REVIEW ARTICLE

Bougainvillea (Commerson and Jussieu): A Pollution and Drought Tolerant Plant

Suresh Chandra Sharma[1*], Yogesh Kumar Sharma[2*]

DOI: 10.18811/ijpen.v6i02.02

Abstract

Bougainvillea, native of South American tropics and subtropics, is a tropical and subtropical woody, evergreen, shrubby vine. Due to its brightly coloured bracts, the Bougainvillea is incomparable both in beauty and utility, particularly in the gardens of the tropics and subtropics. It is grown in the ground as well as, in pots. So far worldwide 18 species have been reported and about 300 varieties have been developed. Many crosses among the various species have produced new hybrid species and important horticultural cultivars. It can thrive well in varied conditions of environment and soil. It can grow in most well-drained soils, and even in small pockets of soil in between rocks. Its roots grow deep into the ground, become self-supporting, and require very little care and attention. Bougainvillea is a pollution tolerant plant and can help in the mitigation of air pollution besides its ornamental value. Bougainvillea is used as an accent plant, a specimen plant, in hanging baskets, in containers, and for bonsai purpose. Drought tolerance makes Bougainvillea ideal for warm climates year-round. It is tolerant to salt, drought and resistant to wind. Due to the great demand, this ornamental plant requires the appropriate management of the large scale plant production, and subsequently the adequate logistics. In fact, during the transport Bougainvillea plants are often subjected to a water stress leading to various physiological disorders. Tolerance of plants to a drought stress increases the resistance to the stress during the transport. Botanical Survey of India and CSIR-National Botanical Research Institute, Lucknow has contributed significantly in its varietal development.

Keywords: Bougainvillea, Drought, Pollution, Tolerance.

International Journal of Plant and Environment (2020); **ISSN:** 2454-1117 (Print), 2455-202X (Online)

Introduction

Bougainvillea, commonly called a paper flower plant, belongs to the Nyctaginaceae (four-o'clock) family of plants. Bougainvillea is a tropical and subtropical woody, evergreen, shrubby vine. It has a spreading, round plant habit with a height and spread of up to 20 feet, typically with multi-trunked or clumping stems. It climbs by sending out slender arching canes armed with stiff curved thorns. Leaves are simple and alternate, with an undulate leaf margin. The leaf blade is 2 to 4 inches long, with many variations in shape: globular, elliptical, ovate, or cordate. Leaves are mid- to deep-green, although some cultivars have variegated foliage. The true, perfect flowers are small, tubular, and surrounded by showy, colorful petaloid bracts. The fruit is an elongated achene less than 1/2-inch long. It is rather inconspicuous, not showy, and has a dry, hard fruit cover. Due to its brightly colored bracts, the Bougainvillea is incomparable both in beauty and utility, particularly in the gardens of the tropics and subtropics. It is grown in the ground, as well as, in pots. As they age, the stems turn from mid-green to dull green-brown. It is deciduous when grown in areas with a long dry season. Numerous cultivars are available, with a striking array of colors. Their colorful "flowers" are really bracts, or modified leaves, 1/2 to 2-inch long structures to which the true flowers are attached at the mid-rib. The genus Bougainvillea has 14 species, with three of them horticulturally important: *B. spectabilis* Willdenow, *B. glabra* Choisy, and *B. peruviana* Humboldt and Bonpland. Lately, different authors accept up to 18 species in the genus (Kobayashi *et al*., 2007). Many crosses among the various species have produced new hybrid species and important horticultural cultivars. Bougainvillea tolerates drying if possible irrigations are adjusted to be a little on the dry side. They are sensitive to over-watering but should not be allowed to completely dry out. Bougainvillea needs regular fertilizing with formulations having NPK ratios of 1:1:1 or 2:1:2. Applications of soluble minor elements help prevent leaf chlorosis. Micronutrient application can be half the recommended dose, twice a year. The plant can be propagated through cuttings, leaf bud cuttings, and grafting. Some cultivars that have little or no chlorophyll in their leaves are difficult to grow from cuttings and need to be grafted onto a vigorous rootstock to be propagated. Grafting is useful with delicate cultivars that have a fragile root system. It is also used when it is desired to have multiple cultivars on one plant. Seeds germinate readily and require no treatment to break dormancy. Bougainvillea has been used for many years in mild climatic areas of California as a landscape plant prized for its profuse display of colorful flower bracts. Such floriferousness

[1]CSIR-National Botanical Research Institute, Lucknow-226001, Uttar Pradesh, India

[2]Botany Department, Lucknow University, Lucknow-226007, Uttar Pradesh, India

***Corresponding authors:** Dr. S. C. Sharma, CSIR-National Botanical Research Institute, Lucknow-226001, Uttar Pradesh, India; Mobile: +91-9415343141; Email: scsharmagardener@gmail.com, and

Prof. Y. K. Sharma, Botany Department, Lucknow University, Lucknow-226007, Uttar Pradesh, India; Mobile: +91-9695095516; Email: yogesh_s26@yahoo.com

How to cite this article: Sharma, S. C., & Sharma, Y. K. (2020). Bougainvillea (Commerson and Jussieu): a pollution and drought tolerant plant. International Journal of Plant and Environment 6(2): 103-109.

Source of support: Nil

Conflict of interest: None

Submitted: 20/01/2020 **Accepted:** 25/04/2020 **Published:** 30/04/2020

is highly regarded not only for landscape plants but also for small container-grown plants sold by florists and nurserymen to decorate indoor and outdoor living areas.

History

It is native of South American tropics and subtropics which was first collected by Commerson, a French Botanist from Rio de Janeiro (Brazil) in 1766. Commerson named the plant after Lois Antoine de Bougainville, the renowned French Navigator and the trusted General of Napoleon Bonaparte, Emperor of France with whom he went on a voyage to South America from 1766 to 1769. The original plant brought by Commerson from Brazil was described by A. L. de Jussieu and illustrated by Lamarck in Genera Plantarum in 1789 under the name *B. spectabilis*. The Bougainvillea moved out to Europe during the 19th century. From there it was introduced into tropical Asia, Africa, Australia, New Zealand, and other countries. According to R. E. Holttum(the foremost authority on the Bougainvillea), the species *B. spectabilis* was the first to be introduced in Europe. Another species *B. glabra* was introduced in Britain and Mauritius in 1860, and later brought to Kolkata (Calcutta) in 1869. The year 1910 was marked by a major discovery in the cultivation of Bougainvillea when Mrs. R. V. Butt brought crimson-colored Bougainvillea cuttings from Cartagena (Columbia) to Trinidad. Over the years, *B.glabra* cultivar is undergoing mutations forming variously colored mutants [Fig. 1(a-i)]. Originally thought to be a distinct species, it was named *B. buttiana* in her honor. However, it was later discovered to be a natural hybrid

Fig. 1 (a-i): Multi-coloured marvelous Bougainvilleas

of a variety of *B. glabra* and possibly *B. peruviana*-a "local pink bougainvillea" from Peru. Natural hybrids were soon found of common occurrence all over the world. This plant reached Kew in 1915 and from there it got distributed to India, Africa, Australia, Malaya, and Singapore. For instance, around the 1930s, when the three species were grown together, many hybrid crosses were created almost spontaneously in East Africa, India, the Canary Islands, and Singapore in 1923 (Holttum, 1955). Variously colored mutants have been produced since then. The cv. "Scarlet Queen" was introduced to India directly from West Indies by Mr. Tom Linson in 1920. Percy Lancaster gave the name Scarlet Queen to this variety. The cv. "Scarlet Queen" produced an orange-colored variety, and it was grown in 1932 at Madras in the garden of Mrs. Louis Wathen. It was named as 'Louis Wathen' by Mr. B. S. Nirody. Subsequently, "Majolica Yellow Sports" appeared from "Louis Wathen" and "Mrs. McClean" by spontaneous bud variation, and were named as "Enid Lancaster" and "Mary Baring" (Pal and Swarup, 1974).

S. Percy Lancaster isolated a purple-colored sport from "Scarlet Queen" in 1942 and named it as "Alick Lancaster". The variegated leaved bud sports from Scarlet Queen has been released as cvs "Scarlet Queen Variegata" and "Rao" (Pal & Swarup, 1974). An important floriferous and recurrent blooming seedling was raised by P. S. Swaminathan at Madras from "Princess Margaret Rose", and named it "Mrs. H.C. Buck" (Lancaster, 1951; Holttum, 1955). The famous bicolored variety "Mary Palmer" was isolated from "Mrs. H.C. Buck" in 1949 by S. Percy Lancaster (Holttum, 1955). This Bougainvillea "Mary Palmer", the well known bicolored cultivar sport does not produce original magenta sprays characteristic of "Mary Palmer" and has been named as "Shubhra" (Lucknow) (Sharma, 1969). A colchi-tetraploid form of *B. spectabilis* var. "Shubhra" raised at National Botanic Gardens has, however, been named and registered as *Baugainvillea spectabilis* var. "Dr. B. P. Pal" (Zadoo & Khoshoo, 1976). Sterile cultivars were the main obstacles in the breeding of Baugainvillea. To overcome the problem of pairing in meiosis is really a critical issue to deal with. However, sterile diploid inter-specific cultivars can regain fertility by colchicine treatment, one of the ways to double sets of chromosomes, which could deal with the problem of pairing. Khoshoo and Zadoo (1969) got success in restoring the fertility of some sterile cultivars and developed hundreds of seedlings with polyploidy.

"Thimma" with variegated foliage and "Shubhra" with pure white bracts were evolved as a sport of Mary Palmer (Pal & Swarup, 1974). The history of the documentation of Bougainvillea is approximately 250 years old. Today, Bougainvillea is commonly grown in gardens and open lands in countries of tropical Asia, such as, India, Pakistan, Ceylon, Myanmar, Singapore, Malaysia, Mauritius, and the Philippines. It is also popular in Africa, especially in Kenya, Nairobi, Natal, Jamaica, and Pretoria. In Europe, it is successfully grown in France, Italy, Spain, Britain, and Germany. In the USA, it thrives in the gardens of Florida, California, and Hawaii. The Bougainvillea is found growing both as a wild and as a cultivated garden plant in its native home in South America, in places like Brazil (especially Rio de Janeiro), Colombia, Ecuador, and Peru. Trinidad is also famous for its Bougainvilleas. On a plant collection tour, *Bougainvillea arborea* was collected from Yercaud (Tamilnadu) in 1995. *B. arborea* is a unique plant with a trunk 7 to 8 meters in diameter, which grows up to 15 to 20 meters. It is a thornless variety bearing mauve-colored sweet-scented bracts (Fig. 2).

Growing Bougainvillea

It does not require any special methods of growing and can thrive well in varied conditions of environment and soil. It can grow in most well-drained soils, and even in small pockets of soil in between rocks. They grow luxuriantly in the light sandy soils of Rajasthan and the red soils of Andhra Pradesh. Once the plant gets established, its roots grow deep into the ground, become self-supporting, and require very little care and attention. Bougainvilleas grow best in full sun. High light intensity is required for good flowering. Low light and shady areas are not suitable, as the plants drop their bracts. Bougainvillea does best at elevations from 10 to 2,500 feet. It can tolerate hot dry locations, with temperatures over 100°F. It does well in locations with a minimum of 65°F at night and 75 to 95°F during the day. The *B. glabra* can tolerate slightly cooler conditions (58–64°F) than *B. spectabilis* (64–68°F). Bougainvillea does best with at least 25 inches of rainfall per year. Bougainvillea grows well in rich, well-drained, and acidic (pH 5.5–6) soil. It does not thrive in soil that is constantly wet. Proper soil pH is essential because it affects the availability of mineral elements. A soil pH above 6 increases the possibility of micronutrient deficiency, particularly iron. Bougainvillea is drought tolerant, salt-tolerant, and wind-resistant. Bougainvillea is very susceptible to girdling during a storm. The bark gets rub off at ground level when stems whip in high-speed winds. The plant is slow to recover from this, compared to other shrubs. If girdling is severe, the entire plant will wilt a few days after a storm. Bougainvillea responds well to pruning. Unless they are pruned regularly, bougainvillea grows into a tangled mass of old and new growth, and overcrowding often leads to pests and diseases. To prevent overcrowding, any undesired shoots

Fig. 2: Bougainvillea arborea

are cut out. All lateral shoots may also cut back leaving two or three buds on the main stem. They bear new flowers and bracts. Regular pruning is necessary to shape the plant and direct its growth because the shoots often grow vigorously. Flowers are borne on new growth, therefore, pinching back and pruning is necessary to induce new growth. Pruning is done after flowering is over. This encourages the new growth on which the next flush of flowers appears. It is not planted in an extremely windy, unprotected area. No pests or diseases are of major concern but occasionally leaf-chewing worms or aphids attack it.

Pollution Tolerance

Environmental pollution adversely affects the health of people. Environment Protection Act 1986 (EPA, 1986) defines a pollutant as any solid, liquid, or gaseous substance present in a concentration as may be, or tend to be injurious to the environment. Air is necessary for the survival of all higher forms of life on earth. Pollution, the major problem in an urban area is compounded by the fact that there is no exhaust for the polluted air to escape. Landscape architects can solve the pollution problems related to urban landscape by creating a micro-climate. There are various ways to mitigate environmental pollution. It is one of the major challenges that the world is facing today. Air pollution is any variation in any atmospheric element than the value, which would have existed without human interference. Vehicular pollution amounts to about 2/3rd of air pollution in the urban cities. The main pollutants released by the vehicles include carbon monoxide, nitric oxide, sulfur dioxides, hydrocarbons, lead (Pb), etc., in addition to the suspended particulate matter (SPM), which has deleterious effects on the human health and ecological balance (Desai, 2018; Orliński *et al*., 2019). Among the various categories, air pollution by automobiles is the most insidious one, which exerts highly detrimental effects on living organisms. Ambient air pollution in several large cities of India is amongst some of the highest in the world (Agarwal, 2005). Among various strategies of controlling atmospheric pollution, absorption of gaseous pollutants by plants, provide one of the natural ways of cleansing the atmosphere (Varshney & Varshney, 1985) and they act as effective indicators of air pollution (Rai *et al*., 2009).

Recent studies have explored the possibility to find out the ability of plants to remove and also act as sinks for air pollutants (Dwivedi & Tripathi, 2007; Tripathi & Gautam, 2007). For the purpose, biomonitoring is a must. It is a low cost and valuable method to evaluate the effect of different air and environment pollutants (Oliva *et al*., 2007). The air pollution tolerance index (APTI) based on four parameters, namely total chlorophyll, ascorbic acid, pH, and relative water content has been used for identifying the tolerance levels of these species (Singh & Rao, 1983). APTI has been extensively used to rank plant species in their order of tolerance to air pollution (Singh & Rao, 1983; Raza & Moorthy, 1988). Evaluation of APTI of 10 selected wild plant species was carried out to assess their response to ambient levels of air pollutants along the busy roadways of Bangalore. Four parameters namely total chlorophyll, ascorbic acid, pH of leaf extract, and relative water content were determined and computed together to signify APTI of plants. A comparison of APTI values from control to polluted sites revealed a maximum reduction in *Bougainvillea spectabilis,* while the least change was noted in *Peltophorum pterocarpum*. Among the plants studied maximum net percent reduction of APTI over control was seen in *B. spectabilis*. It showed that Bougainvillea is a pollution tolerant plant and can help in the mitigation of air pollution besides its ornamental value in the landscaping (Sharma *et al*., 2005). It is also drought-tolerant, salt-tolerant, and wind-resistant (Kobayashi *et al*., 2007).

Bougainvillea glabra for vehicular pollution showed tolerance against the stress as depicted by its greater air pollution tolerance index and excellent anticipated performance index (API). Therefore, this plant is suggested as a model plant to be grown on the roads to reduce the particulate matter owing to its high dust trapping capacity in addition to its tolerance as shown by its high APTI and API values. Among various strategies of controlling atmospheric pollution, absorption of gaseous pollutants by plants provides one of the natural ways of cleansing the atmosphere (Varshney & Varshney, 1985) and they act as effective indicators of air pollution (Rai *et al*., 2009). Recent studies have explored the possibility to find out the ability of plants to remove and also act as a sink for air pollutants (Dwivedi & Tripathi, 2007; Tripathi & Gautam, 2007). Bioremediation by using selected plant species is also an effective method to control pollution which is universally accepted. From the rich germplasm collection in NBRI Botanical Garden, tolerant plants have been tested for roadside plantation in view of

Fig. 3 (a-c): Bougainvilleas growing in different pots

mitigating the environmental pollution (Sharma *et al*., 2005). For selecting the plant species for pollution control the important characteristics could be-evergreen plants, large-leaved, rough bark, indigenous, ecologically compatible, requiring low water and care, high absorption of pollutants, resistant to pollutants, agro-climatic suitability, height, and spread, canopy architecture, growth rate and habit (straight undivided trunk), aesthetic effect (foliage, conspicuous and attractive flower color), pollution tolerance, and dust scavenging capacity.

Plants growing in the dusty environment generally show visible injury symptoms as the surface of the leaf got deposited with a heavy load of particulate pollutants emitted anthropogenically and naturally into the atmosphere through industrial processes, road traffic, as well as, volcanic eruptions and dust storms, etc. The use of vegetation in filtering out the dust, soot, and particulates from the atmosphere has long been accepted, and it is a common practice in some developed countries. A large quantity of dust cover on vegetation has been observed by Yunus *et al*. (1982, 1985) on eight common plants sampled from open fields and closed canopy of the plants, and a convincing relationship between their morphological traits and the number of particulates in the ambient air was established. As plants are very efficient in trapping atmospheric particles, leaves have been used as monitors of particulate pollution (Nriague, 1989). The deposition of dust depends on the physical characteristics of particles, such as, their size, shape, and also plant species (Harrison & Yin, 2000). Depending on the dust load, duration, and tolerance of the plants, particulates may cause negative changes in the leaf surface, the ultra structure of cells, inhibition of growth, and reduction in the area of leaves, which ultimately reduce the photosynthetic efficiency and total biomass.

The foliar surface of plants is continuously exposed to the surrounding atmosphere and is, therefore, the main receptor of particulate pollutants. This physical trait can be used to determine the level of particulate pollution in the surroundings, as well as, the ability of individual plant species to intercept and mitigate particulate pollutants. Kulshreshtha *et al.* (2009) studied the leaf cuticle characters of four common roadside plant species, *viz*., *Bougainvillea* "Mahara" and others, and concluded that it is a dust mitigator and adsorbs the pollutants from the environment, in which it grows.

Green vegetation acts as a sink for particulate air pollutants and is considered an ecologically sustainable, cost-effective strategy to mitigate the ill effects of air pollution in industrialized areas and the urban environment. In this context, the assessment of APTI offers a simple tool for screening and identifying plants that tolerate air pollution. In a study conducted by Manjunath and Reddy (2019), six plants commonly growing in the polluted regions of Bengaluru, including *B. spectabilis*, were selected for assessing the air pollution tolerance response and compared with the plants grown in non-polluted sites of Bengaluru to analyze the response to air pollution. APTI correlations with the biochemical and physicochemical parameters were analyzed to identify the important determinants of air pollution tolerance. Among the plants evaluated, they observed high APTI (> 23) in *B. spectabilis* and *Vinca rosea* indicating that these plants are tolerant to air pollutants at the chosen sites. It was also suggested that *B. spectabilis* with APTI score of > 16 can be used as a green belt in polluted areas.

Plants in urban areas play an essential role to cleanse the pollution in the human environment. Kumar *et al.* (2016) described the choice of eco-friendly plant species among the trees and shrubs, and their right placement in the urban environment to overcome the pollution problems on the basis of their APTI. Plant species (shrubs) are arranged in decreasing order of their APTI (Table 1).

Heavy metals, such as, lead, have caused deleterious effects not only to the environment but also to public health. In the Philippines, the ornamental plant Bougainvillea has been planted on the main roads of cities due to its capacity to thrive in heavily polluted areas. Studies show that Bougainvillea may be utilized to reduce heavy metal pollution through absorption and adsorption in soil and air, respectively.

Drought Tolerance

Drought tolerance is the ability to which a plant maintains its biomass production during arid or *drought* conditions. Plants that have relatively low water requirements or plants that are well adapted to an arid climate are often described as drought-resistant or drought-tolerant. Bougainvillea is drought and salt tolerant, and wind-resistant plant. Bougainvillea is used as an accent plant, a specimen plant, in hanging baskets, in containers, and for bonsai (Kobayashi *et al*., 2007). Drought tolerance makes Bougainvillea ideal for warm climates year-round. Native to the coasts of Brazil, it has a high salt tolerance, which makes it a natural choice for coastal regions.

limited water supply. It is widely used in the arid landscapes in horticulture, agriculture, and environmental industries due to its high adaptability in different agroclimatic conditions

Table 1: Certain physiological parameters and APTI in different plant species

Plant species	*T*	*A*	*P*	*R*	*APTI*
Bougainvillea spectabilis	11.7	6.1	12.39	74	30
Calotropis gigantes	13	6.4	9	94	27
Poinsettia sp	17.1	6	7	80	24
Ricinus communis	17.2	6.2	5	93	21
Citrus lemon	6.68	6	6.25	74	15
Lantana indica	7.51	7.64	6.3	65	14
Rosa indica	4.5	5.5	4.75	74	12

T = total chlorophyll (mg per gram of dry weight); A = ascorbic acid (mg per gram of fresh weight); P = leaf extract pH; R = relative water content (%)

and regions around the world (Saifuddin et al., 2010). Potted *Bougainvillea* plants are a significant part of the Italian ornamental plant industry due to its high demand in national and international markets. Bougainvillea is a genus of thorny ornamental plants that are native to South America. There are more than 300 varieties all over the world. It is one of the best drou ght-tolerant plants that thrive in extremely hot conditions.

Cirillo *et al.* (2015) evaluated the agronomical and physiological responses of five flowering potted Bougainvillea genotypes: *B. glabra* var. Sanderiana, *B. glabra* var. "Variegata," *B. buttiana* var. "Raspberry Ice," *B. buttiana* var. "Rosenka," and *B. aurantiaca* "Lindleyana," widely grown in the ornamental industry. Irrigation treatments were based on daily water use (100, 50, or 25%). The shoot, total biomass, leaf number, and total leaf area decreased in response to an increase in water stress, whereas the number of flowers increased. The total biomass reduction in 50 and 25% treatments was 10 and 18%, respectively, indicating that the severity of the water stress was an important aspect. A number of tolerance mechanisms, such as, increase in stomatal resistance, a decrease in leaf water potential, and in leaf osmotic potential have been observed especially under 25% of water use treatment. The five genotypes studied showed major differences in morphological and physiological responses. As far as water stress tolerance is concerned the two genotypes *B. glabra* var. Sanderiana, *B. glabra* var. 'Variegata" has good potential for use as potted flowering plants (Fig. 3). The adoption of irrigation scheduling, based on 50% of the water has been considered as an effective tool to improve the commercial quality of Bougainvillea. Mansouri and Kurup (2009) enhanced the water stress tolerance by a combination of triadimefon with irrigation frequencies in Bougainvillea. The stomata from the abaxial epidermal peels in the triadimefon treated leaves were sunken, narrow, and appeared partially closed. Both the triadimefon treatments increased the number of trichomes compared to the leaf samples of control plants. Formation of epicuticular wax in treated plants was also noticed, which was probably formed to act as a barrier against water loss, which provides protection against moisture stress in plants.

Effects of paclobutrazol (PP333) on morphology and drought tolerance of Bougainvillea was studied by Ting *et al.* (2014). The result showed that the growth of Bougainvillea was apparently retarded by PP333, and the purpose of controlling morphological features was achieved. The drought tolerance of Bougainvillea was significantly improved by PP333, which was found to be related with the increase in contents of antioxidants in PP333 treated Bougainvillea. In this study, PP333 was found effective in controlling the morphology and increasing the drought tolerance of Bougainvillea, and could be utilized to save the labor costs.

Due to great demand, this ornamental plant requires the appropriate management of the large-scale plant production, and subsequently the adequate logistics. In fact, during the transport Bougainvillea plants are often subjected to water stress leading to various physiological disorders. Although in some cases the controlled water stress is required to control plant height and width, e.g., in *B. spectabilis* (Ma & Gu, 2012) where uncontrolled water stress leads to severe damages of plant material. Currently, little is known about the physiological disorders occurring in the potted plants under water stress conditions. Drought tolerance might be increased by irrigation regime control (Fernández *et al*., 2006). In the study of Li and Yang (2009), the water use efficiency of *Bougainvillea glabra* was reported highest after four days of water stress, indicating that moderate water stress improves water use efficiency. These findings suggest that the pre-adaptation of the plants to drought stress may increase resistance to the stress during the transport.

Landscape Uses

Bougainvillea's growth habit and beautiful showy bracts make it a popular plant for landscapes. It is used in a mass planting, as shrub or bushes, and as ground cover on banks. Bougainvillea provides hedges, barriers, and slope coverings. For large, difficult-to-maintain areas, it is an excellent ground cover. It can cover a whole hillside and can check weed growth. Dwarf cultivars make colorful ground covers. Bougainvillea can be trained as a "standard," a small flowering tree with a single trunk, over arbors, into espaliers, onto walls, or to cascade down a slope. Bougainvillea is also grown as an accent plant, a specimen plant, in hanging baskets, in containers, and for bonsai. Giving plants enough room to grow to maturity without being crowded, its most cultivars do well 6 to 9 feet apart. Smaller cultivars can be planted closer together at 3 to 5 feet spacing. Bougainvillea should not be planted within 4 feet of walkways, as the thorns could catch unsuspecting passersby. In Hawaii, flowering is heaviest from September to April in Bougainvillea. Flowering is promoted by short day length. In addition, cultural practices are important to ensure satisfactory flowering, like avoiding over-watering, over-fertilizing with nitrogen, putting plants in heavy shade, and pruning too frequently. The flowering peak in Guam occurs during the dry months of March through May.

Contribution of CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow, India

Considering the importance and utility of its genetic diversity, CSIR-National Botanical Research Institute (NBRI), Lucknow, India is maintaining a rich *Bougainvillea g*ermplasm collection of approximately 180 species/cultivars comprising both single bracted and double or multi-bracted varieties. NBRI has detected, induced, isolated, established, and commercialized a series of new varieties developed through spontaneous mutation, selective hybridization, chromosome management through colchicine treatment, and gamma ray-induced mutation. Studies have solved many taxonomic problems and phylogenetic relationships, and have also opened a new way to develop new varieties through chromosomal manipulations. Salem *et al*. (2017) have also summarized the evolution of Bougainvillea. In the last decade, its pollution resistance quality has been discussed by the different schools of thought, especially the National Botanical Research Institute, Lucknow.

For its promotion, Bougainvillea Society of India (BSI) was founded by Dr. B. P. Pal from 1962 to 1963 with the main objective to organize the Bougainvillea festival every year to create awareness among the people. BSI, New Delhi has more than 350 life members. Division of Floriculture and Landscaping (Indian Agricultural Research Institute, New

Delhi) is the International Bougainvillea Registration Authority, appointed by the International Society for Horticultural Science, Belgium, for registration of Bougainvillea germplasm since 1966. It has compiled a checklist of about 300 varieties developed all over the world. This check-list is a very useful document for reference purposes providing authentic descriptions of the varieties. At present, the repository maintains more than 95 varieties of Bougainvillea. Datta (2004) has written an overview of the research and development activities carried out at NBRI on Bougainvillea along with some important work done at other organizations. Recently, a technical note on bibliographical studies on Bougainvillea has been written by Singh (2019). Jianyong and Singh (2019) have also comprehensively reviewed the migration of Bougainvillea and its domestication.

References

Agrawal, M. 2005. Effects of air pollution on agriculture: An issue of national concern. *National Academy Science Letter* **28**:93-106.

Cirillo, C., Rouphael, Y., Caputo, R., Raimondi, G. and De Pascale, S. 2015. Water stress responses of five potted Bougainvillea genotypes. *Acta Horticulturae* **1107**:203-208.

Datta, S.K. 2004. Bougainvillea research at National Botanical Research Institute, Lucknow. *Journal of Ornamental Horticulture* **7**(1):1-14

Desai, A.A. 2018. A review on assessment of air pollution due to vehicular emission in traffic area. *International Journal of Current Engineering and Technology* **8**(2):356-360.

Dwivedi, A.K. and Tripathi, B.D. 2007. Pollution tolerance and distribution pattern of plants in surrounding area of coal-fired industries. *Journal of Environmental Biology* **28**(22):257-263.

Environment Protection Act, 1986. Govt. of India, Environment Protection Act, 1986.

Fernàndez, J.A., Balenzategui, L., Banon, S. and Franco, J.A. 2006. Induction of drought tolerance by paclobutrazol and irrigation deficit in *Phillyrea angustifolia* during nursery period. *Scientia Horticulturae* **107**:277-283.

Harrison, R.M. and Yin, J. 2000. Particulate matter in the atmosphere: Which particle properties are important for its effect on health? *Science of the Total Environment* **249**:85-101.

Holttum, R.E. (1955). The cultivated bougainvilleas III: The varieties of *Bougainvillea glabra*. *Malayan Agri-Horticultural Association Magazines* **12**:2-11.

Jianyong, Y. and Singh, S. 2019. Migration of Bougainvillea and its domestication: A study. *The Journal of the Greens and Gardens* **2**(2-3):6-12.

Khoshoo, T.N. and Zadoo, S.N. 1969. New perspectives in Bougainvillea breeding. *Journal of Heredity* **60**(6):357-360.

Kobayashi, K.D., McConnell, J. and Griffis, J. 2007. Bougainvillea. *Ornamentals and Flowers* **38**:1-12.

Kulshreshtha, K., Rai, A., Mohanty, C.S., Roy, R.K. and Sharma, S.C. 2009. Particulate pollution mitigating ability of some plant species. *International Journal of Environmental Research* **3***(1):*137-142.

Kumar, D., Singh, B. and Sharma, R.A. 2016. Research article: Some ethnomedical plant species of Nagpur district and their role in control of air pollution. *International Journal of Advanced Research* **4**(9):368-373.

Lancaster, S.P. 1951. The white Bougainvillea in India. *Journal of Royal Horticultural Society* **76**(8):278.

Li, Y. and Yang, Y. 2009. The effect of water stresses to photosynthesis of *Bougainvillea glabra*. *Northern Horticulture* **1**:181.

Ma, S. and Gu, M. 2012. Effects of water stress and selected plant growth retardants on growth and flowering of "raspberry ice" bougainvillea (*Bougainvillea spectabilis*). *Acta Horticulturae* **937**:237-242.

Manjunath, B.T. and Reddy, J. 2019. Comparative evaluation of air pollution tolerance of plants from polluted and non-polluted regions of Bengaluru. *Journal of Applied Biology and Biotechnology* **7**(3):63-68.

Mansouri, A.J.A. and Kurup, S.S. 2009. Triadimefon induced physiological and ultra structural changes for moisture stress protection in Bougainvillea (*Bougainvillea spectabilis* Willd) at nursery stage. *Emirates Journal of Food and Agriculture* **21**(1):48-58.

Nriagu, J.O. 1989. A global assessment of natural sources of atmospheric trace metals. *Nature* **338**:47-49.

Oliva, S.R., Castrillon, B.V., Dolores, M. and Alvarez, M. 2007. *Nerium oleander* as a means to monitor and minimize the effects of pollution. *Bocconea* **21**:379-384.

Orliński, P., Gis, M., Bednarski, M., Novak, N., Samoilenko, D., and Prokhorenko, A. 2019. The legitimacy of using hybrid vehicles in urban conditions in relation to empirical studies in the WLTC cycle. *Journal of Machine Construction and Maintenance* **1**:25-30.

Pal, B.P. and Swarup, V. 1974. Bougainvilleas. I.C.A.R., New Delhi.

Rai, A., Kulshreshtha, K., Srivastava, P.K. and Mohanty, C.S. 2009. Leaf surface structure alterations due to particulate pollution in some common plants. *Environmentalist* **30**:18-23.

Raza, S.H. and Murthy, M.S.R. 1988. Air pollution tolerance index of certain plants of Nacharam industrial area, Hyderabad. *Indian Journal of Botany* **11**(1):91-95.

Saifuddin, M., Hossain, A.B.M.S., Osman, N., Sattar, M.A., Moneruzzaman, K.M. and Jahirul, M.I. 2010. Pruning impacts on shoot-root-growth, biochemical and physiological changes of *Bougainvillea glabra*. *Australian Journal of Crop Science* **4**(7):530-537.

Salam, P., Bhargav, V., Gupta, Y.C. and Nimbolkar, P.K. 2017. Evolution in Bougainvillea (*Bougainvillea* Commers.): A Review *Journal of Applied and Natural Science* **9**(3):1489-1494.

Sharma, S.C. 1969. A new sport of Bougainvillea. *Indian Horticulture* **13**(3):20-31.

Sharma, S.C., Srivastava, R., and Roy, R.K. 2005. Role of bougainvilleas in mitigation of environmental pollution. *Journal of Environmental Science & Engineering* **47**(2):131-134.

Singh, S. 2019. Technical Note: Bibliographical studies on *Bougainvillea*: An International Journal of Floriculture Science and Landscaping. *The Journal of the Greens and Gardens* **2**(2-3):48-53.

Singh, S.K. and Rao, D.N. 1983. Evaluation of the plants for their tolerance to air pollution. Proceedings Symposium on Air Pollution Control held at IIT, Delhi, pp. 218-224.

Ting, C., Yun-Hua, W. Ai-Min, W., Yun-Quan, L. and Wei, L. 2014. Effects of Paclobutrazol on Morphology and Drought Tolerance of Bougainvillea. *Southwest China Journal of Agricultural Sciences* **2014**:01.

Tripathi, A.K. and Gautam M. 2007. Biochemical parameters of plant as indicators of air pollution. *Journal of Environmental Biology* **28**(21):127-132.

Varshney, S.R.K. and Varshney, C.K. 1985. Response of peroxidase to low levels of SO_2. *Environmental and Experimental Botany* **25**:107-114.

Yunus, M., Dwivedi, A.K., Kulshreshtha, K. and Ahmad, K.J. 1985. Dust loadings on some common plants near Lucknow city. *Environmental Pollution* (Ser. B) **9**:71-80.

Yunus, M., Kulshreshtha, K. and Ahmad, K.J. 1982. Surface replica by Elmer"s Glue: A new imprinting material. *Microchimica Acta* **85**(3):25.

Zadoo, S.N. and Khoshoo, T.N. 1976. Genesis of Bougainvillea "Shubhra" and "Dr. B.P. Pal". *Indian Journal of Horticulture* **33**(1):60.