

**STUDIES ON MORPHOLOGICAL DIVERSITY IN
BOUGAINVILLEA (*Bougainvillea* Comm. ex. Juss.)
CULTIVARS**

M.Sc. (Hort.) Thesis

by

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VISHWAVIDYALAYA, RAIPUR (C.G.)
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**Submitted to the
Indira Gandhi Krishi Vishwavidyalaya, Raipur**

by

Supriya N

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DEGREE OF
Master of Science
in
Horticulture
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CERTIFICATE-I

This is to certify that the thesis entitled "**Studies on Morphological Diversity in Bougainvillea (Bougainvillea Comm. ex. Juss.) cultivars**" submitted in partial fulfilment of the requirement for the degree of **Master of Science in Horticulture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **Supriya N** under my guidance and super vision. The Subject of the thesis has been approved by student's advisory committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by her.

Date: 22-07-2019


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CERTIFICATE-II

This is to certify that the thesis entitled "**Studies on Morphological diversity in Bougainvillea (*Bougainvillea* Comm. ex. Juss.) cultivars**" submitted by **Supriya N** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirements for the degree of **Master of Science in Horticulture** in the **Department of Floriculture and Landscape Architecture** has been approved by the external examiner and student advisory committee after oral examination.

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LIST OF NOTATIONS/SYMBOLS

% - Percent

/ - Per

°C - Degree Celsius

cm - Centimeter

CV - Coefficient of Variance

et al. - Co workers

etc. - Etcetera

Fig - Figure

i.e. - That is

var. - Variety

viz. - videlicet

S. E.(m)- Standard Error of mean

SD - Standard deviation

mm-Milimeter

LIST OF ABBREVIATIONS

DUS- Distinctiveness, Uniformity and Stability

GCV- Genotypic Coefficient of Variance

PCV- Phenotypic Coefficient of Variance

PPV&FRA- Protection of Plant Varieties and Farmer's Rights Authority

Govt.- Government

IGKV- Indira Gandhi KrishiVishwavidyalaya

IARI-Indian Agricultural Research Institute

CSIR -NBRI-National Botanical Research Institute

IIHR- Indian Institute of Horticultural Research

BARC- Bhabha Atomic Research Center

COA- College of Agriculture

ANOVA - Analysis of Variance

Min- Minimum

Max- Maximum

d.f.- Degree of Freedom

h^2 %- Heritability

GA % m- Genetic Advance as percent of mean

r_g - Genotypic correlation

r_p - Phenotypic correlation

MSL- Mean Sea Level

CHAPTER I

INTRODUCTION

Bougainvillea is a magnificent ornamental shrub called “Glory of gardens” because of the flourishing nature in gardens. It is prominently grown in much of the tropics and sub-tropics of the world. The trivial flowers are surrounded by, dazzling coloured papery bracts, which persist long on plant, range from magenta to white includes, red, scarlet, yellow, crimson, pink, purple, orange, mauve and few are dual coloured and multi-coloured on same bracts (Pal and Swarup, 1974). These evergreen shrubs are hardy and versatile; secure a predominant position in landscape gardening. It can be managed in pots, trained as hedge, topiary, bonsai, espaliers, hanging baskets and cascade (Singh *et al.* 2012). It is spread vertically on walls, forms beautiful forth on arches and climbs up a trellis. Landscape designers exploit Bougainvillea significantly as a softscape element in indoor and outdoor gardens. Due to their profuse blooming habit, Bougainvilleas are planted along highways, railway stations, and roadsides, in industries, airports, hospitals, and schools. It is tolerant to high light intensity, salt and drought, it can be grown in dry seasons when it gets water occasionally. It is very well grown in different agro-climatic conditions in India. It flourishes well up to an altitude of 2300 MSL, despite in waterlogged situation.

In India, Bougainvillea gained a lot of popularity due to their adaptability and free blooming habit. The genus (*Bougainvillea* Comm. ex Juss.) belongs within the family Nyctaginaceae. The Bougainvillea is a national flower symbol of Zambia. The Species *Bougainvillea glabra* and *Bougainvillea spectabilis* are entitled as the national flower of Grenada. It is well known in Asian countries viz., India, China, Korea, Malaysia, Myanmar, Srilanka, Singapore, Thailand, Taiwan, Philippines, and Mauritius, due to well suited climatic conditions for plant growth and flowering. The plants are frost sensitive; therefore, it requires frost management in North America and Europe. The Bougainvilleas are lavishly blooms during Feb- April, and Aug-Sept in fortunate parts of South India viz., Mysuru, Bengaluru, Chennai, Mangaluru, and Hyderabad (Roy 2019). In central and towards Western parts uaually extended year-round blooming. In Northern

India viz., Delhi, Chandigarh, Patiala, and Lucknow, blooming takes place during the Sept-Dec and Feb-June. They undergo dormancy during cooler days (Dec-Jan) because of low sunlight.

The Bougainvillea was initially discovered in 1768 by Dr. Philibert Commerson, a French botanist and explorer, while ship anchored off in Rio de Janerio in Brazil, South America. It was named after his companion Louis Antonie de Bougainville, admiral of an expedition that went around the world in 1766-69. The genus name Bugainvillea was published in Genera Plantarum in 1789 by A.L. de Jussieu. However, after several changes finally, the genus was corrected and accepted as *Bougainvillea* by Spach (1841). The plant was introduced to Europe, which was the chief centre for introduction and domestication during the 19th century and then introduced to tropical Asia, Africa, New Zealand, Australia and the rest of the world (Pal and Swarup, 1974). The British Government played a crucial role in the introduction of Bougainvillea to India through the Agri-Horticultural Societies in 1860 (Roy *et al.* 2012). To a great extent the Agri-Horticultural Society of India, Alipore, Calcutta played a revolutionary role. Royal Botanical Garden, Kew introduced *B. spectabilis* to India through this society. Therefore, the enhancement works in society was initiated by the well-known British horticulturist Mr. S. Percy Lancaster. He developed a foremost variety 'Scarlet Queen Variegata' in India in early 1926.

The introduction of crimson variety 'Mrs. Butt' through the Royal Botanic Garden, Kew in 1923 to Agri-Horticultural Society in India. It created wonders in domestication and improvement of Bougainvillea in India. The variety 'Mary Palmer' was developed by Mr. S. P. Lancaster, which relieved in the domestication of Bougainvillea in distinctive parts of India. The variety 'Princess Margret Rose' was developed by Agri-Horticultural Society in Madras in 1935. Lalbagh Botanic garden, Bangalore also done admirable work by releasing a mutant variety Thimma in 1960 and developed many varieties by exploiting the germplasm was carried out efficiently includes: Trinidad, Raman, Gagarin, etc. Some notable varieties were introduced to India from different parts of the world includes 'Asia', 'No.2', 'Kayata', 'Elizabeth', 'Closeburn', 'Isabel Greensmith'

from Kenya, ‘Glady’s Hepburn’, ‘Natalii’ from Durban and ‘Mahara’ and ‘Rose Ville Delight’(Roy 2019). The genus includes about 18 species, where only four species *B. glabra*, *B. peruvian*, *B. spectabilis* and hybrid species *B x buttiana* are extensively used for the horticultural purposes (Singh *et al.*, 2016).

There are insignificant hundreds of varieties noted around the world, most of them evolved through the seedling selection of natural crosses and Natural mutation viz., Bud sport, remaining from Induced mutation and Hybridization. The institutes, nurseries and Horticultural societies had fortunate the way for increasing the popularity of Bougainvillea in India by releasing and sustaining varieties. Moreover, there are many remarkable research and development initiative accomplished by institutes in India includes Indian Institute of Horticultural Research (IIHR), Bengaluru, NBRI, Lucknow, IARI, New Delhi, BAC, Mumbai, Lalbagh Botanic Garden, Bengaluru, Agri-Horticultural Society, Chennai, and Agri-Horticultural Society, Kolkata, which played a significant role in making Bougainvillea an admirable plant in Landscape gardening by developing many varieties. The variety Dr. H. B. Singh was developed from IIHR, Bengaluru by Dr. R. N. Bhat and got patented in Australia in the name of Krishna and secured a lot of admiration (Janakiram *et al*, 2012). There are numerous varieties released by Indian Institutes that fascinate the plant lovers unanimously. The division of Floriculture and Landscaping IARI, New Delhi acknowledged as International Registration Authority for Bougainvilleas by Royal Horticultural Society, U.K, in 1966, it is repository centre and carries out conservation of bougainvillea genotypes.

Bougainvillea can be categorized by their morphological characters like the vegetative and floral characters. It is obviously a great choice to every garden, due to their attention-grabbing bracts flourish well. In every respect, variety got certain reliable characters which differ accordingly. The woody evergreen shrub vines comprise of long arching thorny branches and heart-shaped leaves. The inflorescence is pedunculate, flowers grouped in cymes of 3 and inconspicuous, adorned by vivaciously coloured modified leaves called bracts. The colour of the leaves diverge from dark green to yellowish white and some varieties

has variegated vegetation. The leaves are arranged alternative and can make a distinction by elliptical-lanceolate. The texture of the leaves is glabrous to pubescent. Bougainvillea varieties are visually recognized by their colour of bracts which is a basic way of exposure. Those are enduring long on the branch and they are unambiguously a main attraction to the garden. The bracts of the shrub are papery, single or multi-bracted.

The astonishing colours of bracts outshine the true flower which is creamish yellow to white. The flowers are tubular, bisexual, small, 5 to 6 lobed and pedicle adnate to the midrib. The branches of the shrub are surrounded by the thorns, which give protection and support for the spread, which are a modified form of auxiliary buds on the branches. The Bougainvilleas are grown very well in sunny conditions of tropics. They are majorly propagated by stem cuttings, budding and layering (Sindhu and Ram 2009). Nowadays Bougainvilleas are in extreme requirement in nurseries in view of the fact that there are large extent consumption in urban, highways and polluted areas (Janakiram *et al.* 2012).

In perennial shrub-like Bougainvillea, the fitting breeding objective is deliberate for development of new variety by knowing the phenotypic characters of excellent cultivar among others. However, the effort has been made on the work regarding entitled **“Studies on Morphological Diversity in Bougainvillea (*Bougainvillea* Comm. ex. Juss.) cultivars”** by way of the subsequent objectives:

1. Morphological characterization of Bougainvillea cultivars
2. Identification of suitable Bougainvillea cultivars
3. To study the genetic variability in Bougainvillea cultivars

CHAPTER II

REVIEW OF LITERATURE

The investigation on the morphological characterization, genetic variability, heritability, genetic advance and character association of Bougainvillea cultivars was commenced on 2018-19. The quantitative and qualitative characters are evaluated based of DUS guidelines of Bougainvillea (2014). Comprehension about characterization and genetic variability can enable the identification of the suitable cultivars with feasible utility for precise breeding objectives. The meagre work had done on the morphological evaluation of Bougainvillea. Therefore, explorations of other commercial and ornamental flower crops are also reviewed. An attempt has been made to summarize and present the work done through the review in this chapter.

2.1 Morphological Characterization

2.2 Identification of suitable cultivars

2.3 Genetic Variability

2.4 Heritability and Genetic Advance

2.5 Character association

2.1 Morphological Characterization

Kumar (2001) undertaken an experiment for studying the classification and floral variability in the 61 varieties of bougainvillea. On the flowering behaviour they were classified in five groups like Profuse flowering, Less profuse flowering, Seasonal flowering, Multi-bracted and variegated varieties. The colour of bract, range of length of bract, width of bract, flower length and diameter studied. The variety Mary Palmer Special found excellent in both bract length (4.5-4.9 cm) and bract width (3.6-4.5 cm). The utmost range of flower diameter was

noticed in variety Splendens (0.24-0.32 cm). Numerous varieties in bract colour were noted has purple. There is quite a few variation observed in bract colour.

Prasad *et al.* (2005) investigation on growth and floral categorization in Bougainvillea varieties had shown significant variation in growth habit. The varieties Mary Palmer Special and Mary Palmer noted maximum bract width and bract length, respectively. In this study variety, Arjun recorded the maximum number of branches in the plant. According to the morphological characters, varieties perform better includes- Mary Palmer, Arjun, Chitra, Mahara, Lady Mary Baring and Begum Sikander.

Gupta *et al.* (2006) conducted an investigation on growth and flowering behaviour of Bougainvillea varieties. The variety Arjun recorded the maximum number of branches 11.53. In the varieties, Louis Wathen and Mary Palmer Special variation were noted in bract length ranging from 2.1 to 4.93cm respectively. The varieties in this study Los Banos Beauty, Begum Sikander, Mrs. Butt, Palekar and Mrs. McClean fulfilled better in regard to floral characters.

Singh *et al.* (2006 a) executed an investigation on the varietal performance of 21 bougainvillea cultivars for crucial information for improvement work. Most of the varieties give branches ranging from 4-6. The varieties perceive better main branches range of 4-7 viz., Dr. H. B. Singh, Sanderiana and Partha. Some are exceptional like Wazid Ali Shah and Sonnet are observed 4-7 main branches.

Singh *et al.* (2007) carried out an experiment for flower characterization of bougainvillea varieties. The range of bract size, flower length and diameter is noted along with the bract colour of the varieties. Persident variety recorded highest bract length of (4.2-5.4 cm) and Mary Palmer Special variety of bougainvillea noted greater bract width (3.6-4.5cm). The varieties Scarlet Queen Variegated noticed maximum flower length (4.1-6.5 cm) and Shubra recorded (2.5-3.2 cm) highest among all other varieties. However, on the whole, most of the varieties recorded purple bract colour in the study.

Singh *et al.* (2009) performed research on the growth behaviour in 24 single, 17 multi-bracted, 51 variegated Indian varieties of bougainvillea. The

investigation explicated the significance of appreciating the growing habit and flower colour for choosing the bougainvillea variety precise for landscape gardens. In the single bracted cultivars maximum of the cultivars noted vigorous growth behaviour and followed by medium growth of shrub. The variegated cultivars in the investigation exhibited the absolute growth behaviour has medium. In the multi-bracted cultivars utmost evidenced medium growth behaviour in the study.

Kumar *et al.* (2009) studied the morphological variability and flower quality of few multi-bracted cultivars of bougainvillea. The range of variation for main branch varies from 24.03-34.133 cm, for bract length and diameter has recorded lot of variability in the experiment. In both the years' maximum main branch length was observed in Cherry Blossom. It was comprehended that variation in growth habit observed expected owe to soil and cultural practises. Archana and Roseville's delight varieties found bract length >2cm during both the years.

Ram *et al.* (2010) investigated for 28 bougainvillea cultivars including multi-bracted for floral variability and thorn character. The thorn character observed to be curved in most of the cultivars. Few of them noticed small thorn and slightly curved. The colour of the bract in varieties of bougainvillea has observed range of pink-purple.

Arya *et al.* (2012) pursued survey on 30 varieties of bougainvillea for growth habit, bract colour and star colour. The majority of varieties have outcome of medium plant growth habit. The colour of the star arrived has creamish and prominent. The absolute floral bract colour obtained in range of red to purple.

Kumar *et al.* (2014) evaluated for 100 varieties of Bougainvillea for 38 morphological descriptors. Using the DUS characterization the varieties were classified for different characters. Quantitative characters include leaf length (0.80), bract length (0.57), and peduncle length (0.89) which showed variation among others. Qualitative characters were perceived stable for both the years. Based on Royal Horticultural chart bract colour was noted and the largest part of cultivars was grouped under Red-Purple group.

Singh *et al.* (2016 a) carried out an investigation on the growth and floral characteristics of 25 Bougainvillea varieties. The significant variation observed in nine quantitative characters in the evaluation. The maximum leaf blade width was observed in Chitra (8.10cm) and minimum in Aruna (3.10cm). Bract length was recorded maximum in Begum Sikander (4.50cm) and minimum in Pallavi (2.50cm). Thorn density of plant was noted highest in Los Banos Variegata and Los Banos Variegata ‘Silver Margin’ (19.3) and least in Partha (7.6).

Singh *et al.* (2016 b) carried out an experiment for evaluating 25 Indian varieties of Bougainvillea for 28 morphological traits. Among them, seven varieties had elliptic leaf blade shape while 13 varieties had medium ovate. Nine varieties had variegated leaves and rest were none variegated. The tertiary leaf blade colour was noted in Dr. P.V. Sane, Abhimanyu and Los Banos Variegata. The absence of flower and multiple bracts were noted in Los Banos Variegata, Los Banos Variegata ‘Silver Margin’ and Pallavi. Bracts also had a wide variation from white to magenta colour.

Morphological characterization in other flower crops

Harbaugh *et al.* (2000) evaluated 47 varieties of lisianthus (*Eustoma grandiflorum* (Raf. Shinn). Experiment was carried out for rosetting, plug performance, vegetative and flowering attributes and postharvest longevity of cut flowers. Considerable differences were noticed among cultivars for all of the evaluated attributes. Varieties were categorized based on the classes like flower colour, flower size and number of petals.

Kishanswaroop *et al.* (2004) performed research for four China aster varieties Poornima, Kamini, Shashank and Delhi Local. The variety Delhi Local (43.20 cm) has observed highest plant height happen next by Shashank (38.20 cm) and Poornima (33.40 cm) and least in Kamini (30.8 cm). The variety Poornima noted highest flower diameter (7.44 cm) superior than Delhi Local (7.34 cm) and conceive proficient in Delhi regions. The most minute flower diameter was noticed in Shashank (6.2 cm). The Delhi Local recorded utmost flower stalk length (24.40

cm). The longevity of flower (21 days) and Single flower weight (4.15 g) considered lowest in Kamini.

Martolia (2010) performed trial for evaluation of 12 tuberose varieties. The vast difference is evident with the diversity of the characters over the years and throughout the data. Vaibhav has an utmost spike length and best open flower per spike. Var. Hyderabad double has the highest flower diameter and the number of open flowers per sq. meter. The best time of flowering was attained in var. Double. Swarna Rekha variety recorded highest diameter and flower mass.

Pandey *et al.* (2012) evaluated 56 gladiolus cultivars (32 exotic and 24 Indian) were evaluated for cut flower and corm production. According to analysis four cultivars like White Prosperity, Eurovision, Jyotsana and American Beauty provide superiority over the others for discrete traits viz., vegetative growth, flowering and corm and cormel production. Eurovision revealed highest plants height (133.00 cm), number of leaves for each plant (10.00) and number of florets per spike (19.00). In this study variety White Prosperity noted highest leave length (55.33 cm), long spike (91.16 cm), rachis length (76.16 cm), floret diameter (11.36 cm), bulky corms (121.66 g) and size of corm (6.89 cm). Greatest number of daughter corms (3.10 cm) and number of cormels (68.00) were noticed in cultivar Jyotsana.

Kadam *et al.* (2014) conducted experiment on 26 gladiolus cultivars. Among them, remarked superiority in plant height (115.87 cm) and spike length (101.20 cm) were achieved in cultivar Amsterdam. The cultivar Snow Princess noted highest number of florets per spike (18.60).

Kumar (2015) performed an experiment with 15 gladiolus cultivars for characterisation. The variety Prabha noted highest plant height, where as cultivar Sylbia shown greatest number of leaves for each plant, leaf length and leaf width. American Beauty in the study noticed utmost length of rachis and spike. The Arka Gold cultivar noted most number of flowers on spike, diameter of the flower and corm mass. Whereas the cultivars Punjab Glance and Prabha exhibited least days

needed for the emergence of spike and initial floret opening. Maximum no. of corms and spike are observed in Orange Ginger.

Chourasia *et al.* (2015) aimed to know the growth, flowering, spike yield and corm yield parameters in gladiolus in the experiment. The variety Red Majesty shown high leaf length (69.33cm). White Prosperity noted supreme in days for corm to sprout (26.73), leaf width (4.60cm), spike length (99.80cm) and rachis length (67.80cm). The variety Candiman found best variety in Gujarat regions that it noticed superior in spike diameter (1.230cm), flower neck diameter (1.97cm), flower diameter (15.50cm) and longevity of florets (24.00)

Shahrin *et al.* (2015) evaluated the rose cultivars and classified based on color, fragrance and use. In this study 44 rose cultivars coded from V1 to V44 were varied considerably for the studied qualities like shoots per each plant, leaf area, flower no. per each plant and petals /every flower. Rose cultivars were categorized in nine groups in considerate to colour, three groups in according to the fragrance and two groups in according usage.

Uddin *et al.* (2015) conducted exploration on the growth & flowering performance regarding 32 chrysanthemum cultivars. The range of no. of flowers per plant from 4.3 to 194.6, diameter of flower head varied from 2.8 to 17.6 cm and stalk lengths ranged from 4.4 to 20.1 cm. Along with the lasting of chrysanthemum cultivars V15 (BARI chrysanthemum1) was the maximum flower yielding variety. However, V1 produced the biggest flowers and the variety V21 flowers had the utmost shelf-life.

Atram *et al.* (2015) performed a trail on the morphological and yield traits for 42 varieties of hybrid tea rose. The study exposed that variety Chardony has recorded highest plant height (162.50cm). Alliance variety noted maximum number of flowers per plant (45.50). The variety Chardony recorded maximum flowering stem length of 65cm followed by Kentucky Derby (63.30cm). In case of intermodal length the variety Chardony recorded maximum of about (6.80cm). In this experiment the varieties Chardony, Alliance, Kentucky Derby, Roter

Champagner, Montreal, and Melody performed better in case of morphological traits.

Chowdari *et al.* (2016) pursued an investigation for evaluation of eight varieties of china aster. The study noted that all the characteristics among varieties - Kamini, Poornima, Shashank, Aadya, Archana, Phule Ganesh White, Phule Ganesh Violet and Phule Ganesh Purple are significantly variegated.

Deepa *et al.* (2016) explored an investigation in regard to the length of the plant, number of leaves/plant, spread of plant(N-S, E-W), number of primary branches, number of secondary branches, flower width, fresh flower weight, dry flower weight, petal meal and flower yield per hectare in various hybrids of marigold are evaluated. Because of genetic and environmental factors there is lot of variation observed in length of plant and leaves numeral. The flower diameter was absolute in the hybrid Garland Orange (8.50).

Avendaño-Arrazate *et al.* (2017) undertaken a survey for wild species of *Heliconia* in Mexico. In this study, the morphological characterization of genus *Heliconia* is done by taking 25 accessions, by evaluating 55 qualitative and quantitative characters. The 11 native species are analysed for plant height, leaf, inflorescence, flower, fruit, and seed.

Patel *et al.* (2017) performed research for qualitative and quantitative floral characters are evaluated in favour of seven jasmine species was done by In the study, jasmine varieties like Gundumalli, Madanban, Ramabanam, Single Mohra, CO.1 Mullai, Parimullai and CO.1 Pitchi are utilized. The cultivar Single Mohra remarked maximum diameter of flower bud (0.9cm) although the cultivar CO.1 Pitchi has noted maximum flower bud length (3.85cm). In this study, variety Madanban recorded greatest hundred flower bud weight (28.60g) and single flower bud (0.275g).

Mahantesh *et al.* (2018) conducted survey by evaluating eight African marigold genotypes. The study showed that genotype T5-Double Orange (81.79 cm) noted the maximum plant height. The genotype T1-Arka Agni showed highest

plant spread from N-S and for E-W about 48.83cm and 52.80cm respectively. The highest stem girth noticed in genotype T4-Erecta Naana Moon Light (5.17 cm). The genotype T1-Arka Agni was superior in highest no. of primary branches, secondary branches and stem diameter (12.40), (24.13) and (1.23cm) respectively. The foremost flower opening evidenced in T3Arka Bangara-2 (48.40 days). The greatest flower diameter was witnessed in T4-Erecta Naana Moon Light (6.13 cm).

2.2 Identification of suitable bougainvillea cultivars

Prasad and Kumar (1997) evaluated cultivars of bougainvillea and recommended them based on their performance considering their genetic variability. Chitra cultivar recommended as climber and Shubra was recommended for climber, pot plant, bonsai and on arches and pergola. Dr. R. R. Pal was used as hedge, bush, umbrella shaping, climbing on tree and wall.

Singh (1997) explored bougainvillea cultivars are recommended their suitability in gardens. For pot cultivars, Cherry Blossom, Dr.R. R. Pal, Mahara, Thimma, Vishaka, Chitra and Shubra were found suitable. For standard cultivars suitable are Sonnet, Summer Time, Thimma and Tomato Red were found suitable. As standard many cultivars are recommended among them Chitra, Glabra, Mahatma Gandhi, Shweta and Thimma.

Singh *et al.* (2006) explored cultivars of bougainvillea in this investigation. The cultivars based on their aesthetic value were recommended for different purposes. The cultivars Formosa, Tomato Red, Shubra, Golden Glow, Thimma and Mary Palmer Special were recommended for pot culture. For sloppy places cultivars Glabra, Cherry Blossom, Dr. R. R. Pal and Partha were recommended.

Sindhu and Koundal (2007) explored the cultivars of bougainvillea and classified based on colour of bract. Dr. R. R. Pal noticed fuchsia red colour bract, Alick Lancaster recorded cyclamen purple colour bracts, Sonnet cultivar noted orchid purple and Shubra cultivar recorded glistering white. Rao and Thimma noted variegated leaves.

Singh *et al.* (2009) conducted an experiment on cultivars of bougainvillea and identified the colours of single and multi bracted cultivars. The single bract cultivars shweta noted white green colour, Dr. Rao noted red colour, Sonnet recorded magenta and Shubra observed white colour bract. The multi-bracted cultivar viz., Roseville's Delight noted mars orange, Cherry Blossom noted fuchsine pink colour and Mahara noted purple colour bract.

Roy (2010) explored bougainvillea cultivars in the experiment. The varieties Shubra, Thimma, Glabra were recommended as filler in the avenue plantation. Mahara, Cherry Blossom and Thimma varieties were suitable for road divider. In tubs the varieties Chitra and Shubra were recommended.

Sindhu *et al.* (2012) conducted an exploration on bougainvillea species by identification and explained uses of plant in garden. In pots cultivars viz., Shubra, Dr. R. R. Pal, Mahara, Roseville's Delight and Thimma were recommended. The cultivars suitable on espalier were Partha, Thimma, Shubra and Dr. R. R. Pal.

Singh *et al.* (2016 a) studied characterization of bougainvillea varieties. Some varieties viz., Shweta, Shubhra, Pallavi, Mary Palmer Special, Aida Variegata, Manohar Chandra Variegata, Dr. P.V. Sane, Dr. H. B. Singh, Chitra and Palekar performed better and these were recommended for bedding purpose.

Other flower crops

Uddin *et al.* (2015) pursued survey for 32 chrysanthemum cultivars. The aware of variations in the cultivars facilitated in organizing chrysanthemum, has potted plant and cut flower, based on their quality of flowering.

Chowdari *et al.* (2016) conducted survey for eight china aster varieties. The study revealed variety Archana as best plant suitable for pot plant. In this experiment variety Shashank was suggested for cut flower purpose.

Deepa *et al.* (2016) pursued an investigation on marigold hybrids. The research illustrated that hybrids Bonanza Mix, Mysore Gold, Inadam Gold and Indam Yellow New were mainly recommended for growing as rockery, edging and hanging baskets.

2.3 Genetic Variability

Singh *et al.* (2006 b) studied the coefficient of variation in bougainvillea through 15 attributes for 2 years. The GCV noted highest in number of branches (52.76) and in subsequent year similar value observed in diameter of thorns (57.80). The utmost PCV remarked in number of branches (64.10), while following year sighted in the thorn diameter.

Singh *et al.* (2010 a) conducted an experiment on coefficient of variation in Bougainvillea genotypes for 15 characters. In the experiment the GCV and PCV found with generous variation.

Other crops

Mousumee *et al.* (2001) studied on the genetic variability of dahlia based on the flower aspect. The Phenotypic and Genotypic coefficient of variation remain noted to be significantly high in case of number of flowers.

Kumar and Paul (2003) conducted an analysis on the genetic variability of 11 china aster genotypes with 14 quantitative attributes. The data subjected to heritability had witnessed quite high, indicates that by selecting the characters in the study can improve the yield of the flower. The genotypic coefficient of variation had considered best for plant spread, leaf area, average weight of flower, flower yield per plant.

Kadam *et al.* (2014) conducted an analysis on 26 gladiolus cultivars. Greater standards of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were noticed for cormel weight, i.e. 104.36 and 67.26 and number of cormels per plant, i.e. 99.82 and 71.58, respectively

Latha and Dharmatti (2018) carried out an experiment for 26 genotypes of marigold. Estimated 12 vegetative, floral and yield parameters to study their genetic factors like variability, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). The discrepancy was noted among all

the genotypes in the study. The traits such as no. of petals/flower and plant length are noticed superior value of GCV and PCV.

2.4 Heritability ($h^2\%$) and Genetic Advance (GA)

Singh *et al.* (2006 b) carried out investigation for heritability and genetic advance in bougainvillea through 15 attributes for 2 years. Supreme heritability was acquired in both years for bract length (95.98 and 85.28).

Singh *et al.* (2010 a) carried out exploration on analysis of the heritability, genetic advance in Bougainvillea genotypes for 15 characters. The experiment has revealed the greatest heritability in length of the bract 95.981 and slightest in the thorn diameter 5.902. However, noted that there is very less influence by environment on the characters in the study. The genetic advance and genetic advance w r to mean recorded range of 0.006 to 11.093 and 0.065 to 0.894 in bougainvillea.

Other crops

Mousumee *et al.* (2001) surveyed on the heritability and genetic advance of dahlia based on the flower aspect. The utmost heritability and genetic advance in case of number of flowers and variation remain noted to be significantly high.

Kumar and Paul (2003) conducted an analysis on heritability of 11 china aster genotypes with 14 quantitative attributes. The data subjected to heritability had witnessed quite high, indicating that by selecting the characters in the study can improve the yield of the flower.

Nair and Shiva (2003) carried out an experiment for 25 gerbera genotypes for 11 characters in two seasons. The genetic advance and heritability was ultimate in cut flower yield and area of leaf, signifies additive gene action.

Singh (2008) performed an experiment for heritability and genetic gain of 18 cultivars of Rose (*Rosa* spp.). It revealed the maximum heritability with high genetic gain was noted for thorn density.

Kadam *et al.* (2014) pursued survey on 26 gladiolus cultivars. Superior heritability was stated from being to first floret opening (87.23%) followed by rachis length (82.07%) and days to spike initiation (78.26%). Maximum values for genetic advance were recorded for plant height (26.35) and spike length (23.36). While, negligible genetic advance was proved in favor of days to sprouting (0.04).

Latha and Dharmatti (2018) carried out an investigation for 26 genotypes of marigold. Estimated 12 vegetative, floral and yield parameters to studied, heritability. The greatest heritability was obtained in flower yield (t/ha), flower yield (g/plant), number of flowers per plant, flower diameter and number of petals per flower. In study, characters like plant height, flower yield (t/ha), flower yield (g/plant), flower diameter and internodal length noticed supreme genetic advance over mean.

2.5 Character association

Singh *et al.* (2010 b) pursued an experiment on the data obtained was subjected to path coefficient analysis for 15 attributes in bougainvillea. In the present experiment 35 cultivars were selected for the study. The floral diameter exposed direct effect (0.081) through positive correlation, followed by length of thorn (0.05), length of bract (0.464). The length of the leaf, diameter of floral tube, diameter of thorn and branch length had positive correlation at 5% level of significance.

Singh *et al.* (2010 c) investigated on correlation coefficient in 12 varieties of bougainvillea. The phenotypic correlation coefficient in an experiment observed significant variation for 15 characters. The length of the leaf showed positive correlation with length of main branch, diameter of main branch, internodal length of main branch, number of branches, length of sub-branch, but showed negative correlation with diameter of thorn in the first year. In the subsequent year the internodal length of main branch noted positive correlation with length of main branch (1.000), diameter of main branch (0.476), length of leaf (0.245), width of leaf (0.346), and length of thorn (0.129).

Other crops

Sirohi and Behera (1999) investigated on character association and path coefficient analysis for 57 chrysanthemum genotypes. The study indicated that PCA for the yield of chrysanthemum had positive association with flowers per plant, plant canopy, number of branches/plant. Whereas choosing by the above characters benefit in chrysanthemum advancement in breeding. The experiment implied that number of flowers/plant had exact consequence on yield by means of no. of branches/plant.

Nair and Shiva (2003) carried out an experiment correlation, path coefficient analysis is done 25 gerbera genotypes for 11 characters in two seasons. While in no. of leaves for each plant noted positive and direct correlation by means of cut flower yield, by the result depiction that flower yield can be improved by opting plant with largely number of leaves..

Rashmi (2006) carried out a research work on gladiolus where, considerable variation noticed in all the characters taken in gladiolus. The character spike length noticed positive correlation with standard weight of corm, plant height, girth of spike, weight of the spike, rachis extent, number of florets per spike and number of cormels per plant at genotypic level. Investigation described that gladiolus advancement done by direct selection of essential quantitative and qualitative attributes such as regular weight of corm planted, number of florets/spike, good quality spike per plant, number of cormels per plant and number of days taken in favour of opening initial flower.

Singh (2008) carried out an experiment for character association of 18 cultivars of Rose (*Rosa* spp.). The number of flower each plant had highly significant positive correlation with length of flower bud, considered flower had major contribution in determining the number of flower buds /plant in rose. While, in the study plant height, plant spread, length of primary branches had positive correlation at both genotypic and phenotypic levels.

CHAPTER III

MATERIALS & METHODS

The present evaluation entitled “**Studies on Morphological Diversity in Bougainvillea (*Bougainvillea* Comm. ex. Juss.) cultivars**” executed in Horticulture Research cum Instruction Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (C.G.), inception during 2018-19.

The materials and methods of the investigation are enlightened in this chapter momentarily.

3.1 Experimental area

The research analysis was accomplished in the Horticulture Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, College of Agriculture, Department of Floriculture and Landscape Architecture in 2018-19. Where, appropriate provisions for irrigation and other management were contributed.

3.2 Geographical Situation

The College of Agriculture, Raipur positioned at the core of Chhattisgarh amid latitude of 22°33'N to 21°14'N and longitude high on 82°6'E to 81°38'E with an elevation of around 298m MSL.

3.3 Agro-climatic conditions

The locality of an experiment is situated in Raipur where the summer is extreme with low humidity. The temperature of summer during March –April may exceed to 43°-48°C, that is remarkable in Chhattisgarh. The winter is mild in Raipur commence from Nov to Jan. However, the temperature may reduce up to 6°-5°C which turn into sensibly cold. The Raipur receives less rainfall during months of May and June but receives more during the month of July-Aug. The 1300mm of rainfall noted during the monsoon in Chhattisgarh. The Raipur recorded very less relative humidity from 12-90%. The year 2018-19 meteorological data as noted at

the meteorological observatory, College of Agriculture, Raipur are remarked in Appendix-A.

3.4 Experiment details

The present evaluation carried out for morphological characterization and genetic variability. The 31 treatments including a check had taken, each treatment replication tripled to commence the experiment.

Crop	: Bougainvillea (<i>Bougainvillea</i> Comm. ex. Juss.)
Materials under study	: 31 cultivars along with a check
Treatments	: 32
Replication	: 3

3.4.1 Plant material

The cultivars of bougainvillea exploited for morphological characterization were conserved in Horticultural Research cum Instructional Farm in Department of Floriculture and Landscape Architecture. There were absolutely 31 cultivars along with a check utilized in research work (Table-3.1). The various cultivars were collected from The Bougainvillea Society of India, Division of Floriculture and Landscaping, IARI, New Delhi. The cultivars are one to two years old were maintained in the pots with proper management practises like irrigation and weeding is accomplished efficiently outlook as shown in Plate-3.1

3.5 Observation to be recorded

The plants are exploited for the characterization based on the Distinctiveness Uniformity and Stability of Bougainvillea (2014) by the Nodal centre CSIR-NBRI, Lucknow and other centre IARI, New Delhi during the full flourishing stage.

3.5.1 Morphological Characterization

3.5.1.1 Evaluation Methodology

The evaluation was performed during the year 2018-19 for 31 cultivars of *Bougainvillea* including check. The characters were studied, among them few are quantitative, qualitative and pseudo-qualitative, which were measured and visually evaluated. The Royal Horticulture Society Chart was used to judge the colour of the calyx lobe and bracts in *bougainvillea* which had 920 colours with each and every colour has code and number and in addition name.

In addition to that, the characters were portrayed in the form of growth characteristics Table-3.2 and floral characteristics in the Table-3.3 for better understanding of the morphological description based on DUS along with their respective states and note of characteristics in the study. The qualitative, quantitative, pseudo-qualitative data were collected and assessed in the experiment.

The characteristics which were measurable in numerical form expressed in units and analysed with the help of statistics comes under quantitative characteristics. The qualitative characteristics were examined visually, maybe present or not, depends on whether the gene is responsible for the character it is considered. The characters were not influenced by the environment. The pseudo-qualitative characteristics assessed vary in more than one dimension like elliptical shape of leaf etc.

The morphological attributes of the individual cultivars were described in form of growth characteristics in Table 3.2 and floral characteristics as per Table 3.3; they were stated according to their depiction of the character. The note (0-9) was applied to represent the state of the peculiar character as per the DUS, PPV&FRA of *Bougainvillea* (2014). The colours of the bracts were compared with RHS colour chart, according to those codes and names were given for better understanding of colour.

Table-3.1: List of the cultivars for study of morphological characterization with their origin, parentage, introduced from, related species, breeder and year (Roy 2019 and Kumar 2014)

Sl. No.	Cultivars	Breeder/Introduced or Raised and Year	Origin	Related Species
1	Alick Lancaster	A. Percy Lancaster, Delhi (1930), India	Bud sport of <i>B. x buttiana</i> var. Scarlet queen	<i>B. x buttiana</i>
2	Bangalore Variegata	—	—	—
3	Bridal Bouquet	—	—	—
4	Carpet Purple	Introduction	—	—
5	Cherry Blossom	Reported by Dr. J. V. Pancho(1967), COA, Laugan Philippines	Bud Sport of cv. Los Banos Beauty	<i>B. x buttiana</i>
6	Chitra	T.N. Khoshoo, D. Ohri and S.C.Sharma, NBRI, India, 1981	Hybrid seedling of “Tetra Mrs.Mc Clean x Dr.R.R.Pal”	<i>B. x buttiana</i> and <i>B. peruviana</i>
7	Dr. R.R. Pal	Dr. B.P. Pal, New Delhi, India, 1959	Hybrid seedling of Thomasii(<i>B. x glabra</i>) X Louise Wathen (<i>B. x buttiana</i>)	<i>B. x buttiana</i>
8	Dr. Rao		Bud sport of Mrs. Butt	<i>B. x buttiana</i>
9	Fantasy	B.Rama Rao 3Madras, India	Bud sport of Princess Margaret Rose	<i>B. peruviana</i>
10	Formosa	Brazil, introduced to India by Thomas Royer at LBG, Bengaluru	—	—
11	Glabra	Brazil, 1860	Seedling of <i>B. glabra</i>	<i>B. glabra</i>
12	Golden Glow	Origin- Cuba introduced from Africa to Lalbagh BG, Bengaluru	Bud sport of <i>B.x buttiana</i>	<i>B. x buttiana</i>
13	Gopal	K.S.Gopalaswamienger Son, Bangalore, India, 1935	Seedling of Formosa	<i>B. glabra</i>
14	Magnifica	Australia, 1893	—	<i>B. glabra</i>
15	Mahara	Lalbagh BG, Bengaluru, India, 1961	Bud sport of Mrs. Butt	<i>B. x buttiana</i>

Sl. No.	Cultivars	Breeder/Introduced or Raised and Year	Origin	Related Species
16	Mahatma Gandhi	K.S.Gopalaswamienger Son, Bangalore, India	Seedling of 'Princess Margaret Rose'	<i>B. peruviana</i>
17	Mary Palmer Special	S.N. Zadoo & T.N. Khoshoo NBRI, India, 1974	Hybrid Seedling of Dr. B.P.Pal X Princess Margaret Rose	<i>B. peruviana</i>
18	Mataji Agnihotri		—	—
19	Partha	M/S K.S.Gopalaswamienger Son, Bangalore, India, 1954	Seedling of <i>B. peruviana</i>	<i>B. peruviana</i>
20	Pink beauty	M/S. Soundarya Nursery, Madras India	—	—
21	Queen Violet	New Introduction	—	—
22	Roseville's Delight	Mrs. Lolita, Malabon Rizal, Philippines, 1962	Bud sport of Mrs. McClean	<i>B. x buttiana</i>
23	Scarlet O Hara	New Introduction	—	—
24	Shubra	S.C.Sharma, NBRI, India, 1965	Bud sport of Mary Palmer	<i>B. peruviana</i>
25	Shweta	S.C.Sharma, NBRI, India, 1979	Bud sport of Trinidad	<i>B. glabra</i>
26	Sonnet(Check)	B.P.Pal, New Delhi, India	Seedling of <i>B. x buttiana</i>	<i>B. x buttiana</i>
27	Summer Time	B.P.Pal, New Delhi, India, 1959	Hybrid seedling of Thomsaii x Lousie Wathen	<i>B. spectabilis</i> x <i>B. x buttiana</i>
28	Thimma	Lalbagh BG, Bengaluru, India	Bud sport of Mary Palmer	<i>B. peruviana</i>
29	Tomato red	W.F.Turley, Queensland, Australia		<i>B. spectabilis</i>
30	Torch Glow			
31	Vishaka	B.Singh, R.S.Malik, L.P.Yadav and B.Choudhury, IARI, New Delhi	Bud sport of Mrs. H. C. Buck	<i>B. peruviana</i>
32	Zakiriana		—	<i>B. spectabilis</i>



Plate3.1: View of Bougainvillea experimental field

3.5.1.2 Method of Observations

MG : Measurement of a group of plants or parts of plants as per lone observation.

MS : Measurement concerning number of sole plant or else parts of plant.

VG : Visual judgment of a group of plants or parts of plants in means of a solitary observation.

VS : Visual evaluation of individual plant or parts of plant by observations.

The qualitative and pseudo-qualitative observations acquired with data that can be observed by means of senses like visual, touch and feel are visual assessment (V). In the present experiment the bract colours were assessed visually by using RHS colour chart are described in result. The quantitative observations are collection of data which in form of numbers and values, done through the measurement (M) method by rulers, vernier calliper etc. The data under the

quantitative is accurate, numerical, constant, bias free results are obtained. The observation which are recorded in way of the group of plants/parts of plants are ‘G’ and the individual plant or single plant observation taken are ‘S’. The data which are visual speculated like colour verdict (QL & PQ) are not subjected to any Statistical investigation.

Table-3.2: List of Growth Characteristics for Morphological Characterization used for study as per DUS guidelines of Bougainvillea (2014)

Sl. No.	Characteristics	State	Note	Type of review
1	Plant growth habit (PQ)	Upright	1	VG
		Semi-upright	2	
		Spreading	3	
		Drooping	4	
		Climbing	5	
2	Young shoot colour (PQ)	Light green	1	VG
		Medium green	2	
		Reddish green	3	
		Reddish	4	
3	Length of internodes (cm) (QN)	Short	3	VG/ MS
		Medium	5	
		Long	7	
4	Thorn presence (QL)	Absent	1	VG
		Present	5	
5	Thorns diameter (QN)	Short	1	MS/MS
		Medium	2	
		Broad	3	
6	Thorns density (QL)	Sparse	3	VG
		Medium	5	
		Dense	7	
7	Thorns Length (cm) (QN)	Short	1	MG/MS
		Medium	2	
		Long	3	
8	Thorn curvature (QL)	Straight	1	VG
		Slightly curved	3	
		Curved	5	
9	Thorns Strength (QL)	Weak	1	VG
		Medium	2	
		Strong	3	
10	Leaf Blade Length (QN)	Short	3	MG/MS
		Medium	5	
		Long	7	
11	Leaf Blade Width (QN)	Narrow	3	MG/MS
		Medium	5	
		Broad	7	

Sl. No.	Characteristics	State	Note	Type of review
12	Leaf Blade Shape (PQ)	Lanceolate	1	VG
		Medium ovate	2	
		Broad ovate	3	
		Elliptic	4	
		Circular	5	
		Others	6	
13	Leaf Blade Shape of Apex (PQ)	Acuminate	1	VG
		Acute	2	
		Obtuse	3	
		Others	4	
14	Leaf Blade Shape of Base (PQ)	Attenuate	1	VG
		Acute	2	
		Obtuse	3	
15	Young Leaf Colour (PQ)	Light green	1	VG
		Medium green	2	
		Reddish green	3	
		Reddish	4	
		Others	5	
16	Leaf Blade Main Colour (PQ)	Yellowish white	1	VG
		Yellow	2	
		Yellowish green	3	
		Light green	4	
		Medium green	5	
		Dark green	6	
		Very dark green	7	
		Grey green	8	
		Others	9	
17	Leaf Blade Secondary colour (PQ)	None	1	VG
		White	2	
		Yellowish white	3	
		Yellow	4	
		Light green	5	
		Medium green	6	
		Dark green	7	
		Very dark green	8	
		Grey green	9	
		Others	0	
18	Leaf: Distribution of Secondary Colour (PQ)	Absent	1	VG
		Narrow-marginal	2	
		Broad -marginal	3	
		Around midrib	4	
		Speckled	5	
		Irregular	6	
		Others	7	
19	Leaf Tertiary Colour (PQ)	None	1	VG
		White	2	
		Yellowish white	3	
		Yellow	4	
		Light green	5	
		Medium green	6	

Sl. No.	Characteristics	State	Note	Type of review
20	Leaf Undulation (QL)	Absent or weak	1	VG
		Medium	2	
		Strong	3	
		Others	4	
21	Leaf Texture(QL)	Glabrous	1	VG
		Hairy	2	
		Slightly Hairy	3	
		Tomentose	4	
		Others	5	
22	Petiole Length(QN)	Short	1	MS/MG
		Medium	2	
		Long	3	
23	Petiole Altitude (QL)	Upward	1	VG
		Horizontal	2	
		Downwards	3	
24	Leaf Persistence (QL)	Persistent	1	VG
		Non Persistent	2	

Table-3.3: List of Floral Characteristicsfor Morphological Characterization used for study as per DUS guidelines of Bougainvillea (2014)

Sl. No.	Characteristics	State	Note	Type of asses
1	Inflorescence Length (QN)	Short	3	MS/MG
		Medium	5	
		Long	7	
2	Peduncle Length (QN)	Short	3	MS/MG
		Medium	5	
		Long	7	
3	Arrangement of Bract Clusters (QL)	Terminal	1	VG
		Axillary	2	
		Axillary and Terminal	3	
4	Number of Bract Clusters (QL)	Few	3	VG
		Medium	5	
		Many	7	
5	Bract Density in Clusters (QL)	Sparse	3	VG
		Medium	5	
		Dense	7	
6	Presence of Flowers(QL)	Absent	1	VG
		Present	9	
7	Bract type(QL)	Single	1	VG
		Multiple	3	
		Double	5	
		Others	7	
8	Bract Length (cm)(QN)	Short	3	MG/MG
		Medium	5	
		Long	7	

Sl. No.	Characteristics	State	Note	Type of asses
9	Bract Width (cm)(QN)	Narrow	3	MG/MS
		Medium	5	
		Broad	7	
10	Bract Shape (PQ)	Narrowly Ovate	1	VG
		Medium Ovate	2	
		Broadly Ovate	3	
		Circular	4	
11	BractTip Shape (PQ)	Acute	1	VG
		Obtuse	2	
		Others	3	
12	Bract Base Shape(PQ)	Acute	1	VG
		Obtuse	2	
		Cordate	3	
13	Bract Persistence (QL)	Persistent	1	VG
		Non Persistent	2	
14	Star Diameter (cm) (QN)	Short	1	MG/MS
		Medium	2	
		Broad	3	
15	Reflection of Bract (PQ)	Reflexed	1	VG
		Normal/ Straight	9	
		Others	0	
16	Bract: Single: Calyx Lobes/ Star: Colour of upper side (PQ)			Royal Horticulture Society Colour chart
17	Bract: Single: Main colour of inner side (Star open) (PQ)			RHS colour chart
18	Young Bract: Main colour of inner side (Calyx lobe/ Star not open) (PQ)			RHS colour chart
19	Young Bract: Main colour of inner side (PQ)			RHS colour chart
20	Bract: Double: Young outer Bract: Main colour of inner side (PQ)			RHS colour chart
21	Bract: Double: Young inner Bract: Main colour of inner side (PQ)			RHS colour chart
22	Bract: Main colour (Calyx lobe/ Star wilted / fading) (PQ)			RHS colour chart

3.5.3 Identification of suitable cultivars

The bougainvillea cultivars were recognized maximum by their bract colour and insignificantly by morphological characters. The blooming season of the cultivars were recorded. Based on the morphological description the cultivars

suitability was acknowledged and recommended for various purpose in landscape and beautification.

3.6. Statistical Analysis

The data collected was subjected to various analysis as per the objective:

The 11 quantitative characters data recorded for 31 cultivars and a check were subjected to following analysis.

3.6.1 Analysis of variance

The analysis of variance was worked out for 11 morphological characters. The experimental data was analysed as suggested by Panse and Sukhatme (1985).

The skeleton of analysis of variance is as follows:

ANOVA

Source of variation	Degree of freedom	Sum of Square	Mean sum of square	'F'calculated
Replication	(r-1)	RSS	$RSS/r - 1 = RMSS$	RMSS/EMSS
Treatment	(t-1)	TrSS	$TrSS/t - 1 = TrMSS$	TrMSS/EMSS
Error	(r-1)(t-1)	ESS	$ESS/(r-1)(ab-1) = EMSS$	
Total	(rt-1)	TSS	$TSS/(rt-1) = TMSS$	

Where,

RSS = Replication sum of square

TrSS = Treatment sum of square

ESS = Error sum of square

TSS = Total sum of square

RMSS = Replication mean sum of square

TrMSS = Treatment mean sum of square

EMSS = Error mean sum of square

TMSS = Total mean sum of square

3.6.2 Assessment of variability:

The mean values were worked out for quantitative characters to calculate variability parameter viz., range, mean, standard deviation and coefficient of variation.

a. Range

Range= maximum value-minimum value

b. Mean

$$\bar{X} = \sum \bar{X}_i / N$$

$\sum X_i$ = Summation of all observations

N= Total number of observations

c. Standard Error of mean

$$S E (m) \pm = \sqrt{EMSr}$$

d. Coefficient of Variance

$$CV (\%) = \sqrt{EMSGrandmean} \times 100$$

3.6.3 Genetic variability

(a) Phenotypic coefficient of variation (PCV)

$$\sigma_p = \sigma_g + \sigma_e$$

$$PCV = (\sigma_p / \bar{X}) \times 100$$

$$\text{where, } \sigma_p = \sqrt{\sigma^2_p}$$

(b) Genotypic coefficient of variation (GCV)

$$GCV = (\sigma_g / \bar{X}) \times 100 \quad \text{where, } \sigma_g = \sqrt{\sigma^2_g}$$

Where,

σ^2_p = Phenotypic variance

σ_p = Phenotypic standard deviation

σ^2_g = Genotypic variance

σ_g = Genotypic standard deviation

σ_e = Environment variance

$\bar{X}$ = General mean

3.6.4 Heritability (Broad sense)

It is the ratio of genotypic variance to the phenotypic variance. Heritability for the present study was calculated in broad sense by adopting the formula suggested by Hanson *et al.* (1950).

$$h^2(bs) \% = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

h^2 (bs) = Heritability in broad sense

σ^2g = Genotypic variance

σ^2p = Phenotypic variance

The range of heritability was categorized as:

low (below 50 per cent)

moderate (50-70 per cent)

high (above 70 per cent) as followed by Johnson *et al.* (1955).

3.6.5 Genetic advance

Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. Expected genetic advance (GA) was calculated by the method of Johnson *et al.* (1955).

$$GA = K \cdot \sigma_p \cdot h^2(bs)$$

Where, GA = Genetic advance

K = Constant (Standardized selection differential) having the value of 2.06 at 5 per cent level of selection intensity

h^2 = Heritability of the character

σ_p = Phenotypic standard deviation

3.6.5.1 Genetic advance as percentage of mean

It was calculated by the following formula

$$GA \text{ as percentage of mean} = \frac{\text{Genetic advance}}{\text{General mean}} \times 100$$

GA was categorized as

> 35 per cent = high

25-35 per cent = moderate

< 25 per cent = low

3.6.6 Correlation coefficient analysis

Correlation coefficient among the characters in all possible combination was calculated with the help of procedure given by Miller *et al.* (1958). The

variance and covariance components were used to compute the correlation coefficients, at genotypic and phenotypic level. Correlation coefficients were calculated for all the character combinations at genotypic and phenotypic levels, as per the formula given by Miller *et al.* (1958).

$$r(X_i X_j) = \frac{\text{Cov.}(X_i X_j)}{\sqrt{\text{Var}(X_i) \text{Var}(X_j)}}$$

Where,

$X_i X_j$ = Coefficient of correlation between characters X_i and X_j

$\text{Cov}(X_i X_j)$ = Covariance between characters X_i and X_j

$\text{Var}(X_i)$ = Variance of character X_i

$\text{Var}(X_j)$ = Variance of character X_j

3.6.7 Path coefficient analysis

Path coefficients are standardized partial regression coefficients and as such provide the means to direct influence of one character upon another character. It also permits partitioning of correlation coefficient into direct and indirect effects via other character. For the path coefficient analysis the method originally proposed by Wright (1921), which was further modified by Dewey and Lu (1959).

$$r(x_1, y) = a + r(x_1, x_2)b + r(x_1, x_3)c.$$

$$r(x_2, y) = b + r(x_2, x_1)a + r(x_2, x_3)c.$$

$$R(x, y) = c + r(x_3, x_1)a + r(x_3, x_2)$$

Considering the three factors i.e. x_1 , x_2 and x_3 , the simultaneous equations give above can be matrix notation as:

$$\begin{matrix} \begin{bmatrix} r_{x_1 y} \\ r_{x_2 y} \\ r_{x_3 y} \end{bmatrix} & = & \begin{bmatrix} r_{x_1 x_1} & r_{x_1 x_2} & r_{x_1 x_3} \\ r_{x_2 x_1} & r_{x_2 x_2} & r_{x_2 x_3} \\ r_{x_3 x_1} & r_{x_3 x_2} & r_{x_3 x_3} \end{bmatrix} & \begin{bmatrix} a \\ b \\ c \end{bmatrix} \\ \text{A} & & \text{B} & \text{C} \end{matrix}$$

Where,

$r(x_1, y)$ = Coefficient of correlation between x_1 and y

$r(x_2, y)$ = Correlation coefficient between character x_2 and y

$r(x_3, y)$ = coefficient of correlation between character x_3 and y

a = Direct effect of character x_1 and y

b = Direct effect of character x_2 and y

c =Direct effect of character x_3 and y

The solution for vector c may be obtained as follows: $A=B.C$

Residual effect:

The unexplained variation in the dependent variable was obtained as residual factor from the following equation.

$$R = \sqrt{1 - \sum d_{ij} r_{ij}}$$

Where,

d_i = Direct effect of the i th character

r_{ij} = Correlation coefficient of the i th character with j th dependent character

CHAPTER IV

RESULT AND DISCUSSION

The result obtained from the present evaluation entitled “**Studies on Morphological Diversity in Bougainvillea (*Bougainvillea* Comm. ex. Juss.) Cultivars**” was commenced in 2018-19 in Horticulture Farm, COA, IGKV, Raipur. The investigation was aimed for morphological characterization and evaluation of Bougainvillea cultivars. To acquire transparent representation of variability in cultivars genetic parameters of variability were investigated. The correlation coefficients were assessed to resolve the degree of association of character with bract length and its components. Path analysis was estimated to know the direct and indirect effects of components on bract length; the findings are presented under the following headings:

4.1 Morphological Characterization of Bougainvillea cultivars

4.2 Identification of Suitable Cultivars

4.3 Analysis of Variance

4.4 Genetic Variability, Heritability and Genetic Advance

4.5 Correlation and Path analysis

4.1 Morphological Characterization

The results of morphological characterization and grouping of Bougainvillea cultivars based on qualitative, pseudo-qualitative and quantitative characteristics were carried out as per DUS guidelines of Bougainvillea by PPV&FRA (2014) organized in Table-4.1 and 4.2. Every single cultivar has got precisely plausible characters which differ from the other. The cultivars under study were outstanding for both the growth and floral characters. The study represented that major characters possessed significant variation alongside the

cultivars. The various behavioural attributes of the cultivars were adequate to identify the cultivars uniqueness and characterization.

4.1.1 Qualitative and Pseudo-Qualitative Characteristics

The QL and PQ characters of growth and floral characteristics analysed and results are presented in Table- 4.1 and 4.2 respectively and described below:

4.1.1.1 Growth Characteristics

The vegetative characters include plant growth habit, young shoot colour, thorn presence, thorns density, thorn curvature, thorns strength, leaf shape, leaf apex shape, leaf base shape, young leaf colour, leaf blade main colour, leaf blade secondary colour, leaf blade secondary colour distribution, leaf undulation, leaf texture, petiole attitude and leaf persistence were evaluated and categorized in Table-4.1 and frequency of characters are represented by pie chart in Fig-4.1. All the characters attained significance except thorns presence and leaf blade tertiary colour.

The plant growth habit is crucial part of all 32 cultivars categorized into four groups viz., semi-upright, upright, spreading and climbing. The greatest frequency noted in semi-upright (50%), followed by upright (25%), spreading (22%) and least in climbing (3%). The young shoot colour was grouped into three groups reddish, reddish green, light green and medium green. The greatest frequency observed in reddish green (53%), followed by light green (25%) and least in medium green (22%).

The thorn presence recorded non-significant, frequency of (100%). There was no variation noticed in character because thorns were present in every cultivar in the evaluation. The thorn density was categorized three groups viz., medium, sparse and dense. It recorded the highest frequency in medium (60%), followed by sparse (31%) and least in dense (9%). The thorn curvature was categorized into three groups viz., slightly curved, straight and curved. Its frequency noted similar in slightly curved (38%), straight (37%) and least in curved (8%). Ram et al. (2010) also evidenced the thorn character to be curved in most of the cultivars. The

thorn strength was classified into three groups viz., medium, strong and weak. It recorded highest frequency in medium (44%), followed by strong (31%) and least in weak (25%).

The evaluation of shape of leaf blade was done to know the variation in shape of leaves in different cultivars. Leaf blade shape was stated into four groups viz., broadly ovate, medium ovate, elliptical, lanceolate. Its frequency observed greatest in broadly ovate (44%), followed by medium ovate (37%), elliptical (13%) and least in lanceolate (2%). The leaf apex shape was categorized into acute and acuminate states. It recorded similar frequencies for both the states (groups) 50% of them were acute and 50% of them were acuminate. The leaf base shape grouped into three group's viz., obtuse, acute and attenuate. It noted highest frequency in obtuse (69%), followed by acute (25%) and least in attenuate (6%).

The young leaf colour observed by visually grouped into four groups viz., reddish green, light green, reddish, medium green. The highest frequency observed for reddish green (38%), followed by light green (25%), reddish (25%) and least in medium green (6%). The leaf main colour classified into four groups viz., medium green, light green, dark green and yellowish green. It recorded greatest frequency in medium green colour (53%), followed by dark green (28%), light green (16%) and least in yellowish green (3%).

The leaf blade secondary colour categorized into three groups includes, none, yellow and yellowish white. It observed superior frequency in none (91%), least in yellow (3%) and yellowish white (6%). The leaf: distribution of secondary colour recorded superior frequency in absent (91%) followed by broad marginal (6%) in cultivars Dr. Rao and Bangalore Variegata and minimum in around midrib (3%) in cultivar Thimma. The tertiary colour recorded non-significant, frequency of (100%). There was no variation evidenced in character because tertiary colour was not present in any cultivar in the evaluation.

The leaf undulation was grouped into three groups absent, medium and strong. It observed highest frequency in absent (72%), followed by medium (19%) and least in strong (9%). The leaf texture was grouped into glabrous, hairy and

slightly hairy. It observed superior frequency in glabrous (81%), followed by slightly hairy (13%) and least in hairy (6%). The petiole altitude was grouped into three groups upwards, downwards and horizontal. It recorded greatest frequency upwards (41%), followed by downwards (34%) and horizontal (25%). The leaf persistence was categorized into two states. It recorded highest frequency in non-persistence (78%), followed by persistence (22%).

These outcome also confirmation with the earlier reports of Singh *et al.* (2016 b), Singh *et al.* (2016 a), Singh *et al.* (2009) and Arya *et al.* (2012) on growth characteristics viz., growth habit, leaf blade characters and thorn characters. Avendaño-Arrazate *et al.* (2017) also confirmed the finds with heliconia on leaf, flower and inflorescence characters.

Table-4.1 Morphological description of QL & PQ growth characteristics

Sl. No.	Varieties	Plant growth habit	Young Shoot Colour	Thorn Presence	Thorns Density	Thorn Curvature
1	Alick Lancaster	Spreading	Reddish Green	Present	Medium	Straight
2	Bangalore Variegata	Upright	Light Green	Present	Medium	Curved
3	Bridal Bouquet	Semi-Upright	Reddish Green	Present	Dense	Straight
4	Carpet Purple	Upright	Reddish Green	Present	Sparse	Curved
5	Cherry Blossom	Semi-Upright	Reddish Green	Present	Dense	Straight
6	Chitra	Semi-Upright	Reddish	Present	Sparse	Straight
7	Dr. R. R. Pal	Spreading	Reddish Green	Present	Medium	Straight
8	Dr.Rao	Upright	Light Green	Present	Medium	Straight
9	Fantasy	Upright	Reddish Green	Present	Medium	Straight
10	Formosa	Semi-Upright	Light Green	Present	Medium	S. curved
11	Glabra	Semi-Upright	Light Green	Present	Medium	S. curved
12	Golden Glow	Upright	Reddish Green	Present	Medium	Curved
13	Gopal	Spreading	Light Green	Present	Medium	Straight
14	Magnifica	Upright	Light Green	Present	Sparse	Straight
15	Mahara	Spreading	Reddish Green	Present	Sparse	S. curved
16	Mahatma Gandhi	Semi-Upright	Medium Green	Present	Medium	Straight
17	Mary Palmer Special	Upright	Medium Green	Present	Medium	S. curved
18	Mataji Agnihotri	Semi-Upright	Medium Green	Present	Medium	Curved
19	Partha	Semi-Upright	Light Green	Present	Dense	S. curved
20	Pink beauty	Semi-Upright	Reddish Green	Present	Sparse	S. curved
21	Queen Violet	Spreading	Reddish Green	Present	Medium	S. curved
22	Roseville's Delight	Semi-Upright	Reddish Green	Present	Medium	Straight
23	Scarlet O Hara	Semi-Upright	Reddish Green	Present	Medium	Curved
24	Shubra	Climbing	Light Green	Present	Sparse	Curved
25	Shweta	Semi-Upright	Medium Green	Present	Medium	Curved
26	Sonnet(c)	Semi-Upright	Medium Green	Present	Medium	Straight
27	Summer Time	Semi-Upright	Reddish Green	Present	Sparse	Curved
28	Thimma	Upright	Reddish Green	Present	Sparse	S. curved
29	Tomato red	Spreading	Medium Green	Present	Medium	Straight
30	Torch Glow	Semi-Upright	Reddish Green	Present	Medium	S. curved
31	Vishaka	Spreading	Reddish Green	Present	Sparse	Straight
32	Zakiriana	Semi-Upright	Medium Green	Present	Sparse	S. curved

Note: S. Curved : Slightly Curved

Sl. No.	Varieties	Thorn Strength	Leaf Shape	Leaf Apex Shape	Leaf Base Shape	Young Leaf Colour
1	Alick Lancaster	Strong	Broad Ovate	Acute	Obtuse	R. Green
2	Bangalore Variegata	Strong	Medium Ovate	Acuminate	Obtuse	L. Green
3	Bridal Bouquet	Medium	Medium Ovate	Acute	Acute	L. Green
4	Carpet Purple	Medium	Elliptical	Acuminate	Obtuse	L. Green
5	Cherry Blossom	Medium	Broad Ovate	Acute	Obtuse	R. Green
6	Chitra	Strong	Broad Ovate	Acuminate	Obtuse	Reddish
7	Dr. R. R. Pal	Medium	Broad Ovate	Acute	Obtuse	Reddish
8	Dr.Rao	Strong	Broad Ovate	Acuminate	Obtuse	L. Green
9	Fantasy	Strong	Broad Ovate	Acute	Obtuse	Reddish
10	Formosa	Medium	Broad Ovate	Acute	Acute	L. Green
11	Glabra	Medium	Elliptical	Acute	Obtuse	R. Green
12	Golden Glow	Weak	Broad Ovate	Acute	Obtuse	R. Green
13	Gopal	Medium	Medium Ovate	Acuminate	Attenuate	R. Green
14	Magnifica	Strong	Lanceolate	Acute	Acute	L. Green
15	Mahara	Weak	Medium Ovate	Acute	Obtuse	Reddish
16	Mahatma Gandhi	Strong	Broad Ovate	Acute	Obtuse	Reddish
17	Mary Palmer Special	Medium	Broad Ovate	Acuminate	Obtuse	M. Green
18	Mataji Agnihotri	Weak	Broad Ovate	Acuminate	Obtuse	Reddish
19	Partha	Medium	Medium Ovate	Acute	Acute	R. Green
20	Pink beauty	Weak	Medium Ovate	Acuminate	Obtuse	L. Green
21	Queen Violet	Strong	Medium Ovate	Acute	Acute	M. Green
22	Roseville's Delight	Weak	Broad Ovate	Acute	Obtuse	Reddish
23	Scarlet O Hara	Medium	Broad Ovate	Acute	Acute	R. Green
24	Shubra	Strong	Medium Ovate	Acuminate	Obtuse	L. Green
25	Shweta	Medium	Lanceolate	Acuminate	Attenuate	L. Green
26	Sonnet(C)	Strong	Broad Ovate	Acuminate	Obtuse	R. Green
27	Summer Time	Medium	Elliptical	Acuminate	Acute	R. Green
28	Thimma	Weak	Medium Ovate	Acuminate	Obtuse	R. Green
29	Tomato red	Medium	Medium Ovate	Acute	Obtuse	Reddish
30	Torch Glow	Weak	Medium Ovate	Acuminate	Obtuse	L. Green
31	Vishaka	Medium	Elliptical	Acuminate	Acute	R. Green
32	Zakiriana	Weak	Medium Ovate	Acute	Obtuse	R. Green

Note: R. Green : Reddish Green

M. Green: Medium Green

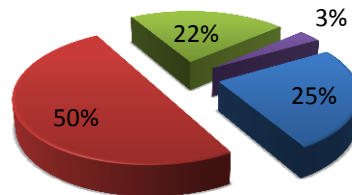
L. Green: Light Green

Sl. No.	Varieties	Leaf Blade Main Colour	Leaf Blade Secondary Colour	Leaf :Distribution of Secondary colour	Leaf Tertiary Colour	Leaf Undulation
1	Alick Lancaster	D. Green	None	Absent	None	Absent
2	Bangalore Variegata	L. Green	Y. White	Broad Marginal	None	Medium
3	Bridal Bouquet	D. Green	None	Absent	None	Absent
4	Carpet Purple	M. Green	None	Absent	None	Absent
5	Cherry Blossom	D. Green	None	Absent	None	Absent
6	Chitra	D. Green	None	Absent	None	Absent
7	Dr. R. R. Pal	D. Green	None	Absent	None	Medium
8	Dr.Rao	Y. Green	Y. White	Broad Marginal	None	Absent
9	Fantasy	D. Green	None	Absent	None	Absent
10	Formosa	L. Green	None	Absent	None	Absent
11	Glabra	D. Green	None	Absent	None	Medium
12	Golden Glow	M. Green	None	Absent	None	Absent
13	Gopal	M. Green	None	Absent	None	Strong
14	Magnifica	M. Green	None	Absent	None	Absent
15	Mahara	M. Green	None	Absent	None	Absent
16	Mahatma Gandhi	D. Green	None	Absent	None	Absent
17	Mary Palmer Special	L. Green	None	Absent	None	Absent
18	Mataji Agnihotri	M. Green	None	Absent	None	Absent
19	Partha	M. Green	None	Absent	None	Absent
20	Pink beauty	M. Green	None	Absent	None	Absent
21	Queen Violet	D. Green	None	Absent	None	Absent
22	Roseville's Delight	M. Green	None	Absent	None	Absent
23	Scarlet O Hara	M. Green	None	Absent	None	Medium
24	Shubra	L. Green	None	Absent	None	Medium
25	Shweta	M. Green	None	Absent	None	Medium
26	Sonnet(C)	M. Green	None	Absent	None	Strong
27	Summer Time	M. Green	None	Absent	None	Absent
28	Thimma	M. Green	Yellow	Around Midrib	None	Absent
29	Tomato red	M. Green	None	Absent	None	Absent
30	Torch Glow	M. Green	None	Absent	None	Absent
31	Vishaka	L. Green	None	Absent	None	Absent
32	Zakiriana	M. Green	None	Absent	None	Strong
Note: Y. White: Yellowish white Y. Green: Yellowish Green		M. Green: Medium Green R. Green : Reddish Green		L. Green : Light Green D. Green : Dark Green		

Sl. No.	Varieties	Leaf Texture	Petiole Altitude	Leaf Persistence
1	Alick Lancaster	Glaborous	Upwards	Non-Persistent
2	Bangalore Variegata	Slightly Hairy	Horizontal	Non Persistent
3	Bridal Bouquet	Glaborous	Upwards	Persistent
4	Carpet Purple	Slightly Hairy	Upwards	Persistent
5	Cherry Blossom	Glaborous	Downwards	Non Persistent
6	Chitra	Glaborous	Horizontal	Non Persistent
7	Dr. R. R. Pal	Slightly Hairy	Upwards	Non Persistent
8	Dr.Rao	Glaborous	Upwards	Non-Persistent
9	Fantasy	Slightly Hairy	Upwards	Non Persistent
10	Formosa	Glaborous	Downwards	Persistent
11	Glabra	Glaborous	Downwards	Non Persistent
12	Golden Glow	Glaborous	Horizontal	Non-Persistent
13	Gopal	Glaborous	Downwards	Non Persistent
14	Magnifica	Glaborous	Horizontal	Non-Persistent
15	Mahara	Glaborous	Downwards	Persistent
16	Mahatma Gandhi	Glaborous	Horizontal	Non Persistent
17	Mary Palmer Special	Glaborous	Downwards	Non Persistent
18	Mataji Agnihotri	Glaborous	Horizontal	Non Persistent
19	Partha	Glaborous	Upwards	Non Persistent
20	Pink beauty	Glaborous	Downwards	Non-Persistent
21	Queen Violet	Glaborous	Downwards	Non-Persistent
22	Roseville's Delight	Glaborous	Upwards	Persistent
23	Scarlet O Hara	Hairy	Horizontal	Persistent
24	Shubra	Glaborous	Downwards	Non-Persistent
25	Shweta	Glaborous	Upwards	Non-Persistent
26	Sonnet	Glaborous	Upwards	Non Persistent
27	Summer Time	Glaborous	Upwards	Non Persistent
28	Thimma	Glaborous	Upwards	Non-Persistent
29	Tomato red	Glaborous	Horizontal	Non Persistent
30	Torch Glow	Glaborous	Downwards	Persistent
31	Vishaka	Glaborous	Horizontal	Non Persistent
32	Zakiriana	Hairy	Downwards	Non-Persistent

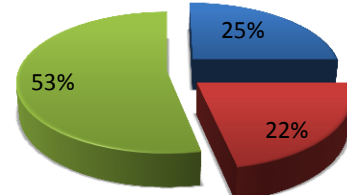
Plant Growth Habit

■ Upright ■ Semi-upright
■ Spreading ■ Climbing

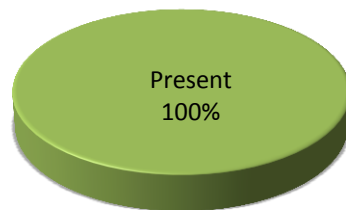


Young Shoot Colour

■ Light green ■ Medium green
■ Reddish green

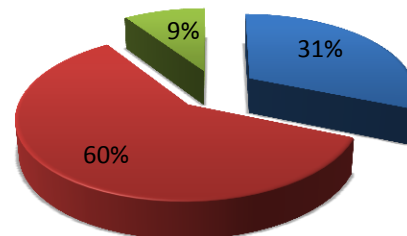


Thorn Presence

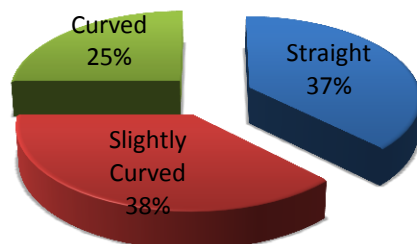


Thorns Density

■ Sparse ■ Medium ■ Dense

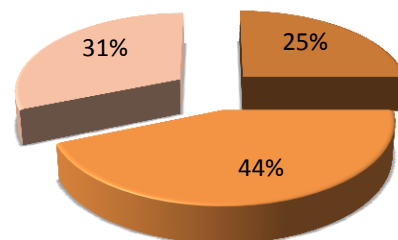


Thorn Curvature



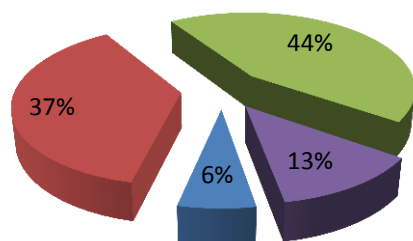
Thorns Strength

■ Weak ■ Medium ■ Strong



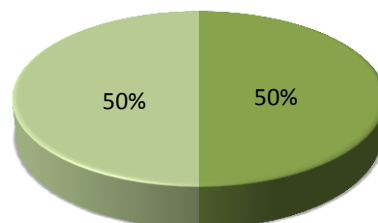
Leaf Blade Shape

■ Lanceolate ■ Medium ovate
■ Broad ovate ■ Elliptic



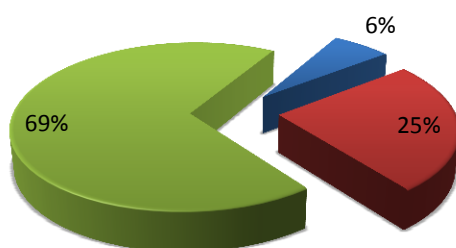
Leaf Apex Shape

■ Acuminate ■ Acute



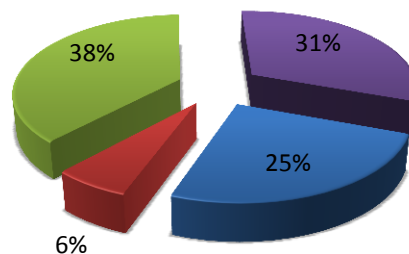
Leaf Base Shape

■ Attenuate ■ Acute ■ Obtuse



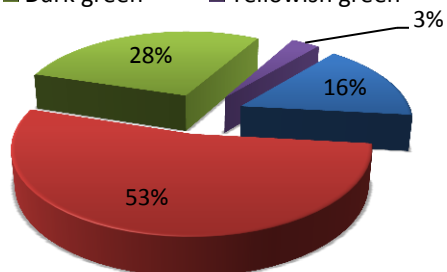
Young Leaf Colour

■ Light Green ■ Medium Green
■ Reddish Green ■ Reddish



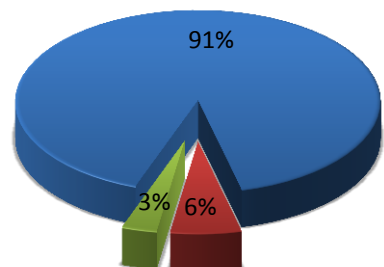
Leaf Blade Main Colour

■ Light green ■ Medium green
■ Dark green ■ Yellowish green



Leaf Blade Secondary Colour

■ None ■ Yellowish white ■ Yellow



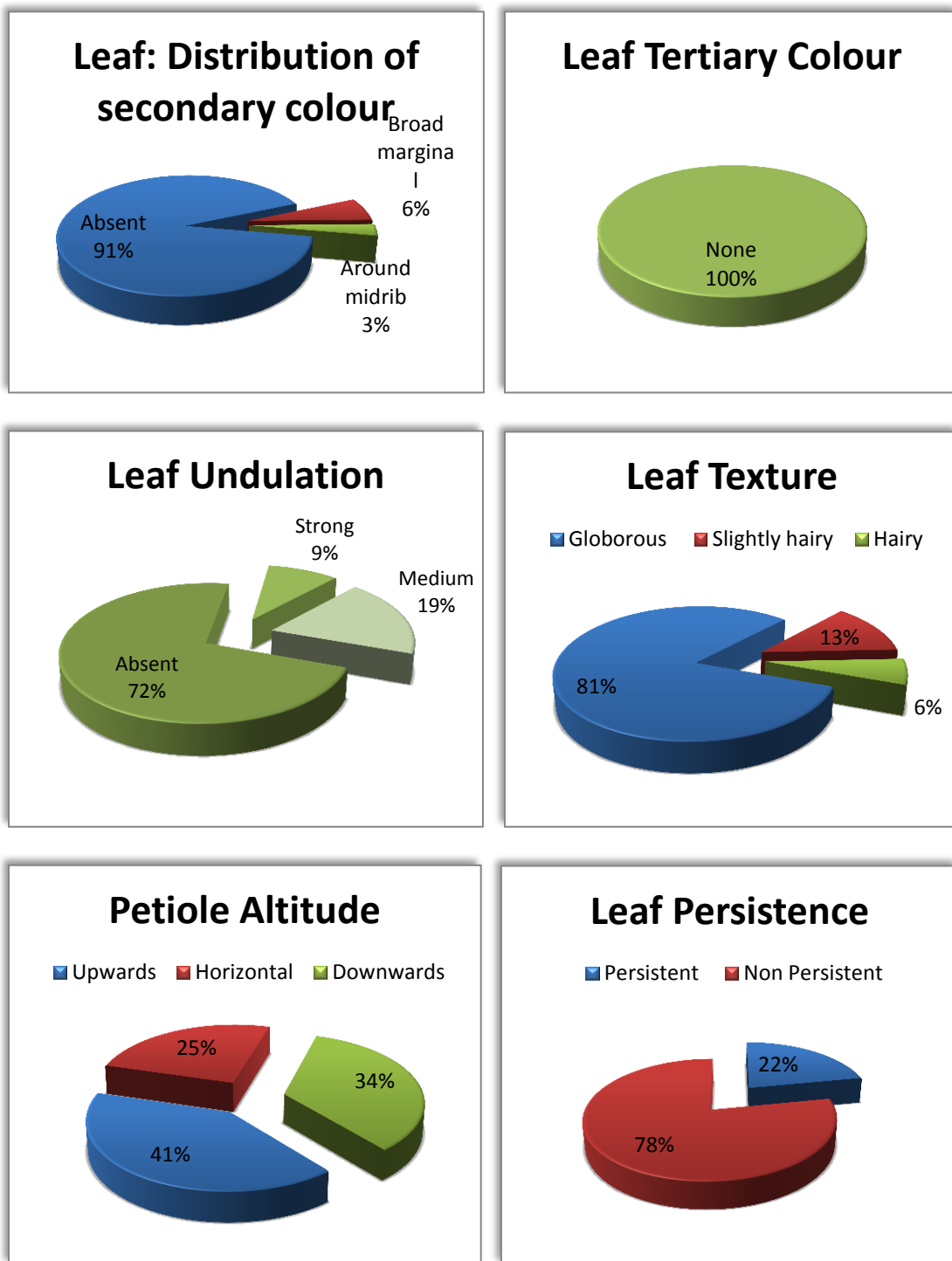


Fig 4.1: Diagrammatic presentation of growth characteristics in bougainvillea cultivars through pie chart

4.1.1.2 Floral Characteristics

The bract, flower and inflorescence characters of bougainvillea cultivars were exhibited significant variation and categorized in Table 4.2 and frequency of each character of bougainvillea are presented in diagrammatically in pie chart in Fig-4.2. The bract colour is divided into categories and the colour of the bract was compared with Royal Horticulture Society colour chart in Plate-4.1 as per DUS guidelines of Bougainvillea (2014), they were grouped according to their colour groups.

The inflorescence of the bougainvillea arrangement of bract clusters was categorized into three groups include, axillary & terminal, terminal and axillary. The greatest frequency is noted in axillary and terminal (62%) followed by terminal (38%). The number of bract clusters was stated into medium, many and few. Its frequency noted highest in medium (56%), followed by many (44%). The bract density in cluster categorized into 3 groups few, medium and dense. Its frequency observed highest in few (53%), followed by medium (34%) and least dense (13%).

The flower character presence of flower is categorized into 2 groups present and absent. The significant difference noted with superior frequency of present (87%), followed by absent (13%). The bract characters of bougainvillea showed significant difference in the experiment. Whereas bract type was categorized into two groups viz., single and multiple. It determines the type of bract, the superior frequency noted in single (87%), followed by least multiple (13%). The bract shape classified into four states include broadly ovate, medium ovate, narrowly ovate and circular. Where the utmost frequency noted in broadly ovate (41%), followed by medium ovate (28%), narrowly ovate (25%) and least in circular (6%).

The bract tip shape classified into two states include, acute and obtuse. The highest frequency noted in acute (81%) and least in obtuse (19%). The bract base shape was categorized into two groups cordate and obtuse. The utmost frequency noted in cordate (54%) and followed by obtuse (41%). The bract persistence was stated into two groups persistent and non-persistent. The superior frequency was

observed in non-persistent (69%) and followed by persistent (31%). The reflection of bract was categorized into two groups normal and reflexed. The frequency noticed superior in normal (97%) and remaining least in reflexed (3%). These results are supported by the findings of Singh et al. (2007) for flower characteristics

Table-4.2 Morphological description of floral characteristics (OL and PQ) description

	Varieties	Arrangement of Bract clusters	Number of Bract Clusters	Bract Density in cluster	Bract Tip Shape	Bract Base Shape
1	Alick Lancaster	A and T	Many	Medium	Obtuse	Cordate
2	Bangalore Variegata	Terminal	Medium	Few	Acute	Obtuse
3	Birdal Bouquet	Terminal	Many	Dense	Acute	Obtuse
4	Carpet Purple	Terminal	Medium	Medium	Acute	Cordate
5	Cherry Blossom	Terminal	Many	Dense	Acute	Obtuse
6	Chitra	Terminal	Medium	Few	Acute	Cordate
7	Dr. R. R. Pal	Terminal	Many	Medium	Acute	Cordate
8	Dr.Rao	Terminal	Medium	Few	Obtuse	Cordate
9	Fantasy	Terminal	Medium	Medium	Acute	Cordate
10	Formosa	A and T	Medium	Few	Acute	Cordate
11	Glabra	A and T	Many	Medium	Acute	Obtuse
12	Golden Glow	Terminal	Medium	Few	Acute	Cordate
13	Gopal	Terminal	Many	Few	Acute	Cordate
14	Magnifica	A and T	Many	Medium	Acute	Obtuse
15	Mahara	Terminal	Many	Dense	Acute	Obtuse
16	Mahatma Gandhi	A and T	Medium	Medium	Obtuse	Cordate
17	Mary Palmer Special	Terminal	Medium	Medium	Obtuse	Cordate
18	Mataji Agnihotri	Terminal	Medium	Medium	Obtuse	Cordate
19	Partha	Terminal	Medium	Few	Acute	Cordate
20	Pink beauty	Terminal	Many	Medium	Acute	Obtuse
21	Queen Violet	Terminal	Many	Few	Acute	Cordate
22	Roseville's Delight	Terminal	Many	Dense	Acute	Obtuse
23	Scarlet O Hara	A and T	Many	Few	Acute	Cordate
24	Shubra	A and T	Many	Few	Acute	Obtuse
25	Shweta	A and T	Medium	Few	Acute	Obtuse
26	Sonnet	A and T	Medium	Few	Acute	Cordate
27	Summer Time	A and T	Medium	Few	Acute	Cordate
28	Thimma	Terminal	Medium	Few	Acute	Obtuse
29	Tomato red	A and T	Medium	Few	Acute	Obtuse
30	Torch Glow	Terminal	Many	Medium	Acute	Obtuse
31	Vishaka	A and T	Medium	Few	Acute	Cordate
32	Zakiriana	Terminal	Medium	Few	Obtuse	Cordate

A and T: Axillary and Terminal

Sl. No.	Varieties	Presence of Flower	Bract type	Bract Shape	Bract Persistence	Bract Reflection
1	Alick Lancaster	Present	Single	B. Ovate	Non Persistent	Straight
2	Bangalore Variegata	Present	Single	N. Ovate	Non Persistent	Normal
3	Birdal Bouquet	Absent	Multiple	M. Ovate	Persistence	Normal
4	Carpet Purple	Present	Single	N. Ovate	Non Persistent	Normal
5	Cherry Blossom	Absent	Multiple	M. Ovate	Persistent	Normal
6	Chitra	Present	Single	Circular	Non Persistent	Normal
7	Dr. R. R. Pal	Present	Single	B. Ovate	Non Persistent	Normal
8	Dr.Rao	Present	Single	B. Ovate	Non Persistent	Normal
9	Fantasy	Present	Single	Circular	Non Persistent	Normal
10	Formosa	Present	Single	B. Ovate	Persistent	Normal
11	Glabra	Present	Single	N. Ovate	Non Persistent	Normal
12	Golden Glow	Present	Single	B. Ovate	Persistent	Normal
13	Gopal	Present	Single	M. Ovate	Non Persistent	Normal
14	Magnifica	Present	Single	N. Ovate	Non Persistent	Normal
15	Mahara	Absent	Multiple	B. Ovate	Persistent	Normal
16	Mahatma Gandhi	Present	Single	B. Ovate	Non Persistent	Normal
17	Mary Palmer Special	Present	Single	B. Ovate	Non Persistent	Normal
18	Mataji Agnihotri	Present	Single	B. Ovate	Non Persistent	Normal
19	Partha	Present	Single	M. Ovate	Non Persistent	Normal
20	Pink beauty	Present	Single	N. Ovate	Persistent	Normal
21	Queen Violet	Present	Single	M. Ovate	Persistent	Straight
22	Roseville's Delight	Absent	Multiple	N. Ovate	Persistent	Normal
23	Scarlet O Hara	Present	Single	B. Ovate	Persistent	Normal
24	Shubra	Present	Single	B. Ovate	Non Persistent	Straight
25	Shweta	Present	Single	N. Ovate	Non Persistent	Reflexed
26	Sonnet	Present	Single	M. Ovate	Non Persistent	Normal
27	Summer Time	Present	Single	B. Ovate	Non Persistent	Normal
28	Thimma	Present	Single	B. Ovate	Non Persistent	Normal
29	Tomato red	Present	Single	M. Ovate	Non Persistent	Normal
30	Torch Glow	Present	Single	N. Ovate	Persistent	Normal
31	Vishaka	Present	Single	M. Ovate	Non Persistent	Normal
32	Zakiriana	Present	Single	M. Ovate	Non Persistent	Straight

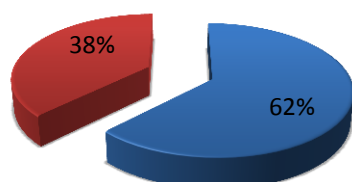
M. Ovate: Medium Ovate,

B. Ovate: Broadly Ovate,

N. Ovate: Narrowly Ovate

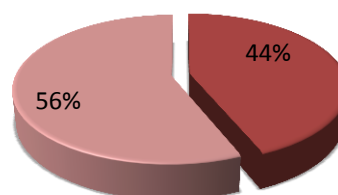
Arrangement of bract clusters

■ Terminal ■ Axillary and Terminal



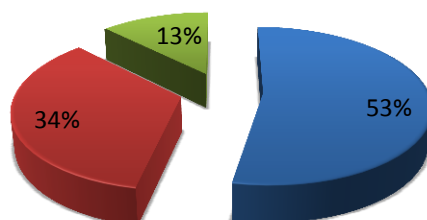
Number of bract clusters

■ Many ■ Medium

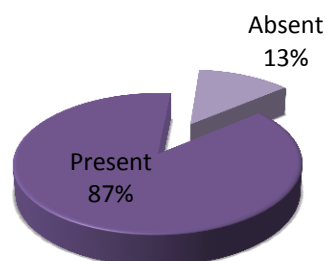


Bract Density in Cluster

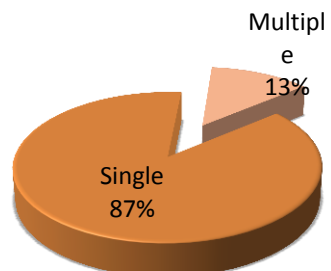
■ Few ■ Medium ■ Dense



Presence of Flowers

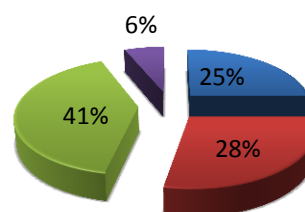


Bract Type



Bract Shape

■ Narrowly ovate ■ Medium ovate ■ Broadly ovate ■ Circular



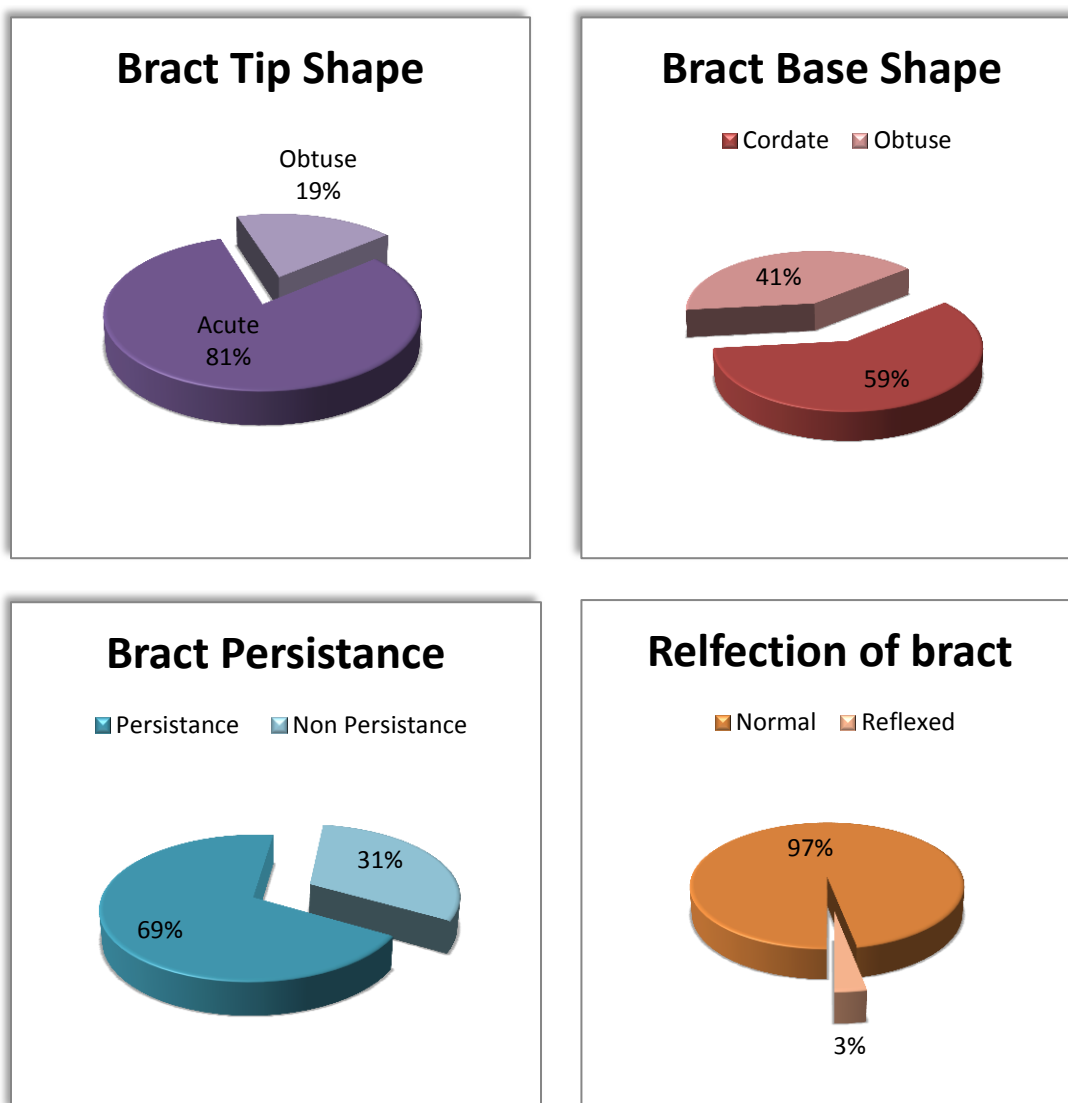
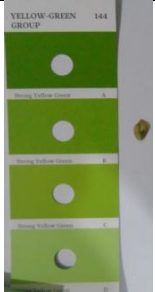
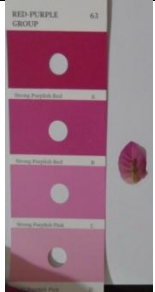
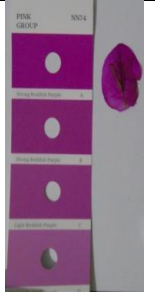
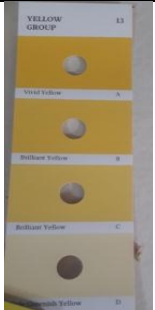
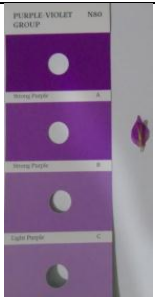
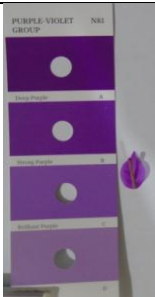
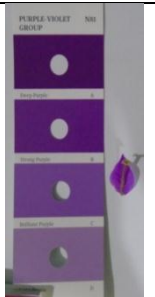
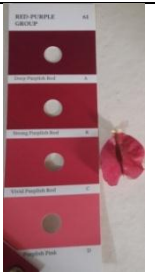
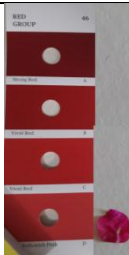
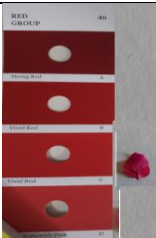
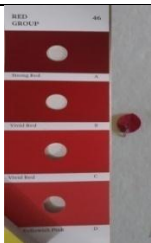
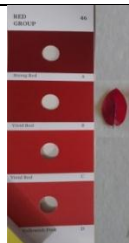
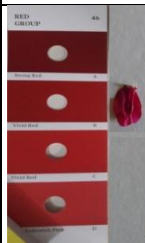
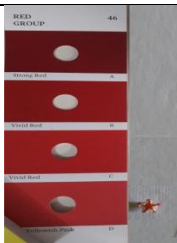
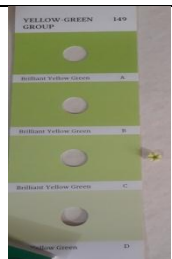


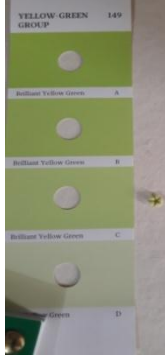
Fig-4.2 Diagrammatic representation of floral characteristics of bougainvillea through pie chart

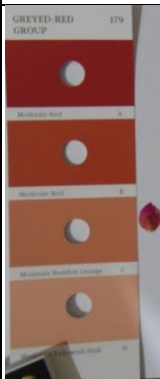
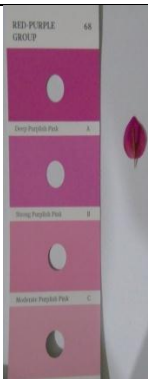
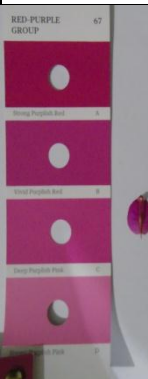
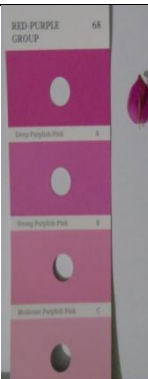
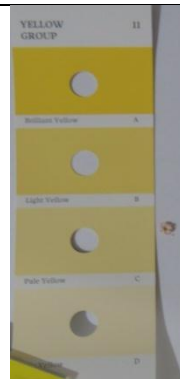
The Bract colour in bougainvillea is categorized into five single bract type and two multiple bract type characteristics, depending on colour groups by comparing the different parts of the bract and flower part with Royal Horticulture Society colour chart and grouped according to their colour groups as per DUS guidelines of Bougainvillea (2014) are presented in Plate-4.1 and Plate 4.2 respectively. All the cultivars are grouped according to their colour chart group which acquired in the result Table-4.3.

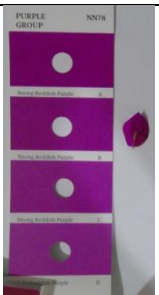
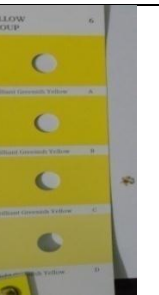
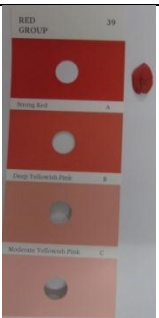
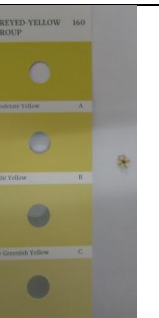
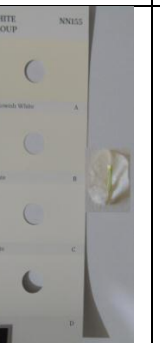
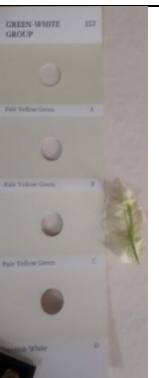
Plate-4.1. List of Single bract type colour description by means of RHS colour chart [DUS guideline Bougainvillea (PPV&FRA in 2014)]

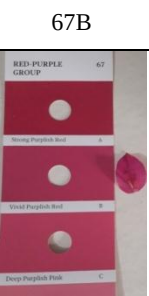
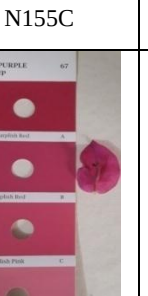
Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
1	Alick Lancaster	 144A	 63B	 NN74B	 NN74B	 3D
2	Bangalore Variegata	 13D	 NN78C	 NN78C	 MM78D	 4C
3	Carpet purple	 N80B	 N81C	 N81C	 N81C	 8C
4	Chitra	 61B	 61C	 61C	 61D	 150B

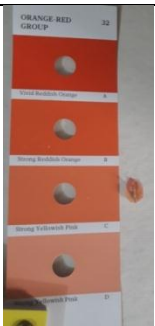
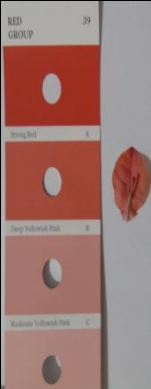
Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
5	Dr. R. R. Pal	 178B	 60D	 N74		 5D
6	Dr. Rao	 46D	 46D		 46C	
7	Fantasy	 46A	 46B	 46B		 46D
8	Formosa	 N75B	 N75C	 N75C	 N75D	 4C
9	Glabra	 84B	 84C	 84C	 84C	 149C

Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
10	Golden Glow	 163A	 163B	 163C	 163D	 4C
11	Gopal	 64D	 NN74A	 NN74B	 NN74B	 1D
12	Magnifica	 75A	 75B	 75B	 75B	 149C
13	Mahatma Gandhi	 67B	 67B	 67D	 NN74D	 1C

Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
14	Mary Palmer Special	 149B	 67C	 67C	 67D	 1C
15	Mataji Agnihotri	 NN74A	 NN74B	 NN74	 NN74D	 9D
16	Partha	 67C	 N74B	 NN74B	 NN74D	 1C
17	Pink Beauty	 179B	 68A	 67C	 68A	 11C

Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
18	Queen Violet	 NN78B	 NN78B	 NN78B	 NN78B	 6C
19	Scarlet O Hara	 173B	 39A	 67A	 67A	 160B
20	Shubra	 157A	 NN155B		 NN155B	 NN155D
21	Shweta	 149B	 149D	 157C	 149D	 1C

Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
22	Sonnet	 63C	 64C	 64C	 63C	 3C
23	Summer time	 NN74C	 NN74B	 NN74A	 NN74B	 4C
24	Thimma	 72C	 67B	 72C	 N155C	 4D
25	Tomato Red	 46A	 67B	 67B	 67B	 1D

Sl. No.	Cultivars	Young bract	Star not opened	Calyx opened	Calyx wilted	Calyx colour
26	Torch Glow	 32C	 68B	 68B	 68C	 10D
27	Vishaka	 NN74B	 NN74B	 NN74B	 NN74C	 2D
28	Zakiriana	 48B	 34C	 39B	 50C	 50D

Note: Young bract- Young Bract: Main colour of inner side

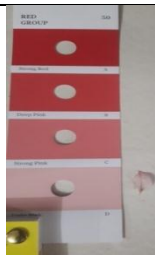
Star not opened- Young Bract: Main colour of inner side (Calyx lobe/ Star not open)

Calyx opened- Bract: Single: Main colour of inner side (Star open)

Calyx wilted- Bract: Main colour (Calyx lobe/ Star wilted / fading)

Calyx colour- Bract: Single: Calyx Lobes/ Star: Colour of upper side

Plate-4.2. List of multiple bract type colour description by means of RHS colour chart as per DUS guidelines Bougainvillea (PPV&FRA in 2014)

Sl. No	Cultivars	Bract: Double: Young outer Bract: Main colour of inner side	Bract: Double: Young inner Bract: Main colour of inner side
1	Bridal Bouquet	 50D	 73C
2	Cherry Blossom	 73A	 73B
3	Mahara	 67B	 67C
4	Roseville's Delight	 31C	 68C

The Star/ Calyx lobe star of bougainvillea observed Yellow – Yellow Green group in maximum cultivars except cultivars Shubra and Zakiriana noticed under White group and Red group respectively, result agreed with prior research by Arya *et al.* (2012). The bracts and star lobe of five single bract and two multiple bract type of pseudo-qualitative characteristics are judged and categorized their colour using RHS colour chart and grouped based on their colour groups given in chart and exhibited in Plate-4.1 and 4.2 respectively.

The results revealed that utmost cultivars are grouped into Red Purple group (11 cultivars), followed by Pink-Red purple group (5 cultivars), Purple group (4 cultivars), White Green - Red Purple (3 cultivars), Orange Red - Red Purple (3 cultivars), White-Yellow Green group (Shubra and Shweta) and least in Greyed Orange (Golden Glow) and Red Purple-Greyed Red (Pink Beauty). These outcomes was also experimentally substantiated by Kumar *et al.* (2014)

Table 4.3 Grouping of bougainvillea cultivars based on the RHS colour chart

Sl. No.	Colour groups	No. of cultivars	Cultivars
1	Pink – Red purple	5	Mataji Agnihotri, Alick Lancaster, Partha, Vishaka, Bridal Bouquet
2	White- Yellow Green	2	Shubra, Shweta
3	White Green - Red Purple	3	Chitra, Mary Palmer Special, Thimma
4	Orange Red - Red Purple	3	Torch Glow, Zakiriana, Roseville's Delight
5	Greyed Orange	1	Golden Glow
6	Red Purple - Greyed Red	1	Pink Beauty
7	Red Purple	11	Dr. R. R. Pal, Dr. Rao, Gopal, Mahatama Gandhi, Scarlet O Hara, Fantasy, Summer Time, Sonnet, Tomato Red, Cherry Blossom, Mahara
8	Purple	4	Bangalore Variegata, Formosa, Magnifica, Queen Violet
9	Purple-violet - Violet	2	Carpet Purple, Glabra

4.1.2 Quantitative characteristics (QN)

The QN growth characters include internodal length (cm), leaf length (cm), leaf width (cm), petiole length (cm), thorn length (cm) and thorn diameter (cm). The floral characters includes bract length (cm), bract width (cm), inflorescence length (cm), peduncle length (cm) and star diameter (cm) were analysed and categorized in Table-4.4 and 4.5, respectively.

4.1.2.1 Growth characteristics

The general mean of cultivars and state of each character were recorded in Table 4.4

4.1.2.1.1 Internodal length (cm)

The internodal length was categorized into three groups short (0.47 cm- 1.2 cm), medium (1.3 cm to 2.2 cm) and long (2.3 cm to 2.9 cm). out of 32 cultivars most of them found in medium (21 cultivars), followed by short (6 cultivars) and long (5 cultivars). The general mean of internodal length of bougainvillea was recorded 1.74 cm.

4.1.2.1.2 Leaf length (cm)

Leaf blade length (cm) was stated is categorized into three groups small (4.38 cm- 3.5 cm), medium (6.29 cm-4.4 cm) and long (8.4cm -6.3 cm). The maximum cultivars noted in both long (13) and medium (13) and least in short (6 cultivars). The leaf length and the general mean of leaf length of bougainvillea cultivar noted 5.798 cm.

4.1.2.1.3 Leaf width (cm)

The leaf blade width was grouped into three states include medium (2.5 cm-3.9cm), broad (4.03 cm-5.8 cm), narrow (1.97 cm-2.4cm). The utmost of cultivars in leaf width character are noted in medium (19 cultivars), followed by broad (10 cultivars) and least in narrow (3 cultivars) and general mean of leaf width in bougainvillea noted 3.596 cm.

4.1.2.1.4 Petiole length (cm)

Petiole length (cm) grouped into three groups includes medium (1.2 cm-0.7 cm), long (2 m -1.3 cm), short (0.6 cm -0.4 cm). The utmost cultivars in petiole length character recorded medium (22), followed by long (8) and minimal in short only two cultivars. and general mean of the petiole length of bougainvillea cultivars noted 1.131 cm.

4.1.2.1.5 Thorn length (cm)

Thorn length was divided into medium (1.1 cm -0.8 cm), short (0.7 cm -0.2 cm) and long (1.6 cm- 1.2 cm). The utmost cultivars noticed short (17 cultivars), followed by medium (12) and minimal in long (3). The general mean of thorn length of bougainvillea cultivars recorded 0.789cm.

4.1.2.1.6 Thorn diameter (cm)

Thorns diameter grouped into three states includes medium (0.25 cm-0.1 cm), short (0.09 cm- 0.05 cm) and broad (0.4 cm-0.24 cm). The medium recorded highest 13 cultivars and short 12 cultivars and least in broad seven cultivars. The general mean of thorn diameter of bougainvillea cultivars noted 0.199 cm.

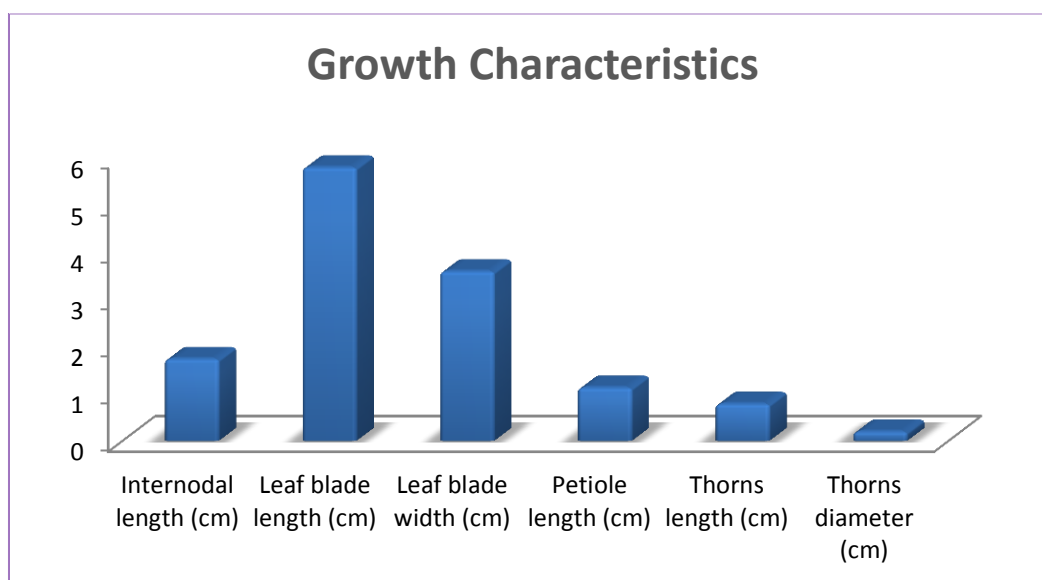


Fig-4.3 : Quantitative growth characteristics mean value

Table:4.4 Mean performance of Bougainvillea growth characteristics

Sl. No.	Varieties	Internodal length (cm)	States	Leaf blade length (cm)	States	Leaf blade width (cm)	States
1	Alick Lancaster	1.81	Medium	8.30	Long	4.93	Broad
2	Bangalore Variegata	1.10	Short	4.71	Medium	2.87	Medium
3	Bridal Bouquet	2.66	Long	4.44	Medium	3.31	Medium
4	Carpet Purple	1.41	Medium	3.99	Short	1.97	Narrow
5	Cherry Blossom	2.41	Medium	6.54	Long	4.14	Broad
6	Chitra	1.87	Medium	7.55	Long	5.8	Broad
7	Dr. R.R.Pal	2.90	Long	5.68	Medium	3.58	Medium
8	Dr. Rao	0.90	Short	4.05	Short	2.85	Medium
9	Fantasy	1.84	Medium	6.96	Long	2.99	Medium
10	Formosa	1.61	Medium	5.50	Medium	2.75	Medium
11	Glabra	1.74	Medium	7.57	Long	3.46	Medium
12	Golden Glow	2.29	Medium	5.84	Medium	3.92	Medium
13	Gopal	1.86	Medium	7.04	Long	4.53	Broad
14	Magnifica	1.25	Short	4.04	Short	2.19	Narrow
15	Mahara	0.96	Short	3.92	Short	3.08	Medium
16	Mahatma Gandhi	2.07	Medium	6.77	Long	3.77	Medium
17	Mary Palmer Special	1.15	Medium	4.69	Medium	3.25	Medium
18	Mataji Agnihotri	2.01	Medium	7.84	Long	4.79	Broad
19	Partha	2.02	Medium	5.60	Medium	2.74	Medium
20	Pink Beauty	0.50	Short	4.46	Medium	2.76	Medium
21	Queen Violet	1.52	Medium	6.26	Medium	3.42	Medium
22	Roseville's Delight	2.36	Long	3.7	Short	2.61	Medium
23	Scarlet O Hara	1.34	Medium	5.58	Medium	3.85	Medium
24	Shubra	2.34	Long	6.59	Long	4.28	Broad
25	Shweta	2.33	Long	6.55	Long	3.52	Medium
26	Sonnet	2.03	Medium	7.44	Long	4.79	Broad
27	Summer Time	1.35	Medium	6.62	Long	5.06	Broad
28	Thimma	1.13	Short	6.5	Long	4.03	Broad
29	Tomato Red	2.03	Medium	6.20	Medium	4.22	Broad
30	Torch Glow	0.47	Short	5.21	Medium	3.79	Medium
31	Vishaka	2.04	Medium	3.50	Short	2.09	Narrow
32	Zakiriana	2.26	Medium	5.80	Medium	3.65	Medium

Sl. No.	Varieties	Petiole Length (cm)	State	Thorn length (cm)	State	Thorn diameter (cm)	State
1	Alick Lancaster	1.27	Medium	0.61	Short	0.23	Medium
2	Bangalore Variegata	0.85	Medium	0.26	Short	0.18	Medium
3	Bridal Bouquet	0.96	Medium	0.53	Short	0.17	Short
4	Carpet Purple	0.49	Short	0.36	Short	0.20	Medium
5	Cherry Blossom	1.23	Medium	0.62	Short	0.20	Medium
6	Chitra	1.77	Long	0.74	Short	0.23	Medium
7	Dr. R.R.Pal	0.92	Medium	1.56	Long	0.24	Broad
8	Dr. Rao	0.91	Medium	0.57	Short	0.14	Short
9	Fantasy	1.01	Medium	1.05	Medium	0.21	Medium
10	Formosa	0.94	Medium	0.90	Medium	0.16	Short
11	Glabra	1.24	Medium	0.83	Medium	0.22	Medium
12	Golden Glow	1.21	Medium	1.14	Medium	0.16	Short
13	Gopal	1.30	Long	1.09	Medium	0.25	Medium
14	Magnifica	0.61	Short	0.59	Short	0.12	Short
15	Mahara	0.77	Medium	0.43	Short	0.24	Broad
16	Mahatma Gandhi	1.20	Medium	1.21	Long	0.24	Broad
17	Mary Palmer Special	1.32	Long	0.78	Short	0.30	Broad
18	Mataji Agnihotri	1.33	Long	0.87	Medium	0.24	Broad
19	Partha	1	Medium	1.22	Long	0.22	Medium
20	Pink Beauty	1.18	Medium	0.46	Short	0.10	Short
21	Queen Violet	1.5	Long	1.03	Medium	0.15	Short
22	Roseville's Delight	0.97	Medium	0.70	Short	0.25	Broad
23	Scarlet O Hara	1.15	Medium	0.96	Medium	0.20	Medium
24	Shubra	1.02	Medium	0.75	Short	0.15	Short
25	Shweta	1.54	Long	0.48	Short	0.17	Short
26	Sonnet	1.30	Long	0.84	Medium	0.22	Medium
27	Summer Time	1.98	Long	0.99	Medium	0.23	Medium
28	Thimma	0.97	Medium	0.89	Medium	0.16	Short
29	Tomato Red	1.25	Medium	1.10	Medium	0.23	Medium
30	Torch Glow	1.19	Medium	0.37	Short	0.10	Short
31	Vishaka	0.74	Medium	0.48	Short	0.25	Broad
32	Zakiriana	0.99	Medium	0.57	Short	0.07	Short

4.1.2.2 Floral Characteristics

The general mean of floral, bract and inflorescence characters are presented in Table-4.5

4.1.2.2.1 Bract length (cm)

Bract length (cm) categorized into three groups includes medium (2.3 cm-3.5cm), long (3.6 cm-4.9 cm) and short (1.8 cm-2.2cm). The maximum cultivars comes under medium (17), followed by long (11) and least in short (4). The general mean of the bract length in bougainvillea cultivars are noted 3.174 cm.

4.1.2.2.2 Bract width (cm)

Within bract width, grouped into three classes includes medium (1.8 cm-2.4 cm), narrow (1.2 cm-1.5 cm) and broad (2.5 cm-3.8 cm). Among them medium (16) noticed maximum, followed by broad (12) and least narrow (4). The general mean of the bract width in bougainvillea recorded 2.389 cm.

4.1.2.2.3 Peduncle length (cm)

Peduncle length was categorized into three groups includes medium (4.2 cm -2.7 cm), long (5.9cm -4.6 cm) and short (2.6 cm-0.3 cm). The most of cultivars comes under medium (17), followed by short (14), least in long (1). The general mean of peduncle length of cultivars noted 2.197 cm.

4.1.2.2.4 Inflorescence length (cm)

The inflorescence length (cm) categorized into 3 groups includes medium (8 cm - 15 cm), long (16 cm-33 cm) and short (6 cm-7 cm). Among 31 cultivars and a check recorded highest in medium (16 cultivars), followed by long (12) and minimal in short (4). The general mean of inflorescence length of bougainvillea cultivars found lot of variation and it recorded 14.358cm.

4.1.2.2.5 Star diameter (cm)

The star diameter was classified into three groups includes medium (0.5cm -0.4 cm), broad (0.7 cm-0.51 cm) and narrow (0.4 cm-0 cm). Among them maximum cultivars found in broad group (21) and least in short in Bangalore Variegata. The general mean of star diameter of bougainvillea noted 0.514 cm in all single bracted cultivars. The star is absent in some multi-bracted cultivars. These findings are close agreement with Kumar (2001)

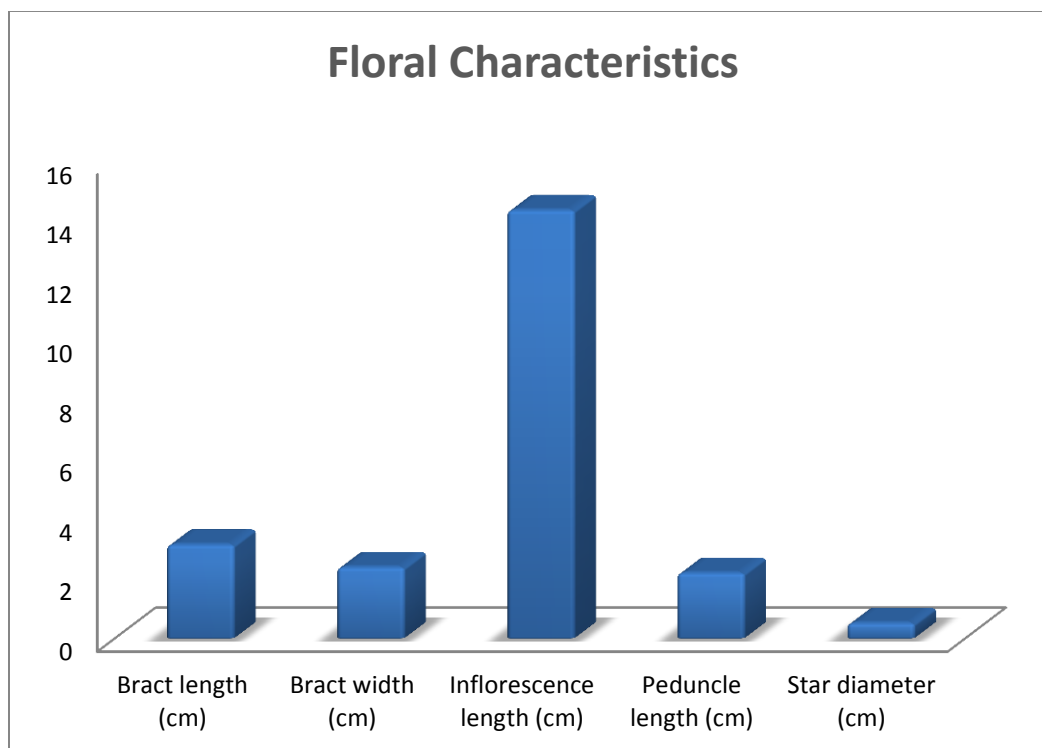


Fig-4.4: Quantitative Floral Characteristics mean value

Table:4.5 Mean performance of Bougainvillea floral characteristics

Sl. No.	Varieties	Bract length (cm)	State	Bract width (cm)	State	Peduncle length (cm)	State
1	Alick Lancaster	3.79	Long	2.77	Broad	1.64	Short
2	Bangalore Variegata	1.92	Short	1.36	Narrow	0.62	Short
3	Bridal Bouquet	2.31	Medium	1.73	Medium	0.85	Short
4	Carpet Purple	2.82	Medium	1.8	Medium	1.50	Short
5	Cherry Blossom	2.65	Medium	1.89	Medium	5.51	Long
6	Chitra	3.31	Medium	2.86	Broad	2.23	Medium
7	Dr. R.R.Pal	3.9	Long	2.92	Broad	2.88	Medium
8	Dr. Rao	2.25	Medium	1.76	Medium	3.18	Medium
9	Fantasy	3.1	Medium	2.88	Broad	1.82	Short
10	Formosa	3.96	Long	2.73	Broad	2.45	Medium
11	Glabra	3.22	Medium	2.15	Medium	1.64	Short
12	Golden Glow	2.55	Medium	2.16	Medium	3.73	Medium
13	Gopal	3.11	Medium	2.41	Medium	3.72	Medium
14	Magnifica	2.82	Medium	1.72	Medium	1.82	Short
15	Mahara	2.32	Medium	1.72	Medium	1.07	Short
16	Mahatma Gandhi	4.10	Long	2.92	Broad	1.75	Short
17	Mary Palmer Special	4.9	Long	3.40	Broad	2.24	Medium
18	Mataji Agnihotri	4.26	Long	3.28	Broad	1.97	Short
19	Partha	3.82	Long	2.83	Broad	2.27	Medium
20	Pink Beauty	1.76	Short	1.33	Narrow	0.56	Short
21	Queen Violet	2.91	Medium	2.42	Medium	1.55	Short
22	Roseville's Delight	2.07	Short	1.39	Narrow	3.3	Medium
23	Scarlet O Hara	3.04	Medium	2.26	Medium	2.17	Medium
24	Shubra	3.24	Medium	2.34	Medium	2.14	Medium
25	Shweta	4.25	Long	2.24	Medium	2.24	Medium
26	Sonnet	3.97	Long	3.84	Broad	2.96	Medium
27	Summer Time	4.09	Long	3.44	Broad	2.64	Medium
28	Thimma	3.56	Medium	2.64	Medium	1.83	Medium
29	Tomato Red	3.22	Medium	2.58	Medium	2.56	Medium
30	Torch Glow	1.84	Short	1.29	Narrow	0.38	Short
31	Vishaka	3.7	Long	3.27	Broad	3.00	Medium
32	Zakiriana	2.62	Medium	2.04	Medium	2.02	Short

Sl.No.	Varieties	Inflorescence length (cm)	State	Star diameter (cm)	State
1	Alick Lancaster	18.26	Long	0.64	Broad
2	Bangalore Variegata	7.1	Short	0.24	Short
3	Bridal Bouquet	11	Medium	0	
4	Carpet Purple	7.92	Short	0.67	Broad
5	Cherry Blossom	10.03	Medium	0	
6	Chitra	13.96	Medium	0.72	Broad
7	Dr. R.R.Pal	15.2	Long	0.61	Broad
8	Dr. Rao	6.51	Short	0.47	Medium
9	Fantasy	8.05	Short	0.58	Broad
10	Formosa	11.23	Medium	0.65	Broad
11	Glabra	19.13	Long	0.65	Broad
12	Golden Glow	10.06	Medium	0.64	Broad
13	Gopal	10.93	Medium	0.55	Broad
14	Magnifica	22.93	Long	0.65	Broad
15	Mahara	9.93	Medium	0	
16	Mahatma Gandhi	33.96	Long	0.46	Medium
17	Mary Palmer Special	20.03	Long	0.65	Broad
18	Mataji Agnihotri	23.13	Long	0.67	Broad
19	Partha	17.73	Long	0.65	Broad
20	Pink Beauty	9.49	Medium	0.47	Medium
21	Queen Violet	11.98	Medium	0.54	Broad
22	Roseville's Delight	8.63	Medium	0	
23	Scarlet O Hara	17.43	Long	0.55	Broad
24	Shubra	26.96	Long	0.45	Medium
25	Shweta	12.2	Medium	0.65	Broad
26	Sonnet	19.06	Long	0.71	Broad
27	Summer Time	10.16	Medium	0.71	Broad
28	Thimma	12.06	Medium	0.64	Broad
29	Tomato Red	21.6	Long	0.63	Broad
30	Torch Glow	13	Medium	0.42	Medium
31	Vishaka	10.4	Medium	0.49	Medium
32	Zakiriana	9.29	Medium	0.57	Broad

4.2 Identification of suitable bougainvillea cultivar

The Bougainvilleas became obviously a great choice to every garden. Every cultivar got some diagnostic character which differs from each other. The morphological characterization in this investigation helped for exploration of diagnostic characters which serve main tool for identification of cultivars. The four species of Bougainvillea viz., *B. peruviana*, *B. x buttiana*, *B. spectabilis*, *B. glabra* were used for evaluation. Respectively there were many characters studied and interpreted by Ram *et al.* 2010, Kumar *et al.* 2010, Jain *et al.*, 2010.

Among them, bract colour is very important to identify the variety, variation in bract and leaves are also helpful in the study. The bougainvillea cultivars bract flourishes in different seasons depending on the cultivars, maximum of them observed no blooming in Jan-Feb months because, the shrubs are sensitive to chilling injury (Roy 2019). The morphological description recommendation based on their character behaviour and blooming season are categorized and summarized in Table-4.8 for better identification and suitability of shrub for different conditions in the landscaping. The numerous varieties starts to flower from Oct to Dec and from Feb to April in Chhattisgarh where considered year round flowering. There was no blooming recorded in Dec end to Feb start because of very low temperature and plants under go dormant stage. It was also experimentally corroborated by Kumar (2001).

The characters are described using DUS guidelines of Bougainvillea (2014) which includes stages of bracts, bract shape, floral tube (calyx/star opened), young shoot, leaf blade shape and young leaf are organized in Plate-4.3 for better identification and suitability to different landscape conditions. It was authenticated by Kumar *et al.* 2014. Any cultivar can be identified by their stable morphological attribute. The characterization results will be useful for identifying the varieties and their use in ornamental gardening on the basis of morphological parameters (Zadoo *et.al.* 1975; Zadoo *et.al.* 1976; Sharma and Roy, 2000).

Table-4.6 List of morphological description, recommendation and blooming season of bougainvillea for identification

Sl. no	Cultivars	Morphological description	Recommendation based on characters	Blooming season
1	Alick Lancaster	Spreading plant habit, glabrous leaves, broad ovate magenta purple bracts and leaves. Thorns are strong and medium density. Obtuse tip and cordate base bracts.	Potted plant	Oct-Dec & Feb-March
2	Bangalore Variegata	Leaves are variegated, secondary colour pale yellow distributed broad margins; bracts are small and purple colour.	Hedge, Topiary, Potted plant	Feb-April
3	Bridal Bouquet	Medium ovate, glabrous leaves & semi-upright plant. The bracts are multiple, densely arranged and pink to white colour bracts.	Climber, Pergola, Espalier and pot plant	Oct-Dec and Feb- March
4	Carpet Purple	The plant is upright, leaves are elliptical, acuminate tip and leaves are persistent. Bracts are electric violet colour, narrowly ovate and long inflorescence.	Potted plant, Bonsai and Hedge	Oct-Dec and March-April
5	Cherry Blossom	The bracts are multiple, densely arranged, colour is pink to light pink.	Pergola, Potted plant	Oct-Dec and Feb-March
6	Chitra	Plants is semi-upright, leaves are broadly ovate, are large coppery and glabrous. Circular bract and colour of bract is white in midrib and red around midrib. Floral tube swollen at base.	Bushy climbing shrub, along highways, potted plant	Oct-Dec and Feb-March
7	Dr. R.R.Pal	Plants are spreading, dark green colour leaves & broadly ovate. The bracts are red purple group.	Potted plant, Bonsai, Climber, Cascade, Espalier, Ground cover and Hedge	Oct-Dec and Feb-March

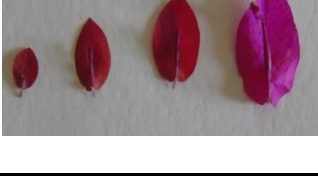
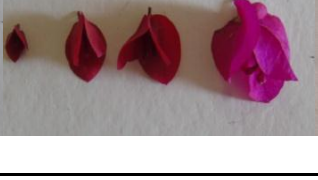
Sl. no	Cultivars	Morphological description	Recommendation based on characters	Flourishing season
8	Dr. Rao	The plant is upright, leaves are broadly ovate and secondary colour pale yellow broad margins. Bracts are carmine red and star is non-prominent.	Potted plant	Oct-Dec
9	Fantasy	Plant is upright, slightly hairy and broadly ovate leaves. Bracts are red purple group.	Potted plant	Oct-Dec
10	Formosa	Plant is semi-upright, broadly ovate, persistent leaves and bract. The bracts are floral purple colour, cordate at base of bract.	Potted plant and Hanging basket	Feb-March
11	Glabra	Profuse flowering, bracts are purple, semi-upright plant, elliptical leaves and dwarf growing.	Potted plant, Bonsai, Bush, Cascade, Ground cover, Climber, Hanging basket and Hedge	Oct-Dec
12	Golden Glow	Amber orange colour bracts, plant is upright, broad ovate leaves.	Potted plant and ground cover	Oct-Dec and Feb-March
13	Gopal	Spreading plant, medium ovate, glabrous leaves and magenta colour bracts.	Potted plant	Oct-Dec and feb-March
14	Magnifica	Plant is upright, leaves are elliptical, bracts are reflexed, horizontal petiole altitude, and bracts are purple colour.	Hedge, Cascade, Bonsai, Highways divider, best potted plant	Oct-Dec and March-May
15	Mahara	Bracts are multiple type, densely arranged, bract and leaves are persistent, colour of bract is crimson red and plant is spreading.	Pergola, Potted plant,	Oct-Dec and Feb-March
16	Mahatma Gandhi	The plant semi-upright, large leaves, broadly ovate, bracts are undulated and magenta purple colour.	Potted plant, Pergola, Climber and on divider	Oct-March

Sl. no	Cultivars	Morphological description	Recommendation based on characters	Flourishing season
17	Mary Palmer Special	Upright, broadly ovate leaves, bracts are patched dual colour lime green young bract and parchment white colour.	Standard, Potted plant	Feb-May
18	Mataji Agnihotri	Semi-Upright plant, broadly ovate, dark green colour leaves, bracts are broadly ovate and magenta colour.	Potted plant	Oct-March
19	Partha	Plant is semi-upright, pink colour and medium ovate bracts,	Hedge, Potted plant	Oct-Dec
20	Pink Beauty	Bract is narrowly ovate, leaves are densely arranged on main branch, purple red colour bracts, plant is semi-upright, bract and leaves are persistent.	Climber, Pergola, Espalier and Hanging basket	Oct-Dec and Feb- May
21	Queen Violet	Bracts are dark purple colour, medium ovate, leaves are globorous leaves and plant Spreading.	Potted plant and Ground cover	Oct-Dec and Feb-May
22	Roseville's Delight	Plant is semi-upright, bracts are multiple, orange red colour bracts densely arranged and leaves are broadly ovate.	Arch, Climber and on dividers	Feb-May
23	Scarlet O Hara	Leaves are coppery hairy, bracts are red and pink colour, persistent, young leaf is reddish green and plant is semi-upright.	Potted plant and Bush	Oct-Dec and Feb-May
24	Shubra	Plant is climbing, leaves are glabrous, vigorous growth, bract white colour, and profuse flowering.	Climber, Bushes, Ground cover, Bonsai, Cascade, Espalier and on pergola	Oct-March
25	Shweta	Plant is dwarf, semi-upright, bracts are white green colour and bracts are reflexed in nature.	Hanging basket, Ground cover and potted plant	Oct-May

Sl. no	Cultivars	Morphological description	Recommendation based on characters	Flourishing season
26	Sonnet (C)	The bracts are magenta colour, profuse flowering, leaves are broadly ovate and semi-upright growth.	Potted plant and ground cover	Oct-Dec and Feb-May
27	Summer Time	Plant is semi-upright growth, flowers are red colour, elliptical and glabrous leaves.	Shrub and Bonsai	Feb-May
28	Thimma	The leaves are variegated yellow white colour around the midrib, bracts are dual coloured white and magenta colour and plant is upright.	Hedge, Potted, Standard, Ground cover, Bush, slopes and mounds	Oct-Dec and Feb-May
29	Tomato Red	The young leaves are coppery, leaves are glabrous, bracts are dark red colour and plant is spreading	Potted plant	Oct-Dec and Feb-May
30	Torch Glow	Plant is semi-upright, vigorous growth, leaves are densely arranged, bracts are profuse blooming, bracts are orange red coloured, persistent bracts and leaves.	Espalier, Climber, Slopes and Hanging basket	Oct-Dec and Feb-March
31	Vishaka	Plant is spreading, bracts are red coloured, glabrous and petiole altitude is horizontal.	Ground cover, Potted plant	Jan - March
32	Zakiriana	The leaves are undulated, light green coloured leaves, bracts are orange red and it is semi-upright growth.	Potted plant and Bonsai	Oct-May

Plate-4.3: DUS descriptors for identification of bract shape, stages of bract, floral colour, young shoot, leaf blade shape and young leaf colour

Sl. No	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
1	Alick Lancaster						
2	Bangalore Variegata						
3	Bridal Bouquet						
4	Carpet Purple						

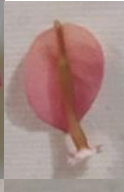
Sl. No	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
5	Cherry Blossom						
6	Chitra						
7	Dr. R. R. Pal						
8	Dr. Rao						
9	Fantasy						

Sl. No	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
10	Formosa						
11	Glabra						
12	Golden Glow						
13	Gopal						
14	Magnifica						

Sl. No	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
15	Mahara						
16	Mahatma Gandhi						
17	Mary Palmer Special						
18	Mataji Agnihotri						
19	Partha						

Sl. No	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
20	Pink beauty						
21	Queen Violet						
22	Rose Ville Delight						
23	Scarlet O Hara						

Sl. No	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
24	Shubra						
25	Shweta						
26	Sonnet						
27	Summer Time						

Sl. No.	Cultivars	Bract shape	Stages of bract	Floral tube	Young shoot	Leaf blade shape	Young leaf
28	Thimma						
29	Tomato red						
30	Torch Glow						
31	Vishaka						
32	Zakiriana						

4.3 Analysis of Variance of Bougainvillea cultivars

The results of analysis of variance of growth and floral characteristics of Bougainvillea cultivars were disclosed in Table- 4.7 and mean performance in Table- 4.8, showed significance in leaf blade length (cm), leaf blade width (cm), inflorescence length (cm), peduncle length (cm) and bract length (cm). It represented variation in the characters under study.

The Internodal length (cm) ranged from 0.47 cm to 2.90 cm and mean performance 1.74 cm. The leaf blade length (cm) ranged from 3.50 cm to 8.30 cm and mean performance 5.79 cm. The leaf blade width ranged from 1.97 cm to 5.8 cm and mean performance 3.59 cm.

The petiole length ranged from 0.49cm to 1.98 cm and mean performance of 1.131 cm. The thorns length ranges from 0.26 cm to 1.56 cm and mean performance of 0.786 cm. The thorns diameter ranges from 0.07 cm to 0.30 cm and mean performance of 0.19 cm.

Table 4.7 Analysis of quantitative data

Characters (cm)	Min	Max	Range	Sum	Mean	S.E.(m)	S.D	C.V%
Internodal length	0.47	2.90	2.43	55.67	1.74	0.46	0.60	9.59
Leaf length	3.50	8.30	4.79	185.53	5.79	0.55	1.33	3.15
Leaf width	1.97	5.8	3.83	115.06	3.59	0.48	0.91	4.15
Petiole length	0.49	1.98	1.49	36.21	1.13	0.29	0.31	7.91
Thorn length	0.26	1.56	1.29	25.13	0.78	0.33	0.30	4.73
Thorn diameter	0.07	0.30	0.23	6.37	0.19	0.12	0.05	6.80
Bract width	1.29	3.84	2.54	76.46	2.38	0.44	0.68	5.17
Inflorescence length	6.51	33.9	27.4	459.4	14.35	1.67	6.36	2.94
Peduncle length	0.38	5.51	5.12	70.3	2.19	0.70	1.04	10.01
Star diameter	0	0.72	0.72	16.4	0.51	0.30	0.22	12.89
Bract length	1.76	4.9	3.13	101.4	3.17	0.45	0.80	3.481

The bract width ranges from 1.298 cm to 3.843 cm and mean performance of 2.389 cm. The inflorescence length ranges from 6.516 cm to 33.96 cm and mean performance ranges from 14.35 cm. The peduncle length ranges from 0.386 cm to 5.51 cm and mean performance 2.197 cm. The star diameter ranges from 0 cm to 0.722 cm and mean performance of 0.514 cm. The bract length ranges from 1.763 cm in Pink Beauty to 4.9 cm in Mary Palmer Special and mean performance of 3.174 cm. Earlier findings of Gupta *et al.* (2006), Kumar *et al.* (2009) were conformed with the result obtained.

Table 4.8 Mean performance of quantitative characters

Characters(cm)	Mean Sum of Square		
	Replication	Treatments	Error
d.f.	2	31	62
Internodal length	0.012	1.082	0.028
Leaf blade length	0.078	5.382**	0.033
Leaf blade width	0.024	2.522**	0.022
Petiole length	0.022	0.288	0.008
Thorns length	0.001	0.275	0.001
Thorns diameter	0.000	0.009	0.000
Bract width	0.000	1.390	0.015
Inflorescence length	0.126	123.69**	0.179
Peduncle length	0.007	3.258**	0.049
Star diameter	0.000	0.148	0.000
Bract length	0.046	1.960*	0.012

Note : *Significant at 5% and **Significant at 1%

4.4 Genetic Variability, Heritability and Genetic Advance

4.4.1 Genetic Variability

The accomplishment of any investigation is achieved by level of genetic variability accessible among cultivars. It helps for effectual and capable selection of varieties from the existing, which can be exploited for advance study. All the characters in the study were recorded highest PCV and GCV.

The greatest PCV is obtained in peduncle length (48.10), followed by inflorescence length (44.78), star diameter (44.69), thorns length (38.68), internodal length (35.38), bract width (28.78), petiole length (28.13), thorns diameter (27.37), leaf blade width (25.72), bract length (25.65) and leaf blade length (23.24).

The utmost GCV is obtained in peduncle length (47.04), followed by inflorescence length (44.68), star diameter (42.78), thorns length (38.39), internodal length (34.05), bract width (28.31), petiole length (27.002), thorns diameter (26.52), leaf blade width (25.38), bract length (25.41) and leaf blade length (23.02).

Table-4.9 Genetic variability, h% and GA %m of quantitative characters

Characters (cm)	Heritability %	Genetic advance	Genetic advance % mean	Phenotypic CV%	Genotypic CV%
Internodal length	92.65	1.17	67.52	35.38	34.05
Leaf blade length	98.1	2.72	47.00	23.24	23.02
Leaf blade width	97.39	1.85	51.60	25.72	25.38
Petiole length	92.09	0.60	53.38	28.13	27.00
Thorns length	98.49	0.61	78.49	38.68	38.39
Thorns diameter	93.82	0.10	52.91	27.37	26.52
Bract width	96.76	1.37	57.39	28.78	28.31
Inflorescence length	99.57	13.18	91.85	44.78	44.68
Peduncle length	95.66	2.08	94.79	48.10	47.04
Star diameter	91.6	0.45	88.46	44.69	42.78
Bract length	98.1	1.64	51.86	25.65	25.41

4.4.2 Heritability (%)

Heritability calculated in the investigation in broad sense, analysis ranged from 99.567 to 91.6 presented in Table-4.9.

The high heritability was attained in all characters of cultivars ranges from inflorescence length (99.567) followed by thorn length (98.499), leaf length (98.159), bract length (98.1), leaf width (97.392), bract width (96.766), peduncle length (95.663), thorn diameter (93.823), internodal length (92.65), petiole length (92.090) and star diameter (91.6).

4.4.3 Genetic advance as % of mean (GA % mean)

The genetic advance as % of mean ranged from 47.046 to 23.028 presented in Table-4.9

The high GA % mean was noted in peduncle length (94.046), followed by Inflorescence length (91.858), star diameter (88.460) and thorn length (78.493). The moderate GA % m was recorded in internodal length (67.529), bract width (57.394), petiole length (53.381), thorn diameter (52.918), bract length (51.866), leaf width (51.605) and low in leaf length (47.00). The findings of GV, $h^2\%$, GA % m were also reported by Singh *et al.* (2006 b) and Singh *et al.* (2010 a)

4.5 Correlation and Path Analysis

4.5.1 Correlation analysis

The coefficients of correlation were determined. The result revealed that genotypic correlation was noted greatest than phenotypic correlation are presented in Table 4.10. This stipulates that inherent association is convenient among the characters.

In the analysis the internodal length attained highly significant and positive correlation with leaf blade length ($r_g=0.305$), thorns length ($r_g=0.437$), thorn diameter ($r_g=0.298$), bract width ($r_g=0.305$), peduncle length ($r_g=0.513$) and bract length ($r_g=0.368$) and significant correlation and positive with leaf blade width ($r_g=0.215$) and inflorescence length ($r_g=0.201$), genotypic level. It had highly significant and positive correlation with leaf blade length ($r_p=0.299$), followed by thorn length ($r_p=0.418$), thorn diameter ($r_p=0.267$), bract width ($r_p=0.296$), peduncle length ($r_p=0.465$) and bract length ($r_p=0.356$) and significant and positive correlation in leaf blade width ($r_p=0.205$) in phenotypic levels.

The leaf blade length attained highly significant and positive correlation with leaf blade width ($r_g=0.809$, $r_p=0.799$), petiole length ($r_g=0.659$, $r_p=0.624$), thorns length ($r_g=0.433$, $r_p=0.425$), bract width ($r_g=0.523$, $r_p=0.512$), inflorescence length ($r_g=0.394$, $r_p=0.392$), star diameter ($r_g=0.454$, $r_p=0.450$) and bract length ($r_g=0.554$, $r_p=0.544$) in both genotypic level and phenotypic levels.

The leaf blade width had attained highly significant and positive correlation petiole length ($r_g=0.785$, $r_p=0.734$), thorns length ($r_g=0.303$, $r_p=0.296$), bract width ($r_g=0.443$, $r_p=0.434$), inflorescence length ($r_g=0.292$, $r_p=0.289$), and bract length and significant and positive correlation with peduncle length ($r_g=0.210$, $r_p=0.202$) and star diameter ($r_g=0.258$, $r_p=0.254$) in both genotypic and phenotypic levels.

The petiole length attained highly significant and positive correlation with thorns length ($r_g=0.289$, $r_p=0.278$), bract width ($r_g=0.427$, $r_p=0.393$), star diameter

($r_g=0.304$, $r_p=0.290$) and bract length ($r_g=0.367$, $r_p=0.345$) in both genotypic and phenotypic levels.

The thorns length attained highly significant and positive correlation with thorns diameter ($r_g=0.352$, $r_p=0.338$), bract width ($r_g=0.558$, $r_p=0.546$), inflorescence length ($r_g=0.374$, $r_p=0.368$), peduncle length ($r_g=0.367$, $r_p=0.361$), star diameter ($r_g=0.391$, $r_p=0.384$), bract length ($r_g=0.492$, $r_p=0.482$) in both genotypic and phenotypic levels.

The thorns diameter attained highly significant and positive correlation with bract width ($r_g=0.560$, $r_p=0.540$), peduncle length ($r_g=0.317$, $r_p=0.311$) and bract length ($r_g=0.483$, $r_p=0.466$) and significant and positive correlation with inflorescence length ($r_g=0.241$, $r_p=0.233$) in both genotypic and phenotypic correlation.

The bract width attained highly significant and positive correlation with inflorescence length ($r_g=0.399$, $r_p=0.393$), peduncle length ($r_g=0.280$, $r_p=0.273$), star diameter ($r_g=0.591$, $r_p=0.576$) and bract length ($r_g=0.911$, $r_p=0.894$) in both genotypic and phenotypic levels.

The inflorescence length attained highly significant and positive correlation with star diameter ($r_g=0.290$, $r_p=0.289$) and bract length ($r_g=0.507$, $r_p=0.501$) in both genotypic and phenotypic level. The peduncle length attained significant and positive correlation with bract length ($r_g=0.249$, $r_p=0.241$) at genotypic and phenotypic levels.

The star diameter attained significant and positive correlation with bract length ($r_g=0.612$, $r_p=0.604$) in both phenotypic and genotypic levels. The outcome of present evaluation also authenticated with past reports of Singh *et al.* (2010 b) and Singh *et al.* (2010 c).

Table-4.10 Correlation coefficient (genotypic and phenotypic correlation) among bract length and its components in bougainvillea

Characters(cm)		Internodal length	Leaf blade length	Leaf blade width	Petiole length	Thorns length	Thorns diameter	Bract width	Infl. Length	Peduncle length	Star diameter	Bract Length
Internodal length	G	1.000	0.305**	0.215*	0.075	0.437**	0.298**	0.305**	0.201*	0.513**	-0.071	0.368**
	P	1.000	0.299**	0.205*	0.054	0.418**	0.267**	0.296**	0.192	0.465**	-0.072	0.356**
Leaf blade length	G		1.000	0.809**	0.659**	0.433**	0.180	0.523**	0.394**	0.156	0.454**	0.554**
	P		1.000	0.799**	0.624**	0.425**	0.167	0.512**	0.392**	0.150	0.450**	0.544**
Leaf blade width	G			1.000	0.785**	0.303**	0.199	0.443**	0.292**	0.210*	0.258*	0.379**
	P			1.000	0.734**	0.296**	0.189	0.434**	0.289**	0.202*	0.254*	0.373**
Petiole length	G				1.000	0.289**	0.197	0.427**	0.137	0.164	0.304**	0.367**
	P				1.000	0.278**	0.184	0.393**	0.131	0.157	0.290**	0.345**
Thorn length	G					1.000	0.352**	0.558**	0.374**	0.367**	0.391**	0.492**
	P					1.000	0.338**	0.546**	0.368**	0.361**	0.384**	0.482**
Thorn diameter	G						1.000	0.560**	0.241*	0.317**	0.002	0.483**
	P						1.000	0.540**	0.233*	0.311**	0.004	0.466**
Bract width	G							1.000	0.399**	0.280**	0.591**	0.911**
	P							1.000	0.393**	0.273**	0.576**	0.894**
Infl. Length	G								1.000	-0.083	0.290**	0.507**
	P								1.000	-0.079	0.289**	0.501**
Peduncle length	G									1.000	-0.021	0.249*
	P									1.000	-0.022	0.241*
Star diameter	G										1.000	0.612**
	P										1.000	0.604**
Bract Length	G											1.000
	P											1.000

Note: **Significant at 1% and * Significant at 5%

Infl. length: Inflorescence length

4.5.2 Path Coefficient Analysis

The correlation coefficient provides magnitude of association between pairs of attributes. There is importance to know the direct and indirect effect of other characters with dependent character bract length (cm). The correlation coefficient as such is not sufficient to present intensity in relations of characters. The path coefficient technique used by Dewey and Lu (1959) for influencing the dependent variable-contributing character, which is useful for indirect selection of character.

The direct and indirect effect characters on bract length (cm) are categorized in in geneotypic and phenotypic path analysis coefficient in Table 4.11 and 4.12. The genotypic correlation coefficients of bract length along with their components were partitioned into direct and indirect effect considering bract length as dependent variable. The genotypic path coefficient shown direct and indirect effects with different characters are shown in Table 4.11

The bract width had greatest positive direct effect with bract length and followed by leaf blade length (0.204), inflorescence length (0.185), internodal length (0.139), star diameter (0.133), petiole length (0.074), peduncle length (0.051) and least with thorn diameter. The bract width has greatest negative direct effect with leaf blade width (-0.265) and lesser in thorn length (-0.173)

The internodal length exhibit positive indirect effects with bract length via bract width (0.235), followed by leaf blade length (0.062), inflorescence length (0.037), peduncle length (0.026), petiole length (0.005) and least in thorns diameter (0.003). Internodal length had negative indirect effect with thorns length (-0.075), leaf blade length (-0.057) and star diameter (-0.009).

The leaf blade length had positive indirect effect with bract length via bract width (0.402), inflorescence length (0.073), star diameter (0.060), petiole length (0.049), internodal length (0.042), peduncle length (0.008) and thorns diameter (0.001) and negative indirect effect with thorns length (-0.075) and leaf blade width (-0.214).

The leaf blade width had positive indirect effect with bract length via bract width (0.341), leaf blade width (0.165), petiole length (0.058), inflorescence length (0.054), star diameter (0.034), internodal length (0.030), peduncle length (0.010), thorn diameter (0.002) and negative indirect effect with thorns length (-0.052).

Petiole length had positive indirect effect with bract length via bract width (0.328), leaf blade length (0.135), star diameter (0.04), inflorescence length (0.025), internodal length (0.01), peduncle length (0.008), thorns diameter (0.001) and negative indirect effect with leaf blade width (-0.208) and thorns length (-0.05).

Thorns length had positive indirect effect with bract length via bract width (0.429), leaf blade length (0.088), inflorescence length (0.069), internodal length (0.061), star diameter (0.052), petiole length (0.021), peduncle length (0.018), thorn diameter (0.003) and negative indirect effect with leaf blade width (-0.080).

Thorns diameter had positive indirect effect with bract length via bract width (0.431), inflorescence length (0.044), internodal length (0.041), leaf blade length (0.036), peduncle length (0.016), petiole length (0.014), star diameter (0.00) and negative indirect effect with leaf blade width (-0.052), and thorn length (-0.060).

The bract width had positive indirect effect with bract length via leaf blade length (0.107), star diameter (0.079), inflorescence length (0.074), internodal length (0.042), petiole length (0.031), peduncle length (0.014), thorn diameter (0.005) and bract length had negative indirect effect with leaf blade width (-0.117) and thorn length (-0.096).

Inflorescence length had positive indirect effect with bract length via bract width (0.307), leaf blade length (0.080), star diameter (0.038), internodal length (0.028), petiole length (0.010), thorn diameter (0.002) and it had negative indirect effect with leaf blade length (-0.077), thorn length (-0.064) and peduncle length (-0.004).

Table 4.11 Genotypic path analysis coefficient of bract length (cm) and its components in Bougainvillea

Characters (cm)	Internodal length	Leaf blade length	Leaf blade width	Petiole length	Thorns length	Thorns diameter	Bract width	Inflo. length	Peduncle length	Star diameter	r _g
Internodal length	0.139	0.062	-0.057	0.005	-0.075	0.003	0.235	0.037	0.026	-0.009	0.368
Leaf blade length	0.042	0.204	-0.214	0.049	-0.075	0.001	0.402	0.073	0.008	0.060	0.554
Leaf blade width	0.030	0.165	-0.265	0.058	-0.052	0.002	0.341	0.054	0.010	0.034	0.379
Petiole length	0.010	0.135	-0.208	0.074	-0.05	0.002	0.328	0.025	0.008	0.040	0.367
Thorns length	0.061	0.088	-0.080	0.021	-0.173	0.003	0.429	0.069	0.018	0.052	0.492
Thorns diameter	0.041	0.036	-0.052	0.014	-0.060	0.010	0.431	0.044	0.016	0.000	0.483
Bract width	0.042	0.107	-0.117	0.031	-0.096	0.005	0.77	0.074	0.014	0.079	0.911
Inflo. Length	0.028	0.080	-0.077	0.010	-0.064	0.002	0.307	0.185	-0.004	0.038	0.507
Peduncle length	0.071	0.031	-0.055	0.012	-0.063	0.003	0.215	-0.015	0.051	-0.002	0.249
Star diameter	-0.009	0.092	-0.068	0.022	-0.067	0.000	0.455	0.053	-0.001	0.133	0.612

Note: Inflo. length: Inflorescence length

Diagonally darkened values are direct effect of bract length (cm)

Residual value: 0.097

Table 4.12 Phenotypic path analysis coefficient of bract length (cm) and its components in Bougainvillea.

Characters (cm)	Internodal length	Leaf blade length	Leaf blade width	Petiole length	Thorns length	Thorns diameter	Bract width	Infl. length	Peduncle length	Star diameter	r _p
Internodal length	0.309	-0.004	0.035	0.001	0.013	0.009	0.015	0.001	0.042	-0.002	0.356
Leaf blade length	0.005	0.220	0.002	0.008	-0.003	-0.020	-0.006	-0.023	0.018	0.002	0.544
Leaf blade width	0.085	-0.003	-0.128	0.002	-0.061	-0.001	0.010	0.009	-0.033	0.002	0.373
Petiole length	0.013	-0.059	0.008	-0.029	-0.008	0.033	-0.003	-0.001	0.019	-0.005	0.345
Thorns length	-0.016	-0.003	0.031	0.000	0.254	0.003	-0.024	0.005	-0.071	0.000	0.482
Thorns diameter	0.021	0.035	-0.001	0.007	-0.006	-0.129	-0.003	0.042	0.003	-0.007	0.466
Bract width	-0.054	-0.016	-0.015	0.001	-0.070	0.004	0.087	0.008	0.117	0.002	0.894
Inflo. Length	0.003	0.035	0.008	-0.000	-0.009	0.036	-0.005	-0.149	0.019	0.009	0.501
Peduncle length	0.036	-0.011	-0.011	0.001	0.050	0.001	-0.028	0.007	-0.359	0.000	0.241
Star diameter	-0.024	-0.019	0.011	-0.005	-0.004	-0.027	-0.006	0.044	0.008	-0.032	0.604

Note: Infl. length: Inflorescence length

Diagonally darkened values are direct effect of bract length (cm)

Residual value: 0.699

Peduncle length had positive indirect effect with bract length via bract width (0.215), internodal length (0.071), leaf blade length (0.031), petiole length (0.012), thorn diameter (0.003) and it had negative indirect effect with leaf blade width (-0.055), thorn length (-0.063), inflorescence length (-0.015), star diameter (-0.022).

Star diameter had positive indirect effect with bract width (0.455), leaf blade length (0.092), inflorescence length (0.053), petiole length (0.022), thorn diameter (0.000) and remaining shown negative indirect effect with star diameter.

These results are supported by Singh *et al.*, (2010 b) and Pavithra *et al.* (2015)

CHAPTER V

SUMMARY AND CONCLUSION

Bougainvilleas blooms irrespective of the season, the gorgeous colourful bracts fascinate attention of visitors in gardens. It adorns gracefully odd corners of the garden and flourishes profusely even in harsh climatic conditions, when other ornamental plants lack to perform. The array of bract colour, immensity of flowering and rage are truly amazing which change the face of garden into stunning landscape. Considering the view, present evaluation entitled “**Studies on Morphological Diversity in Bougainvillea (*Bougainvillea* Comm. ex. Juss.) cultivars**” enlightened the importance for investigating bougainvillea morphological characterization and their association. The present study implicated 31 cultivars and a check of bougainvillea origin from indigenous and exotic for characterization and each treatment replicated thrice. The investigation was accomplished at Department of Floriculture and Landscape Architecture, College of Agriculture, IGKV, Raipur during the year 2018-19.

The experiment performed for 46 morphological characterizations in form of 14 qualitative, 21 pseudo-qualitative and 11 quantitative growth and floral characteristics of bougainvillea were exploited as per DUS guidelines of Bougainvillea developed by CSIR-NBRI, Govt. of India (PPV&FRA in 2014) and results of investigation are summarized as follows:

The quantitative observations measured in ‘cm’ includes internodal length, leaf blade length, leaf blade width, petiole length, thorns length, thorns diameter, bract length, bract width, peduncle length, inflorescence length and star diameter were analysed and most of them are significant. It is apparently clear that most of the characters evidenced substantial variability among the cultivars of bougainvillea.

The qualitative and pseudo qualitative growth and floral characteristics evidenced significant variation except in leaf blade tertiary colour and thorn presence, because there are no tertiary colour noted in leaves and thorns are present

in every cultivar in the experiment and it's absolutely effective in identifying character excellent cultivars.

Amongst the qualitative and pseudo-qualitative growth characteristics, plant growth habit evidenced that, most of cultivars among 31 cultivars and a check belonged to semi-upright (16 cultivars). Most of the cultivars appeared reddish green (17 cultivars) under character young shoot colour. The thorn density recorded utmost cultivars under medium (19 cultivars). 12 cultivars each in character thorn curvature observed slightly curved and straight. The thorn strength observed maximum in medium (14 cultivars) state.

In case of leaf blade shape 14 cultivars appeared under broadly ovated. The leaf apex shape divided into acute and acuminate type and each contains 16 cultivars among 31 cultivars and a check. The character leaf base shape noted maximum in obtuse (22 cultivars). The young leaf colour in cultivars noted greatest in reddish green (12). Among leaf blade main colour most of cultivars noted medium green (17 cultivars).

Within character leaf blade secondary colour recorded yellowish white in Dr. Rao & Bangalore Variegata and Yellow in Thimma. Among leaf: distribution of secondary colour broad margin was evidenced in Dr, Rao and Bangalore Variegata and around midrib in Thimma. The character leaf texture observed most of the cultivars under glabrous (26 cultivars). The leaf undulation noticed in many cultivars in absent 23 cultivars. Petiole altitude observed utmost under upwards (13 cultivars). Leaf persistence exist in most cultivars belongs to non persistent group (25) and least in persistent (7).

Among QL & PQ floral characteristics, arrangement of inflorescence noticed most of the cultivars under terminal (20). The character number of bract clusters, 18 cultivars were recorded under medium. The inflorescence density and presence of flower evidenced dense and absences of flower in multiple bract cultivars Mahara, Bridal Bouquet, Cherry Blossom and Roseville's Delight.

The floral character bract shape evidenced most of cultivars under broadly ovate (13 cultivars). The bract tip shape recorded maximum cultivars under acute

(26) and in bract base shape, most of cultivars noticed under cordate (19 cultivars). The character bract persistent grouped into two states maximum noted non-persistent (22 cultivars) and least in persistent (10 cultivars).

The bract colour for single and multiple types are evaluated by comparing with Royal Horticulture Society colour chart. The Bougainvillea cultivars are acknowledged best through identification of bract colour. They are categorized into nine groups, among them most of cultivars grouped to Red purple (11 cultivars), followed by Pink-Red purple (5) and least in Greyed orange (Golden glow) and Red purple-Greyed red (Pink Beauty). The numerous cultivars are recommended for potted planting, bonsai, hedge, topiary, standard, centre verge planting and on pergolas considering their morphological characters. Most of the bougainvillea cultivars blooming period starts from Oct-Dec and Feb-April in Raipur condition.

The highest mean of quantitative characters recorded in comparison with check (Sonnet) for internodal length greatest in cultivar Dr. R. R. Pal and least mean noted in Torch Glow. Superior leaf blade length noted in cultivar Alick Lancaster and least mean noted in cultivar Vishaka. The greatest leaf blade width noted in cultivar Chitra and least in Carpet Purple. The highest petiole length noted in Summer Time and least in cultivar Carpet Purple. The highest thorn length noted in cultivar Dr. R. R. Pal and least in Bangalore variegata. The highest thorn diameter noted in cultivar Mary Palmer Special and least in cultivar Zakiriana.

The bract length of bougainvillea noted highest mean in cultivar Mary Palmer Special and least in cultivar Pink Beauty. The utmost bract width noted in check Sonnet and least in cultivar Torch glow. The peduncle length of bougainvillea noted highest in Cherry Blossom and minimum in cultivar Torch Glow. The inflorescence length of bougainvillea evidenced utmost in cultivar Mahatma Gandhi and least in cultivar Dr. Rao. The star diameter of bougainvillea noted highest in Chitra and least in cultivar Bangalore Variegata and absent in all multi-bracted varieties Cherry Blossom, Bridal Bouquet, Mahara and Roseville's Delight recorded (0 cm).

The greatest PCV and GCV were obtained in peduncle length, followed by inflorescence length, star diameter, thorns length and internodal length. The least GCV and PCV noted in leaf blade length.

Heritability noted high in all the characters investigated. The inflorescence length, star diameter, peduncle length and thorn length noted high heritability and high genetic advance % mean signifies magnitude of additive gene action in those characters. However, in leaf blade length, petiole length, thorns diameter, bract width, internodal length and bract length noted high heritability and moderate genetic advance % mean.

In the analysis the internodal length attained highly significant and positive correlation of bract length with leaf blade length, thorns length, thorn diameter, bract width and peduncle length. The significant and positive correlation with leaf length and inflorescence length genotypic level. It had highly significant and positive correlation with leaf blade length, followed by thorn length, thorn diameter, bract width, peduncle length, bract width and significant and positive correlation in leaf blade width in phenotypic level.

The path coefficient analysis revealed positive direct effect of bract width (0.77), leaf blade length (0.204), inflorescence length (0.185), internodal length (0.139), star diameter (0.133), petiole length (0.074), peduncle length (0.051) and least with thorn diameter on bract length. It exhibited negative direct effect with leaf blade width (-0.265) and thorn length (-0.173).

CONCLUSION

With the support of results attain from present evaluation, the following conclusions are illustrated:

The statistical analysis of quantitative characteristics revealed significant variation in leaf blade length, leaf blade width, inflorescence length, peduncle length and bract length.

The QL & PQ growth and floral characteristics revealed significant variation in all characters expect in thorn presence and leaf blade tertiary colour. Implementations of DUS guidelines were enlightening and most resourceful for identification, description and grouping of cultivars for each character.

The cultivars noted highest mean performance of bract length in Mary Palmer Special as evaluated with a check.

The inflorescence length, star diameter, peduncle length and thorn length evidenced high heritability concurrently with greatest genetic advance intimates reliability of characters in selection.

The correlation result revealed that extremely significant and positive correlation exist between bract length and its components viz. growth characters like internodal length, leaf blade length, thorns length, thorn diameter and floral characters of bract width, and peduncle length. Significant and positive correlation exists between leaf blade width and inflorescence length.

The path analysis for bract length and its components revealed highest positive and direct effect with bract width, leaf blade length, inflorescence length, internodal length, star diameter, petiole length, peduncle length. It had highest negative direct effect with leaf blade width.

SUGGESTIONS FOR FUTURE RESEARCH WORK

By virtue of result prevailed subsequently through the present evaluation, the following relevant perspective highlights the future extent of the investigation:

- There is necessitating for investigating more quantitative characters is essential in bougainvillea.
- The cultivars evaluation can be pursued in different locations of Chhattisgarh.
- In bract and flower characters like bract longevity on plant, bract shelf life and floral tube length can be studied.
- In the growth characters there is need for studying branch length, no. of leaves on branch, thorn density, chlorophyll content, pigment extraction and leaf area index.
- Since the investigation is on morphological characterization, there is need for further studies for molecular characterization and clustering which helps in identification and documentation of cultivars to trace out affinity of unknown origin groups.
- Attempt should be made for mutation study of bougainvillea cultivars.

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APPENDIX - A

Weekly meteorological data: 2018-19

Wee k No.	Month	Date	Max. Temp. (°C)	Min. Temp. (°C)	Rainfall (mm)	Relative Humidity (%)	Relative Humidity (%)	Vapour Pressure (mm of Hg)	Vapour Pressure (mm of Hg)	Wind speed (Kmph)	Evaporation (mm)	Sun Shine (hours)
41	OCT	1-8	34.0	23.7	0.0	81.5	44.7	21.5	17.1	0.6	4.0	8.0
42		9-16	32.2	22.2	0.0	87.1	47	18.7	19	2.6	3.8	7.1
43		17-24	33.8	21.6	0.0	86.6	44	18.3	16.8	0.9	3.3	8.1
44		25-31	31.3	17.6	0.0	85	45	14.3	14.9	1.7	3.2	9.1
45	NOV	1-5	31.8	20.1	0.0	89	46	17.2	15.8	2.2	4.0	9.1
46		6-12	32.0	16.9	0.0	84	33	13.1	11.1	1.4	3.5	8.5
47		13-19	31.9	12.8	0.0	86	30	11.8	10.7	1.0	3.2	8.8
48		20-30	33.4	15.6	0.0	97	33	12.7	10.3	1.3	3.1	8.7
49	DEC	1-10	28.4	14.7	0.0	87	41	11.5	11.3	0.9	2.5	4.1
50		11-17	26.7	15.2	0.0	86	55	12.0	12.1	2.0	2.3	1.7
21		18-24	22.4	10.0	40.2	92	47	8.9	9.7	2.1	1.9	5.9
52		25-31	25.2	8.6	0.0	87	25	8.0	5.7	1.3	2.4	7.3
01	JAN	1-7	27.4	8.5	0.0	88	28	7.9	7.3	0.7	2.4	7.7
02		8-14	27.1	10.2	0.0	87	34	8.9	8.7	0.9	2.4	6.1
03		15-21	28.1	9.2	0.0	80	21	7.6	5.8	0.9	2.7	8.1
04		22-31	36.4	17.7	11.8	86	44	10.0	9.3	2.0	2.7	5.0
05	FEB	1-11	23.2	11.8	3.4	83	32	9.6	8.6	1.2	3.1	8.1
06		12-18	30.1	13.6	9.0	87	34	11.8	10.0	1.8	2.9	8.3
07		19-28	33.4	15.5	0.0	79	30	12.7	11.0	2.0	4.2	8.9
08	MAR	1-11	32.1	17.4	0.2	70	36	11.7	12.3	6.1	5.1	8.5
09		12-18	22.6	21.6	0.0	72	33	15.0	13.5	3.1	6.0	6.8
10		19-25	34.5	19.8	0.0	80	28	15.5	11.2	2.4	5.3	8.4
11		26-31	37.7	20.3	0.0	63	20	13.0	9.4	1.5	6.2	9.0
12	APRIL	1-7	39.8	22.8	1.5	53.	18	13.5	9.6	3.2	7.4	8.1
13		8-14	40.3	26.0	0.0	45.8	20.1	13.1	11.1	4.3	8.4	8.0
14		15-22	38.4	24.1	1.4	60.2	25.5	15.3	12.2	4.3	8	9.1
15		23-30	42.2	27	0.0	45.3	15.7	12.7	9.8	3.2	8.6	8.9

Source: Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur

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TITLE - Morphological characterization of Bougainvillea (*Bougainvillea spp.*) cultivars

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