EVALUATION OF ORNAMENTAL FLOWERING SHRUBS FOR TROPICAL LANDSCAPES

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Evaluation of ornamental flowering shrubs for tropical landscapes"** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Evaluation of ornamental flowering shrubs for tropical landscapes"** is a record of research work done independently by Mr. Najeeb Naduthodi under my guidance and supervision and that it has not previously formed the basis for award of any degree, fellowship or associateship to him.

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Introduction

1. INTRODUCTION

Shrubs are one of the most versatile elements in a landscape. They are similar to trees in that both are woody perennials and relatively permanent fixtures; in fact, certain species can be trained to tree shapes. Shrubs also fill many of the same roles as perennials, providing foliage and flowers in a wide range of colors, shapes, and textures.

Ornamental flowering shrubs, being perennial in habit, occupy a permanent place in the garden. The shrubbery should occupy the middle place between trees and herbaceous annuals. Besides, shrubs may be planted solitarily or in small groups for creating different effects. Shrubs, unlike trees, are not single-stemmed plants. A number of branches grow from the base of the plants. Their height ranges from 50 centimeters to five meters. Their flowering time also varies. With a proper selection of cultivars, a shrubbery can flower throughout the year.

Flowering shrubs, in a garden, are a perennial source of enjoyment. Colourful flowers can be had through all seasons from a well-grown shrub garden. The colourful wings of visiting butterflies add beauty and elegance to a floriferous shrub garden. The humming of bees and the chirping of small birds in a shrubbery improve the environment by maintaining an eco-balance. Dust and noise pollution is reduced to a great extent by thick shrub plantings around the house (Dey, 2001).

Shrubs amaze us with their unique habits, including: low, creeping mats or crawling ground covers; globular tufts or rangy spreaders; and arching sprays or thorny barriers. Used in combination, they can fill a landscape with constant, yet ever-changing interest and provide structural elements such as green carpets, backgrounds thick or thin, and divisions between garden beds, activity areas, and entire properties. With such versatility, it is no wonder we find so many shrubs in formal and informal gardens worldwide, always dependably providing framework and ornamental value (Tenenbaum, 1999).

Literature pertaining to studies of the shrubs that might be used by the designer has been well documented by writers over a long period. Most have treated the subject from a strictly professional viewpoint. The botanist's principal concern focused upon the proper identification of plant materials in the field, emphasizing important identification characteristics including twig, bud, leaf, flower, and fruit differences. Horticultural publications concentrated on proper plant culture. This included different propagation techniques, cultural practices and plant protection methods. Foresters traditionally stressed the identification and classification of plant community types and floristic composition. The potential uses of plant materials in the designed landscape have been largely explored in the literature of landscape gardeners, horticulturists, and more recently landscape architects. Visual aspects of plants (including qualities of form, texture, color, and seasonal change) have generally been discussed in a broad theoretical sense (Heightshoe, 1987).

The selection of the shrub for each landscaping use is based on several characters like the silhouette of the shrub, its branching structure, size, texture, density, colour contribution, hardiness and resistance to insects and diseases. Like trees, shrubs can also be used in landscapes to control air pollution.

The study is planned to evaluate ornamental shrubs based on the above characters and to classify them aesthetically and functionally for various uses in tropical landscapes. The study also planned to evaluate the Air Pollution Tolerance Index of shrubs and ability to remove volatile organic compounds for using them as pollution indicators or for controlling pollution in the outdoor environment.

Review of Literature

2. REVIEW OF LITERATURE

Shrubs are defined as woody, semi woody or herbaceous perennial plants with branches close to ground level; generally they are less than 8 m tall when fully grown. A number of branches grow from the base of the plants. The plants are usually erect and bushy but some are decumbent or prostrate. Shrubs are diverse groups in terms of mature size and shape, rate of growth, and adaptation to different growing conditions. It is very important to choose shrubs carefully before they are planted.

2.1 Shrubs in landscapes

Evergreen and deciduous shrubs of all shapes and sizes are the building blocks of a home landscape, useful as single specimens, in mixed borders, as an understory beneath tall trees, in foundation plantings, as ground covers, and for hedges and edgings. Their versatility reflects the variety of shrub shapes and sizes. Some shrubs can be ignored for decades, while others are fussy and need frequent pruning and maintenance (Buchanan, 2000).

There are numerous reasons for selecting a certain species of shrub for use in the landscape, like the silhouette of the shrub, its branching structure, size, texture and density, colour contributions, attractions to birds and butterflies, existing soil conditions, hardiness, and resistance to attack by pest and diseases.

Many shrubs have rigid, geometric shapes. As such, they function in the role of specimen or accent plants. Other shrubs are softer and less defined in their silhouettes. They mass easily; thereof several can be used in one landscape to create a desired effect. Sometimes the branching structure of shrub must be considered at the time of selection. If traffic control is expected of the shrub, the branching pattern should probably be more vertical and intertwined. The thorniness of the shrub might also be a desirable feature for traffic control (Ingels, 1978).

The size of mature, fully grown, plant determines how much security or privacy the shrub will provide. To offer full visual privacy to an outdoor living room, the shrub must be at least 1.8m tall. Privacy increases as the width of shrub and its branching density increase.

Foliage texture and density determine the visual effect of the shrub and the ability of the shrub to absorb noise, dust and wind. Generally, coarse textured shrubs attract the eye more than fine-textured shrubs. Thus, more fine-textured plants are required to counterbalance the effect of coarse texture in the landscape. Fine-textured shrubs are especially well suited for providing a background for flowers. Thick coarse textured-shrubs also aid in noise absorption and help to break strong winds. Leaves with finely haired surfaces can help to purify air by collecting dust particles from it (Ingels, 1978). Hardiness, disease and insect resistance, and colour are also important aspects in shrub selection.

2.2 Tropical environment and landscaping

In the Köppen climate classification it is a non-arid climate in which all twelve months have mean temperatures above 18 °C (64 °F). Unlike the extra-tropics, where there are strong variations in day length and temperature, with season, tropical temperature remains relatively constant throughout the year and seasonal variations are dominated by precipitation (Wikipedia, 2011).

The tropics are the area between the Tropic of Cancer and the Tropic of Capricorn. Frost is unheard of and the climate may be wet or dry, but warm weather is year-round. Tropical areas of the world include Malaysia, the Philippines, the South Pacific, the Hawaiian Islands, Indonesia, India, the West Indies, the Caribbean, Central and Northern South America, and West, Central, and East Africa. These areas are where the tropical shrubs originated and still grow as natives (Jarrett, 2003).

A tropical garden requires lots of sunlight and lots of water. The large leaves that feature in tropical plants require the soil to be humid at all times, so irrigation might be a must-have for some gardens. One of the great characteristics of tropical plants is that they keep growing all season. Color and relaxation are the essential characteristics of tropical style accessories.

2.3 Aesthetic considerations

Beauty is not only in the eye of the beholder, there are common design characteristics that are generally considered to have aesthetic value. Most people enjoy nature and the variety of form, color and texture that plants offer. The major factors that determine the suitability of a particular plant to landscapes are plant size, form, texture and colour. These are the major design components of a landscape garden.

2.3.1 Plant size

Plant size should be the primary consideration for selecting a shrub for landscaping. Large plants should be located first in a landscape. Larger shrubs provide background, visual weight and structural framework (Perry, 2007). Plant height and spread are the components which make up the volume of a shrub. Spatial definition with plants means to create an interesting, functional and solid mass and void composition. The plants are the mass and the empty spaces are the void. The landscape design deals mainly with the formation of the mass and voids (Colvin, 1997)

The relative size of plants in a design changes; some grow faster than others. Plant size is one of the most often overlooked characteristics when plant materials are selected. Selected plant materials frequently are too large for the space in which they are planted. It is very important to consider the size of the plant when it is fully mature (Denny and Hansen, 2010).Plants also can be too small for the space or application. A privacy hedge that only grows to 1 m tall is not adequate for most situations.

Shrubs can be classified based on their un-pruned height and maintainable heights as well. Height of shrubs is an arbitrary feature. Ornamental shrubs of different heights serve different functions in a landscape. Shrubberies form a permanent feature of garden and cannot be changed from year to year. So the shrubs should be selected based on their maintainable height (Bright, 2002). Generally shrubs up to 2 m height are grouped as *low* shrubs and above 2 m as *tall* shrubs (Read, 1994).

For more specific landscaping purposes, Jarrett (2003) classified ornamental flowering shrubs based on their mature, unpruned height, and maintainable height. Ornamental flowering shrubs are classified in to three groups, like small shrubs (height up to 1.2 m), medium shrubs (1.2 m to 3 m) and tall shrubs (height above 3 m) based on their mature, unpruned height. Flowering shrubs classified into four different groups based on their maintainable heights, like dwarf shrub (up to 0.60 m), small shrubs (0.60 m 1.2 m), Intermediate shrubs (1.2 m- 1.8 m) and tall shrubs (above 1.8 m). Heightshoe (1987) also grouped ornamental shrubs in to four different groups based on their height, like large shrubs (4 m – 6 m), mid-height shrubs (2 m – 4 m), small shrubs (1 m – 2 m) and very small shrub (< 1 m).

2.3.2 Form in landscaping

Each species of shrubs has a characteristic shape when grown in an open field under favorable environmental conditions. The shape of a particular shrub refers to the outline of the crown as perceived in silhouette. The plant form or silhouette link the visual principle of mass and line with biological properties of growth forms and habit (Robinson, 2004). Form is determined by the line, direction, and arrangement of branches and twigs. The resulting mass influences the scale (Whiting and de Jong, 2007). Form or shape is a second important consideration in a planting composition.

Seven basic crown forms for natural, open grown shrubs are described. They are globular, low and creeping, spreading, arching, pyramidal, upright and loose and columnar (Ingels, 2009).

Different forms have got different utility in the landscape. Globular silhouette can be used for focalization. It does not mass well and easily attract eyes. Low and creeping shrubs can be used to edge a walk and cascade over a wall. It can be used in front of tall shrubs. It's a loose irregular and informal shape. It masses well. Spreading form is seen in medium to larger shrubs; it's wider than it is tall. It can be used in out curves, and placed at corners of building. It is useful for screening, privacy and traffic control (Ingels, 2009).

Arching form is wider than it is tall. This form prevents the growth of other plants beneath itself. It helps to provide screening and dense enclosure, soften building corners and lines. It can be used as background for flowers, statuary and fountains. Pyramidal form is rigid and stiff. It attracts attention easily and can be used as accent plant and focal point. It is used at entries and outcurves. Columnar and pyramidal-shaped plants, such as tall-hedge, have visual characteristics that suggest vertical edges in an outdoor space. They create a major contrast with the more common rounded or spreading plants (Perry, 2007; Ingels, 2009). Upright and loose form is a loose, informal shape and is useful for screening and framing views. It usually require pruning to prevent leggy growth. (Ingels, 2009). The picturesque and weeping forms of plants, such as weeping birch or willow, are useful as accents or focal points in the planting design when used sparingly.

Form and size are the primary determinants of location. Choose the plant form most appropriate for the desired function and the shape and size of the space. Consideration of form also helps determine if plant material should be used in masses or as individual specimens (Denny and Hansen, 2010).

2.3.3 Texture in landscaping

Texture can be defined as the relationship between the foliage and twig size, and the mass of the plants. It refers to the visual roughness or smoothness of a plant. Close-up, texture comes from the size and shape of the leaves, the size of twigs,

spacing of leaves and twigs, the colors and shading, the gloss or dullness of leaves. At a distance, texture comes from the entire mass effect of plants and the qualities of light and shadows.

Textures get finer with distance. It is recommended to place the fine textured plants in the distant corner with coarser textured plants towards the viewer (Whiting and de Jong, 2007). All plants have texture, but shrubs dominate the landscape because of their year-round appearance. Texture can be determined by a shrub's shape, size, shape and mobility of its foliage, twigginess of its branches and growth pattern of its bark (Hériteau, 2005).

Coarse texture is dominating while fine is delicate. By combining these textures effectively a sense of interest and some variety can be created in a garden. A plant that looks fine in leaf could have a dark, corky bark and a wild branching habit to make it look coarse (Stoecklein, 2001). According to Hansen and Alvarez (2011) the size and shape of the leaves most often determine the perceived texture of the plant.

In coarse textured plants, leaves can be large, broad, dark, glossy, toothed or densely held. They have large prominent branches and open spacing (Heightshoe, 1987). Coarse shrubs are useful in the landscape in creating a focal point or in making a yard look smaller. These shrubs should be used with discretion and only to add emphasis to the garden. Generally, coarse-textured shrubs attract the eye more than fine-textured shrubs (Perry, 2007). Thus, more fine-textured plants are required to counterbalance the effect of coarse textures in the landscape.

Shrubs classified as being of medium texture have qualities of both coarse and fine. The leaves may look delicate, but the branching underneath is wiry and tangled. They have branches and twigs of intermediate diameter and spacing (Heightshoe, 1987). Leaves are medium in colour, slightly toothed or loosely held on branches.

Many of these shrubs could also be pruned into hedges because of the twiggy habit and little leaves.

Fine-textured shrubs appear delicate. Leaves are small, thin, sparse, smooth or light coloured. Branches and twigs are conspicuously slender, spacing closed. Bark is usually smooth, papery or thin, appear delicate and tend to recede from view (Perry, 2007; Hansen and Alvarez 2011). These shrubs should be used more frequently in a landscape because of their ease on the eyes. They also make a small space seem larger, an advantage in urban yards. Fine-textured shrubs are especially well suited for providing a background for flowers (Carpenter *et al.*, 1975).

Texture in the landscape is due essentially to different foliage patterns. Texture appears coarse or medium or fine because of leaf size which is a function primarily of leaf length and width. Heightshoe (1987) classified plants in to five textural categories based on their leaf area. They are coarse (more than 100 cm^2), medium coarse (60 - 100 cm^2), medium (20 – 60 cm^2), medium fine (10-20 cm^2) and fine (less than 10 cm^2).

Texture is more subtly influenced by spacing of leaves, shape and division of leaves, surface quality of leaves or by length and stiffness of petioles. If leaves are spaced closer together and denser, the effect is somewhat less coarse. Fineness, like coarseness, may be more apparent when leaves are more widely spaced or sparser. Foliage texture and density determine the visual effect of the shrub and the ability of the shrub to absorb noise, dust, and wind (Ingels, 1978).

2.3.4 Colour in landscaping

Color is one of the most important visual plant characteristics. It includes the color of leaves, flowers, fruit, branches, and bark. Green is the predominant plant color, but has seasonal variations. With evergreens, the same color is present year round. The color of the summer foliage has the longest seasonal effect and the most

importance in design composition. A variety of greens have more visual appeal when displayed against a uniform neutral green background. A common mistake is to use too many different colors. Plant color can be used as an attractor, to call attention to some area in the landscape. Dark-colored plants contrasted with light-colored plants create focal points in a planting composition (Perry, 2007).

According to Whiting and de Jong (2007), colour is the most powerful of the design elements. Colour is powerful in creating mood and feelings. Choose colors carefully to create the mood desired in the story line. Warm colours can induce a feeling of motivation and activeness, while cool colours induce calmness and relaxation.

Cool colours can be used in the home landscape to give a feeling of peace and relaxation. If scale is high with the brightly colored flowers, the action feeling of high scale helps people move through. (Whiting and de Jong, 2007). Light qualities of the site, sunny or shady areas, affect the perception of color. Warm, bright colors, such as yellows and whites, are best for shade, and all colors work well in sunny areas (Denny and Hansen, 2010).

Color theory, the science of color combinations, can help guide the selection of a color scheme for mixed plantings. Different colour schemes have got different psychological functions in the landscape. Monochromatic colour scheme induces quiet and soothing feeling. Analogous colour schemes are used for more dramatic than monochromatic. Complementary scheme demands attention immediately (Anonymous, 2000).

Neutral colours add depth to the composition; make other colors look brighter and deeper; divide colors that clash or are too strong; tone down complementary color schemes in daylight; and glow in the dark. Polychrome colour scheme, *i.e.* mixture of many colors, works most of the time because flowers naturally blend together (Anonymous, 2000).

2.4 Flowering phenology

Flowering phenology is an important factor that should be considered while selecting any ornamental flowering plant for landscape gardening. The observation and evaluation of phenological periodicity, conducted over a long term, may help us to better use particular plant species in landscaping.

'Vegetation waves' and phenological 'side-runs' are newer concepts in landscaping. The existence of vegetation wave was first described by Dierschke (1995). According to him, 'Vegetation waves' are the group of plants that can be classified in to aesthetically impressive and time specific groups. According to Bulir (2009) a 'side-run' is the situation where a particular plant species reaches an attractive phonological phase, either full blooming or full foliage colouration.

By conducting long term phenologiacal observations on particular clearly defined area, we may discover creative solution that arises from yearly repetition of concurrent aesthetic activity of broader plant groups. Dierschke (1995) widely studied and described the phenology of 'Vegetation wave' and 'Side-run'. Bulir (2009) after four year monitoring of 'side-runs', observed that if there is remarkable time shift in onset of any phenophase like delayed spring season, and the progress of phenophase is faster, the 'side-run' tend to behave in the same way.

The phenological periodicity of plants is well studied along with impact of climate change (Schwartz, 2003). Bulir (2011) classified ornamental shrubs in a single year in to 10 phenophases. According to him, the phonological phases in individual year differ considerably apart from genetically determined factors, this is due to difference in average temperature, rainfall and to their distribution time. CHMU (1987) and Coufal. *et al.* (2004) developed methods for observing phenophases.

Intensity and pattern of rainfall also play an important role in flower production in tropical flowering shrubs. Dominguez (1995) observed that a significant proportion

(15.4%) of phenotypic variation in flowering initiation was accounted for by environmental variance especially the pattern of rainfall in the flowering shrub *Erythroxylum havanense*.

2.5 Pollution control

Shrubs having rough or hairy surface texture with larger surface area help to reduce dust pollution by scavenging dust particles on the surface (Ingels, 1978). The shrubs with glossy, smooth leaf surface texture do not have this function in landscaping. Under the observed shrubs, different plants possessed hairy or rough leaf surface. These plants can be used for areas where more dust pollution problems are there. Along with leaf surface texture, leaf area and number of leaves per unit area are also important in dust control. More leaf surface area and leaf number help in reducing dust pollutants.

2.5.1 Air Pollution Tolerance Index (APTI)

In the last decade, India witnessed rapid growth of industrialization which lead to unplanned expansion of urban areas by large scale felling of trees. Rapid migration and increase in population also lead to large scale spreading of air and water pollution, garbage etc., and also impairing aesthetic value of land. In response, urban greening has to be promoted to maintain the social and natural sustainability in cities by increasing vegetated surface in urban landscape in outdoors (Joshi and Gautam, 2010). Thus by adding vegetation in urban areas and also by providing ecological diversity, we can mitigate several negative effects of urbanization physically and psychologically, especially, the air pollution and its effects.

Different plant species vary considerably in their susceptibility to air pollutants. The identification and categorization of plants into sensitive and tolerant groups is important because the former can serve as indicators and the latter as sinks for the abatement of air pollution in the indoors and proper care can be provided to

those sensitive plants from the effect of pollution. To screen plants for their sensitivity/tolerance level to air pollutants, a proper selection of plant characteristics is of vital importance. Singh and Rao (1983) has computed a formula to obtain an empirical value signifying the Air Pollution Tolerance Index (APTI) of species using four parameters namely ascorbic acid content, total chlorophyll content, relative water content and leaf extract pH.

With the APTI values, Singh *et al.* (1991) evaluated 69 plant species, including herbs, shrubs and trees and categorised them into sensitive, intermediate, moderately tolerant and tolerant classes.

On the basis of APTI and some relevant biological and socio-economic characteristics, the anticipated performance of 30 plant species in a Green Belt plantation at Kolkata and Howrah was calculated. Plant categories were graded as best, excellent, good, moderate and poor. Species belonging to the first four categories were recommended (Shannigrahi *et al.*, 2004) for controlling air pollution. Mondal *et al.* (2011) evaluated ten tree species of Burdwan town, West Bengal by Anticipated Performance Index (API) using APTI values together with other socio-economic and biological parameters and recommended tolerant species for green belt development.

Gaikwad (2006) estimated APTI values of plants growing along the roadside of Vishrambag and Shashtri Chowk, Sangli city and observed that plants were affected by increased atmospheric pollution and it was found that plants can be used as bio-indicators to assess the accumulation of autoexhaust pollutants like SO_2, NO_2 and particulate matter. In the same way, some tree species grown in Dehradun city were also evaluated to test the effect of automobile pollution on plants and found pollutants emitted from automobiles adversely affecting the ambient air and tree pigments and thus creating adverse impacts on human health (Chauhan, 2010), and emphasized the use of trees as bio-indicators for such pollution.

Sulistijorini *et al.* (2008) examined the combination of the relative growth rate (RGR) and physiological responses (APTI) in determining tolerance levels of plant species to air pollutants. Among the eight roadside tree species tested, *Lagerstroemia speciosa* was categorised as a tolerant species and *Pterocarpus indicus, Delonix regia, Swietenia microphylla* as moderately tolerant species. They also recommended *Lagersroemia speciosa* as a potent tree for roadside planting. They concluded that the combination of RGR and APTI values would be better to determine tolerance level of plants to air pollutant than merely APTI method.

Lakshmi *et al.* (2008) estimated the APTI values of tree species grown in industrial area of Visakhapatnam city and found that among 24 species tested, 20 were having low values of APTI and remaining species identified as moderately tolerant. Thus they suggested that estimation of APTI values help to identify tolerant species to air pollution and which may further help in proper selection of species in urban plantation programme. They also observed that tree species like *Ficus religiosa, Zizypus jujuba, Phyllanthus emblica* and *Cassia fistula* showed their moderate response by changing their biochemical contents according to the level of air pollution. Singh (1993) also suggested that the APTI can be used as a good indicator of the impact of pollution on plants.

Liu and Ding (2008) have collected 23 plant species growing near a Beijing steel factory and estimated their APTI values. From the results, they highlighted the need for APTI measurements to be conducted throughout the growing season, when evaluating pollution tolerance of individual species and they stressed that the APTI of species was indicated as an ideal measure for landscape planting in the vicinity of polluting industry.

In Moradabad city, Tripathi *et al.* (2009) evaluated ten different plant species from residential, industrial and commercial area for their APTI values. They found that as the city is meant for Brass and allied industries, they are the prominent sources

responsible for the elevated level of air pollutants at the industrial site. Highly significant results were obtained by them in industrial site. They proposed that analysing such parameters would be useful for the better understanding and management of air quality as well as in selection of suitable plant species for plantation in industrial areas as well as roadside and this may become the main strategy for the abatement of city's air pollution.

Jyothi and Jaya (2010) carried out an evaluation study with a view to find out the air pollution tolerance as well as sensitivity of the plant species growing adjacent to NH-47 passing through Thiruvananthapuram during different seasons. The study identified different species of trees and shrubs tolerant and sensitive to air pollutants as bio-accumulator and bio-indicator respectively to be planted along the highways.

2.6 Drought tolerance

Drought is a major limitation to plant growth and development so the identification of suitable screening techniques and quantifiable traits associated with drought tolerance can potentially help reduce the impact of water deficit on plant replacement needs and allow for remedial action where necessary to be undertaken. Fern *et al* (2011) examined drought tolerance of ornamental shrubs using the chlorophyll fluorescence ratio and digital image analysis of green foliage coverage. Both methods have been confirmed to be reliable indicators in the identification of drought tolerant and susceptible species. Evaluation of whole shrubs using chlorophyll fluorescence is found to be an efficient means to identify the susceptibility of plants to water stress.

Transpirational water loss through the stomata is a key determinant of drought tolerance (Xiong et al., 2002). According to Moussa and Abdel-Aziz (2008), the high relative water content could help the tolerant genotype to perform physiobiochemical processes more efficiently under water stress conditions than susceptible genotype.

Of the antioxidants found in plants, ascorbic acid is the most abundant. Ascorbic acid is present in plant species in millimolar concentrations that range from 10 to 300 mM (Smirnoff, 2000). Mittler (2002) observed that higher the leaf ascorbic acid content, the higher will be the detoxification power to the Reactive Oxygen Intermediates (RIO) in the plant leaves. Thus it helps to reduce the effect of water stress in plant leaves.

Most of the shrubs native to humid tropical climate are drought sensitive. Shrub species growing in humid condition responded well to soil moisture and irrigation and developed a bigger canopy than those under non irrigated condition. Also the drought tolerant plants didn't show any difference in canopy size under irrigated and non-irrigated condition (Scheiber *et al.* 2008). Native species are most useful for landscaping because of their ability to adapt to abiotic stresses like heat, drought, rainfall and salinity.

2.7 Landscaping uses of shrubs

2.7.1 Accent or specimen plant

Certain shrubs are suitable for accent or as specimen plant. An accent or specimen plant is one which, because of its unique stem arrangement, attractive foliage, or particularly showy flowers, stands out from all other plantings in the garden. Specimen shrubs are planted to show off their perfect unusual form, foliage colouring or bloom (Zucker, 1995). Focal points of the garden, specimen shrubs must look good all year long. Shrubs provide color to a landscape composition through their flowers, fruits, stems, or foliage (Sinnes, 1980).

Most deciduous shrubs contribute color through a profusion of bloom and range of flowering season. Others, such as *Syzigium zeylanicum*, *Hamelia patens* etc. provide color and interest by bearing attractive fruits or berries. The foliage of certain species contributes greatly to the color scheme of the garden. A plant grown for accent

or specimen purposes must be used alone, so that it attracts the observer's attention immediately (Morrisey and Giles, 1990).

Whistler (2000) suggested that *Odontonema cuspidatum* can be used as an accent plant due to its striking red coloured spikes. Francis (2002) recommended *Allamanda cathartica* for using as specimen plant due to its year round blooming habit.

2.7.2 Foundation planting

Foundation planting anchors a house to the surrounding landscape (Webber and White, 2002). It also helps to screen the foundation (Ingels, 2009). Most of the shrubs require regular pruning to keep them in shape.

The constant pruning ruins their natural shape. Flowering shrubs suffer the most because their blossoms are constantly being removed by frequent shearing. Although many foundation plantings consist of neatly clipped plants, it isn't necessary to have everything geometrically shaped. Many plants, such as the shrimp plant (*Justicia brandegeana*) and thryalis (*Galphimia gracilus*), need pruning only twice a year to keep them in shape. Their graceful forms and profuse flowers make a natural and unfussy statement without a lot of maintenance (Jarrett, 2003). Large shrubs should be planted on either side of the porch and at the front corner of the house. The space between are to be filled in with a line of shrubs (Garner *et al.*, 2001).

The house is the chief feature of the landscape setting, so plantings near the foundation should harmonize with each other as well as complement the architectural design of the structure. Taller foundation plants should be sighted against plain wall or in between the windows (Erler, 2005). For the most part, the plants should be easy to maintain, and the number of species should be limited to avoid striking contrasts of texture, form, and color, which may detract from the beauty of the home (Webber and White, 2002).

2.7.3 Background planting

Deep-green plants make an excellent background for their more colorful, foreground plants. They are generally one solid color rather than variegated to show off plants in the foreground. Some may have attractive flowers but their basic form is simple and consistent with dense, leafy growth from the ground up. Shrubs are arranged so as to get varied skyline (Snyder, 2000). Shrubs can be the perfect backdrop for flowers. Fisher *et al.* (2011) suggested usage of contrasting coloured leaves as background for flowers for getting the most decorative effect.

The height of the background depends solely on what is being placed in the foreground. Appropriate shrubs include viburnum, king's mantle (*Thunbergia erecta*) and orange jasmine (*Murraya paniculata*) (Jarrett, 2003). Shrubs used as background plants are planted in a mass or group (Lennox-Boyd *et al.*, 2002).

2.7.4 Screening and privacy

Using plants as screens provides a remedy for numerous common landscape problems. These living barriers provide privacy, block unsightly views, buffer wind, and reduce noise (Needham, 2008). Recommended plants are fast growers, bear dense foliage, and may be pruned for a formal effect or left to grow naturally. Select shrubs of adequate height to ensure the offending object is hidden. Suitable screening plants include Surinam cherry (*Eugenia uniflora*) and Firebush (*Hamelia patens*) (Jarrett, 2003).

Like trees and vines, shrubs are useful for screening undesirable views from within the property. Many shrubs maintain their branches and foliage from ground up and thus provide an effective screen (Klett and Cox, 2012). Frequently, taller shrubs, particularly evergreens, serve the dual purpose of providing a background for smaller shrubs, flower beds, and garden features and at the same time serving as a screen

(Hyland and Hyland, 1994). Francis (2002) recommended *Allamanda cathartica* plant for screening purpose.

The size of the fully grown plant determines how much security or privacy the shrubs will provide. To offer full visual privacy to an outdoor living room, the shrubs must be at least 2m tall. Privacy increases as the width of the shrub and its branching density increase. Foliage texture and density determine the visual effect of the shrub and the ability of the shrub to absorb noise, dust, and wind (Ingels, 1978).

2.7.5 Traffic control

An edging of ground cover plants along an entranceway or at corners of a walk helps direct attention and movement of people. Traffic movement along walks and drives can be controlled with shrubs (Sydnor, 2001). If traffic control is expected of the shrub, the branching pattern should be more vertical and intertwined. The thorniness of the shrub might also be a desirable feature for traffic control (Arora, 1990).

Shrubs can be used to control access to parking lots, to make traffic diverter prominent, and to direct the flow of traffic within the lot. When planted next to highway or in median strips, trees and shrubs can form an effective crash barrier (Chau, 2004).

2.7.6 Hedge making

There are two types of hedges: formal and informal. Formal hedges are sheared in to geometric shapes such as rectangles, squares, and circles. Informal hedges are generally pruned twice a year to keep down thick and full, but they're not sheared into shapes (Fisher, 2001). Shrubs with dense growth habit and smaller leaves are best suited for making formal hedge (Steiner, 2012). Foliage size, flowers, and growth rate are important factors when selecting shrubs for a formal hedge (Holmes and Buchnan, 2005). Shrubs that have dense, branched growth and short internodes should be

suitable for a hedge (McIndoe, 2005).Suitable shrubs bear dense growth, twiggy, leafy stems with small foliage: and inconspicous or petite flowers.

The informal look is easier to maintain and includes a wide selection of shrubs. Many flowering plants are suitable candidates since they are able to bloom fully without being pruned.

2.7.7 Topiary

Topiary is the horticultural practice of training live perennial plants by clipping the foliage and twigs of trees, shrubs and sub-shrubs to develop and maintain clearly defined shapes (Wikipedia, 2012). A shape is acquired by selectively cutting off branches which are growing in the wrong direction, and pinching stem tips. Dense and full shrubs like small-leaved evergreens are best suited for topiary. It is extensively used in gardens and amusement parks to form beautiful decorative forms and also hedges, dividers or fences, logos and hedge mazes, which are the simpler forms of topiary gardening.

A formal garden is most suitable for topiary work because it creates an Old World appearance. The most common examples used for such purposes are *Buxus sempervirens, Cupressus macropoda, Murraya exotica* and *Taxus baccata* (Randhawa, 1961).

2.7.8 Mass planting or shrub grouping

Massing, like ground-cover is a term used to describe many plants of the same type grown in one bed, planted together for a big splash of colour (Fisher, 2001). Mass plantings provide consistency of color, form, scale, and texture, usually over a large area. When dwarf shrubs are massed together, it will give a height and textural interest to the composition when compared to traditional ground cover (Scarfone, 2007).

Shrubs can be grouped in a landscape to serve a dividing function. However, in the case of a mass planting, shrubs in an island bed serve more of a landscape statement than a screening function. As such, they add dimension and drama to the landscape. Mass plantings are used in large landscapes that can accommodate this use of shrubs. Mounding and spreading shrubs look best in a mass (Hansen and Alvarez, 2011).

Grouping numerous shrubs together is an easy way to add difference to the garden. Group planting offers different accents for different seasons (Miller, 2006). Plant three or more of the same shrubs together in a cluster gives better appeal. The key to a good group is to use uneven numbers (Three, five, seven etc) as the odd man out gets to go in the middle. Many shrubs are suitable for grouping as long as they have enough space to mature.

2.7.9 Shrub border

A shrub border is full of different kinds of shrubs and may be intermingled with perennials, bulbs, and bedding plants (Bisgrove, 2000). A consistent massing of bedding plants or ground covers at the feet of the taller plants ties everything together. Mix up the textures so it doesn't become monotonous, and be thoughtful about the colors, whether it's foliage or flowers (Snyder, 2000).

Double face shrubbery border is made to get the pleasing effect of the shrubbery border from both the sides. In this type, tall shrubs are planted in the center followed by medium and dwarf shrubs both the ways (Jarrett, 2003). A shrubbery is a wide border to a garden where shrubs are thickly planted; or a similar larger area with a path winding through it.

Shrubs are useful to make the transition from wood's edge to lawn or meadow. Many flowering shrubs prefer part shade to do their best. Amid the shelter of trees, shrubs will soften the bold, bare look of tree trunks Shrubs are important tools of the

garden designer as they provide the glue that holds mixed plantings (trees, shrubs, groundcovers, perennials, grasses). This is because of the horizontal effects they can provide. Such effects can come, for example, from the horizontal branching habits of such larger shrubs. Because groundcovers also form horizontal lines, a similar effect can be produced by massing one kind of low-growing shrub as a groundcover (Hyland *and* Hyland, 1994).

2.7.10 Corner planting

One of the most natural places to position a focal point is in the corner of the outdoor room. When bed lines converge at the corner from two directions, the eyes of viewers follow willingly to the point of convergence. Incurve, *i.e.* the point of convergence easily accepts a focal feature such as a specimen plant or an accent plant. The incurve plant is usually taller than the other plants that extend from it to the outer reaches of the corner bed. The viewer's eye will step up from the outcurves to the incurve. Many variations are possible for the corner planting. A garden ornament, bench, or fountain might be used instead of a plant as the focal feature at the incurve. Flowers could be used directly at the in- curve in front of the focal feature to lend some seasonal variation to the design (Ingels, 1978).

2.7.11 Fragrant garden

A fragrant garden is composed of with full of fragrant flowering plants. Within a fragrant garden, each plant has its own unique smell. The source of fragrance in plants depends a bit on the species; some plants' flowers produce scent in specialized glands to attract potential insect pollinators. Other plants may have aromatic oils in their foliage, only to be released if bruised or crushed. To fully enjoy fragrant plants in the garden, introduce the plants in calm areas out of the wind and breeze. Such areas also may be created under arbors or by fences, walls or hedges (Perry, 2001)

Studies have shown a significant influence of certain fragrances on affective as well as cognitive states in humans. Inoue *et al.* (2003) demonstrated that pleasant odors positively affect mood and decrease arousal, whereas unpleasant odors have opposite effects. Strong odors induce higher arousal than weak odors (Bensafi *et al.* 2002), while the relationship between odor intensity and mood is less clear. Weber and Heuberger (2008) studied the effect of fragrance mood and perception under field conditions and observed that the fragrances improved subjective ratings of calmness, alertness, and mood depending on the sequence of the conditions but independent of visual features of the environment.

2.7.12 Container planting

Container gardening includes all shapes and sizes of containers, usually sitting on the ground, sometimes massive enough to hold all types of plant species including woody plants, perennials, and bulbs (Anonymous, 2000). Consider plants of varying heights which possess different foliage textures, and display blending or contrasting colors in the flowers and/or leaves when putting them together in a container (OSU, 2005).

A plant can fulfill different positions in a design depending on the size of the container. Center plants provide compact, upright growth to fill in the crown of the container. Filler plants typically have compact, upright growth and round out the top of the container (Anonymous, 2000). Corner plants grow well over the container's edge and benefit from a corner position where they have maximum elbowroom. Edge plants drape over the edge, softening the look of the container and filling out the space between its corners.

2.7.13 Covering sloppy banks

Shrubs are often used to consolidate slopes in the urban landscape. Bors-Oprişa *et al* (2011) studied rooting pattern of shrubs like *Forsythia suspensa, Berberis*

thunbergii, Lonicera pileata and *Pyracantha coccinea* under different slopes. Plants suitable for bank covers are sprawling shrubs with tenacious roots and tooting stems that hold the soil together.

Amoroso *et al.* (2010) evaluated the performance of 25 ornamental shrub species or cultivars grown in a slope during two seasons. Shrubs for bank covering purpose should be given enough spacing as most of them are fast spreading (Jarrett , 2003). Shrubs which have a fastest spreading rate and having larger ground covering area are found to be ideal for consolidation of slopes (Amorso *et al.* 2010)

2.7.14 Xeriscaping

Xeriscaping refers to landscaping and gardening in ways that reduce or eliminate the need for supplemental water from irrigation (Anonymous, 1999). It is promoted in regions that do not have easily accessible, plentiful, or reliable supplies of fresh water, and is gaining acceptance in other areas as climate patterns shift.

Implementing xeriscape principles can save a homeowner an estimated 20 to 80% of the water used in the landscape (Lockett, 2000). Use of native plants in landscape can reduce water requirements. O'Brien (1996) identified and categorised a number of native shrub species which belongs to families like *Malvacea, Rosaceae* etc., which are suitable for growing in xeriscape gardens in California.

Fern *et al* (2011) examined drought tolerance of ornamental shrubs using the chlorophyll fluorescence ratio and digital image analysis of green foliage coverage. Both methods have been confirmed to be reliable indicators in the identification of drought tolerant and susceptible species. Thompson *et al* (1995) hybridized a non-arid adapted coyote bush (*Baccharis pilularis*) and the arid-adapted desert broom (*B. sarothroides*) for developing hybrids for using in arid environments.

2.7.15 Moon garden

Moon gardens are meant to enjoy their beauty in the late evening and night hours. Moon garden uses white flowered plants and plants with grey or silvery foliages (Chandoha, 2005). There are more number of tropical white flowered plants, like Angel's trumpet (*Datura* sp.), Moon flower (*Ipomea alba*) which are well suited for making moon gardens (Mason, 2004). Shrubs with fragrant flowers like *Cestrum nocturnum, Grdenia* sp., *Jasminum* sp., *Rosa* sp., *Lonicera* sp. *etc.*, are used in moon gardens (Erler, 2005). Typically, flowers classified as those fitting for a moon garden open at night hours or late afternoon. However, there are others that may be open all day, yet release their intoxicating scent as evening approaches.

2.7.16 Rock garden

A rock garden, also known as a rockery or an alpine garden, is a type of garden that features extensive use of rocks or stones, along with plants native to rocky or alpine environments. Shrubs with xerophytic characters are used in rock gardens (Webster, 2006). Generally, plants that are low growing and have a clumping habit are preferred (Klett and Cox, 2012). Low growing or dwarf shrubs are mainly used in rock gardens. Taller Shrubs are used as companion plants in rock gardens with other plants (Grey-Wilson, 2009). Dwarf shrubs are particularly useful blended with perennials and annuals in a rock garden (Lonnee *et al.*, 2011).

Yi and Zhiyi (2007) evaluated the landscaping uses of *Eurya* species and found that low growing species can be used for planting in rock gardens. Elliott and Thornton-Wood (1997) evaluated the performance of Dwarf *Penstemon* species for using in rock gardens. Payne (1997) evaluated two *Scaevola* species which are sub-shrub to shrub in habitats for using in rockery.

2.7.17 Butterfly garden

Butterfly gardens are constructed to enjoy the beauty of garden along with the watching beauty of butterflies. Shrubs are an integral part of butterfly gardens. Nectar plants provide the sugars that adult butterflies need for nourishment and energy. Color, fragrance and shape all play a role in attracting butterflies. Most adult butterflies rely on flower nectar for food. While many tend to be attracted to a variety of available brightly colored blossoms, different butterfly species have distinct color preferences, feeding behaviors, and proboscis lengths (Daniels *et al.*, 2011). The nectar plants should be of different heights so that it will give the butterflies a wider visual picture of the colorful blossoms (Smith *et al.*, 1992). Also, the nectar plants should offer nectar flowers throughout the growing season (Lewis and Bauchnan, 1995)

Odontonema cuspidatum attracts butterflies and hummingbirds that feed on the nectar (Watkins, 1975). In butterfly bush (*Buddleia davidii*), visitation rates were low on those having white or pale lavender flowers and greatest on those having red, pink, or lavender-pink flowers. This is probably due to the fact that butterflies, unlike many insects, can perceive red wavelength colors (Culin, 1993). In general, brightly colored simple flowers with wide perching platforms attract most of the species. Flowers with scent usually provide the most nectar also. Typically, large butterflies take nectar from large flowers and small butterflies take nectar from small flowers. Although many white flowers have been found to reflect ultraviolet (UV) rays, which is highly attractive to many insects (Culin, 1993).

Many caterpillars will only eat one species of plant so it is crucial to choose the right plants for garden to attract the butterflies native to a particular area (Lewis and Bauchnan, 1995). Most of the caterpillars are family specific, as they prefer leaves from certain plant families, and a few are species specific (Gochfeld and Burger, 1997). As they fly about, adults use their highly developed sense of smell to

ensure they lay their eggs on the correct plants. When space is limited, look for plants that provide larval hosts for several species.

2.8 Propagation of flowering shrubs

Any garden soil is suitable for growing shrubs. Height and rate of growth depend upon to some extent on type of soils. Shrubs vary in their requirement of rooting and planting media. Buta *et al.* (2011) experimented on using different media for planting shrubs of *Ardisia* genus (a tropical- subtropical flowering shrub). They found that *A. crenata* showed better rooting under peat+perlite+garden soil in 3:1:1 ratio and *A. pusilla* showed best result was obtained in the mixture consisting of peat+sand+mature manure 2:1:1 ratio. The different kinds of soil conditioners like inorganic minerals, inert materials, decomposable organic material, synthetic organic conditioners, wetting agents and soil inoculates increase shrub establishment in a landscape (Wallace, 1998).

Majority of the shrubs are propagated by cuttings. Plant height, plant diameter, and the date of anthesis were the same regardless of the type of cutting, when terminal and subterminal cuttings were used for propagation in *Hamelia patens* (Davis *et al.*, 1991). In *Mussaenda erythrophylla,* a good propagule was at least 2-3 node partially mature green stem taken from the tip to the 8th node from the current season's growth (Protacio *et al.*, 2001)

Rooting hormones are used for better rooting and establishment in flowering shrubs. Stem cuttings of *Allamanda cathartica* gave 55% rooting when treated with 100 p.p.m. IAA solution (Shanmugavelu, 1960). Rooting was highest (92.5%) in softwood cuttings treated with 2000 p.p.m. IBA, followed by semi-hardwood and hardwood cuttings treated with 3000 p.p.m. IBA which gave 87.5% rooting in both

Seed germination and multiplication of shrubs like *Pereskia acculeata* (Rojas-AreHchiga and VaHzquez-Yanes, 1999) *Calliandra haematocephala* (Elias and Nevling, 1971) , *Thevetia peruviana* (Yépez and Arboleda, 2009) and *Hamelia patens* (Levey, 1987) were also reported.

For large scale multiplication, *invitro* propagation is also practiced in ornamental shrubs, especially for using in large landscape gardens. *Invitro* propagation methods were done for ornamental flowering shrubs like *Eranthemum nervosum* (Suraninpong and Te-chato, 2010) , *Bougainvillea sp.* (Shah *et al.*, 2006) *Ixora coccinea* (Dalal and Rai, 2001) *Hamelia patens* (Sankhla *et al.* , 1995) Murraya paniculata (Asănică and Şelaru, 2008).

2.9 Management of flowering shrubs

Controlled water supply can increase efficiency of water use and save water resource. Plant grown under medium water deficiency condition have shown temporary wilting without influence on ornamental effect (Hui *et al.* 2007). Kjelgren (1996) Identified Midday leaf temperature (T_l) minus air temperature (T_a) method as a potential tool for calculating irrigation timing for shrubs with dense canopies. Irrigation of certain shrubs in a landscape with dense canopies can be timed to increases in T_l-T_a. For drier regions or location where irrigation facilities are rare, use drought tolerant ornamental species. Chlorophyll fluorescence ratio and digital image analysis are found to be reliable sources for identification of drought tolerant and susceptible plant species (Fern *et al.* 2011).

The response of five Mediterranean ornamental shrubs (*Arbutus unedo* L., *Myrtus communis* L., *Pistacia lentiscus* L., *Pittosporum tenuifolium* "Variegatum" Gaertn., *Sarcococca confusa* Sealy) to water stress conditions was studied by evaluating morphological (number of shoots, height, total dry weight, growth indices) and ecophysiological parameters (leaf water potential, leaf gas exchange) (Mugnai *et al.* , 2005). *Pittosporum tenuiflorum* showed the best tolerance to water stress, as it can

maintain a slow but constant growth even in water limiting situations. *Arbutus* strongly reduced its growth in terms of dry weight, height increase and number of new shoots during water deficiency, showing a low tolerance to water stress.

The compost added to peat soil at 20% improved the uptake of phosphorus and potassium by flowering shrubs *Physocarpus opulifolius* L. 'Diabolo', *Potentilla fruticosa* L. 'Gold Drop' and *Spiraea japonica* L. 'Pruhoniciana' (Matysiak and Falkowski, 2010). Schacht *et al.* (2006) studied the effects of organic N fertilizers on the growth and yield of transplanted ornamental shrubs (*C. sanguinea*) from manure sources like shredded castor beans, cow manure and horn meal and found that there is no significant difference in effects on the yield of the ornamental shrub during the 2 years of growth after transplanting. Gonzalez and Cooperband (2002) found that the use of compost and organic manures increased the total carbon content, aggregate stability, moisture holding capacity and saturated hydraulic conductivity, under the flowering shrubs.

Shrubs need careful pruning. Shrubs are pruned by either heading-back or thinning. Hedging is a technique for more controlled shaping (Meade and Hensley, 1998). All the superfluous growth, old or weak branches are best out at ground level or as low as possible without leaving the stub. Shrubs species like *Allamanda, Oleander, Hibiscus*, and *Bougainvillea* require light pruning periodically throughout the year after a blooming flush to encourage new shoot development (Meade and Hensley, 1998). Proper pruning should be done at the correct time and season. If a plant has adventitious sprout, it should not be pruned strongly. There should be a balance between the tree root and canopy (Altinçekiç, 2002). Most shrubs respond well to pruning. Shrubs are able to re grow to at least 50% of the crown area and 70% of the height of the unsheared plants (Rupp *et al.* 1997)

2.10 Pest and diseases

Pest and diseases are also a problem in ornamental shrub growing. Prathapan *et al.* (2009) reported *Cleonaria bicolor*, a new coleopteran pest on *Ixora* sp. Sheela and Ramani (2012) reported serious chlorosis of phytophaoug mite pest on ornamental shrub species like *Justicia adhatoda*, *Hibiscus rosasinensis* and *Ixora coccinia*. Srinivasa (1987) reported coffee green scale (*Coccus viridis*) attack on ornamental shrubs *Nerium indicum* and *Hamelia patens*. Aishwariya *et al.* (2007) revealed that ornamental plants like , *Hibiscus mutabilis*, *Hibiscus schizopetalus*, *Ixora chinensis*, *Ixora coccinea*, *Jasminum auriculatum*, *Plumeria alba* and *Tabernaemontana coronaria* are infested by spiraling white fly.

It is better to select plant species resistant to pest attack. Salawu and Darabidan (2010) reported that *Nerium orleander* and *Thunbergia erecta* were resistant to nematode *Meloidogyne incognita* infection. Certain shrub species contain some insecticidal chemical contents which repel pests. These shrubs are used as organic pest control measures. Lustrino *et al.* (2008) revealed that *Allamanda cathartica* seeds can be used for controlling *Bradybaena similaris*, a moluscan pest in agricultural crops. Tablets made of garlic bulbs and *Allamanda* leaves tremendously increased germination and reduced damping-off, seed rot, seedling blight and tip over of vegetables (egg-plant, tomato, chilli) in the nursery and leaf blight, anthracnose, fruit rot, root knot and leaf curl/mosaic of tomato and carrot in the field (Meah, 2010).

Shrub species are also susceptible to various diseases. Alves and Barreto (2010) reported *Pseudocercospora ixoricola* causing leaf spots on *Ixora coccinea*. According to Rodrigues *et al.* (2008) *Brevipalpus*-transmitted plant viruses (BTrV) was observed in different shrub species, as green spot in *Allamanda chatartica*, chlorotic spot in *Gardenia* sp., chlorotic ringspot and green spot in *Mussaenda erythrophylla*. Glawe (2010) reported powdery mildew of *Tecomaria capensis* caused by *Erysiphe peruviana*.

Certain shrub species have also got anti microbial activities. Manonmani *et al.* (2009) revealed antibacterial properties of shrubs like *Nerium oleander* and *Hibiscus rosasinensis*. Singha *et al.* (2011) reported anti fungal activity of *Allamanda cathartica*.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled "Evaluation of ornamental flowering shrubs for tropical landscapes" was carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2010-2012. Thirty species of ornamental shrubs were evaluated and they were classified aesthetically and functionally for different landscaping uses.

3.1 MAJOR ASPECTS OF THE STUDY

a) Morphological description of ornamental flowering shrubs belonging to different genera and species.

b) Evaluation and classification based on plant and flower characters.

c) Observing flower phenology and identifying side-runs.

d) Estimation of pollution tolerance index of the flowering shrubs.

e) Selection of shrubs for landscaping uses.

3.2 PLANT MATERIALS

Thirty tropical ornamental flowering shrubs grown in the open field condition were selected for evaluation of their suitability for various landscaping purposes. Shrubs selected for the study are given in Table 1.

Table 1. Shrubs selected for the study

No.	Scientific name	Common name	Family
1	*Allamanda violacea*	Purple allamanda	Apocynaceae
2	*Allamanda cathartica*	Golden trumpet	Apocynaceae
3	*Allamanda cathartica* 'Dwarf'	Dwarf golden trumpet	Apocynaceae
4	*Allamanda neriifolia*	Bush allamanda	Apocynaceae
5	*Bauhinia acuminata*	White Orchid-tree	Leguminaceae
6	*Brunfelsia latifolia*	Yesterday-Today-Tomorrow	Solanaceae
7	*Calliandra haematocephala*	Red Powder Puff	Leguminaceae
8	*Clerodendrum macrosiphon*	Musical note shrub	Verbanaceae
9	*Hamelia patens*	scarletbush,	Rubiaceae
10	*Ixora chinensis*	Chinese ixora	Rubiaceae
11	*Ixora coccinea*	Ixora	Rubiaceae
12	*Ixora rosea*	Pink ixora	Rubiaceae
13	*Kopsia fruticosa*	Shrub Vinca, Pink Kopsia	Apocynaceae
14	*Lonicera japonica*	Japanese Honeysuckle	Caprifoliaceae
15	*Murraya paniculata*	Orange jasmine	Rootaceae
16	*Mussaenda erythrophylla*	Mussaenda	Rubiaceae
17	*Nerium indicum*	Nerium, purple oleander	Apocynaceae
18	*Odontonema cuspidatum*	Firespike, cardinal flower	Acanthaceae
19	*Otacanthus caeruleus*	Brazilian Snapdragon,	Scrophulariaceae
20	*Pereskia bleo*	Deseart rose	Euphorbiaceae
21	*Pseuderanthemum graciliflorum*	Blue Twilight	Acanthaceae
22.	*Pseuderanthemum reticulatum*	Yellow vein eranthemum	Acanthaceae
23	*Rondeletia odorata*	Panama rose	Rubiaceae
24	*Russelia juncea*	Coral Fountain	Plantaginaceae
25	*Tabernaemontana coronaria*	Crape jasmine	Apocynaceae
26	*Tabernaemontana coronaria* 'Nana'	Dwarf tabernae	Apocynaceae
27	*Tabernaemontana coronaria* 'Variegata'	Variegated tabernae	Apocynaceae
28	*Tecomaria capensis*	Cape Honeysuckle	Bignoniaceae
29	*Thevetia peruviana*	Yellow oleander	Apocynaceae
30	*Wrightia antidyseterica*	Snow flake	Apocynaceae

3.3 METHODS

3.3.1 Characterisation

Ornamental flowering shrubs selected for the study were morphologically described based on growth habit, foliage characters, branching characters and flower characters.

3.3.2 Evaluation and classification based on plant and flower characters

Observations were recorded on biometrical and morphological characters of the shrubs selected for the study. Biometrical characters were recorded at monthly interval. Flowering season and flower characters were also recorded.

3.3.3 Configuration of phenological calendar and identification of side-runs

The mean value of total flowers produced in all replications was calculated each month and expressed as percentage of the maximum flower production. Months with values below 25 were considered as non flowering. When a shrub reached at least 25 % of its full bloom, it was considered to be at its phenophase. Four phenophases i.e. Dec-Feb, March-May, June-Aug. and Sept-Nov, were recorded and shrubs were categorized to respective phenophases based on observations made on the blooming. Different combinations of plants (side-runs) which behaved identically in a particular time point were found out.

3.3.4 Estimation of pollution tolerance index of the flowering shrubs

Air pollution tolerance index (APTI) of selected shrubs coming under different groups suitable for landscaping were computed by using the values obtained from the estimation of ascorbic acid, chlorophyll a and b, relative water content and leaf extract pH.

The APTI value was worked out as follows

APTI = (A(T+P)+R)/10

Where A -Ascorbic acid content (mg/g) T - Total chlorophyll (mg/g

P - pH of leaf extract R – Relative water content of leaf (%)

3.3.5 Selection of shrubs for landscaping uses

Shrubs were selected for various landscaping uses based on the observed plant, leaf and flower characters.

3.3.6 *Management of plants*

Ornamental shrubs were grown in open field condition. To boost up growth, Organic manure application in the form of cowdung, done twice a year at 10 kg per plant. Irrigation was daily during the summer period and after cessation of the rainy season. Regular weeding were done to keep the field weed free.

3.3.7. Design of the experiment

For field experiments a completely randomised design with three replications was laid out.

3.4 Climate

Vellanikkara is located at an altitude of 22.25 m above MSL and between 10°31' N latitude and 76°10'E longitude. The area enjoys tropical humid climate. Meteorological data during the period of investigation are presented in Appendix- No.1.

3.5 OBSERVATIONS

The following observations were recorded for evaluating the landscape uses of ornamental flowering shrubs.

3.5.1 Vegetative characters

3.5.1.1 Plant height (cm)

Height of the plant was measured from the from ground level to tip of the plant. Observations were recorded at monthly interval.

3.5.1.2 Spread (cm)

Spread of the plant was taken at monthly interval by measuring in east west and north south direction. The mean value was taken and expressed as spread in centimeters.

3.5.1.3 Length and girth of petiole (cm)

The length of the leaf from the basal lobe to the tip was measured in centimetres. Maximum leaf width at the centre of the leaf was measured in centimetres.

3.5.1.4 Leaf area (cm^2)

Dot method (Bleasdale, 1977) was used to measure the leaf area and the same was expressed in square centimetres.

3.5.1.5 Number of leaves

Number of leaves per unit area was counted. The leaf number was counted taking an iron rectangle frame of 1000 cm^2.

3.5.1.6 Leaf length, breadth (cm)

Leaf length and breadth were measured and expressed in cm. The length of the leaf from the basal lobe to the tip was measured in centimetres. Maximum leaf width at the centre of the leaf was measured in centimetres.

3.5.1.7 Shape of leaf lamina

Shape of the leaf lamina, shape of leaf margin and leaf tip were observed and described.

Shape-linear, lanceolate, ovate, cordate

3.5.1.8 Type of leaf base, margin and tip

Base- acute, obtuse, rounded, attenuate

Margin-entire, wavy, serrate, palmatifid

Tip- acute, obtuse, mucronate

3.5.1.9 Leaf surface texture

Leaf surface texture also observed and categorized like smooth, verrucose, leathery, cereous etc.

3.5.1.10 Pubescence

Leaf lamina was observed for pubescence and described.

3.5.1.11 Branching habit

Pattern of branching was observed and described.

3.5.1.12 Colour of leaves

Both upper and lower leaf colour were observed and described.

3.5.2 Flower characters

3.5.2.1 Flower type

Type of flower/ inflorescence was observed and recorded.

3.5.2.2 Size of flower

Size of single flower was measured and recorded in the case of solitary flowers and in the case of inflorescence, length and diameter of single floret as well as diameter of whole inflorescence was measured.

3.5.2.3 Length of flower stalk

Length of flower stalk from point of emergence to calyx were measured and recorded.

3.5.2.4 Interval of flower production

Interval of flower production on each inflorescence was observed and recorded.

3.5.2.5 Number of flower produced

Total number of flowers/ inflorescence produced was counted and recorded every month.

3.5.2.6 Colour of flower

Flower colour was observed visually and described.

3.5.2.7 Fragrance

Flowers were observed for fragrance and described.

3.5.2.8 Attraction to butterflies

Flowers were observed for attraction to butterflies as well as larval caterpillars.

3.5.3 Flowering period

3.5.3.1 Season of flowering

Flowering seasons of each shrub were observed and recorded

3.5.3.2 Time taken for flower opening (Days)

Time taken to open up a flower bud from its stage of appearance counted

3.5.3.3 Flower persistence (Days)

Persistence of single flower as well as inflorescence recorded

3.5.4 Evaluation of tolerance level of shrubs to air pollution

3.5.4.1 Ascorbic acid content

Ascorbic acid content of leaves is estimated and recorded. For the determination of ascorbic acid content, a homogenate was prepared by using 4% oxalic acid, and was dehydrogenated by bromination. The dehydroascorbic acid was then reacted with 2, 4-nitrophenyl hydrazine to form osazone and dissolved in sulphuric acid to give an orange-red colour solution which was measured at 540 nm (Sadasivam and Manickam, 1996).

3.5.4.2 Chlorophyll content

Chlorophyll a, Chlorophyll b and total chlorophyll content of leaves were estimated and recorded. Chlorophyll was extracted in 80% acetone and the absorption at 663 nm and 645 nm were read in a spectrophotometer. Using the absorption coefficients, the amount of chlorophyll was calculated.

3.5.4.3 Leaf water content

Relative leaf water content of leaves was estimated using fresh weight, dry weight and turgid weight. The percentage relative water content was calculated by using the initial weight, turgid weight and dry weights of leaf samples (Wood and Burchett, 1995).

3.5.4.4 Leaf extract pH

Leaf extract pH was calculated and recorded. Fresh leaf (0.5 g) sample was homogenized using 50 ml distilled water and the supernatant was fed into digital pH meter for detection of pH (Jyothi and Jaya, 2010).

3.5.5 Estimation of transpiration rate

Transpiration rate of leaf lamina was estimated using IRGA and recorded. Transpiration rate was directly recorded with Infra Red Gas Analyser (IRGA).

3.5.7 Statistical tool used

All the tabulated data were statistically analysed using SPSS version 16

Results

4. RESULTS

The results of the "Evaluation of ornamental flowering shrubs for tropical landscapes" conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2010-2012 are presented in this chapter.

4.1 MORPHOLOGICAL DESCRIPTION

Morphological descriptions of 30 ornamental flowering shrubs selected for the study are given below. Descriptions are based on observations recorded on four year old flowering shrubs maintained in the shrubbery of the Department of Pomology and Floriculture.

4.1.1 Allamanda cathartica Linn. *(Plate 1a)*

Common name : Golden trumpet/ Buttercup flower

Family : Apocynaceae

Centre of origin : Brazil/ Northern South America and Brazil

An evergreen glabrous shrub which is capable of assuming a climbing or rambling habit. Branches smooth, green; reaches to height of 261.2 cm and have spread of 185.8 cm. Leaves opposite in whorls of four, 133 cm long and 5.17 cm wide, obovate or oblanceolate in shape, acute at the base, shortly acuminate at the tips, margin entire, smooth and glabrous surface texture; petiole very short, 0.32 cm long and have girth of 0.58 cm; internodal length 12.0 cm, branches weeping. Twigs, petioles and leaves produce a milky exudates.

Flowers large and showy, yellow, in terminal (afterward axillary) cymose panicles; calyx of five sepals, glabrous; corolla of two distinct portions, lower portion is narrow tubular and upper portion is campanulate in shape, ending above in five orbicular lobes; single flower is 10.00 cm long and , 8.00 cm in diameter; stalk length 1.2 cm. Blooms profusely year round.

4.1.2 Allamanda cathartica 'Dwarf' Linn. *(Plate 1b)*

Common name : Dwarf golden trumpet

Family : Apocynaceae

Centre of origin : South America

An evergreen glabrous shrub with climbing or rambling habit, dwarf growth habit without supporting structures; height 80.4 cm and spread 58.5 cm; branches smooth, green, smooth. Leaves in whorls of four, 6.30 cm long and 1.13 cm wide, narrowly lanceolate in shape, acute at the base, shortly acuminate at the tips, margin entire, smooth glossy in surface texture; petiole very short, 0.30 cm long, 0.48 cm in girth; internodal length 1.77 cm; branching pattern ascending.

Flowers large and showy, yellow, in terminal (afterward axillary) cymose panicles; calyx of five sepals, glabrous; corolla of two distinct portions, lower portion is narrow tubular and upper portion is campanulate in shape, ending above in five orbicular lobes; single flower is 5.83 cm long and , 5.67 cm in diameter; stalk length 0.8 cm. Blooms year round.

4.1.3 Allamanda neriifolia Hook. *(Plate 1c)*

Common name : Bush allamanda

Family : Apocynaceae

Centre of origin : Central and North America

Medium sized shrub reaches up to 152.9 cm in height, and having spread of 138.9 cm. Form is globular. Leaves are elliptical, 6.5 cm long and 3.20 cm wide, cuneate at the base, acuminate at the tip, margin entire; leaf surface texture is coriaceous; whorled arrangement of leaves; petiole 0.89 cm long and 0.57 cm in girth. Internodal length is 1.90 cm; branching pattern picturesque.

Flowers showy, yellow, in terminal as well as axillary cymose panicles; calyx of five sepals; corolla of two distinct portions, lower portion is narrow tubular and upper portion is campanulate in shape, ending above in five orbicular lobes, single flower is

3.50 cm long and , 3.90 cm in diameter; stalk length 0.4 cm. Blooms irregularly throughout the year.

4.1.4 Allamanda violacea Gardn. *(Plate 1d)*

Common name : Purple allamanda

Family : Apocynaceae

Centre of origin : Northern South America and Brazil

An erect, sometimes scrambling shrub; reaches to height of 254.2 cm and spread of 153.0 cm. Leaves verticillate, 11.17 cm long and 6.40 cm wide; very shortly petioled, 0.18 cm long and 0.40 cm girth for petiole. Leaves obovate or oblong in shape, acute at the base, cuspidate or abruptly acuminate at the apex, entire on the margins, rough on both surfaces with short, stiff, stout hairs on lamina; internodal length 11.67 cm; branching pattern weeping; twigs, petioles and leaves produce a milky exudates.

Inflorescence a few flowered cyme, terminal. Flowers large and showy, violet, purplish brown or purplish; stalk 1.2 cm long; calyx of five separate lobes; corolla tube up to 6.7 cm of two parts, the lower tubular narrow and upper campanulate part, ending above in a five orbicular or broadly ovate lobes; flowers 8.00 in diameter and 10.00 cm long. Blooms throughout the year.

4.1.5 Bauhinia acuminata Linn. *(Plate 1e)*

Common name : White orchid tree, Snow orchid tree

Family : Leguminosae

Centre of origin : Central India, Srilanka and Malaya

An erect shrub with height 241.7 cm and spread 148.6 cm; leaves alternate, 12.17 cm long and 11.00 cm wide; petioles 2.97 cm long, 0.70 cm thick, swollen at the base and apex, downy; compound leaf blade, 9-11 nerved from the base, the common midrib being produced as a very short spur, orbicular in shape, acuminately 2-lobed, base cordate, margin entire; coriaceous in surface texture, glabrous above, pubescent on the

nerves beneath; internodal length 3.87 cm; upright-ascending branching habit, grayish brown branches.

Flowers are pure white, close, shortly peduncled, in axillary corymbose racemes. Stalk 0.9 cm long; calyx tubular, reflexed and divided in to five lobes below when flower opens; petals 5.6 cm long, 1.8 cm wide, oblong-obtuse, white, rounded at the base; flower diameter 8.00 cm and length 6.00 cm. Blooms from February to June and August-December.

4.1.6 Brunfelsia latifolia Benth. *(Plate 1f)*

Family : Solanaceae

Common name : Yesterday-Today-Tomorrow

Centre of origin : Tropical America

A small shrub with height 86.5 cm and spread 56.8 cm. Leaves arranged alternately, elliptic or obovate in shape, 8.00 cm long and 3.20 cm wide, cuneate at base, acute at tip, margin entire; surface glabrous and dark green above, slightly pubescent and lighter green below; petiole 0.73 cm long and 0.43 cm thick; internodal length 2.00 cm; ascending branching pattern, spreading branches, and green smooth glabrous twigs.

Flowers arranged in terminal clusters, or few flowered axillary cymes. Stalk 0.6 cm long; calyx erect, campanulate; corolla hypocrateriform, pale violet or mauve in colour with white centre, fading a few days after opening to a pure white; tube 3.50 cm long, slender, slightly curved; lobes five, orbicular, little undulate; corolla head diameter 3.50 cm. Blooming period March-June and August-November.

4.1.7 *Calliandra haematocephala* Hassk. *(Plate 1g)*

Family : Leguminosae

Common name : Red powder puff

Centre of origin : Bolivia

Tall shrub which reach to a height of 319.4 cm and having spread of 269.7 cm. Compound leaves are paripinnate, with 7-9 leaflet pairs, arranged alternately. Leaflets are obliquely lanceolate, 4.89 cm long and 4.26 cm wide; sparsely pilose at the margin, base oblique, apex obtuse, mucronate, coriaceous or papery in texture, dark green in colour; petiole 3.63 cm long and 1.47 cm in girth; internodal length 1.63 cm; branches in ascending pattern.

Inflorescence axillary head, 7.80 cm in diameter (including filaments); peduncles 1.56 cm; calyx campanulate; corolla purplish; Stamens numerous, scarlet, reddish purple in colour; staminal tube white, 0.70 cm long, mouth inside with a subulate appex; filaments deep red, 4.17 cm long. Season of blooming is August to March.

4.1.8 *Clerodendrum macrosiphon* Hook. f. *(Plate 1h)*

Common name : Musical note plant

Family : Verbenaceae

Centre of origin : Africa - Nigeria

Medium shrub with dense canopy, reaches up to height of 153.1 cm and spread of 129.8 cm. Leaves are spathulate to lanceolate in shape, 8.20 cm long and 3.67 cm wide; attenuate leaf base, acuminate or acute tip, margin serrate, arranged in opposite deccusate pattern, surface texture downy; petiole length is 1.10 cm and girth 0.60 cm, purplish tinge for the petiole; intermodal length is 1.83 cm; upright-ascending branching habit.

a. Allamanda cathartica

b. Allamanda cathartica 'Dwarf'

c. Allamanda neriifolia

d. Allamanda violacea

e. Bauhinia acuminata

f. Brunfelsia latifolia

g. Calliandra haematocephala

h. Clerodendrum macrosiphon

Plate 1. Flowering shrubs-I

Inflorescence is head like terminal cyme or leafy panicle. Unopened flower bud is like musical note. Flowers are trumpet shaped. Stalk length 0.4 cm; corolla white coloured, corolla tube 6.40 cm long, corolla head diameter 1.90 cm; inflorescence diameter 9.67 cm; stamens showy and reddish purple in colour, which outgrow the flowers. Blooming period is March to June and August to December.

4.1.9 Hamelia patens Jacq. *(Plate 2a)*

Common name : Fire bush, Scarlet bush

Family : Rubiaceae

Centre of origin : Tropical America

Tall growing shrub with branches reddish, covered with a short crisped pubescence, quadrangular when young, afterward rounded. Reaches to height of 248.6 cm and spread of 185.1 cm. Leaves stipulate, 4.9 cm long and 4.03 cm wide; petiole 1.30 cm long and 0.40 cm in girth; leaves elliptic or oblong in shape, narrowed or acute at both ends, margin entire, olive-green above, paler beneath, membraneous texture, opposite or in whorls of three; nerves tinged with red beneath; petiole reddish and hairy; internodal length 2.53 cm; branching pattern horizontal.

Inflorescence terminal, in cymes up to 8.10 cm long, principal axis short; secondary axis up to 2.5 cm long bearing 3-5 flowers arranged in a scorpioid cyme; pedicels very short; calyx tube adnate to the ovary, campanulate, reddish in colour; corolla tube cylindrical, ridged, shortly pubescent, 2.07 cm long, and 0.33 cm in diameter, slightly attenuate just above the base, cylindrical, 5- lobed, valvate in bud stage; inflorescence diameter 4.60 cm. Blooms throughout the year.

4.1.10 Ixora chinensis Lamk. *(Plate 2b)*

Common name : Chinese ixora

Family : Rubiaceae

Centre of origin : Malaya- China region

A small shrub with straight branches, covered with smooth dark brown bark. Height 122.8 cm and spread of 45.5 cm. Leaves opposite, 10.60 cm long and 4.53 cm wide, stipulate; subsessile, petiole 0.36 cm long and girth 0.68 cm; obovate or obovate-oblong lamina; entire leaf margin, cuneate at base and obtuse at tip, smooth on both surfaces; internodal length 2.17 cm; branching pattern upright.

Inflorescence is terminal and consists of dense corymbs; branches of inflorescence trichotomous, smooth, glabrous, reddish. Calyx tube adnate to ovary; corolla tube cylindrical, slender, single flower 2.43 cm long and 1.90 cm in diameter; corolla 4-lobed, almost orbicular; inflorescence diameter 9.00 cm. The colour of flowers is first orange, becoming a deeper salmon-red, as flowers become fully open. Profuse flowering from August to January.

4.1.11 Ixora coccinea Linn. *(Plate 2c)*

Common name : Scarlet ixora

Family : Rubiaceae

Centre of origin : Western Chinese peninsula-Myanmar

A compact shrub, glabrous all over, reaches height up to 152. 7 cm and spread to 145.0 cm. Leaves almost sessile, opposite, elliptic, ovate or obovate in shape, acuminate at the tip, somewhat cordate at the base, thickly coriaceous in texture, glossy green in colour; 16.97 cm long and 6.23 cm wide; petiole 0.48 cm long and 0.69 cm in girth; intermodal length 4.07 cm; branching pattern upright.

Inflorescence terminal, supported by two small, leaf like bracts, strongly contracted, forming a compact corymb. Calyx urceolate, green, with four triangular

acute lobes, reddish or purplish at the tips; corolla hypocrateriform, with slender tube 3.27 cm long, surrounded by four spreading ovate-acute lobes 0.7 cm long, which later reflexed, crimson red coloured; single flower diameter 2.86 cm; inflorescence diameter 10.67 cm. In bud stage the lobes are twisted to left. Blooms throughout the year.

4.1.12 Ixora rosea Wall. *(Plate 2d)*

Common name : Pink ixora

Family : Rubiaceae

Centre of origin : Indonesia and China

A low growing bushy shrub, older stems covered with slate-grey brown glabrous bark; younger plants dark green, covered with a fine downy pubescence. Height 94.7 cm and spread 72.3 cm. Leaves subsessile, elliptic-obovate in shape; leaf length 11.03 cm and breadth 6.23 cm; leaves cuspidate at the tip, rounded or slightly cordate at the base, coriaceous in texture, glossy green above, pale below, glabrous; petiole 0.43 cm long and 0.70 cm in girth; intermodal length 3.00 cm; branching pattern upright.

Inflorescence peduncled corymb; peduncles supported at the base by small bracts. Flowers shortly pedicelled, each with a pair of bracteoles below the calyx. Calyx urn-shaped, red coloured; corolla hypocrateriform, tube 3.00 cm long, rose coloured, minutely hairy, ending above in four elliptic-obtuse lobes, 0.7 cm long; single flower diameter 1.47 cm; inflorescence diameter 8.50 cm. Flowers throughout the year.

4.1.13 Kopsia fruticosa (Ker.) A. DC. *(Plate 2e)*

Common name : Shrub vinca

Family : Apocynaceae

Centre of origin : South-East Asia

It is a medium sized shrub which reaches to a height of 164.9 cm and having a spread of 118.1 cm. Form is globular to round. Leaves are glabrous, 13.97 cm long and 5.70 cm wide, elliptical to narrowly elliptical, acute at the base, tip acuminate, margin entire or little wavy, surface smooth and glabrous, arranged in opposite pattern; petiole 1.23 cm long and 0.78 cm in girth; intermodal length of 6.00 cm; branching pattern upright.

It flowers in terminal corymb, peduncle up to 1 cm, bracteoles 1.5 mm, pubescent. Pedicel 5.7 cm, sepals ovoid; corolla pink, tube 4.00 cm, throat pubescent, lobes oblong, corolla diameter 3.50 cm; inflorescence diameter 9.67 cm; colour light pink, which fades to paler colour as time. It flowers throughout the year, except in the high rainy months.

4.1.14 Lonicera japonica Thunb. *(Plate 2f)*

Family : Caprifoliaceae

Common name : Japanese honeysuckle

Centre of origin : China – Japan region

A crawling or creeping shrub; stems glandular- hairy, cylindrical. Height 49.9 cm and spread 73.1 cm. Leaves opposite, 5.67 cm long and 2.43 cm wide, petioled, ovate to oblong oblique at the base, acute or obtuse at the tip, glabrous or sparsely hairy on the upper surface, ciliate on the margins; petiole covered with soft yellow hairs, 0.42 cm long and 0.48 cm in girth; intermodal length 2.07 cm; branching pattern horizontal.

Flowers in axillary pedunculate pairs, or collected in to spikes of whorled pairs. Pairs of flowers supported by foliaceous bracts; calyx adnate to ovry, very hairy, ending in five subulate hairy teeth; corolla two lipped, softly and shortly hairy within and outside, white colour changing to dull yellow in second day; upper lip four lobed and lower single lobed; single flower 3.2 cm in length and 1.47 cm in diameter;

inflorescence diameter 4.83 cm. Flowers have fragrance. It blooms well in summer season and irregularly in rainy season.

4.1.15 Murraya paniculata Linn. *(Plate 2g)*

Common name : Orange jasmine

Family : Rootaceae

Centre of origin : China, South East Asia and India

Medium sized shrub, with oval form, reaches up to 178.5 cm height and having spread of 126.7 cm .Leaves are compound, odd pinnate, arranged alternately. Leaflets are orbicular to ovate, tip obtuse, base acute, margin entire. Leaflets have length of 5.71 cm and width of 2.50 cm. Petiole 1.73 cm long, and have girth of 0.50 cm; intermodal length 2.43 cm. Leaf surface is smooth and glabrous, with dark green colour; branching pattern upright.

Inflorescences terminal or terminal and axillary, in 3-flowered cymes. Flowers pentamerous, fragrant; sepals ovate to lanceolate, to 2 mm, persistent in fruit; petals white, narrowly elliptic to oblanceolate, to 2 cm; single flower diameter 2.00 cm, length 2.00 cm; inflorescence diameter 6.33 cm. It flowers throughout the year irregularly.

4.1.16 Mussaenda erythrophylla Linn. *(Plate 2h)*

Common name : Peach mussaenda

Family : Apocynaceae

Centre of origin : South East Asia

A tall shrub with arching form, reaches to 291.7 cm height and spread of 248.3 cm. Leaves are elliptical, base acute, tip acute-obtuse, leaf margin entire; leaf length of 14.50 cm and breadth of 7.50 cm; leaves arranged in opposite pattern; pubescent in texture; petiole 1.15 cm long and 0.75 cm in girth; internodal length 4.03 cm;

a. Hamelia patens

b. Ixora chinensis

c. Ixora coccinea

d. Ixora rosea

e. Kopsia fruticosa

f. Lonicera japonica

g. Murraya paniculata

h. Mussaenda erythrophylla

Plate 2. Flowering shrubs-II

ascending or recurving branching pattern; branches are woody and grey-brown coloured.

The flowers are small and tubular 1.83 cm in diameter; the corolla is five-lobed, spreading and bright yellow to white; borne in terminal clusters (cymes or panicles). Surrounding calyx has five lobes, with one lobe conspicuously enlarged, leaf-like and usually brightly colored; length of single petal 6.88 cm; whole inflorescence measure 32.67 cm in diameter. All five sepals are enlarged, coloured pink. Blooms year round except from December to February.

4.1.17 Nerium indicum Mill. *(Plate 3a)*

Common name : Oleander

Family : Apocynaceae

Centre of origin : India and the Mediterranean

A glabrous erect shrub, reaches to height of 254.1 cm and spread of 79.97 cm. Leaves mostly in threes, sometimes twos, whorled, linear shaped, tapering at both ends, thick, coriaceous, with thick midrib; leaf lamina length 22.33 cm and width 2.43 cm; petiole 1.97 cm long, and 0.79 cm in girth; internodal length 2.47 cm; branching pattern upright; young shoots greenish, thin, brown, emitting milky sap when cut.

Flowers arranged in a terminal panicles, pink or white, single, fragrant, peduncle and pedicel minutely pubescent, bracts small, 0.75 cm long. Calyx divided nearly to the base in to five linear, acute, pubescent lobes; corolla-tube 1.75 cm long, lower half tubular, hairy within, upper half campanualte, ending above in five rounded overlapping petals; corona of five scales present in the throat of corolla, each cleft in to 3-7 segments; inflorescence diameter 14.00 cm; single flower diameter 2.50 cm. Blooms throughout the year.

4.1.18 Odontonema cuspidatum (Nees) Kuntze. *(Plate 3b)*

Common name : Cardinals' guard, Mottled toothed thread

Family : Acanthaceae

Centre of origin : Mexico and Panama

A medium to small shrub reaches to height of 83.2 cm and spread of 46.03 cm. Form is irregular upright. Leaves are succulent, smooth, elliptically arranged in opposite pattern. Leaves 13.00 cm long and 7.37 cm wide; leaf base is acute, tip acuminate, margin entire; petiole 1.30 cm long and 0.60 cm in girth; internodal length is 6.67 cm. The stems are upright, branched, and semi-woody; Young shoots have purple tinge, branching pattern leggy.

The inflorescences are terminal racemes, sometimes branched, composed of tubular flowers of scarlet colour, produces abundant flowers, 24.5 cm long inflorescence, 5.00 cm in diameter, upright panicles of brilliant red tubular flowers; individual flowers are up to 3.73 cm long, 0.30 cm in corolla tube diameter, tubular with 5 triangular-ovate lobes. It blooms throughout the year with less blooming in rainy period.

4.1.19 Otacanthus caeruleus Lindl. *(Plate 3c)*

Common name : Brazilian snap dragon, Amazon blue

Family : Scrophulariaceae

Centre of origin : Brazil

Small herb to shrub, with loose irregular form, attains form of support, reaches to height of 81.0 0 cm and have spread of 50.53 cm. Leaves are lanceolate, 6.17 cm long and 2.60 cm wide, arranged in opposite deccusate pattern. Leaf base is attenuate, tip acute, margin crenate to serrate; sessile leaves; leaf surface is slightly rough with hairs, little succulent; intermodal length 2.13 cm; branching pattern upright.

Racemose inflorescence comprised of exactly 4 flowers joined together at common base; calyx is Light green, 5 very small calyxes fused together; flowers have a slender, 3.13 cm long floral tube and are bilaterally symmetrical with fan-shaped upper and lower lips, lower lip has a conspicuous white "eye" at the base; inflorescence diameter 5.67 cm. Blooms throughout the year.

4.1.20 Pereskia bleo (Kunth) DC. *(Plate 3d)*

Common name : Wax rose, Rose cactus

Family : Cactaceae

Centre of origin : Central America

An erect growing shrub, reaches up to 239.8 cm and spread 86.4 cm. Form is irregular upright. Leaves are smooth and succulent, arranged in spiral pattern. The elliptical leaves are 16.83 cm long and 5.77 cm wide. Leaf base is acute, tip acuminate, margin entire to wavy; petiole 2.97 cm long and have girth 0.84 cm; intermodal length is 1.43 cm; branching pattern upright.

Flowers in terminal, singly or in clusters of two; stalk length 1.22 cm; flowers with 8-11 petals, length of petals 1.53 cm; flower diameter 3.00 cm; length of single flower 2.23 cm; flowers crimson red or orange red in colour. It blooms irregularly year round.

4.1.21 Pseuderanthemum graciflorum (Nee.) Ridl. *(Plate 3e)*

Family : Acanthaceae

Common name : Blue Twilight, Blue Crossandra

Centre of origin : Sri Lanka, India and Malaya.

Small shrub of 81.6 cm height and 58.5 cm spread. Leaves narrowly ovate to elliptical, 11.33 cm long and 5.17 cm wide, arranged in opposite deccusate pattern. Leaf base acute, tip acuminate, margin entire to wavy; surface texture is coriaceous;

petiole 1.53 cm long and girth of 0.60 cm; internodal length 2.67 cm; branching pattern recurving.

Panicle of trichotomous, arises from branched terminals spikes, bracteoles small, narrow; calyx 5-lobed, lobes narrow, subequal; corolla subsalverform, tube basally cylindric, long, slender, throat sometimes inconspicuous; limb 5-lobed; lobes obovate, subequal, contorted in bud; single flower length 3.73 cm, diameter 1.53 cm; inflorescence length 21.84 cm, diameter 6.50 cm. Flowers from October to June.

4.1.22 Pseuderanthemum reticulatum (Hook.f.) Radlk. *(Plate 3f)*

Common name : Yellow vein eranthemum

Family : Acanthaceae

Centre of origin : Polynesia and Melanesia

Erect, multibrached medium sized shrub, reaches to height of 131.9 cm and have spread of 46.2 cm. Form is irregular upright. Leaves are ovate arranged in opposite deccusate pattern, have length of 8.97 cm and breadth of 6.60 cm; leaf base is rounded, tip acute or obtuse, margin entire; leaf colour yellowish green with intrinsic network of yellow veins; leaves are smooth, glossy and succulent; petiole 1.07 cm long and 0.66 cm in girth; intermodal length is 1.63 cm; branching pattern ascending or upright.

Large flower spikes produced from the end of branches. Inflorescence is three branched spike. The calyx is highly reduced with more numerous minute teeth. The corolla is sympetalous, pentamerous, and two lipped; small white flowers have bluish purple patches, and grow in colourful loose erect clusters. Inflorescence length 18.6 cm, diameter 5.67 cm; single flower length 1.97 cm, length also 1.90 cm. Flowers year round.

4.1.23 Rondeletia odorata Jacq. *(Plate 3g)*

Family : Rubiaceae

Common name : Panama Rose

Centre of origin : West Indies and Mexico

A medium sized dense, upright shrub; young parts covered with a setose pubescence. Height up to 137.6 cm and spread 89.0 cm. Leaves opposite, 5.07 cm long and 2.50 cm wide, stipulate, ovate or elliptic or ovate in shape, subacutely acuminate tip, cordate or rounded at the base, entire; younger leaves sparsely pilose on the nerves, ciliate; surface scabrous and rugous; petioles setosely pilose, 0.19 cm long and 0.43 cm in girth; internodal length 3.33 cm; branching pattern upright or ascending.

Inflorescence of many-flowered, terminal, corymbose cymes up to diameter; bracts ovate-lnceolte, obtuse or subacute; calyx campanulate; corolla with cylindrical tube 1.47 cm long reddish orange in colour, diameter 0.48 cm, puberculous outside, pilose within, 5-6 lobed; lobes oblong with rounded tip, rose coloured; inflorescence diameter 3.67 cm. Blooms in April-June and August- December.

4.1.24 Russelia juncea Zucc. *(Plate 3h)*

Common name : Coral plant, Fountain plant

Family : Scrophulariaceae

Centre of origin : Mexico

A much branched shrub, with glabrous, noded stems. Branches whorled, noded, smooth and glabrous, angled and grooved, nodding at the tips. Photosynthesis is undertaken by stems and branches. Height reaches to 86.4 cm and spread up to 83.07 cm. The leaves are usually reduced to mere scales at the nodes; if present, leaves are opposite or whorled, very small, ovate-lanceolate or liner obtuse, crenate at margin, 0.70 cm long and 0.80 cm wide, sessile leaves; intermodal length 5.33 cm; branching pattern weeping.

a. Nerium indicum

b. Odontonema cuspidatum

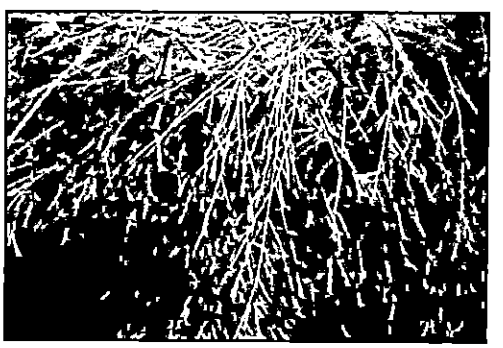
c. Otacanthus caeruleus

d. Pereskia bleo

e. Pseuderanthemum graciflorum

f. Pseuderanthemum reticulatum

g. Rondeletia odorata



h. Russelia juncea

Plate 3. Flowering shrubs-III

Inflorescences are produced at the tips of whorled branches. The flowers are arranged on 2-3 flowered peduncles and are produced in profusion all the year round. Pedicels very slender, bell shaped; corolla tubular in shape, of rose-red coloured, ending above in five rounded imbricating lobes, glandular inside and at the base, flowers 2.73 cm long, 0.35 cm in diameter. Blooms round the year.

4.1.25 Tabernaemontana coronaria R. Br. *(Plate 4a)*

Common name : Crape jasmine

Family : Apocynaceae

Centre of origin : India

A glabrous shrub, exuding a copious milky juice when cut. Height reaches up to 146.6 cm; spread up to 104.3 cm. The leaves are elliptic-oblong, 13.93 cm long and 6.23 cm wide, elliptical-oblong in shape, acute base, acuminate tip and entire-wavy margin, membraneous in texture, dark green colour; petioles 1.10 cm long and 0.77 cm in thick; branching pattern ascending; young shoots bright green in colour and lenticellate; internodal length 5.67 cm.

Inflorescence of geminate or solitary few-flowered cymes at terminals of branches as well as leaf axils; flowers white, double, fragrant; calyx gamosepalous, tube campanualte, Corolla tube 2 cm long, cylindrical, slightly dilated below the top, where it divided in to five obliquely ovate lobes which are horizontal, and 1.25 cm long, corolla head diameter 4.7 cm, single flower length 4.2 cm. Blooms November to June.

4.1.26 Tabernaemontana coronaria 'Nana' R. Br. *(Plate 4b)*

Family : Apocynaceae

Common name : Dwarf crape jasmine

Centre of origin : India and South East Asia

Small shrub reaching up to height of 71.3 cm and having spread of 53.7 cm. Form is dense round or globular. Leaves are narrowly elliptical, arranged in opposite deccusate pattern. Leaves are 3.83 cm long and 0.90 cm wide. Leaf base are cuneate, tip acuminate, and margin entire. Leaf colour is dark green; .surface texture is smooth and glossy; petiole length 0.37 cm and girth 0.38 cm; intermodal length 1.17 cm; branching habit ascending.

Inflorescence is a terminal corymb of cymes; flowers are white coloured, corolla head 2.80 cm in diameter. Single flower length is 2.83 cm Inflorescence diameter is 5.77 cm. Blooms throughout the year, but sparse flowering in the rainy months.

4.1.27 Tabernaemontana coronaria 'Variegata' R. Br. *(Plate 4c)*

Common name : Variegated crape jasmine

Family : Apocynaceae

Centre of origin : India and South East Asia

Medium to small shrub with globular form, and reaches to height of 80.6 cm and having spread of 68.7 cm. Leaves are variegated, with white and whitish green colour. The lanceolate leaves are arranged in opposite pattern. Leaf lamina length 9.2 cm and breadth 3.8 cm, attenuate at the base, acuminate at the tip, margin wavy; petiole is 1.10 cm long and 0.62 cm thick; internodal length 2.50. Texture is smooth and glossy.

Inflorescence is a terminal corymb of cymes; flowers are white coloured, corolla head 3.00 cm in diameter. Single flower length is 3.00 cm. Inflorescence diameter is 5.90 cm. Blooms throughout the year.

4.1.28 Tecomaria capensis Thunb. *(Plate 4d)*

Common name : Cape honey suckle

Family : Bignoniaceae

Centre of origin : South Africa

A medium shrub with height reaches to 127.8 cm and spread 101.8 cm. Leaves opposite, 11.07 cm long and 5.10 cm wide, compound, odd pinnate. Leaflets 7-9, long and broadly ovate to almost orbicular in shape, glabrous, shortly petiolate, coarsely serrate; teeth often obtuse. Petiole 1.80 cm long and 0.58 cm in girth. Internodal length 2.27 cm. Branching pattern ascending. Stem and branches slender, brown, with prominent raised lenticels.

Inflorescence a peduncled terminal rceme. Flowers seated on pedicels up to 1.25 cm long. Calyx gamosepalous and cup shaped. Corolla tubular or funnel shaped, slightly curved, gamopetlous, 4.77 cm long, 2.56 cm in corolla head diameter;inflorescence diameter 5.6 cm; yellow coloured, on the outer side with brownish tinge; ending in four lobes, the upper of which is notched. It blooms profusely from September to May.

4.1.29 Thevetia peruviana Juss. *(Plate 4e)*

Common name : Yellow oleander, Trumpet flower

Family : Apocynceae

Centre of origin : Tropical America

Stems and shoot quite glabrous, exuding copious milky juice when cut. Reaches to height of 259.8 cm and spread of 202.8 cm. Leaves alternate spiral, 10.47 cm long and 1.03 cm wide, narrowly liner in shape, shortly accuminate and obtuse at the apex, decurrent at the base, shining green above, paler and dull below, coriaceous, glabrous; margins revolute; central nerve very prominent below; secondary nervation invisible; sessile leaves; internodal length 1.23 cm; branching pattern ascending.

Flowers apricot coloured, arranged in subterminal few-flowered cymes, seated on pedicels from 1.76 cm long. Sepals five, 0.75-1 cm long, long-accuminate, sharp, spreading thin joined below in a short tube. Petals five, 2.8 cm long, oblong-acute, joined below in to a tube which is 2-2.5 cm long, cylindrical at the base and broadly campanulate at its junction with the petals, single flower 3.80 cm in diameter and 5.00 cm long; with two hairy wings in the cylindrical portion and with hairy scale at the base of campanulate portion. It flowers throughout the year.

4.1.30 Wrightia antidysenterica (Linn.) Wall. *(Plate 4f)*

Common name : Arctic snow, Milky-way snow flake

Family : Apocynaceae

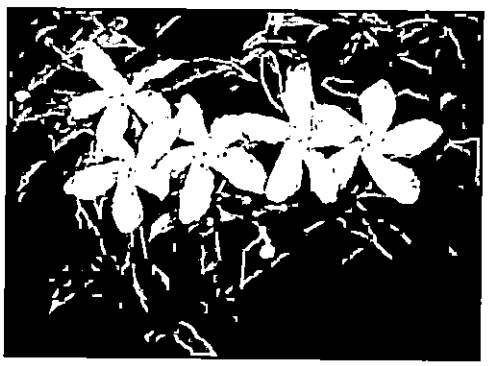
Centre of origin : Srilanka

It is a medium to small shrub, irregular upright form, which reaches to height of 94.7 cm and have spread of 43.4 cm. Leaves are elliptical to ovate, 4.33 cm long and 2.93 cm wide, arranged in opposite pattern on the branches. Leaf base is acute, tip acute or obtuse, margin entire; petiole is very short, up to 0.33 cm long and have girth 041 cm. Internodal length is 2.50 cm. Branches arranged in upright pattern.

Inflorescence is terminal or axillary corymb of cymes. Calyx five lobed, lobes are blunt. Corolla hypocrateriform, corona of five fimbricate scales present at the throat, corolla lobes white coloured, 2 cm long with yellow colour at the base; corolla head diameter is 3.00 cm and single flower length is 2.70 cm. It flowers irregularly throughout the year.

a. Tabernaemontana coronaria

b. Tabernaemontana coronaria 'Nana'



c. Tabernaemontana coronaria 'Variegata'

d. Tecomaria capensis

e. Thevetia peruviana

f. Wrightia antidysenterica

Plate 4. Flowering shrubs-IV

4.2 QUANTITATIVE CHARACTERS

4.2.1 Plant size

Growth parameters of the 30 ornamental shrubs selected for the study were recorded at monthly interval. They were grouped in to three groups, such as tall, medium and dwarf, based on their maintainable height after one year of observation. Tall group shrubs included those having maintainable height above 3 m, medium group shrubs having maintainable height between 1 m and 2 m, and dwarf group shrubs having their maintainable height below 1 m. Among the 30 shrubs, 9 came under tall growing group, 10 under medium and 11 under dwarf group. All the further comparison and grouping was done according to this classification.

4.2.1.1 Plant height

Shrubs were compared with respect to their plant height, within each group. With respect to height, shrubs differed significantly. Height varied from 49.9 cm in *Lonicera japonica* to 319.4 cm. in *Calliandra haematocephala.*

In tall shrubs, *Calliandra haematocephala* showed highest value for height (319.4 cm), followed by *Mussaenda erythrophylla* (291.7 cm) . *Pereskia bleo* showed the lowest value for height in the tall category (239.7 cm). Monthly height of the tall growing shrubs is given in Table 2.

In the medium growing group, *Murraya paniculata* showed the highest value for height (178.4 cm). It was followed by *Kopsia fruticosa* (164.8 cm), *Clerodendrum macrosiphon* (153.1 cm), *Ixora coccinea* (152.6 cm) and *Allamanda neriifolia* (152.86cm) which were on par. *Ixora chinensis* (122.8 cm) showed the lowest value for height in this group. Monthly height of the medium growing shrubs is given in Table 3.

Table 2. Height increments of ornamental flowering shrubs (Tall group)

No.	Shrub	Jan (cm)	Feb (cm)	Mar (cm)	Apr (cm)	May (cm)	June (cm)	July (cm)	Aug (cm)	Sept (cm)	Oct (cm)	Nov (cm)	Dec (cm)
1	*Allamanda cathartica*	184.7	192.7	201.0	210.6	219.9	226.9	232.7	238.6	245.0	251.2	256.2	261.2[d]
2	*Allamanda violacea*	177.8	185.8	194.3	203.9	213.2	220.2	225.8	231.7	238.0	244.2	249.2	254.2[c]
3	*Bauhinia acuminata*	174.5	181.8	188.6	196.1	203.7	209.3	214.3	219.3	224.3	229.4	235.7	241.7[a]
4	*Calliandra haematocephala*	213.7	224.0	235.2	246.8	258.8	268.4	277.2	285.3	293.4	301.9	310.5	319.4[f]
5	*Hamelia patens*	180.2	186.6	193.4	200.4	207.3	213.5	219.4	225.4	231.3	237.3	243.0	248.6[b]
6	*Mussaenda erythrophylla*	205.3	214.3	223.3	232.4	241.3	249.9	257.8	265.2	272.1	278.6	285.1	291.7[e]
7	*Nerium indicum*	184.5	193.9	201.2	208.1	215.1	220.9	226.7	232.1	237.7	243.0	248.6	254.1[bc]
8	*Pereskia bleo*	167.0	174.6	182.6	190.8	199.0	206.0	211.9	217.7	223.2	228.7	234.3	239.8[a]
9	*Thevetia peruviana*	180.0	188.0	196.2	204.5	212.9	220.5	227.4	233.9	240.4	247.0	253.4	259.8[d]
												CD Value	7.316

Table 3. Height increments of ornamental flowering shrubs (Medium group)

No.	Shrub	Jan (cm)	Feb (cm)	Mar (cm)	Apr (cm)	May (cm)	June (cm)	July (cm)	Aug (cm)	Sept (cm)	Oct (cm)	Nov (cm)	Dec (cm)
1	*Allamanda neriifolia*	90.0	96.5	102.6	108.8	115.0	121.1	126.7	132.2	137.4	142.7	147.8	152.9[e]
2	*Clerodendrum macrosiphon*	87.3	93.1	99.1	105.1	111.1	117.1	123.1	129.1	135.1	141.1	147.1	153.1[e]
3	*Ixora chinensis*	70.0	75.0	80.1	85.2	90.4	95.4	100.1	104.8	109.4	113.9	118.4	122.8[a]
4	*Ixora coccinea*	88.4	94.5	100.7	106.9	113.2	118.9	124.1	129.8	135.2	140.9	146.8	152.7[e]
5	*Kopsia fruticosa*	100.5	106.8	112.8	119.1	125.3	131.5	137.4	143.0	148.4	153.8	159.3	164.9[f]
6	*Murraya paniculata*	112.3	118.0	124.4	130.8	137.2	143.4	149.2	155.0	160.9	166.7	172.5	178.5[g]
7	*Pseuderanthemum reticulatum*	76.9	81.9	87.0	92.3	97.6	102.7	107.6	112.4	117.2	122.1	127.0	131.9[bc]
8	*Rondeletia odorata*	82.4	87.5	92.7	98.0	103.3	108.4	113.3	118.0	122.9	127.7	132.6	137.6[c]
9	*Tabernaemontana coronaria*	80.4	86.6	92.6	98.6	104.6	110.6	116.6	122.6	128.6	134.6	140.6	146.6[d]
10	*Tecomaria capensis*	72.7	77.8	82.9	88.1	93.4	98.5	103.4	108.2	113.1	117.9	122.8	127.8[b]
												CD value	5.936

Table 4. Height increments of ornamental flowering shrubs (Dwarf group)

No.	Shrub	Jan (cm)	Feb (cm)	Mar (cm)	Apr (cm)	May (cm)	June (cm)	July (cm)	Aug (cm)	Sept (cm)	Oct (cm)	Nov (cm)	Dec (cm)
1	*Allamanda cathartica* 'Dwarf'	44.9	48.2	51.5	54.9	58.4	61.8	65.1	68.1	71.2	74.3	77.4	80.4^{e}
2	*Brunfelsia latifolia*	44.6	48.1	52.1	56.2	60.4	64.6	68.5	72.0	75.6	79.3	83.0	86.5^{d}
3	*Ixora rosea*	52.5	56.5	60.6	64.8	69.0	72.9	76.4	80.0	83.6	87.3	90.9	94.7^{e}
4	*Lonicera japonica*	41.8	42.9	43.6	44.3	45.0	45.8	46.5	47.2	47.9	48.6	49.3	49.99^{a}
5	*Odontonema cuspidatum*	51.5	54.6	57.6	60.8	64.0	67.3	70.1	72.6	75.3	77.9	80.5	83.2^{cd}
6	*Otacanthus caeruleus*	38.7	42.6	46.6	50.7	54.9	59.1	63.0	66.5	70.1	73.8	77.5	81.0^{cd}
7	*Pseuderanthemum graciliflorum*	39.4	43.2	47.2	51.3	55.5	59.7	63.6	67.1	70.7	74.3	78.0	81.6^{cd}
8	*Russelia juncea*	44.2	48.2	52.3	56.5	60.7	64.6	68.1	71.7	75.3	79.0	82.6	86.4^{cd}
9	*Tabernaemontana coronaria* 'Nana'	39.7	42.1	45.5	49.1	52.7	56.3	59.2	62.2	64.6	66.9	69.1	71.3^{b}
10	*Tabernaemontana coronaria* 'Variegata'	38.9	43.8	47.7	51.6	55.6	59.6	63.2	66.7	70.1	73.5	77.0	80.6^{c}
11	*Wrightia antidysenterica*	52.5	56.5	60.6	64.8	69.0	72.9	76.4	80.0	83.7	87.4	90.9	94.7^{e}
												CD value	5.169

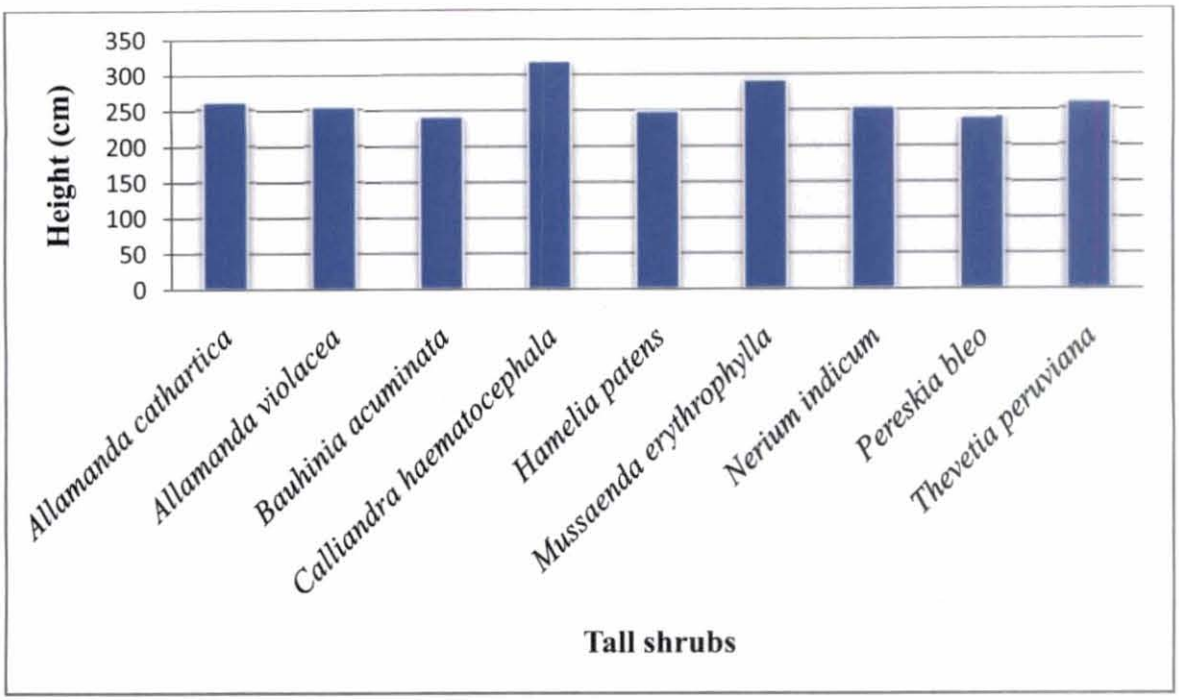


Figure 1. Plant height (Tall shrubs)

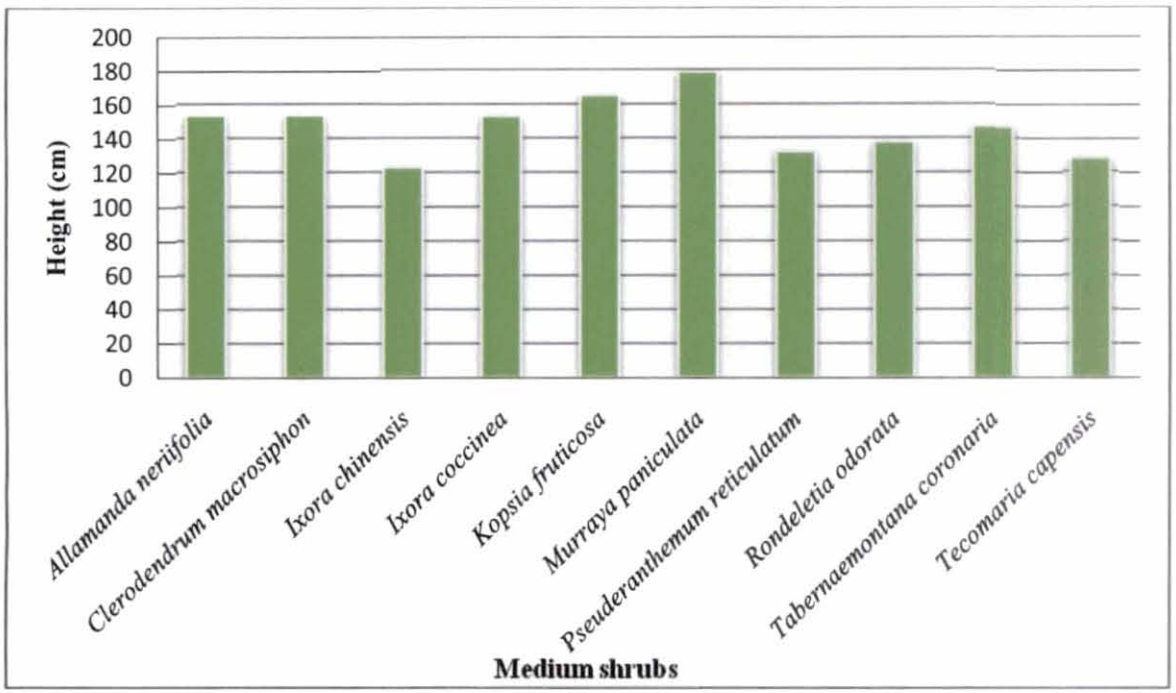


Figure 2. Plant height (Medium shrubs)

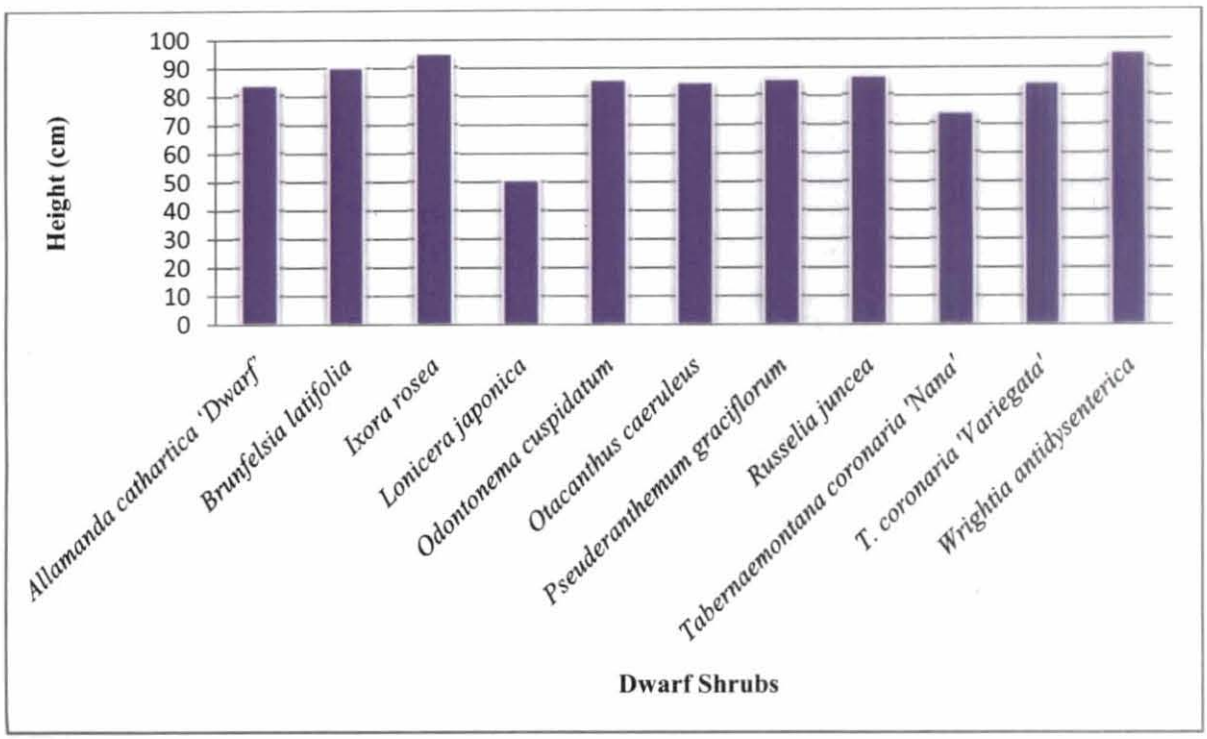


Figure 3. Plant height (Dwarf shrubs)

In the dwarf growing group, *Ixora rosea* (94.6 cm) and *Wrighti antidysenterica* (94.7 cm) showed the highest value for height, which were on par. *Odontonema cuspidatum* (83.1 cm), *Otacanthus caeruleus* (81.1 cm), *Pseuderanthemum graciflorum* (81.6 cm) and *Russelia juncea* (82.6 cm) were on par. The least height was showed by *Lonicera japonica* (49.9 cm). Monthly height of the dwarf growing shrubs is given in Table 4.

Fig. 1-3 shows plant height of shrubs belongs to the three categories.

4.2.1.2 Plant spread

Shrubs were compared with respect to their plant spread, within each group. With respect to spread, shrubs differed significantly. Spread varied from 43.4 cm in *Wrightia antidysenterica*, to 269.7 cm in *Calliandra haematocephala*.

Under tall shrubs, *Calliandra haematocephala* (269.7 cm) and *Mussaenda erythrophylla* (248.3 cm) showed the highest spread, both were on par also. *Thevetia peruviana* (202.8 cm), *Allamanda cathartica* (185.8 cm) and *Hamelia patens* (185.1 cm) were on par with respect to spread. The least spread was observed in *Nerium indicum* (79.9 cm) and *Pereskia bleo* (86.34 cm). The mean spread of shrubs in tall groups is given in the Table 5 and Fig. 4.

In the medium group, *Ixora coccinea* (145.0 cm) and *Allamanda neriifolia* (138.9 cm) showed the highest spread, which were on par. These shrubs were followed by *Clerodendrum macrosiphon* (129.8 cm) and *Murraya paniculata* (126.7 cm) which were on par. The least spread in this category was observed in *Ixora chinensis* (45.5 cm) and *Pseuderanthemum reticulatum* (46.2 cm). The mean spread of shrubs in this category is given in Table 6 and Fig. 5.

Russelia juncea showed the highest spread under the dwarf shrubs (83.0 cm), which was followed by *Ixora rosea* (72.3 cm) and *Lonicera japonica* (73.1 cm), which were on par. The lowest value for spread in this category was observed for *Wrightia*

Table 5. Spread increments of ornamental flowering shrubs (Tall group)

No.	Shrub	Jan (cm)	Feb (cm)	Mar (cm)	Apr (cm)	May (cm)	June (cm)	July (cm)	Aug (cm)	Sept (cm)	Oct (cm)	Nov (cm)	Dec (cm)
1	*Allamanda cathartica*	140.0	144.2	148.3	152.5	156.7	160.8	165.0	169.2	173.3	177.5	181.7	185.8[c]
2	*Allamanda violacea*	112.8	116.5	120.1	123.8	127.4	131.1	134.7	138.4	142.0	145.7	149.3	153.0[b]
3	*Bauhinia acuminata*	108.5	112.1	115.8	119.4	123.1	126.7	130.4	134.0	137.7	141.3	145.0	148.6[b]
4	*Calliandra haematocephala*	212.7	217.9	223.1	228.3	233.5	238.6	243.8	249.0	254.1	259.4	264.5	269.7[d]
5	*Hamelia patens*	132.2	137.8	142.1	145.8	150.9	155.5	161.3	166.7	172.1	176.0	180.8	185.1[c]
6	*Mussaenda erythrophylla*	196.8	201.5	206.2	210.8	215.5	220.2	224.9	229.6	234.3	239.0	243.7	248.3[d]
7	*Nerium indicum*	50.2	53.3	56.3	59.3	62.4	65.3	68.2	70.8	73.3	75.6	77.8	79.9[a]
8	*Pereskia bleo*	44.6	47.0	50.2	53.9	58.2	62.5	66.5	71.4	75.7	79.7	83.5	86.4[a]
9	*Thevetia peruviana*	174.5	158.0	162.4	166.9	171.4	175.9	180.4	184.8	189.3	193.8	198.3	202.8[c]
												CD value	21.440

Table 6. Spread increments of ornamental flowering shrubs (Medium group)

No.	Shrub	Jan (cm)	Feb (cm)	Mar (cm)	Apr (cm)	May (cm)	June (cm)	July (cm)	Aug (cm)	Sept (cm)	Oct (cm)	Nov (cm)	Dec (cm)
1	*Allamanda neriifolia*	105.7	108.7	111.8	114.8	117.8	120.8	123.8	126.9	129.9	132.9	135.9	138.9[fg]
2	*Clerodendrum macrosiphon*	95.4	98.5	101.7	104.8	107.9	111.0	114.2	117.3	120.4	123.5	126.7	129.8[e]
3	*Ixora chinensis*	36.9	37.6	38.4	39.2	40.0	40.8	41.6	42.3	43.1	43.9	44.7	45.5[a]
4	*Ixora coccinea*	116.3	118.9	121.5	124.1	126.7	129.3	131.9	134.5	137.1	139.7	142.4	145.0[g]
5	*Kopsia fruticosa*	83.6	86.8	90.0	93.1	96.2	99.3	102.5	105.6	108.7	111.8	115.0	118.1[d]
6	*Murraya paniculata*	86.6	90.2	93.8	97.5	101.1	104.8	108.4	112.1	115.7	119.4	123.0	126.7[e]
7	*Pseuderanthemum reticulatum*	34.7	35.8	36.8	37.9	38.9	40.0	41.0	42.0	43.1	44.1	45.2	46.2[a]
8	*Rondeletia odorata*	47.0	50.2	54.0	58.3	62.5	66.5	71.4	75.7	79.7	83.5	86.5	89.0[b]
9	*Tabernaemontana coronaria*	81.4	83.5	85.6	87.6	89.7	91.8	93.9	96.0	98.1	100.1	102.2	104.3[c]
10	*Tecomaria capensis*	70.8	73.7	76.5	79.3	82.1	84.9	87.7	90.5	93.3	96.2	99.0	101.8[c]
												CD value	10.317

Table 7. Spread increments of ornamental flowering shrubs (Dwarf group)

No.	Shrub	Jan (cm)	Feb (cm)	Mar (cm)	Apr (cm)	May (cm)	June (cm)	July (cm)	Aug (cm)	Sept (cm)	Oct (cm)	Nov (cm)	Dec (cm)
1	*Allamanda cathartica* 'Dwarf'	40.2	41.9	43.6	45.2	46.9	48.6	50.2	51.9	53.6	55.2	56.9	58.5^{d}
2	*Brunfelsia latifolia*	38.9	40.2	41.9	43.6	45.2	46.9	48.6	50.2	51.9	53.6	55.2	56.8^{c}
3	*Ixora rosea*	37.9	38.3	40.9	44.7	47.9	51.0	54.4	58.5	62.2	65.5	69.4	72.3^{f}
4	*Lonicera japonica*	41.7	45.1	48.7	52.2	55.8	58.7	61.7	64.1	66.4	68.6	70.8	73.1^{ef}
5	*Odontonema cuspidatum*	34.6	35.6	36.7	37.7	38.8	39.8	40.8	41.9	42.9	44.0	45.0	46.0^{a}
6	*Otacanthus caeruleus*	41.9	42.6	43.4	44.2	45.0	45.8	46.6	47.3	48.1	48.9	49.7	50.5^{b}
7	*Pseuderanthemum graciliflorum*	47.1	48.1	49.2	50.2	51.3	52.3	53.3	54.4	55.4	56.5	57.5	58.5^{c}
8	*Russelia juncea*	67.0	68.5	69.9	71.4	72.9	74.3	75.8	77.2	78.7	80.1	81.6	83.0^{g}
9	*Tabernaemontana coronaria* 'Nana'	37.6	38.1	39.6	41.2	42.8	44.3	45.9	47.4	49.0	50.6	52.1	53.7^{c}
10	*Tabernaemontana coronaria*	53.8	55.2	56.5	57.9	59.2	60.6	61.9	63.3	64.6	66.0	67.4	68.7^{e}
11	*Wrightia antidysenterica*	35.6	36.3	37.0	37.7	38.5	39.2	39.9	40.6	41.3	42.0	42.7	43.4^{a}
												CD value	3.736

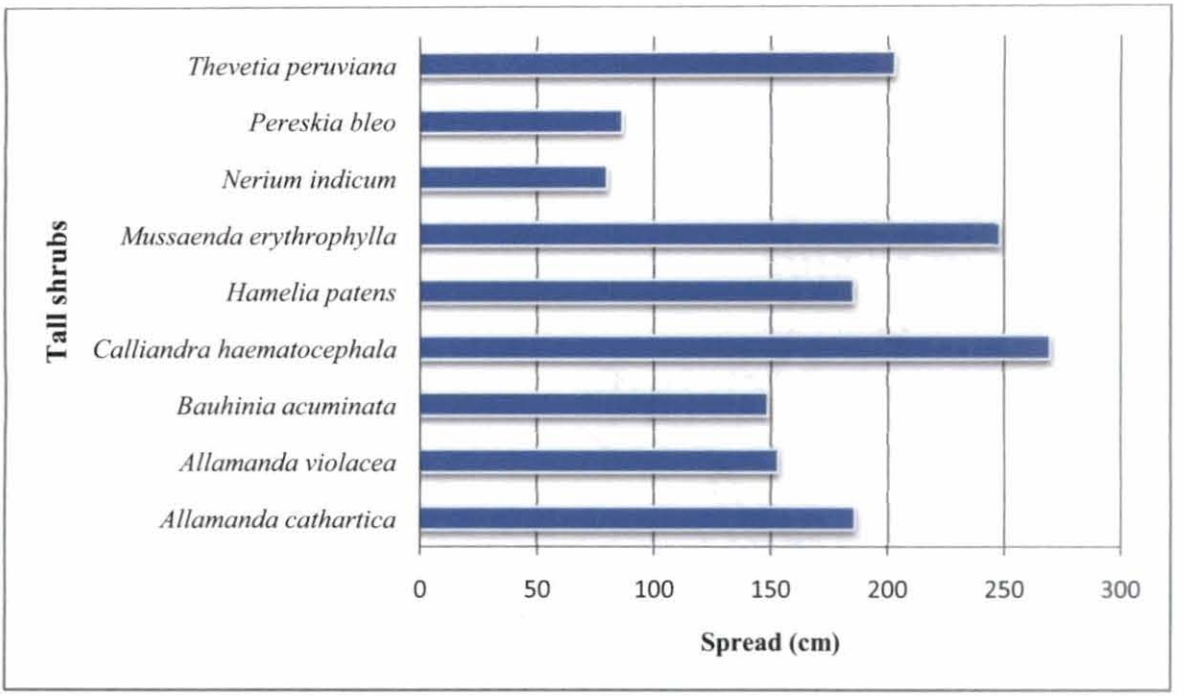


Figure 4. Plant spread (Tall shrubs)

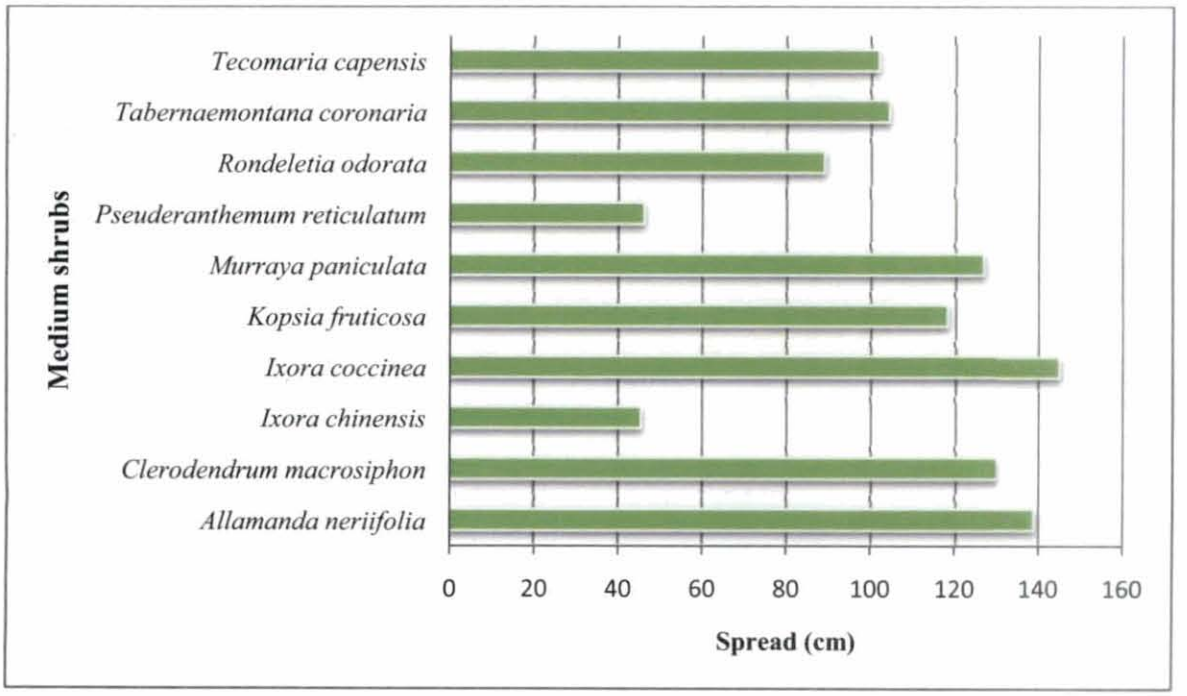


Figure 5. Plant spread (Medium shrubs)

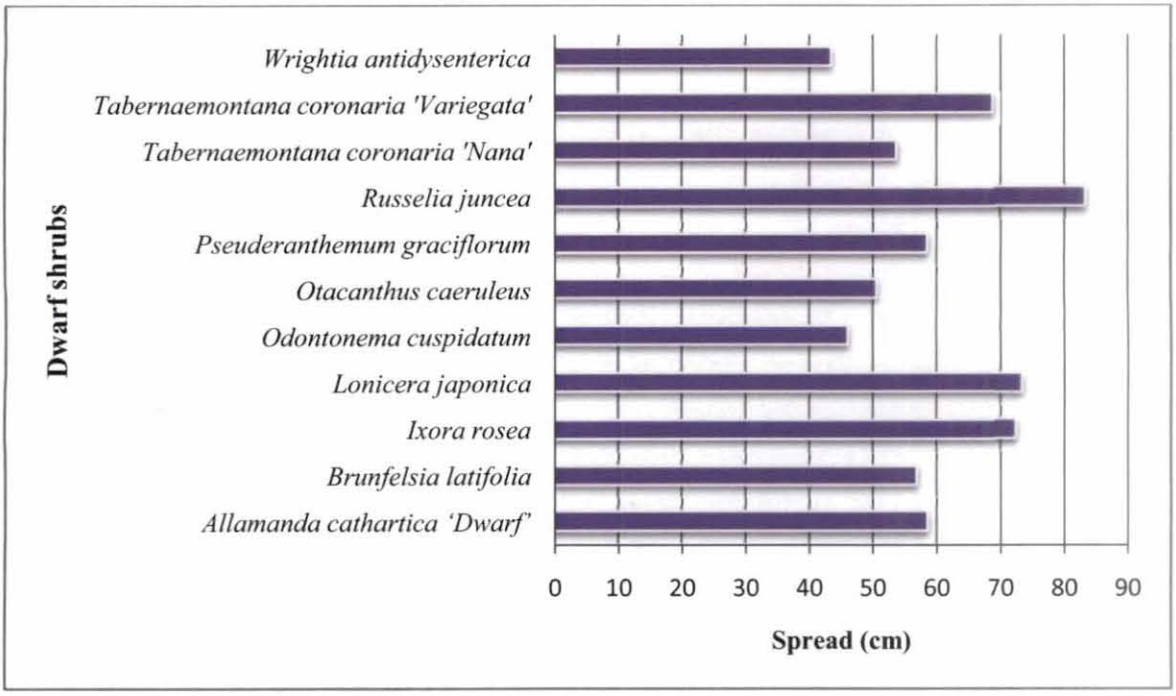


Figure 6. Plant spread (Dwarf shrubs)

antidysenterica (43.4 cm) and *Odontonema cuspidatum* (46.0 cm) which were also on par. The mean spread of dwarf shrubs is given in Table 7, Fig.6.

4.2.1.3 Spread by height index

The spread by height indicator is an effective tool for selecting suitable plants for specific landscape usage. Spread by height value for the shrubs of the three categories was calculated to get the spread by height indicator.

Under tall shrubs, *Mussaenda erythrophylla* (0.85) and *Calliandra haematocephala* (0.84) showed the highest values which were on par. *Thevetia peruviana* (0.78) and *Hamelia patens* (0.75) were also with high spread by height index. The least value was showed by *Pereskia bleo* (0.26). The spread by height index of tall shrubs is given in the Table 8, Fig. 7.

In the medium group shrubs *Tecomaria capensis* was having maximum spread by height value (1.14), which was followed by *Allamanda neriifolia* (0.91) and *Clerodendrum macrosiphon* (0.85). In this category, the least value was observed for *Pseuderanthemum reticulatum* (0.35). The spread by height index values of medium shrubs are given in Table 9, Fig. 8.

Lonicera japonica showed the highest spread by height value in the small category (1.42), which was followed by *Russelia juncea* (0.96). The least index value was shown by *Wrightia antidysenterica* (0.46). The spread by height index values of dwarf shrubs is given in Table 10, Fig. 9.

4.2.1.4 Regression equation of height to predict spread

For shrubs *Nerium indicum*, *Thevetia peruviana*, *Odontonema cuspidatum*, *Otacanthus caeruleus*, *Pseuderanthemum graciflorum*, *Tabernaemontana coronaria* 'variegata'and *Wrightia antidysenterica* the predicted equation could not be fitted as the coefficient of determination was very poor. Hence a 'Factor' multiplier of height

Table 8. Spread by Height Index (Tall shrubs)

No.	Shrub	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	*Allamanda cathartica*	0.76	0.75	0.74	0.72	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
2	*Allamanda violacea*	0.64	0.63	0.62	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
3	*Bauhinia acuminata*	0.62	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.62	0.62	0.62
4	*Calliandra haematocephala*	1.00	0.97	0.95	0.93	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84
5	*Hamelia patens*	0.73	0.74	0.74	0.73	0.73	0.73	0.74	0.74	0.74	0.74	0.74	0.75
6	*Mussaenda erythrophylla*	0.96	0.94	0.92	0.91	0.89	0.88	0.87	0.87	0.86	0.86	0.86	0.85
7	*Nerium indicum*	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.32	0.32	0.32	0.32	0.32
8	*Periskia bleo*	0.28	0.29	0.30	0.31	0.31	0.32	0.34	0.35	0.36	0.37	0.37	0.37
9	*Thevetia peruviana*	0.97	0.84	0.83	0.82	0.81	0.80	0.79	0.79	0.79	0.79	0.78	0.78

Table 9. Spread by Height Index (Medium shrubs)

No.	Shrub	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	*Allamanda neriifolia*	1.18	1.13	1.09	1.06	1.02	1.00	0.98	0.96	0.95	0.93	0.92	0.91
2	*Clerodendrum macrosiphon*	1.09	1.06	1.03	1.00	0.97	0.95	0.93	0.91	0.89	0.88	0.86	0.85
3	*Ixora chinensis*	0.53	0.50	0.48	0.46	0.44	0.43	0.42	0.40	0.39	0.39	0.38	0.37
4	*Ixora coccinea*	0.80	0.78	0.76	0.74	0.73	0.71	0.71	0.70	0.69	0.68	0.67	0.67
5	*Kopsia fruticosa*	0.81	0.80	0.78	0.77	0.76	0.75	0.74	0.73	0.73	0.72	0.72	0.71
6	*Murraya paniculata*	0.77	0.77	0.75	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.71	0.71
7	*Pseuderanthemum reticulatum*	0.45	0.44	0.42	0.41	0.40	0.39	0.38	0.37	0.37	0.36	0.36	0.35
8	*Rondeletia odorata*	0.57	0.57	0.58	0.60	0.61	0.61	0.63	0.64	0.65	0.65	0.65	0.65
9	*Tabernaemontana coronaria*	1.01	0.96	0.92	0.89	0.86	0.83	0.81	0.78	0.76	0.74	0.73	0.71
10	*Tecomaria capensis*	1.60	1.53	1.47	1.41	1.36	1.31	1.28	1.24	1.21	1.18	1.16	1.14

Table 10. Spread by Height Index (Dwarf shrubs)

No.	Shrub name	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	*Allamanda cathartica* 'Dwarf'	0.96	0.94	0.91	0.89	0.86	0.84	0.82	0.81	0.80	0.79	0.78	0.77
2	*Brunfelsia latifolia*	0.90	0.87	0.84	0.81	0.79	0.78	0.76	0.76	0.76	0.75	0.75	0.75
3	*Ixora rosea*	0.73	0.72	0.74	0.74	0.74	0.75	0.77	0.78	0.78	0.79	0.79	0.80
4	*Lonicera japonica*	0.93	0.97	1.03	1.10	1.16	1.22	1.26	1.31	1.34	1.37	1.39	1.42
5	*Odontonema cuspidatum*	0.65	0.63	0.62	0.60	0.59	0.58	0.57	0.56	0.56	0.55	0.55	0.54
6	*Otacanthus caeruleus*	1.01	0.98	0.91	0.86	0.81	0.76	0.73	0.70	0.68	0.65	0.63	0.61
7	*Pseuderanthemum graciliflorum*	1.15	1.09	1.02	0.96	0.91	0.86	0.82	0.80	0.77	0.75	0.72	0.71
8	*Russelia juncea*	1.52	1.42	1.34	1.26	1.20	1.15	1.11	1.08	1.05	1.01	0.99	0.96
9	*Tabernaemontana coronaria* 'Nana'	1.29	1.23	1.16	1.10	1.04	0.99	0.96	0.93	0.90	0.88	0.86	0.84
10	*T. coronaria* 'Variegata'	0.68	0.64	0.61	0.58	0.56	0.54	0.52	0.51	0.49	0.48	0.47	0.46
11	*Wrightia antidysenterica*	0.96	0.94	0.91	0.89	0.86	0.84	0.82	0.81	0.80	0.79	0.78	0.77

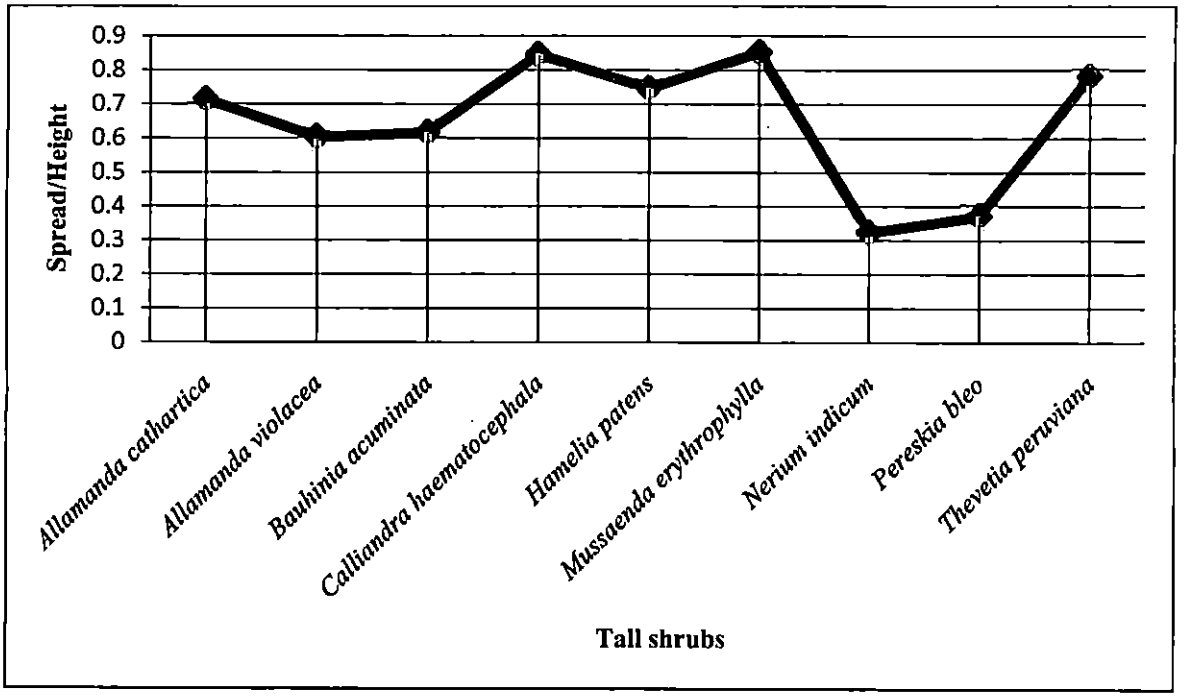


Fig. 7. Spread by height value (Tall shrubs)

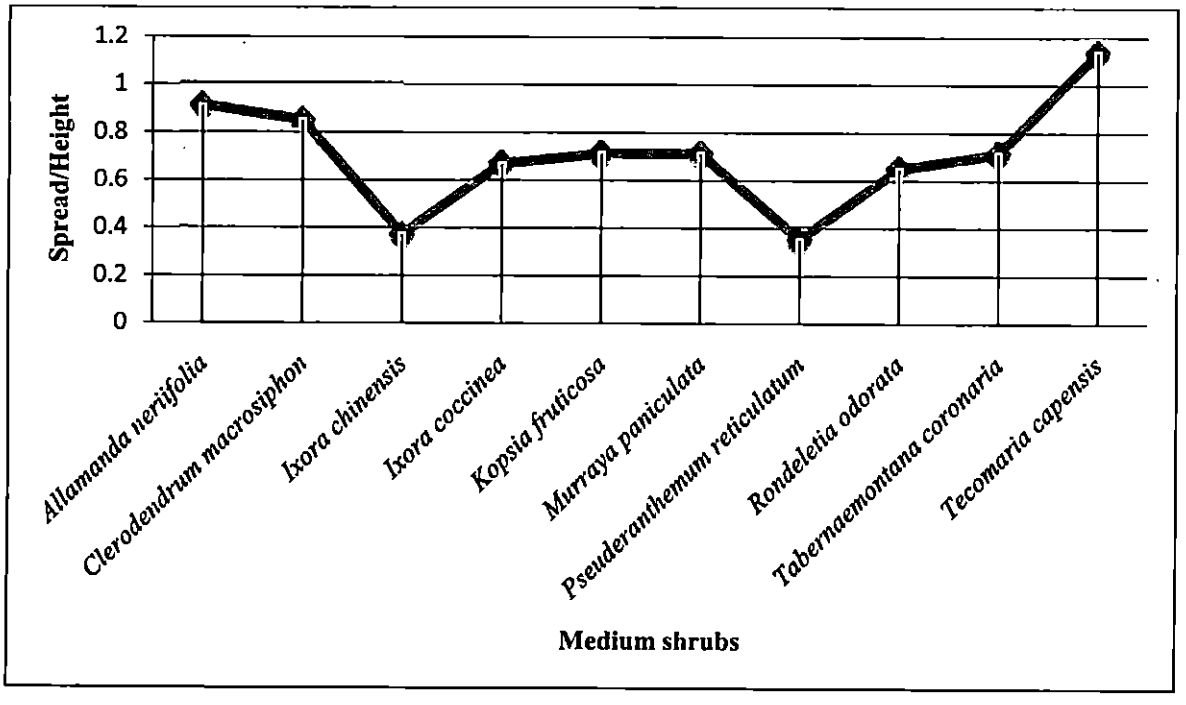


Fig. 8. Spread by height value (Medium shrubs)

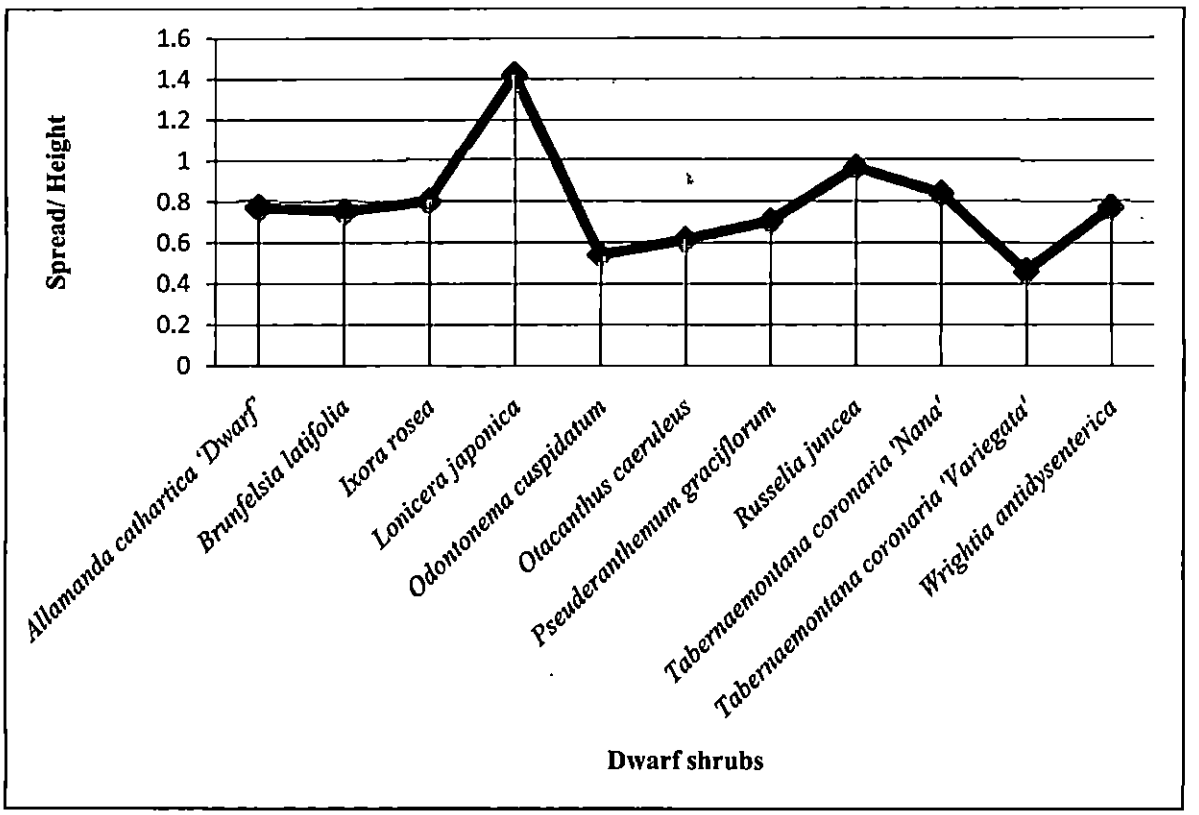


Fig. 9. Spread by height value (Dwarf shrubs)

Table 11. Regression equation of height to predict spread

No.	Shrub	Regression equation Y- Spread; X- Height	R^2
1	*Allamanda cathartica*	Y= 35.999+.560*X	.551
2	*Allamanda violacea*	Y= 16.591+.529*X	.717
3	*Bauhinia acuminata*	Y= 10.203+.564*X	.639
4	*Calliandra haematocephala*	Y= 95.821+.539*X	.752
5	*Hamelia patens*	Y= 1.557+.730*X	.669
6	*Mussaenda erythrophylla*	Y= 80.617+.565*X	.685
7	*Nerium indicum*	Equation poor fitting	
8	*Pereskia bleo*	Y= -57.296+.611*X	.959
9	*Thevetia peruviana*	Equation poor fitting	
10	*Allamanda neriifolia*	Y= 58.137+.522*X	.833
11	*Clerodendrum macrosiphon*	Y= 45.697+.557*X	.757
12	*Ixora chinensis*	Y= 24.159+.175*X	.634
13	*Ixora coccinea*	Y= 24.798+.508*X	.856
14	*Kopsia fruticosa*	Y= 29.198+.537*X	.539
15	*Murraya paniculata*	Y= 32.956+.510*X	.648
16	*Pseuderanthemum reticulatum*	Y= 20.475+.191*X	.563
17	*Rondeletia odorata*	Y= -16.800+.775*X	.881
18	*Tabernaemontana coronaria*	Y= 51.812+.361*X	.746
19	*Tecomaria capensis*	Y= 80.176+.501*X	.506
20	*Allamanda cathartica* 'Dwarf'	Y= 26.730+.418*X	.624
21	*Brunfelsia latifolia*	Y= 14.109+.506*X	.810
22	*Ixora rosea*	Y= -9.888+.899*X	.992
23	*Lonicera japonica*	Y= -75.462+2.871*X	.815
24	*Odontonema cuspidatum*	Equation poor fitting	
25	*Otacanthus caeruleus*	Equation poor fitting	
26	*Pseuderanthemum graciliflorum*	Equation poor fitting	
27	*Russelia juncea*	Y= 45.925+.442*X	.502
28	*Tabernaemontana coronaria* 'Nana'	Y= 10.640+.607*X	.933
29	*Tabernaemontana coronaria* 'Variegata'	Equation poor fitting	
30	*Wrightia antidysenterica*	Equation poor fitting	

Table 12. Factor multiplier of height to predict spread

	Shrub	Factor	Range	Minimum	Maximum
1	*Allamanda cathartica*	0.7208	0.19	0.64	0.83
2	*Allamanda violacea*	0.6058	0.14	0.55	0.69
3	*Bauhinia acuminata*	0.6132	0.12	0.55	0.67
4	*Calliandra haematocephala*	0.9007	0.25	0.81	1.06
5	*Hamelia patens*	0.7374	0.15	0.66	0.81
6	*Mussaenda erythrophylla*	0.8895	0.21	0.8	1.02
7	*Nerium indicum*	------			
8	*Pereskia bleo*	0.3294	0.12	0.26	0.39
9	*Thevetia peruviana*	------			
10	*Allamanda neriifolia*	1.0092	0.37	0.87	1.24
11	*Clerodendrum macrosiphon*	0.9494	0.37	0.81	1.18
12	*Ixora chinensis*	0.4321	0.2	0.35	0.55
13	*Ixora coccinea*	0.7193	0.21	0.63	0.84
14	*Kopsia fruticosa*	0.751	0.29	0.63	0.92
15	*Murraya paniculata*	0.733	0.25	0.64	0.89
16	*Pseuderanthemum reticulatum*	0.3922	0.19	0.32	0.51
17	*Rondeletia odorata*	0.6184	0.18	0.51	0.69
18	*Tabernaemontana coronaria*	0.8335	0.39	0.68	1.07
19	*Tecomaria capensis*	1.324	0.73	1.05	1.78
20	*Allamanda cathartica* 'Dwarf'	0.8349	0.38	0.67	1.04
21	*Brunfelsia latifolia*	0.717	0.27	0.61	0.88
22	*Ixora rosea*	0.7607	0.1	0.71	0.81
23	*Lonicera japonica*	1.2507	0.51	0.94	1.45
24	*Odontonema cuspidatum*	------			
25	*Otacanthus caeruleus*	------			
26	*Pseuderanthemum graciliflorum*	------			
27	*Russelia juncea*	1.1719	0.74	0.9	1.63
28	*Tabernaemontana coronaria* 'Nana'	0.7928	0.17	0.74	0.91
29	*Tabernaemontana coronaria* 'Variegata'	------			
30	*Wrightia antidysenterica*	------			

to predict spread was worked out for all the shrubs. The regression equation of height to predict spread is given in Table 11.

The ratio of the plant spread to height for each shrub under a variety was calculated to obtain an estimate of 'factor' of spread in relation to height. For all the shrubs, the range of variation of the ratio thus calculated was minimal. Factor multiplier of height to predict spread is given in the Table 12. Hence the means of the ratio for each shrub could be taken a factor, which when multiplied with plant height will give a measure of spread.

4.2.2 Quantitative plant and leaf characters

4.2.3.1 Tall shrubs

Among the observed tall shrubs, *Nerium indicum* showed the highest leaf length (22.33 cm) and *Hamelia patens* (8.53 cm) showed the lowest leaf length. The highest leaf breadth in this group was observed for *Bauhinia acuminata* (11.00 cm) and lowest for *Thevetia peruviana* (1.03 cm). In this group, the highest leaf area was observed for *Bauhinia acuminata* (83.33 cm^2) and lowest for *Hamelia patens* (13.77 cm^2).

The petiole length in the tall group varied from 0.18 cm in *Allamanda violacea* and *Thevetia peruviana* to 3.63 cm in *Calliandra haematocephala*. Highest petiole girth was also observed for *Calliandra haematocephala* (1.47 cm).The lowest value for petiole girth observed for *Thevetia peruviana* (0.29 cm) in this group. Highest leaf number per unit area observed in *Hamelia patens* (154.02) and lowest in *Nerium indicum* (29.00), in the tall group. Internodal length was the highest in *Allamanda cathartica* (12.00 cm) and *Allamanda violacea* (11.67 cm) and the lowest in *Thevetia peruviana* (1.23 cm), and *Pereskia bleo* (1.43 cm). The quantitative plant and leaf characters for tall shrubs are given in Table 13.

4.2.3.2 Medium shrubs

Ixora coccinea showed the highest value for leaf length among the observed medium group shrubs (16.97 cm) and the minimum leaf length was observed for *Rondeletia odorata* (5.07 cm). *Murraya paniculata* Showed the highest width (7.20 cm) for the single whole leaf and the lowest breadth was observed for *Rondeletia odorata* (2.50 cm). In this category, highest leaf area was observed for *Ixora coccinea*(80.74 cm^2) and minmum for *Tecomaria capensis* (7.74 cm^2). The petiole length in the medium group varied from 0.19 cm in *Rondeletia odorata* to 1.80 cm in *Tecomaria capensis.*

Highest petiole girth was observed for *Kopsia fruticosa* (0.78 cm) and *Tabernaemontana coronaria* (0.77 cm) .The lowest value for petiole girth observed for *Rondeletia odorata* (0.43 cm) in this group. Highest leaf number per unit area observed in *Clerodendrum macrosiphon* (117.00) and lowest in *Tabernaemontana coronaria* (36.67), in the medium group. Internodal length was the highest in *Kopsia fruticosa* (6.00 cm) and the lowest in *Pseuderanthemum reticulatum* (1.63 cm), and *Clerodendrum macrosiphon* (1.83 cm). The quantitative plant and leaf characters for medium shrubs are given in Table 14.

4.2.3.3 Dwarf shrubs

In the dwarf shrubs observed, the highest and the lowest leaf length were showed by *Odontonema cuspidatum* (13.00 cm) and *Russelia juncea* (0.70 cm) respectively. The highest leaf breadth was observed for *Odontonema cuspidatum* (7.37 cm) and the minimum for *Russelia juncea* (0.80 cm). The leaf area was the highest in *Ixora rosea* (46.04 cm^2) and the lowest in *Russelia juncea* (0.80 cm^2).

The petiole length in the tall group varied from 0.18 cm in *Russelia juncea* to 1.53 cm in *Pseuderanthemum graciflorum.* Highest petiole girth was observed for *Odontonema cuspidatum* (0.60 cm) and *Pseuderanthemum graciflorum* (0.60 cm).The

Table 13. Leaf quantitative characters (Tall shrubs)

No.	Shrub	Leaf		Area (cm^2)	No. of leaves/ 1000 cm^2	Petiole		Inter nodal length (cm)
		Length (cm)	Breadth (cm)			Length (cm)	Girth (cm)	
1	*Allamanda cathartica*	13.33^{e}	5.17^{d}	42.33^{b}	42.00 (6.52)	0.32^{b}	0.58^{c}	12.00^{f}
2	*Allamanda violacea*	11.17^{cd}	6.40^{e}	58.20^{c}	40.67 (6.42)	0.18^{a}	0.40^{b}	11.67^{f}
3	*Bauhinia acuminata*	12.17^{d}	11.00^{g}	83.33^{d}	32.00 (5.70)	2.97^{e}	0.70^{d}	3.87^{c}
4	*Calliandra haematocephala*	4.89^{a}	4.26^{e}	14.90^{a}	77.33 (8.82)	3.63^{f}	1.47^{f}	1.63^{b}
5	*Hamelia patens*	4.90^{a}	4.03^{c}	13.77^{a}	154.02 (12.42)	1.30^{c}	0.40^{b}	2.53^{c}
6	*Mussaenda erythrophylla*	14.50^{f}	7.50^{f}	62.27^{d}	36.00 (6.04)	1.15^{c}	0.75^{d}	4.03^{e}
7	*Nerium indicum*	22.33^{h}	2.43^{b}	58.23^{c}	29.00 (5.43)	1.97^{d}	0.79^{de}	2.47^{c}
8	*Pereskia bleo*	16.83^{g}	5.77^{d}	53.13^{c}	44.67 (6.72)	2.97^{e}	0.84^{e}	1.43^{a}
9	*Thevetia peruviana*	10.47^{bc}	1.03^{a}	10.03^{a}	101.02 (10.06)	0.18^{a}	0.29^{a}	1.23^{a}
	CD value	2.24	0.86	3.60	8.75 (0.44)	0.31	0.08	2.51

*values given in the paranthesis are square root transformation

Table 14. Leaf Quantitative characters (Medium shrubs)

No.	Shrub	Leaf		Area (cm^2)	No. of leaves/ 1000 cm^2	Petiole		Inter nodal length (cm)
		Length (cm)	Breadth (cm)			Length (cm)	Girth (cm)	
1	*Allamanda neriifolia*	6.50^{b}	3.20^{b}	9.43^{a}	102.00 (10.12)	0.89^{c}	0.57^{c}	1.90^{ab}
2	*Clerodendrum macrosiphon*	8.20^{c}	3.67^{bc}	12.77^{ab}	117.00 (10.84)	1.10^{d}	0.60^{d}	1.83^{a}
3	*Ixora chinensis*	10.60^{de}	4.53^{c}	33.50^{d}	59.67 (7.75)	0.36^{ab}	0.68^{f}	2.17^{b}
4	*Ixora coccinea*	16.97^{h}	6.23^{e}	80.74^{h}	48.67 (7.01)	0.48^{b}	0.69^{f}	4.07^{d}
5	*Kopsia fruticosa*	13.97^{g}	5.70^{de}	66.51^{g}	42.33 (6.54)	1.23^{d}	0.78^{g}	6.00^{ef}
6	*Murraya paniculata*	12.97^{f}	7.20^{f}	9.09^{a}	81.00 (9.03)	1.73^{e}	0.50^{b}	2.43^{b}
7	*Pseuderanthemum reticulatum*	8.97^{c}	6.60^{e}	50.73^{ef}	40.00 (6.36)	1.07^{d}	0.66^{e}	1.63^{a}
8	*Rondeletia odorata*	5.07^{a}	2.50^{ab}	8.04^{a}	90.67 (9.54)	0.19^{a}	0.43^{a}	3.33^{c}
9	*Tabernaemontana coronaria*	13.93^{g}	6.23^{e}	49.75^{e}	36.67 (6.09)	1.10^{d}	0.77^{g}	5.67^{e}
10	*Tecomaria capensis*	11.07^{e}	5.10^{d}	7.74^{a}	40.00 (6.36)	1.80^{e}	0.58^{cd}	2.27^{b}
	CD value	1.28	0.37	3.05	7.30 (0.22)	0.68	0.09	1.82328

*values given in the paranthesis are square root transformation

Table 15. Leaf quantitative characters (Dwarf shrubs)

No.	Shrub	Leaf (cm)		Area (cm^2)	No. of leaves/ 1000 cm^2	Petiole (cm)		Inter nodal length (cm)
		Length (cm)	Breadth (cm)			Length (cm)	Girth (cm)	
1	*Allamanda cathartica* 'Dwarf'	6.30^{e}	1.13^{ab}	7.94^{b}	125.67 (11.23)	0.30^{b}	0.48^{cd}	1.77^{ab}
2	*Brunfelsia latifolia*	8.00^{f}	3.20^{d}	13.99^{c}	71.00 (8.45)	0.73^{d}	0.43^{c}	2.00^{b}
3	*Ixora rosea*	11.03^{g}	6.23^{f}	46.04^{e}	75.67 (8.73)	0.43^{c}	0.70^{f}	3.00^{d}
4	*Lonicera japonica*	5.67^{de}	2.43^{c}	8.63^{bc}	112.33 (10.62)	0.42^{c}	0.48^{cd}	2.07^{b}
5	*Odontonema cuspidatum*	13.00^{h}	7.37^{g}	48.07^{e}	39.33 (6.31)	1.30^{e}	0.60^{ef}	6.67^{f}
6	*Otacanthus caeruleus*	6.17^{e}	2.60^{c}	12.29^{c}	64.00 (8.03)	0.13^{a}	0.57^{e}	2.13^{b}
7	*Pseuderanthemum graciliflorum*	11.33^{g}	5.17^{e}	45.18^{e}	42.67 (6.57)	1.53^{f}	0.60^{ef}	2.67^{c}
8	*Russelia juncea*	0.70^{a}	0.80^{a}	0.80^{a}	127.67 (11.32)	0.07^{a}	0.08^{a}	5.33^{e}
9	*Tabernaemontana coronaria* 'Nana'	3.83^{bc}	0.90^{a}	3.23^{ab}	209.33 (14.48)	0.37^{bc}	0.38^{bc}	1.17^{ab}
10	*Tabernaemontana coronaria* 'Variegata'	9.20^{f}	3.80^{d}	16.27^{cd}	85.00 (9.24)	1.10^{e}	0.62^{f}	2.50^{bc}
11	*Wrightia antidysenterica*	4.33^{c}	2.93^{cd}	10.28^{c}	31.67 (5.66)	0.33^{b}	0.41^{c}	2.50^{bc}
	CD value	0.69	0.37	2.15	13.04 (0.60)	0.87	0.12	1.52

*values given in the paranthesis are square root transformation

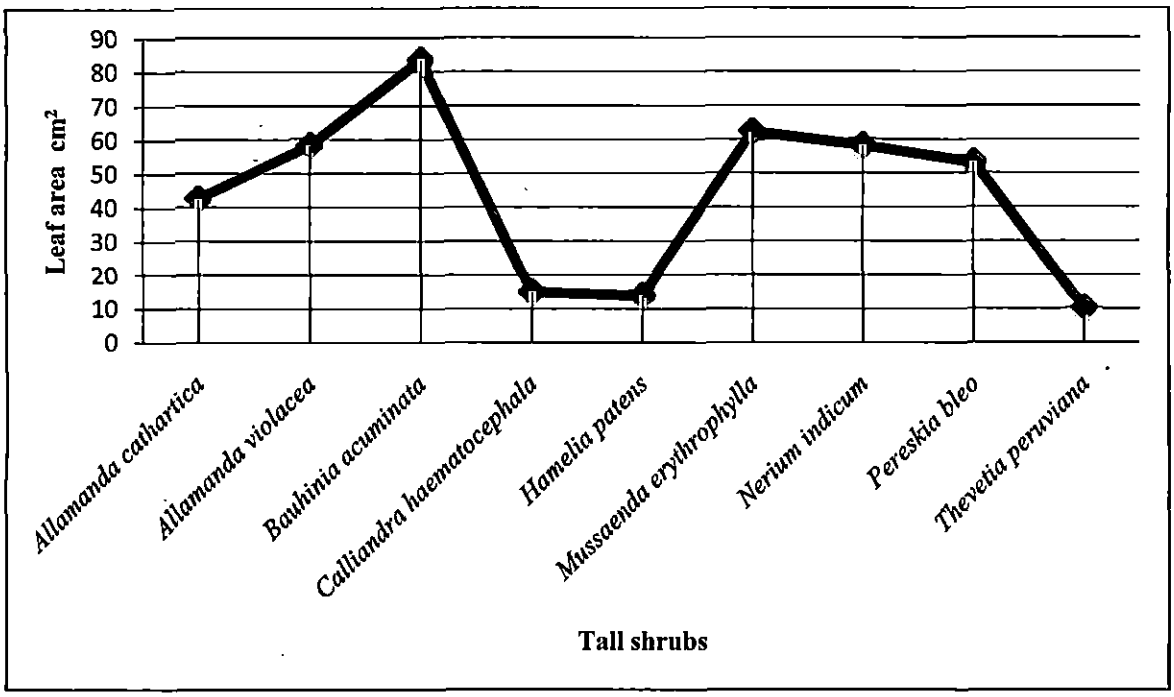


Fig. 10. Leaf area (Tall shrubs)

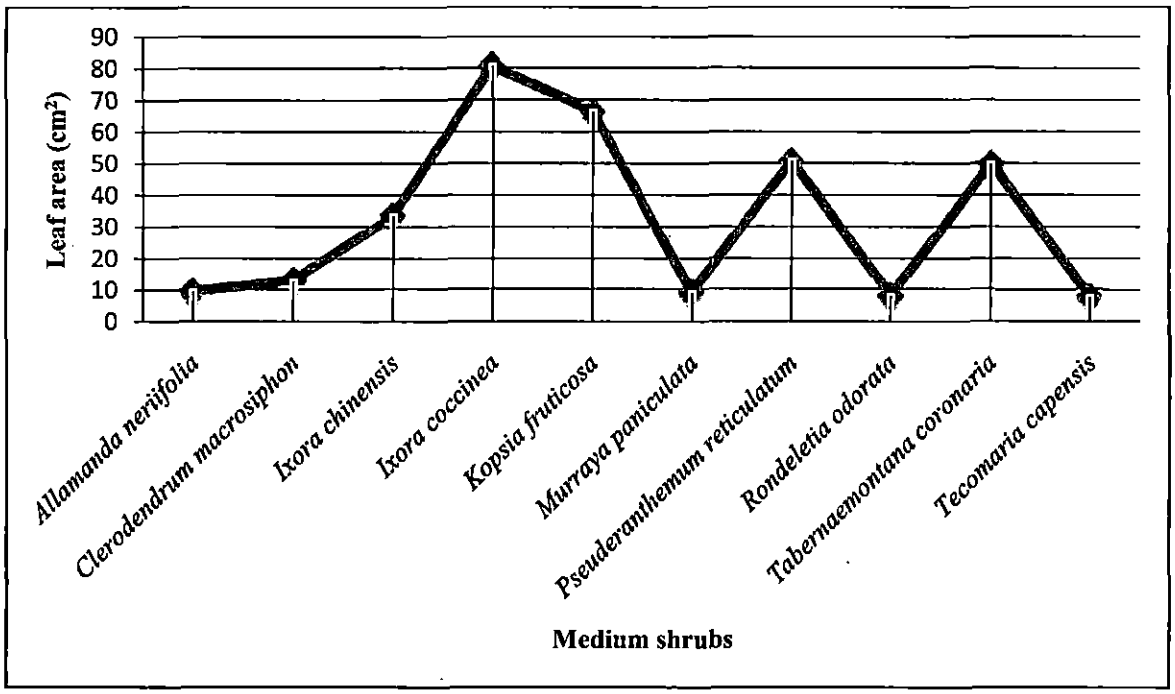


Fig. 11. Leaf area (Medium shrubs)

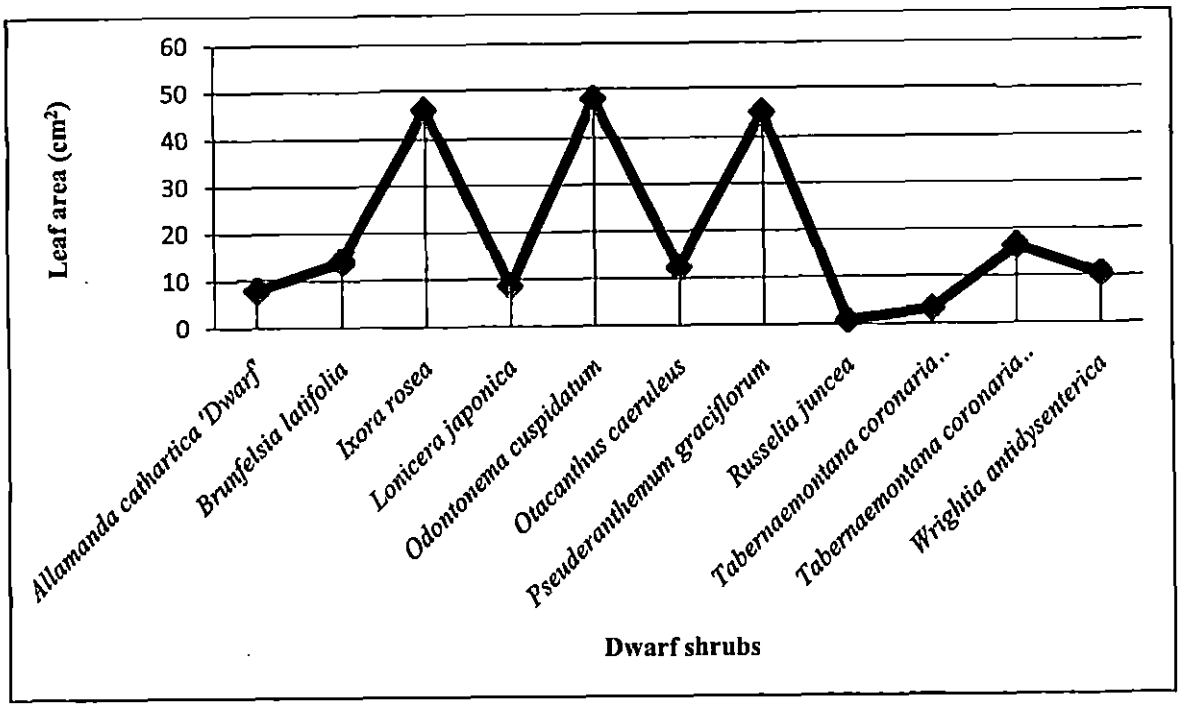


Fig. 12 . Leaf area (Dwarf shrubs)

lowest value for petiole girth was observed for *Russelia juncea* (0.29 cm) in this group. Highest leaf number per unit area was observed in *Tabernaemontana coronaria* 'Nana' (209.33) and lowest in *Wrightia antidysenterica* (31.67). Internodal length was the highest in *Odontonema cuspidatum* (6.67 cm) and the lowest in *Tabernaemontana coronaria* 'Nana' (1.17 cm). The quantitative plant and leaf characters for tall shrubs are given in Table 15.

4.2.4 Flower quantitative characters

4.2.4.1 Size of flower and diameter of inflorescence

The flower quantitative characters like inflorescence diameter and length and breadth of single flower were measured (inflorescence diameter measured for inflorescences other than cymes). Inflorescence diameter was found highest for *Mussaenda erythrophylla* (32.6 cm) and minimum for *Calliandra haematocephala* (3.9 cm). Single flower diameter was highest for *Allamanda cathartica* and *A. violacea* (8.0 cm). *Bauhinia acuminata* also produced bigger flowers (8.0 cm) diameter. *Hamelia patens* (0.3 cm) and *Calliandra haematocephala* (0.4 cm) showed minimum breadth for single floret. The length of single was also higher for *Allamanda cathartica* and *A. violacea* (10.0 cm). Size of flower and diameter of inflorescence for tall group is given in the Table 16.

Ixora coccinea (10.6 cm) showed the maximum inflorescence diameter followed by *Kopsia fruticosa*(9.6 cm) and *Clerodendrum macrosiphon* (9.6 cm) in the medium shrubs for flower diameter, lower value was observed in the case of *Rondeletia odorata* (3.6 cm). Maximum diameter for single flower is observed for *Tabernaemontana coronaria* (4.7 cm) and minimum by *Rondeletia odorata* (0.4 cm). The floret length was highest for *Clerodendrum macrosiphon* (6.4 cm). The least length was observed for *Rondeletia odorata* (1.4 cm). Size of flower and diameter of inflorescence for medium shrubs is given in the Table 17.

Among the dwarf shrubs, *Ixora rosea* showed the maximum inflorescence diameter (8.50 cm) and lowest was observed for *Tabernaemontana coronaria* 'Nana' (5.70 cm). Single flower diameter found higher in *Allamanda cathartica* 'Dwarf' (5.60 cm). *Russelia juncea* have minimum flower diameter in this category (0.30 cm). Length of single flower was higher in *Allamanda cathartica* 'Dwarf' (5.60 cm) and it was minimum in *Russelia juncea* (2.70 cm). Size of flower and diameter of inflorescence for dwarf shrubs is given in the Table 18.

The shrubs differed with respect to the length of their single flower stalk. *Thevetia peruviana* showed the highest value for stalk length (1.4 cm). *Allamanda cathartica* and *Tecomaria capensis* also produced longer single flower stalk (1.2 cm) and shortest single flower stalks were observed for shrubs like *Lonicera japonica* and *Otacanthus caeruleus* (0.1 cm). The single flower stalk lengths of different shrubs observed are given in Table 18.

4.2.4.2 Number of flowers produced per inflorescence

Shrubs showed significant difference in the number of flowers produced per inflorescence. Among the tall shrubs, *Hamelia patens* produced highest number of flowers per inflorescence (61.33) and the lowest number was observed for *Pereskia bleo* (1.67). *Calliandra haematocephala* also produced more number of flowers per inflorescence (48.33). In the medium shrubs, *Ixora coccinea* produced highest number of flowers per inflorescence (105.00). *Murraya paniculata* also produced more number of flowers per inflorescence (55.00). *Allamanda neriifolia* produced the lowest number of flowers per inflorescence (6.67) among the medium shrubs. And in dwarf shrubs, *Russelia juncea* produced highest number of flowers per inflorescence (303.00) and the lowest number of flower per inflorescence is observed for *Brunfelsia latifolia* (2.67). The numbers of flowers produced by tall, medium and dwarf shrubs are given in Tables 16-18.

Table 16. Flower quantitative characters (Tall shrubs)

No.	Shrub	Diameter of inflorescence (cm)	Diameter of single flower corolla head (cm)	Length of single flower (cm)	Total number of flowers/ inflorescences produced a year	Number of flowers per inflorescence	Stalk length (cm)
1	*Allamanda cathartica*	---	8.0^{d}	10.0^{f}	319.00 (17.87)	7.67 (2.86)	1.2^{e}
2	*Allamanda violacea*	---	8.0^{d}	10.0^{f}	277.00 (16.65)	7.67 (2.86)	0.9^{de}
3	*Bauhinia acuminata*	---	8.0^{d}	6.0^{e}	131.00 (11.44)	15.00 (3.94)	0.8^{d}
4	*Calliandra haematocephala*	7.8^{b}	0.7^{a}	4.1^{c}	249.00 (15.78)	48.33 (6.97)	0.2^{a}
5	*Hamelia patens*	4.6^{a}	0.3^{a}	2.0^{ab}	1371.00 (37.03)	61.33 (7.85)	0.7^{b}
6	*Mussaenda erythrophylla*	32.6^{c}	1.8^{b}	6.3^{e}	558.00 (23.63)	27.33 (5.27)	0.7^{b}
7	*Nerium indicum*	14.0^{b}	1.8^{b}	1.7^{a}	70.00 (8.32)	26.67 (5.21)	0.4^{b}
8	*Pereskia bleo*	---	3.0^{c}	2.2^{b}	106.00 (10.28)	1.67 (1.46)	0.8^{d}
9	*Thevetia peruviana*	---	3.8^{c}	5.0^{d}	192.00 (13.86)	7.67 (2.86)	0.4^{b}
	CD value	3.06	1.07	1.57	39.45 (1.47)	7.09 (0.52)	0.12

* Inflorescence diameter of single flowers/ cyme inflorescence not measured

*Values given in the paranthesis are square root transformations

Table 17. Flower quantitative characters (Medium shrubs)

No.	Shrub	Diameter of inflorescence (cm)	Diameter of single flower corolla head (cm)	Length of single flower (cm)	Total flower produced	Number of flowers per inflorescence	Stalk length (cm)
1	*Allamanda neriifoliaolia*	---	3.5^{d}	3.9^{c}	139.00 (11.78)	6.67 (2.67)	0.6^{c}
2	*Clerodendrum macrosiphon*	9.6^{de}	1.9^{b}	6.4^{e}	398.00 (19.96)	30.00 (5.51)	0.2^{a}
3	*Ixora chinensis*	9.0^{d}	1.9^{b}	2.4^{b}	86.00 (9.24)	35.00 (5.95)	0.2^{a}
4	*Ixora coccinea*	10.6^{f}	3.5^{d}	3.2^{c}	208.00 (14.42)	105.00 (10.27)	0.2^{a}
5	*Kopsia fruticosa*	9.6^{de}	3.5^{d}	4.0^{cd}	363.00 (19.06)	25.00 (5.03)	0.3^{b}
6	*Murraya paniculata*	6.3^{bc}	2.0^{bc}	2.0^{ab}	509.00 (22.57)	55.00 (7.44)	0.8^{c}
7	*Pseuderanthemum reticulatum*	5.6^{b}	1.9^{b}	1.9^{a}	71.00 (8.38)	51.67 (7.21)	0.4^{b}
8	*Rondeletia odorata*	3.6^{a}	0.4^{a}	1.4^{a}	161.00 (12.69)	13.00 (3.66)	0.2^{a}
9	*Tabernaemontana coronaria*	---	4.7^{e}	2.5^{b}	82.00 (9.02)	9.00 (3.08)	1.1^{d}
10	*Tecomaria capensis*	5.6^{b}	2.5^{c}	4.6^{d}	246.00 (15.69)	32.00 (5.70)	1.2^{d}
	CD value	1.12	0.81	0.91	39.17 (1.62)	7.57 (0.63)	0.11

* Inflorescence diameter of single flowers/ cyme inflorescence not measured

*Values given in the paranthesis are square root transformations

Table 18. Flower quantitative characters (Dwarf shrubs)

No.	Shrub	Diameter of inflorescence (cm)	Diameter of single flower corolla head (cm)	Length of single flower (cm)	Total flower produced	Number of flowers per inflorescence	Stalk length (cm)
1	*Allamanda cathartica* 'Dwarf'	---	5.6^{f}	5.8^{c}	435.00 (20.86)	9.00 (3.08)	0.4^{d}
2	*Brunfelsia latifolia*	---	3.5^{d}	3.5^{b}	106.00 (10.28)	2.67 (1.74)	0.3^{c}
3	*Ixora rosea*	8.5^{e}	1.4^{b}	3.0^{ab}	121.00 (10.99)	35.00 (5.95)	0.3^{c}
4	*Lonicera japonica*	1.4^{a}	4.8^{e}	3.2^{b}	65.00 (8.01)	12.33 (3.57)	0.1^{a}
5	*Odontonema cuspidatum*	5.0^{c}	0.3^{a}	3.7^{b}	72.00 (8.44)	90.00 (9.50)	0.3^{c}
6	*Otacanthus caeruleus*	5.6^{c}	1.9^{bc}	3.1^{ab}	165.00 (12.84)	30.00 (5.51)	0.1^{a}
7	*Pseuderanthemum graciliflorum*	6.5^{d}	1.5^{b}	3.7^{b}	193.00 (13.89)	55.00 (7.44)	0.3^{c}
8	*Russelia juncea*	3.4^{b}	0.3^{a}	2.7^{a}	202.00 (14.21)	303.00 (17.31)	0.2^{b}
9	*Tabernaemontana coronaria* 'Nana'	5.7^{c}	$3.0c^{d}$	3.0^{ab}	264.00 (16.25)	25.00 (5.03)	0.3^{c}
10	*T. coronaria* 'Variegata'	5.9^{cd}	2.8^{c}	2.8^{a}	192.00 (13.86)	25.00 (5.03)	0.4^{d}
11	*Wrightia antidysenterica*	---	3.0^{cd}	2.7^{a}	120.00 (10.94)	4.00 (2.11)	0.2^{b}
	CD value	1.11	0.96	1.13	38.95 (1.70)	21.86 (0.88)	0.10

* Inflorescence diameter of single flowers/ cyme inflorescence not measured

*Values given in the paranthesis are square root transformations

4.2.4.3 Total number of inflorescence produced

Shrubs varied significantly in total number of inflorescence produced in one year. In the tall shrubs, *Hamelia patens* produced highest number of inflorescence a year (1371.00) and the lowest value was observed for *Nerium indicum* (70.00). *Mussaenda erythrophylla* also produced higher number of inflorescence (558.00). In the medium shrubs *Clerodendrum macrosiphon* (398.00) and *Kopsia fruticosa* (363.00) produced higher number of inflorescence a year. The lowest value in this group was observed for *Pseuderanthemum reticulatum* (71.00). In the dwarf shrubs *Allamanda cathartica* 'Dwarf' produced maximum number of inflorescence (435.00) and the lowest value was observed for *Lonicera japonica* (65.00) in this group. The total numbers of inflorescence produced by tall, medium and dwarf shrubs is given in Tables 16-18.

4.2.4.4 Time taken to open inflorescence

Shrubs were observed for their respective time taken for flower opening from the bud emergence. It was counted from days of bud emergence to first flower opening. Shrubs under all categories varied in their time taken for flower opening.

In tall shrubs, *Mussaenda erythrophylla* (21.6 days) and *Bauhinia acuminata* (21.0 days) took maximum time for flower opening (In the case of *Mussaenda erythrophylla*, development of full colour in first calyx lobe is considered as flower opening). Shrubs varied their times from 10.3-21.6 days. Least time taken among the observed tall shrubs is by *Thevetia peruviana* (10.3 days). Time taken for opening of inflorescences of tall group shrubs given in Table 19.

In the medium shrubs, *Ixora coccinea* showed maximum time (22.7 days) followed by *Ixora chinensis* (15.3 days). *Clerodendrum macrosiphon* (7.3 days) showed minimum time for opening up of flower in this category. *Pseuderanthemum*

reticulatum also took lesser time (8.0 days). Time taken for opening of inflorescences of intermediate group shrubs given in the Table 20.

Ixora rosea (19.0 days) and *Lonicera japonica* (7.3 days) showed maximum time and minimum time respectively in the dwarf category. *Russelia juncea* (16.0 days) and *Wrightia antidysenterica* (13.3 days) also took more time for flower opening. Time taken for opening of inflorescences of dwarf shrubs are given in the Table 21.

4.2.4.5 Persistence of single flower and inflorescence

All the selected shrubs were observed for persistence of single flower as well as inflorescence. Shrubs showed variation in their persistence of flower/ inflorescence. Time taken from first flower opening to the shedding of last flower of the inflorescence is counted. For single flower, time taken from its opening to its shedding from the inflorescence is counted.

Among the tall shrubs observed, *Mussaenda erythrophylla* showed maximum persistence time for both single flower (22.7 days) (In the case of *Mussaenda erythrophylla*, the value is taken for the five calyx lobes surrounding the true flower) and inflorescence (35.0 days). *Hamelia patens* (21.0 days) also showed higher inflorescence persistence time. The least persistence in this category observed for *Nerium indicum* and *Thevetia peruviana* (1.3 days). *Hamelia patens* and *Bauhinia acuminata* also showed lesser flower persistence time (1.7 days). Flower persistence time of tall group shrubs is given in Table 19.

In medium category, *Ixora coccinea* (22.7 days) and *Ixora chinensis* (21.0 days) showed maximum inflorescence persistence time. *Clerodendrum macrosiphon* (2.0 days) and *Murraya paniculata* (2.0 days) showed the least time of flower persistence among all the observed shrubs. The whole inflorescence opening and shedding had taken place within two days. The single flower persistence time was

Table 19. Flower and inflorescence longevity (Tall shrubs)

No.	Shrub	Time taken to open (days)	Persistence of inflorescence (days)	Persistence of single flower (days)	Interval of flower opening in an inflorescence/ cluster (days)
1	*Allamanda cathartica*	13.6 (3.76)	18.0 (4.30)	6.0 (2.54)	2.0 (1.41)
2	*Allamanda violacea*	14.0 (3.81)	18.0 (4.30)	6.0 (2.54)	2.0 (1.41)
3	*Bauhinia acuminata*	21 (4.64)	19.0 (4.41)	1.7 (1.46)	2.0 (1.41)
4	*Calliandra haematocephala*	19 (4.41)	11.0 (3.39)	2.3 (1.68)	2.7 (1.64)
5	*Hamelia patens*	15.3 (3.98)	21.0 (4.64)	1.7 (1.46)	1.8 (1.34)
6	*Mussaenda erythrophylla*	21.6 (4.71)	35.0 (5.95)	22.7 (4.81)	9.2 (3.03)
7	*Nerium indicum*	19.0 (4.41)	16.0 (4.06)	1.3 (1.34)	1.7 (1.30)
8	*Pereskia bleo*	15 (3.94)	5.0 (2.34)	1.7 (1.46)	4.2 (2.05)
9	*Thevetia peruviana*	10.3 (3.23)	1.3 (1.34)	1.7 (1.46)	3.5 (1.87)
	CD value	3.252 (0.49)	2.54 (0.34)	3.11 (0.40)	0.10 (0.31)

*Values given in the paranthesis are square root transformations

Table 20. Flower and inflorescence longevity (Medium shrubs)

No.	Shrub	Time taken to open (days)	Persistence of inflorescence (days)	Persistence of single flower (days)	Interval of flower opening in an inflorescence/ cluster (days)
1	*Allamanda neriifolia*	11.0 (3.39)	11.0 (3.39)	3.3 (2.0)	1.6 (1.26)
2	*Clerodendrum macrosiphon*	7.3 (2.80)	11.0 (3.39)	1.3 (1.3)	0.6 (0.77)
3	*Ixora chinensis*	15.3 (3.98)	21.0 (4.64)	4.0 (2.1)	0.8 (0.89)
4	*Ixora coccinea*	22.7 (4.81)	22.7 (4.81)	6.3 (2.6)	0.9 (0.95)
5	*Kopsia fruticosa*	14.0 (3.81)	13.7 (3.76)	2.3 (1.7)	0.8 (0.89)
6	*Murraya paniculata*	13.0 (3.67)	8.0 (2.91)	1.3 (1.3)	0.4 (0.63)
7	*Pseuderanthemum reticulatum*	8.0 (2.91)	13.0 (3.67)	2.3 (1.7)	0.8 (0.89)
8	*Rondeletia odorata*	13.3 (3.72)	7.0 (2.73)	6.0 (2.5)	1.2 (1.10)
9	*Tabernaemontana coronaria*	19.0 (4.41)	19.0 (4.41)	5.3 (2.4)	4.6 (2.14)
10	*Tecomaria capensis*	11.0 (3.39)	16.0 (4.06)	1.7 (1.5)	1.2 (1.10)
	CD value	2.24 (0.28)	2.39 (0.31)	1.16 (0.30)	0.10 (0.31)

*Values given in the paranthesis are square root transformations

Table 21. Flower and inflorescence longevity (Dwarf shrubs)

No.	Shrub	Time taken to open (days)	Persistence of inflorescence (days)	Persistence of single flower (days)	Interval of flower opening in an inflorescence/ cluster (days)
1	*Allamanda cathartica* 'Dwarf'	11.0 (3.4)	13.3 (3.7)	3.0 (1.86)	2.7 (1.64)
2	*Brunfelsia latifolia*	11.0 (3.4)	9.3 (3.1)	4.0 (2.11)	2.6 (1.61)
3	*Ixora rosea*	19.0 (4.4)	19.0 (4.4)	4.3 (2.20)	1.2 (1.10)
4	*Lonicera japonica*	7.3 (2.8)	5.0 (2.3)	2.3 (1.68)	1.0 (1.0)
5	*Odontonema cuspidatum*	10.7 (3.3)	32.7 (5.8)	2.3 (1.68)	2.5 (1.58)
6	*Otacanthus caeruleus*	9.0 (3.1)	17.3 (4.2)	5.3 (2.41)	1.8 (1.34)
7	*Pseuderanthemum graciliflorum*	13.3 (3.7)	22.0 (4.7)	2.3 (1.68)	0.8 (0.89)
8	*Russelia juncea*	16.0 (4.1)	27.7 (5.3)	2.3 (1.68)	1.4 (1.18)
9	*Tabernaemontana coronaria* 'Nana'	9.0 (3.1)	13.3 (3.7)	3.0 (1.86)	2.1 (1.45)
10	*Tabernaemontana coronaria* 'Variegata'	9.7 (3.2)	13.3 (3.7)	3.3 (1.95)	2.3 (1.52)
11	*Wrightia antidysenterica*	13.3 (3.7)	13.0 (3.7)	2.0 (1.56)	2.3 (1.52)
	CD value	1.95 (0.27)	3.04 (0.36)	1.29 (0.35)	0.10 (0.31)

*Values given in the paranthesis are square root transformations

higher in *Ixora coccinea* (7 days) and the least in *Murraya paniculata* and *Clerodendrum macrosiphon* (1.3 day). Flower persistence time of tall group shrubs is given in Table 20.

Odontonema cuspidatum (32.7 days) showed maximum inflorescence persistence time under the dwarf shrub category and the least persistence time noticed for *Lonicera japonica* (5.0 days). *Lonicera japonica* also showed the least time for single flower persistence (2.3 days). *Otacanthus caeruleus* showed maximum single flower persistence time under this group (5.3 days). Flower persistence time of tall group shrubs is given in Table 21.

4.2.4.6 Interval of flower opening

The time period between openings of two flowers in an inflorescence or flower cluster counted and expressed in days. Among the tall shrubs observed, *Mussaenda erythrophylla* showed maximum time interval between two consecutive flower openings (9.2 days) and the least value was observed for *Nerium indicum* (1.7 days). In the medium shrubs, *Tabernaemontana coronaria* showed the highest value (4.6 days) and *Murraya paniculata* showed the lowest (0.4 days). Among the dwarf shrubs, highest value was observed for *Allamanda cathartica* 'Dwarf' (2.7 days) and lowest for *Pseuderanthemum graciflorum* (0.8 days). The time intervals of flower opening for the shrubs observed are given in Table 21.

4.3 QUALITATIVE CHARACTERS

4.3.1 Qualitative plant and leaf characters

The plant and leaf qualitative characters varied among the observed shrubs. Except *Calliandra haematocephala*, *Tecomaria capensis* and *Murraya paniculata*, all others were having simple leaves. The leaves were evenly pinnate in *Calliandra haematocephala* while it was odd pinnate in *Murraya paniculata* and *Tecomaria*

capensis. Leaf shapes also varied between shrubs. Elliptic, lanceolate, ovate or their variations were observed mostly.

The leaf base was acute in most of the shrubs. Other forms like rounded, attenuate, obtuse, cuneate, attenuate, cordate and oblique leaf base also observed. Acute, acuminate, cuspidate and obtuse leaf tips were observed. Leaf margin was entire in most shrubs. In *Otacanthus caeruleus*, leaf margin was crenate and in *Clerodendrum macrosiphon* and *Tecomaria capensis* it was serrate. The leaf surface texture was varying among different shrubs. Smoot glabrous and coriaceous were mostly observed mostly. It was succulent in *Pseuderanthemum reticulatum* and *Pereskia bleo.*Hairy leaf surface was observed in *Allamanda violacea* and *Mussaenda erythrophylla*. In *Rondeletia odorata* it was rough and rugous.

Variegated leaf colour was observed in *Tabernaemontana coronaria* 'Variegata'. In *Pseuderanthemum reticulatum* the leaf colour was yellowish green or green leaves with yellow veinations. In all other shrubs, leaves were either green or dark green in colour.

Alternate, opposite and whorled leaf arrangements were observed. All *Allamanda* species showed whorled leaf arrangement. Different branching patterns observed were weeping, upright, ascending, picturesque, horizontal, leggy and recurving. Ascending branching pattern was common among the observed shrubs. Most of the shrubs with ascending type of branching produced an open canopy. Ascending branching pattern was observed in *Calliandra haematocephala, Hamelia patens, Tecomaria capensis, Allamanda cathartica* 'Dwarf', *Brunfelsia latifolia, Tabernaemontana coronaria* and *T. coronaria* 'Nana'. Shrubs with upright branching habit showed lesser spread. Upright form was also common. This pattern of branching observed in *Pereskia bleo, Nerium indicum, Ixora chinensis, I. coccinea, Murraya paniculata, Otacanthus caeruleus* and *Wrightia antidysenterica*. Weeping branching pattern observed in *Allamanda cathartica* and *A. violacea*.

Table 22. Qualitative plant and leaf characters (Tall shrubs)

No.	Shrub	Shape	Base	Tip	Margin	Texture	Colour	Leaf arrangement	Branching pattern
1	*Allamanda cathartica*	Obovate-oblanceolate	Acute	Acuminate	Entire	Smooth glabrous	Green	Whorled	Weeping
2	*Allamanda violacea*	Obovate	Acute	cuspidate	Entire	Hispid	Green	Whorled	Weeping
3	*Bauhinia acuminata*	Orbicular	Cordate	Acute-cordate	Entire	Coriaceous papery	Dark green	Alternate	Upright-ascending
4	*Calliandra haematocephala*	Evenly pinnate, obliquely lanceolate	Oblique	Obtuse-mucronate	Entire, sparsely pilose	Coriaceous	Dark green	Alternate	Ascending
5	*Hamelia patens*	Elliptical	Acute	Acute	Entire	Smooth	Olive green	Whorled	Ascending-horizontal
6	*Mussaenda erythrophylla*	Elliptical	Rounded	Acute-obtuse	Entire	Hairy	Green	Opposite	Ascending-recurving
7	*Nerium indicum*	Linear	Acute	Acute	Entire	Coriaceous	Dark green	Whorled	Upright
8	*Pereskia bleo*	Elliptical	Acute	Acuminate	Wavy	Succulent	Dark green	Alternate spiral	Upright
9	*Thevetia peruviana*	Linear	Acute	Obtuse and shortly acuminate	Entire	Smooth glabrous	Green	Alternate spiral	Picturesque

Table 23. Qualitative plant and leaf characters (Medium shrubs)

No.	Shrub	Shape	Base	Tip	Margin	Texture	Colour	Leaf arrangement	Branching pattern
1	*Allamanda neriifolia*	Elliptical	Cuneate	Acuminate	Entire	Smooth-coriaceous	Green	Whorled	Picturesque
2	*Clerodendrum macrosiphon*	Spatulate-lanceolate	Attenuate	Acuminate	Serrate	Downy	Green	Opposite deccusate	Upright-ascending
3	*Ixora chinensis*	Obovate	Cuneate	Obtuse	Entire	Smooth glabrous	Green	Opposite deccusate	Upright
4	*Ixora coccinea*	Elliptical	Cordate	Acuminate	Entire	Thick, coriaceous	Green-yellowish green	Opposite deccusate	Upright
5	*Kopsia fruticosa*	Narrowly elliptical	Acute	Acuminate	Entire, little wavy	Smooth glabrous	Green	Opposite	Upright-ascending
6	*Murraya paniculata*	Odd pinnate	Acute	Obtuse	Entire	Smooth glabrous	Dark green	Alternate	Upright
7	*Pseuderanthemum reticulatum*	Ovate	Rounded	Acute	Entire	Succulent	Yellowish green	Opposite deccusate	Upright-ascending
8	*Rondeletia odorata*	Elliptic-ovate	Cordate	Acutely acuminate	Entire-wavy	Scabrous and rugous	Dark green	Opposite deccusate	Ascending-upright
9	*Tabernaemontan coronaria*	Elliptic-oblong	Acute	Acuminate	Entire-wavy	Smooth glabrous, membraneous	Dark green	Opposite	Ascending
10	*Tecomaria capensis*	Odd pinnate	Acute	Acute	Serrate	Succulent-coriaeous	Green	Opposite deccusate	Ascending

Table 24. Qualitative plant and leaf characters (Dwarf shrubs)

No.	Shrub	Shape	Base	Tip	Margin	Texture	Colour	Leaf arrangement	Branching pattern
1	*Allamanda cathartica* 'Dwarf'	Narrowly lanceolate	Acute	Acuminate	Entire	Smooth, glossy	Green	Whorled	Ascending
2	*Brunfelsia latifolia*	Elliptic-lanceolate	Cuneate	Acute	Entire	Smooth glabrous	Dark green	Alternate	Ascending
3	*Ixora rosea*	Elliptic-obovate	Round, shortly cordate	Cuspidate	Entire	Smooth glabrous	Dark green	Opposite deccusate	Upright
4	*Lonicera japonica*	Ovate	Oblique	Acute	Entire, ciliate	Smooth glabrous, sparsely hairy	Green	Opposite	Horizontal
5	*Odontonema cuspidatum*	Elliptic	Acute	Acuminate	entire	Glabrous	Green	Opposite	Leggy
6	*Otacanthus caeruleus*	Lanceolate	Attenuate	Acute	Crenate	Succulent	Green	Opposite deccusate	Upright
7	*Pseuderanthemum graciliflorum*	Narrowly ovate	Acute	Acuminate	Entire-wavy	Coriaceous	Green	Opposite deccusate	Recurving
8	*Russelia juncea*	Orbicular	Round	Obtuse	Dentate	Smooth	Green	Whorled	Whorled
9	*Tabernaemontana coronaria* 'Nana'	Narrowly elliptical	Cuneate	Acuminate	Entire	Smooth glabrous	Dark green	Opposite deccusate	Ascending
10	*Tabernaemontana coronaria* 'Variegata'	Oblanceolate	Attenuate	Acuminate	Wavy	Smooth glabrous	Variegated, white and whitish green	Opposite	Recurving
11	*Wrightia antidysenterica*	Elliptic	Cuneate	Acute	Entire	Smooth	Dark green	Opposite deccusate	Upright

The qualitative plant and leaf characters of tall, medium and dwarf shrubs are given in Tables 22-24.

4.3.2. Qualitative flower characters

The qualitative characters of the shrubs were observed and recorded. All the shrubs varied in their qualitative flower characters like type of flower, position of flower, flower colour and fragrance.

Shrubs were observed for their flower colour. All shrubs showed different coloured flowers. Certain shrubs showed two or more different colours on the same flower. In *Rondeletia odorata* flowers were with yellow throat and red corolla, in *Otacanthus caeruleus*, white eye marking on the throat region, and in *Pseuderanthemum reticulatum*, purple spots on throat region were observed. A few shrubs showed change in flower colour in successive days. *Brunfelsia latifolia* produced blue flowers, which turned to light purple next day and on the third day it became white. Flowers of *Ixora chinensis* changed colour from orange to salmon red. *Lonicera japonica* flowers changed colour from pure white to pale yellow-brown. Flowers of *Otacanthus caeruleus* and *Kopsia fruticosa* tend to fade off every day. Flower colour observed for all the shrubs are listed in Table 25.

The shrubs were observed for their position of flower. Most of them produced flowers terminally. A few shrubs produced both terminal and axillary flowers/ inflorescence. In *Bauhinia acuminata* and *Calliandra haematocephala* most of the flowers were axillary. *Lonicera japonica, Clerodendrum macrosiphon, Brunfelsia latifolia* and *Otacanthus caeruleus* produced flowers terminally and subterminally in leafy panicles. *Allamanda cathartica, A.violacea, A. cathartica* 'Dwarf' *and A. neriifolia* produced flowers in terminal cymose inflorescence followed by axillary clusters. Positions of inflorescences of the shrubs are given in the Table 25.

Table 25. Flower qualitative characters of shrubs

No.	Shrub	Type of flower	Colour	Position	Fragranc
	Tall shrubs				
1	*Allamanda cathartica*	Few flowered terminal clusters or axillary cymes	Yellow	Terminal or axillary near end of branches	No
2	*Allamanda violacea*	Few flowered terminal clusters or axillary cymes	Purple	Terminal or axillary near end of branches	No
3	*Bauhinia acuminata*	Few flowers in loose bunch axillary raceme	Snow white	Axillary raceme	Fragrant
4	*Calliandra haematocephala*	Head	Red	Axillary	No
5	*Hamelia patens*	Terminal clusters- cyme	Yellow, yellow orange, orange red	Terminal	No
6	*Mussaenda erythrophylla*	Corymbs	Light pink	Terminal	No
7	*Nerium indicum*	Terminal panicle	Hot pink	Terminal	Fragrant
8	*Pereskia bleo*	Single flower or two flowrered cluster	Ornge red	Terminal	No
9	*Thevetia peruviana*	Few flowered terminal clusters	Yellow -apricot	Terminal	Fragrant
	Medium shrubs				
10	*Allamanda neriifolia*	Few flowered terminal clusters or axillary cymes	Bright yellow with purplish brown tinch on corolla tube	Terminal or axillary near end of branches	No
11	*Clerodendrum macrosiphon*	Head like terminal cyme	Snow white	Terminal and leaf axils	No
12	*Ixora chinensis*	Dense corymb	Orange red to salmon red	Terminal	No
13	*I. coccinea*	Compact corymb	Scarlet red	Terminal	No
14	*Kopsia fruticosa*	Corymb	Light pink	Terminal	No
15	*Murraya paniculata*	Terminal panicle	Flower white	Terminal	Fragrant
16	*Pseuderanthemum reticulatum*	Panicle	White with purplish spots on corolla	Terminal	No
17	*Rondeletia odorata*	Many flowered corymbos cyme	Orange corolla with yellowish throat	Terminal	No
18	*Tabernaemontana coronaria*	Cymes in terminal ends or solitary few flowered axils	White	Terminal	Fragrant
19	*Tecomaria capensis*	Terminal clusters	Yellow	Terminal	No
	Dwarf shrubs				
20	*Allamanda cathartica* 'Dwarf'	Few flowered terminal clusters or axillary cymes	Bright yellow	Terminal or axillary near end of branches	No
21	*Brunfelsia latifolia*	Few flowered terminal clusters or axillary cyme	Blue, light violet, white	Terminal and axillary	No
22	*Ixora rosea*	Corymb	Pink	Terminal	No
23	*Lonicera japonica*	Axillary pedunculate pairs or spikes of whorled pair	White and dull yellow	Terminal leaf axils	Fragrant
24	*Odontonema cuspidatum*	3-5 branched terminal raceme-panicle	Purplish red	Terminal	No
25	*Otacanthus caeruleus*	Racemes 4 flower at one panicle	Blue with white marking on throat	Terminal leaf axils	No
26	*Pseuderanthemum graciflorum*	Terminal Panicle	Light violet	Terminal	No
27	*Russelia juncea*	2-3 flowered peduncles on tip of whorled branches	Red	Terminal	No
28	*Tabernaemontana coronaria* 'Nana'	Corymb	White	Terminal	No
29	*T.coronaria* 'Variegata'	Corymb	White	Terminal	No
30	*Wrightia antidysenterica*	Corymb like cyme	Snow white	Terminal	No

The qualitative plant and leaf characters of tall, medium and dwarf shrubs are given in Tables 22-24.

4.3.2. Qualitative flower characters

The qualitative characters of the shrubs were observed and recorded. All the shrubs varied in their qualitative flower characters like type of flower, position of flower, flower colour and fragrance.

Shrubs were observed for their flower colour. All shrubs showed different coloured flowers. Certain shrubs showed two or more different colours on the same flower. In *Rondeletia odorata* flowers were with yellow throat and red corolla, in *Otacanthus caeruleus*, white eye marking on the throat region, and in *Pseuderanthemum reticulatum*, purple spots on throat region were observed. A few shrubs showed change in flower colour in successive days. *Brunfelsia latifolia* produced blue flowers, which turned to light purple next day and on the third day it became white. Flowers of *Ixora chinensis* changed colour from orange to salmon red. *Lonicera japonica* flowers changed colour from pure white to pale yellow-brown. Flowers of *Otacanthus caeruleus* and *Kopsia fruticosa* tend to fade off every day. Flower colour observed for all the shrubs are listed in Table 25.

The shrubs were observed for their position of flower. Most of them produced flowers terminally. A few shrubs produced both terminal and axillary flowers/ inflorescence. In *Bauhinia acuminata* and *Calliandra haematocephala* most of the flowers were axillary. *Lonicera japonica, Clerodendrum macrosiphon, Brunfelsia latifolia* and *Otacanthus caeruleus* produced flowers terminally and subterminally in leafy panicles. *Allamanda cathartica, A.violacea, A. cathartica* 'Dwarf' *and A. neriifolia* produced flowers in terminal cymose inflorescence followed by axillary clusters. Positions of inflorescences of the shrubs are given in the Table 25.

Different shrubs produced different types of inflorescence (Table 25.). Shrubs like *Pereskia bleo* and *Brunfelsia latifolia* produced single flowers or a few flowered cymes. Shrubs which belonged to Apocynaceae family produced terminally as well as axillary cymes. Panicle type of inflorescence was produced by *Nerium indicum, Pseuderanthemum reticulatum and Pseuderanthemum graciflorum. Lonicera japonica* produced whorled spikes. Racemes were found in *Otacanthus caeruleus and Odontonema cuspidatum.*

Shrubs observed for their fragrant flowers. Few shrubs produced fragrant flowers. Shrubs like *Bauhinia acuminate, Thevetia peruviana, Murraya paniculata, Tabernaemontana coronaria, and Lonicera japonica* were observed for their fragrant flowers. The flower qualitative characters observed are given in Table 25.

4.4 LANDSCAPING DESIGN COMPONENTS

The major design components of a landscape garden are form (silhouette), texture and colour. The shrubs were grouped according to their silhouette, leaf texture and flower colour.

4.4.1 Classification based on silhouette

Different canopy silhouettes were observed for the ornamental shrubs, they were under study. Columnar, upright, loose upright, open, vase, globular, arching, spreading, compact and clumping types of silhouette forms were observed.

Allamanda cathartica and *A.violacea* showed vase shaped canopy form, with little support. Their branching form is weeping. Open silhouette form was most common, as observed in *Bauhinia acuminata, Thevetia peruviana, Ixora coccinea, Allamanda cathartica* 'Dwarf', *Brunfelsia latifolia,* and *Otacanthus caeruleus.* Shrubs with ascending branching pattern showed open canopy form. Shrubs with upright branching habit formed dense upright or loose upright canopy form. Loose upright

Allamanda cathartica Height= 261.2 cm Spread=185.8 cm  Vase	***Allamanda violacea*** Height = 254.2 cm Spread = cm  Vase	***Bauhinia acuminata*** Height =241.7 cm Spread =148.6cm  Open
Calliandra haematocephala Height =319.4 cm Spread =269.7 cm  Wide oval	***Hamelia patens*** Height =248.6 cm Spread =185.1 cm  Arching	***Mussaenda erythrophylla*** Height =291.7 cm Spread =248.3 cm  Arching
Nerium indicum Height =254.1 cm Spread =79.9 cm  Loose upright	***Pereskia bleo*** Height = 239.8 cm Spread = 86.4 cm  Loose upright	***Thevetia peruviana*** Height =259.8 cm Spread =202.8 cm  Open
Allamanda neriifolia Height =152.9 cm Spread =138.9 cm  Arching	***Clerodendrum macrosiphon*** Height = 153.1 cm Spread =129.8 cm  Round	***Ixora chinensis*** Height = 122.8 cm Spread = 45.5 cm  Loose upright

Plate 5. Shrub silhouettes - I

Ixora coccinea Height =152.7 cm Spread =145.0 cm  Open	***Kopsia fruticosa*** Height =164.9 cm Spread = 118.1 cm  Round	***Murraya paniculata*** Height =178.5 cm Spread = 126.7 cm  Oval
Pseuderanthemum reticulatum Height =131.9 cm Spread =46.2 cm  Loose upright	***Rondeletia odorata*** Height =137.6 cm Spread =89.0 cm  Dense upright	***Tabernaemontana coronaria*** Height =146.6 cm Spread =104.3 cm  Round
Tecomaria capensis Height =127.8 cm Spread =101.8 cm  Open	***Allamanda cathartica* 'Dwarf'** Height =80.4 cm Spread =58.5 cm  Open	***Brunfelsia latifolia*** Height =86.5 cm Spread =56.8 cm  Open
Ixora rosea Height =94.7 cm Spread =72.3 cm  Columnar	***Lonicera japonica*** Height =49.9 cm Spread =73.1 cm  Creeping	***Odontonema cuspidatum*** Height =83.2 cm Spread =46.0 cm  Loose upright
Otacanthus caeruleus Height =81.0 cm Spread =50.5 cm  Open	***Pseuderanthemum graciflorum*** Height =81.6 cm Spread =58.5 cm  Spreading	***Russelia juncea*** Height =86.4 cm Spread =83.0 cm  Cascading
***Tabernaemontana coronaria* 'Nana'** Height =71.3 cm Spread =53.7 cm  Compact	***Tabernaemontana coronaria* 'Variegata'** Height =80.6 cm Spread =68.7 cm  Arching	***Wrightia antidysenterica*** Height =94.7 cm Spread =43.4 cm  Loose upright

Plate. 6. Shrub silhouettes - II

Table 26. Plant textural classification based on leaf area

Leaf texture group	Tall shrub	Medium shrub	Dwarf shrub
Coarse (more than 100 cm^2)	----	----	----
Medium coarse (60-100 cm^2)	*Bauhinia acuminata* *Mussaenda erythrophylla*	*Ixora coccinea* *Kopsia fruticosa*	----
Medium (20-60 cm^2)	*Allamanda cathartica* *A. violacea* *Nerium indicum* *Pereskia bleo*	*Tabernaemontana coronaria* *Ixora chinensis* *Pseuderanthemum reticulatum*	*Ixora rosea* *Odontonema cuspidatum* *Pseuderanthemum graciflorum*
Medium fine (10-20 cm^2)	*Thevetia peruviana* *Hamelia patens* *Calliandra haematocephala*	*Clerodendrum macrosiphon*	*Brunfelsia latifolia* *Otacanthus caeruleus* *Tabernaemontana coronaria* 'Variegata' *Wrightia antidysenterica*
Fine (less than 10 cm^2)	----	*Allamanda neriifolia* *Murraya paniculata* *Rondeletia odorata* *Tecomaria capensis*	*Russelia juncea* *Allamanda cathartica* 'Dwarf' *Lonicera japonica* *Tabernaemontana coronaria* 'Nana'

Shrubs under different textural category are given in Table 26.

4.4.3 Classification of shrubs based on flower colour

All the three categories of colour, i.e. warm, cool and neutral colours were observed. Shrubs with warm colours were *Allamanda cathartica*, , *A. cathartica 'Dwarf'*, *Allamanda neriifolia*, *Calliandra haematocephala*, *Hamelia patens*, *Ixora coccinea*, *I.chinensis*, *I. rosea*, *Nerium indicum*, *Odontonema cuspidatum* , *Pereskia bleo*, *Rondeletia odorata*, , *Russelia juncea*,*Thevetia peruviana*, and *Tecomaria capensis*.

Cool coloured flowers are produced by *Allamanda violacea*, *Pseuderanthemum reticulatum*, *Brunfelsia latifolia*, *Otacanthus caeruleus* and *Pseuderanthemum graciflorum*.

Neutral colour (white) flowers are produced by *Bauhinia acuminata*, *Murraya paniculata*, *Clerodendrum macrosiphon*, *Lonicera japonica*, *Tabernaemontana coronaria*, *T. coronaria* 'Nana' and *T.coronaria* 'Variegata'. Shrubs like *Lonicera japonica* and *Brunfelsia latifolia* showed colour change in consecutive days. The flower colours of different shrubs given in Table 27.

4.5 ATTRACTION TO BUTTERFLIES

Shrubs were observed for attraction to butterflies. Butterflies were more often visited shrubs like *Hamelia patens*, *Kopsia fruticosa*, *Ixora chinensis*, *I coccinea*, *I. rosea* and *Odontonema cuspidatum*. These shrubs produced flowers year round. Shrubs like *Calliandra haematocephala*, *Clerodendrum macrosiphon* and *Murraya paniculata* produced flowers profusely during their blooming periods and attracted more butterflies.

More number of butterflies observed between 10.00 A.M. and 11.00 A.M. Commonly observed butterflies were *Atrophaneura aristolochiae* (common rose),

Table 27. Classification of shrubs based on flower colour

	Warm colours	Cool colours	Neutral colours
Tall	*Allamanda cathartica* (yellow) *Calliandra haematocephala* (pinkish red) *Hamelia patens* (orange red) *Mussaenda erythrophylla* (Pink) *Nerium indicum* (pink) *Pereskia bleo* (orange red) *Thevetia peruviana* (apricot yellow)	*Allamanda violacea* (purple)	*Bauhinia acuminata* (white)
Medium	*Allamanda neriifolia* (yellow) *Ixora coccinea* (scarlet red) *I. chinensis* (orange red- salmon red) *Rondeletia odorata* (orange red with yellow throat) *Tecomaria capensis*(yellow)	*Pseuderanthemum reticulatum* (white with purple spot at throat)	*Murraya paniculata*(white) *Tabernaemontana coronaria* (white) *Clerodendrum macrosiphon* (white)
Dwarf	*Allamanda cathartica* 'Dwarf' (yellow) *Ixora rosea* (pink) *Odontonema cuspidatum* (red) *Russelia juncea* (red)	*Brunfelsia latifolia* (blue-light violet-white) *Otacanthus caeruleus* (blue flowers with white 'eye' marking) *Pseuderanthemum graciflorum* (light violet)	*Lonicera japonica* (white) *Tabernaemontana coronaria* 'Nana' (white) *T.coronaria* 'Variegata' (white)

Catopsilia pyranthe (mottled emigrant), *Danaus genutia, Delias eucharis* (common jezbel), *Eurema hecabe* (common grass yellow), *Hypolimnas misippus* (danaid eggfly), *Moduza procris* (commander), *Papilio polytes, P. demoleus, P. budha* (Peacock) and *Parantica aglea* (glassy tiger).

Butterfly caterpillar was observed on leaves of *Mussaenda erythrophylla* (commander butterfly), *Pseuderanthemum reticulatum* (milk weed butterfly) and *Nerium indicum* (danaid egg fly). These plants also helps to attract butterflies.

4.6 FLOWERING PHENOLOGY

4.6.1 Intensity of flowering

Flowering was observed every week, for whole the year and peak blooming seasons of the different shrubs were identified. The monthly variations in flowering intensity were also recorded. The flowering intensity was computed by counting total number of inflorescence produced by a plant a month and expressed as percentage of total inflorescence produced by the plant the whole year.

In the observed tall shrubs *Hamelia patens* showed flowering throughout the year continuously. *Nerium indicum* , *Allamanda cathartica* and *Allamanda violacea* also showed year round flowering, with irregularity in profuseness. *Bauhinia acuminata* produced flowers only in dry months. The flowering intensity of tall shrubs is given in Table 28 and Fig.13 & 14.

In the intermediate category, *Ixora coccinea* shown almost year round blooming, with little irregularity in flowering. *Ixora chinensis* showed profuse flowering from July- Dec. *Kopsia fruticosa* also produced flowers year round with lesser blooms in the rainy months. The flowering phenology of intermediate shrubs is given in Table 29 and Fig.15 & 16.

Table 28. Flowering intensity of Tall shrubs (Percentage of total flowering)

No.	Shrub	Flowering intensity (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Allamanda cathartica*	6.9	5.0	1.3	14.1	17.6	15.4	4.7	5.6	6.9	5.6	10.3	6.6
2	*Allamanda violacea*	5.8	4.3	1.8	6.5	7.2	10.1	7.9	18.8	17.3	10.1	4.3	5.8
3	*Bauhinia acuminata*	0.0	10.7	16.0	18.3	14.5	12.2	0.0	3.1	10.7	7.6	3.8	3.1
4	*Calliandra haematocephala*	21.3	12.9	9.6	0.0	0.0	0.0	0.0	4.8	11.2	12.0	14.1	14.1
5	*Hamelia patens*	7.3	8.8	9.3	6.9	8.0	11.7	8.8	8.0	6.2	8.0	6.9	10.1
6	*Mussaenda erythrophylla*	2.5	0.4	2.2	11.6	10.8	14.3	15.6	14.3	9.3	2.2	6.8	10.0
7	*Nerium indicum*	1.4	5.7	7.1	10.0	21.4	5.7	7.1	4.3	5.7	2.9	7.1	21.4
8	*Pereskia bleo*	15.1	30.2	6.6	12.3	11.3	6.6	0.0	3.8	3.8	10.4	0.0	0.0
9	*Thevetia peruviana*	5.7	12.5	20.8	12.5	10.4	5.7	0.0	3.1	2.1	3.1	5.7	18.2

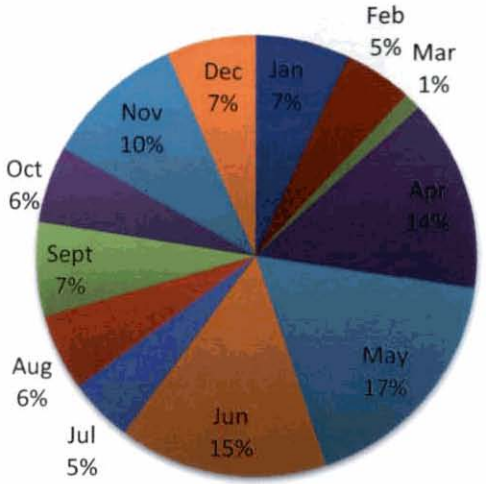
Table 29. Flowering intensity of Medium shrubs (Percentage of total flowering)

No.	Shrub	Flowering intensity (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Allamanda nerifolia*	5.8	0.0	10.8	12.9	15.1	6.5	2.2	23.0	7.2	4.3	5.8	6.5
2	*Clerodendrum macrosiphon*	0.0	0.0	1.5	7.3	12.6	23.4	0.0	23.1	12.6	3.5	2.0	14.1
3	*Ixora chinensis*	9.3	2.3	2.3	3.5	4.7	4.7	4.7	11.6	12.8	8.1	9.3	26.7
4	*Ixora coccinea*	10.1	7.7	6.7	3.8	5.8	6.7	10.6	21.2	6.3	3.8	5.8	11.5
5	*Kopsia fruticosa*	11.0	12.9	8.8	12.4	8.3	7.7	3.3	2.2	1.1	11.0	8.3	12.9
6	*Murraya paniculata*	11.0	0.0	0.0	14.9	16.7	12.8	0.0	11.8	3.9	12.8	2.4	13.8
7	*Pseuderanthemum reticulatum*	2.8	0.0	11.3	8.5	22.5	4.2	0.0	5.6	8.5	22.5	8.5	5.6
8	*Rondeletia odorata*	3.1	1.2	0.0	18.6	23.0	13.7	0.0	8.1	9.9	9.3	10.6	2.5
9	*Tabernaemontana coronaria*	15.9	7.3	25.6	3.7	14.6	7.3	0.0	4.9	0.0	9.8	7.3	3.7
10	*Tecomaria capensis*	16.3	10.6	4.9	18.3	3.3	1.2	0.8	0.0	8.9	5.7	6.5	23.6

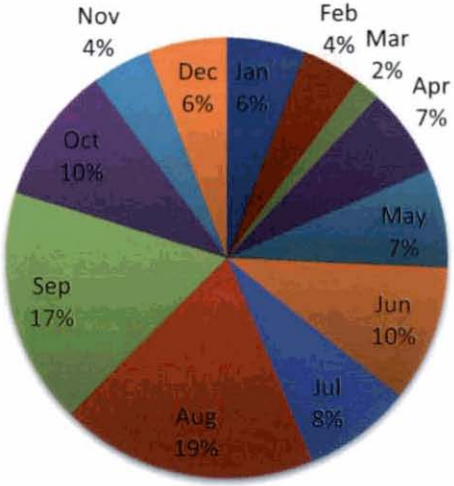
Table 30. Flowering intensity of Dwarf shrubs (Percentage of total flowering)

No.	Shrub	Flowering intensity (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Allamanda cathartica* 'Dwarf'	12.1	8.4	7.9	9.8	15.6	12.7	11.9	7.9	4.0	10.0	6.6	7.9
2	*Brunfelsia latifolia*	0.0	3.8	5.7	15.1	11.3	3.8	0.0	19.8	14.2	15.1	7.5	3.8
3	*Ixora rosea*	3.3	5.0	3.3	3.3	5.0	5.0	9.1	5.8	6.6	11.6	30.6	11.6
4	*Lonicera japonica*	3.1	21.5	6.2	21.5	12.3	0.0	18.5	9.2	4.6	0.0	0.0	3.1
5	*Odontonema cuspidatum*	15.3	11.1	11.1	5.6	6.9	5.6	2.8	4.2	4.2	5.6	8.3	19.4
6	*Otacanthus caeruleus*	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
7	*Pseuderanthemum graciflorum*	16.6	6.2	7.8	13.5	19.7	6.2	0.0	0.0	3.6	5.2	0.0	21.2
8	*Russelia juncea*	9.9	8.4	8.9	10.9	11.9	5.9	3.5	0.0	5.9	13.9	11.9	8.9
9	*Tabernaemontana coronaria* 'Nana'	3.8	3.0	18.2	15.9	4.5	5.7	0.0	12.1	4.5	15.2	11.4	5.7
10	*T.coronaria* 'Variegata'	6.3	4.7	5.2	12.5	6.3	4.2	2.1	16.7	25.0	8.3	4.7	4.2
11	*Wrightia antidysenterica*	5.8	15.0	20.0	3.3	4.2	6.7	3.3	6.7	5.0	12.5	15.0	2.5

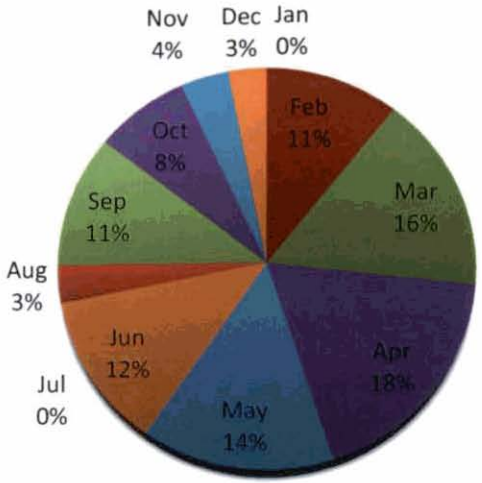
a. Allamanda cathartica



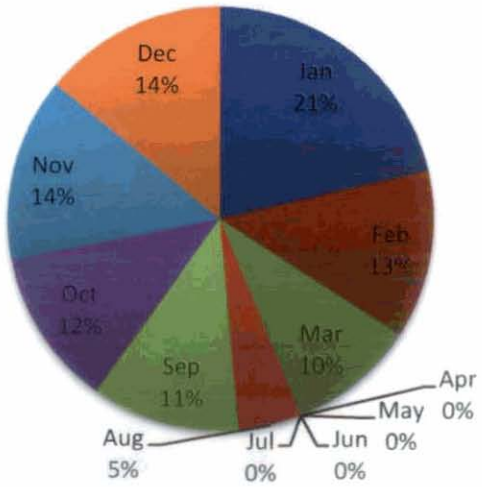
b. Allamanda violacea



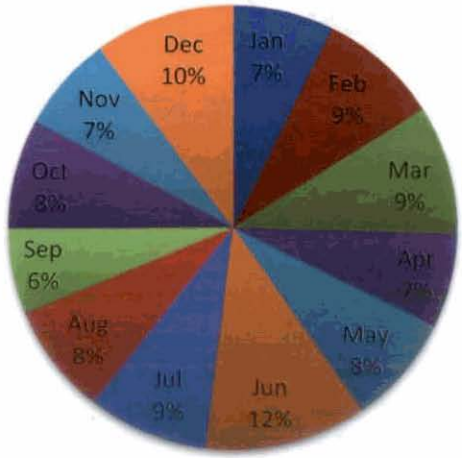
c. Bauhinia acuminata



d. Calliandra haematocephala



e. Hamelia patens



f. Mussaenda erythrophylla

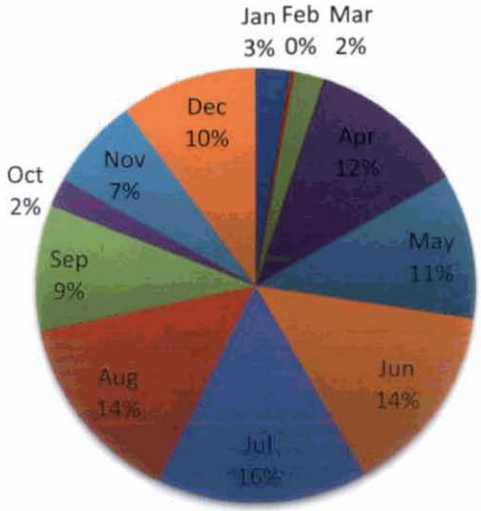


Fig.13. Blooming percentage (Tall shrubs)-I

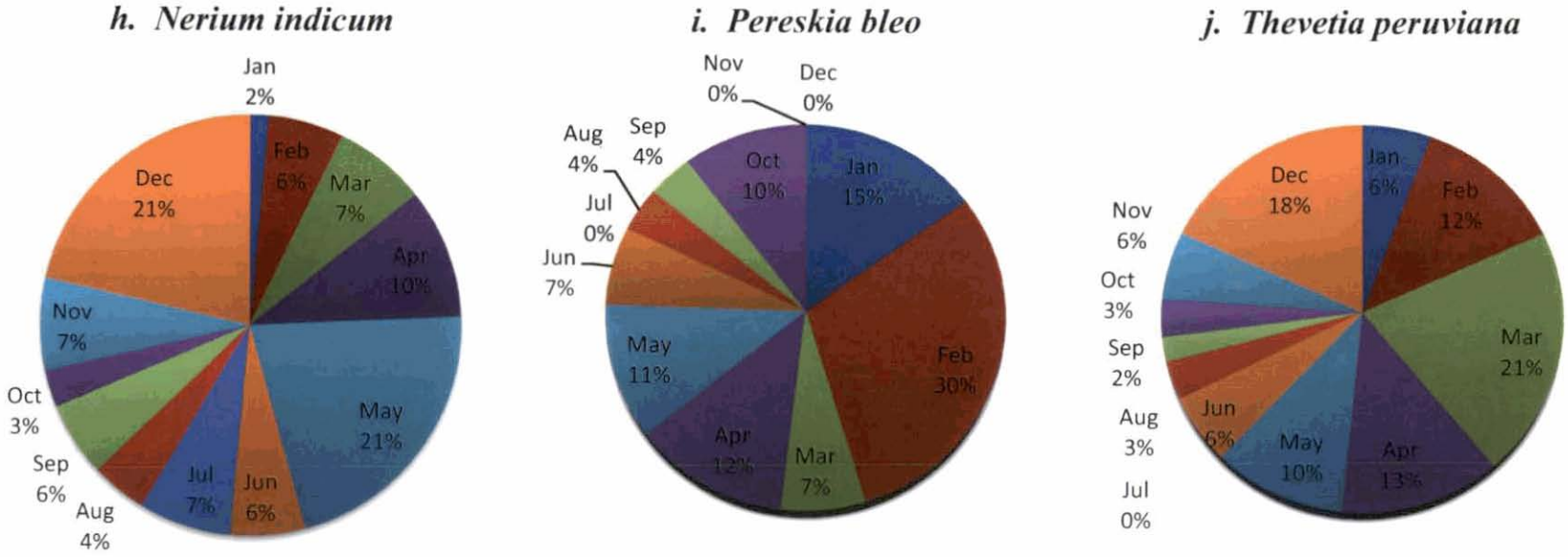
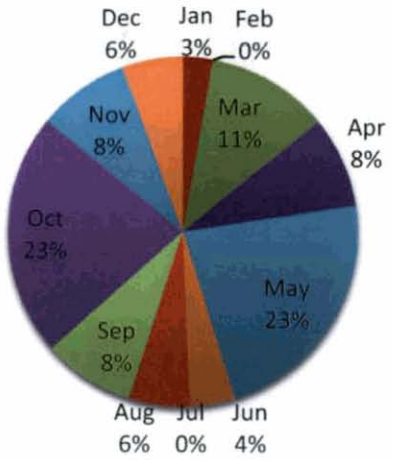
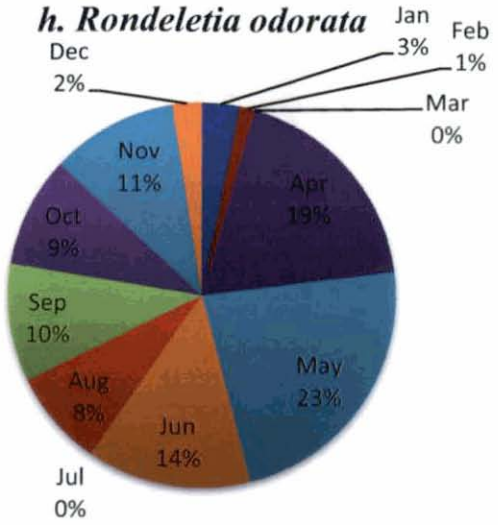


Fig. 14. Blooming percentage (Tall shrubs)-II

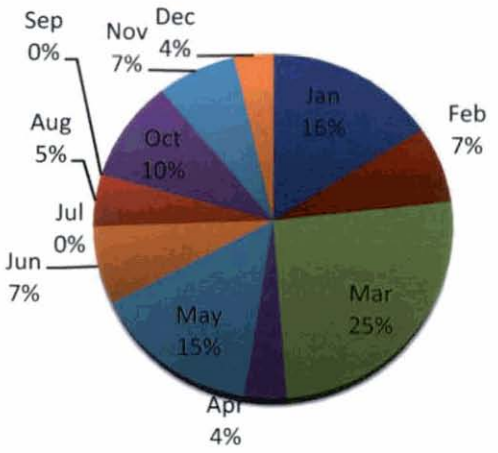
g. Pseuderanthemum reticulatum



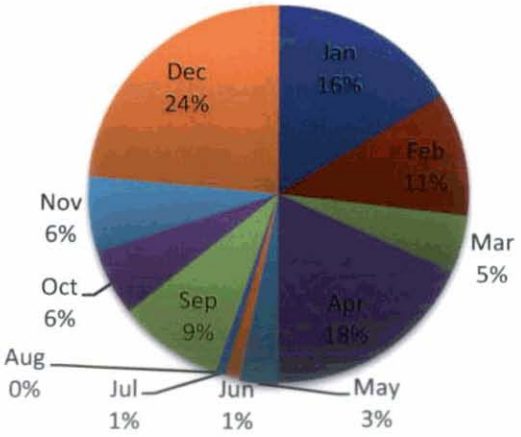
h. Rondeletia odorata



i. Tabernaemontana coronaria

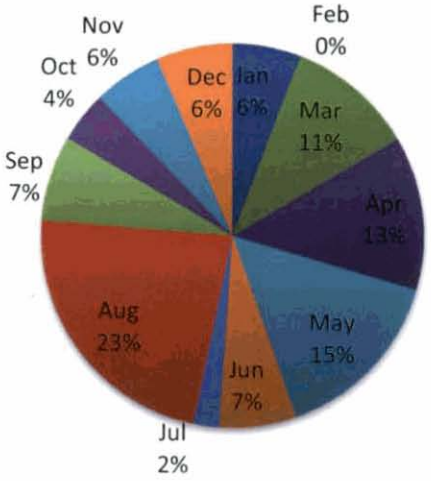


j. Tecomaria capensis

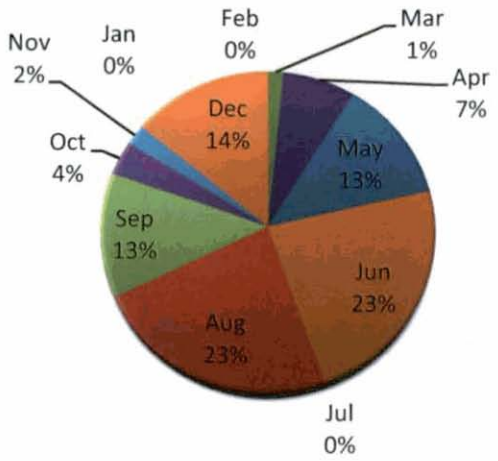


Blooming percentage (Medium shrubs)-II

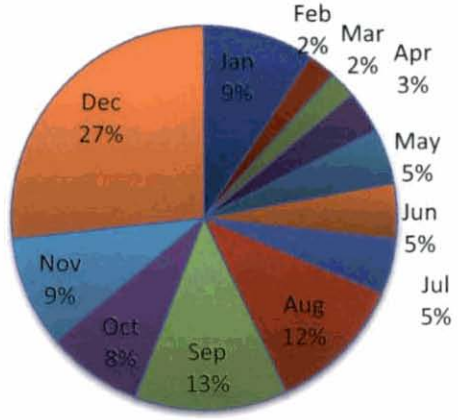
a. Allamanda neriifolia



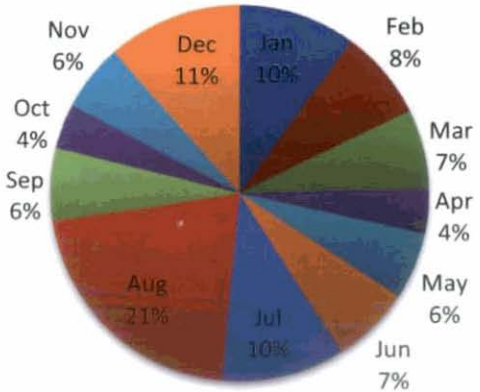
b. Clerodendrum macrosiphon



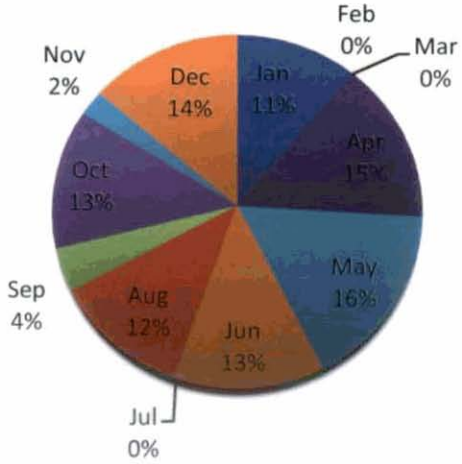
c. Ixora chinensis



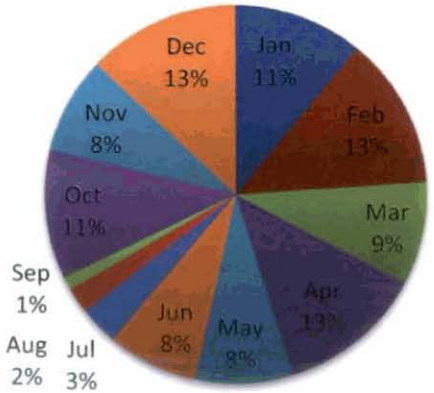
d. Ixora coccinea



e. Murraya paniculata

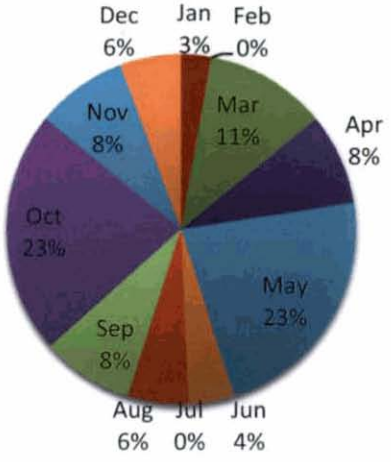


f. Kopsia fruticosa

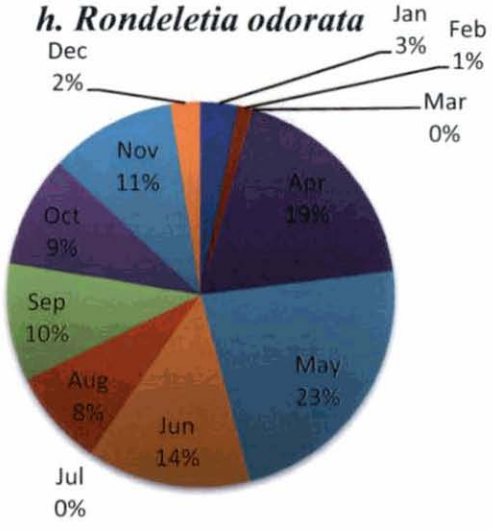


ooming percentage (Medium shrubs)-I

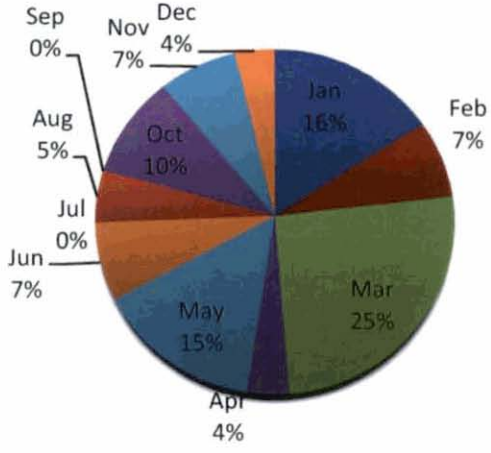
g. *Pseuderanthemum reticulatum*



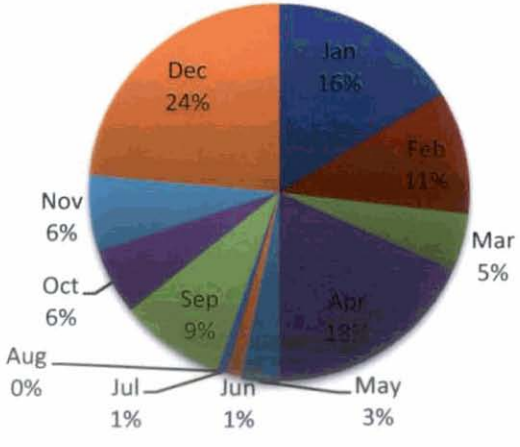
h. *Rondeletia odorata*



i. *Tabernaemontana coronaria*

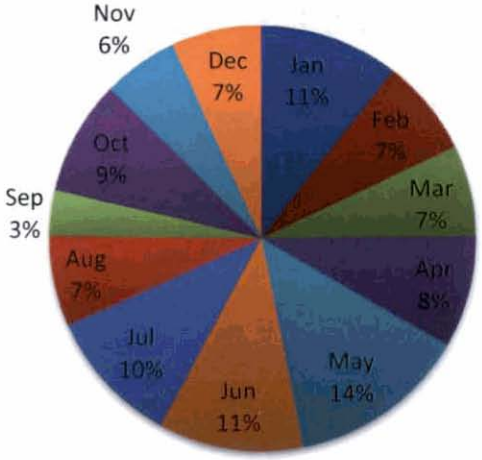


j. *Tecomaria capensis*

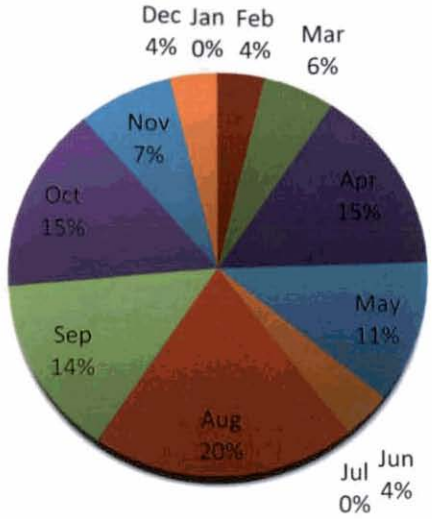


Blooming percentage (Medium shrubs)-II

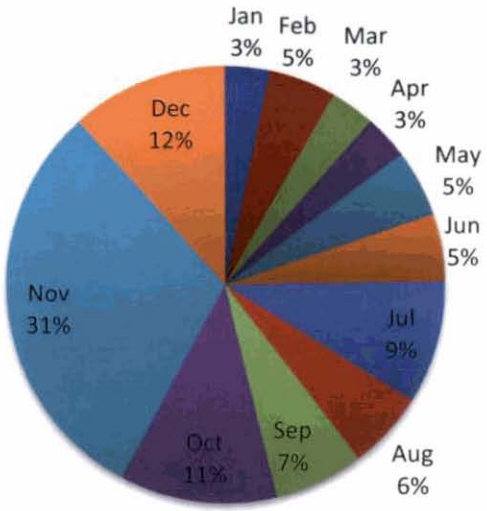
a. Allamanda cathartica 'Dwarf'



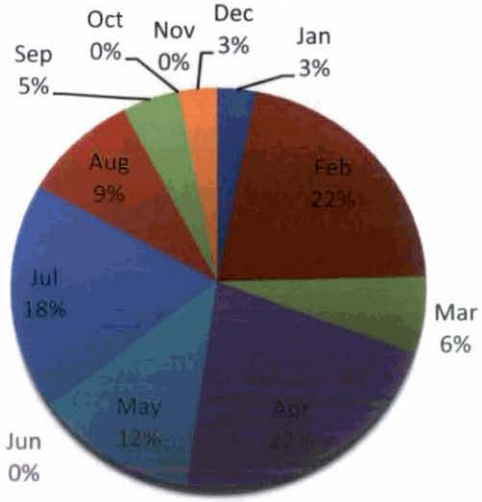
b. Brunfelsia latifolia



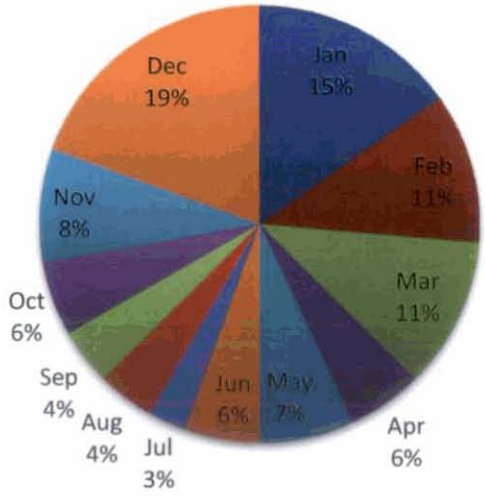
c. Ixora rosea



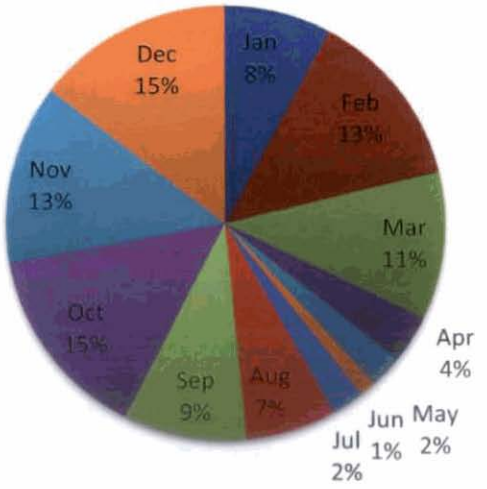
d. Lonicera japonica



e. Odontonema cuspidatum

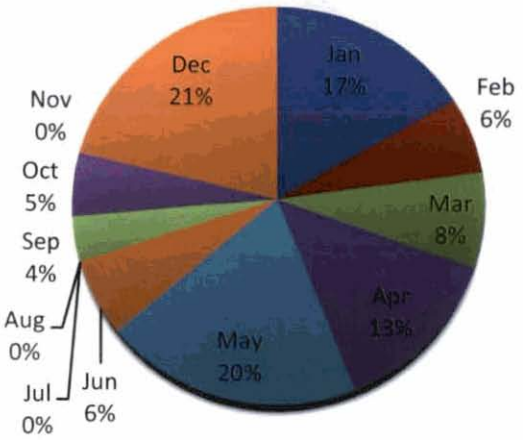


f. Otacanthus caeruleus

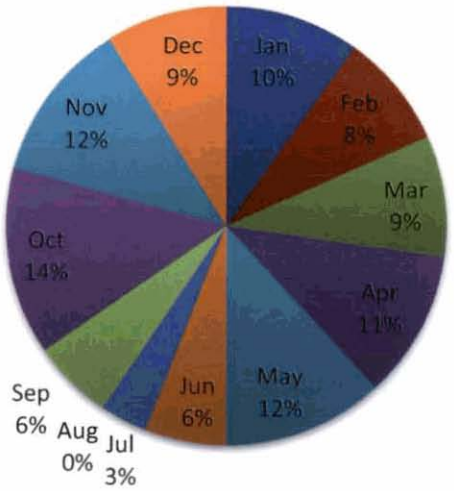


g. 17. Blooming percentage (Dwarf shrubs)-I

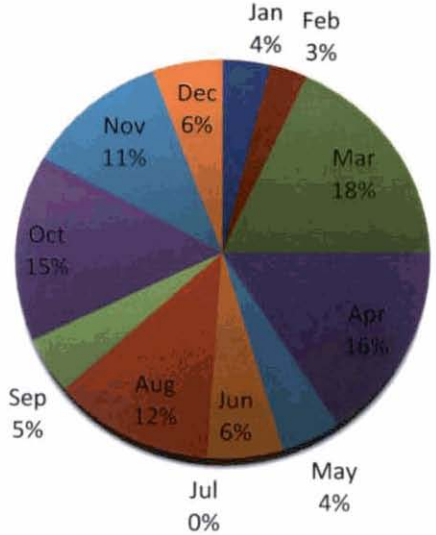
g. Pseuderanthemum graciflorum



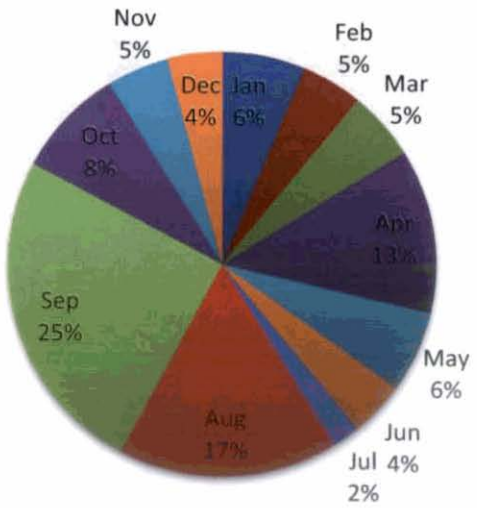
h. Russelia juncea



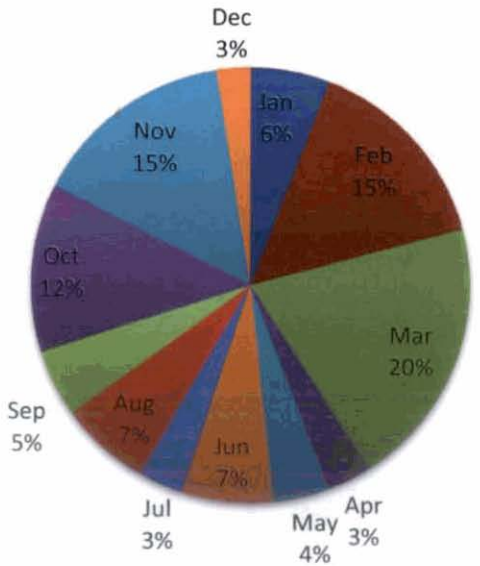
***i. Tabernaemontana coronaria* 'Nana'**



***j. Tabernaemontana coronaria* 'Variegata'**



h. Wrightia antidysenterica



. 18. Blooming percentage (Dwarf shrubs)-II

Among the observed small group shrubs, *Odontonema cuspidatum* and *Russelia juncea* showed year round blooming with a few bloom free periods. *Wrightia antidysenterica* also showed year round blooming, but irregularity was there. *Ixora rosea* flowered well in the rainy months. The flowering phenology of small shrubs is given in Table 30 and Fig.17 & 18.

4.6.2 Configuration of phenologiacal groups of shrubs

Shrubs were observed for their visually attractive phenophases, i.e. full blooming and categorized them accordingly. All 30 shrubs were observed for their flowering phenology. Shrubs varied in their blooming time and periodicity. The mean value of total flowers produced in all replications was calculated each month and expressed as percentage of the maximum flower production (Tables 31-33). Months with values below 25 were considered as non flowering. When a shrub reached at least 25 % of its full bloom, it was considered to be at its phenophase. Four phenophases i.e. Dec-Feb, March-May, June-Aug. and Sept-Nov, were recorded and shrubs were categorized to respective phenophases based on observations made on the blooming.

Different combinations of plants (side-runs) which behaved identically in a particular time point were found out. The combinations could be used in shrub border at different layers to get year round blooming. The configurations of phenological groups of shrubs are given in Table 34.

In a single phenologial phase different colour combinations were also observed. Plants having contrasting colours or augmenting colours can be grouped together for best visual appeal. Group planting can also be done with plants having warm colours or plants with cool colours, by analyzing their phenophase.

Table 31. Flowering phenology of Tall shrubs (percentage of maximum flowering)

No.	Shrub	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Allamanda cathartica*	39.3	28.6	7.1	80.4	100.0	87.5	26.8	32.1	39.3	32.1	58.9	37.5
2	*Allamanda violacea*	30.8	23.1	9.6	34.6	38.5	53.8	42.3	100.0	92.3	53.8	23.1	30.8
3	*Bauhinia acuminata*	0.0	58.3	87.5	100.0	79.2	66.7	0.0	16.7	58.3	41.7	20.8	16.7
4	*Calliandra haematocephala*	100.0	60.4	45.3	0.0	0.0	0.0	0.0	22.6	52.8	56.6	66.0	66.0
5	*Hamelia patens*	62.5	75.0	80.0	58.8	68.8	100.0	75.0	68.8	53.1	68.8	59.4	86.9
6	*Mussaenda erythrophylla*	16.1	2.3	13.8	74.7	69.0	92.0	100.0	92.0	59.8	13.8	43.7	64.4
7	*Nerium indicum*	6.7	26.7	33.3	46.7	100.0	26.7	33.3	20.0	26.7	13.3	33.3	100.0
8	*Pereskia bleo*	50.0	100.0	21.9	40.6	37.5	21.9	0.0	12.5	12.5	34.4	0.0	0.0
9	*Thevetia peruviana*	27.5	60.0	100.0	60.0	50.0	27.5	0.0	15.0	10.0	15.0	27.5	87.5

Table 32. Flowering phenology of Medium shrubs (percentage of maximum flowering)

No.	Shrub	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Allamanda neriifolia*	25.0	0.0	46.9	56.3	65.6	28.1	9.4	100.0	31.3	18.8	25.0	28.1
2	*Clerodendrum macrosiphon*	0.0	0.0	6.5	31.2	53.8	100.0	0.0	98.9	53.8	15.1	8.6	60.2
3	*Ixora chinensis*	34.8	8.7	8.7	13.0	17.4	17.4	17.4	43.5	47.8	30.4	34.8	100.0
4	*Ixora coccinea*	47.7	36.4	31.8	18.2	27.3	31.8	50.0	100.0	29.5	18.2	27.3	54.5
5	*Kopsia fruticosa*	85.1	100.0	68.1	95.7	63.8	59.6	25.5	17.0	8.5	85.1	63.8	100.0
6	*Murraya paniculata*	65.9	0.0	0.0	89.4	100.0	76.5	0.0	70.6	23.5	76.5	14.1	82.4
7	*Pseuderanthemum reticulatum*	12.5	0.0	50.0	37.5	100.0	18.8	0.0	25.0	37.5	100.0	37.5	25.0
8	*Rondeletia odorata*	13.5	5.4	0.0	81.1	100.0	59.5	0.0	35.1	43.2	40.5	45.9	10.8
9	*Tabernaemontana coronaria*	61.9	28.6	100.0	14.3	57.1	28.6	0.0	19.0	0.0	38.1	28.6	14.3
10	*Tecomaria capensis*	69.0	44.8	20.7	77.6	13.8	5.2	3.4	0.0	37.9	24.1	27.6	100.0

Table 33. Flowering phenology of Dwarf shrubs (percentage of maximum flowering)

No.	Shrub	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Allamanda cathartica* 'Dwarf'	78.0	54.2	50.8	62.7	100.0	81.4	76.3	50.8	25.4	64.4	42.4	50.8
2	*Brunfelsia latifolia*	0.0	19.0	28.6	76.2	57.1	19.0	0.0	100.0	71.4	76.2	38.1	19.0
3	*Ixora rosea*	10.8	16.2	10.8	10.8	16.2	16.2	29.7	18.9	21.6	37.8	100.0	37.8
4	*Lonicera japonica*	14.3	100.0	28.6	100.0	57.1	0.0	85.7	42.9	21.4	0.0	0.0	14.3
5	*Odontonema cuspidatum*	78.6	57.1	57.1	28.6	35.7	28.6	14.3	21.4	21.4	28.6	42.9	100.
6	*Otacanthus caeruleus*	54.2	91.7	75.0	25.0	16.7	8.3	16.7	45.8	62.5	100.0	91.7	100.
7	*Pseuderanthemum graciflorum*	78.0	29.3	36.6	63.4	92.7	29.3	0.0	0.0	17.1	24.4	0.0	100.
8	*Russelia juncea*	71.4	60.7	64.3	78.6	85.7	42.9	25.0	0.0	42.9	100.0	85.7	64.3
9	*Tabernaemontana coronaria* 'Nana'	20.8	16.7	100.0	87.5	25.0	31.3	0.0	66.7	25.0	83.3	62.5	31.3
10	*T. coronaria* 'Variegata'	25.0	18.8	20.8	50.0	25.0	16.7	8.3	66.7	100.0	33.3	18.8	16.7
11	*Wrightia antidysenterica*	29.2	75.0	100.0	16.7	20.8	33.3	16.7	33.3	25.0	62.5	75.0	12.5

Table 34. Configuration of phenologiacal groups of shrubs.

Pheno phase	Side-runs		
	Tall shrubs	**Medium shrubs**	**Dwarf shrubs**
December January February	*Allamanda cathartica* *Allamanda violacea* *Calliandra haematocephala* *Hamelia patens* *Nerium indicum* *Thevetia peruviana*	*Allamanda neriifolia* *Ixora chinensis* *Ixora coccinea* *Kopsia fruticosa* *Murraya paniculata* *Tabernaemontana coronaria* *Tecomaria capensis*	*Allamanda cathartica* 'Dwarf' *Ixora rosea* *Odontonema cuspidatum* *Otacanthus caeruleus* *Pseuderanthemum graciflorum* *Russelia juncea* *Wrightia antidysenterica*
March April May	*Allamanda cathartica* *Allamanda violacea* *Bauhinia acuminata* *Calliandra haematocephala* *Hamelia patens Mussaenda erythrophylla* *Nerium indicum* *Pereskia bleo* *Thevetia peruviana*	*Allamanda neriifolia* *Clerodendrum macrosiphon* *Ixora coccinea* *Kopsia fruticosa* *Murraya paniculata* *Pseuderanthemum reticulatum* *Rondeletia odorata* *Tabernaemontana coronaria*	*Allamanda cathartica* 'Dwarf' *Brunfelsia latifolia* *Ixora rosea* *Lonicera japonica* *Odontonema cuspidatum* *Otacanthus caeruleus* *Pseuderanthemum graciflorum* *Russelia juncea* *Tabernaemontana coronaria* 'Nana' *T. coronaria* 'Variegata' *Wrightia antidysenterica*
June July August	*Allamanda cathartica* *Allamanda violacea* *Bauhinia acuminata* *Hamelia patens* *Mussaenda erythrophylla* *Nerium indicum*	*Allamanda neriifolia* *Clerodendrum macrosiphon* *Ixora coccinea* *Kopsia fruticosa* *Murraya paniculata* *Rondeletia odorata*	*Allamanda cathartica* 'Dwarf' *Russelia juncea* *Tabernaemontana coronaria* 'Nana' *Wrightia antidysenterica*
September October November	*Allamanda cathartica* *Allamanda violacea* *Bauhinia acuminata* *Calliandra haematocephala* *Hamelia patens* *Mussaenda erythrophylla* *Nerium indicum*	*Allamanda nerifolia* *Ixora chinensis* *Ixora coccinea* *Kopsia fruticosa* *Pseuderanthemum reticulatum* *Rondeletia odorata* *Tabernaemontana coronaria* *Tecomaria capensis*	*Allamanda cathartica* 'Dwarf' *Brunfelsia latifolia* *Ixora rosea* *Odontonema cuspidatum* *Otacanthus caeruleus* *Russelia juncea* *Tabernaemontana coronaria* 'Nana' *T. coronaria* 'Variegata' *Wrightia antidysenterica*

4.7 POLLUTION CONTROL

4.7.1 Dust pollution control

Under the observed shrubs, different plants possessed hairy or rough leaf surface. These plants can be used for areas where more dust pollution problems are there. Along with leaf surface texture, leaf area and number of leaves per unit area also important in dust control. More leaf surface area and leaf number helps in reducing dust pollutants. *Allamanda violacea* produced leaves with hairy surface and having a leaf area of 58.2 cm^2 and 41 leaves per 1000 cm^2. *Mussaenda erythrophylla* also showed leaves with hairy surface (Area-62.27 cm^2 and number 36/ 1000cm^2). *Rondeletia odorata* showed leaves with rough scabrous and rugous surface (Area-8 cm^2 and number 90.6/ 1000cm^2). *Otacanthus caeruleus* also showed little hairs on the succulent leaf surface.

4.7.2 Air Pollution Tolerance Index value

APTI values of 30 tropical ornamental flowering shrubs were estimated to find out their relative tolerance to air pollution. Tolerance index of shrubs and the ability to remove volatile organic compounds studied for using them as pollution indicators or for controlling pollution in the outdoor environment. Plants with high index value were tolerant to air pollution and *vice-versa*. On the basis of their indices, different plants were categorized into sensitive, intermediate, moderately tolerant, and tolerant classes (Table 39).

Shrubs like *Calliandra haematocephala* and *Clerodendrum macrosiphon* were tolerant and *Hamelia patens* and *Pereskia bleo* were sensitive to air pollution. Shrubs like *Allamanda cathartica, Tabernaemontana coronaria* and *Pseuderanthemum reticulatum* comes under intermediate category and plants like *Murraya exotica, Nerium indicum* and *Tecomaria capensis* comes under moderately tolerant category.

APTI values of 30 ornamental flowering shrubs were estimated to find out their relative tolerance to air pollution.

4.7.2.1. Tall shrubs

Among the tall shrubs, *Calliandra haematocephala* showed the maximum leaf Ascorbic acid content (26.54 mg/g) and the minimum observed in *Hamelia patens* (1.19 mg/g). Leaf chlorophyll content was also the maximum in *Calliandra haematocephala* (2.74 mg/g) and the minimum leaf chlorophyll content was observed in *Allamanda cathartica* (1.12 mg/g). Relative water content among the tall shrubs, was the highest for *Hamelia patens* (87.47 %) and the lowest observed for *Bauhinia accuminata* (69.19 %). The leaf pH was highest for *Bauhinia acuminata* (7.26) and the minimum for *Hamelia patens* (5.16). APTI value was the maximum for *Calliandra haematocephala* (31.77) and the minimum for *Hamelia patens* (9.48). The APTI value and its components are given in Table 35, Fig. 19.

4.7.2.2. Medium shrubs

Among the intermediate shrubs, *Ixora chinensis* showed the maximum leaf ascorbic acid content (25.94 mg/g) and the minimum value was observed in *Pseuderanthemum reticulatum* leaves (5.74 mg/g). Chlorophyll content was the highest in *Clerodendrum macrosiphon* (2.4 mg/g) and the minimum in *Pseuderanthemum reticulatum* (0.96 mg/g). Relative leaf water content was the highest for *Kopsia fruticosa* (89.09 %) and the lowest for *Tabernemontana coronaria* (80.56 %). pH value was the maximum in *Tabernemontana coronaria* (7.01) and the lowest for *Ixora chinensis* (4.8). APTI value was the maximum for *Clerodendrum macrosiphon* (25.94) and the minimum for *Pseuderanthemum reticulatum* (5.74). The APTI value and its components are given in Table 36, Fig. 20.

4.7.2.3. Dwarf shrubs

In the dwarf shrubs, leaf ascorbic acid content was found to the highest *in Ixora rosea* (24.04 mg/g) and the lowest in *Allamanda cathartica* 'Dwarf' (1.54 mg/g). Chlorophyll content was the maximum in *Wrightia antidysenterica* (1.61 mg/g) and the minimum in *Otacanthus caeruleus* (1.114 mg/g). Relative leaf water content was the highest for *Otacanthus caeruleus* (89.51 %) and the lowest for *Allamanda cathartica* 'Dwarf' (80.99 %). The pH value was the maximum for *Odontonema cuspidatum* (7.2) and the lowest for *Tabernaemontana coronaria* 'Nana' (22.91). APTI value was the maximum for *Russelia juncea* (22.91) and the minimum for *Allamanda cathartica* 'Dwarf' (9.27). The APTI value and its components are given in Table 37, Fig. 21

Based on the obtained APTI values shrubs were classified in to four categories, *i.e.* sensitive, intermediate, moderately tolerant and tolerant (Singh *et. al.* 1989). For sensitive category APTI value is $\leq$ 14; for intermediate, the value is 15-19; for moderately tolerant, 20-24 and for tolerant group, APTI value is > 24. *Calliandra haematocephala, Mussaenda erythrophylla, Clerodendrum macrosiphon* and *Ixora coccinea* came under the tolerant category while *Hamelia patens, Pereskia bleo, Thevetia peruviana, Pseuderanthemum reticulatum, Kopsia fruticosa, Allamanda cathartica* 'Dwarf', *Odontonema cuspidatum, Tabernaemontana coronaria* 'Variegata', and *Wrightia antidysenterica* came under the sensitive category. The plant categories based on the APTI value is given in Table 39.

4.7.2.4. Transpiration rate

Transpiration rate of the shrubs varied significantly. In tall shrubs, transpiration rate varied from 2.5 mmol/sec in *Pereskia bleo* to 8.3 in *Hamelia patens*.in the medium shrubs, *Clerodendrum macrosiphon* showed the highest value for transpiration rate (9.1 mmol/sec)and *Ixora chinensis* showed the lowest (1.2 mmol/sec). In the dwarf group highest value was observed for *Allamanda cathartica*

Table 35. APTI values (Tall shrubs)

No.	Shrub	AA (mg/g)	Chl (mg/g)	RWC (%)	pH	APTI
1	*Allamanda cathartica*	10.54^{c}	1.12^{b}	74.90^{b}	6.35^{c}	15.33^{c}
2	*Allamanda violacea*	18.34^{e}	1.37^{d}	78.31^{c}	6.25^{b}	21.78^{d}
3	*Bauhinia acuminata*	17.34^{d}	1.68^{f}	69.19^{a}	7.26^{h}	22.39^{d}
4	*Calliandra haematocephala*	26.54^{g}	2.74^{i}	69.89^{a}	6.61^{e}	31.77^{f}
5	*Hamelia patens*	1.19^{a}	1.26^{c}	87.47^{d}	5.16^{a}	9.48^{a}
6	*Mussaenda erythrophylla*	20.14^{f}	1.91^{h}	85.60^{d}	6.93^{f}	26.33^{e}
7	*Nerium indicum*	9.99^{c}	0.93^{a}	83.82^{d}	6.62^{e}	15.89^{c}
8	*Pereskia bleo*	2.99^{b}	1.84^{g}	86.20^{d}	6.45^{d}	11.06^{b}
9	*Thevetia peruviana*	3.04^{b}	1.49^{e}	78.86^{c}	7.02^{g}	10.43^{b}
	CD value	0.929	0.000	3.398	0.094	0.929

Table 36. APTI values (Medium shrubs)

No.	Shrub	AA (mg/g)	Chl (mg/g)	RWC (%)	pH	APTI
1	*Allamanda nerifolia*	16.74^{e}	1.37^{c}	87.83^{d}	6.14^{d}	21.36^{e}
2	*Clerodendrum macrosiphon*	25.94^{h}	2.40^{h}	87.25^{cd}	6.34^{e}	31.42^{g}
3	*Ixora chinensis*	21.04^{f}	1.57^{f}	84.02^{abc}	4.85^{a}	21.93^{e}
4	*Ixora coccinea*	23.14^{g}	1.57^{f}	83.41^{ab}	5.85^{b}	25.52^{f}
5	*Kopsia fruticosa*	7.24^{b}	1.22^{b}	89.09^{d}	6.04^{c}	14.17^{ab}
6	*Murraya paniculata*	11.49^{c}	1.58^{f}	85.37^{bcd}	6.90^{g}	18.28^{c}
7	*Pseuderanthemum reticulatum*	5.74^{a}	0.96^{a}	82.66^{ab}	8.08^{i}	13.45^{a}
8	*Rondeletia odorata*	16.04^{e}	1.42^{d}	85.92^{bcd}	5.84^{b}	20.24^{d}
9	*Tabernaemontana coronaria*	8.04^{b}	1.52^{e}	80.56^{a}	7.01^{h}	14.91^{b}
10	*Tecomaria capensis*	13.79^{d}	1.97^{g}	81.25^{a}	6.43^{f}	19.70^{d}
	CD value	0.922	0.000	3.374	0.093	0.922

Table 37. APTI values (Dwarf shrubs)

No.	Shrub	AA (mg/g)	Chl (mg/g)	RWC (%)	pH	APTI
1	*Allamanda cathartica* 'Dwarf'	1.54^{a}	1.22^{d}	80.99^{a}	6.38^{c}	9.27^{a}
2	*Brunfelsia latifolia*	13.04^{f}	1.53^{f}	81.27^{a}	6.62^{e}	18.82^{e}
3	*Ixora rosea*	24.04^{i}	1.59^{h}	85.48^{bcd}	4.70^{a}	23.69^{g}
4	*Lonicera japonica*	13.79^{f}	1.55^{g}	86.25^{bcde}	6.37^{c}	19.55^{e}
5	*Odontonema cuspidatum*	5.24^{c}	1.40^{e}	89.44^{e}	7.75^{h}	13.73^{c}
6	*Otacanthus caeruleus*	18.29^{h}	1.11^{a}	89.51^{e}	6.52^{d}	22.91^{fg}
7	*Pseuderanthemum graciflorum*	7.79^{d}	1.60^{h}	85.22^{bcd}	7.20^{g}	15.37^{d}
8	*Russelia juncea*	17.34^{g}	1.14^{b}	86.74^{cde}	6.78^{f}	22.41^{f}
9	*Tabernaemontana coronaria* 'Nana'	9.84^{e}	1.60^{h}	87.78^{de}	5.90^{b}	16.16^{d}
10	*Tabernaemontana coronaria* 'Variegata'	6.04^{c}	1.17^{c}	83.81^{abc}	6.66^{e}	13.11^{c}
11	*Wrightia antidysenterica*	3.84^{b}	1.61^{h}	82.59^{ab}	7.20^{g}	11.64^{b}
	CD value	0.917	0.000	3.355	0.093	0.917

Table 38. Transpiration rate of shrubs

No.	Shrubs	Transpirn. mmol/sec	No.	Shrubs	Transprn. mmol/sec
	Tall shrubs		16	*Pseuderanthemum reticulatum*	3.48^{f}
1	*Allamanda cathartica*	5.29^{e}	17	*Rondeletia odorata*	4.64^{g}
2	*Allamanda violacea*	7.95^{h}	18	*Tabernaemontana coronaria*	1.46^{b}
3	*Bauhinia accuminata*	3.07^{b}	19	*Tecomaria capensis*	6.76^{i}
4	*Calliandra haematocephala*	7.44^{g}		**Dwarf shrubs**	
5	*Hamelia patens*	8.32^{i}	20	*Allamanda cathartica* 'Dwarf'	7.73^{k}
6	*Mussaenda erythrophylla*	3.29^{c}	21	*Brunfelsia latifolia*	3.13^{b}
7	*Nerium indicum*	3.48^{d}	22	*Ixora rosea*	4.57^{e}
8	*Pereskia bleo*	2.56^{a}	23	*Lonicera japonica*	6.89^{i}
9	*Thevetia peruviana*	5.59^{e}	24	*Odontonema cuspidatum*	4.29^{c}
	Medium shrubs		25	*Otacanthus caeruleus*	4.52^{d}
10	*Allamanda nerifolia*	5.26^{h}	26	*Pseuderanthemum graciflorum*	2.04^{a}
11	*Clerodendrum macrosiphon*	9.19^{j}	27	*Russelia juncea*	7.20^{j}
12	*Ixora chinensis*	1.27^{a}	28	*Tabernaemontana coronaria* 'Nana'	6.07^{g}
13	*Ixora coccinea*	3.38^{e}	29	*Tabernaemontana coronaria* 'Variegata'	4.80^{f}
14	*Kopsia fruticosa*	2.45^{e}	30	*Wrightia antidysenterica*	6.76^{h}
15	*Murraya paniculata*	2.99^{d}			

Table 39. Classification of shrubs based on Air Pollution Tolerance Index

APTI category	Tall shrub	Medium shrub	Dwarf shrub
Sensitive (≤ 14)	*Hamelia patens* *Pereskia bleo* *Thevetia peruviana*	*Pseuderanthemum reticulatum* *Kopsia fruticosa*	*Allamanda cathartica* 'Dwarf' *Odontonema cuspidatum* *Tabernaemontana coronaria* 'Variegata' *Wrightia antidysenterica*
Intermediate (15-19)	*Allamanda cathartica* *Nerium indicum*	*Murraya paniculata* *Tecomaria capensis*	*Brunfelsia latifolia* *Lonicera japonica* *Pseuderanthemum graciflorum* *Tabernaemontana coronaria* 'Nana'
Moderately tolerant (20-24)	*Allamanda violacea* *Bauhinia acuminata*	*Allamanda nerifolia* *Ixora chinensis* *Rondeletia odorata*	*Ixora rosea* *Otacanthus caeruleus* *Russelia juncea*
Tolerant (>24)	*Calliandra haematocephala* *Mussaenda erythrophylla*	*Clerodendrum macrosiphon* *Ixora coccinea*	

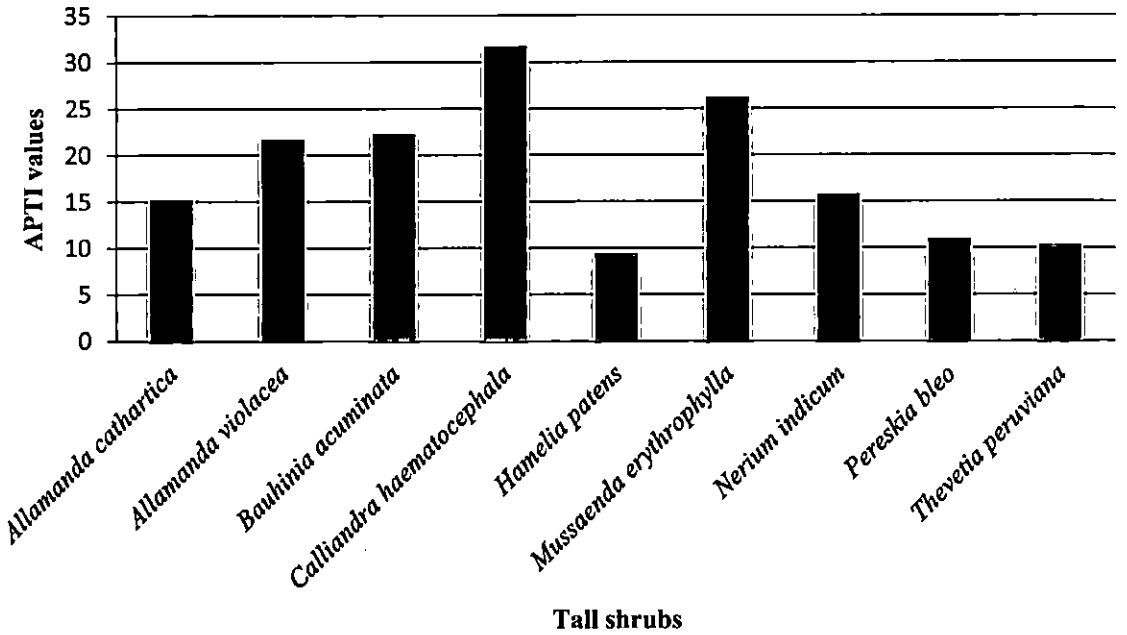


Fig. 19. APTI values for Tall shrubs

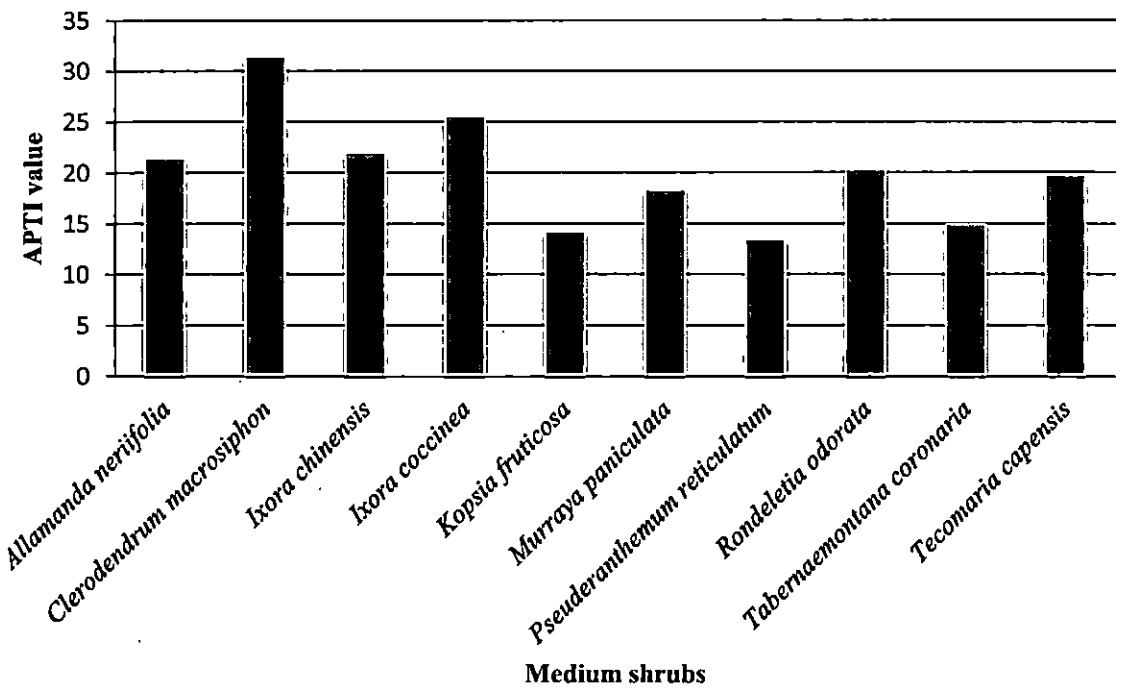


Fig. 20. APTI values for Medium shrubs

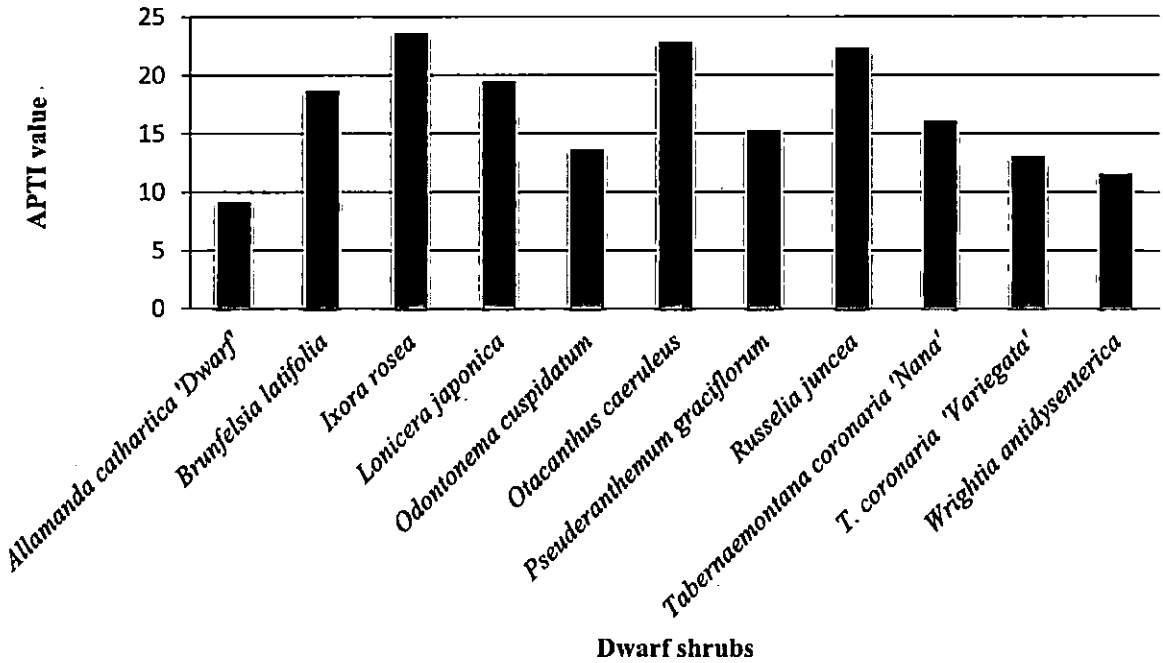


Fig. 21. APTI values for Dwarf shrubs

'Dwarf' (7.7 mmol/sec) and the lowest value for *Pseuderanthemum graciflorum* (2.0 mmol/sec). The transpiration rates of all the shrub are given in the Table 38.

4.8 SELECTION FOR LANDSCAPING USES

4.8.1 Accent plant or Specimen plant

An accent or specimen plant is one which, because of its unique stem arrangement, attractive foliage, or particularly showy flowers, stands out from all other plantings in the garden. Specimen shrubs are planted to show off the perfect unusual form, foliage colouring or bloom. Group planting of tall shrubs in odd numbers of three or five can also create interest in the garden style, and can be used as focal point.

Allamanda cathartica and *Allamanda violacea* have got climbing habitat, which can be trialed up on peculiar shaped trellis or pergolas, can be used as accent plants. Their blooming periods are also year round. *Hamelia patens* blooms year round profusely. It also produces bead like fruits, and the shrub can be used as accent plant. *Mussaenda erythrophylla*, with its tree like form, when planted single, create interest in the landscape; it also produces profuse bloom round the year. *Nerium indicum* in groups of three or five can be used as a focal point, with its attractive pink flowers which are produced year round. As this shrub is having low spread (79.9 cm), group planting is preferred.

In the medium shrubs, *Pseuderanthemum reticulatum* with its reticulated yellowish green foliage and whitish flower spikes, when planted in group can act as a centre of attraction. In the dwarf shrubs, *Russelia juncea* and *Brunfelsia latifolia* can be used for this purpose. *Russelia juncea* when planted at an elevated site, its branches will hang down and produce a cascading effect. *Brunfelsia latifolia* with flowers changing colours, can be used as specimen plant.

4.8.2 Foundation planting

Shrubs with geometrical shape and dense canopy are preferred for foundation planting. Medium sized and dwarf shrubs are usually used for this purpose. Taller plants with lesser spread are preferred for planting near the corner, and the area in between is planted with low growing shrubs. Also taller plants are better displayed against plain wall.

Pereskia bleo having compact upright and erect canopy, is suitable for planting along the corner. Tall spreading shrubs are not used for foundation planting. *Allamanda neriifolia* (Arching form), *Clerodendrum macrosiphon* (Round form), *Kopsia fruticosa* (Round form) are suitable as foundation plants, especially against plain walls. These shrubs have geometrical shape and compact canopy. In the dwarf group, *Ixora rosea* has dense canopy and geometrical shape (Columnar form). *Pseuderanthemum graciflorum* (Spreading form), *Russelia juncea* (Cascading form) *Tabernaemontana coronaria* 'Nana' (Compact form) and *Tabernaemontana coronaria* 'Variegata' (Arching form) are also best suited for foundation planting.

4.8.3 Background planting

Dense leafy plants with simple and consistent leaf texture and dark green, solid leaf colour are preferred for using as a background plant. Tall and medium sized shrubs are usually used for the purpose.

In the tall shrubs, *Hamelia patens* and *Calliandra haematocephala* have compact, dense canopy with uniform leaf texture and dark green coloured leaves. Their number of leaves per unit area is higher (77.3 and 154 per 1000 cm,^{2} respectively). *Thevetia peruviana* (101 leaves/ 1000 cm^2) can also be used as it has got narrow leaves with solid and single green colour. In the medium group, plants suited are *Allamanda neriifolia* (102 leaves/ 1000 cm^2), *Clerodendrum macrosiphon* (117 leaves/ 1000 cm^2) showed higher leaf density and consistent leaf texture and colour.

In the dwarf group shrubs, *Tabernaemontana coronaria* 'Nana' (ht. 71.3 cm and 209.3 leaves/ 1000 cm^2) can be used as a background for low growing annuals and bulbs. *Lonicera japonica* (ht. 49.9 cm and 112.3 leaves/ 1000 cm^2) also provide the same function. Both have got consistent leaf texture with single, solid deep green colour.

4.8.4 Screening and privacy

Fast growing shrubs with dense foliage are used for screening purpose. The foliage cover should start from the ground level itself. In the tall group, *Calliandra haematocephala* with dense foliage from bottom can be used for the purpose. *Pereskia bleo* with upright branches, and closed canopy when planted with closer spacing can act as a live screen. *Hamelia patens* with dense foliage cover can also be used for screening purpose. *Nerium indicum* in line planting can be used for reducing glare in highway median.

Medium group shrubs offer privacy mainly up to chest height. *Allamanda neriifolia*, *Clerodendrum macrosiphon*, *Murraya paniculata* and *Kopsia fruticosa* can be used for providing partial privacy.

4.8.5 Traffic control

For using a shrub for traffic control, its branching pattern should be more vertical and intertwined. Also the branches should be more rigid or stiff. The thorniness of the shrub might also be a desirable feature for traffic control. *Pereskia bleo* with upright branches and closed canopy when planted with closer spacing can act as a physical barrier. The thorniness of the shrub also helps in this function. *Kopsia fruticosa* is having stiff, upright branches, and it can be used for traffic control in larger areas. *Murraya paniculata*, when planted in closer spacing, can be used as a physical barrier. For smaller spaces, *Tabernaemontana coronaria* 'Nana' can be used for demarcating the area boundary as well as traffic regulation.

4.8.6 Hedge making

For formal hedges, shrubs used should be having dense canopy with narrow leaves, small, intertwined and upright branches. Also the shrub should withstand severe pruning. *Tabernaemontana coronaria* 'Nana' is suitable for formal hedge planting. *Murraya paniculata* also can be used for making a formal hedge.

For informal hedge planting, shrubs with upright branches are preferred. In the informal hedges, shrubs are pruned twice only in a year. Suitable shrubs are *Ixora chinensis, Pseuderanthemum reticulatum, Ixora rosea,Kopsia fruticosa* and *Murraya paniculata.*

4.8.7 Topiary

For making topiary, shrubs used should be having dense canopy with narrow leaves, small, inter-twined and upright branches. Also the shrub should withstand severe pruning. *Tabernaemontana coronaria* 'Nana' is suitable for formal hedge planting. *Murraya paniculata* also can be used for making a formal hedge.

4.8.8 Shrub group and mass planting

Mass planting of shrubs are done to get big splash of colour or to provide consistency of colour, form, scale and texture. Mass planting is usually done in larger landscapes. Dwarf shrubs and medium growing shrubs are preferred for this landscaping use so that their upper surface area also should be visible. *Odontonema cuspidatum* (ht. 83.2 cm; spr.46.03cm), *Otacanthus caeruleus* (ht. 81.0 cm; spr. 50.53 cm), *Allamanda cathartica* 'Dwarf'(ht. 80.4 cm; spr. 58.5 cm), *Brunfelsia latifolia* (ht. 86.5 cm; spr. 56.8 cm), *Lonicera japonica* (ht. 49.9 cm; sp. 73.1 cm), *Tabernaemontana coronaria* 'Nana'(ht. 71.3 cm; spr. 53.7cm) and *T.coronaria* 'Variegata' (ht. 80.6 cm; spr. 68.7 cm) are fitted for this use.

Pseuderanthemum reticulatum (ht. 131.9 cm; spr. 46.2 cm) and *Ixora chinensis* (ht. 122.8 cm; spr.45.5 cm) are suited for group planting and mass planting.

4.8.9 Shrubbery and shrub border

Shrubbery is a wide border of a garden where shrubs are thickly planted. Shrub border is full of different kinds of shrubs may be intermingled with perennials, bulbs and bedding plants. Shrubs are very thickly planted in the borders. So the selected shrub should fit into the border properly. A shrubbery is made with in different rows of plants of different height. In the front row, low growing shrubs are planted. In the middle medium tall shrubs, and in the back row, tall shrubs are planted.

Medium and dwarf shrubs are best suited for shrubbery and shrub boarder. Among tall growing shrubs, plants with lesser spread are preferred for shrubbery in back row.

Allamanda neriifolia with a height of 152.9 cm and spread 138.9 cm an blooms almost the year, suited for back row. *Clerodendrum macrosiphon* (ht.153.8 cm; spr. 129.8 cm) also best fitted into shrub border in the back row, as its dense foliage with purplish tinge and attractive flower shape with snow white colour adds contrast to the border. *Ixora coccinea* (ht. 152.7 cm; spr. 145.0 cm) is suited for the back row for its yellowish green foliage and scarlet red flowers, produced year round. *Rondeletia odorata* (ht.152.7 cm; spr.89.0 cm), and *Tabernaemontana coronaria* (ht. 146.6 cm; spr.104.3 cm) is also suitable for medium rows in the shrubbery and shrub border.

For the front row, low growing shrubs are to be selected. Medium tall shrubs with tall upright and loose canopy can be planted intermingling with low growing dwarf shrubs. *Pseuderanthemum reticulatum* (ht. 131.9 cm; spr. 46.2 cm) and *Ixora chinensis* (ht. 122.8 cm; spr. 45.5 cm) are suitable for planting in front row along with dwarf shrubs. Low growing shrubs like *Brunfelsia latifolia* (ht. 86.5 cm; spr. 56 cm),

Odontonema cuspidatum (ht. 83.2 cm; spr.46.03cm), *Otacanthus caeruleus* (ht. 81.0 cm; spr.50.53 cm), *Pseuderanthemum graciflorum* (ht. 81.6cm; spr. 50.53 cm) and *Russelia juncea* (ht.86.4 cm; spr. 83.07cm) can be best used in the front row of a shrubbery. *Wrightia antidysenterica* (ht.94.7 cm; Sp.43.4 cm) can also be used in between the spreading low shrubs.

4.8.10 Corner planting

Incurve is planted with a focal feature such as a specimen plant or an accent plant. The incurve plant is usually taller than the other plants that extend from it to the outer reaches of the corner bed. Also, low spreading specimen plants are more preferred for incurve planting. For out curves, low and spreading plants are suitable.

Specimen plants like *Allamanda cathartica, Allamanda violacea, Hamelia patens* and *Nerium indicum* are suitable for planting in incurves. *Mussaenda erythrophylla* is suited for planting in incurves or larger compounds, as its spread is much higher (248.3 cm).

For outcurves, low and spreading plants like *Lonicera japonica* (ht. 49.9 cm and spr. 73.1Cm) and *Pseuderanthemum graciflorum* (ht. 81.6 cm and spr. 58.5 cm) are best suited. Dwarf shrubs like *Russelia juncea* (ht.86.4 cm and spr. 83 cm) *Tabernaemontana coronaria* 'Nana'(ht. 71.3 cm and spr. 53.7 cm) and *Otacanthus caeruleus* (ht. 81 cm and spr p. 50.5 cm) also suitable for outcurves.

4.8.11 Fragrant garden

Fragrant gardens are gardens which are meant to enjoy sweet smell of flowers along with visual beauty. For fragrant garden, flowering shrubs with fragrant flowers are used. Under the observed plants, few shrubs possessed sweet smelling flowers. The fragrance of tall shrubs can be best enjoyed while walking or standing. *Nerium indicum, Thevetia peruviana* and *Bauhinia acuminata* produced fragrant flowers in the tall group. Though their single flower persistence time was very less, their

inflorescence persistence time was more. Fragrance of medium group shrubs can be best enjoyed while walking as well as sitting. Under this group, *Murraya paniculata* and *Tabernaemontana coronaria* produced fragrant flowers. The fragrant flowered dwarf shrubs include *Lonicera japonica, Tabernaemontana coronaria* 'Nana' amd *T. coronaria* 'Variegata'. These shrubs should be planted close to sitting benches as their fragrance is best enjoyed at lower height level.

4.8.12 Pot and Container planting

Low growing and compact shrubs are suitable for planting in pots and containers. In pots single plants are planted while in container, mixed planting adopted. Shrubs suitable for pot planting should be having dwarf, upright and compact growth habit, with lesser spread. Shrubs suitable are *Tabernaemontana coronaria* 'Nana'(ht. 71.3 cm and spr. 53.7 cm) *Otacanthus caeruleus* (ht. 81 cm and spr. 50.5 cm), and *Odontonema cuspidatum* (ht. 83.2 cm; spr. 46.03cm). *Pseuderanthemum reticulatum* (ht. 131.9 cm; spr. 46.2 cm) also can be used for pot planting.

4.8.13 Covering sloppy banks

Plants suitable for covering sloppy banks are sprawling shrubs with tenacious roots and rooting stems that hold the soil together. Among the observed shrubs, *Lonicera japonica* only showed creeping and crawling growth form. It has got a spreading growth habit with a spread of 70.87 cm, and dense foliage cover of 112.33 leaves/ 1000 cm^2. The root system of the plant was also much extensive.

4.8.14 Xeriscaping

Plants with xerophytic adaptations are usually planted in a xeriscape garden. The plant will be having a either physical or physiological mechanism or modification to control the water usage. In *Russelia juncea,* the leaves are reduced to minute scales. The photosynthetic activity is undertaken by stem and branches which are also with chlorophyll. *Nerium indicum* is having a thick waxy coating over the epidermis to

prevent the water loss. In *Lonicera japonica*,the root system is much extensive, which is also a xerophytic adaptation.

4.8.15 Moon garden

Moon gardens are those gardens which are meant to enjoy their beauty at late evening hours. Plants selected for moon garden should be having either white coloured flowers or white, variegated or silvery leaves. Fragrant white flowers are much preferred for moon gardens.

In the tall group, *Bauhinia acuminata* produced white flowers. In the medium group, *Clerodendrum macrosiphon* produced snow white flowers profusely at a time. *Murraya paniculata* produced white fragrant flowers. *Pseuderanthemum reticulatum* produced white flowers with reticulated pale yellowish green leaves, which appear beautiful at night hours also. *Tabernaemontana coronaria* produced white fragrant flowers.

Among the dwarf shrub group, *Brunfelsia latifolia* produced white and pale violet flowers. *Lonicera japonica* produced fragrant white flowers. This shrub is also low growing so can be planted near walkways. *Tabernaemontana coronaria* 'Nana' produced numerous small white flowers which projected out against the dark foliage background in the nigh hours. *T. coronaria* 'Variegata' is best suited for moon garden as it produces variegated leaves and white flowers as well. *Wrightia antidysenterica* also produced snow white flowers in large number.

4.8.16 Rock garden

Shrubs with xerophytic characters are used in rock gardens. Generally, plants that are low growing and have a clumping habit are preferred. Low growing or dwarf shrubs are mainly used in rock gardens. *Russelia juncea* is suitable for Xeriscaping as it has got a low growing cascading form. It also adapted to xerophytic condition, as the leaves are reduced to scales and photosynthesis is undertaken by stem and branches.

Lonicera japonica is having a low creeping form, reaching only up to 49.9 cm in height. Its root system is also extensive, which is a xerophytic adaptation.

4.8.17 Butterfly garden

Nectar plants provide the sugars that adult butterflies need for nourishment and energy. Certain shrubs like, *Hamelia patens, Kopsia fruticosa, Ixora coccinea,I. chinensis* and *I. rosea* produced flowers year round and were frequently visited by butterflies. Shrubs like, *Calliandra haematocephala, Clerodendrum macrosiphon* and *Murraya paniculata* also produced profuse flowers with more nectar, and were frequently visited by butterflies in the blooming period. These shrubs can be planted in butterfly garden to attract butterflies.

A butterfly garden also will be having foliage plants to help butterflies in breeding. Butterfly caterpillars were observed on the leaves of *Calliandra haematocephala, Mussaenda erythrophylla, Pseuderanthemum reticulatum, Tabernaemontana coronaria* and *Nerium indicum.* These plants can be used in the butterfly garden, to attract butterflies for breeding.

Suitability of different shrubs to different landscaping uses are given in Tables 40 and 41.

4.9 PEST AND DISEASE

There were minor incidences of pest and disease attack in the experimental plot.

4.9.1 Pest incidence

The attack noticed include, leaf eating caterpillar in *Nerium indicum, Tabernaemontana coronaria, Calliandra haematocephala, Ixora coccinea* and *Mussaenda erythrophylla,* flower bud borer caterpillar in *Wrightia antidysenterica.* Flower beetle damage was observed on *Tabernaemontana coronaria* 'Variegata'

flower. Mealy bug attack was observed in *Nerium indicum, Mussaenda erythrophylla* and *Wrightia antidysenterica.* Hardscale incidence was noticed in *Nerium indicum.*

4.9.2 Disease incidence

Leaf spots observed in *Kopsia fruticosa, Ixora coccinea, Pseuderanthemum reticulatum* and *Brunfelsia latifolia.* Leaf blight symptoms were observed in *Tabernaemontana coronaria.*

Table 40. Landscaping uses of the shrubs-I

No.	Shrub	Accent plant	Shrub group	Shrub border	Backgro-und planting	Founda-tion planting	Corner planting	Traffic control	Screening
	Tall shrubs								
1	*Allamanda cathartica*	√	—	—	—	—	—	—	—
2	*Allamanda violacea*	√	—	—	—	—	—	—	—
3	*Bauhinia acuminata*	—	—	—	—	—	—	√	—
4	*Calliandra haematocephala*	—	—	—	√	—	—	√	√
5	*Hamelia patens*	√	—	—	√	—	—	√	√
6	*Mussaenda erythrophylla*	√	—	—	—	—	—	√	—
7	*Nerium indicum*	—	—	√	—	—	—	—	√
8	*Pereskia bleo*	—	—	—	—	—	√	√	√
9	*Thevetia peruviana*	—	—	—	√	—	—	√	—
	Medium shrubs								
10	*Allamanda nerifolia*	—	—	√	√	—	—	√	√
11	*Clerodendrum macrosiphon*	—	—	—	√	√	—	√	√
12	*Ixora chinensis*	—	√	√	—	√	—	—	—
13	*Ixora coccinea*	—	√	√	—	—	—	—	—
14	*Kopsia fruticosa*	—	√	√	—	√	√	—	√
15	*Murraya paniculata*	—	—	—	√	√	√	√	√
16	*Pseuderanthemum reticulatum*	√	√	√	—	—	—	—	—
17	*Rondeletia odorata*	—	√	√	√	√	—	—	—
18	*Tabernaemontana coronaria*	—	√	√	√	—	—	—	—
19	*Tecomaria capensis*	—	√	√	√	√	—	—	—
	Dwarf shrubs								
20	*Allamanda cathartica* 'Dwarf'	—	√	√	—	—	—	—	—
21	*Brunfelsia latifolia*	—	√	√	—	—	—	—	—
22	*Ixora rosea*	—	√	√	—	√	—	√	—
23	*Lonicera japonica*	—	√	√	—	√	—	—	—
24	*Odontonema cuspidatum*	—	√	√	—	—	—	—	—
25	*Otacanthus caeruleus*	—	√	√	—	—	—	—	—
26	*Pseuderanthemum graciflorum*	—	√	√	—	√	—	—	—
27	*Russelia juncea*	√	√	√	—	√	—	—	—
28	*Tabernaemontana coronaria* 'Nana'	—	√	√	√	√	√	—	—
29	*Tabernaemontana coronaria* 'Variegata'	—	√	√	—	√	√	—	—
30	*Wrightia antidysenterica*	—	√	√	—	—	√	—	—

Table 41. Landscaping uses of the shrubs-II

No.	Shrub	Hedge	Topiary	Butterfly garden	Fragrant garden	Moon garden	Rock garden	Xeriscaping	Pot planting	Covering slopes
	Tall shrubs									
1	*Allamanda cathartica*	—	—	—	—	—	—	—	—	—
2	*Allamanda violacea*	—	—	—	—	—	—	—	—	—
3	*Bauhinia acuminata*	—	—	√	√	√	—	—	—	—
4	*Calliandra haematocephala*	—	—	√	—	—	—	√	—	—
5	*Hamelia patens*	—	—	√	—	—	—	—	—	—
6	*Mussaenda erythrophylla*	—	—	√	—	—	—	—	—	—
7	*Nerium indicum*	—	—	—	√	—	—	√	—	—
8	*Pereskia bleo*	—	—	—	—	—	—	—	—	—
9	*Thevetia peruviana*	—	—	—	√	—	—	—	—	—
	Medium shrubs									
10	*Allamanda neriifolia*	—	—	—	—	—	—	—	—	—
11	*Clerodendrum macrosiphon*	—	—	√	—	√	—	—	—	—
12	*Ixora chinensis*	√	—	√	—	—	—	—	—	—
13	*Ixora coccinea*	—	—	√	—	—	—	—	—	—
14	*Kopsia fruticosa*	√	—	—	—	—	—	—	—	—
15	*Murraya paniculata*	—	√	√	√	√	—	—	—	—
16	*Pseuderanthemum reticulatum*	√	—	√	—	√	—	—	√	—
17	*Rondeletia odorata*	—	—	—	—	—	—	—	—	—
18	*Tabernaemontana coronaria*	—	—	—	√	√	—	—	—	—
19	*Tecomaria capensis*	—	—	—	—	—	—	—	—	—
	Dwarf shrubs								—	
20	*Allamanda cathartica* 'Dwarf'	—	—	—	—	—	—	—	—	—
21	*Brunfelsia latifolia*	—	—	—	—	√	—	—	—	—
22	*Ixora rosea*	√	—	√	—	—	—	—	—	—
23	*Lonicera japonica*	—	—	√	√	√	√	√	—	—
24	*Odontonema cuspidatum*		—	√	—	—	—	—	√	√
25	*Otacanthus caeruleus*	—	—	—	—	—	—	—	√	—
26	*Pseuderanthemum graciflorum*	—	—	√	—	—	—	—	—	—
27	*Russelia juncea*	—	—	√	—	—	√	√	—	—
28	*Tabernaemontana coronaria* 'Nana'	√	√	—	—	√	—	—	√	—
29	*Tabernaemontana coronaria* 'Variegata'	—	√	—	—	√	—	—	—	—
30	*Wrightia antidysenterica*	—	—	√	—	√	—	—	√	—

Discussion

5. DISCUSSION

The results of the "Evaluation of ornamental flowering shrubs for tropical landscapes" conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2010-2012 are discussed in this chapter.

The main objectives of the study were to evaluate ornamental shrubs based on the above characters and to classify them aesthetically and functionally for various uses in tropical landscapes, and, to evaluate the Air Pollution Tolerance Index (APTI) of shrubs and ability to remove volatile organic compounds for using them as pollution indicators or for controlling pollution in the outdoor environment.

Thirty tropical ornamental flowering shrubs grown in the open field condition were selected for evaluation of their suitability for various landscaping purposes.

5.1 Plant size

It is important to have an idea of the approximate size at maturity of the trees and shrubs commonly used in landscape plantings. Mature size is greatly influenced by the length of the growing season, temperature, light, water, soil type, fertility, and many other factors. This makes it impossible to predict the exact mature size of a plant. Plants in shade will often grow taller with a thinner crown than those growing in an open area.

Shrubs can be classified according to their un-pruned mature height. Jarrett (2003) classified shrubs based on their unpruned height into small (<1.2 m), medium (1.2-3 m) and tall (>3 m) shrubs. Read (1994) also classified shrubs to low shrubs (<2 m) and tall shrubs (>2 m) based on their mature height.

For more specific landscaping uses, classification based on the maintainable height is more suitable. With annual pruning, shrubs can be maintained to an optimum height. Maintainable height is the height at which the shrubs keep good canopy form

and density without affecting flower production. Heightshoe (1987) grouped ornamental shrubs into four different groups based on their height, like large shrubs (4– 6 m), mid-height shrubs (2– 4 m), small shrubs (1– 2 m) and very small shrub (< 1 m).

In the present study, plant height of shrubs observed varied from 49.9 cm in *Lonicera japonica* to 319.4 cm in *Calliandra haematocephala*. According to maintainable height, shrubs were classified in to three groups, i.e. tall, medium and dwarf. Tall shrubs included those having height above 2 m, medium shrubs with height beteen 1m-2m and dwarf shrubs with height below 1 m. Among the observed shrubs, nine came under the tall group, ten under medium group and eleven under dwarf group.

All the shrubs with height above 2 m, even up to 5 m provide screening function. So these shrubs may be grouped together as tall shrubs, in the landscaping point of view. Jarrett (2003) also classified shrubs based on their maintainable heights in to dwarf (<0.60 m), small (0.6-1.2 m), intermediate (1.2-1.8 m) and tall (>1.8 m).

Plant height and spread are the components which make up the volume of a shrub. Spatial definition with plants means to create an interesting, functional and solid mass and void composition. The plants are the mass and the empty spaces are the void. The landscape design deals mainly with the formation of the mass and voids (Colvin, 1997).

In the present study, shrubs were compared with respect to their plant height, within each group. With respect to height, shrubs differed significantly. Height varied from 49.9 cm in *Lonicera japonica* to 319.4 cm. in *Calliandra haematocephala*.

In tall shrubs, *Calliandra haematocephala* showed highest value for height, followed by *Mussaenda erythrophylla*. *Pereskia bleo* showed the lowest height in the tall category. In the medium growing group, *Murraya paniculata* showed the highest

value for height. *Ixora chinensis* showed the minimum height in this group. In the dwarf shrubs, *Ixora rosea* showed the maximum height which was on par with *Wrightia antidysenterica*. The least height was showed by *Lonicera japonica*.

In landscape gardens, plants are chosen not only for their height but also for how far they will spread, or grow, laterally. The spread of plant is an important tool in designing, to create dense, full gardens or to fill the bare spaces between plants. Information on plant spread is important when planning formal gardens or when gardening in areas with limited space.

In the present study, shrubs were compared with respect to their plant spread, within each group. With respect to spread, shrubs differed significantly. Spread varied from 45.03 cm in *Ixora chinensis*, to 269.70 cm in *Calliandra haematocephala*.

Under tall category, *Calliandra haematocephala* showed the maximum spread. The least spread was observed in *Nerium indicum*. In the medium group, *Ixora coccinea* showed the maximum spread. The least spread in this category was observed in *Ixora chinensis*. *Russelia juncea* showed the highest spread under the dwarf group, which was followed by *Ixora rosea* and *Lonicera japonica*. The least spread in this category was observed for *Wrightia antidysenterica* and *Odontonema cuspidatum*.

Monthly observations on plant growth were recorded. The growth did not correlate with any of the meteorological parameters. The observed shrubs were having an age of four years, their active growth stage almost over, and they reached full blooming stage. By regular annual pruning, they grow almost consistently every month. Also the plants were irrigated in dry periods every day.

Plant height was found to be highly correlated with plant spread in most of the shrubs. Spread by height index value for the shrubs calculated. It gives a measure of the horizontal volume, a shrub adds to the landscape.

Regression equation was formulated for the shrubs, to predict the spread when the height is known. This can be used in designing landscape, for allocation of the shrubs and other plant components.

5.2 Form

The plant form or silhouette links the visual principle of mass and line with biological properties of growth forms and habit (Robinson, 2004). Form is determined by the line, direction, and arrangement of branches and twigs. The resulting mass influences the scale (Whiting and de Jong, 2007). Ingels (2009) described six different crown forms. They are globular, low and creeping, spreading, arching, pyramidal, upright and loose and columnar. Different plant forms have got different uses in landscape designs.

Among the shrubs evaluated, different canopy silhouettes were observed. Columnar, upright, loose upright, open, vase, globular, arching, spreading, compact and clumping types of silhouette forms were observed among the shrubs.

Allamanda cathartica and *A.violacea* showed vase shaped canopy form, with little support. Their branching form is weeping. Open silhouette form was most common, observed in *Bauhinia acuminata, Thevetia peruviana, Ixora coccinea, Allamanda cathartica* 'Dwarf', *Brunfelsia latifolia,* and *Otacanthus caeruleus.* Shrubs with ascending branching pattern showed open canopy form. Shrubs with upright branching habit formed dense upright or loose upright canopy form. Loose upright form observed in *Nerium indicum, Pereskia bleo, Ixora chinensis, Pseuderanthemum reticulatum, Wrightia antidysenterica* and *Odontonema cuspidatum.* Upright and loose form is a loose, informal shape and is useful for screening and framing views. It usually require pruning to prevent leggy growth (Ingels, 2009). Dense upright form was observed in *Rondeletia odorata.*

Round form was observed in *Kopsia fruticosa, Clerodendrum macrosiphon* and *Tabernaemontana coronaria*. Plants with round forms help to make contrast with plants having Columnar and pyramidal-shaped plants (Perry, 2007). Arching observed in *Hamelia patens*, *Tabernaemontana coronaria* 'Variegata' and *Mussaenda erythrophylla*. Other observed forms were columnar, creeping, oval cascading, spreading and compact. Creeping form was observed in *Lonicera japonica*. Creeping form helps to create neutral patterns in contrast with more unusual forms of plants (Perry, 2007). Consideration of form also helps determine if plant material should be used in masses or as individual specimens (Denny and Hansen, 2010).

5.3 Texture

Texture can be determined by a shrub's shape, size, shape and mobility of its foliage, twigginess of its branches and growth pattern of its bark (Hériteau, 2005). Foliage texture and density determine the visual effect of the shrub and the ability of the shrub to absorb noise, dust, and wind (Ingels, 1978). Close-up, texture comes from the size and shape of the leaves, the size of twigs, spacing of leaves and twigs, the colors and shading, the gloss or dullness of leaves. At a distance, texture comes from the entire mass effect of plants and the qualities of light and shadows.

According to Hansen and Alvarez (2011) the size and shape of the leaves most often determine the perceived texture of the plant. Texture in the landscape is due essentially to different foliage patterns. Texture appears coarse or medium or fine because of leaf size which is a function primarily of leaf length and width. Heightshoe (1988) classified plants in to five textural categories based on their leaf area. They are coarse (more than 100 cm^2), medium coarse (60 -100 cm^2), medium (20 – 60 cm^2), medium fine (10-20 cm^2) and fine (less than 10 cm^2). Among the observed shrubs, leaves with surface area more than 100 cm^2 (coarse texture) were not observed. In the present study, this textural classification was adopted.

Among the shrubs selected for the study, four shrubs came under medium coarse, ten shrubs came under medium, eight under medium fine and eight under fine textural category.

Bauhinia acuminata, Mussaenda erythrophylla, Ixora coccinea and *Kopsia fruticosa* came under medium coarse category. *Allamanda cathartica, Allamanda violacea, Nerium indicum, Pereskia bleo, Tabernaemontana coronaria, Ixora chinensis, Pseuderanthemum reticulatum, Ixora rosea, Odontonema cuspidatum* and *Pseuderanthemum graciliflorum* were the medium textured plants.

Medium fine textured plants are *Thevetia peruviana, Hamelia patens, Calliandra haematocephala, Clerodendrum macrosiphon, Brunfelsia latifolia, Otacanthus caeruleus, Tabernaemontana coronaria* 'Variegata' and *Wrightia antidysenterica.*

Fine-textured shrubs are especially well suited for providing a background for flowers (Carpenter *et.al.*, 1975). Fine textured plants include *Allamanda cathartica* 'Dwarf', *Allamanda neriifolia, Lonicera japonica, Murraya paniculata, Rondeletia odorata, Russelia juncea, Tabernaemontana coronaria* 'Nana' and *Tecomaria capensis.*

Generally, coarse-textured shrubs attract the eye more than fine-textured shrubs (Perry, 2007). Thus, more fine-textured plants are required to counterbalance the effect of coarse textures in the landscape. Textures get finer with distance. Whiting and de Jong (2007) recommended placing the fine textured plants in the distant corner with coarser textured plants towards the viewer to get the sequence.

5.4 Colour

According to Whiting and de Jong (2007), colour is the most powerful of the design elements. Colour is powerful in creating mood and feelings. Choose colors carefully to create the mood desired in the story line. Warm colours can induce a

feeling of motivation and activeness, while cool colours induce calmness and relaxation. So colour should be choosen carefully.

Warm, bright colors, such as yellows and red, are best for shade, and all colors work well in sunny areas (Denny and Hansen, 2010). If scale is high with the brightly colored flowers, the action feeling of high scale helps people move through (Whiting and de Jong, 2007). Among 30 shrubs evaluated, shrubs with warm colours were *Allamanda cathartica, A. cathartica 'Dwarf', Allamanda neriifolia, Calliandra haematocephala, Hamelia patens, Ixora coccinea, I.chinensis, I. rosea, Nerium indicum, Odontonema cuspidatum , Pereskia bleo, Rondeletia odorata, , Russelia juncea,Thevetia peruviana,* and *Tecomaria capensis.*

Cool colours and deep shades like blue and green help to make feel a place more distant or deeper (Ingram, 2003). Cool coloured flowers are produced by *Allamanda violacea, Pseuderanthemum reticulatum, Brunfelsia latifolia, Otacanthus caeruleus* and *Pseuderanthemum graciliflorum.*

Neutral colours add depth to the composition, divide colors that clash or are too strong, tone down complementary color schemes in daylight and glow in the dark (Anonymous, 2000) Neutral colour (white) flowers are produced by *Bauhinia acuminata, Murraya paniculata, Clerodendrum macrosiphon, Lonicera japonica, Tabernaemontana coronaria, T. coronaria* 'Nana' and *T.coronaria* 'Variegata'. Shrubs like *Lonicera japonica* and *Brunfelsia latifolia* showed colour change in consecutive days.

Dark-colored plants contrasted with light-colored plants create focal points in a planting composition. (Perry, 2007)

5.5 Flowering phenology

Flowering phenology is an important factor that should be considered while selecting any ornamental flowering plant for landscape gardening. From the

landscaping point of view, the variability of plants throughout the year is a problem which remains largely unaddressed, despite its importance. Identification of 'Vegetation waves' and phenological 'side-runs' also helps in proper design of the landscape garden, for imparting time specific interests to garden (Dierschke, 1995).

Bulir (2009) described phenophase as a situation when more than 50 % of individuals of the species fulfilled the requirements described for the development of aesthetically impressive phenophase i.e. full blooming or full foliage colouration. A plant which blooms throughout the year is very rare in temperate climatic conditions. In temperate condition, the floral blushing takes place during May, June and July, when most of the ornamental shrubs enrich the flower framework of each of the green space. Starting with August, the floral spectrum shrinks (Posedaru *et. al.*, 2008). But in tropics, the blooming period is much extended. So we cannot assess the full bloom as 50 % of the maximum flowering. Therefore, in the present study, 25 % blooming was considered as onset of a phenophase. Also, in the present study, no shrub showed foliage colour change or foliage colouration. Therefore blooming intensity alone is considered for determining phenophase.

Total number of inflorescences produced are counted and expressed as blooming intensity. It helps to get an idea of distribution of flowering phases annually. Posedaru *et. al.* (2008) studied the decorative phenological characters of ornamental plants based on their blooming intensity

Among tall shrubs observed, *Hamelia patens* showed flowering throughout the year continuously. *Nerium indicum* , *Allamanda cathartica* and *Allamanda violacea* also showed year round flowering, with irregularity in profuseness. *Bauhinia acuminata* produced flowers only in dry months. In the medium category, *Ixora coccinea* showed almost year round blooming, with little irregularity in flowering. *Ixora chinensis* showed profuse flowering from July- December. *Kopsia fruticosa* also produced flowers year round with lesser blooms in the rainy months. Among the

dwarf shrubs observed, *Odontonema cuspidatum* and *Russelia juncea* showed year round blooming with a few bloom free periods. *Wrightia antidysenterica* also showed year round blooming, but irregularity was there. *Ixora rosea* flowered well in the rainy months.

In certain tropical shrubs, the flowering period is showing a lesser peak in the rainy months. Dominguez and Dirzo (1995) reported that intensity and pattern of rainfall also play an important role in flower production in the flowering shrubs *Erythroxylum havanense*. But in the present study, some shrubs which bloom well in the rainy months also were identified. Shrubs like *Mussaenda erythrophylla, Nerium indicum, Allamanda violacea, Ixora coccinea, Ixora chinensis, Lonicera japonica, Tabernaemontana coronaria* 'Nana' and *T.coronaria* 'Variegata' showed more blooming in rainy season also. These shrubs can be used in a garden to get year round blooming.

The flowering patterns are in some way influenced or constrained by phylogeny and as a result, taxonomically related species will tend to show similar flowering times (Waser 1979; Kochmer & Handel 1986; Johnson 1992; Bolmgren et al . 2003). According to Johnson (1992), similarities in related groups may include flowering duration and intensity. In the present study, shrubs belonging to the same genus showed similarity in the flowering pattern. All the species belonging to *Allamanda* genus showed year round blooming. Also the *Ixora* species showed a similar blooming pattern.

The whole year is divided into four phenophase according to profuse blooming of the shrubs *i.e.* Dec-Feb (mild winter months), Mar-May (summer months), Jun.-Aug (monsoon months)., and Sep-Nov (monsoon and post monsoon months). Bulir (2011) made eight phenological distinct groups based on the observations made on temperate shrubs, like early spring, mid winter *etc.*. Under the temperate condition, the

seasons are well marked with distinct climatic conditions. The observed shrubs showed variations in their phenophases.

Side-runs were identified within a phenophase, species reaching their full blooming at the same time (Bulir, 2011). Side-runs are obtained from the three different height groups, tall, medium and dwarf. Based on the side-runs identified, phenological configurations were made. In a single phenophase, different colour combinations were also observed. Plants having contrasting or augmenting colours can be grouped together for best visual appeal. Group planting can also be done with plants having warm colous or plants with cool colours, by analyzing their phenophases.

Different combinations of plants (side-runs) behave identically in a particular time point. The combinations can be used in shrub border at different layers to get year round blooming. The analysis of the result may serve as a basis for a practical group classification of plants for landscaping purposes. The studies were made on the shrub groups only. Study of the flowering phonologies of other plant components of landscapes like annuals, bulbs, perennials and trees will help to make suitable combinations for better designing.

5.6 Air pollution tolerance index of foliage plants

Polluted atmosphere is one of the major challenges that man has to face today for his existence. In some circumstances, poor indoor air quality may pose serious health risks, particularly in susceptible individuals. Plants are our resource and weapon to fight against this. The air pollution tolerance index of plants can be used to maintain the quality of air. As suggested by Singh *et al.* (1991), APTI can be calculated by estimating four parameters viz., total chlorophyll content, leaf extract pH, relative water content and ascorbic acid content.

5.6.1 Total chlorophyll content

Among the different parameters that determine the tolerance level of plants to pollution, chlorophyll content plays an important role as it indicates the photosynthetic activity as well as the growth and development of biomass (Bell and Mudd, 1976; Jyothi and Jaya, 2010). Tolerance of plants to SO_2 is reported to be linked with synthesis or degradation of chlorophyll (Bell and Mudd, 1976; Ninave *et al.*, 2001). Thus, plants having high chlorophyll content are generally found tolerant to air pollutants (Singh *et al.*, 1991). Further the total chlorophyll content is also related to ascorbic acid productivity (Aberg, 1958) which is having a strong reductant action against the pollutants and ascorbic acid is concentrated mainly in chloroplast (Franke and Heber, 1964). In the present study, plants showed variation for chlorophyll content. *Calliandra haematocephala, Clerodendrum macrosiphon, Pereskia bleo, Mussaenda erythrophylla* and *Tecomaria capensis* showed higher leaf chlorophyll content. Shrubs like *Pseuderanthemum reticulatum, Nerium indicum, Tabernaemontana coronaria* 'Variegata' and *Otacanthus caeruleus* showed lower APTI values. The total chlorophyll content of the foliage plants was evidently influenced by prevailing light conditions during the seasons and also variegation of leaves. Plants with dark green leave have more chlorophyll content compared to plants with variegated leaves (Wood and Burchett, 1995).

5.6.2 Leaf extract pH

Leaf pH is the determining factor for most of the biochemical reactions in leaf. Moreover, photosynthetic efficiency strongly depends on this factor (Liu and Ding, 2008). Türk and Wirth (1975) reported that photosynthetic efficiency was found to be low in plants when the leaf pH was low. It has been reported that, in the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in plants which are sensitive to pollution compared to tolerant ones (Scholz and Reck, 1977). Thus, a higher level of leaf-extract pH in plants under polluted conditions may increase their tolerance level (Singh *et al.*, 1991). Further, the presence of an acidic pollutant may

turn the cell sap acidic and decrease the efficiency of conversion of hexose sugar to ascorbic acid. However, the reducing activity of ascorbic acid is pH dependent being more at higher and less at lower pH (Jyothi and Jaya, 2010). In the present study, Shrubs showed variation in their leaf pH value. *Pseuderanthemum reticulatum, Odontonema cuspidatum, Pseuderanthemum graciliflorum, Bauhinia acuminate* and *Thevetia peruviana* higher leaf pH value and lower pH values observed for *Ixora rosea, Ixora chinensis, Rondeletia odorata* and *Ixora coccinea.*

5.6.3 Relative Water Content (RWC)

Relative water content is associated with protoplasmic permeability (Oleinikova, 1969) and the air pollutants increase cell permeability (Keller, 1986) in the case of sensitive species (Farooq and Beg, 1980). Pollutant induced increased permeability in cells causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Masuch *et al.*, 1988). Therefore it is likely that plants with high RWC under polluted conditions may be tolerant to pollutants (Singh *et al.*, 1991). Further, high water content within a plant body will help to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are usually high and high water content favours drought resistance in plants. If transpiration rate is reduced due to air pollution, plants cannot sustain due to loss of capacity to pull water up with roots for photosynthesis. Then, the plants neither bring minerals from the roots to leaves where biosynthesis occurs, nor reduce the leaf temperature (Liu and Ding, 2008). In the present study, *Kopsia fruticosa, Otacanthus caeruleus,* and *Odontonema cuspidatum* showed higher value for relative leaf water content. Shrubs like *Calliandra haematocephala* and *Bauhinia acuminate* showed much lower leaf water content. *Allamanda cathartica, Thevetia peruviana* and *Allamanda violacea* also showed lower leaf water content.

5.6.4 Ascorbic acid

Ascorbic acid content of plants is considered to be more important than any other parameter to determine the susceptibility level. Though a plant possesses relatively low pH, chlorophyll content, and RWC, there is a great chance for the plant to have a higher APTI as the low values can be counter-balanced by the ascorbic acid multiplier effect in the APTI formula (Wood and Burchett, 1995). Moreover, studies showed that ascorbic acid is a strong reductant and a higher content favours pollution tolerance in plants (Lee *et al.*, 1984). The level of this acid declines on exposure to pollutants. Thus, plants maintaining high ascorbic acid level even under polluted conditions are considered to be tolerant to air pollutants (Singh *et al.*, 1991). Conklin (2001) reported that ascorbic acid plays a vital role in cell wall synthesis, defense and cell division. Chaudhary and Rao (1977) are of the opinion that higher ascorbic acid content in plants is a sign of its tolerance against sulphur dioxide pollution. Tripathi and Gautam (2007) also reported that the increase in the concentration of ascorbic acid in the leaves of *Mangifera indica* near roadsides is due to enhanced pollution from automobiles. In the present study, higher leaf ascorbic acid values were obtained for shrubs like *Calliandra haematocephala, Clerodendrum macrosiphon* and *Ixora rosea.* The lower value for ascorbic acid was observed for shrubs like *Hamelia patens, Allamanda cathartica* 'Dwarf' *Pereskia bleo, Thevetia peruviana,* and *Wrightia antidysenterica.*

5.6.5 APTI and susceptibility levels

The APTI values were computed for each species using the above four parameters. *Calliandra haematocephala*, *Clerodendrum macrosiphon* and *Mussaenda erythrophylla* showed maximum value for APTI. *Allamanda cathartica* 'Dwarf', *Hamelia patens* and *Thevetia peruviana* showed lower APTI value. It is evident that, no species had the maximum value for all the four parameters and each parameter plays a distinctive role in the determination of susceptibility of plants.

Though different parameters were taken, wide variation was seen only in ascorbic acid and it increased its impact by its multiplier effect in the APTI formula. Studies reveal that ascorbic acid through its reducing power protects chloroplasts against SO_2-induced H_2O_2, O_2- and OH accumulation, and thus protects the enzyme of the CO_2 fixation cycle and chlorophyll from inactivation (Tanaka *et al.*, 1982). Together with leaf pH, APTI plays a significant role in determining the SO_2-sensitivity of plants (Chaudhary and Rao, 1977). Its reducing power is more at higher and lower at low pH values. Thus, it may be possible that ascorbic acid protects chloroplasts and chlorophyll functions from pollutants through its pH-dependent reducing power. RWC, one of the parameters to compute APTI shows the capacity of the cell membrane to maintain its permeability under polluted condition. Thus, the combination of four parameters is suggested as representing the best index of the susceptibility levels of plants under any condition.

5.7 Selection of shrubs for different landscaping uses

5.7.1 Accent plant or specimen plant

An accent or specimen plant is one which, because of its unique stem arrangement, attractive foliage, or particularly showy flowers, stands out from all other plantings in the garden. Specimen shrubs are planted to show off its perfect unusual form, foliage colouring or bloom (Zucker, 1995). Group planting of tall shrubs in odd numbers of three or five can also create interest in the garden style, and can be used as focal point (Miller, 2006).

As focal points of the garden, specimen shrubs must look good all year long. Shrubs provide color to a landscape composition through their flowers, fruits, stems, or foliage (Sinnes, 1980). *Allamanda cathartica* and *Allamanda violacea* have got climbing habitat, when trailed up on peculiar shaped trellis or pergolas, they can be used as accent plants. Their blooming periods are also year round. *Hamelia patens* blooms year round, in profuse. It also produces bead like fruits, and the shrub can be

used as accent plant. Gilman and Meerow (1999) recommended *Hamelia patens* as accent plant, for its year round blooming character as well as its attractive beaded fruits. *Mussaenda erythrophylla*, with its tree like form, when planted single, create interest in the landscape; it also produces profuse blooms profusely round the year. *Nerium indicum* in groups of three or five can be used as a focal point, as its attractive pink flowers produced year round. Group planting is preferred. Scheper (1996) recommended *Nerium indicum* for using as an accent plant.

Among the medium tall shrubs, *Pseuderanthemum reticulatum* with its reticulated yellowish green foliage and whitish flower spikes, when planted in group can act as a centre of attraction. Among the dwarf shrubs, *Russelia juncea* and *Brunfelsia latifolia* can be used for this purpose. *Russelia juncea* when planted at an elevated site, its branches will hang down and produce a cascading effect. *Brunfelsia latifolia* with its flowers changing colour can be used as specimen plant.

5.7.2 Foundation planting

Foundation planting anchors a house to the surrounding landscape (Webber and White, 2002). It also helps to screen the foundation (Ingels, 2009). Most of the shrubs require regular pruning to keep them in shape. Shrubs with geometrical shape and dense canopy are preferred for foundation planting (Jarrett, 2003). Large shrubs should be planted on either side of the porch and at the front corner of the house. The space between are to be filled in with a line of shrubs (Ingels, 1978).

Medium sized and dwarf shrubs are usually used for this purpose. Gilman and Meerow (1999) recommended the use of *Hamelia patens* for foundation planting in front of large buildings because of its geometrical shape. *Pereskia bleo* having compact upright and erect canopy, is suitable for planting along the corner. Tall spreading shrubs are not used for foundation planting. Medium shrubs like *Allamanda nerifolia* with arching form, *Clerodendrum macrosiphon* with round form, *Kopsia*

fruticosa with round form are suitable as foundation plants, especially against plain walls. These shrubs have geometrical shape and compact canopy.

In the dwarf group, *Ixora rosea* have dense canopy and geometrical shape (columnar canopy). *Pseuderanthemum graciliflorum* (spreading form), *Russelia juncea* (cascading form) *Tabernaemontana coronaria* 'Nana' (compact form) and *Tabernaemontana coronaria* 'Variegata' (arching form) are also best suited for foundation planting.

5.7.3 Background planting

Dense leafy plants with simple and consistent leaf texture and dark green, solid leaf colour are preferred for using as a background plant (Snyder, 2000). Tall and medium sized shrubs are usually used for the purpose (Jarrett, 2003).

Among the tall shrubs, *Hamelia patens* and *Calliandra haematocephala* have compact, dense canopy with uniform leaf texture and dark green coloured leaves. In the medium group, plants suited are *Allamanda neriifolia*, *Clerodendrum macrosiphon*, and *Murraya paniculata*. *Thevetia peruviana* can also be used as it has got narrow leaves with solid green colour. Gilman and Meerow (1999) suggested *Hamelia patens* as an excellent background plant for medium sized and dwarf shrubs, as it got dense foliage cover of small leaves. Burke (2005) also recommended *Hamelia patens* for background planting.

According to Fisher (2011) certain plants with their foliage texture or colour, can act as perfect background by making a contrast with the foreground plant. In the dwarf group shrubs, *Tabernaemontana coronaria* 'Nana' can be used as a background for low growing annuals and bulbs. *Lonicera japonica* also provide the same function.

5.7.4 Screening and privacy

Fast growing shrubs with dense foliage are used for screening purpose (Jarrett, 2003). The foliage cover should start from the ground level itself (Klett and Cox, 2012). Taller shrubs serve the dual purpose of providing a background for smaller shrubs, flower beds, and garden features and at the same time serving as a screen (Hyland and Hyland, 1994). In the tall group, *Calliandra haematocephala* with dense foliage from bottom can be used for the purpose. *Pereskia bleo* with upright, closed canopy when planted with closer spacing can act as physical barrier. The thorniness of the shrub also helps in the function. *Hamelia patens* with dense foliage cover can also be used for screening purpose. *Nerium indicum* in line planting can be used for reducing glare in highway median.

Medium group shrubs offer privacy mainly up to chest height. *Allamanda nerifolia*, *Clerodendrum macrosiphon*, *Murraya paniculata, Kopsia fruticosa* and *Rondeletia odorata* can be used for this purpose. Burke (2005) also suggested *Murraya paniculata* for screening purpose. Jarrett (2003) recommended *Tecomaria capensis* for screening use.

5.7.5 Traffic control

For using a shrub for traffic control, its branching pattern should be more vertical and intertwined. Also the branches should be more rigid or stiff. The thorniness of the shrub might also be a desirable feature for traffic control. *Pereskia bleo* with upright branches and closed canopy when planted with closer spacing can act as physical barrier. The thorniness of the shrub also helps in the function. *Kopsia fruticosa* is having stiff, upright branches, and it can be used for traffic control in larger areas. *Murraya paniculata*, when planted in closer spacing, can be used as a physical barrier. For smaller spaces, *Tabernaemontana coronaria* 'Nana' can be used for demarcating the area boundary as well as traffic regulation.

5.7.6 Hedge making

For formal hedges, shrubs used should be having dense canopy with narrow leaves, small, intertwined and upright branches (McIndoe, 2005; Steiner, 2012). Also the shrub should with stand severe pruning. *Tabernaemontana coronaria* 'Nana' is suitable for formal hedge planting. *Murraya paniculata* also can be used for making a formal hedge.

For informal hedge planting, shrubs with upright branches are preferred. In the informal hedges, shrubs are pruned twice in an year (Fisher, 2001). Suitable shrubs recommended based on the study are *Ixora chinensis, Pseuderanthemum reticulatum, Ixora rosea,Kopsia fruticosa* and *Murraya paniculata.* Gilman and Meerow (1999) also recommended *Hamelia patens* for making hedge, but with regular clipping.

5.7.7 Topiary

For making topiary, shrubs used should be having dense canopy with narrow leaves, small, inter-twined and upright branches. Also the shrub should withstand severe pruning. In the present study it was found that *Tabernaemontana coronaria* 'Nana' is suitable for formal hedge planting. *Murraya paniculata* also can be used for making a formal hedge. Whistler (2000) and Little *et.al.* (1974) suggested that *Murraya paniculata* can be pruned into animal and other shapes (topiary).

5.7.8 Shrub group and mass planting

Mass planting of shrubs are done to get big splash of colour or to provide consistency of colour, form, scale and texture (Fisher, 2001). Mass planting is usually done in larger landscapes. Dwarf shrubs and medium growing shrubs are preferred for this landscaping use so that their upper surface area also should be visible. It will give height and textural interest to the composition when compared to traditional ground cover (Scarfone, 2007). Mounding and spreading shrubs look best in a mass (Hansen and Alvarez, 2011). *Odontonema cuspidatum, Otacanthus caeruleus, Allamanda*

cathartica 'Dwarf', *Brunfelsia latifolia*, *Lonicera japonica*, *Tabernaemontana coronaria* 'Nana'and *T.coronaria* 'Variegata' are fitted for this use. *Pseuderanthemum reticulatum* and *Ixora chinensis* were also found to be suited for group planting and mass planting. Harrison (2009) also recommended *Odontonema cuspidatum* for mass planting.

5.7.9 Shrubbery and shrub border

Shrubbery is a wide border of a garden where shrubs are thickly planted. Shrub border is full of different kinds of shrubs, may be intermingled with perennials, bulbs and bedding plants (Bisgrove, 2000). Shrubs are very thickly planted in the borders. So the selected shrub should fit in to the border properly. A shrubbery is made with different rows of plants of different height. In the front row, low growing shrubs are planted. In the middle medium tall shrubs, and in the back row, tall shrubs are planted (Jarrett, 2003).

Medium and dwarf shrubs are best suited for shrubbery and shrub boarder. Among tall growing shrubs, plants with lesser spread are preferred for shrubbery in back row.

Allamanda neriifolia blooming almost all the year, suited for back row planting. *Clerodendrum macrosiphon* is also best fitted into shrub border in the back row, as its dense foliage with purplish tinge and snow white flowers with attractive shape add contrast to the border. *Ixora coccinea* is also suited for back row planting for its yellowish green foliage and scarlet red flowers, are produced year round. *Rondeletia odorata*, and *Tabernaemontana coronaria* are suitable for medium rows in the shrubbery and shrub border. Orwa *et. al.*, (2009) and Jarrett (2003) recommended *Tecomaria capensis* for shrub border, as it compact well in the shrub group. Jarrett (2003) also recommended *Allamanda neriifolia* and *Murraya paniculata* as back row plants for shrub border.

For the front row, low growing shrubs are to be selected. Medium tall shrubs with upright and loose canopy can be planted intermingling with low growing dwarf shrubs. Low growing shrubs like *Brunfelsia latifolia*, *Odontonema cuspidatum*, *Otacanthus caeruleus*, *Pseuderanthemum graciliflorum* and *Russelia juncea* can be best used in the front row of a shrubbery. *Wrightia antidysenterica* can also be used in between the spreading low shrubs. Rogers (2012) recommended *Wrightia antidysenterica* for small spaces, due to its compactness, so that it can be fitted well in shrub border. *Pseuderanthemum reticulatum* and *Ixora chinensis* having similar habitat of *Wrightia antidysenterica*, are suitable for planting in front row along with dwarf shrubs.

5.7.10 Corner planting

In incurve, corner planting is planted with a focal feature such as a specimen plant or an accent plant. The incurve plant is usually taller than the other plants that extend from it to the outer reaches of the corner bed (Ingels, 1978). Specimen plants like *Allamanda cathartica, Allamanda violacea, Hamelia patens* and *Nerium indicum* are suitable for planting in incurves. *Mussaenda erythrophylla* suited for planting in incurves or larger compounds due to its wider spread.

Low spreading specimen plants are more preferred for incurve planting. For out curves, low and spreading plants are suitable (Ingels, 1978). For outcurves, low and spreading plants like *Lonicera japonica* and *Pseuderanthemum graciliflorum* which are low and spreading, are best suited. Dwarf shrubs like *Russelia juncea, Tabernaemontana coronaria* 'Nana', and *Otacanthus caeruleus* are also suitable for outcurves.

5.7.11 Fragrant garden

Fragrant gardens are gardens which are meant to enjoy sweet smell of flowers along with visual beauty. For fragrant garden, fragrant flowered shrubs are used. Pleasant odors positively affect our mood (Inoue *et. al.* 2003).

Under the observed plants, a few shrubs possessed sweet smelling flowers. The fragrance of tall shrubs can be best enjoyed while walking or standing. *Nerium indicum, Thevetia peruviana* and *Bauhinia acuminata* produced fragrant flowers in the tall group. Though their single flower persistence time was very less, their inflorescence persistence time was more. Fragrance of medium group shrubs can be best enjoyed while walking as well as sitting. Under this group, *Murraya paniculata* and *Tabernaemontana coronaria* produced fragrant flowers. The fragrant flowered dwarf shrubs include *Lonicera japonica, Tabernaemontana coronaria* 'Nana' amd *T. coronaria* 'Variegata'. These shrubs should be planted close to sitting benches as their fragrance is best enjoyed at lower height.

5.7.12 Pot and container planting

Low growing and compact shrubs are suitable for planting in pots and containers. In pots single plants are planted while in container, mixed planting is adopted. Shrubs suitable for pot planting should be having dwarf, upright and compact growth habit, with lesser spread. Shrubs suitable are *Tabernaemontana coronaria* 'Nana' *Otacanthus caeruleus*, and *Odontonema cuspidatum*. *Pseuderanthemum reticulatum,* a medium growing shrub, also having low spread, can be used for pot planting.

Scheper (1996) recommended the use of *Nerium indicum* as pot plant. Burke (2005) recommended *Ixora chinensis* for pot planting.

5.7.13 Covering sloppy banks

Plants suitable for bank covers are sprawling shrubs with tenacious roots and tooting stems that hold the soil together. Shrubs which have a fastest spreading rate and having larger ground covering area are found to be ideal for consolidation of slopes. Shrubs for bank covering purpose should be given enough spacing as most of them are fast spreading (Jarrett , 2003).

Among the observed shrubs, *Lonicera japonica* only showed creeping and crawling growth form. It has got a spreading growth habit and dense foliage cover. The root system of the plant was also much extensive.

5.7.14 Xeriscaping

Xeriscaping refers to landscaping and gardening in ways that reduce or eliminate the need for supplemental water from irrigation (Anonymous, 1999).

Plants with xerophytic adaptations are usually planted in a xeriscape garden. The plant will be having either a physical or physiological mechanism or modification to control the water usage. In *Russelia juncea,*the leaves are reduced to minute scales. The photosynthetic activity is undertaken by stem and branches which are also with chlorophyll. *Nerium indicum* is having a thick waxy coating over the epidermis to prevent the water loss. In *Lonicera japonica,*the root system is much extensive, which is also a xerophytic adaptation.These plants are recommended for Xeriscaping.

5.7.15 Moon garden

Moon gardens are those gardens which are meant to enjoy their beauty at late evening hours. The plant selected should be having either white coloured flowers or white, variegated or silvery leaves (Chandoha, 2005). Fragrant white flowers are much preferred for moon gardens.

In the tall group, *Bauhinia acuminata* produced white flowers. In the medium group, *Clerodendrum macrosiphon* produced snow white flowers in profuse at a time. *Murraya paniculata* produced white fragrant flowers. *Pseuderanthemum reticulatum* produced white flowers with reticulated pale yellowish green leaves, which appear beautiful at night hours also. *Tabernaemontana coronaria* produced white fragrant flowers.

In the dwarf shrub group, *Brunfelsia latifolia* produced white and pale violet flowers. *Lonicera japonica* produced fragrant white flowers. This shrub is also low growing so can be planted near walkways. *Tabernaemontana coronaria* 'Nana' produced numerous small white flowers which projected out against the dark foliage background in the nigh hours. *T. coronaria* 'Variegata' is best suited for moon garden as it produces variegated leaves and white flowers as well. *Wrightia antidysenterica* also produced snow white flowers in large number. So these shrubs are recommended for moon garden.

Chandoha (2005) recommended combined usage of plants which flower at different height levels, to make a layered effect. Shrubs from the tall, medium and dwarf groups can be combined to get the layered effect.

5.7.16 Rock garden

Low growing or dwarf shrubs are mainly used in rock gardens. Taller Shrubs are used as companion plants in rock gardens with other plants (Grey-Wilson, 2009). Shrubs with xerophytic characters are used in rock gardens (Webster, 2006). Dwarf shrubs are particularly useful blended with perennials and annuals in a rock garden (Lonnee *et. al.*, 2011).

In the present study *Russelia juncea* is recommended for Xeriscaping as has it got a low growing cascading form. It is also adapted to xerophytic condition, as the leaves are reduced to scales and photosynthesis is undertaken by stem and branches.

Lonicera japonica is having a low creeping form. Its root system is also extensive, which is a xerophytic adaptation.

5.7.19 Butterfly garden

Shrubs were observed for attraction to butterflies. Butterflies were more often visited shrubs like *Hamelia patens, Kopsia fruticosa, Ixora chinensis, I coccinea, I. rosea* and *Odontonema cuspidatum.* Watkins (1975) also observed that *Odontonema cuspidatum* attracts butterflies and hummingbirds that feed on the nectar. These shrubs produced flowers year round. Shrubs like *Calliandra haematocephala, Clerodendrum macrosiphon* and *Murraya paniculata* produced flowers profusely during their blooming periods and attracted more butterflies.

More number of butterflies observed between 10.00 A.M. and 11.00 A.M. Commonly observed butterflies were *Atrophaneura aristolochiae (*common rose), *Catopsilia pyranthe* (mottled emigrant), *Danaus genutia, Delias eucharis* (common jezbel), *Eurema hecabe* (common grass yellow), *Hypolimnas misippus* (danaid eggfly), *Moduza procris* (commander), *Papilio polytes, P. demoleus, P. budha* (Peacock) and *Parantica aglea* (glassy tiger).

Butterfly caterpillar was observed on leaves of *Mussaenda erythrophylla* (commander butterfly), *Pseuderanthemum reticulatum* (milk weed butterfly) and *Nerium indicum* (danaid egg fly). These plants also help to attract butterflies.

5.8 Pest and disease

There were only minor incidences of pest and diseases. The attack noticed include, leaf eating caterpillar in *Nerium indicum, Tabernaemontana coronaria, Calliandra haematocephala, Ixora coccinea* and *Mussaenda erythrophylla,* flower bud borer caterpillar in *Wrightia antidysenterica.* Flower beetle damage was observed on *Tabernaemontana coronaria* 'Variegata' flower. Mealy bug attack was observed in *Nerium indicum, Mussaenda erythrophylla* and *Wrightia antidysenterica* during the

summer period. Ben-Dov *et. al.* (2001) also reported mealy bug attack on *Mussaenda* Sp.. Hardscale incidence was noticed in *Nerium indicum.* Srinivasa (1987) also reported coffee green scale (*Coccus viridis*) attack on *Nerium indicum.*

Leaf spots observed in *Kopsia fruticosa, Ixora coccinea, Pseuderanthemum reticulatum* and *Brunfelsia latifolia.* Leaf blight symptoms were observed in *Tabernaemontana coronaria.*

Summary

6. SUMMARY

The present study entitled "Evaluation of ornamental flowering shrubs for tropical landscapes" was carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from Jan. 2011 to Dec. 2011. The objectives were to evaluate ornamental flowering shrubs for suitability to various landscaping uses and to compute Air Pollution Tolerance Index.

The study comprised of evaluation of 30 tropical ornamental flowering shrub species or varieties for their growth parameters, morphologiacal characters, flowering phenologies, Air Pollution Tolerance Index (APTI) and assessing their potential for various landscaping uses.

The summary of the present study is given below:

1. Morphological descriptions

Thirty ornamental flowering shrubs selected for the study were described morphologically based on plant, leaf and flower characters..

2. Growth parameters

Growth of shrubs was measured in terms of height and spread. Based on the manageable height, they were classified into three groups, *i.e.* Tall (height above 2 m), Medium (height 1m-2m) and Dwarf (height below 1m). Among the 30 shrubs evaluated, the maximum height was observed for *Calliandra haematocephala* (319.4 cm) and the minimum for *Lonicera japonica* (49.9 cm). In tall shrubs, *Calliandra haematocephala* showed highest value for height, followed by *Mussaenda erythrophylla. Pereskia bleo* showed the lowest height in the tall category. In the medium growing group, *Murraya paniculata* showed the highest value for height. *Ixora chinensis* showed the minimum height in this group. In the dwarf shrubs, *Ixora rosea* showed the maximum height which was on par with *Wrighti antidysenterica.* The least height was showed by *Lonicera japonica.*

Plant spread varied from 43.4 cm in *Wrightia antidysenterica* to 269.7 cm in *Calliandra haematocephala*. Regression equation of height for predicting spread was formulated using the monthly data on height and spread. Under tall category, *Calliandra haematocephala* showed the maximum spread. The least spread was observed in *Nerium indicum*. In the medium group, *Ixora coccinea* showed the maximum spread. The least spread in this category was observed in *Ixora chinensis*. *Russelia juncea* showed the highest spread under the dwarf group, which was followed by *Ixora rosea* and *Lonicera japonica*. The least spread in this category was observed for *Wrightia antidysenterica* and *Odontonema cuspidatum*.

Plant height was found to be highly correlated plant spread in most of the shrubs. Spread by height index was calculated for each shrub. Regression equation was formulated for the shrubs, to predict the spread when the height is known. This can be used in designing landscape, for allocation of the shrubs and other plant components.

3. Quantitative and qualitative characters

Quantitative plant characters like length, breadth and area of leaves, length and girth of petiole, internodal length, number of leaves per unit area, flower stalk length, length and diameter of single flower and inflorescence diameter were recorded.
Qualitative plant characters like leaf shape, colour and surface texture, arrangement of leaves, branching pattern, flower/ inflorescence type and position, flower colour and fragrance were also recorded.

4. Plant form, texture and colour

Under the studied shrubs, different canopy silhouettes were observed. Columnar, upright, loose upright, dense upright, open, vase, globular, arching, spreading, compact and clumping types of silhouette forms were observed among the shrubs. *Allamanda cathartica* and *A.violacea* showed vase shaped canopy form, with little support. Their branching form is weeping. Open silhouette form was most common, observed in *Bauhinia acuminata, Thevetia peruviana, Ixora coccinea, Allamanda cathartica* 'Dwarf', *Brunfelsia latifolia,* and *Otacanthus caeruleus.* Shrubs with ascending branching pattern showed open canopy form. Shrubs with upright

branching habit formed dense upright or loose upright canopy form. Loose upright form observed in *Nerium indicum, Pereskia bleo, Ixora chinensis, Pseuderanthemum reticulatum, Wrightia antidysenterica* and *Odontonema cuspidatum.* Dense upright form observed in *Rondeletia odorata.* Round form was observed in *Kopsia fruticosa, Clerodendrum macrosiphon* and *Tabernaemontana coronaria.* Arching canopy was observed in *Hamelia patens, Tabernaemontana coronaria* 'Variegata' and *Mussaenda erythrophylla.* Other observed forms were columnar, creeping, oval cascading, spreading and compact.

Shrubs were grouped in to five textural categories based on their leaf area. They are coarse (more than 100 cm^2), medium coarse (60 -100 cm^2), medium (20 – 60 cm^2), medium fine (10-20 cm^2) and fine (less than 10 cm^2). Among the observed shrubs, leaves with surface area more than 100 cm^2 (coarse texture) were not observed. Four shrubs, *Bauhinia acuminata, Mussaenda erythrophylla, Ixora coccinea* and *Kopsia fruticosa*, came under medium coarse category. Fine textured plants include *Allamanda cathartica* 'Dwarf', *Allamanda neriifolia, Lonicera japonica, Murraya paniculata, Rondeletia odorata, Russelia juncea, Tabernaemontana coronaria* 'Nana' and *Tecomaria capensis.* Ten shrubs came under medium and eight came under medium fine textural category.

All the three categories of colour, i.e. warm, cool and neutral flower colours were observed. Shrubs with warm colours were *Allamanda cathartica, A. cathartica 'Dwarf', Allamanda neriifolia, Calliandra haematocephala, Hamelia patens, Ixora coccinea, I.chinensis, I. rosea, Nerium indicum, Odontonema cuspidatum , Pereskia bleo, Rondeletia odorata, , Russelia juncea,Thevetia peruviana,* and *Tecomaria capensis.* Cool coloured flowers are produced by *Allamanda violacea, Pseuderanthemum reticulatum, Brunfelsia latifolia, Otacanthus caeruleus* and *Pseuderanthemum graciliflorum.* Neutral colour (white) flowers produced by *Bauhinia acuminata, Murraya paniculata, Clerodendrum macrosiphon, Lonicera japonica, Tabernaemontana coronaria, T. coronaria* 'Nana' and *T.coronaria* 'Variegata'. Shrubs like *Lonicera japonica* and *Brunfelsia latifolia* showed colour change in consecutive days.

5. Phenological configurations and identification of side-runs

Shrubs were observed for their visually attractive phenophases, i.e. full blooming and categorized them accordingly. All 30 shrubs were observed for their flowering phenology. Shrubs varied in their blooming time and periodicity. Flowering seasons of the shrubs were observed and accordingly they were categorized into four different phenological phases *i.e.* Dec-Feb, Mar-May, June- Aug and Sep-Nov. Side-runs were observed and phenological configurations were made. Different combinations of plants (side-runs) which behaved identically in a particular time point were found out. In a single phenologial phase different colour combinations were also observed.

6. Air Pollution Tolerance Index

Air Pollution Tolerance Indices of the shrubs were calculated. *Calliandra haematocephala*, *Clerodendrum macrosiphon* and *Mussaenda erythrophylla* showed higher values for APTI. *Allamanda cathartica* 'Dwarf', *Hamelia patens* and *Thevetia peruviana* showed lower APTI values. Shrubs were categorized into sensitive (value ≤14), intermediate (15- 19), medium tolerant (20-24) and tolerant (> 24) groups based on their APTI values. *Calliandra haematocephala, Mussaenda erythrophylla, Clerodendrum macrosiphon* and *Ixora coccinea* came under the tolerant category while *Hamelia patens, Pereskia bleo, Thevetia peruviana, Pseuderanthemum reticulatum, Kopsia fruticosa, Allamanda cathartica* 'Dwarf', *Odontonema cuspidatum, Tabernaemontana coronaria* 'Variegata', and *Wrightia antidysenterica* came under the sensitive category.

7. Selection of shrubs for landscaping uses

Based on the observations made on the plant morphological characters, shrubs were selected for different landscaping uses as given below.

Accent plant or Specimen plant: *Allamanda cathartica, Allamanda violacea, Hamelia patens, Mussaenda erythrophylla, Nerium indicum, Pseuderanthemum reticulatum, Russelia juncea* and *Brunfelsia latifolia.*

Foundation planting: *Pereskia bleo, Allamanda neriifolia, Clerodendrum macrosiphon, Kopsia fruticosa, Ixora rosea, Pseuderanthemum graciliflorum, Russelia juncea, Tabernaemontana coronaria* 'Nana' and *T. coronaria* 'Variegata'.

Background planting: *Hamelia patens, Calliandra haematocephala, Thevetia peruviana, Allamanda neriifolia, Clerodendrum macrosiphon, Tabernaemontana coronaria* 'Nana' and *Lonicera japonica.*

Screening and privacy: *Calliandra haematocephala, Pereskia bleo, Hamelia patens, Nerium indicum, Allamanda neriifolia, Clerodendrum macrosiphon, Murraya paniculata* and *Kopsia fruticosa.*

Traffic control: *Pereskia bleo, Kopsia fruticosa, Murraya paniculata* and *Tabernaemontana coronaria* 'Nana'.

Formal hedge making: *Tabernaemontana coronaria* 'Nana' and *Murraya paniculata.*

Informal hedge making: *Ixora chinensis, Pseuderanthemum reticulatum, Ixora rosea, Kopsia fruticosa* and *Murraya paniculata.*

Topiary: *Tabernaemontana coronaria* 'Nana' and *Murraya paniculata*

Shrub group and mass planting: *Odontonema cuspidatum, Otacanthus caeruleus, Allamanda cathartica* 'Dwarf', *Brunfelsia latifolia, Lonicera japonica, Tabernaemontana coronaria* 'Nana', *T.coronaria* 'Variegata', *Pseuderanthemum reticulatum* and *Ixora chinensis*

Shrubbery and shrub border: *Allamanda neriifolia, Clerodendrum macrosiphon, Rondeletia odorata, Tabernaemontana coronaria, Pseuderanthemum reticulatum, Ixora chinensis, Brunfelsia latifolia, Odontonema cuspidatum, Otacanthus caeruleus, Pseuderanthemum graciliflorum, Russelia juncea* and *Wrightia antidysenterica*

Corner planting: *Allamanda cathartica, Allamanda violacea, Hamelia patens, Nerium indicum* and *Mussaenda erythrophylla* for incurve and *Lonicera japonica Pseuderanthemum graciliflorum, Russelia juncea, Tabernaemontana coronaria* 'Nana' and *Otacanthus caeruleus* for out curve.

Fragrant garden: *Nerium indicum, Thevetia peruviana, Bauhinia acuminate, Murraya paniculata, Tabernaemontana coronaria* and *Lonicera japonica.*

Pot and container planting: *Tabernaemontana coronaria* 'Nana', *Otacanthus caeruleus Odontonema cuspidatum, Pseuderanthemum reticulatum.*

Covering sloppy banks*: Lonicera japonica.*

Xeriscaping: *Russelia juncea, Nerium indicum Lonicera japonica.*

Moon garden: *Bauhinia acuminata, Clerodendrum macrosiphon, Murraya paniculata, Pseuderanthemum reticulatum, Tabernaemontana coronaria, Brunfelsia latifolia, Lonicera japonica, Tabernaemontana coronaria* Nana', *T. coronaria* 'Variegata' and *Wrightia antidysenterica.*

Rock garden: *Russelia juncea Lonicera japonica.*

Butterfly garden*: Hamelia patens, Kopsia fruticosa, Ixora coccinea, I. chinensis* and *I. rosea, Calliandra haematocephala, Clerodendrum macrosiphon* and *Murraya paniculata* for honey and *Calliandra haematocephala, Mussaenda erythrophylla, Pseuderanthemum reticulatum, Tabernaemontana coronaria* and *Nerium indicum* for larval feed.

8. Incidence of pest and disease

Shrubs were observed for pest and disease incidence. Major pests were leaf eating caterpillars in *Mussaenda erythropylla, Nerium indicum, Calliandra haematocephala* and *Ixora coccinea*, flower bud borer in *Wrightia antidysenterica*, mealy bug and scales. Shrubs were not severely affected by diseases. Minor leaf spots were observed in certain shrubs.

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* Original not seen.

Appendix

Appendix 1. Weather data vellanikkara

Months	Temperature (°C)		Relative Humidity (%)		Sun-shine (hrs)	Rainfall (mm)	Number of rainy days
	Max.	Min.	Max.	Min.			
Jan-11	32.7	22.2	76.2	40.6	8.5	0.0	0.0
Feb-11	33.7	22.0	75.3	37.5	8.5	77.5	3.0
Mar-11	34.8	23.9	85.0	43.2	8.7	10.0	2.0
Apr-11	34.3	24.5	88.1	57.7	6.6	207.1	5.0
May-11	33.0	24.9	90.6	63.0	6.8	198.5	7.0
Jun-11	29.3	23.6	95.5	82.4	2.5	799.6	27.0
Jul-11	29.1	22.9	94.8	80.8	1.6	588.2	26.0
Aug-11	29.4	22.9	95.6	78.5	2.2	713.8	25.0
Sep-11	30.0	23.1	94.2	74.7	4.4	435.2	15.0
Oct-11	32.1	23.5	90.7	65.1	6.1	190.0	9.0
Nov-11	31.4	22.9	79.4	56.8	6.3	240.0	9.0
Dec-11	31.9	22.6	75.5	48.5	7.3	2.4	0.0
Jan-12	32.8	21.3	75.2	39.9	9.5	0.0	0.0
Feb-12	35.1	22.1	74.7	33.3	9.2	0.0	0.0
Mar-12	35.2	24.2	86.4	49.4	7.6	4.5	1.0
Apr-12	34.8	24.8	88.5	55.0	6.6	16.0	3.0

EVALUATION OF ORNAMENTAL FLOWERING SHRUBS FOR TROPICAL LANDSCAPES

By

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ABSTRACT OF THE THESIS
Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

The present study entitled "Evaluation of ornamental flowering shrubs for tropical landscapes" was carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from Jan. 2011 to Dec. 2011. The objectives were to evaluate ornamental flowering shrubs for suitability to various landscaping uses and to compute Air Pollution Tolerance Index.

The study involved evaluation of 30 tropical ornamental flowering shrub species or varieties. The selected shrubs were four years old, maintained in the shrubbery of the Department of Pomology and Floriculture. The experiment was laid out in CRD with three replications. Various vegetative and floral characters were recorded and data analysed and correlation studies were made with weather parameters. Shrubs selected for the study were described based on morphological characters.

Growth of shrubs was measured in terms of height and spread. Based on the manageable height, they were classified into three groups, *i.e.* Tall (height above 2 m), Medium (height 1m-2m) and Dwarf (height below 1m). Among the 30 shrubs evaluated, the maximum height was observed for *Calliandra haematocephala* (319.4 cm) and the minimum for *Lonicera japonica* (49.9 cm). Plant spread varied from 43.4 cm in *Wrightia antidysenterica* to 269.7 cm in *Calliandra haematocephala*. Regression equation of height for predicting spread was formulated using the monthly data on height and spread.

Foliage characters like leaf length, leaf area, petiole length, girth and internodal length were measured. Based on leaf area, plants were categorized into medium coarse, medium, medium fine and fine textured. Qualitative characters of the foliage like shape of leaf, base, tip, margin and colour of leaf were observed and used for plant description as well as categorizing them into different texture classes. Shrub canopy shape (silhouette) was observed and used for making schematic diagram.

Qualitative characters of flowers like type of inflorescence, position of inflorescence, colour and fragrance were observed. Time taken to open up the inflorescence from bud stage, persistence of single flower as well as the inflorescence were also observed. Quantitative

characters like inflorescence diameter, single flower length and diameter and number of flowers per inflorescence were also recorded.

Flowering seasons of the shrubs were observed and accordingly they were categorized into four different phenological phases *i.e.* Dec-Feb, Mar-May, June- Aug and Sep-Nov. Side-runs were observed and phenological configurations were made.

Air Pollution Tolerance Indices of the shrubs were calculated. *Calliandra haematocephala* (31.7) showed the highest APTI value and the minimum value was observed for *Allamanda cathartica* 'Dwarf' (9.2). Shrubs were categorized into sensitive (value ≤14), intermediate (15-19), medium tolerant (20-24) and tolerant (> 24) groups based on their APTI values.

Based on the different characters studied, shrubs were classified into different landscape utility groups such as, accent plant, foundation planting, screening and privacy, hedges and topiary, shrub border, background planting, corner planting, Shrub group and mass planting, Pot and Container planting, fragrant garden, moon garden, xeriscaping, rock garden, covering sloppy banks and butterfly garden.

Shrubs were observed for pest and disease incidence. Major pests were leaf eating caterpillars in *Mussaenda erythropylla, Nerium indicum, Calliandra haematocephala* and *Ixora coccinea*, flower bud borer in *Wrightia antidysenterica*, mealy bug and scales. Shrubs were not severely affected by diseases. Minor leaf spots were observed in certain shrubs.

In the present study, shrubs were recommended for various functional uses in the landscapes based on their growth, flowering and morphological characters. Based on flowering season, they were categorized into four phenological phases. Side-runs were observed and phenological configurations were made. Air Pollution Tolerance Indices of the shrubs were also computed and the plants were categorized according to their APTI values.