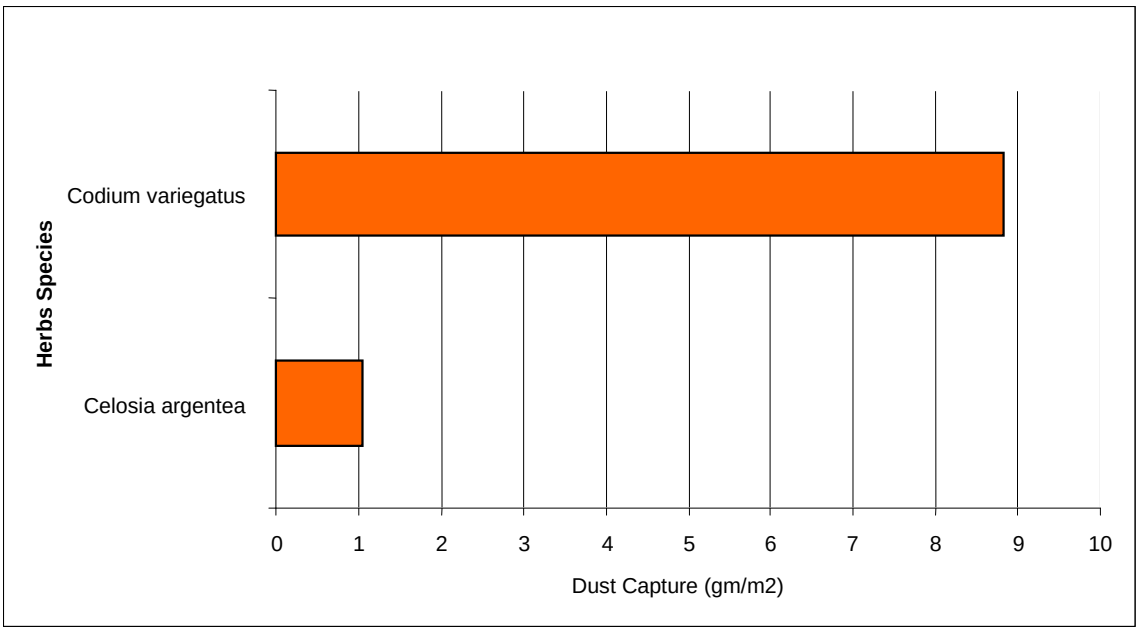


Fig. 5.16: Average Dust Capture Efficiency based on Canopy area of Herbs Plant at Kolkata

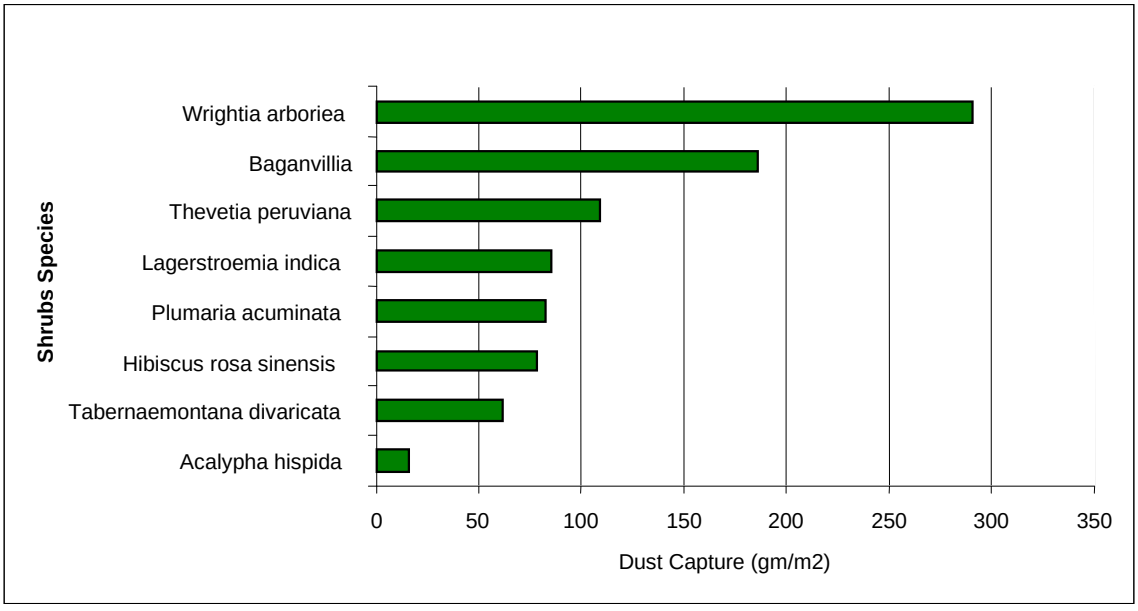


Fig. 5.17: Average Dust Capture Efficiency based on Canopy area of Shrubs Plant during at Kolkata

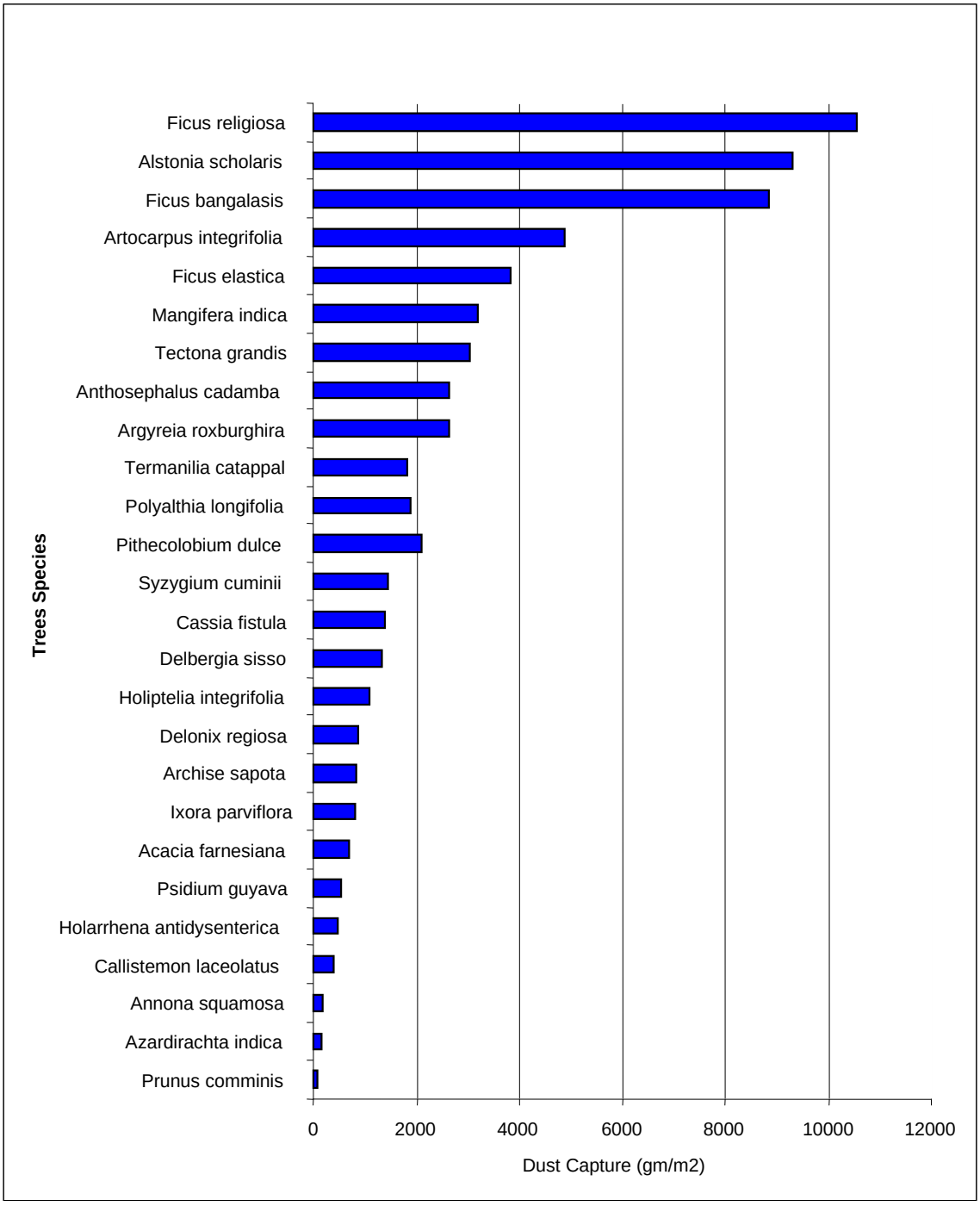


Fig. 5.18: Average Dust Capture Efficiency based on Canopy area of Trees Plant at Kolkata

- The average Maximum Dust capturing efficiency of **Herb** 8.82 gm/m^2 to Minimum 1.045 gm/m^2. The maximum Dust capturing leaf of Herb is *Codium variegates* whereas the minimum dust capturing leaf of Herb is *Celosia argentea*.

- The average Maximum Dust capturing efficiency of **Shrub** 185.77 gm/m^2 to Minimum 16.12 gm/m^2. The average maximum Dust capturing leaf of Shrub is *Wrightia arborea* whereas the average minimum dust capturing leaf of Herb is *Acalypha hispida*.

- The average Maximum Dust capturing efficiency of Tree is 10570.6 gm/m^2 to Minimum is 97.28 gm/m^2. The average maximum Dust capturing leaf of Tree is *Ficus religiosa* whereas the minimum dust capturing leaf of Herb is *Prunus comminis.*

5.4 DUST CAPTURING EFFICIENCY OF PLANT SPECIES AT COAL MINE AREA, DHANBAD

Dhanbad is situated at Latitude of 23,73^0 E and Longitude of 86,58^0 E. Major air pollutant sources at Coal Mine Area, Dhanbad are Coal & Coal Ash during handling burning activities, vis-à-vis air pollution.The sampling locations have been identified based on High SPM level at all the directions & inside the Factory premises.

The Ambient Air Quality is being monitoring by Central Pollution Control Board under National Ambient Air Quality Monitoring Program. The following 5 sites have been selected based on air quality status covering the entire city:

Table 5.11: Sampling Locations at Coal Mine Area, Dhanbad

S. No.	Sampling Station
01	East Side of Jharia, Near RSP College/Water Tank
02	West Side of Jharia Near RSP College/Water Tank
03	North Side of Jharia Near RSP College/Water Tank
04	South Side of Jharia Near RSP College/Water Tank
05	East Side of Sindhri Near Birla Institute of Technology { BIT}
06	West Side of Sindhri Near Birla Institute of Technology { BIT}
07	North Side of Sindhri Near Birla Institute of Technology { BIT}
08	South Side of Sindhri Near Birla Institute of Technology { BIT}

Fig. 5.19 : Distribution of Sampling Locations in Coal Mine Area, Dhanbad

Dust capture efficiency of Plant Species at Coal Mine Area Dhanbad during Summer & Winter

The leaf samples of plant species were collected 0.25, 0.50, 0.75 and 1 Kms distance around East, West, North & South direction of Traffic island at Dhanbad. The leaf area of each species with respect to quantity of dust captured was calculated.

- The average Dust capturing efficiency of Shrubs (Fig. 5.20) ranged from 0.006 gm/cm^2 to 0.0554 gm/cm^2 during summer and 0.0027 gm/cm^2 to 0.062 gm/cm^2 during winter at Coal Mine Area Dhanbad. The maximum Dust capturing leaf of Shrub is *Ipomea nil* whereas the minimum dust capturing leaf of Shrub is *Plumera rubraforma*.

- The average Dust capturing efficiency of Trees (Fig. 5.21) is ranged from 0.0003 gm/cm^2 to 0.2413 gm/cm^2 during summer and 0.0008 gm/cm^2 to 0.2554 gm/cm^2 during winter at Coal Mine Area Dhanbad. The maximum Dust capturing leaf of Tree is *Ficus elastica* whereas the minimum dust capturing leaf of Tree *Delonix regiosa.*

Table 5.12: Dust capture of Plant Species at Coal Mine Area Dhanbad during Summer & Winter

S. No.	Common Name	Botanical Name	Family	Dust Capture/Leaf gm/cm^2	
				Summer	Winter
SHRUBS					
1	Temple Tree	Plumaria rubraforma	Apocyanaceae	0.006	0.0215
2	Kaner (Yellow)	Thevetia peruviana	Apocyanceae	0.0045	0.0036
3	Bougainvallea	Bougainvallea glavra	Nyctagenaceae	0.0034	0.0046
4	Kanare (Pink)	Nerium indicum	Apocyanceae	0.0057	0.0036
5	Gurhal	Hibiscus Rosa Sinsis	Malvaceae	0.0095	0.0027
6	Dudhi	Wrightia arboria	Apocyanceae	0.0581	0.062
7	Chandni	Tabernaemontana drivaricata	Apocyanceae	0.0151	0.0228
8	Besharam	Ipomea nil	Convulvulaceae	0.0554	0.0396
TREES					
9	Gulmohar	Delonix regiosa	Caesalpiniaceae	0.0003	0.0008
10	Jangli jalebi	Pithecolobium dulce	Mimosceae	0.0007	0.0009
11	Sainjna	Moringa oleifera	Morinaceae	0.0009	0.0009
12	Vilayati Kikker	Accacia farnesiana	Mimosceae	0.001	0.0004
13	Ashoka	Polyalthia longifolia	Annoniaceae	0.0022	0.034
14	Plum	Prunus comminis	Rosaceae	0.0026	0.0083
15	Satni	Alstonia scholaris	Apocyanceae	0.0032	0.0113
16	Sheesham	Delbergia sissoo	Fabaceae	0.0037	0.0055
17	Neem	Azardirachta indica	Meliaceae	0.0044	0.005
18	Baelpatra	Aegle marmelos	Rutaceae	0.0069	0.0152
19	Chakotra	Citrus maxima	Rutaceae	0.007	0.007
20	Amrood	Psidium guyava	Myrtaceae	0.0074	0.0187
21	Amaltas	Cassia fistula	Caesalpiniaceae	0.0083	0.0067
22	Arjun	Terminalia arjuna	Combrataceae	0.016	0.0446
23	Jack fruit	Artocarpus integrifolia	Myrtaceae	0.0123	0.0304
24	Sugar Apple	Annona squamosa	Annoniaceae	0.0136	0.0144
25	Mango	Mangifera indica	Ancardiaceae	0.0139	0.062
26	Khajoor	Phoenix dactylifera	Palmaceae	0.0148	0.0042
27	Peepal	Ficus religiosa	Moraceae	0.0182	0.0371
28	Jamun	Syzium cumini	Myrtaceae	0.0313	0.0614
29	Banyan Tree	Ficus bengalensis	Moraceae	0.0527	0.2554
30	Kadam	Antocephalus cadamba	Rubiaceae	0.0551	0.023
31	Palas	Butea monosperma	Fabaceae	0.0612	0.0227
32	Rubber	Ficus elastica	Moraceae	0.2413	0.2371

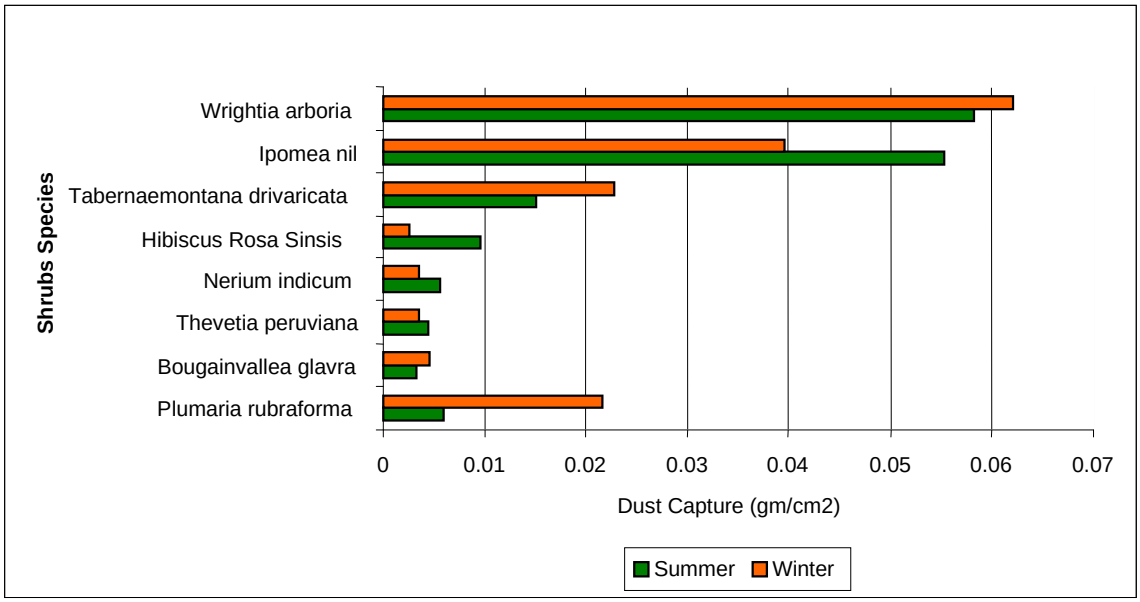


Fig. 5.20: Average Dust capture by Shrubs during Summer & Winter at Coal Mine area Dhanbad

The Dust capturing efficiency of plant species was determined with respect to the Canopy area (Crown Area of Plants in meter^2) during Summer & Winter Season. The following are the observations:

- The Average Maximum Dust capturing efficiency based on canopy area of Shrubs ranged from 215.32 gm/m^2 to 231.62 gm/m^2 with an average of 223.5 gm/m^2 to Minimum 12.94 to 13.31 gm/m^2 with an average of 13.1 gm/m^2. The maximum Dust capturing leaf of Shrub is ***Wrightia arborea*** *whereas* the minimum dust capturing leaf of Herb is ***Nerium indicum***.

- The average Maximum Dust capturing efficiency based on canopy area of Trees ranged from 2039.91 gm/m^2 to 7479.98 gm/m^2 with an average of 4759.9 gm/m^2 to Minimum 18.12 to 40.26 gm/m^2 with an average of 29.2 gm/m^2. The average maximum Dust capturing leaf of Tree is ***Ficus banglasis*** *whereas* the minimum dust capturing leaf of Tree ***Prunus comminis.***

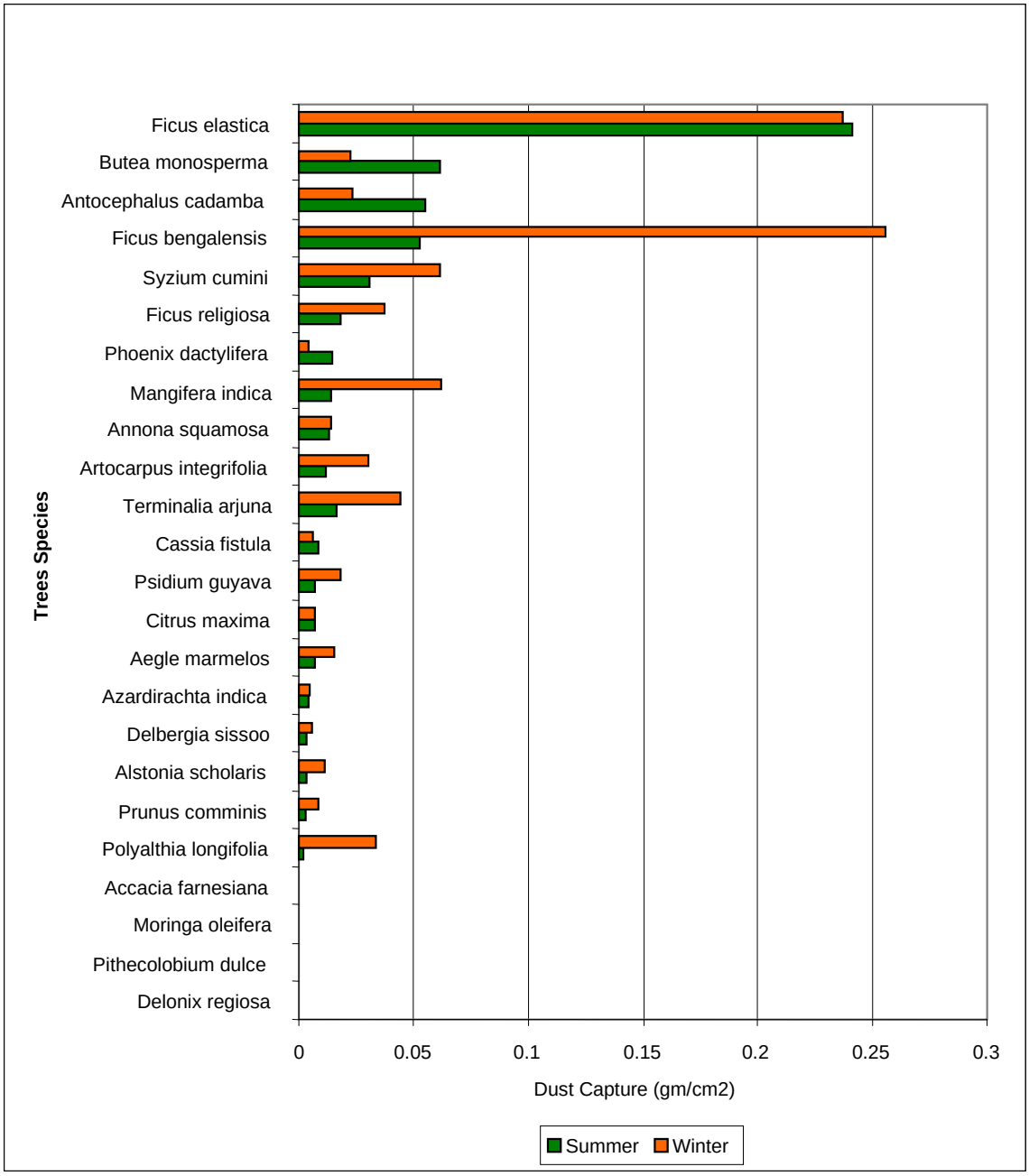


Fig 5.21 : Average Dust capture of Trees during Summer & Winter at Coal Mine Area Dhanbad

Table 5.13: Average Dust capture by Shrubs & Trees Plant Species based on canopy area at Coal Mine Area Dhanbad during Summer & Winter

S. No.	Common Name	Botanical Name	Family	Dust Capture by Plant (meter^2) Canopy Area		
				Summer	Winter	Average
SHRUBS						
1	Pink Kaner	Nerium indicum	Apocyanaceae	12.94	13.31	13.1
2	Yellow Kaner	Thevetia peruviana	Apocyanacea	14.7	11.71	13.2
3	Bougainvallea	Bougainvilliea glavara	Nyctagenaceae	21.2	35.07	28.1
4	Beshram	Ipomea nil	Convovulaceae	30.63	35.98	33.3
5	Gurhal	Hibiscus rosa sinensis	Malvaceae	52.57	14.46	33.5
6	Chandani	Tabernaemontana divaricata	Apocyanaceae	38.87	48.51	43.7
7	Temple Tree	Plumaria acuminata	Apocyanaceae	46.66	126.49	86.6
8	Dudhi	Wrightia arboriea	Apocyanceae	215.32	231.62	223.5
TREES						
9	Plums	Prunus comminis	Rosaceae	18.12	40.26	29.2
10	Amrood	Psidium guyava	Myrtaceae	74.43	178.07	126.3
11	Neem	Azardirachta indica	Meliaceae	123.29	163.1	143.2
12	Amaltas	Cassia fistula	Caesalpinioaceae	191.37	139.46	165.4
13	Sugar apple	Annona squamosa	Annanaceae	162.53	172.43	167.5
14	Bel	Aegle farnesiana	Rutaceae	195.36	432.92	314.1
15	Satni	Alstonia scholaris	Apocyanaceae	212.93	518.56	365.7
16	Chakotra	Citrus maxima	Rutaceae	356.19	379.14	367.7
17	Arjun	Terminalia arjuna	Combrataceae	309.03	470.64	389.8
18	Khajoor	Phoenix dactylifera	Palmae	582.38	341.24	461.8
19	Shesham	Delbergia sisso	Fabaceae	418.87	575.62	497.2
20	Palas	Butea monosperma	Fabaceae	764.11	238.31	501.2
21	Ashoka	Polyalthia longifolia	Annoniaceae	134.38	1018	576.2
22	Jangali Jalabi	Pithocellobium dule	Mimoseae	774.65	421.86	598.3
23	Vilayati Kikkar	Acacia farnesiana	Mimoseae	754.31	477.15	615.7
24	Sahajan	Moringa olieifera	Morangaceae	600.09	741.29	670.7
25	Kadam	Anthosephalus cadamba	Rubiaceae	1023.95	377.76	700.9
26	Mango	Mangifera indica	Ancardiaceae	419.94	1611.6	1015.8
27	Jamun	Syzygium cuminii	Myrtaceae	992.21	1216.58	1104.4
28	Gulmohar	Delonix regiosa	Caesalpiniaceae	796.51	1835.59	1316.1
29	Peepal	Ficus religiosa	Moraceae	1064.82	2823.97	1944.4
30	Jack Fruit	Artocarpus integrifolia	Moraceae	1950.95	3246.43	2598.7
31	Indian Rubber	Ficus elastica	Moraceae	4333.65	3828.06	4080.9
32	Banyan Tree	Ficus bengalensis	Moraceae	2039.91	7479.98	4759.9

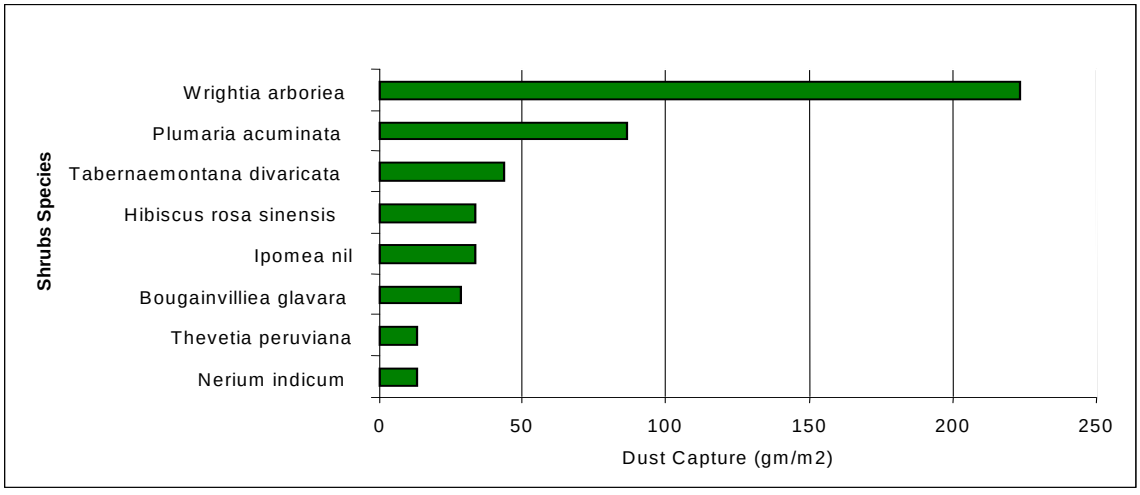


Fig. 5.22 : Average Dust capture Efficiency of Shrubs at Coal Mine Area Dhanbad

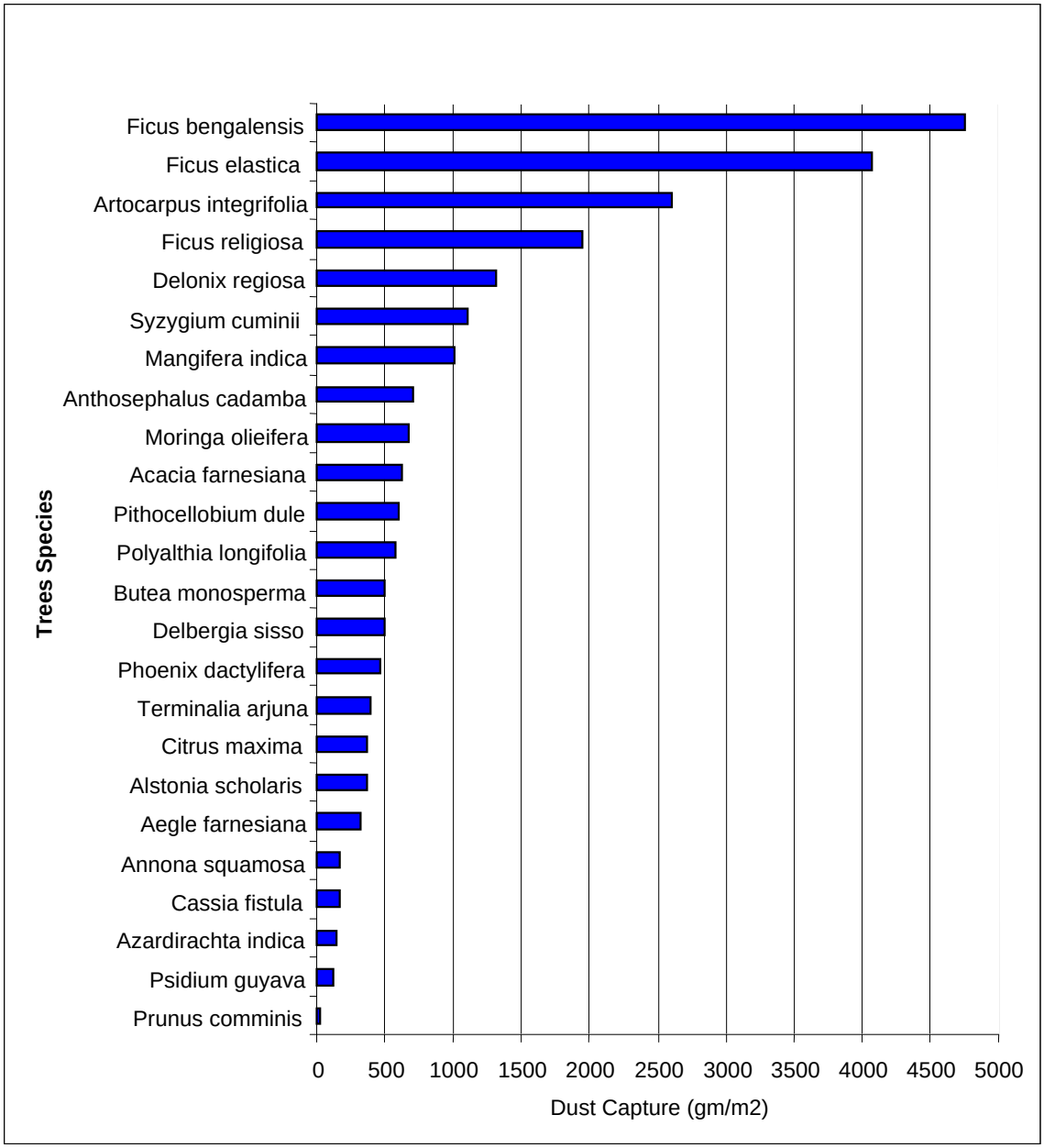


Fig. 5.23 : Average Dust capture Efficiency of Trees at Coal Mine Area Dhanbad

5.5 DUST CAPTURING EFFICIENCY OF PLANT SPECIES IN VICINITY OF CEMENT PLANT, PAONTA SAHIB

Paonta Sahib (Sirmour, Himachal Pradesh) is a pilgrimage to the Paonta Sahib at Sirmour District and visit the Langar that serves food free to some 2,000 to 5,000 visitors every day. It lies 77º 40' north and 30º 45' east, at an elevation of 397.7 m above msl. Hot in summer and cold in winter. Paonta Sahib, a city sacred to the memory of Guru Gobind Singh, the tenth Guru of the Sikhs. It retains tangibly memorials to the martial Guru in the form of his weapons and a majestic Gurudwara and recalls his presence even in the name of the city which is derived from "paon" meaning "foot".

Paonta Sahib is one of the Sub-Divisional Headquarters of District Sirmour and is about 45 km. Form Nahan on Shimla-Nahan-Dehra Dun road at an elevation of 397.7 meters from the sea level. This place is of great religious sanctity for the Sikhs and Hindu alike. The Yamuna flows close by on its east, turning partly to its south. So situated on the right bank of the river Yamuna, it commands a superb view of the Dun valley. Paonta main advantage is its situation. Within the town is a famous Gurudwara overlooking the Yamuna? Guru Govind Singh, the tenth Guru of the Sikhs stayed here for about 4 years from 1742 to 1745. Origin of the name of Paonta Sahib is also attributed to the guru and more than one legend are still fresh in the memory of the local inhabitants. It is said that with the setting of his foot on the soil of t his place and his subsequent stay here the place was named as Paon-tika (foot-rested) subsequently corrupted to Paonta. Another version which finds mention in the Revenue Report of Majra of 1889, and perhaps more reliable and official is that while bathing in the Yamuna the illustrious guru's foot ornament called "Paonta", slipped and was lost for ever in the river. Hence, the place was christened as Paonta after this incident. He fought various battles against the combined forces of Rajas of Garhwal and Bilaspur. Gurudwara of Paonta Sahib is located at the victory point. This place attracts pilgrims from all over India.

Paonta sahib is having lot of Mining activities and is having Cement & Lime factories near by city. **Major air pollutant sources at Cement Factory, Paonta Sahib are Stone Crushing & Lime during handling burning activities. vis-à-vis air pollution. There are number of Cement Manufacturing units operated under Cement Corporation of India (CCI) a leading public sector in India. The details of various unit operating in India under CCI are as follows:**

The case studies undertaken for the present study has been undertaken for Rajban Cement Factory, a unit of Cement Corporation of India (CCI), Paonta Sahib, Himachal Pradesh. The manufacturing details are given as follows:

Rajbari Cement Factory, CCI, Paonta Sahib

Location : Rajban Cement Plant is located at 60 km from Dehradun and 70 km from Yamunanagar by road. It is 10 Kms from Ponta Sahib by road. Distt. - Sirmaur. State - Himachal Pradesh

Capacity : 1, 98,000 MT per Annum

Commencement Of Production : 01.04.1980

Process : Dry process

Type of Cement : Ordinary Portland cement, Pozzolina Portland Cement**.**

Total layout area :	**Factory area + Township**	**Mining Area**
	---	---
Leased Land	136.338 acres	242.3 hectares
Freehold land	34 bighas and 11 biswas	13.4 hectares

7. Facility Available: Own township having 449 Nos. of residential accommodation with facilities of health centre, shopping complex, recreation club, Guest house, Bank, Post office , LPG Shop, Telephone exchange and co-operative store.

8. Production during last eight years :

Year	Cement (MT)
1995-96	1,67,630
1996-97	1,48,640
1997-98	1,45,026
1998-99	1,59,150
1999-2000	1,62,155
2000-2001	1,06,231
2001-2002	1,38,520
2002-2003	1,30,438
2003-2004 (upto Jan.'04)	1,21,135

9. Raw Materials Consumed : 369.01

The sampling locations have been identified on the basis of area of High SPM level at all the four directions & inside the Factory premises. The Ambient Air Quality is monitored by Central Pollution Control Board under National Ambient Air Quality Monitoring Program. Based on the Ambient Air Quality status with reference to particulate matter, the following 10 sites have been selected for the study.

Table 5.14: Sampling Locations at Cement Factory, Paonta Sahib

S. No.	Sampling Location
01	Inside Cement Factory at Paonta Sahib
02	East Side of Cement Factory at Paonta Sahib
03	West Side of Cement Factory at Paonta Sahib
04	North Side of Cement Factory at Paonta Sahib
05	South Side of Cement Factory at Paonta Sahib
06	Inside of Lime Factory, at Paonta Sahib
07	East Side of Lime Factory, at Paonta Sahib
08	West Side of Lime Factory, at Paonta Sahib
09	North Side of Lime Factory, at Paonta Sahib
10	South Side of Lime Factory, at Paonta Sahib

Fig. 5.24 : Distribution of Sampling Locations in Vicinity of Cement Factory, Paonta Sahib

5.5.1 Dust capture By Leaf of Plant Species at Cement Factory, Paonta Sahib during Summer & Winter

The leaf sample of Plant species was collected at 0.25, 0.50, 0.75 and 1 km distance in East, West, North & South direction in the vicinity of Cement Factory. The following are salient observations.

- The average Dust capturing efficiency of Herbs ranged from 0.0009 gm/cm^2 to 0. 0517 gm/cm^2 during summer and 0.0003 to 0.0784 gm/cm^2 during winter at Cement Factory, Paonta Sahib. The average minimum Dust capturing Herb ranged from 0.0003 to 0.0009 gm/cm^2 by *Tagetes patula* while the maximum dust capture was ranged from 0.0273 to 0.0351 gm/cm^2 by *Lilium species* were observed at Cement Factory, Paonta Sahib (Table 5.15, Fig. 5.25).

- The average Dust capturing efficiency of Shrubs ranged from 0.0051 gm/cm^2 to 0.2467 gm/cm^2 during summer and 0.0171 gm/cm^2 to 0.3568 gm/cm^2 during winter at Cement Factory, Paonta Sahib. The maximum Dust capturing Shrub is *Withania somnifera* whereas the minimum dust capturing Shrub is *Rosa indica*. (Table 5.15, Fig. 5.26).

- The average Dust capturing efficiency Trees ranged from 0.0002 gm/cm^2 to 0.1751 gm/cm^2 during summer and 0.0002 gm/cm^2 to 0.2137 gm/cm^2 during winter at Cement Factory, Paonta Sahib. The maximum Dust capturing Tree is *Anthosephalus cadamba* whereas the minimum dust capturing Tree is *Delonix regiosa* (Table 5.15, Fig. 5.27).

Table 5.15:Average Dust Capture by Leaf of Plant Species at Cement Factory, Paonta Sahib during Summer & Winter

S. No.	Common Name	*Botanical Name*	*Family*	Dust Capture by Plant (gm/meter^2)		
				Summer	**Winter**	**Average**
HERBS						
1	Elephant's Ear	Colocasia antiquorum	Araceae	0.16	0.20	0.18
2	Genda	Tagetes patula	Asteraceae	2.49	0.71	1.60
3	Dracaena	Dracaena	Liliaceae	1.73	2.06	1.90
4	Lily	Lillium	Liliaceae	2.32	2.97	2.65
5	Chaulai	Amaranthus hypochondricecus	Amaranthaceae	7.77	6.71	7.24
SHRUBS						
6	Rose	Rosa indica	Rosaceae	1.33	5.68	3.51
7	Croton	Codium variegates	Euphorbiaceae	12.99	8.30	10.65
8	Asgandha	Withania somnifera	Solancea	9.69	13.93	11.81
9	Sarpgandha	Rauvolfia serpentine	Apocyanceae	13.19	10.63	11.91
10	Copper leaf	Acalypha hispida	Euphorbiaceae	14.61	19.83	17.22
11	Beshram	Ipomea nil	Convovulaceae	27.46	17.67	22.57
12	Yellow Kaner	Thevetia peruviana	Apocyanacea	51.80	30.97	41.39
13	Pink Kaner	Nerium indicum	Apocyanaceae	70.86	19.51	45.19
14	Chandani	Tabernaemontana divaricata	Apocyanaceae	65.15	50.17	57.66
15	Crape Myrtle	Lagerstroemia indica	Lythraceae	76.10	86.62	81.36
16	Moyur Pankhi	Thuja Species	Gymnosperm	60.16	105.45	82.81
17	Bougainvillea	Bougainvillea glavara	Nyctagenaceae	37.20	147.09	92.15
18	Temple Tree	Plumaria acuminate	Apocyanaceae	90.15	116.99	103.57
19	Gurhal	Hibiscus rosa sinensis	Malvaceae	219.38	204.00	211.69
20	Dudhi	Wrightia arboriea	Apocyanceae	212.57	213.18	212.88
TREES						
21	Bel	Aegle mamelos	Rutaceae	140.81	98.09	119.45
22	Lamon	Citrus limon	Rutaceae	35.85	606.70	321.28
23	Arjun	Terminalia arjuna	Combrataceae	303.66	342.85	323.26
24	Kari Leaves	Miliusa tomentosa	Annonaceae	371.11	331.90	351.51
25	Sal	Shorea robusta	Dipterocarpaceae	472.74	309.56	391.15
26	Siris	Albizzia lebbek	Casesalpiniaceae	468.71	463.85	466.28
27	Amrood	Psidium guyava	Myrtaceae	224.35	897.67	561.01
28	Gulmohar	Delonix regiosa	Caesalpiniaceae	728.84	538.70	633.77
29	Torch Tree	Ixora parviflora	Rubiaceae	622.59	766.13	694.36
30	Bottle Brush	Callistemon laceolatus	Myrtaceae	630.35	907.63	768.99
31	Satni	Alstonia scholaris	Apocyanaceae	862.95	551.76	707.36
32	Sheesham	Delbergia sisso	Papilionaceae	871.22	1020.91	946.07
33	Jamun	Syzygium cuminii	Myrtaceae	1501.66	1349.57	1425.62
34	Ashoka	Polyalthia longifolia	Annoniaceae	239.97	2772.29	1506.13
35	Blue gum	Eucalyptus globules	Myrtaceae	1051.29	1967.06	1509.18
36	Teak	Techtona grandis	Verbenaceae	1684.41	1589.96	1637.19
37	Vilayati Kikkar	Acacia farnesiana	Mimoseae	1577.03	2266.35	1921.69
38	Silver fire	Abies pindrow	Pinaceae	1861.18	1989.54	1925.36
39	Neem	Azardirachta indica	Meliaceae	478.51	2335.95	1407.23
40	Amaltas	Cassia fistula	Ceasalpinieae	678.82	3750.10	2214.46
41	Babul	Accacia nelotica	Mimoseae	2534.36	1991.28	2262.82
42	Mulberry	Morus alba	Moraceae	835.82	4352.68	2594.25
43	Mango	Mangifera indica	Ancardiaceae	1377.40	4664.27	3020.84
44	Peepal	Ficus religiosa	Moraceae	1962.09	6813.03	4387.56
45	Indian Rubber	Ficus elastica	Moraceae	2807.18	6774.27	4790.73
46	Kadam	Anthosephalus cadamba	Rubiaceae	8478.22	10979.94	9729.08

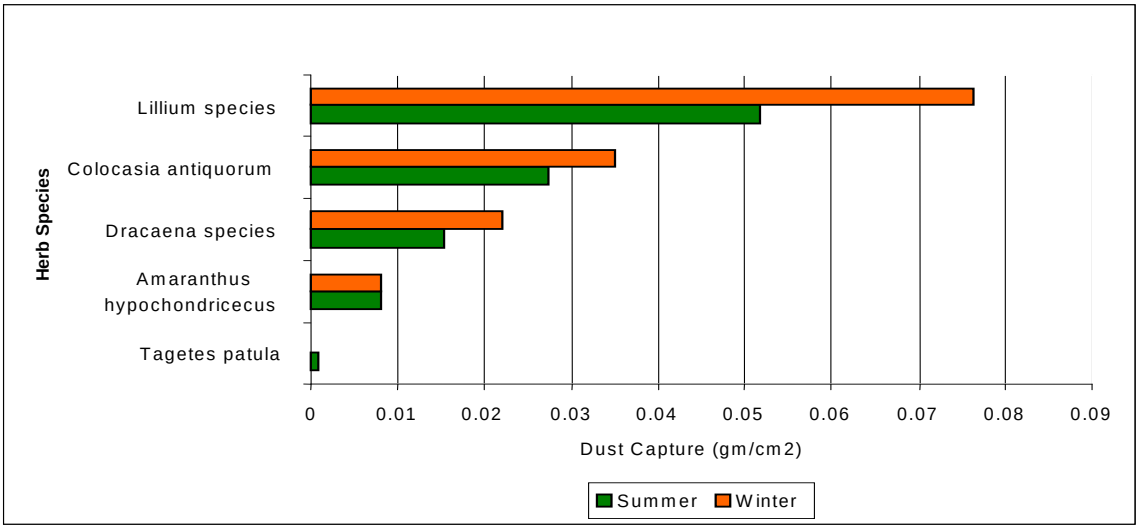


Fig. 5.25 : Average Dust capture by Herbs during Summer & Winter in Vicinity of Cement Plant, Paonta Sahib

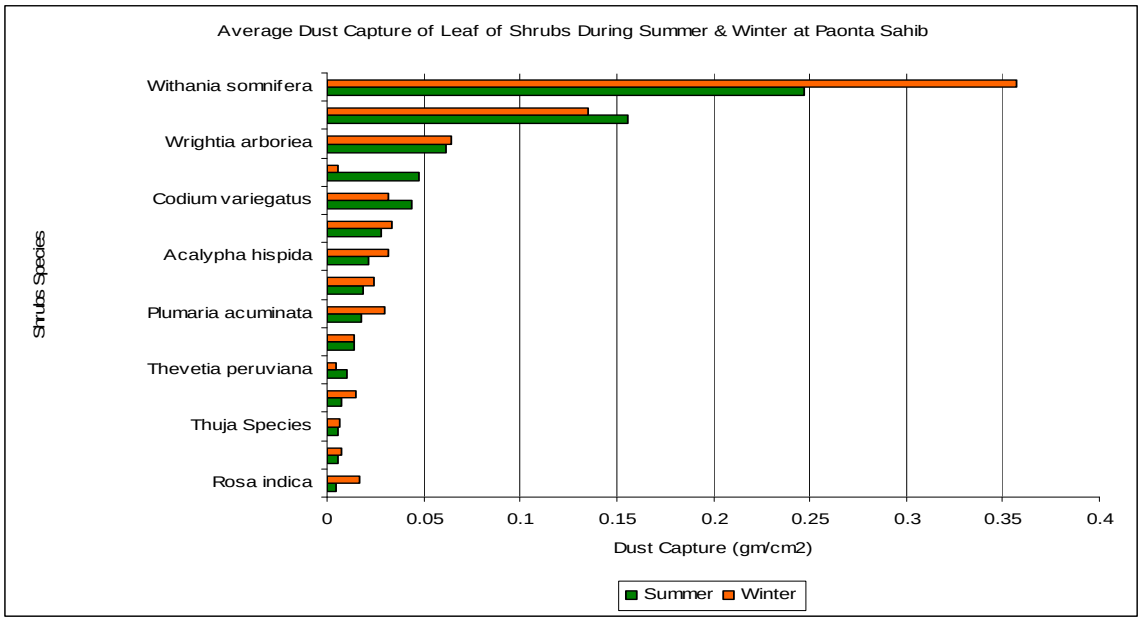


Fig. 5.26 : Average Dust capture by Shrubs, during Summer & Winter at Vicinity of Cement Factory, Paonta Sahib

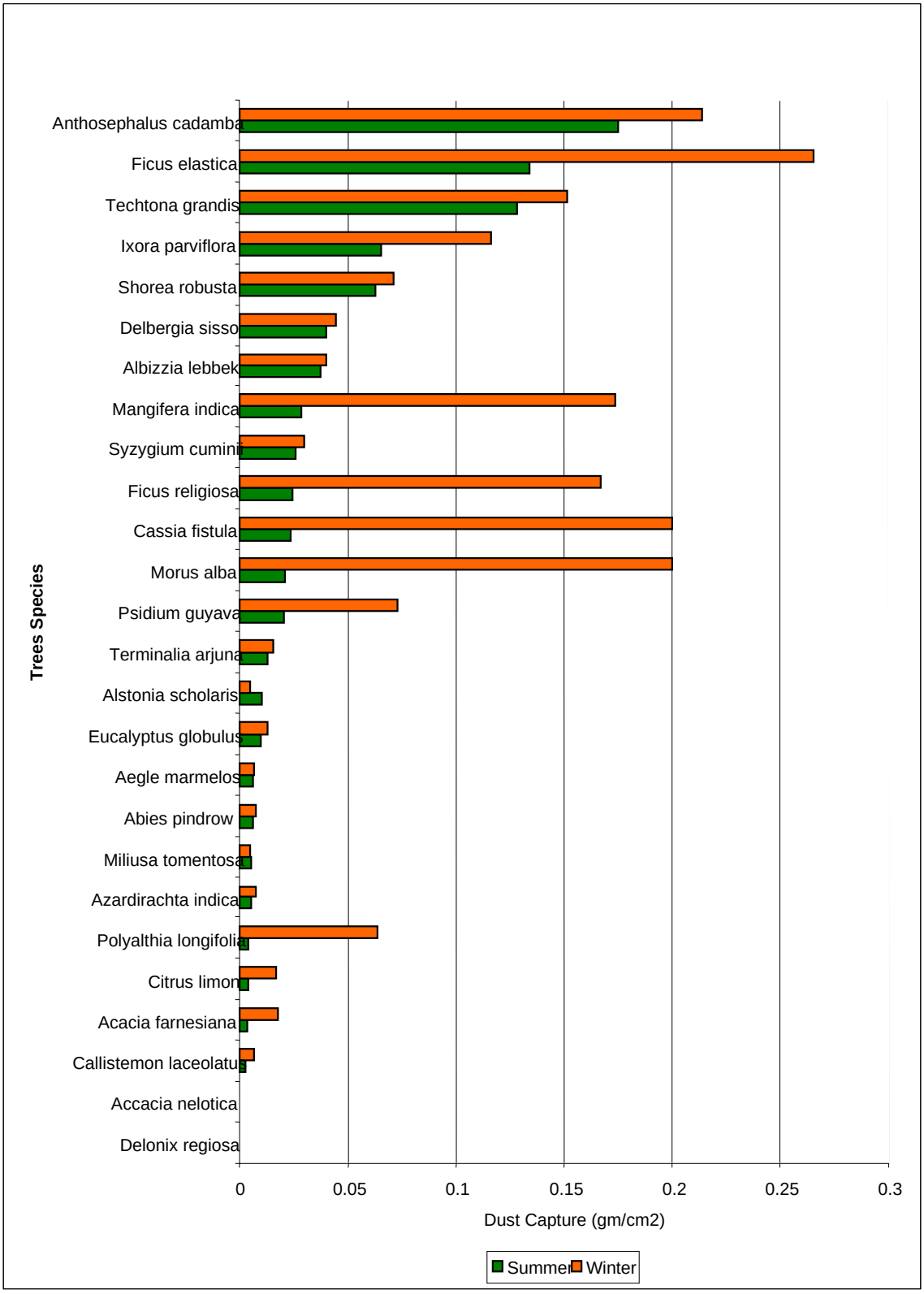


Fig. 5.27 : Average Dust capture by Trees during Summer & Winter in Vicinity of Cement Plant, Paonta Sahib

The Dust capturing efficiency of plant species was also determined with respect to the Canopy area (Crown Area of Plants in meter^2) during Summer & Winter Season.

- The Average maximum Dust capturing efficiency of Herbs based on canopy area (Fig. 5.28) ranged from 6.71 gm/m^2 to 7.77 gm/m^2 with an average of 7.24 gm/m^2 in *Ammaranthus hypochondriceous* where as the minimum average dust capturing efficiency is ranged from 0.16 to 0.20 gm/m^2 with an average of 0.19 gm/cm^2 in *Colocasia antiquorum* were observed at Cement Factory, Paonta Sahib.

- The Average Maximum Dust capturing efficiency of Shrubs based on canopy area ranged from 212.57 gm/m^2 to 213.18 gm/m^2 with an average of 212.88 gm/m^2 to Minimum 1.33 to 5.68 gm/m^2 with an average of 3.51 gm/m^2. The maximum Dust capturing leaf of Shrub is *Wrightia arboriea* whereas the minimum dust capturing leaf of Shrub *Rosa indica*.

- The average Maxmum Dust capturing efficiency of Trees based on canopy area (Fig. 5.29) ranged from 8478.22 gm/m^2 to 10979.94 gm/m^2 with an average of 9729.08 gm/m^2 to Minimum 98.98 to 140.81 gm/m^2 with an average of 119.45 gm/m^2. The average maximum Dust capturing leaf of Tree is *Anthosephalus cadamba whereas* the minimum dust capturing leaf of Herb is *Aegle mamelos*.

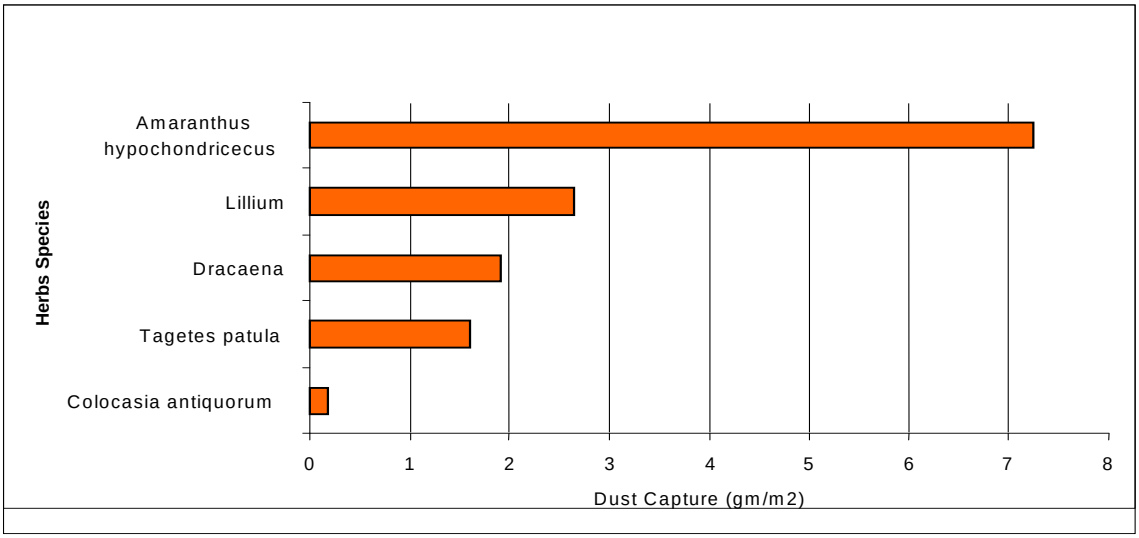


Fig. 5.28 : Average Dust Capturing Efficiency of Herbs based on canopy area in Vicinity of Cement Plant at Paonta sahib

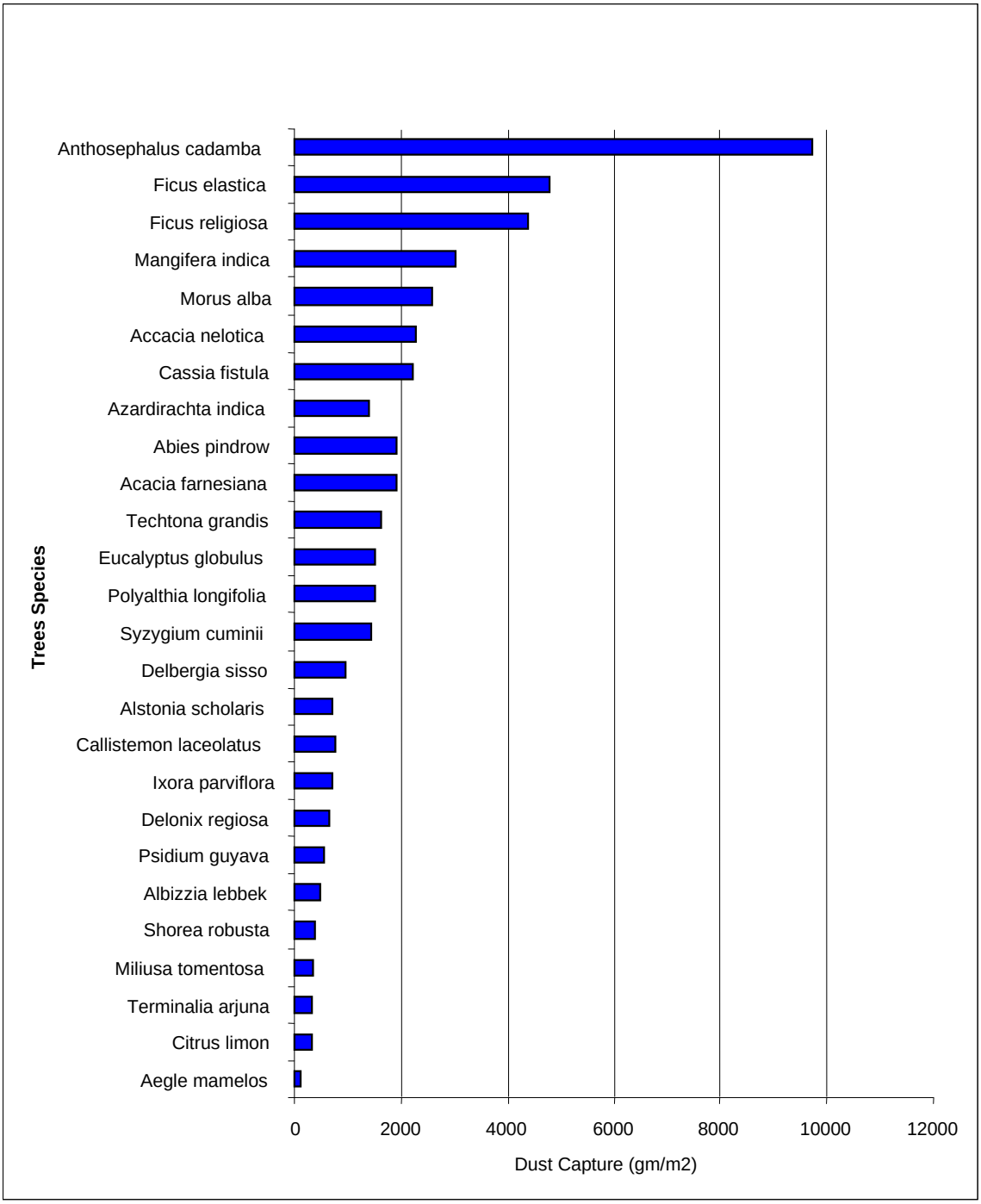


Fig. 5.29 : Average Dust Capturing Efficiency of Trees based on Canopy area in the Vicinity of Cement Factory at Paonta sahib

5.6 DUST CAPTURING EFFICIENCY OF PLANT SPECIES IN VICINITY OF STONE CRUSHER

Haridwar town is located at 29 58' North latitude and 70 10' East longitudes on the right bank of river Ganga at the foothills of Shivalik Ranges. It is situated on Dehradun-Lucknow route of Northern Railway at a distance of 52 Km from Dehradun towards south. It is well connected by road to Rishikesh (25 Km), Dehradun (52 Km), Roorkee (30 Km) and Delhi (200 Km). State Highway No. 58 from Delhi to Niti Pass passes through the town. This is the important city of the newly formed Uttaranchal State.

The town is over a long belt between foothills and right bank of river Ganga. The topography of the town quite undulating. The area has a general slope towards river Ganga with a few humps existing in certain places such as Har-Ki-Pauri, Rishikkul Medical College and Jwalapur railway station. From Har-Ki-Pauri the ground is sloping towards Bhimgoda in north and towards Mayapur in south. Bhopatwala area is sloping towards river Ganga and the seasonal river Baghrow. The area between river Baghrow and Bhimgoda is almost flat. Kankhal area is sloping towards southeast, and Jwalapur area towards south west. Depth of sub soil below ground level varies from 6m to 21 meters.

Stone Crusher at Hardwar is situated at Hardwar Laksar State Highway at Bhogpur Village. The climate of Stone Crusher at Hardwar region is typical steppe. The prevalence of continental air from nearby Himalayan region. and the South – West Monsoon recurring from last week of June to September. The heavy rains during monsoon months act as “Scrubber” scavenging the atmosphere of air pollution loads. The winter seasons extends from December to March, during which the night temperature is substantially lower than day temperature, thus following diurnal weather cycle.

Major air pollutant sources at the vicinity of Stone Crusher at Haridwar are Transport (Vehicles), Stone Crushing activities.vis-à-vis air pollution. Identification of Sampling Station has been done on the basis of area of High SPM level at all the four directions & inside the Factory premises. The Ambient Air Quality is monitoring by Central Pollution Control Board under National Ambient Air Quality Monitoring Program. . Based on the Ambient Air Quality data, the following 5 sites, covering the whole city and as given in Table 5.16 and Fig. 5.30 were selected for the studies:

Table 5.16: Sampling Locations at Vicinity of Stone Crusher, Haridwar

S. No.	Sampling Location
01	Inside of Stone Crusher Industry
02	East Side of Stone Crusher Industry
03	West Side of Stone Crusher Industry
04	North Side of Stone Crusher Industry
05	South of Stone Crusher Industry

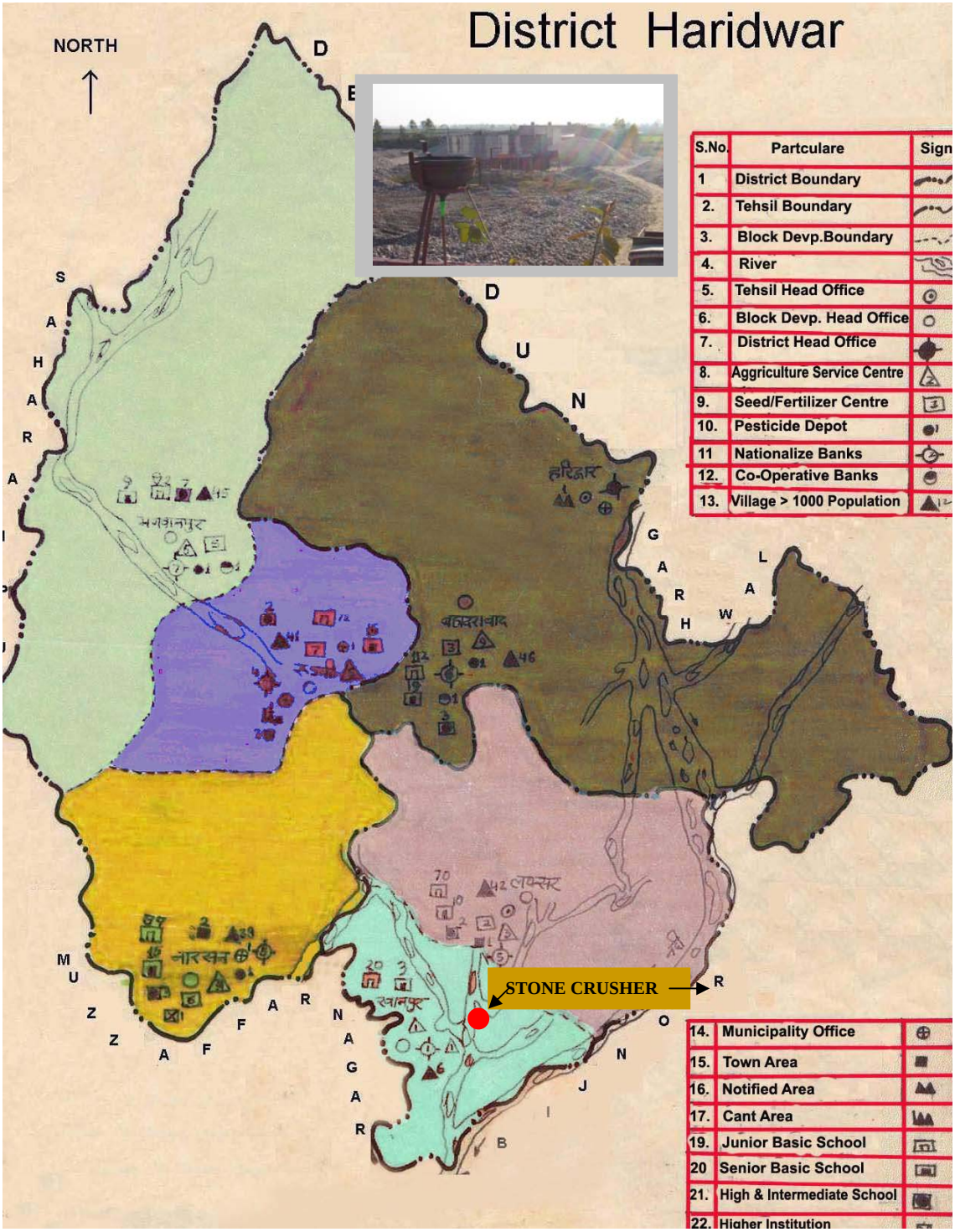


Fig. 5.30 : Sampling Location in vicinity of Stone Crusher at Hardwar

5.6.1 Average Dust capture by Leaves of Plant Species in the vicinity of Stone Crusher during Summer & Winter at Haridwar

- The average Dust capturing efficiency of Leaf of Herbs ranged from 0.0011 gm/cm^2 to 0. 0172 gm/cm^2 during summer and 0.0008 gm/cm^2 to 0.0202 gm/cm^2 during winter at the vicinity of Stone Crusher at Hardwar. The maximum Dust capturing leaf of Herb was (Fig. 5.31) *Celosia argentea* whereas the minimum dust capturing leaf of Herb was *Tagetes patula*.

- The average Dust capturing efficiency of Leaf of Shrubs ranged from 0.044 gm/cm^2 to 0.4057 gm/cm^2 during summer and 0.0077 gm/cm^2 to 0.4095 gm/cm^2 during winter at the vicinity of Stone Crusher at Hardwar(Fig.5.32). The maximum Dust capturing leaf of Shrub *Withania somnifera* whereas the minimum dust capturing leaf of Shrub is *Rosa indica*.

- The average Dust capturing efficiency of Leaf of Trees ranged from 0.0004 gm/cm^2 to 0.2559 gm/cm^2 (Fig. 5.33) during summer and 0.0018 gm/cm^2 to 0.7472 gm/cm^2 during winter at the vicinity of Stone Crusher at Hardwar. The maximum Dust capturing leaf of Tree is *Tectona grandis* whereas the minimum dust capturing leaf of Tree is *Melia azidirecta.*

Table 5.17: Average Dust capture of Leaf of Plant Species at the vicinity of Stone Crusher at Hardwar during Summer & Winter

S. No.	Common Name	Botanical Name	Family	Average Dust Capture by Leaves of Plant Species	
				Summer Dust (gm/cm^2)	Winter Dust (gm/cm^2)
HERBS					
1	Genda	Tagetese minuta	Asteraceae	0.0011	0.0008
2	CrownDaisy	Chrysanthamum	Astraceae	0.0172	0.0202
3	Cock'scomb	Celosia argentea	Amaranthaceae	0.011	0.0085
4	Rose	Rosa indica	Rosaceae	0.044	0.0077
SHRUBS					
5	Croton	Croton oblongifolius	Euphorbiaceae	0.0074	0.0084
6	Bamboo	Bambusa	Rutaceae	0.033	0.0131
7	Bougainvillea	Bougainvillea glavara	Nyctagenaceae	0.041	0.0102
8	Chandani	Tabernaemontana divaricata	Apocyanaceae	0.0176	0.0415
9	Beshram	Ipomea nil	Convulvulaceae	0.0686	0.0353
10	Ashgandh	Withania somnifera	Solanceae	0.4057	0.4095
TREES					
11	Melia	Melia azidircta	Meliaceae	0.0004	0.0018
12	Gulmohor	Delonix regiosa	Caesalpinaceae	0.0009	0.0011
13	Babul	Accacia nelotica	Mimoseae	0.0015	0.0003
14	Shisham	Delbergia sisso	Papilionaceae	0.0018	0.003
15	Plum	Prunus comminis	Rosaceae	0.0021	0.0023
16	Blue Gum	Eucalyptus globulus	Myrtaceae	0.0062	0.0197
17	Popular	Populus trimuloides	Salicaceae	0.0105	0.0109
18	Amaltas	Cassia fistula	Caesalpiniaceae	0.0126	0.0121
19	Ashoka	Polylthia longifolia	Annoniaceae	0.0142	0.0444
20	Jamun	Syzygium cuminii	Myrtaceae	0.0156	0.0116
21	Amrood	Psidium guyava	Myrtaceae	0.0162	0.0376
22	Mulbery	Morus alba	Moraceae	0.0206	0.021
23	Kachnar	Bauhinia varigata	Caesalpinaceae	0.021	0.0617
24	Samal	Bombax ceiba	Malvaceae	0.0228	0.0382
25	Mango	Mangifera indica	Anacardiaceae	0.0238	0.0591
26	Peepal	Ficus religiosa	Moraceae	0.0368	0.1359
27	Pine	Pinus contora	Pnaceae	0.0225	0.0231
28	Palas	Butea monosperma	Fabaceae	0.1108	0.1309
29	Teak	Tectona grandis	Verbenaceae	0.2559	0.7472

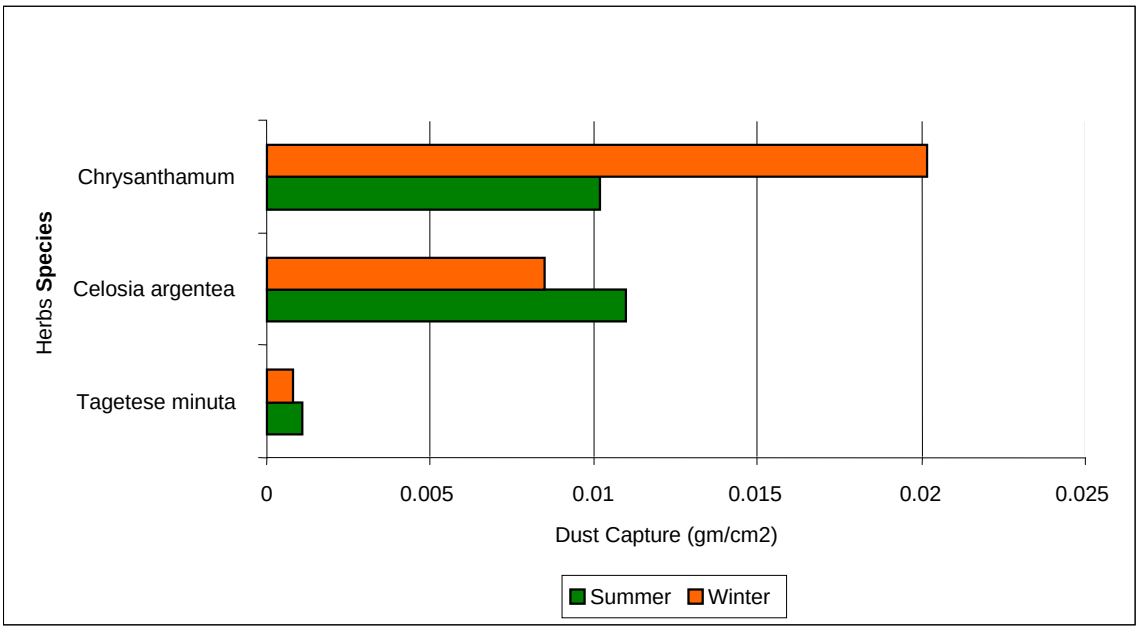


Fig. 5.31 : Average Dust capture of Leaf of Herbs during Summer & Winter in Vicinity of Stone Crusher

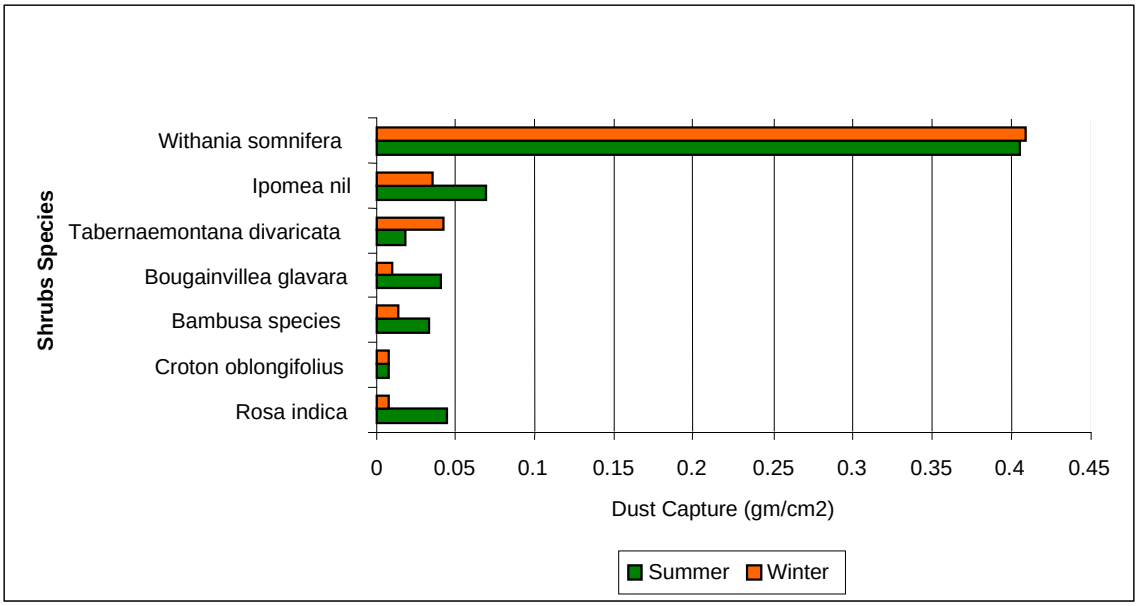


Fig. 5.32 : Average Dust capture of Leaf of Shrubs during Summer & Winter in Vicinity of Stone Crusher

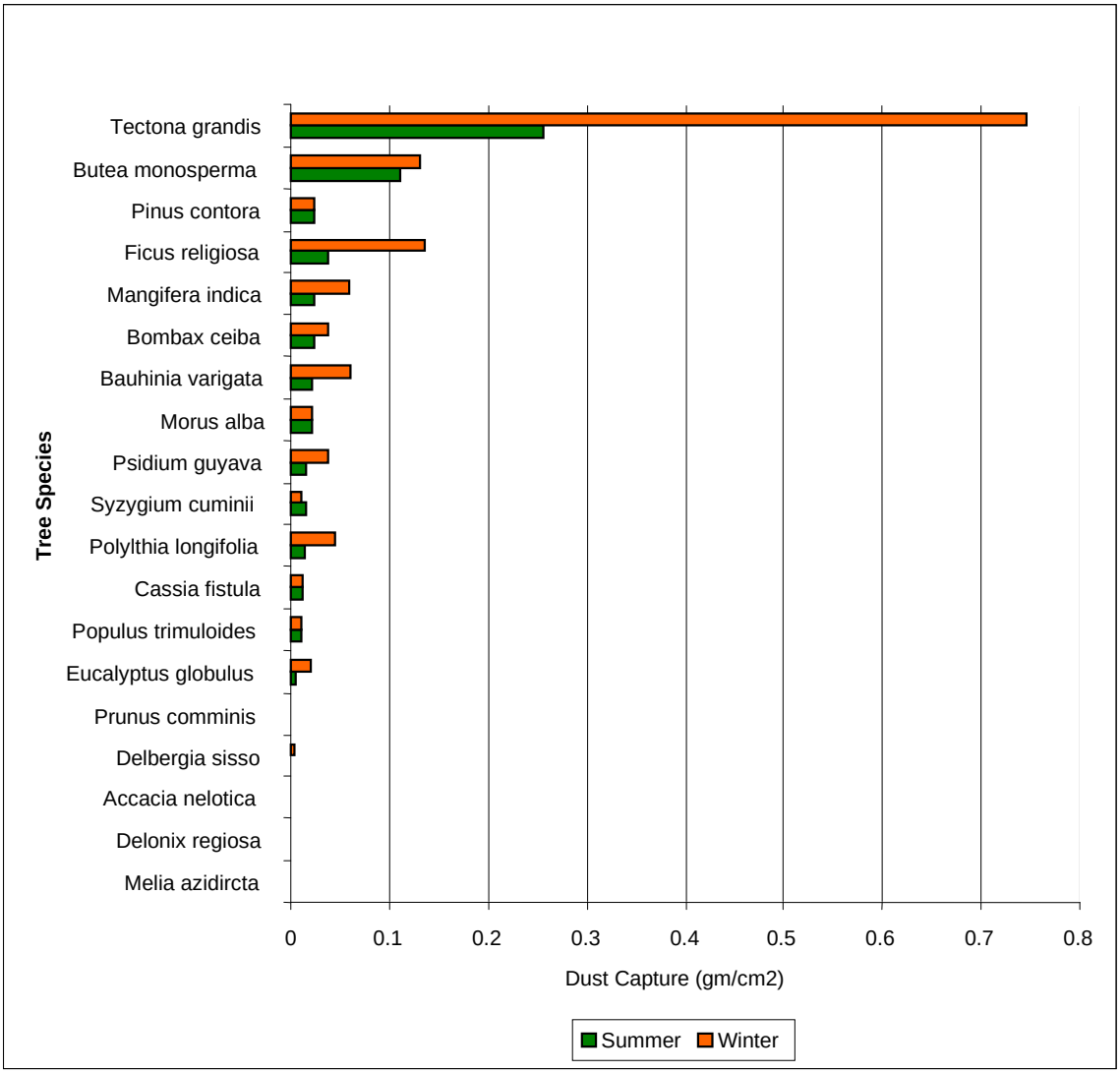


Fig. 5.33 : Average Dust captures of Leaf of Trees during Summer & Winter in Vicinity of Stone Crusher

The Dust capturing efficiency of plant species was determined with respect to the Canopy area (Crown Area of Plants in meter^2) during Summer & Winter Season (Table 5.18). The salient observations are:

- The Maximum Dust capturing efficiency of Herbs based on canopy area (Fig. 5.34) ranged from 1.87 gm/m^2 to 2.17 gm/m^2 with an average of 2.02 gm/m^2, minimum 1.27 to 1.41 gm/m^2 with an average of 1.34 gm/m^2. The maximum Dust capturing leaf of Herb is *Tegetese minuta* whereas the minimum dust capturing leaf of Herb is *Celosia argenta*.

- The Maximum Dust capturing efficiency of Shrubs based on canopy area (Fig. 5.35) ranged from 82.01 gm/m^2 to 332.26 gm/m^2 with an average of 207.135 gm/m^2 to Minimum 4.67 to 4.87 gm/m^2 with an average of 4.77 gm/m^2. The maximum Dust capturing leaf of Shrubs was *Bambusa species* whereas the minimum dust capturing leaf of Herb is *Withania somnifera*.

- The Maximum Dust capturing efficiency of Trees based on canopy area (Fig. 5.36) ranged from 2740.73 gm/m^2 to 6084.44 gm/m^2 with an average of 5782.95 gm/m^2 to Minimum 26.43 to 34.01 gm/m^2 with an average of 30.22 gm/m^2. The maximum Dust capturing leaf of Tree is *Tectona grandis* whereas the minimum dust capturing leaf of Tree was *Prunus comminis.*

Table 5.18: Average Dust Capture Efficiency of Plant Species in Vicinity of Stone Crusher, Hardwar

S. No.	Common Name	Botanical Name	Family	Dust Capture based on plant canopy ara gm/m^2		
				Summer	Winter	Average
HERBS						
1	Cock'scomb	Celosia argentea	Amaranthaceae	1.27	1.41	1.34
2	CrownDaisy	Chrysanthamum	Astraceae	1.69	1.98	1.835
3	Genda	Tagetese minuta	Asteraceae	2.17	1.87	2.02
SHRUBS						
4	Ashgandh	Withania somnifera	Solanceae	4.87	4.67	4.77
5	Rose	Rosa indica	Rosaceae	9.19	2.48	5.835
6	Croton	Croton oblongifolius	Euphorbiaceae	7.50	9.32	8.41
7	Chandani	Tabernaemontana divaricata	Apocyanaceae	24.18	57.68	28.84
8	Beshram	Ipomea nil	Convulvulaceae	45.74	27.46	36.6
9	Bougainvillea	Bougainvillea glavara	Nyctagenaceae	166.39	34.44	100.415
10	Bamboo	Bambusa	Rutaceae	332.26	82.01	207.135
TREES						
11	Plum	Prunus comminis	Rosaceae	26.43	34.01	30.22
12	Popular	Populus trimuloides	Salicaceae	95.67	97.84	96.755
13	Amrood	Psidium guyava	Myrtaceae	133.89	290.75	212.32
14	Amaltas	Cassia fistula	Caesalpiniaceae	301.55	291.30	246.43
15	Jamun	Syzygium cuminii	Myrtaceae	380.39	430.36	405.38
16	Pine	Pinus contora	Pnaceae	445.91	422.68	434.295
17	Mulbery	Morus alba	Moraceae	650.35	629.74	640.045
18	Shisham	Delbergia sisso	Papilionaceae	290.18	994.04	642.11
19	Palas	Butea monosperma	Fabaceae	596.46	783.69	690.075
20	Melia	Melia azidircta	Meliaceae	352.28	1121.99	737.135
21	Kachnar	Bauhinia varigata	Caesalpinaceae	563.66	917.86	740.76
22	Blue Gum	Eucalyptus globulus	Myrtaceae	504.69	1792.82	1148.755
23	Mango	Mangifera indica	Anacardiaceae	754.99	1775.70	1265.345
24	Ashoka	Polylthia longifolia	Annoniaceae	628.71	3306.89	1967.8
25	Gulmohor	Delonix regiosa	Caesalpinaceae	2655.04	2762.68	2708.86
26	Samal	Bombax ceiba	Malvaceae	2322.39	3815.72	3069.055
27	Peepal	Ficus religiosa	Moraceae	1229.85	5099.66	3164.33
28	Babul	Accacia nelotica	Mimoseae	3528.86	3982.57	3755.715
29	Teak	Tectona grandis	Verbenaceae	2740.73	6084.44	5782.95

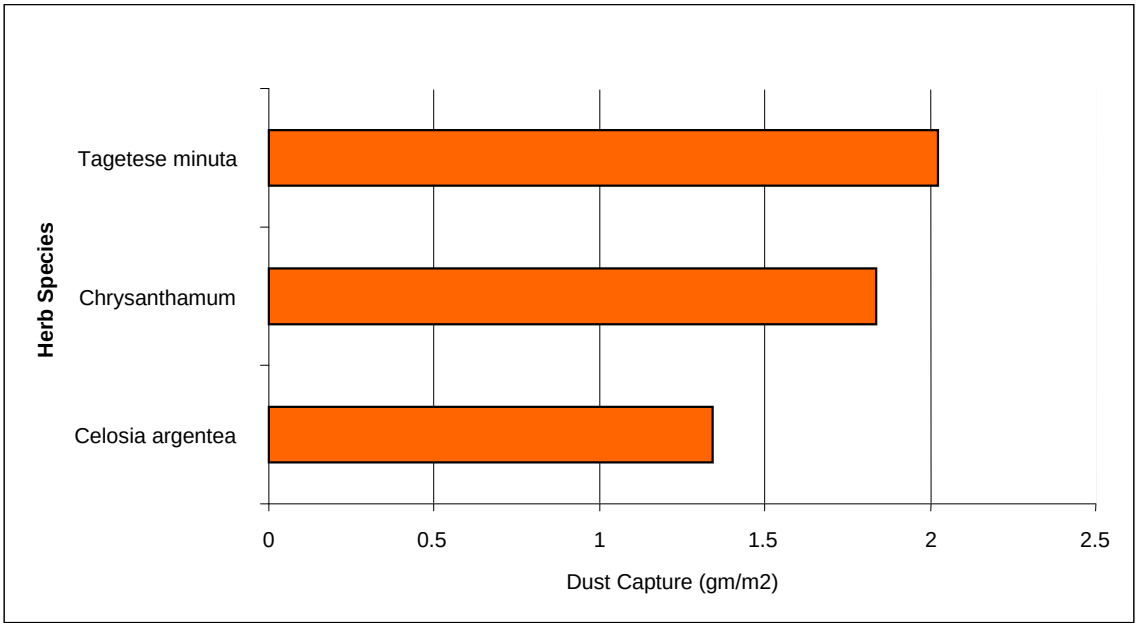


Fig. 5.34 : Average Dust Capture Efficiency of Herbs based on Plant Canopy Area in Vicinity of Stone Crusher

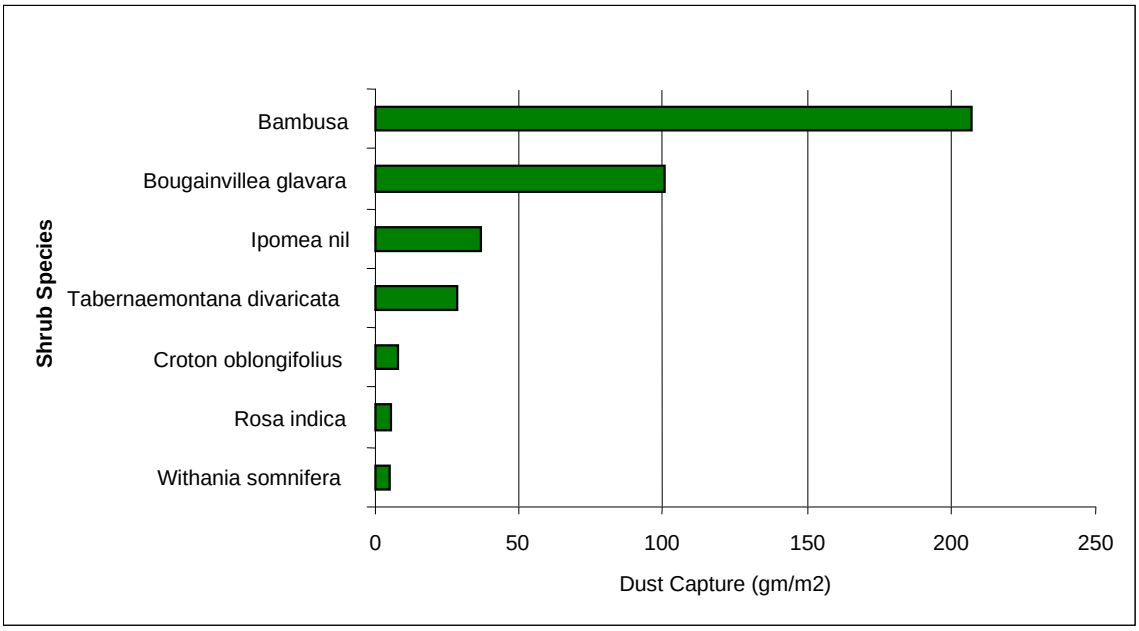


Fig. 5.35 : Average Dust Capture Efficiency of Shrubs based on Plant Canopy Area in Vicinity of Stone Crusher at Hardwar

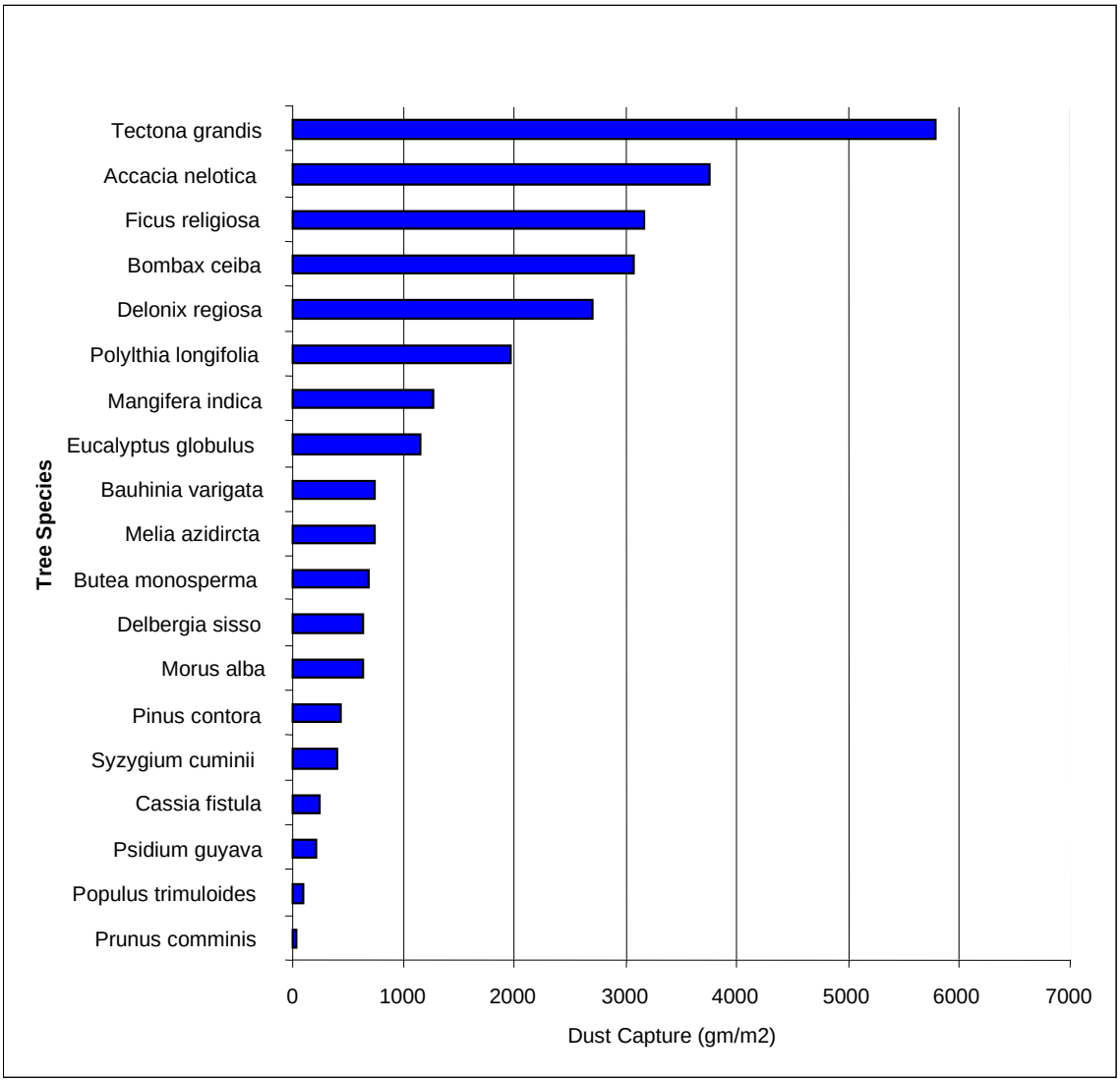


Fig. 5.36 : Average Dust Capture Efficiency of Trees based on Plant Canopy Area in Vicinity of Stone Crusher

5.7 DUST CAPTURING EFFICIENCY OF PLANT SPECIES IN VICINITY OF THERMAL POWER STATION, HARIDWAR

The Thermal Power Station are produces large quantity of dust due to Coal burning in which large amount of fly ash also produced which is a major problem of fugitive emission.

The case study in vicinity of Thermal Power Plant at Haridwar was selected. Identification of Sampling Station has been done on the basis of area of High SPM level at all the four directions & inside the Factory premises.

Table 5.19: Sampling Locations in vicinity of Thermal Power Station at Haridwar

S. No.	Sampling Location
01	Inside Thermal Power Station Industry
02	East Side of Thermal Power Station Industry
03	West Side of Thermal Power Station Industry
04	North Side of Thermal Power Station Industry
05	South of Thermal Power Station Industry

5.7.1 Average Dust Capture Efficiency by Leaf of Plant Species in vicinity of Thermal Power Station during Summer & Winter

- The average Dust capturing efficiency of Leaf of Herbs ranged from 0.0011 gm/cm^2 to 0. 014 gm/cm^2 at At the vicinity of Thermal Power Station at Hardwar. The Dust capturing leaf of Herb was 0.0011 gm/cm2 during summer & 0.0014 gm/cm2 during winter by a leaf of *Tagetes patula* were observed at the vicinity of Thermal Power Station, Hardwar**.** (Fig. 5.37)

- The average Dust capturing efficiency of Leaf of Shrubs (Fig. 5.38) ranged from 0.0014 gm/cm^2 to 0.6103 gm/cm^2 during summer and 0.0132 gm/cm^2 to 0.6275 gm/cm^2 during winter at At the vicinity of Thermal Power Station at Hardwar. The maximum Dust capturing leaf of Shrub was *Withania somnifera* whereas the minimum dust capturing leaf of Shrub was *Hibiscus rosa sinensis*.

- The average Dust capturing efficiency of Leaf of Trees ranged from 0.0002 gm/cm^2 to 0.2943 gm/cm^2 during summer and 0.0002 gm/cm^2 to 0.2932 gm/cm^2 during winter at At the vicinity of Thermal Power Station, Hardwar (Fig.5.39). The maximum Dust capturing leaf of Tree was *Ficus bengalensis* whereas the minimum dust capturing leaf of Tree was *Delonix regiosa.*

Table 5.20: **Average Dust capture of Leaf of Plant Species in vicinity of Thermal Power Station, during Summer & Winter**

S. No.	Common Name	Botanical Name	Family	Dust Capture/Leaf gm/cm^2	
				Summer	Winter
HERBS					
1	Genda	Tagetes patula	Asteraceae	0.0011	0.0014
2	Gurhal	Hibiscus rosa sinensis	Malvaceae	0.0014	0.0132
3	Bougainvillea	Bougainvillea	Nyctaginaceae	0.0015	0.0019
4	Yellow Kaner	Thevetia peruviana	Apocyanacea	0.0033	0.0041
5	Rose	Rosa indica	Rosaceae	0.0045	0.0052
6	Temple Tree	Plumaria acuminata	Apocyanaceae	0.0077	0.0075
7	Crape Myrtle	Lagerstroemia indica	Lythraceae	0.0077	0.0087
8	Chandani	Tabernaemontana divaricata	Apocyanaceae	0.1499	0.023
9	Asgandh	Withania somnifera	Solancea	0.6103	0.6275
TREES					
10	Gulmohar	Delonix regiosa	Caesalpiniaceae	0.0002	0.0002
11	Babul	Accacia nelotica	Mimosaceae	0.0002	0.0002
12	Bottle Brush	Callistemon laceolatus	Myrtaceae	0.0005	0.0007
13	Shoe Babul	Leacena leucophloea	Mimosaceae	0.0005	0.0004
14	Neem	Azardirachta indica	Meliaceae	0.0012	0.0017
15	Blue gum	Eucalyptus globulus	Myrtaceae	0.0020	0.0027
16	Plums	Prunus comminis	Rosaceae	0.0022	0.0026
17	Lemon	Citrus limon	Rutaceae	0.0039	0.0044
18	Shesham	Delbergia sisso	Papilionaceae	0.0067	0.0065
19	Kanchnar	Bauhinia variegata	Caesalpiniaceae	0.0075	0.0079
20	Sal	Shorea robusta	Dipterocarpaceae	0.0078	0.0058
21	Pilkhan	Ficus infectorja	Moraceae	0.0085	0.0081
22	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	0.0098	0.0103
23	Ashoka	Polyalthia longifolia	Annoniaceae	0.0108	0.0115
24	Vilayati Kikkar	Acacia farnesiana	Mimosaceae	0.0241	0.0286
25	Bel	Aegle mamelos	Rutaceae	0.0281	0.0276
26	Semal	Bombax ceiba	Bombaceae	0.0358	0.0371
27	Mango	Mangifera indica	Anacardiaceae	0.0436	0.0388
28	Amaltas	Cassia fistula	Caesalpiniceae	0.0445	0.0428
29	Amrood	Psidium guyava	Myrtaceae	0.0505	0.0495
30	Palas	Butea monosperma	Fabaceae	0.0646	0.0611
31	Jamun	Syzygium cuminii	Myrtaceae	0.0845	0.0877
32	Teak	Techtona grandis	Verbeniaceae	0.2087	0.2181
33	Peepal	Ficus religiosa	Moraceae	0.2844	0.2518
34	Banyan Tree	Ficus bengalensis	Moraceae	0.2943	0.2932

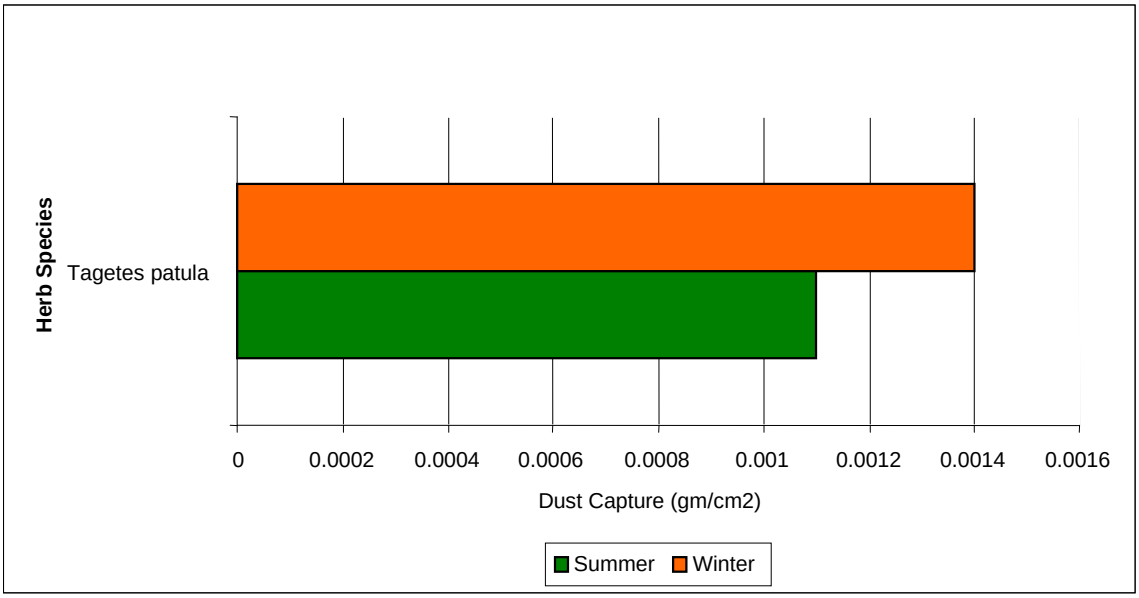


Fig. 5.37 : Average Dust capture of Leaf of Herbs during Summer & Winter in vicinity of Thermal Power Station, Hardwar

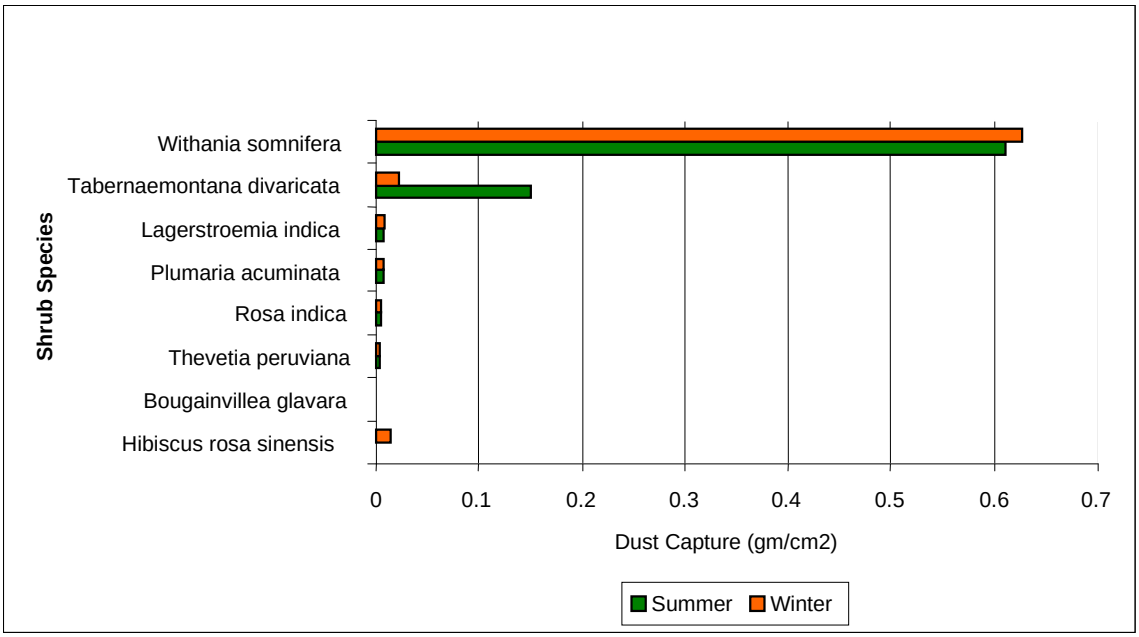


Fig. 5.38: Average Dust capture of Leaf of Shrubs during Summer & Winter in vicinity of Thermal Power Station, Hardwar

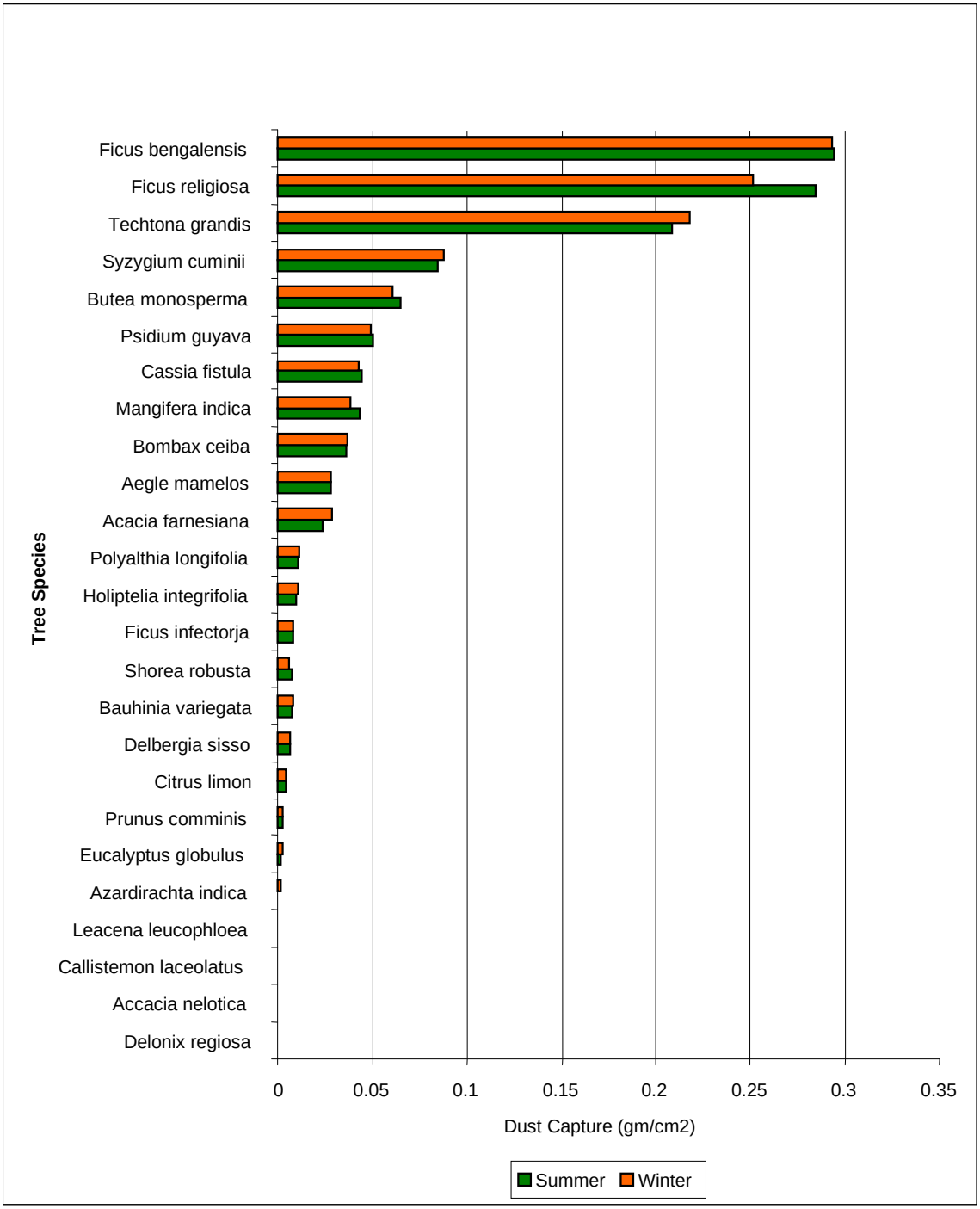


Fig. 5.39 : Average Dust capture of Leaf of Trees during Summer & Winter in vicinity of Thermal Power Station

The Dust capturing efficiency of plant species were also determined with respect to the Canopy area (Crown Area of Plants in meter^2) during Summer & Winter Season. The observations are as below:

- The Average Dust capturing efficiency of Herbs based on plant canopy area ranged from 3.27 gm/m^2 to 3.65 gm/m^2 with an average of 3.5 gm/m^2 in *Tegetese minuta)* were observed at At the vicinity of Thermal Power Station at Hardwar.

- The Average Maximum Dust capturing efficiency of Shrubs based on plant canopy area ranged from 39 gm/m^2 to 227.33 gm/m^2 with an average of 133.2 gm/m^2 to Minimum 1.45 to 1.62 gm/m^2 with an average of 1.5 gm/m^2.The maximum Dust capturing leaf of Shrub was *Tabernaemontana divaricata* whereas the minimum dust capturing leaf of Shrub was *Rosa indica*.

- The average Maximum Dust capturing efficiency of Trees based on plant canopy area ranged from 5903.01 gm/m^2 to 6142.3 gm/m^2 with an average of 6022.70 gm/m^2 to Minimum 21.01 to 23.95 gm/m^2 with an average of 22.50 gm/m^2. The average maximum Dust capturing leaf of Tree is *Ficus bengalensis* whereas the minimum dust capturing leaf of Herb is *Prunus comminis.*

Table 5.21: Average Dust capture of Leaf of Plant Species in vicinity of Thermal Power Station, Hardwar during Summer & Winter

S. No	Common Name	Botanical Name	Family	Dust Capture by Plant (meter^2)		
				Summer	Winter	Average
HERBS						
1	Genda	Tagetes patula	Asteraceae	3.27	3.65	3.5
SHRUBS						
2	Rose	Rosa indica	Rosaceae	1.45	1.62	1.5
3	Asgandh	Withania somnifera	Solancea	8.36	7.34	7.9
4	Bougainvillea	Bougainvillea glavara	Nyctaginaceae	10.15	13.21	11.7
5	Gurhal	Hibiscus rosa sinensis	Malvaceae	2.78	25.89	14.3
6	Yellow Kaner	Thevetia peruviana	Apocyanacea	14.56	15.87	15.2
7	Temple Tree	Plumaria acuminata	Apocyanaceae	28.21	23.18	25.7
8	Crape Myrtle	Lagerstroemia indica	Lythraceae	75.43	67.69	71.6
9	Chandani	Tabernaemontana divaricata	Apocyanaceae	227.33	39.16	133.2
TREES						
10	Plums	Prunus comminis	Rosaceae	21.01	23.95	22.5
11	Lemon	Citrus limon	Rutaceae	24.97	28.18	26.6
12	Neem	Azardirachta indica	Meliaceae	33.79	45.41	39.6
13	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	140.74	145.1	142.9
14	Bottle Brush	Callistemon laceolatus	Myrtaceae	174.01	206.42	190.2
15	Amrood	Psidium guyava	Myrtaceae	323.35	316.99	320.2
16	Blue gum	Eucalyptus globulus	Myrtaceae	350.52	492.08	421.3
17	Ashoka	Polyalthia longifolia	Annoniaceae	461.92	438.69	450.3
18	Kanchnar	Bauhinia variegata	Caesalpiniaceae	468.09	458.8	463.4
19	Palas	Butea monosperma	Fabaceae	511.72	483.26	497.5
20	Shoe Babul	Leacena leucophloea	Mimosaceae	618.84	582.44	600.6
21	Sal	Shorea robusta	Dipterocarpaceae	346.51	1113.1	729.8
22	Amaltas	Cassia fistula	Caesalpiniceae	772.26	711.21	741.7
23	Shesham	Delbergia sisso	Papilionaceae	1167.7	925.13	1046.4
24	Jamun	Syzygium cuminii	Myrtaceae	1318.87	1390.9	1354.9
25	Gulmohar	Delonix regiosa	Caesalpiniaceae	1429.64	1281.7	1355.7

S. No	Common Name	Botanical Name	Family	Dust Capture by Plant (meter^2)		
				Summer	Winter	Average
26	Mango	Mangifera indica	Anacardiaceae	1417.84	1574.2	1496.0
27	Pilkhan	Ficus infectorja	Moraceae	1393.05	1628.2	1510.6
28	Teak	Techtona grandis	Verbeniaceae	1752.35	1754.9	1753.4
29	Bel	Aegle mamelos	Rutaceae	1510.85	1388.6	1449.7
30	Vilayati Kikkar	Acacia farnesiana	Mimosaceae	2617.15	2335.9	2476.6
31	Babul	Accacia nelotica	Mimosaceae	3097.55	2478.0	2787.8
32	Semal	Bombax ceiba	Bombaceae	2833.73	2888.6	2861.2
33	Peepal	Ficus religiosa	Moraceae	5582.91	5426.9	5504.9
34	Banyan Tree	Ficus bengalensis	Moraceae	5903.01	6142.3	6022.7

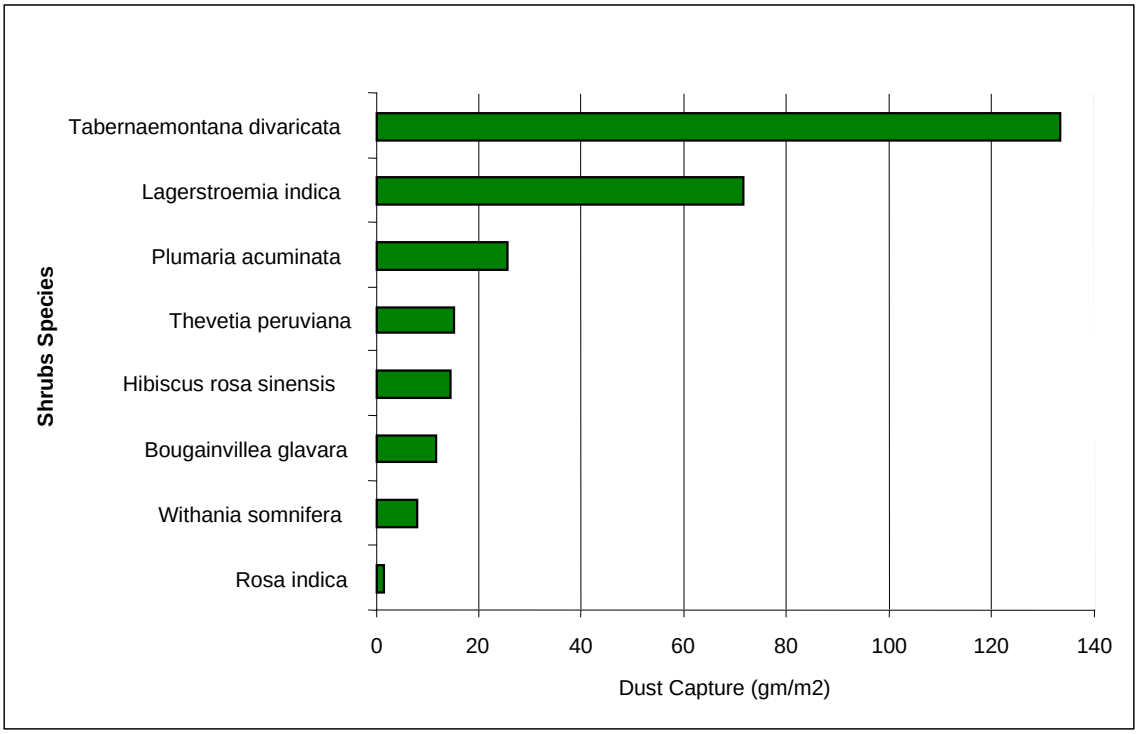


Fig. 5.40 : Average Dust capture by Shrubs during Summer & Winter in vicinity of Thermal Power Station

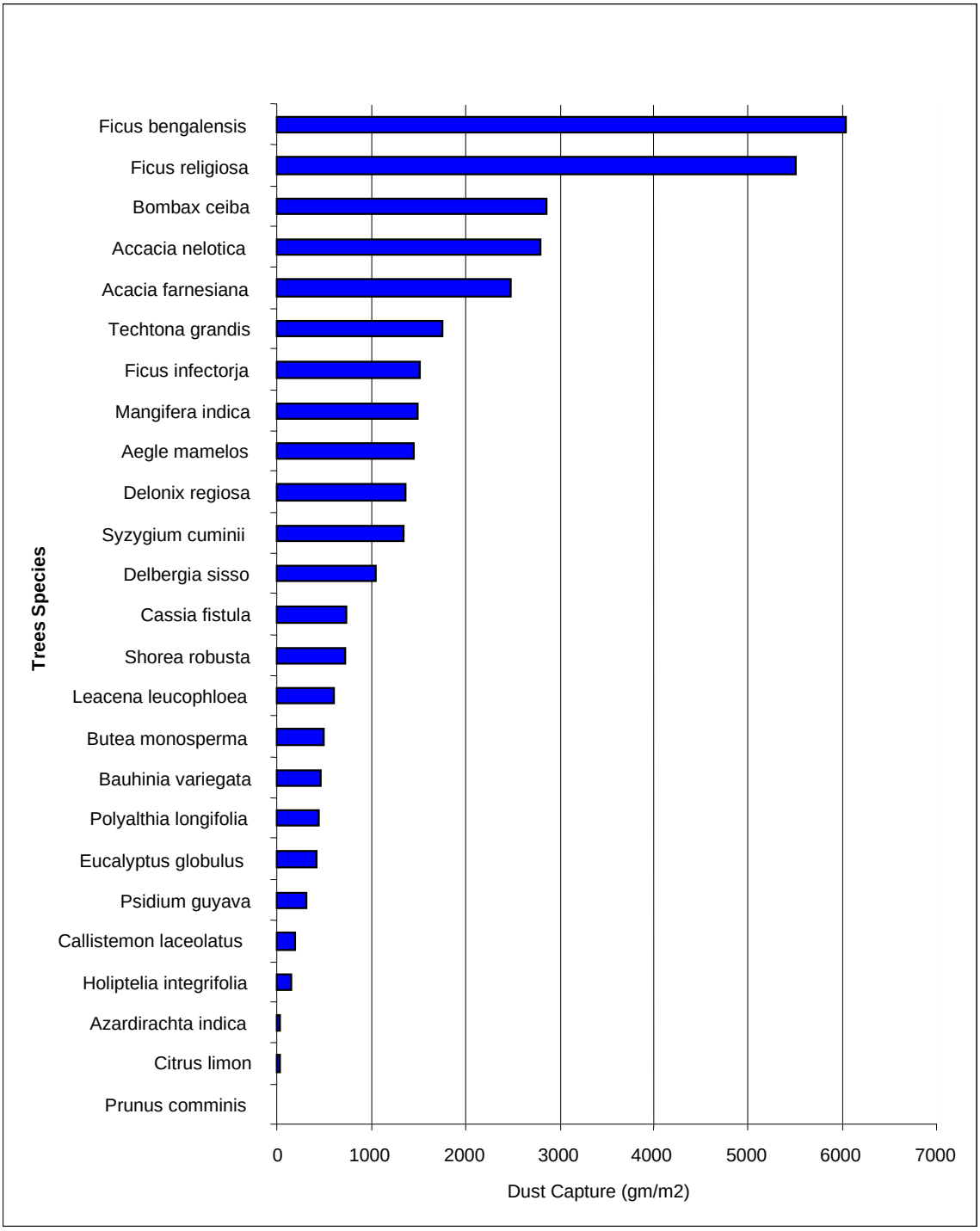


Fig. 5.41 : Average Dust capture by Trees during Summer & Winter in vicinity of Thermal Power Station, Hardwar

- The Average Dust capturing efficiency of Herbs ranged from 3.27 gm/m^2 to 3.65 gm/m^2 with an average of 3.5 gm/m^2 in *Tegetese minuta)* has been only monitored in vicinity of Thermal Power Station, Hardwar (Fig 5.39).

- The Average Maximum Dust capturing efficiency of Shrubs 133.2 gm/m^2 to Minimum 1.5 gm/m^2. The average maximum Dust capturing leaf of Shrub was *Tabernaemontana divaricata whereas* the minimum dust capturing leaf of Shrub was *Rosa indica*. (Fig.5.40)

- The average Maximum Dust capturing efficiency of Trees was from 6022.70 gm/m^2 to Minimum 22.50 gm/m^2. The average maximum Dust capturing leaf of Tree is *Ficus bengalensis whereas* the minimum dust capturing leaf of Herb is *Prunus comminis.* (Fig. 5.41)

5.8 FIELD EXPERIMENTAL STUDIES TO ASSESS DUST CAPTURING EFFICIENCY OF PLANTS

The studies was conducted with the highly dust capturing plant species identified during field studies during summer & winter season at Stone Crusher Unit & in Vicinity of Thermal Power Station situated at Hardwar. The objective of experimental study was "*to study relative exposure vs dust capturing capacity of various identified plant species*" and to determined retention capacity of leaf of the highly dust capturing plant species.

METHODOLOGY

On the basis of field observations of various dust capturing plant species at Mumbai, Delhi, Kolkata, Dhanbad, Paonta Sahib & Hardwar, 20 plant species were selected for the Pot Culture experiment and these plant species were Exposed to High Dust producing Environment i.e. in vicinity of Stone Crusher & Thermal Power Station. The plants sampling were grown in Nursery by their Seeds/seedling/cutting. The attempt has been made to keep uniform Plant height & diameter of Crown Area (Leaf Covered Area) at the two selected sites.

The Dust Fall Jars were installed following method detailed in IS 5182 (Part-1) -1069 in vicinity of Stone Crusher & Thermal Power Station. The quantity of Dust Deposition in Dust Fall Jar were estimated as per the method IS 5182 (Part 1) – 1969. The leaves of the exposed plant species were observed weekly along with the other related parameters like plant growth Plant height, Leaf Area by Leaf Area Meter and Graphical Method, & diameter of Leaf Crown Area.

5.8.1 Observations in Vicinity of Stone Crusher

Weekly observation was taken for Dust Deposition in Dust Fall Jar & on various plant species exposed at Stone Crusher site. The detailed Results of analysis of Dust Quantity, Leaf Area & Dust Retention are presented in Table 5.22. The Dust retention capacity of various plant species of Herbs, Shrubs & Trees were calculated considering Plant Height (cm), Leaf Area (cm^2), Crown Area of Plant (cm^2), Diameter of Crown Area of Plant (cm2) and The Dust Deposition on Leaf (gm/cm^2). The following are the salient observations:

- The average dust retention on leaf of Herbs species were ranged from 0.09 to 0.48 gm/cm^2 and the total retention of dust by Herbs plant species was ranges from 0.86 to 4.82 gm/cm^2. It is seen that *Tagetese patula* (Genda) has retained highest dust 4.82 gm/cm^2 then the *Colcasia argentea* (Cock scumbh) 2.32 gm/cm^2 then the *Colocasia antiquorum* (Elephant's Ear) 0.86 gm/cm^2 at Stone Crusher, Hardwar (Fig. 5.42)

- The average dust retention on leaf of the Shrubs species was 0.09 gm/cm^2 and the total retention of dust by shrubs plant species was ranges from 0.32 to 1.01 gm/cm^2. It is seen that *Bougainvillea glavara* (Bougainvillea) has retained highest dust 1.01 gm/cm^2 then the *Tabermaemontana divaricata* (Chandani) 0.70 gm/cm^2 then the *Ipomea nil* (Beshram) 0.49 gm/cm^2 then the *Acalypha hispida* (Copper Leaf) 0.32 gm/cm^2 at Stone Crusher, Hardwar (Fig. 5.43)

- The average dust retention on leaf of all the Trees ranged from 0.09 to 3.71 gm/cm^2 and the total retention of dust by Tree plant species was ranges from 1.01 to 5.57 gm/cm^2. It has been observed that *Cassia fistula* (Amaltas) has retained highest dust 5.57 gm/cm^2 while *Populus trimuloides* (Popular) has retained lowest dust i.e. 0.10 gm/cm^2 near Stone Crusher at Haridwar (Fig. 5.44).

Table 5.22: Dust Retention Capacity of Herb Shrubs & Trees at Stone Crusher, Haridwar

S. No	Common Name	Botanical Name	Family	Dust Fall in 7 days (gm/cm^2)	Dust on leaf in 7 days (gm/cm^2)	Dust capture by tree in 7 days (gm/cm^2)
HERBS						
1	Elephant's Ear	Colocasia antiquorum	Araceae	0.33	0.09	0.86
2	Cock Scumb	Celosia argentea	Amaranthaceae	0.33	0.23	2.32
3	Genda	Tagetes patula	Asteraceae	0.33	0.48	4.82
SHRUBS						
4	Copper leaf	Acalypha hispida	Euphorbiaceae	0.33	0.09	0.32
5	Beshram	Ipomea nil	Convovulaceae	0.33	0.09	0.49
6	Chandani	Tabernaemontana divaricata	Apocyanaceae	0.33	0.09	0.70
7	Bougainvillea	Bougainvillea glavra	Nyctaginaceae	0.33	0.09	1.01
TREES						
8	Popular	Populus trimuloides	Siliaceae	0.33	0.08	0.10
9	Bottle Brush	Callistemon laceolatus	Myrtaceae	0.33	0.09	0.13
10	Jack Fruit	Artocarpus integrifolia	Moraceae	0.33	0.09	0.18
11	Arjun	Terminalia arjuna	Combrataceae	0.33	0.10	0.19
12	Jangal Badam	Termanilia catappal	Combrataceae	0.33	0.10	0.19
13	Blue gum	Eucalyptus globulus	Myrtaceae	0.33	0.09	0.21
14	Indian Rubber	Ficus elastica	Moraceae	0.33	0.09	0.26
15	Peepal	Ficus religiosa	Moraceae	0.33	0.11	0.30
16	Banyan Tree	Ficus bengalensis	Moraceae	0.33	0.10	0.29
17	Satni	Alstonia scholaris	Apocyanaceae	0.33	0.09	0.45
18	Kadam	Anthosephalus cadamba	Rubiaceae	0.33	0.11	0.46
19	Neem	Azardirachta indica	Meliaceae	0.33	0.09	2.61
20	Amaltas	Cassia fistula	Caesalpiniaceae	0.33	3.71	5.57

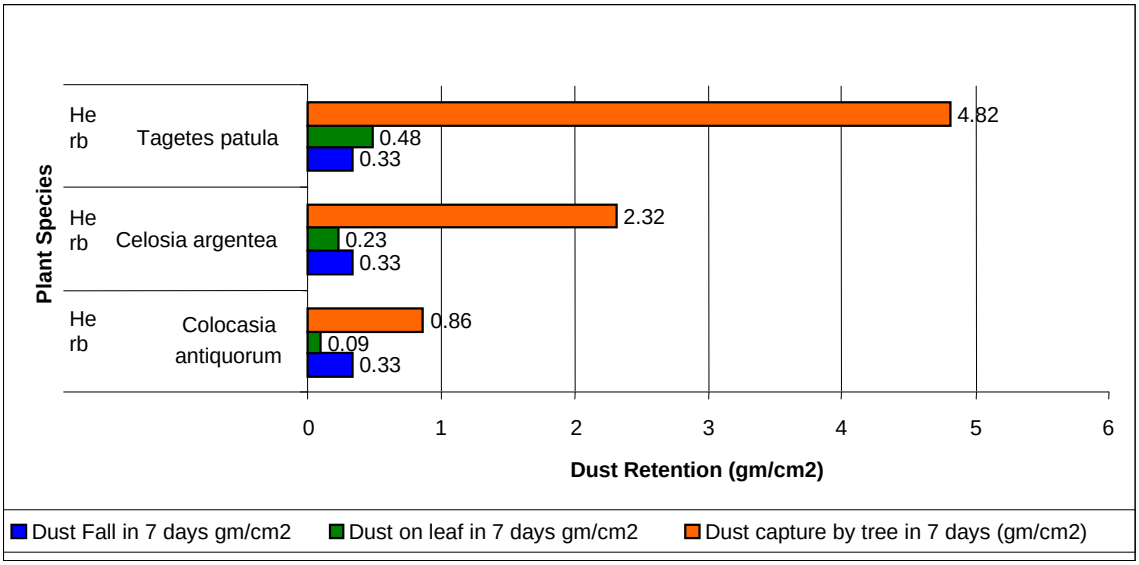


Fig. 5.42 : Dust Retention Capacities of Herbs Plant Species in Vicinity of Stone Crusher

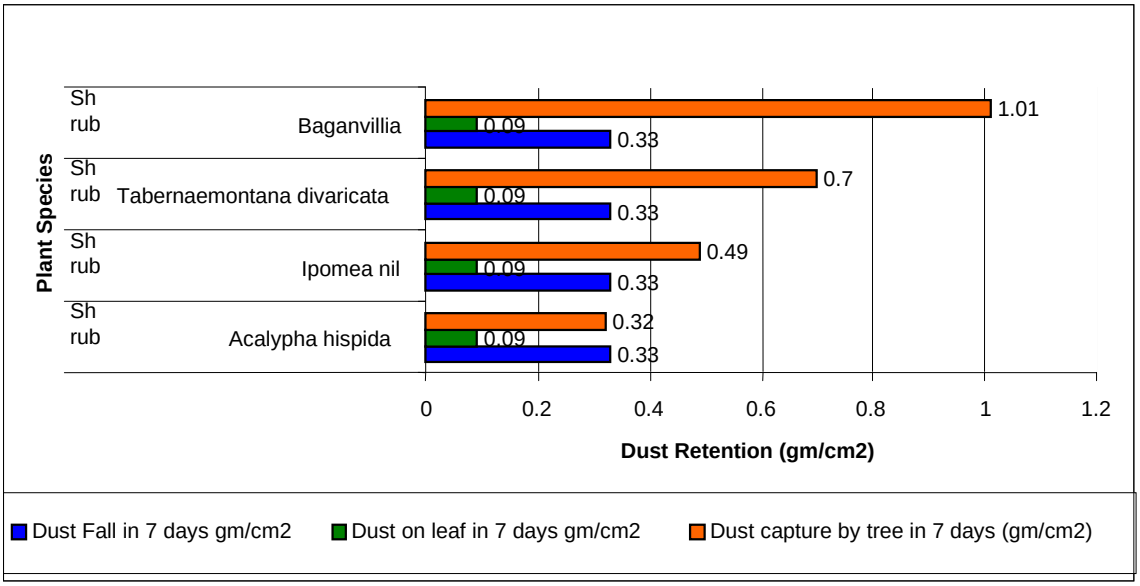


Fig. 5.43: Dust Retention Capacities of Shrubs Plant Species in Vicinity of Stone Crusher

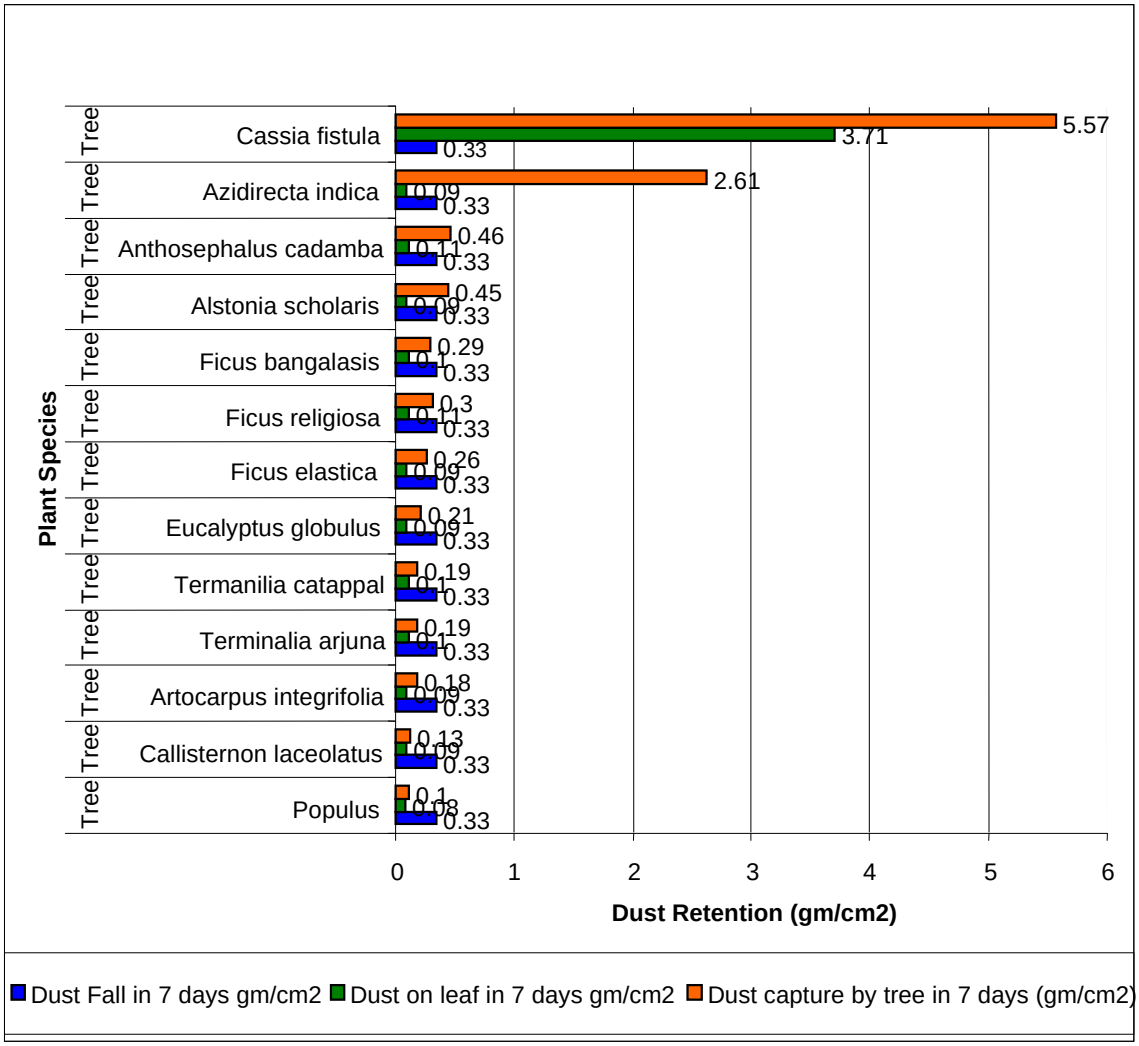


Fig. 5.44 : Dust Retention Capacities of Trees Plant Species in Vicinity of Stone Crusher

Table 5.23: DUST DEPOSITION ON DUST FALL JAR PLANT SPECIES UNDER POT CULTURE EXPERIMENT IN VICINITY OF STONE CRUSHER, HARIDWAR

S. No.	Common Name	Botanical Name	Family	1st Week			2nd Week			3rd Week			4th Week		
				Dust Fall Jar (gm)	Leaf Area	Dust (g/cm)	Dust Fall Jar(gm2)	Leaf Area cm2	Dust (g/cm2)	Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fal Jar (gm)	Leaf Area (cm2)	Dust (g/cm2)
HERBS															
1	Genda	Tagetes patula	Asteraceae	200	1.35	0.0008	215	1.4	0.001	230	1.48	0.002	242	1.68	0.002
2	Elephant's Ear	Colocasia antiquorum	Araceae	200	132.3	0.035	215	132	0.085	230	133	0.135	242	133	0.185
3	Cock'scomb	Celosia argentea	Amaranthaceae	200	19.03	0.009	215	19.5	0.014	230	20	0.019	242	20.5	0.235
SHRUBS															
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	200	44.64	0.042	215	44.7	0.092	230	45.2	0.142	242	45.7	0.192
5	Copper leaf	Acalypha hispida	Euphorbiaceae	200	42.88	0.027	215	42.9	0.077	230	43.4	0.127	242	43.9	0.177
6	Bougainvillea	Bougainvillea	Nyctaginaceae	200	25.54	0.03	215	25.9	0.08	230	26.1	0.13	242	26.6	0.18
7	Beshram	Ipomea nil	Convovulaceae	200	56.42	0.035	215	56.5	0.086	230	57	0.137	242	57.5	0.188
TREES															
8	Jack Fruit	Artocarpus integrifolia	Moraceae	200	86.45	0.089	215	86.6	0.139	230	87.1	0.189	242	87.6	0.239
9	Jangal Badam	Termanilia catappal	Combrataceae	200	155.8	0.157	215	116	0.657	230	156	0.157	242	157	1.657
10	Bottle Brush	Callistemon laceolatus	Myrtaceae	200	8.81	0.007	215	8.9	0.012	230	9.4	0.017	242	9.9	0.022
11	Amaltas	Cassia fistula	Caesalpiniaceae	200	48.91	0.072	215	49	0.122	230	49.5	0.172	242	50	2221
12	Satni	Alstonia scholaris	Apocyanaceae	200	50.1	0.045	215	50.6	0.095	230	51.1	0.145	242	51.6	0.195
13	Popular	Populus trimuloides	Salicaceae	200	104.9	0.011	215	105	0.016	230	105	0.021	242	106	0.026
14	Blue gum	Eucalyptus globulus	Myrtaceae	200	45.68	0.02	215	45.7	0.07	230	46.2	0.12	242	46.7	0.17
15	Neem	Azardirachta indica	Meliaceae	200	5.03	0.002	215	5.08	0.007	230	5.58	0.012	242	6.08	0.017
16	Banyan	Ficus bengalensis	Moraceae	200	171	0.539	215	171	1.039	230	172	1.539	242	172	2.039
17	Indian Rubber	Ficus elastica	Moraceae	200	266.3	0.529	215	267	1.029	230	267	1.529	242	268	2.029
18	Peepal	Ficus religiosa	Moraceae	200	124.1	0.136	215	124	0.636	230	125	1.136	242	125	1.636
19	Arjun	Terminalia arjuna	Combrataceae	200	21.86	0.017	215	21.1	0.067	230	22.4	0.117	242	22.9	0.167
20	Kadam	Anthosephalus cadamba	Rubiaceae	200	196	0.146	215	196	0.646	230	197	1.146	242	197	1.646

Table 5.24 : DUST DEPOSITION ON DUST FALL JAR & PLANT SPECIES UNDER POT CULTURE EXPERIMENT IN VICINITY OF STONE CRUSHER, HARIDWAR

S. No.	Common Name	Botanical Name	Family	5th Week			6th Week			7th Week			8th Week		
				Dust Fall Jar(gm)	Leaf Area	Dust (g/cm)	Dust Fal Jar(gm)	Leaf Area Cm2	Dust (g/cm2)	Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fal Jar (gm)	Leaf Area (cm2)	Dust (g/cm2)
HERBS															
1	Genda	Tagetes patula	Asteraceae	255	1.9	0.003	265	21.5	0.0033	280	2.25	0.004	290	2.4	0.0043
2	Elephant's Ear	Colocasia antiquorum	Araceae	255	134	0.235	265	134.2	0.2854	280	134.8	0.335	290	135.5	0.3854
3	Cock'scomb	Celosia argentea	Amaranthaceae	255	21	0.029	265	71.6	0.0335	280	22.1	0.039	290	22.8	0.0435
SHRUBS															
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	255	46.2	0.242	265	46.72	0.2915	280	48.3	0.342	290	48.81	0.3915
5	Copper leaf	Acalypha hispida	Euphorbiaceae	255	44.4	0.227	265	45	0.2767	280	45.6	0.327	290	46.15	0.3767
6	Bougainvillea	Bougainvillea	Nyctaginaceae	255	27.1	0.23	265	27.7	0.2802	280	28.31	0.33	290	28.9	0.3802
7	Beshram	Ipomea nil	Convovulaceae	255	58	0.239	265	58.6	0.2903	280	59.2	0.341	290	59.8	0.3923
TREES															
8	Jack Fruit	Artocarpus integrifolia	Moraceae	255	88.1	0.289	265	88.62	0.3391	280	89.11	0.389	290	89.7	0.4391
9	Jangal Badam	Termanilia catappal	Combrataceae	255	157	2.157	265	157.7	2.6572	280	158.3	3.157	290	158.9	3.6572
10	Bottle Brush	Callistemon laceolatus	Myrtaceae	255	10.4	0.027	265	10.72	0.0319	280	11.05	0.037	290	11.4	0.0419
11	Amaltas	Cassia fistula	Caesalpiniaceae	255	50.6	0.272	265	51.08	0.3221	280	51.6	0.372	290	52.1	0.4221
12	Satni	Alstonia scholaris	Apocyanaceae	255	52.1	0.245	265	52.6	0.2947	280	53.2	0.345	290	53.81	0.3947
13	Popular	Populus trimuloides	Salicaceae	255	106	0.031	265	107	0.0359	280	107.61	0.041	290	108.2	0.0459
14	Blue gum	Eucalyptus globulus	Myrtaceae	255	47.3	0.22	265	47.92	0.2697	280	48.5	0.32	290	49.1	0.3697
15	Neem	Azardirachta indica	Meliaceae	255	6.6	0.022	265	7	0.0268	280	7.3	0.032	290	7.6	0.0368
16	Banyan	Ficus bengalensis	Moraceae	255	173	2.539	265	173.5	.0.386	280	174.1	3.539	290	174.6	4.0386
17	Indian Rubber	Ficus elastica	Moraceae	255	268	2.529	265	269.2	3.0291	280	271.1	3.529	290	272.5	4.0293
18	Peepal	Ficus religiosa	Moraceae	255	126	2.136	265	126	2.6364	280	126.6	3.137	290	127.1	3.6366
19	Arjun	Terminalia arjuna	Combrataceae	255	23.2	0.217	265	23.5	0.2673	280	23.8	0.317	290	24	0.3673
20	Kadam	Anthosephalus cadamba	Rubiaceae	255	197	2.146	265	197.8	2.646	280	198.2	3.146	290	198.5	3.646

Table 5.25: DUST DEPOSITION ON DUST FALL JAR & PLANT SPECIES UNDER POT CULTURE EXPERIMENT IN VICINITY OF STONE CRUSHER, HARDWAR

S. No.	Common Name	Botanical Name	Family	9th Week			10th Week			11th Week			12h Week		
				Dust Fall Jar(gm)	Leaf Area	Dust (g/cm)	Dust Fall Jar (gm)	Leaf Area Cm2	Dust (g/cm2)	Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fal Jar (gm)	Leaf Area (cm2)	Dust (g/cm2)
HERBS															
1	Genda	Tagetes patula	Asteraceae	300	2.5	0.0048	309	2.61	0.005	320	2.75	0.0058	330	2.9	0.006
2	Elephant's Ear	Colocasia antiquorum	Araceae	300	136.05	0.4354	309	136.55	0.485	320	137	0.5354	330	138	0.585
3	Cock'scomb	Celosia argentea	Amaranthaceae	300	23.42	0.0485	309	23.95	0.054	320	24.5	0.0585	330	25	0.064
SHRUBS															
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	300	49.35	0.4415	309	49.9	0.492	320	50.4	0.5415	330	50.9	0.592
5	Copper leaf	Acalypha hispida	Euphorbiaceae	300	46.6	0.4267	309	47.2	0.477	320	47.8	0.5267	330	48.4	0.577
6	Bougainvillea	Bougainvillea	Nyctaginaceae	300	29.41	0.4302	309	29.9	0.48	320	30.4	0.5302	330	30.8	0.58
7	Beshram	Ipomea nil	Convovulaceae	300	60.3	0.4433	309	60.8	0.494	320	61.3	0.5453	330	61.9	0.596
TREES															
8	Jack Fruit	Artocarpus integrifolia	Moraceae	300	90.2	0.4891	309	90.7	0.539	320	91.1	0.5891	330	91.6	0.639
9	Jangal Badam	Termanilia catappal	Combrataceae	300	159.5	4.1572	309	180.1	4.657	320	161	5.1572	330	161	5.657
10	Bottle Brush	Callistemon laceolatus	Myrtaceae	300	11.7	0.0469	309	12	0.052	320	12.4	0.0569	330	12.7	0.062
11	Amaltas	Cassia fistula	Caesalpiniaceae	300	52.6	0.4721	309	52.2	0.522	320	52.7	0.5721	330	53.1	0.622
12	Satni	Alstonia scholaris	Apocyanaceae	300	54.3	0.4447	309	54.8	0.495	320	55.2	0.5447	330	55.6	0.597
13	Popular	Populus trimuloides	Salicaceae	300	108.7	0.0509	309	109.2	0.056	320	110	0.0609	330	110	0.066
14	Blue gum	Eucalyptus globulus	Myrtaceae	300	49.5	0.4197	309	49.9	0.47	320	50.3	0.5197	330	50.5	0.57
15	Neem	Azardirachta indica	Meliaceae	300	8	0.0418	309	8.3	0.047	320	8.5	0.0518	3330	8.7	0.057
16	Banyan	Ficus bengalensis	Moraceae	300	175.1	4.5386	309	175.6	5.039	320	176	5.5386	330	176	6.039
17	Indian Rubber	Ficus elastica	Moraceae	300	274	4.5294	309	275.6	5.03	320	277	5.5296	330	278	6.03
18	Peepal	Ficus religiosa	Moraceae	300	127.7	4.1367	309	128.2	4.637	320	129	5.1369	330	5.14	5.637
19	Arjun	Terminalia arjuna	Combrataceae	300	24.3	0.4173	309	24.6	0.467	320	24.9	0.5173	330	0.52	0.567
20	Kadam	Anthosephalus cadamba	Rubiaceae	300	190	4.146	309	199.4	4.646	320	200	5.146	330	5.15	5.646

5.8.2 Observations in Vicinity of Vicinity of Thermal Power Station

Weekly observation was taken for Dust Deposition in Dust Fall Jar & on various plant species exposed to Vicinity of Thermal Power Station site. The detailed Results of analysis of Dust Quantity, Leaf Area & Dust Retention are given Table 5.26. The Dust retention capacity of various plant species of Herbs, Shrubs & Trees were calculated using Plant Height (cm), Leaf Area (cm2), Crown Area of Plant, Diameter of Crown Area of Plant (cm2) and The Dust Deposition on Leaf (gm/cm^2). The salient observations are as below:

- The average dust deposition in Dust fall Jar was 0.20 gm/week where as the average dust retention by Herbs plant species ranged from 0.0010 to 0.0024 gm/cm^2 and the total retention of dust by Herbs plant species was ranges from 0.0101 to 0.0240 gm/cm^2. It is observed that *Colcasia argentea* (Cock's cumbh) has retained highest dust 0.0240 gm/cm^2 then *Tagetese patula* (Genda) 0.0194 gm/cm^2 (Fig. 5.45).

- The average dust deposition in Dust fall Jar was 0.20 gm/week where as the average dust retention on Shrubs plant species was ranged from 0.0024 to 0.0069 gm/cm^2 and the total retention of dust by shrubs plant species was ranges from 0.0240 to 0.0543 gm/cm^2. It is observed that *Tabermaemontana divaricata* (Chandani) has retained highest dust 0.0543 gm/cm^2 while *Bougainvillea glavara* (Bougainvillea) has retained lowest dust 1.01 gm/cm^2 in Vicinity of Thermal Power Station, Hardwar. **(**Fig. 5.46**).**

- The average dust deposition in Dust fall Jar was 0.20 gm/week where as the average dust retention on leaf of all the Trees was ranges from 0.0004 to 0.0029 gm/cm^2 and the total retention of dust by Tree plant species was ranges from 0.0005 to 0.0867 gm/cm^2. It is seen that the *Azardirachta indica* (Neem) has retained highest dust 0.0867 gm/cm^2 then the *Ficus religiosa* (Peepal) 0.0373 gm/cm^2 then the *Ficus bengalensis* (Banyan Tree) 0.352 gm/cm2 then the *Ficus elastica* (Indian rubber) 0.0331 gm/cm^2 then the *Anthosephalus cadamba* (Kadam) 0.0120 gm/cm^2 then the *Artocarpus integrifolia* (Jack Fruit) 0.0103 gm/cm^2 then the *Alstonia scholaris* (Satani) 0.0063 gm/cm^2 then the *Cassia fistula* (Amaltas) 0.0063 gm/cm^2 then the *Termanilia catappal* (Jangali Badam) 0.0032 gm/cm^2 then the *Eucalyptus globulus* (Blue gum) 0.0013 gm/cm^2 then the *Terminalia arjuna* (Arjun) 0.0013 gm/cm^2 then the *Callistemon laceolatus* (Bottle Brush) 0.0005 gm/cm^2 and then the *Populus trimuloidess* (Popular) 0.0005 gm/cm^2 at Vicinity of Thermal Power Station, Hardwar. **(**Figure 5.47).

Table 5.26: Dust Retention Capacity of Herb Shrubs & Trees at Vicinity of Thermal Power Station, Haridwar

S. No.	Common Name	Botanical Name	Family	Dust Fall in 7 days (gm/cm2)	Dust on leaf in 7 days (gm/cm2)	Dust capture by tree in 7 days (gm/cm2)
1	Elephant's Ear	Colocasia antiquorum	Araceae	0.20	0.0010	0.0101
2	Genda	Tagetes patula	Asteraceae	0.20	0.0019	0.0194
3	Cock Scumb	Celosia argentea	Amaranthaceae	0.20	0.0024	0.0240
4	Bougainvillea	Bougainvillea	Nyctaginaceae	0.20	0.0019	0.0209
5	Copper leaf	Acalypha hispida	Euphorbiaceae	0.20	0.0072	0.0263
6	Beshram	Ipomea nil	Convovulaceae	0.20	0.0087	0.0486
7	Chandani	Tabernaemontana divaricata	Apocyanaceae	0.20	0.0069	0.0543
8	Popular	Populus trimuloides	Siliaceae	0.20	0.0004	0.0005
9	Bottle Brush	Callistemon laceolatus	Myrtaceae	0.20	0.0007	0.0010
10	Arjun	Terminalia arjuna	Combrataceae	0.20	0.0007	0.0013
11	Blue gum	Eucalyptus globulus	Myrtaceae	0.20	0.0010	0.0024
12	Jangal Badam	Termanilia catappal	Combrataceae	0.20	0.0017	0.0032
13	Amaltas	Cassia fistula	Caesalpiniaceae	0.20	0.0042	0.0063
14	Satni	Alstonia scholaris	Apocyanaceae	0.20	0.0017	0.0085
15	Jack Fruit	Artocarpus integrifolia	Moraceae	0.20	0.0050	0.0103
16	Kadam	Anthosephalus cadamba	Rubiaceae	0.20	0.0027	0.0120
17	Indian Rubber	Ficus elastica	Moraceae	0.20	0.0119	0.0331
18	Banyan Tree	Ficus bengalensis	Moraceae	0.20	0.0122	0.0352
19	Peepal	Ficus religiosa	Moraceae	0.20	0.0141	0.0373
20	Neem	Azardirachta indica	Meliaceae	0.20	0.0029	0.0867

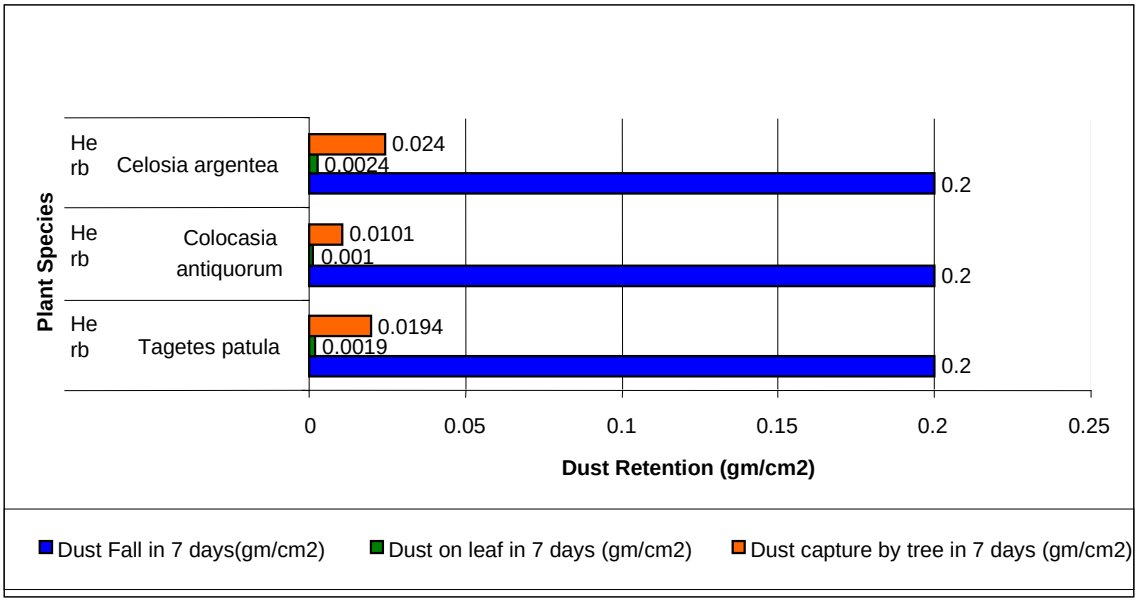


Fig. 5.45 : Dust Retention Capacities of Herb Plants in Vicinity of Thermal Power Station, Haridwar

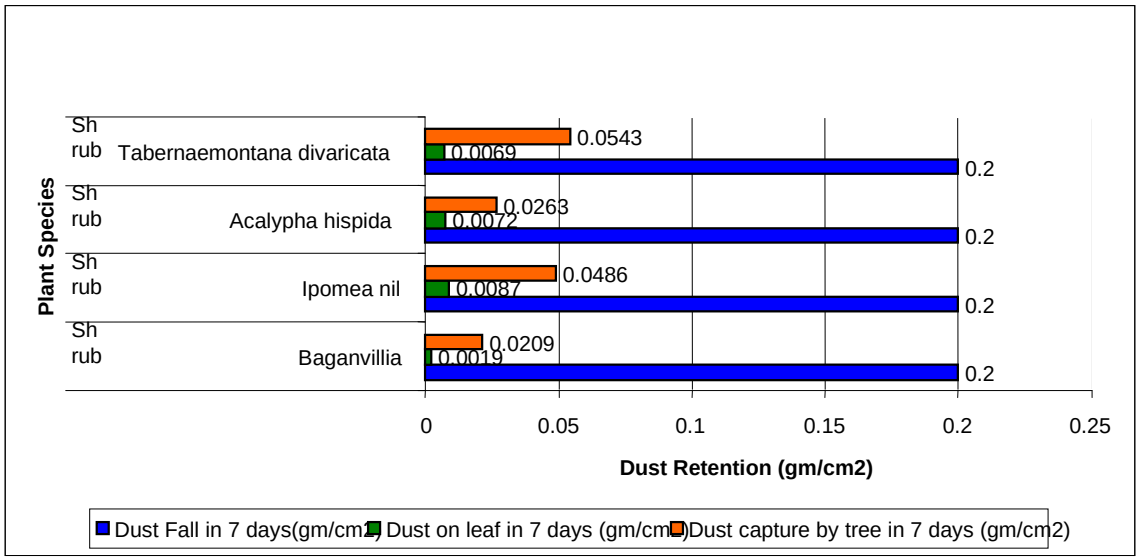


Fig. 5.46 : Dust Retention Capacities of Shrub Plants in Vicinity of Thermal Power Station, Haridwar

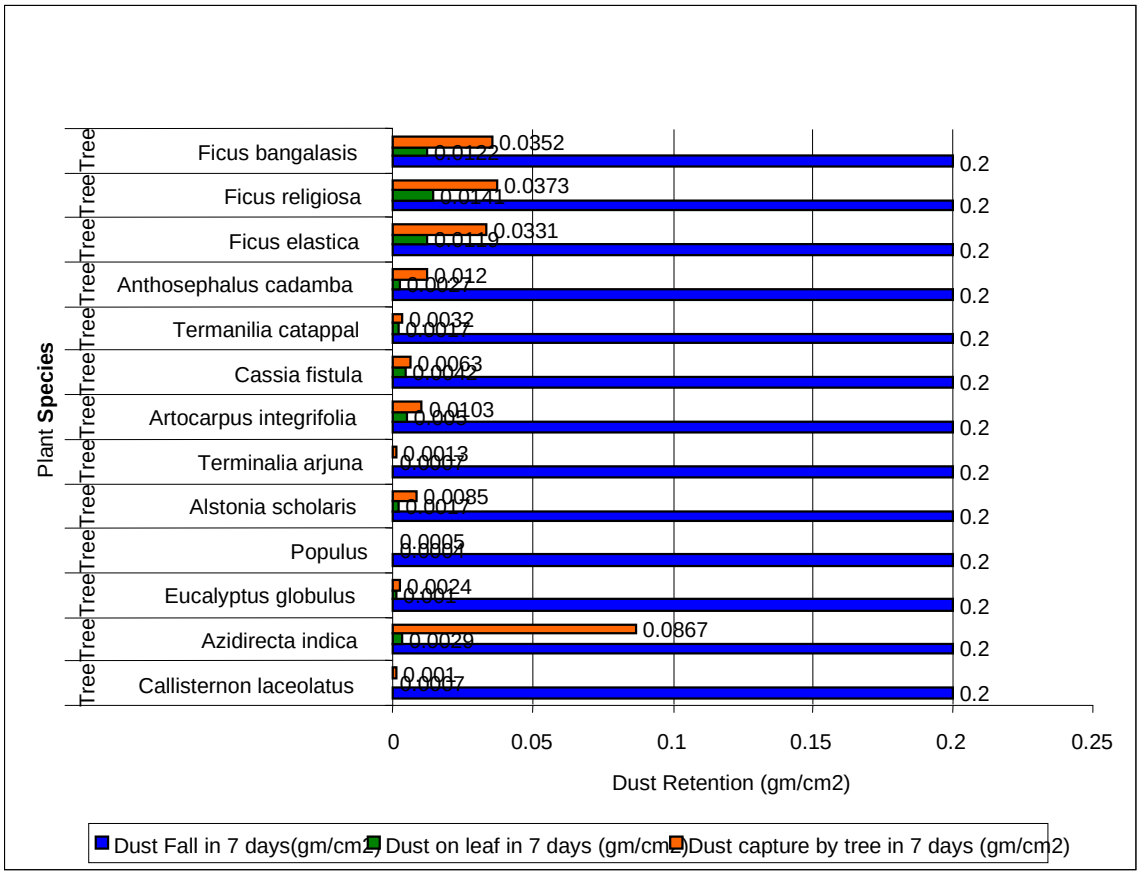


Fig. 5.47 : Dust Retention Capacities of Tree Plants in Vicinity of Thermal Power Station, Haridwar

Table 5.27: DUST DEPOSITION ON DUST FALL JAR & LEAVES OF PLANT SPECIES UNDER POT CULTURE EXPERIMENT AT THERMAL POWER STATION, HARIDWAR

SN	Common Name	Botanical Name	Family	1st Week			2nd Week			3rd Week			4th Week		
				Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm)	Dust Fal Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fal Jar (gm)	Leaf Area (cm2)	Dust (g/cm2)
HERBS															
1	Genda	Tagetes patula	Asteraceae	100	1.05	0.0004	110	1.14	0.0009	120	1.21	0.0014	131	1.3	0.0019
2	Elephant's Ea	Colocasia antiquorum	Araceae	100	119	0.0181	110	120.45	0.0681	120	120.9	0.1181	131	121.5	0.1681
3	Cock'scomb	Celosia argentea	Amaranthaceae	100	32.25	0.0078	110	32.7	0.0128	120	33.2	0.0178	131	33.71	0.0228
SHRUBS															
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	100	41	0.0236	110	41.6	0.0736	120	42.1	0.1236	131	42.6	0.1736
5	Copper leaf	Acalypha hispida	Euphorbiaceae	100	38.16	0.0188	110	38.5	0.0688	120	39	0.1188	131	39.7	0.1688
6	Bougainvillea	Bougainvillea	Nyctaginaceae	100	13.05	0.002	110	13.61	0.007	120	14.1	0.012	131	14.6	0.017
7	Beshram	Ipomea nil	Convovulaceae	100	31	0.0159	110	31.5	0.0659	120	32	0.1159	131	32.5	0.1659
TREES															
8	Jack Fruit	Artocarpus integrifolia	Moraceae	100	55	0.0173	110	56	0.0673	120	56.8	0.1173	131	57.71	0.1673
9	Jangal Badam	Termanilia catappal	Combrataceae	100	200	0.0701	110	201	0.1201	120	201.9	0.1701	131	202.8	0.2201
10	Bottle Brush	Callistemon laceolatus	Myrtaceae	100	3.75	0.0007	110	3.85	0.0012	120	4	0.0017	131	4.2	0.0022
11	Amaltas	Cassia fistula	Caesalpiniaceae	100	72	0.0441	110	72.8	0.0941	120	73.6	0.1441	131	74.3	0.1941
12	Satni	Alstonia scholaris	Apocyanaceae	100	21.25	0.0106	110	21.5	0.0156	120	21.75	0.0206	131	21.95	0.0256
13	Popular	Populus trimuloides	Salicaceae	100	78.16	0.0075	110	79	0.0125	120	80.1	0.0175	131	80.9	0.0225
14	Blue gum	Eucalyptus globulus	Myrtaceae	100	27	0.0026	110	27.6	0.0073	120	28.2	0.0123	131	28.7	0.0173
15	Neem	Azardirachta indica	Meliaceae	100	8.4	0.0014	110	8.7	0.0064	120	8.95	0.0114	131	9.2	0.0164
16	Banyan	Ficus bengalensis	Moraceae	100	243	0.2832	110	244	0.7832	120	245.1	1.2832	131	245.9	1.7832
17	Indian Rubber	Ficus elastica	Moraceae	100	236.75	0.1341	110	238	0.6341	120	238.9	1.1341	131	241	1.6341
18	Peepal	Ficus religiosa	Moraceae	100	206	0.231	110	207.1	0.731	120	208.2	1.231	131	209.1	1.731
19	Arjun	Terminalia arjuna	Combrataceae	100	51.1	0.0119	110	51.8	0.0169	120	52.6	0.0219	131	53.2	0.0269
20	Kadam	Anthosephalus cadamba	Rubiaceae	100	123	0.0721	110	124.2	0.1221	120	125	0.1721	131	125.8	0.2221

Table 5.28: DUST DEPOSITION ON DUST FALL JAR & LEAVES OF PLANT SPECIES UNDER POT CULTURE EXPERIMENT AT THERMAL POWER STATION, HARIDWAR

S. No.	Common Name	Botanical Name	Family	5th Week			6th Week			7th Week			8th Week		
				Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm)	Dust Fal Jar(gm)	Leaf Area Cm2	Dust (g/cm2)	Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fal Jar (gm)	Leaf Area (cm2)	Dust (g/cm2)
HERBS															
1	Genda	Tagetes patula	Asteraceae	140	1.4	0.0024	150	1.51	0.0029	162	1.6	0.0034	175	1.7	0.0039
2	Elephant's Ear	Colocasia antiquorum	Araceae	140	121.95	0.2181	150	122.4	0.2681	162	122.8	0.3181	175	123.3	0.3681
3	Cock'scomb	Celosia argentea	Amaranthaceae	140	34.3	0.0278	150	34.9	0.0328	162	35.4	0.0378	175	35.8	0.0428
SHRUBS															
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	140	43.21	0.2236	150	43.8	0.2736	162	43.35	0.3236	175	43.9	0.3736
5	Copper leaf	Acalypha hispida	Euphorbiaceae	140	40.3	0.2188	150	40.5	0.2688	162	41	0.3188	175	41.4	0.3688
6	Bougainvillea	Bougainvillea	Nyctaginaceae	140	15.1	0.022	150	15.62	0.027	162	16.1	0.032	175	16.6	0.037
7	Beshram	Ipomea nil	Convovulaceae	140	32.9	0.2159	150	33.4	0.2659	162	33.8	0.3159	175	34.2	0.3659
TREES															
8	Jack Fruit	Artocarpus integrifolia	Moraceae	140	58.32	0.2173	150	58.8	0.2673	162	59.4	0.3173	175	59.9	0.3673
9	Jangal Badam	Termanilia catappal	Combrataceae	140	203.5	0.2701	150	204.1	0.3201	162	204.6	0.3701	175	205.1	0.4201
10	Bottle Brush	Callistemon laceolatus	Myrtaceae	140	4.4	0.0027	150	4.65	0.0032	162	4.8	0.0037	175	4.9	0.0042
11	Amaltas	Cassia fistula	Caesalpiniaceae	140	74.9	0.2441	150	75.5	0.2941	162	76	0.3441	175	76.4	0.3941
12	Satni	Alstonia scholaris	Apocyanaceae	140	22.15	0.0306	150	22.3	0.0356	162	22.4	0.0406	175	22.5	0.0456
13	Popular	Populus trimuloides	Salicaceae	140	81.7	0.0275	150	82.4	0.0325	162	83.1	0.0375	175	83.7	0.0425
14	Blue gum	Eucalyptus globulus	Myrtaceae	140	29.2	0.0223	150	29.7	0.0273	162	30.1	0.0323	175	30.51	0.0373
15	Neem	Azardirachta indica	Meliaceae	140	9.5	0.0214	150	9.8	0.0264	162	10.2	0.0314	175	10.5	0.0364
16	Banyan	Ficus bengalensis	Moraceae	140	246.8	2.2832	150	247.7	2.7832	162	248.5	3.2832	175	249.3	3.7832
17	Indian Rubber	Ficus elastica	Moraceae	140	242	2.1341	150	242.8	2.6341	162	243.6	3.1341	175	244.2	3.6341
18	Peepal	Ficus religiosa	Moraceae	140	210	2.231	150	210.8	2.731	162	211.6	3.231	175	212.3	3.731
19	Arjun	Terminalia arjuna	Combrataceae	140	53.5	0.0319	150	54	0.0369	162	54.4	0.0419	175	54.8	0.0469
20	Kadam	Anthosephalus cadamba	Rubiaceae	140	126.4	0.2721	150	127	0.3321	162	128.7	0.3721	175	129.2	0.4221

Table 5.29: DUST DEPOSITION ON DUST FALL JAR & LEAVES OF PLANT SPECIES UNDER POT CULTURE EXPERIMENT AT THERMAL POWER STATION, HARIDWAR

S. No.	Common Name	Botanical Name	Family	9th Week			10nd Week			11th Week			12h Week		
				Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm)	Dust Fal Jar(gm)	Leaf Area Cm2	Dust (g/cm2)	Dust Fall Jar(gm)	Leaf Area cm2	Dust (g/cm2)	Dust Fall Jar (gm)	Leaf Area (cm2)	Dust (g/cm2)
HERBS															
1	Genda	Tagetes patula	Asteraceae	185	1.81	0.0044	200	1.9	0.0049	210	1.99	0.0054	225	2.08	0.0059
2	Elephant's Ear	Colocasia antiquorum	Araceae	185	123.7	0.4181	200	124.1	0.4681	210	124.5	0.518	225	124.8	0.5681
3	Cock'scomb	Celosia argentea	Amaranthaceae	185	36.2	0.0478	200	36.6	0.0528	210	36.92	0.0578	225	37.2	0.0628
SHRUBS															
4	Chandani	Tabernaemontana divaricata	Apocyanaceae	185	44.4	0.4236	200	44.9	0.4736	210	45.4	0.5236	225	45.8	0.5736
5	Copper leaf	Acalypha hispida	Euphorbiaceae	185	41.8	0.4188	200	42.2	0.4688	210	42.5	0.5188	225	42.7	0.5688
6	Bougainvillea	Bougainvillea	Nyctaginaceae	185	17	0.042	200	17.41	0.047	210	17.8	0.052	225	18.1	0.057
7	Beshram	Ipomea nil	Convovulaceae	185	34.6	0.4159	200	35	0.4659	210	35.3	0.5159	225	35.6	0.5659
TREES															
8	Jack Fruit	Artocarpus integrifolia	Moraceae	185	60.4	0.4173	200	60.8	0.4673	210	61.2	0.5173	225	61.5	0.5673
9	Jangal Badam	Termanilia catappal	Combrataceae	185	205.5	0.4701	200	206	0.5201	210	206.4	0.5701	225	206.7	0.6201
10	Bottle Brush	Callistemon laceolatus	Myrtaceae	185	5	0.0047	200	5.1	0.0052	210	5.18	0.0057	225	5.25	0.0062
11	Amaltas	Cassia fistula	Caesalpiniacea	185	76.81	0.4441	200	77.2	0.4941	210	77.6	0.5441	225	77.9	0.5941
12	Satni	Alstonia scholaris	Apocyanaceae	185	23	0.0506	200	23.4	0.0556	210	23.7	0.0606	225	24	0.0656
13	Popular	Populus trimuloides	Salicaceae	185	84.3	0.0475	200	84.9	0.0525	210	85.4	0.0575	225	35.73	0.0625
14	Blue gum	Eucalyptus globulus	Myrtaceae	185	31	0.0423	200	31.4	0.0473	210	31.8	0.0523	225	32.1	0.0573
15	Neem	Azardirachta indica	Meliaceae	185	10.8	0.0414	200	11.1	0.0464	210	11.3	0.0514	225	11.5	0.0564
16	Banyan	Ficus bengalensis	Moraceae	185	250	4.2832	200	250.7	4.7832	210	251.2	5.2832	225	251.6	5.7832
17	Indian Rubber	Ficus elastica	Moraceae	185	244.8	4.1341	200	245.5	4.6341	210	246	5.1341	225	246.4	5.6341
18	Peepal	Ficus religiosa	Moraceae	185	213	4.231	200	213.6	4.731	210	214	5.231	225	214.2	5.731
19	Arjun	Terminalia arjuna	Combrataceae	185	55.2	0.0519	200	55.5	0.0569	210	55.8	0.0619	225	56	0.0669
20	Kadam	Anthosephalus cadamba	Rubiaceae	185	129.7	0.4712	200	130.1	0.5221	210	130.3	0.5721	225	130.6	0.6221

Dust retention capabilities of 20 vegetative species (Tables 5.27 to 5.29) were studied after exposure at Stone Crusher & Vicinity of Thermal Power Station. Their leaves had been exposed to the dust for 12 Weeks and their dust retention capacity have been analyzed. The highest dust retention capacity was highly for *Tagetese patula* (Genda) 4.82 gm/cm^2 amongst Herbs in *Bougainvillea glavara* (Bougainvillea) 1.01 gm/cm^2 amongst shrubs *Cassia fistula* (Amaltas) 5.57 gm/cm^2 amongst trees in vicinity of Stone Crusher, Haridwar.

Whereas in vicinity of Thermal Power Plant the highest dust retention Herb was *Colcasia argentea* (Cock scumbh) 0.0240 gm/cm^2 *Tabermaemontana divaricata* (Chandani) 0.0543 gm/cm^2 amongst shrubs and *Azarddirachta indica* (Neem) 0.0867 gm/cm^2 amongst trees.

CHAPTER VI

LOW, MODERATE & HIGH DUST CAPTURING PLANT SPECIES

The analysis of data indicated that there were significant differences among different plant species in intercepting particulate matter (PM2.5). The data indicated the relative comparisons of the experimental species in terms of their ability to remove PM2.5 (Table 6.1). Trees can act as efficient biological filters, removing significant amounts of particulate pollution from urban atmospheres. Up to some extend that trees they can control particulate pollution there is potential for improved air quality and substantial cost savings. This study will help to quantify the relative ability of individual tree species in removing PM2.5. Therefore, urban trees can be evaluated by decision makers in terms of money saved associated with avoided investment in new control strategies.

Table 6.1: Dust Removal Capacities of Various Plant Species

S. No	Common Name	Botanical name	Family	Crown Area Meter2	Average Dust Gm/ meter2	Percentage of Dust Removal (%)
HERBS						
1	Chaulai	Amaranthus hypochondricecus	Amaranthaceae	0.32	7.24	4.42
2	Crape Jasmine	Gardenia jasminoides	Rubiaceae	0.32	6.69	4.78
3	Rat Ki Rani	Cestrum nocturnum	Solanaceae	0.32	6.45	4.96
4	Crown Daisy	Chrysanthamum	Astraceae	0.16	1.8	8.72
5	Lily	Lillium species	Liliaceae	0.32	2.65	12.08
6	Dracaena	Dracaena species	Liliaceae	0.32	3.65	14.28
7	Sunflower	Helianthus annuus	Asteraceae	0.32	2.02	15.84
8	Genda	Tagetes patula	Asteraceae	0.32	2.09	17.7
9	Money Plant	Pothos aureus	Araceae	0.74	3.72	19.89
10	Elephants Ear	Colocasia antiquorum	Araceae	0.06	0.27	24.15
11	Cock'scomb	Celosia argentea	Amaranthaceae	0.32	1.19	27.25
SHRUBS						
12	Moyur Pankhi	Thuja Species	Gymnosperm	0.32	82.81	0.39
13	Sarpgandha	Rauvolfia serpentina	Apocyanceae	0.32	11.91	2.69
14	Asgandha	Withania somnifera	Solancea	0.32	8.16	4.49
15	Acanthus	Acanthus species	Acanthaceae	24.38	263.6	9.25
16	Bamboo	Bambusa species	Poaceae	22.83	207.13	11.02
17	Crape Myrtle	Lagerstroemia indica	Lythraceae	9.19	156.87	11.39
18	Kaner(P)	Nerium indicum	Apocyanceae	4.13	122.59	12.3
19	Croton	Codium variegatus	Euphorbiaceae	3.36	175.95	12.43
20	Kaner (Y)	Thevetia peruviana	Apocyanceae	2.89	38.83	12.56
21	Dudhi	Wrightia arboriea	Apocyanceae	32.19	258.92	12.75
22	Rose	Rosa indica	Rosaceae	0.39	3.35	14.78
23	Beshram	Ipomea nil	Convovulaceae	4.39	30.82	14.87
24	Chandani	Tabernaemontana divaricata	Apocyanceae	6.2	61.86	15.4
25	Copper leaf	Acalypha hispida	Euphorbiaceae	2.86	16.7	17.17
26	Temple Tree	Plumaria acuminata	Apocyanceae	10.17	66.1	19.28
27	Gurhal	Hibiscus rosa sinensis	Malvaceae	9.41	71.24	21.09
28	Bougainvilliea	Bougainvilliea glavra	Nycaginaceae	8.62	97.95	21.35
TREES						
29	Hersingar	Nyctanthese arbor tritis	Oliaceae	6.28	243.31	2.58
30	Silver fire	Abies pindrow	Pinaceae	89.53	1925.36	4.65
31	Babul	Accacia nelotica	Mimosaceae	186.85	3195.51	6.12
32	Kurchi or Kutaja	Holarrhena antidysenterica	Apocyanaceae	30.66	468.85	6.54
33	Glorry bower	Clerodenrum inerme	Verbinaceae	350.9	4703.42	7.46
34	Banyan	Ficus bengalensis	Moraceae	516.56	7057.28	7.72
35	Kari Leaves	Miliusa tomentosa	Annonaceae	30.53	351.51	8.69
36	Ran Bhindi	Thespesia populania	Matvaceae	220.73	2381.39	9.27

S. No	Common Name	Botanical name	Family	Crown Area Meter2	Average Dust Gm/ meter2	Percentage of Dust Removal (%)
37	Shoe Babool	Leacena leucophloea	Mimosaceae	49.51	474.06	11.24
38	Chilgoja	Pinus gerardiana	Pinaceae	101.59	848.26	11.98
39	Indian Rubber	Ficus elastica	Moraceae	491.14	3744.8	12.07
40	Sugar apple	Annona squamosa	Annanaceae	30.53	551.34	12.09
41	Mango	Magifera indica	Ancardiaceae	223.96	2346.2	12.25
42	Wolly Morning Glorry	Argyreia roxburghira	Convolvualaceae	348.35	3080.33	12.28
43	Peepal	Ficus religiosa	Moraceae	465.54	5219.87	12.94
44	Vilayati Kikkar	Acacia farnesiana	Mimosaceae	153.88	2982.27	13.08
45	Amrood	Psidium guava	Myrtaceae	41.78	393.72	13.33
46	Plums	Prunus comminis	Rosaceae	5.5	86.53	13.86
47	Jamun	Syzygium cuminii	Myrtaceae	149.18	1293.17	14.39
48	Teak	Techtona grandis	Verbinaceae	262.28	2612.84	14.94
49	Lemon	Citrus lamon	Rutaceae	19.16	173.7	15.96
50	Mulberry	Morus alba	Moraceae	166.88	2158.76	16.33
51	Chikkoo	Archise sapota	Sapotaceae	150.21	922.31	16.39
52	Kadam	Anthosephalus cadamba	Rubiaceae	300.42	3707.81	16.71
53	Sal	Shorea robusta	Dipterocarpacea	94.66	560.47	16.87
54	Shesham	Delbergia sissoo	Papilionaceae	149.35	1110.17	17.02
55	Gulmohar	Delonix regiosa	Caesalpinaceae	185.85	1282.53	18.05
56	Siris	Albizzia lebbek	Caesalpinaceae	85.32	466.28	18.3
57	Jack Fruit	Artocarpus integrifolia	Moraceae	652.06	3788.89	18.4
58	Torch Tree	Ixora parviflora	Rubiaceae	116.52	670.79	18.45
59	Kanchnar	Bauhinia variegata	Ceasalpinaceae	131.25	852.26	18.58
60	Sahajan	Moringa olieifera	Morangaceae	126.02	670.7	18.79
61	Bel	Aegle marmelos	Rutaceae	99.06	805.19	18.9
62	Jangali jalabi	Pithecolobium dule	Mimosaceae	147.18	1711.73	19.21
63	Amaltas	Cassia fistula	Caesalpinaceae	134.61	1731.47	23.03
64	Pine	Pinus contora	Pnaceae	101.59	434.29	23.39
65	Semal	Bombax ceiba	Malvaceae (Bombacaceae)	514.65	2429.33	24.36
66	Palas	Butea monosperma	Fabaceae	134.42	562.92	24.44
67	Satani	Alstonia scholaris	Apocyanaceae	253.59	3170.8	25.39
68	Neem	Azardirachta indica	Meliaceae	35.31	474.99	25.54
69	Ashoka	Polyalthia longifolia	Annonaceae	246.27	1318.77	29.84
70	Bottle Brush	Callistemon laceolatus	Myrtaceae	115.39	542.93	29.88
71	Jangal Badam	Termanilia catappal	Combrataceae	146.78	1059.62	30.12
72	Arjun	Terminalia arjuna	Combrataceae	125.57	413.56	30.54
73	Melia	Melia azedarch	Meliaceae	313.53	1112.96	31.77
74	Khajoor	Phoenix dactylifera	Palmae	148.11	461.8	32.07
75	Pilkhan	Ficus infectorja	Moraceae	508.55	1510.6	33.67
76	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae	134.42	1761.26	35.01
77	Blue Gum	Eucalyptus globulus	Myrtaceae	415.72	2569.88	35.88
78	Mahua	Madhuca indica	Sapotaceae	134.94	347.66	38.81
79	Chakotra	Citrus maxima	Rutaceae	150.52	367.7	40.94
80	Quaking aspen	Populus tremuloides	Siliaceae	94.14	204.22	63.75

It has been observed that some species indicate better efficiency in removing particle pollution, the total contribution to pollution removal is based on the canopy size as well as age and other plant and environmental factors. It is therefore possible that a mature ***Popular species*** tree would contribute more to particle removal than a Jack fruit (***Artocarpus integrifolia***) tree due to the larger canopy size. *Species with smaller total leaf areas seems to do a better task of removing particles may be because of their extensive fatique and large canopy area*. However, it is to be mentioned that the leaf morphology, anatomy & physiology of these trees are different. Stomata conductance and net-photosynthetic capability of trees were affected by the exposure to PM 2.5.

The dust capturing efficiency of Plants (Table 6.2) is depended upon the Morphological features of leaf, types of Stomata and the Transpiration efficiency of plants.

Table 6.2: Dust Collection Efficiency based Low, Moderate & High Dust Capturing Herbs, Shrubs & Trees

Dust Collection Efficiency	Plant Species		
	Herbs	**Shrubs**	**Trees**
Low <10%	1.*Amaranthus hypchondriceus* (Chaulai) 2. *Gardenia jasminoides* (Crape Jasmine) 3. *Cestrum nocturmum* (Rat Ki Rani) 4. *Chrysanthamum species* (Crown Daisy)	1.*Thuja species* (Moyur Pankhi) 2.*Ravuvoifia serpentine* (Serpgandha) 3.*Withania somnifera* (Ashawagandha) 4.*Acanthus species* (Acanthus)	1.*Nyctanthese arbortritis* (Harsingar) 2.*Abis pindrow* (Silver fire) 3. *Accacia nelotica* (Babool) 4.*Holarrhena antidysentrica* (Kurchi) 5. *Clerodenrum inerme* (Glorry bower) 6. *Ficus bengalensis* (Banyan) 7.*Miliusa tomentosa* (Kari Leaves) 8.*Thespesia populania* (Ran Bhindi)
Medium 11 to 20%	1.*Lilium species* (Lily) 2.*Draceana species* 3.*Halianthus annuus* (Sunflower) 4. *Tegetes patula* (Genda) 5.*Pothus aureus* (Money Plant)	1. *Bambusa species* (Bamboo) 2. *Lagerstomia indica* (Crape Myrtle) 3. Nerium indicum (Kaner Pink) 4.*Codium varigatus* (Croton) 5.*Thevetia peruviana* (Kaner Yellow) 6.*Wrightia arborea* (Dudhi) 7.*Rosa indica* (Rose) 8.*Ipomea nil* (Beshrum) 9.*Tabermaemontana divaricata* (Chandani) 10.*Acalypha hispida* (Copper leaf) 11*Plumeria acuminate* (Temple Tree)	1.*Luecena leucophloea* (Shoe Babool) 2.*Pinus gerardiana* (Chilgoja) 3.*Ficus elastica* (Indian Rubber) 4.*Annona squamosa* (Suger Apple) 5.*Mangifera indica* (Mango) 6.*Argyreia roxburghira* (Wooly Morning Glorry) 7.*Ficus religiosa* (Peepal) 8.*Acacia famesiana* (Vilayati Kikkar) 9. *Psidium guyava* (Amrood) 10. *Prunus comminis* (Plums) 11. *Syzygium cuminii* (Jamun) 12.*Tectona grandis*(Teak) 13.*Citrus lamina* (Lamon) 14.*Morus alba* (Mulberry) 15.*Archis sapota* (Chikoo) 16.*Anthosephalus cadamb*a (Kadam) 17.*Shorea robusta* (Sal) 18.*Delbergia sisso* (Sheasm) 19.*Delonix regiosa* (Gulmohar) 20.*Albizzia lebbek* (Siris) 21. *Artocarpus integrifolia* (Jack Fruit) 22.*Ixora parviflora* (Torch Tree) 23.*Bauhinia varigata* (Kanchnar) 24.*Moringa olieifera* (Drum Stick) 25.*Aegle famesiana* (Beal) 26.*Pithocolobium dule* (Jangali jalabi)
High >21%	1. *Colocasia antiquorum* (Elephants Ear) 2.*Celosia argentea* (Cock'scomb)	1*. Hibiscus rosa sinensis* (Gurhal) 2.*Bougainvillea glavra* (Bougainvillea)	1.*Cassia fistula* (Amaltas) 2.*Pinu*s *contora* (Pine) 3.*Bombax ceiba* (Samal) 4.*Butea monosperma* (Palas) 5.*Alstonia scholaris* (Satani) 6.*Azardirachta indica* (Neem) 7.*Polyalthia longifolia* (Ashoka) 8.*Callistemon citrinus* (Bottle Brush) 9.*Termanilia catappa*l (Jangal Badam) 10.*Terminalia arjuna* (Arjun) 11*. Melia azedarch* (Melia) 12.*Phoenix dactylifera* (Khjoor) 13.*Ficus infectorja* (Pilkan) 14.*Holiptelia integrifolia* (Papadi) 15.*Eucalyptus globules* (Blue Gum) 16.*Madhuca indica* (Mahua) 17.*Citrus maxima* (Chaktora) 18.*Populus tremuloides*(Quaking aspe

6.2 CLIMATIC CONDITIONS BASED DUST CAPTURING HERBS, SHRUBS & TREES

During the study more than 80 plant species have been identified as having higher dust capturing efficiencies, which is further influenced by local climatic and geographical condition.

Mumbai

The following plant species have been identified and recommended for better removal of dust for Mumbai ascending order of dust capture Efficiency :

Herbs

Pathos aureus <Dracena < Colocassia antiquorum

Shrubs

Plumaria acuminate < *Acanthus,*< *Tabernaemontana divaricata* ,< *Boganvillia glavra* Thevetia peruviana, < *Lagerstroemia* indica < Nerium indicum < Codium variegates < Hibiscus rosa *sinensis.*

Trees

Artocarpus integrifolia < *Ficus elastica* < *Cassia fistula* < *Pinus gerardiana* < *Polyalthia longifolia* < *Bombax ceiba* < *Syzgium cumini*< *Celerodenrum inerme*< *Delbergia sisso*< *Ficus bangalasis*< *Pithobium dule*< *Ficus religiosa* < *Magifera indica*< *Anthocesephalus cadamba* < *Delonix regiosa*< *Nyctanthese arbor tritis* < *Holiptelia integrifolia* < *Annona squamosa* < *Azadirecta indica* < *Prunus comminis* < *Acacia farmesiana* < *Psidium guajava* .

Delhi

The following plant species have been identified and recommended for the better removal of dust for Delhi environment based on the ascending order of dust capture Efficiency

Herbs

Gardenia jasminoides < *Cestrum noctumum* < Helianthus annuus < *Draceana species.* <*Colocasia antiquorum* and < *Tegetes patula* .

Shrubs

Citrus lamina <*Prunus comminis* < *Wrightia arborea* < *Nerium indicum* < *Rosa indica* < *Thevetia peruviana* < *Boganvillia glavra* < *Lagerstromea indica* < *Plumaria acuminate* < *Hibiscus rosa sinensis and Tabernaemontana divaricata*

Trees

Accacia nilotica. < *Cassia fistula* <*Ficus bangalasis* ,< *Eucalyptus globulus* ,< *Agel mamelos* ,< *Ficus elastica* ,< *Bauhinia variegate* < *Syzgium cumini* <*Alstonia scholaris* <*Magifera indica* <*Callisternon laceolatus* <*Leacena leucophloea* <*Archise sapota* <*Acacia famesiana* <*Argyreior roxburghira* <*Morus alba* <*Delbergia sisso* <*Melia azedarch* <*Ficus religiosa* <*Psidium guajava* <*Delonix regiosa* <*Terminalia arjuna* <*Ixora parviflora* <*Populus species* <*Techtona grandis* <*Holiptelia integrifolia* <*Polyalthia longifolia* <*Anthosephalus cadamba* <*Bombax ceiba* <*Madhuca indica* < *Azidirecta indica and* < *Termanilia catappal*.

Kolkata

The following plant species have been identified and recommended for the better removal of dust from Kolkata environment in ascending order of dust capture Efficiency .

Herbs
Codium varigataus < *Colocasia antiquorum*

Shrubs
Thevitia peruviana < *Boganvillia glavra* < *Hibiscus rosa sinensis* < *Tabernaemontana divaricata* < *Lagerstromea indica* < *Wrightia arborea* < *Plumaria acuminate* < *Acalypha hispida*

Trees
Alstonia scholaris < *Ficus religiosa* < *Prunus comminis* < *Ficus bangalasis* < *Holarrhe*na *antidysenterica* < *Pithocellobium dule* < *Mangifera indica* < *Termanilia catappal* < *Anthosephalus cadamba* < *Techtona grandis* < *Psidium guajava* < *Syzgium cumini* < *Polyalthia longifolia* < *Cassia fistula* < *Holiptelia integrifolia* < *Ficus elastica* < *Argyreior roxburghira* < *Artocarpus integrifolia* < *Annona squamosa* < *Azidirecta indica* < *Archise sapota* < *Ixora parviflora* < *Delonix regiosa* < *Acacia famesiana* < *Callisternon laceolatus* .

Vicinity of Coal Mine

In vicinity of coal mine areas, the following plant species have been identified and recommended for the better removal of dust from the environment.

Shrubs
Plumaria acuminate < *Ipomea nil* < *Tabemaemontana divaricata* < *Wrightia arboriea* < *Hibiscus rosa sinensis* < *Thevetia peruviana* < *Nerium indicum* < and *Boganvillia glavra*

Trees
Ficus bangalasis < *Ficus elastica* < *Syzgium cumini* < *Delonix regiosa* < *Annona squamosa* < *Moringa oliefera* < *Prunus comminis* < *Ficus religiosa* < *Pithocellobium dule* < *Acacia farmesiana* < *Artocarpus integrifolia* < *Butea monosperma* < *Aegle mamelos* < *Anthocephalus cadamba* < *Phonix dactylifera* < *Delbergia sisso* < *Psidium gujava* < *Polyalthia longifolia* < *Terminalia arjuna* < *Citrus maxiuma* < *Alstonia scholaris and* < *Cassia fistula* .

Vicinity of Cement Plant

In vicinity of cement plant, the following plant species have been identified and recommended for the better removal of dust from the environment.

Herbs
Amaranthus hypochondricecus < *Lilium species* < *Dracaena species* < *Tagetes patula* and < *Colocasia antiquorum*

Shrubs
Thuja species < *Rauvolfia serpentine* <*Withania somnifera*< *Thevetia peruviana* < *Nerium indicum* < *Boganvillia glavera* < *Plumaria acuminate* < *Tabemaemontana divaricata* < *Rosa indica* < *Lagerstromia indica* < *Hibiscus rosa sinensis* < *Wrightia arborea* < *Codium varigatus* < *Acalypha hispida* and < *Ipomea nil* .

Trees
Abies pindrow < *Cassia fistula* <*Delbergia sisso* < *Anthosephalus cadama* < *Morus alba Ixora parviflora* < *Magifera indica* < *Acacia farmesiana* < *Acacia nilotica*,< *Psidium gujava* < *Miliusa tomentosa* < *Citrus lamina* < *Ficus elastica* < *Syzgium cumini* < *Ficus religiosa* < *Polyalthia longifolia* < *Callisternon laceolatus* < *Techtona grandis*< *Shorea robusta* < *Azidirecta indica* < *Albizzia lebbek* < *Terminalia arjuna* < *Aegle mamelos* < *Eucaltputus globules* < *Delonix regiosa and* < *Alstonia scholaris*

Vicinity of Stone Crusher

In vicinity of stone crushers, the following plant species have been identified and recommended for better removal of dust from the environment.

Herbs
Chysthanum species < *Tagetese minuta* and < *Celosia argenta.*

Shrubs
Rosa indica < *Withania somnifera* < *Boganvillia glavra* < *Bambusa species* < *Ipomea nil* < *Croton oblongifolius* and *Tabernaemontana divaricata*

Trees
Techtona grandis < *Accacia nilotica* ,< *Delonix religiosa* ,< *Ficus religiosa* ,< *Mangifera indica* ,< *Bauhinia variegate* < *Prunus cumminis)* < *Butea monosperma* < *Bobax ceiba* <*Psidium gujava* < *Pinus contora* < *Morus alba* <*Delbergia sisso* < *Eucaltputus globules* < *Syzgium cumini* < *Melia azidirecta* < *Cassia fistula and* < *Populus deltoides*

Vicinity of Thermal Power Station

The following plant species have been identified and recommended for the better removal of dust from the environment in vicinity of Thermal Power Stations

Herb
Tagetese patula

Shrubs
Withania somnifera < *Tabemaemontana divaricata* < *Lagerstromia indica* < *Thevetia peruviana* < *Rosa indica* < *Plumaria acuminate* < *Hibiscus rosa sinensis* < and *Boganvillia glavra.*

Trees
Acacia farmesiana < *Acacia nilotica* < *Leacena leucophloea* < *Ficus religiosa* < *Aegle mamelos* < *Syzgium cumini* < *Delonix regiosa* < *Techtona grandis* < *Magifera indica* < *Psidium gujava* < *Cassia fistula* <*Delbergia sisso* < *Shorea robusta* < *Bombax ceiba* < *Citrus lamina* < *Prunus comminis* < *Butea monosperma* < *Bauhinia variegate* < *Ficus infectoria* < *Azidirecta indica* < *Callisternon laceolatus* < *Polyalthia longifolia* < *Holiptelia integrifolia and* < *Eucaltputus globules.*

CHAPTER VII

RECOMMENDATIONS

It has been deduced from present study that there are diversity in agro-climatic conditions, social structure; customs and traditions; the selection of plant species for environment management programme is complex requiring continuous research inputs. The following recommendations are suggested based on the study:

1. Green Belt urban trees constituting Dust capturing plant species should be developed since plants can act as efficient biological filters; removing significant amounts of particulate pollution from urban atmospheres.

2. Based on the studies, the following Herbs; Shrubs & Trees have been observed as are the more efficient dust capturing plant species. These plants are recommended for the Green Belt / Urban Forest Development in vicinity of Residential areas; Road Sides and Industrial Sites.

   Herbs

   Chaulai (*Amaranthus hypochondricecus*) ; Crape Jasmine (*Gardenia jasminoides*) ; Rat Ki Rani (*Cestrum nocturnum*) ; Crown Daisy (*Chrysanthamum species*) ; Lily (*Lillium species*) ; Dracaena (*Dracaena species*) ; Sunflower (*Helianthus annuus*) ; Genda (*Tagetes patula*) ; Money Plant (*Pothusaureus*) ; Elephants Ear (*Colocasia antiquorum*) and Cock's comb (*Celosia argentea*)

   Shrubs

   Moyur Pankhi (*Thuja Species*) ; Sarpgandha (*Rauvolfia serpentine* Ashawagandha (*Withania somnifera*) ; Acanthus (*Acanthus species*) ; Bamboo (*Bambusa species)* ; Crape Myrtle (*Lagerstroemia indica*) ; Pink Kaner (*Nerium* indicum) ; Croton (*Codium variegates*) ; Yellow Kaner (*Thevetia peruviana*) ; Dudhi (*Wrightia arboriea*) ; Rose (*Rosa indica*) ; Beshram (*Ipomea nil*) ; Chandani (*Tabernaemontana divaricata*) ; Copper leaf (*Acalypha hispida*) ; Temple Tree (*Plumeria acuminate*) ; Gurhal (*Hibiscus rosa sinensis*) and Bougainvillea (*Bougainvillea glavra*)

   Trees

   Hersingar (*Nyctanthese arbor tritis*) ; Silver fire (*Abies pindrow*) ; Babool (*Accacia nelotica*) ; Kurchi or Kutaja (*Holarrhena antidysenterica*); Glorry bower (*Clerodenrum inerme*) ; Banyan (*Ficus bengalensis*) ; Kari Leaves (*Miliusa tomentosa*) ; Ran Bhindi (*Thespesia populania*) ; Shoe Babool (*Leacena leucophloea*) ; Chilgoja (*Pinus gerardiana*) ; Indian Rubber (*Ficus elastica*) ; Sugar apple (*Annona squamosa*) ; Mango (*Mangifera indica*) ; Wolly Morning Glorry (*Argyreia roxburghira*) ; Peepal (*Ficus religiosa*) ; Vilayati Kikkar (*Acacia*

farnesiana) ; Amrood (*Psidium guyava*) ; Plums (*Prunus comminis*) ; Jamun (*Syzygium cuminii*) ; Teak (*Tectona grandis*) ; Lamon (*Citrus lamina*) ; Mulberry (*Morus alba*) ; Chikkoo (*Archise sapota*) ; Kadam (*Anthosephalus cadamba*) ; Sal (*Shorea robusta*) ; Seesham (*Debergia* sissoo) ; Gulmohar (Delonix regiosa) ; Siris (*Albizzia lebbek*) ; Jack Fruit (*Artocarpus integrifolia*) ; Torch Tree (*Ixora parviflora*) ; Kanchnar (*Bauhinia variegate*) ; Drumstick (*Moringa olieifera*) ; Beal (*Aegle marmelos*) ; Jangali jalabi (*Pithocolobium dule*) ; Amaltas (*Delonix regiosa*) ; Pine (*Pinus contora*) ; Samal (*Bombax ceiba*) ; Palas (*Butea monosperma*) ; Satani (*Alstonia scholaris*) ; Neem (Azardirachta indica) ; Ashoka (*Polyalthia longifolia*) ; Bottle Brush (*Callistemon citrinus*) ; Jangal Badam (*Termanilia catappal*) ; Arjune (*Terminalia arjuna*) ; Melia (*Melia azedarch*) ; Khajoor (*Phoenix dactylifera*) ; Pilkhan (*Ficus infec torja*) ; Kanju; Papadi (*Holiptelia integrifolia*) ; Blue Gum (*Eucalyptus globules*) ; Mahua (*Madhuca indica*) ; Chakotra (*Citrus maxima*) and Quaking Aspen (*Populus tremuloides*).

3. It has been observed that some species depict better efficiency in removing particle pollution; the total contribution to pollution removal are based on the canopy size, age and other morphological and environmental factors.

4. There is a negative correlation between the species with high total leaf area and their efficiency in removing particles. Species with smaller total leaf areas may do a better task of removing particles. However, the leaf morphology have been found playing major role in dust capturing by plant species.

5. The position of stomata on leaves also play an important role in better dust capturing efficiency of plants. The stomata presence on Upper & lower epidermis gives more moisture on leaf surfaces then stomata present either at Upper or lower surface of leaf or the embedded manner & sunken type's stomata. Stomata conductance and net-photosynthetic and Transpiration capability of plant species, presence of stomata on the surface are observed as more dust capturing plant species.

6. The plant species with deep channels on leaves, dense hair of leaf surface had greater affect on dust removal while plant species with smoother leaves have weaker effect.

7. The Geographical, Environmental, Morphological, Anatomical & Physiological aspects of plants species have been found influencing the dust capture by plant species, therefore following criteria should be adopted for selection of plant species for urban forest green belt development.

    - The species should be adapt to site and should be able to produce optimum harvest on a sustained basis for example tree like Ficus ***religiosa*** (Peepal), ***Ficus bengalensis*** (Banyan), ***Ficus elastica*** (Indian Rubber) and ***Artocarpus integrifolia*** (Jack Fruit).

    - The leaf litter should decompose quickly thus adding organic matter to the soil tree like ***Acacia farmesiana*** (Vilayati kicker), ***Delonix regiosa*** (Gulmohar), ***Accacia nelotica*** ((Babul), ***Azardirachta indica*** (Neem) ***Melia azedarch*** (Melia) are suitable for the purpose.

- The species should preferably be capable of enriching soil through nitrogen fixation or any other mechanism tree like members of Leguminaceare family such as ***Luceana leucophloea*** (Shoe babool), ***Acacia farmesiana*** (Vilayati kicker) are better nitrogen fixing capabilities.

- The morphological characters of the species must suit the objectives of plantation and the cultivation practice; e.g. a wide crown may be preferred for dust capturing and fuel wood plantation but small-narrow crown with minimum effect on agriculture crop and providing valuable wood.

- The following plant species have been observed as low, moderate and high dust capturing efficient plants during present study

Low, Moderate & High Dust Capturing Herbs, Shrubs & Trees

Dust Capture Level	Plant Species		
	Herbs	**Shrubs**	**Trees**
Low <10%	1.*Amaranthus hypchondriceus* (Chaulai) 2. *Gardenia jasminoides* (Crape Jasmine) 3. *Cestrum nocturmum* (Rat Ki Rani) 4. *Chrysanthamum species* (Crown Daisy)	1.*Thuja species* (Moyur Pankhi) 2.*Ravuvoifia serpentine* (Serpgandha) 3.*Withania somnifera* (Ashawagandha) 4.*Acanthus species* (Acanthus)	1.*Nyctanthese arbortritis* (Harsingar) 2.*Abis pindrow* (Silver fire) 3. *Accacia nelotica* (Babool) 4.*Holarrhena antidysentrica* (Kurchi) 5. *Clerodenrum inerme* (Glorry bower) 6. *Ficus bengalensis* (Banyan) 7.*Miliusa tomentosa* (Kari Leaves) 8.*Thespesia populania* (Ran Bhindi)
Medium 11 to 20%	1 *Lilium species* (Lily) 2.*Draceana species* 3.*Halianthus annuus* (Sunflower) 4. *Tegetes patula* (Genda) 5.*Pothus aureus* (Money Plant)	1. *Bambusa species* (Bamboo) 2. *Lagerstomia indica* (Crape Myrtle) 3. Nerium indicum (Kaner Pink) 4.*Codium varigatus* (Croton) 5.*Thevetia peruviana* (Kaner Yellow) 6.*Wrightia arborea* (Dudhi) 7.*Rosa indica* (Rose) 8.*Ipomea nil* (Beshrum) 9.*Tabermaemontana divaricata* (Chandani) 10.*Acalypha hispida* (Copper leaf) 11*Plumeria acuminate* (Temple Tree)	1.*Luecena leucophloea* (Shoe Babool) 2.*Pinus gerardiana* (Chilgoja) 3.*Ficus elastica* (Indian Rubber) 4.*Annona squamosa* (Suger Apple) 5.*Mangifera indica* (Mango) 6.*Argyreia roxburghira* (Wooly Morning Glorry) 7.*Ficus religiosa* (Peepal) 8.*Acacia famesiana* (Vilayati Kikkar) 9. *Psidium guyava* (Amrood) 10. *Prunus comminis* (Plums) 11. *Syzygium cuminii* (Jamun) 12.*Tectona grandis*(Teak) 13.*Citrus lamina* (Lamon) 14.*Morus alba* (Mulberry) 15.*Archis sapota* (Chikoo) 16.*Anthosephalus cadamb*a (Kadam) 17.*Shorea robusta* (Sal) 18.*Delbergia sisso* (Sheasm) 19.*Delonix regiosa* (Gulmohar) 20.*Albizzia lebbek* (Siris) 21. *Artocarpus integrifolia* (Jack Fruit) 22.*Ixora parviflora* (Torch Tree) 23.*Bauhinia varigata* (Kanchnar) 24.*Moringa olieifera* (Drum Stick) 25.*Aegle famesiana* (Beal) 26.*Pithocolobium dule* (Jangali jalabi)
High >21%	1. *Colocasia antiquorum* (Elephants Ear) 2.*Celosia argentea* (Cock'scomb)	1. *Hibiscus rosa sinensis* (Gurhal) 2.*Bougainvillea glavra* (Bougainvillea)	1.*Cassia fistula* (Amaltas) 2.*Pinus contora* (Pine) 3.*Bombax ceiba* (Samal)

			4.*Butea monosperma* (Palas) 5.*Alstonia scholaris* (Satani) 6.*Azardirachta indica* (Neem) 7.*Polyalthia longifolia* (Ashoka) 8.*Callistemon citrinus* (Bottle Brush) 9.*Termanilia catappa*l (Jangal Badam) 10.*Terminalia arjuna* (Arjun) 11*. Melia azedarch* (Melia) 12.*Phoenix dactylifera* (Khjoor) 13.*Ficus infectorja* (Pilkan) 14.*Holiptelia integrifolia* (Papadi) 15.*Eucalyptus globules* (Blue Gum) 16.*Madhuca indica* (Mahua) 17.*Citrus maxima* (Chaktora) 18.*Populus tremuloides*(Quaking aspe

- Multi-purpose tree plant species have a special significance in fulfilling the objectives of environment as well as needs of the people. The combination of species to address the local needs are more beneficial. The trees like Quaking Aspen (*Populus tremuloides*); Blue Gum (*Eucalyptus globules;* *Acacia farmesiana* (Vilayati kicker), *Delonix regiosa* (Gulmohar), *Accacia nelotica* ((Babul), *Azadirecta indica* (Neem) *Melia azedarch* (Melia) are more valuable.

- The tree products should have acceptable characteristics to suit local customs and traditions like flowering Herbs & shrubs species like Crape Jasmine (*Gardenia jasminoides*) ; Crown Daisy (*Chrysanthamum species*) ; Lily (*Lillium species*) ; Sunflower (*Helianthus annuus*) ; Genda (*Tagetes patula*) ; Crape Myrtle (*Lagerstroemia indica*) ; Pink Kaner (*Nerium* indicum) ; Croton (*Codium variegates*) ; Yellow Kaner (*Thevetia peruviana*) ; Dudhi (*Wrightia arboriea*) ; Rose (*Rosa indica*) ; Beshram (*Ipomea nil*) ; Chandani (*Tabernaemontana divaricata*) ; Copper leaf (*Acalypha hispida*) ; Temple Tree(*Plumeria acuminate*) ; Gurhal (*Hibiscus rosa sinensis*) and Bougainvillea (*Bougainvillea glavra*) fulfil these requrement apart from playing role in dust capture from environment.

8. The interactive factors involving urban trees and air quality needs to be further investigated in order to understand the impact of urban trees on air quality. Future research should be needed to investigate the interactive relationships of pollution removal; trace gas emissions; and air temperature and building energy use effects of urban trees on overall air quality.

9. The particulate level at various urban areas are moderate to critical level therefore critical level, cost effective particulate control technology will be necessarily required for controlling fugitive emissions

10. The plant species constituting Green Belt of Effective Dust capturing plant species should be developed around residential areas/ industrial area, as the Trees can act as efficient biological filters, removing significant amounts of particulate pollution from urban atmospheres. This is a cost effective technology for controlling particulate and gaseous emission generated due to vehicular movement, domestic emission and even industrial emissions.

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