

# Horto-Taxonomical Studies on Bougainvillea: Pollen Grain Characters

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**Submitted:** 2024, Feb 01; **Accepted:** 2024, May 24; **Published:** 2024, Jul 03

**Citation:** Datta, S. K., Datta, K. (2024). Horto-Taxonomical Studies on Bougainvillea: Pollen Grain Characters. *Curr Res Env Sci Eco Letters*, 1(2), 01-21.

## Abstract

Horto-taxonomical characterization of Bougainvillea is most important for the correct identification of cultivars and Plant Variety Rights (PVR). Different parameters have already been standardized for characterization. In Bougainvillea, there is always the development of new and novel varieties through classical breeding, sports, selection, and induced mutagenesis. The new varieties differ from the original variety mostly in one promising character for commercial utilization. All these factors have led to a lot of confusion in the identification of these cultivars. Many times, the same cultivar has been differently named at different places and in some cases even the same name has been given to cultivars of different origins. This study aims to verify the taxonomic usefulness of the pollen grain morphological characters at a variety level. 83 cultivars were selected and pollen morphological characters were investigated and found a wide range of variations in pollen grain ornamentations at the variety level. The structural diversity in pollen structure within the varieties is recommended as an important tool in addition to other techniques for the identification and classification of the varieties.

**Keywords:** Horto-Taxonomy, Bougainvillea, Characterization, Pollen Grain, Exine Ornamentation, Variety, Plant Variety Right

## 1. Introduction

Much has been written and worked out about the taxonomy of wild plants but the cultivated plants have always been neglected for taxonomical analysis. Taxonomical characterization of different ornamentals is little disparaging and difficult. Here only the identification of family, genus, and species does not relieve. There is always the development of new and novel varieties that differ from the original variety mostly in one promising character for commercial utilization like - flower color/size/number/shape. These plants need to be studied taxonomically to arrange all vegetative and floral variations systematically. The Horto-taxonomical study deals with the fixity of names to the cultivars according to the rules of 'The International Code of Nomenclature for Cultivated Plant', their detailed morphological account including ancestry, habit, growth, flowering behavior, affinities with color illustrations, and their usage. Cultivar identification and cultivar relatedness are important issues for horticultural breeders. It helps to understand genetic diversity, trace out the phylogenetic relationship, and taxonomical status, preparation of the catalog, variation patterns, identification of desirable/novel genes, hybridization, registration, plant variety protection, farmer's rights, etc. In floriculture, taxonomical characterization work is very limited. Each cultivar should be registered and typified with authentic specimen and description, year and place

of origin and introduction, exact ancestry, etc. Horto-taxonomical characterization and documentation of ornamental germplasm are one of the major activities of CSIR-NBRI, Lucknow, India.

*Bougainvillea* is the most important and widely accepted multipurpose ornamental horticulture/ floriculture plant due to its wide range of variability. A wide range of bract colors and chlorophyll-variegated leaves of *Bougainvillea* make the environment more colorful. It grows very well in differing climatological zones under tropical and sub-tropical conditions and in almost all soil types. Bougainvillea's for their impressive captivating diversity are used as bush, climbers, specimen plants, hedges, topiaries, ground covers, standards, on pergolas and trees, arches, pot culture, cut flowers, slopes, and mounds, bonsai, hanging baskets, cascade etc. It is widely used for general and industrial landscaping as it has developed unique drought, saline, and pollution-tolerant attributes [1,2]. Present-day *Bougainvillea* represents the collective diversity of different characters. Diversity is most prominent in different characteristics like - use; growth habit; bract color; bract size; flower size; leaf color; leaf size; shape of the leaf apex; number of branches per unit area; number of thorns per unit area; thorn size; stem color; stomata index; cytogenetics; phenolic compounds in leaves and bracts; bract pigment; molecular diversity etc. The author attempted to

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put together the range of diversity in all these characters and the source of diversification to develop complete documentation [3].

All *Bougainvillea* varieties need to be studied taxonomically to arrange all variations systematically. Horto-taxonomical sketch of the leading *Bougainvillea* species/cultivars has been prepared according to their affinities to the species and hybrid seedlings [4-9]. Studies have solved many taxonomic problems, and phylogenetic relationships and also have opened a new way to synthesize new variety through chromosomal manipulations. Pollination mechanism, breeding system, and cross-compatibility relationship have also been studied. The first author cataloged different characteristics like plant growth habits (upright, semi-upright, spreading, drooping, climbing), length of internode (short, medium, long), young shoots (glabrous, tomentose, densely villous), thorn (long, slender, short slender), bract arrangement, bract color, bract size, bract apex, bract tip, bract base, flower size, leaf color, leaf size, leaf lamina, the shape of the leaf apex, petiole length, number of branches, number of leaves, number of thorns, thorn size, stem color, stomata index, moisture content of bracts, flower tube (shape, color, grade of pubescence, filament length, hair, star), the relative position of the stigma and anthers, pollen grain sterility and size, chlorophyll content of leaves, phenolic compounds in leaves and bracts, bract pigment, RAPD etc. for horto-taxonomical characterization of *Bougainvillea* and *Chrysanthemum* and rose [3,10-13].

In the present study, pollen grain characters were selected for characterization of different *Bougainvillea* cultivars. The significance of pollen grain characters in classical taxonomy and also in solving complicated problems of interrelationships between various taxa and assessment of their status in the classification, particularly concerning the families, subfamilies, tribes, genera, species, and subspecies have been highlighted earlier. The most idiosyncratic features of pollen grains used for taxonomic studies are pollen grain size (length, width, and length: width ratio), exine sculpturing, number of pores, pollen unit, pollen symmetry, polarity, number and position of furrows, etc. Pollen morphology is a meaningful expression of the genome. The quantum of literature is huge. Only a few are mentioned as ready reference [14-24]. Swarup and Singh, and Nair and suggested pollen morphology to be a more stable character for the classification of species and cultivars of *Bougainvillea* [25,26].

The following short outline of *Bougainvillea* is very important to exculpate the present study. The *Bougainvillea* belongs to the family Nyctaginaceae. As mentioned, *Bougainvillea* is the most widely spread ornamental throughout the world. It includes approximately 18 species (*B. berberidifolia*, *B. Bettina*, *B. campanulate*, *B. glabra*, *B. herzogiana*, *B. infesta*, *B. Lachmannian*, *B. Lehmann*, *B. malmeana*, *B. modesta*, *B. pachyphylla*, *B. peruviana*, *B. pomacea*, *B. praecox*, *B. specialist*, *B. spinosa*, *B. stipitate*, and *B. trollies*) as reported in "The Plant List" (The Plant List). Only three species (*B. specialist* Wild., *B. glabra* Choisy, and *B. peruviana* H & B) out of the eighteen *Bougainvillea* are ornamental. there are three basal species, namely *B. specialist* Wild., *B. glabra* Choisy, and *B.*

*peruviana* Humb [27]. and Bond., and three hybrid groups, namely *B. x but Tiana* (*glabra* x *peruviana*), *B. x Spector-peruviana* and *B. x spec to-glabra*. Most of the cultivars are classified under any of the basal species or the hybrid groups. It is a matter of debatable question about the exact number of basal/elemental species under the genus *Bougainvillea* and their role in the evolution of varieties. Within the species only '*B. specialist*', '*B. glabra*' and '*B. peruviana*' are primary whereas the rest are hybrids obtained from natural or artificial interbreeding of the above-mentioned species. The *Bougainvillea* is native to South America from Brazil west to Peru and South to Southern Argentina. Now *Bougainvillea* is a popular plant in Southern California, Florida, the Caribbean, and other areas with tropical and warm climates. The plant was discovered in Rio de Janeiro during an expedition that took place in 1768 by the French naturalist Dr. Philibert Commerson. According to more predictable scientific information, *B. but Tiana* was recorded in India, Mexico and Thailand; *B. glabra* in Italy, Spain, France, Bangladesh, India, China, Egypt, Israel, Thailand, Philippines, Madagascar, Nigeria, Hawaii, Bolivia, Colombia, Costa Rica, Cuba, Ecuador, Salvador, United States of America, Guatemala, Honduras, Virgin Islands, Mexico, Nicaragua, Puerto Rico, Dominican Republic, Venezuela, and Brazil; *B. specialist* was reported in Nigeria, Bahamas, Bolivia, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Panama, Puerto Rico, Dominican Republic, Tanzania, Trinidad and Tobago, India, Montenegro, Pakistan, Australia, Brazil, and Vietnam; *B. spinosa* was reported in Argentina; *B. peruviana* in China, India, and Peru [28]. Breeders developed hybrids for commercial exploitation and developed following interesting hybrids - *B. x spectoperuviana*, *B. x SpectaGuard* (a hybrid of *B. specialist* and *B. peruviana*-China) and *B. glabra peruviana* (or *B. x but Tiana* - a hybrid of *B. glabra* and *B. peruviana* - Mexico, India, England, and China) (c.f. [28]. During the domestication process of more than 200 years, an enormous range of diversity has developed in *Bougainvillea*. The majority of the diversity took place outside their native home, first in the temperate conditions of the European countries and then in the warmer parts of the Mediterranean, Canary Islands, East African countries, and India. Diversity covers growth habit, winter hardiness, floriferous nature, extended blooming period, and color [29]. *B. glabra* and *B. specialist* show natural variation in the shape of leaves and bracts, the color of bracts, and the degree of hairiness. *B. peruviana* does not show any variability and is represented by only one cultivar. *B. glabra* and *B. specialist* are similar in essential morphological features. *B. peruviana* differs from the two species in leaf shape, division of floral cyme, the shape of a floral tube, and unbranched main shoot.

All the present-day diversity in *Bougainvillea* resulted due to variability within species *B. specialist* and *B. glabra* through indiscriminate hybridization and somatic mutations among themselves and with *B. peruviana*, geographical movement of elemental species, adaptation, human selection pressure, spontaneous mutation, natural and intentional breeding, chromosomal manipulations, induced mutation, etc. Spontaneous hybridization and/or bud sports specially created a wide range of variations in bract shape, size, and color during cultivation.

*Bougainvillea* is perhaps one ornamental plant where remarkable changes have taken place in growth habits during domestication through selection pressure. Drought, saline, and pollution tolerant are unique characteristics of *Bougainvillea*. The probable route of origin of different cultivars having affinity with the but Tiana group, specialist group, and glabra group has already been worked out as shown in Figure 1 [30]. These affinities were determined based on cytological, breeding, and biochemical parameters [27,29,31-40]. One of the most significant hybrids in the history of *Bougainvillea*

diversification was 'Mrs. Butt', an accidental garden hybrid between the Brazilian species *Bougainvillea glabra* and the northern Andean species *Bougainvillea peruviana*. 'Mrs. Butt' is having the characters of both parents. 'Mrs. Butt' is considered a model hybrid to understand the genetic heterozygous nature of hybrid bearing genes of many ancestors and how bud sport developed different bract color and chlorophyll variegation in leaves including double bracted status through evolutionary network (Figure 2) [30,41].

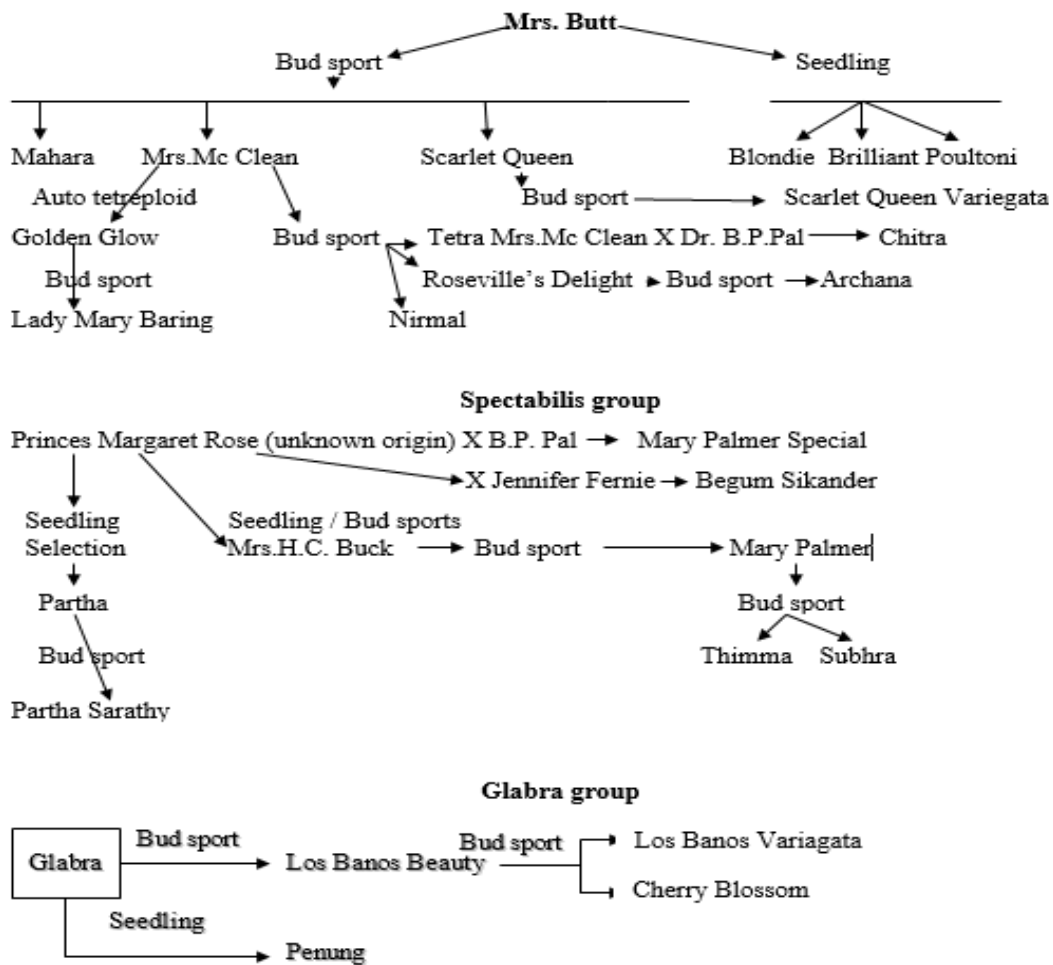


Figure 1: Affinities and Origin of Varieties in Different Groups



explored with the aim of micromorphological characterization of the cultivars using different pollen grain features which may cater to significant diagnostic attributes for identification of cultivars. The present study had two objectives – 1. To characterize different varieties based on pollen micromorphological characters. 2. Sensitivity of pollen grain characters to different mechanisms like geographical movement, adaptation, human selection pressure, spontaneous mutation, natural and intentional breeding,

chromosomal manipulations, induced mutation, etc.

## 2. Materials and Methods

83 cultivars of *Bougainvillea* were included in the present palynological investigations which were collected from CSIR-NBRI, Lucknow, India, and other sources. The details of experimental varieties (origin, bract color, and affinities to species) have been shown in Table 1.

**B. glabra Choice** : ‘Dream’ (seedling, pale mauve); ‘Eisha’ (seedling of ‘Formosa’, pale green to lilac pink); ‘Floribunda’ (purple); ‘Glabra’ (phlox purple); ‘Gopal’ (seedling of ‘Formosa’, dark mauve); ‘Dr. Harbhajan Singh’ (hybrid seedling of ‘Trinidad’ and ‘Formosa’, mauve); ‘Lilac Perfection’; ‘Rose Queen’ (seedling selection of cross between ‘B. glabra’ and ‘Lady Mountbatten’ – B. specialist, B. spec to-glabra, cyclamen purple); ‘Stanza’ (seedling selection of B. glabra, chrysanthemum crimson); ‘Sydney’ (pale purple); ‘Shweta’ (bud sport of ‘Trinidad’, white).

**B. specialist Wild** : ‘Aida’ (seedling of B. specialist, rose madder to rose Bengal), ‘Flame’ (hybrid seedling, rose red); ‘Dog star’ (hybrid seedling, phlox purple); ‘Dwarf Gem’ (seedling, spinel pink); ‘Happiness’ (seedling of ‘Lateritic’, carmine red to bright orange); ‘Jubilee’ (seedling of B. specialist, train purple); ‘A lick Lancaster’ (bud sport of ‘Scarlet Queen’, cyclamen purple); ‘Mrs. Fraser’ (hybrid seedling, terra-cotta); ‘Profusion’ (parent unknown, rosy terracotta); , ‘Refulgent’ (cyclamen purple or deep purplish mauve); ‘Summer Time’ (seedling between b. specialist – ‘Thomasson’, syn. ‘Roseau’) and B. but Tiana, ‘Louise Wathana’, cardinal red); ‘Rosea’ (syn. Thomasi, purple); ‘Star’ (purple).

**B. peruviana Hamb.** : ‘Arjuna’ (leaf variegated induced mutant of ‘Paratha’, pinkish purple); ‘Isabel Greens MTh’ (hybrid seedling, rose pink); ‘Krumbiegal’ (seedling of ‘Mahatma Gandhi’, rhodamine purple); ‘Lady Hudson of Ceylon’ (neuron rose turning to phlox pink); ‘Mary Palmer’ (bud sport of ‘Mrs. H.C. Buck’, white and magenta); ‘Mary Palmer Special’ (seedling between ‘DR. R.R. Pal’ and ‘Princess Margaret Rose’, white, magenta or blotched); ‘Paratha’ (seedling of ‘Princess Margaret Rose’, fuchsia purple); ‘Palekar’ (current red to solferino purple); ‘Parthasarathy’ (variegated bud sport of ‘Paratha’, brick red changing to fuchsia purple); ‘Princess Margaret Rose’ (seedling, parent unknown, scarlet rose to fuchsia pink); ‘Lady Hudson’ (Syn. ‘Princess Margaret Rose’, hybrid seedling, scarlet rose to fuchsia pink); ‘Rosea Fuchsea’ (parent unknown, rhodamine purple to fuchsia purple); ‘Shubhra’ (bud sport of ‘Mary Palmer’ – B. peruviana, white).

**B. x buttiana** (B. x glabra-peruviana) : ‘Jaya’ (induced mutant of ‘Jayalakshmi’, fuchsia purple); ‘Scarlet Queen’ (bud sport of B. x but Tiana var. ‘Mrs. Butt’, fuchsia purple); ‘Mrs. McClean’ (Syn. ‘Orange King-Pretorius’, bud sport of B. x but Tiana var. ‘Mrs. Butt’, apricot orange changing to pale mauve); ‘Louis Wathen’ (syn. ‘Orange Glory’, bud sport of ‘Mrs. Butt’ or ‘Scarlet Queen’, empire rose); ‘Louis Wathana Intermediate’ (golden salmon pink); ‘Lady May Baring’ (bud sport of B. x buttiana var. ‘Golden Glow’, Indian yellow); ‘Magenta Queen’ (bud sport of ‘Mrs. Butt’, magenta purple); ‘New Red’ (bracts like ‘Mrs. Butt’, fuchsia purple); ‘Enid Lancaster’ (bud sport of ‘Louise Wathana’, yellow shaded Spanish orange); ‘A lick Lancaster’ (Syn. ‘Lilac Queen’, bud sport of ‘Scarlet Queen’, cyclamen purple); ‘Pad mi’ (seedling of ‘Mrs. Butt’ var. ‘Bfasiensis’, bright orange changing to rose in purple); ‘President Roosevelt’ (seedling selection but parent unknown, fuchsia purple); ‘Srinivasa’ (seedling of

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| <p>‘Jayalakshmi’, orange scarlet changing to carmine with paler shade); ‘Killer Campbell’ (seedling of B. but Tiana, coppery red to bright red); ‘Manohar Chandra variegated’ (bud sport of ‘Manohar Chandra’, currant red changing to magenta), ‘Pad mi’ (seedling of ‘Mrs. Butt’ var. ‘Brasiliensis’, bright orange to rose in purple, ); ‘Poulton Special’ (seedling of B. x buttiana, solferino purple); ‘Poulton’ (seedling of B. x buttiana , pink ); ‘Rurarka’(cyclamen purple); ‘Scarler Glory’ (bud sport of ‘Pad mi’ – B. but Tiana, train purple changing to fuchsia purple); ‘Spring Festival’ (natural seedling selection of the cross between ‘Thomasi’ – B. specialist and ‘Louise Water’ –B. x buttiana, solferino purple); ‘Srinivasa’ (seedling selection of ‘Jayalakshmi’ –B. x buttiana, and B. x buttiana, orange scarlet changing to carmine with paler shade); ‘Summer Time’ ( natural seedling selection between ‘Thomasi’ – B. specialist and ‘Louise Wathena’ – B. but Tiana, cardinal red); ‘Surekha’ (variegated bud sport of ‘Scarlet Queen’ – B. x buttiana, dark fuchsia purple ); ‘Tetra Mrs. McClean’ (induced tetraploid of .Mrs. McClean’ – B. x buttiana, burnt orange).</p> |
| <p><b>B. x spectra-glabra</b> : ‘Jubilee’ (hybrid seedling, train purple); ‘Golden Glow’ (bud sport of ‘Mrs. McClean’, other report bud sport of ‘Mrs. Butt’, yellow shaded Spanish orange); ‘Krumbiegal’ (seedling of ‘Mahatma Gandhi’ syn. ‘Mrs. Buck’, rhodamine purple); ‘Zakeriana’ (variegated bud sport of ‘Maharaja of Mysore’ – B. spec to-glabra, orange)</p>  |
| <p><b>B. X spectaperuviana</b> : ‘Mary Palmer’ (Syn. ‘Surprise’, bud sport of B. peruviana var. ‘Mrs. H.C. Buck’, white and magenta); ‘Thimma’ (bud sport of B. peruviana var. ‘Mary Palmer’, double colored – magenta and white); ‘Shubhra’ (bud sport of B. peruviana var. ‘Mary Palmer’, white); ‘Pad mi’ (seedling of B. buttiana var. ‘Brasiliensis’, bright orange changing to rose in purple); ‘Spring Festival’ (hybrid seedling of natural cross between B. specialist var. ‘Thomasi’ x B. x but Tiana var. ‘Louis Wathena’, solferino purple); ‘Summer Time’ (hybrid seedling of natural cross between B. specialist var. ‘Thomasi’ and B. x but Tiana var. ‘Louis Wathena’, cardinal red); ‘Krumbiegal’ (seedling of B. peruviana var. ‘Mahatma Gandhi’, rhodamine purple); ‘Turkey’s Special’ (Syn. ‘Rosea’, seedling of ‘Thomasi, fuchsia purple); ‘Thimma’ (variegated bud sport of ‘Mary Palmer’ – B. peruviana, double colored – magenta and white).</p>   |
| <p><b>Unknown Group</b> : ‘Abraham Konoor’, ‘Charles William’ (magenta); ‘Cleopatra’, ‘Ecstasy’ (Magenta); ‘Garnet Glory’, ‘Glabra Magnificat’ (purple); ‘Glabra manifesto Trails’, ‘Glabra Sanderanea’, ‘Gillian Green Smith’, ‘Golden glory’, ‘Joede Livers’, ‘Leopaldi’, ‘Lucifer Red’, ‘Machaka’s’, ‘Pisil’, ‘Rhodamine’, ‘Singapore Dark Red (Red);’, ‘Sumatra’, ‘Summer Queen’, ‘Sundar’, ‘Theresa Jacobs’.</p>  |

**Table 1: Name of Experimental Varieties, their Bract Color and their Affinity to Species or Maternal Species**

Pollen preparation for pollen morphological studies was made by the acetolysis method [14]. For pollen morphological studies, mature flower buds/anthers containing pollen grains were plucked just before anthesis and fixed in glacial acetic acid then transferred directly to the brass sieve, crushed and washed down to the centrifuge tube with 70% alcohol. The suspension was then centrifuged and decanted. Acetolysis mixture was prepared by adding conc. Sulphur acid : acetic anhydride (1:9 v/v). The material was then suspended in the acetolysis mixture and stirred carefully by a glass rod. Then the mixture was heated to about 100°C in a water bath, kept in a boiling point of water for 2-3 minutes. After heating the mixture was allowed to stand for a few

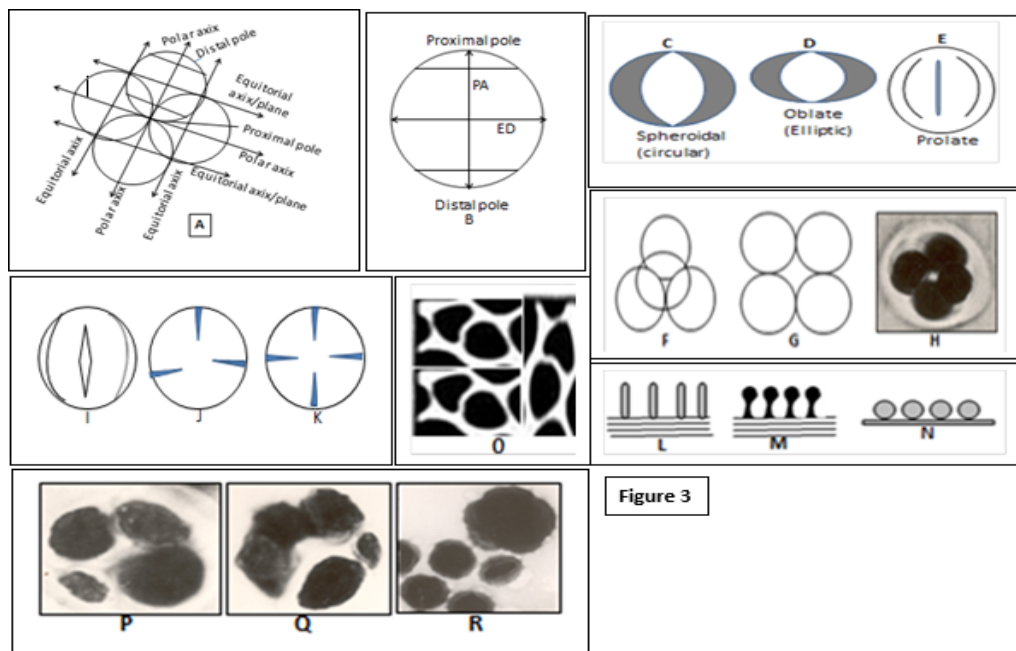
minutes, then centrifuged and decanted. A little distilled water was added to the sediment and was shaken thoroughly, then centrifuged and decanted. The process was repeated once and the foam was removed by a few drops of alcohol (95%) or acetone. The mixture was then filtered through a fine sieve and centrifuged. After decanting, distilled water was added to the sediment, half of it was kept for chlorination and 50% glycerin was added to the other half. For chlorination 5 cc of glacial acetic acid, 1-2 drops of conc. Sodium chlorate solution and a few drops of conc. Hydrochloric acid were added and the mixture was stirred by a glass rod. The mixture was then centrifuged, decanted and washed thoroughly to remove all traces of chlorine. After centrifuging and decanting

50% glycerin was added to it. Then the two parts (non-chlorinated and chlorinated) were mixed together, centrifuged and decanted. Then the tubes containing acetolyses polliniferous sediments were kept in inverted condition on filter paper for a couple of hours.

For light microscopic studies, a minute piece of glycerin jelly was taken on a clear platinum needle touched carefully to the bottom of the test tube (where the pollen grains were collected) and placed on a glass slide. Then the slide was heated gently and after the jelly was spread evenly by the platinum needle a round cover glass was placed on the material and sealed off with paraffin. The acetolyses Pollen grains were dehydrated in ethanol series placed onto coverslips, left for ethanol evaporation then attached to copper/aluminum stubs by double sided adhesive tape, coated with 15/20/30 nm gold/ gold-palladium using fine coat ion sputter. Pollen grains were examined and photographed at 10 kV in Philips XL20 scanning electron microscope (SEM). Photomicrographs of whole pollen were taken in 1500-3000 magnification and for

resolving details of exine ornamentation, a uniform magnification of 10,000 was maintained.

The present article is focused on horto-taxonomical studies on floriculture crops. Therefore, an attempt has been made to provide a brief narration of pollen terminology used in the present analysis and schematic representation of different pollen characters (Figure 3). This will help the floriculture scientists to use this technical knowledge as a ready reference. The terminology used is based on Erdtman, Faegri and Iversen, Nair, Punt *et al.*, Moore *et al.*, Hoen, Hesse *et al.*, etc [11,14,17,26,53-57]. Pollen shape is mostly determined based on the ratio of polar diameter (P) to equatorial diameter (E). The shape of pollen varies in different views. The shape of pollen grain in equatorial view is mostly determined from the ratio value between the polar and equatorial diameters. The ratio can be determined either by P/E or P/E multiplied by 100 [14,26].



**Figure 3: A. Polarity in Tetrad Stage. 3b. Length of Polar Axis (pa) and Length of Equatorial Diameter (ed) in a Monad Grain. 3c. Spheroidal Pollen Grain. 3d. Oblate Pollen Grain. 3e. Prolate Pollen Grain. 3f. Tetrahedral Tetrad Pollen Grain. 3g and h. Tetragonal Tetrad Pollen. 3i. 3-Colpate in Equatorial View. 3j. 3-Colpate in Polar View. 3k. 4-Colpate in Polar View. 3l-n. Exine Ornamentation. 3l. Bacula 3m. Pila 3n. Gemma. 3o. Reticulation Showing Lumina (black) and Muri (white). 3p & q. Pollen Mother Cells with Different Number and Size of Pollen Grains. 3r. Dimorphic Pollen Grains.**

## 2.1. Terminology

- **Amb:** Outline i.e. circumference of a pollen grain seen in the polar view (polar axis directed straightly towards the observer) is called amb.
- **Annulus (pl. annuli, adj. annulate):** A distinct area of the ectexine/sexine encircling a pore (ring-like thickening or thinning). It can be precisely distinguished due to its specific nature.
- **Aperture (adj. aperture):** An aperture is a very important characteristic feature of pollen grains. It is a specific thinner region of exine (sporoderm). Pollen grains are classified based on number,

position, and type of apertures (mono-, di-, tri-, tetra-, etc. prorate). It is believed to work usually as a germination site.

- **Baculum (pl. Bacula, adj. Baculate):** Rod-like/cylindrical, free-standing element on exine. It is longer (more than 1µm) than wide.
- **Bronchus (pl. bronchi, adj. broch ate):** a brocus is made up of one lumen of reticulum and half of the width of the adjacent muri.
- **Colpus (pl. colpi, adj. colpate):** Simple long elongated aperture situated along the equatorial region of the grain or spread regularly over the grain. Length: breadth ratio >2. The pollen grains of this apertural type are referred to as Colpate.

- **Dyads:** When pollen grains are united in pairs.
- **Exine (pl. sexiness, adj. exonal):** It is the outermost layer of the pollen grain made up of sporopollenin.
- **Equatorial Diameter:** A hypothetical straight line perpendicular to the polar axis and lying in the equatorial plane.
- **Equatorial View:** The Equatorial plane of pollen grain is directed towards the viewer.
- **Gemma (pl. gemmates, adj. gemmate):** A sexine sculpturing element (Gemma) higher than 1µm. Height and width are almost the same.
- **Heterobrochate:** Pollen grain surface reticulated with bronchi of diverse sizes.
- **Lolongate:** End aperture elongated longitudinally. The vertical axis of the pollen aperture is longer than the horizontal one.
- **Lumen (Pl. Lumina):** The terminology used to mark the space surrounded by muri.
- **Murus (Pl. muri):** A ridge that separates two laminae either in a reticulate pollen grain or in striate pollen grain.
- **Oblate:** Pollen grain shape is described as oblate when the polar axis is shorter than the equatorial diameter. Here the polar axis and equatorial diameter ratio is 0.50 to 0.75.
- **Oblate Spheroidal:** Narrate pollen grain shape when the polar axis and equatorial diameter ratio is 0.88 to 1.00.
- **Operculum:** A definite thick membrane of either of ectexinous, endexinous or both which covers the aperture. It may be circular, elliptical, annular or bridge-like.
- **Perforate:** Pollen surface with small holes less than 1µm in diameter. It is generally situated in the tectum. Pollen grains with porous apertures are referred to as Portae
- **Pilum (pl. pila, adj. Pilate):** It is a blunt and rod-shaped element with a swollen more or less round or elongated top (caput) standing directly on the nexin. A pilum is taller than one micron.
- **Polarity:** Polarity is resolved from the orientation of pollen grains in tetrads or from the distribution of apertures.
- **Polar View:** The polar axis of the pollen grain is directed towards the viewer. In this view, the pollen/ spores are viewed with one of the poles exactly uppermost.
- **Polar Axis:** It is a hypothetical straight line between the distal and proximal poles of a pollen grain.
- **Pore:** A thin-walled area (absent of exine) on pollen grain through which pollen tube emerges. It is a circular or elliptic aperture with a length/breadth ratio of less than 2. It helps in the identification of pollen grains. The pollen grains with porous apertures are referred to as Portae.
- **Prolate:** It defines pollen grain shape with a polar axis longer than the equatorial diameter.
- **Prolate Spheroidal:** This is pollen grain shape where the ratio between the polar axis and the equatorial diameter is 1.00-1.14.
- **Psilate (adj.):** Pollen grain surface completely smooth.
- **Reticulum: (pl. reticula, adj. reticulate):** With a sculptural pattern consisting of bronchi. Sculpturing elements looks network-like design consisting of Lumina or other spaces wider than 1µm bordered by elements narrower than the Lumina.
- **Regulate (adj.):** Special ornamentation made up of elongated sexing elements that are greater than 1µm long, irregularly arranged, and resemble an intermediate between reticulate and

striate.

- **Scab Rate:** It is an ornamentation element of any shape less than 1µm in diameter.
- **Spheroidal:** It defines pollen grain shape where the polar axis and the equatorial diameter are approximately equal. Here the ratio polar axis : equatorial diameter is 0.88- 1.14.
- **Spiraperturate:** Pollen grains with one or more spiral apertures. The colpi are fused giving the spiral appearance around the pollen grain.
- **Sub Oblate:** Pollen shape where the ratio between the polar axis and the equatorial diameter is 0.75-0.88 [14].
- **Sub Prolate:** Pollen shape where the ratio between the polar axis and the equatorial diameter is 1.14-1.33 [14].
- **Sub Spheroidal:** Pollen shape where the ratio between the polar axis and the equatorial diameter is 0.75-1.33 [14].
- **Sulcus:** Sulci are constitutionally latitudinal apertures on pollen grains. It is an elongated boat-shaped ectoaperture situated at the distal or proximal pole of a pollen grain. Pollen grains with sulcus aperture are called Sulcate.
- **Tetrads:** Tetrad is a group of four haploid and immature pollen grains developed through meiotic cell division of pollen mother cell.
- **Tetrahedral Tetrad:** Pollen grains are positioned in two different planes. Three grains are arranged in one plane and one grain remains midpoint over the other three. Three microspores are observed when viewed from one side and the fourth microspore is at the backside.
- **Tetragonal Tetrad:** All four pollen grains are arranged in one plane (uniplanar) where the grains are in connection at the center of the tetrad.
- **Tricolpate:** Tricolpate (tricorporate, trip orate) pollen grains have three meridionally placed furrows on their surface.
- **Verruca (pl. verrucae, adj. verrucae):** Verruca is a rounded (wart-like) projection on the tectum where the breadth (diameter of radial projection at the lower part) is greater than the length. The base of verruca is never constricted.

### 3. Results

The pollen morphology of all the selected varieties of Bougainvillea was investigated. A comprehensive description of the pollen features in terms of the equatorial diameter (ED), polar axis length (PA), the ratio of polar length to equatorial length (P/E), size, shape in equatorial view in the light microscope, and exine ornamentation studies under scanning electron microscope are presented. Variations in pollen grain size were observed in many cultivars. Pollen grains were categorized (normal, big, medium, mini) tentatively on the basis of measurements.

**Abraham Konnor:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.9µ (30-37) and ED 33.9µ (20-30), P/A 100, pollen shape sub prolate in equatorial view, exine highly reticulate, exine thickness 3.2µ, some bacula is present inside the muri.

**Aida:** Aperture 3-(4) colpate, pollen size variations, normal grain size PA 34.1µ (32-36) and ED 27.1µ (24-28), P/A 125.83, pollen



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shape sub prolate in equatorial view, exine densely reticulate, exine thickness 4.0 $\mu$ , small grains comparatively less, small bacula is present inside the muri.

**A lick Lancaster:** Aperture 3-colpate, pollen size variations, mini grain size PA 19.5 $\mu$  (19-39) and ED 18.5 $\mu$  (18-37), P/A 105.40, small grain size PA 26.5 $\mu$  (26-27) and ED 20.5 $\mu$  (20-21), P/A 129.27, big grain size PA 55 $\mu$  and ED 49 $\mu$ , P/A 112.24, normal grain size PA 40.1 $\mu$  (35-46) and ED 31.8 $\mu$  (30-46), P/A 126.10, pollen shape convex (round), exine densely reticulate, not always angular, exine thickness 4.0-5.0 $\mu$ , two sets of bacula present, bigger one Pilate, top of muri not exactly smooth, abnormal grains are found, top of muri not very smooth.

**Arjun:** Aperture 3- colpate, pollen size uniform, normal grain size PA 32.6 $\mu$  (30-36) and ED 26.9 $\mu$  (25-32), P/A 121.19, pollen shape sub prolate in equatorial view, exine highly reticulate, exine thickness 3.0 $\mu$ , colpa is not visible, smaller bacula, 2nd set bacula present inside the muri, spines are visible on the exine surface.

**Charles William:** Aperture not distinct, pollen size variations, big grain size PA 54-55 $\mu$  and ED 63-70 $\mu$ , P/A 84.61, small grain size PA 23 $\mu$  and ED 30 $\mu$ , P/A 76.67, normal grain size PA 29.3 $\mu$  (26-40) and ED 37.2 $\mu$  (35-44), P/A 78.76, pollen shape oblate spheroidal at equatorial view, exine reticulate, top of muri smooth, Lumina sometimes angular, tetrads found.

**Cleopatra:** Aperture 3-colpate, pollen size uniform, normal grain size PA 30.4 $\mu$  (28-35) and ED 26.1 $\mu$  (22-29), P/A 116.47, pollen shape sub prolate in equatorial view, exine highly reticulate, exine thickness 3.6 $\mu$ , some bacula are observed inside the muri.

**Dog Star:** Aperture 3-colpate but colpa is not visible, pollen size uniform, normal grain size PA 31.1 $\mu$  (30-35) and ED 25.7 $\mu$  (24-28), P/A 121.01, pollen shape sub prolate in equatorial view, exine very highly reticulate, exine thickness 2.9 $\mu$ , small baculi are present inside the muri.

**Dream:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.1 $\mu$  (28-36) and ED 38.6 $\mu$  (35-43), P/A 73.83, grain almost spheroidal lateral view, exine reticulation regular (angular) Lumina, exine thickness 3.0 $\mu$ , 2 sets of bacula, some bacula forming muri are bigger than the adjacent baculi, [pollens much similar to those of Swetha].

**Dwarf Gem:** Aperture 3-(4 colpate), pollen size uniform, normal grain size PA 28.5 $\mu$  (25-33) and ED 36.3 $\mu$  (33-42), P/A 73.83, shape round convex in proximal view and oblong spheroidal in equatorial view, exine thickness +3.0 $\mu$ , + regular reticulation, two sets of bacula, 4-colpate very rare, narrow size range.

**Ecstasy:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.9 $\mu$  (30-35) and ED 26.3 $\mu$  (24-28), P/A 128.90, pollen shape sub prolate in equatorial view, exine densely reticulate and so colpa is not visible, exine thickness 4.3 $\mu$ , smaller baculi present inside the muri.

**Eisha:** Aperture 3-colpate, pollen size uniform, normal grain size PA 46.2 $\mu$  (39-51) and ED 39.8 $\mu$  (31-45), P/A 116.08, pollen grain round triangular in polar view, round, convex in AMB, exine thickness 3.0 $\mu$ , exine ornamentation much different baculate or reticulate, bacula straight, free forming rugulo-reticuloid type pattern, exine thickness 3.0 $\mu$ , exine Pilate, number of pollen grains found in slide scanty.

**Enid Lancaster (Syn. Golden Glow?):** Aperture 3-(4) colpate, pollen size variations, mini grain size PA 19.0 $\mu$  (16-22) and ED 16.5 $\mu$  (14-19), P/A 115.15, big grain size PA 50.5 $\mu$  (48-53) and ED 41.0 $\mu$  (40-42), P/A 123.17, big grains mostly 4-colpate, normal grain size PA 38.3 $\mu$  (34-44) and ED 28.4 $\mu$  (26-35), 134.86, pollen shape sub prolate in equatorial view, exine normal reticulate, angular, exine thickness 3.5 $\mu$  (2.5+1.0), Lumina are of different sizes, angular, muri made up of longer bacula, shorter bacula are present within Lumina, top of muri smooth, bacula head at the angle of the muri are visible, 2nd set of bacula few.

**Flame:** Aperture not distinct, pollen size variations, big pollen grain size PA 49 $\mu$  and ED 62 $\mu$ , P/A 79.03, mini grain size PA 17 $\mu$  and ED 20.5 $\mu$ , P/A 82.92, normal grain size PA 29.8 $\mu$  (26-39) and ED 35.8 $\mu$  (33-39), P/A 83.24, pollen shape oblate spheroidal in equatorial view, reticulation thick, luminary not angular, exine thickness 3.0 $\mu$  (2.01-1.0), two sets of bacula present, top of muri not smooth.

**Floribunda:** Aperture not distinct, pollen size variations, big pollen grain size PA 56.5 $\mu$  (53-60) and ED 68.0 $\mu$  (65-71), P/A 83.24, normal grain PA 28.3 $\mu$  (25-35) and ED 36.5 $\mu$  (33-38), P/A 77.53, exine ornamentation ruguloreticuloid, exine wall of big grain 4.0-5.0 $\mu$  and normal grain 3.5-4.0 $\mu$ , maximum abnormal type pollen, grains mostly found in diad and tetrad condition [may be due to incomplete cytokinesis], some diads have regular reticulation with 2-sets of bacula, single grains are also present, in monads luminary bacula are not found in many grains, in some abnormal grains the exine ornamentation deviates drastically from the normal grains, variation in exine ornamentation observed, exine is infested with gemmate and Pilate excreces of different dimensions, in some grains reticulations are incomplete, in addition to regular reticulate grains where smaller bacula are found inside Lumina there are grains where the muri do not form closed Lumina, the bacula are verrucate in such grains, size variation present in diads, bridges found.

**Garnet Glory:** Aperture not distinct, pollen size variations, normal grain size PA 26.2 $\mu$  (24-31) and ED 35.9 $\mu$  (32-39), P/A 72.98, mini grain size PA 14 $\mu$  and ED 16, P/A 87.5, pollen shape convex round in polar view, oblate spheroidal in equatorial view, exine reticulate, few grains showed abnormal reticulation, 2 sets of bacula present.

**Glabra:** Aperture 3-colpate, pollen size variations, normal grain size PA 38.8 $\mu$  (32-50) and ED 34.8 $\mu$  (31-44), P/A 111.49, mini grain size PA 22.0  $\mu$  and ED 16.0 $\mu$ , P/A 137.5, exine reticulate, exine thickness 3.0 $\mu$  (lateral view) and 2.0+1.0 $\mu$  (proximal view), grains

with abnormal reticulation found, irregular exine ornamentation e.g. Gemmate, Verrucate, etc. noted, bacula head broad forming thick prominent reticulation, the second set (smaller) bacula not prominent in LM, top of muri is not smooth, gemmate, verrucate, etc. all are normal grains, diads and tetrads present.

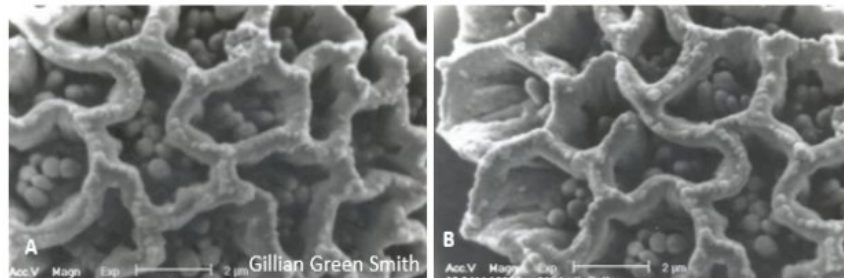
**Glabra Magnificat:** Aperture 3- colpate, pollen size uniform, normal grain size PA 30.2 $\mu$  (27-41) and ED 38.6 $\mu$  (33-50), P/A 78.23, pollen shape sub oblate, exine reticulation regular, exine thickness 3.5 $\mu$  lateral view, Lumina angular, muri top very smooth, 2 sets of bacula, muri top very smooth.

**Glabra Manifesto Trails:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 32.0 $\mu$  (25-35) and ED 35.7 $\mu$  (30-39), P/A 95.51, pollen shape suboblate, exine regular reticulate,

angular Lumina, exine thickness 3.0-4.0 $\mu$ , 2 sets of bacula.

**Glabra Sanderanea:** Aperture 3- colpate, pollen size uniform, normal grain size PA 34.1 $\mu$  (28-39) and ED 29.6 $\mu$  (25-33), P/A 115.20, pollen shape sub prolate in equatorial view, exine very densely reticulate, reticulation is very big and fine, exine thickness 3.4 $\mu$ , some baculate is present inside the muri.

**Gillian Green Smith:** Aperture 3-colpate, pollen size uniform, normal grain size PA 36.2 $\mu$  (27-42) and ED 27.0  $\mu$ (21-34), P/A 134.07, exine regulo-reticulate, exine thickness 3.0 $\mu$  (2.0 + 1.0), Lumina angular, muri top smooth, bacula straight (head not swollen), bacula head free i.e. muri not continuous seems dotted from the top view, regulate type ornamentation in some grains, one set of bacula present, in some grains reticulation forming true Lumina and muri is present (Figure 4A & B).

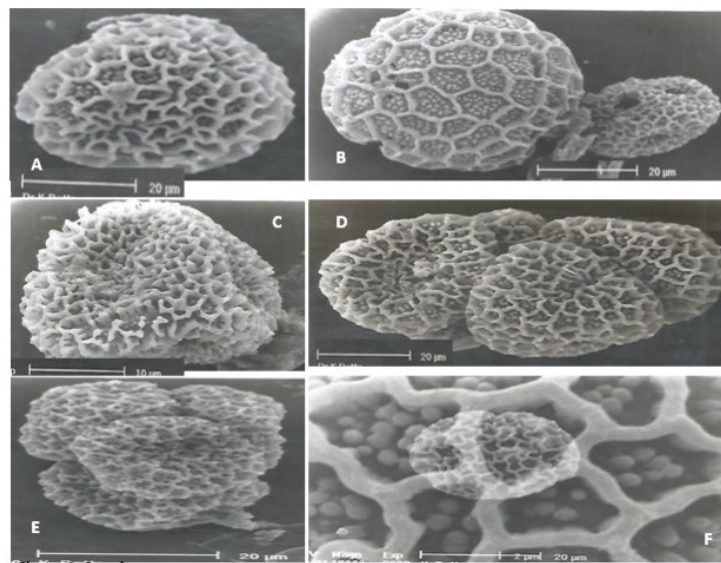


**Figure 4: A and B. Cultivar ‘Gillian Green smith’. Muri not Angular with Different Shape. 2nd Set of Bacula with Short Length.**

**Golden Glory:** Aperture 3-colpate, pollen size uniform, normal grain size PA 34.7 $\mu$  (32-37) and ED 27.4 $\mu$  (22030), P/A 126.64, pollen shape sub prolate in equatorial view, exine highly reticulate, exine size 2.9 $\mu$ , spines visible on exine surface, baculi are present inside the muri, colpa is not clear.

PA 48.6 $\mu$  (40-56) and ED 56.3 $\mu$  (50-61), P/A 86.32, normal grain size PA 27.8 $\mu$  (25-30) and ED 36.8 $\mu$  (33-41), P/A 75.54, pollen shape round convex, pollen shape sub prolate in equatorial view, exine reticulate, angular, in some grains reticulation like Thimma, Shubhra, exine thickness + 4.0 $\mu$ , tetrads and diads frequent, tetrads mostly tetragonal, tetrahedral tetrads were also noticed, 4-colpate grains bigger, 2 sets of bacula (Figure 5).

**Gopal:** Aperture 3-colpate, pollen size variations, bigger grain size



**Figure 5: Cultivar ‘Gopal’. A. Pollen Grain in Equatorial View Showing Angular Muri and Free Bacula in Lumina. Bacula with Shorter Length. B. Pollen Grain in Equatorial View, Reticulated with Angular Muri. Small Grain in Equatorial View and Showing 3 Colpa with Distinct Muri and Longer Bacula. C. Pollen Grain in Polar View Showing 3 Colpa. D. Tetragonal Tetrad Pollen Grain. E. Tetrahedral Tetrad Pollen Grain. F. Pollen Grain Showing Irregular Muri.**

**Happiness:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 28.2 $\mu$  (23-30) and ED 37.3 $\mu$  (34-40), P/A 75.60, pollen shape convex (round), exine reticulate, 2 sets of bacula, bacula head not joined in optical section.

**Harbhajan Singh:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.7 $\mu$  (28-35) and ED 28.2 $\mu$  (25-30), P/A 115.96, pollen shape sub prolate in equatorial view, exine densely reticulate, exine thickness 3.4 $\mu$ , small baculi is present inside the muri.

**Isabel Greens MTh:** Aperture not distinct, pollen size variations, normal pollen grain size PA 28.2 $\mu$  (23-36) and ED 36.1 $\mu$  (30-40), P/A 78.11, few bigger grains present ( PA 37-46 $\mu$  and ED 49-50 $\mu$ , P/A 84.84), exine reticulate, exine thickness 4.0 $\mu$  (3.0+1), pollen shape oblate spheroidal in equatorial view, abnormal exine ornamentation found – Verrucate type.

**Jaya:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 31.8 $\mu$  (27-36) and ED 38.5 $\mu$  (36-41), P/A 82.60, pollen shape sub oblate, exine reticulate, exine thickness 4.0-5.0 $\mu$ , reticulation angular, muri formed by Pilate baculi, height of pila + 3.0-4.0 $\mu$ , size and shape of Lumina variable, Lumina not always angular, two sets of bacula, bigger Pilate, shorter ordinary.

**Joede Liversa:** Aperture 3-colpate, pollen size variations, normal grain size PA 26.8 $\mu$  (23-31) and ED 32.6 $\mu$  (30-36), P/A 82.20, big grain size PD 39.6 $\mu$  (34-50) and ED 47.3 $\mu$  (42-57), P/A 83.72, pollen shape round, exine reticulate, exine thickness 3.0-4.0 $\mu$ , both angular and non-angular Lumina types are found, abnormal (not properly formed reticulation) exine ornamentation is found in a few grains, two sets of bacula present, bigger forming the muri joined from lower, few grains with abnormal exine ornamentation.

**Jubilee:** Aperture 3-colpate, pollen size variations, big grain size PA 53.0 $\mu$  (46-59) and ED 48.0 $\mu$  (40-55), P/A 110.41, normal grain size PA 34.1 $\mu$  (30-38) and ED 26.8 $\mu$  (23-35), P/A 127.23, pollen shape sub prolate in equatorial view, exine reticulate, exine thickness 3.7 $\mu$ , colpa not visible due to high reticulation, small baculi is present inside the muri.

**Killer Campbell:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.4 $\mu$  (28-39) and ED 27.0 $\mu$  (25-30), P/A 120.0, pollen shape sub prolate in equatorial view, exine densely reticulate, exine thickness 2.7 $\mu$ , spines are visible on exine, bacula are present inside the muri.

**Krumbiegal:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 27.5 $\mu$  (24-30) and ED 37.2 $\mu$  (33-45), P/A 73.92, most grains are in polar view, oblate spheroidal, exine reticulate, reticulation not fully closed, exine thickness 3.0 $\mu$ , no gap between adjacent muri's, bacula are of two sizes.

**Lady Hydson of Ceylon:** Aperture 3-colpate, pollen size uniform, normal grain size PA 29.5 $\mu$  (25-34) and ED 25.2 $\mu$  (23-31), P/A 117.06, pollen shape sub prolate in equatorial view, exine reticulate,

exine thickness 3.4 $\mu$ , colpa is not visible due to high reticulation, small bacula are present inside the muri.

**Lady Mary Baring:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.4 $\mu$  (25-41) and ED 39.2 $\mu$  (30-44), P/A 85.20, pollen shape sub oblate, exine reticulate, angular, exine thickness 4.0-5.0 $\mu$ , regular reticulation, 2 sets of bacula, number of luminaires bacula many, top of muri almost smooth.

**Leopaldi:** Aperture 3-(4) colpate, 4-colpate condition very rare, pollen size uniform, normal grain size PA 25.5 $\mu$  (20-32) and ED 33.2 $\mu$  (31-36), P/A 76.80, pollen shape suboblate, exine reticulate, reticulation angular, exine thickness 4.0 $\mu$ , grains with rounded amb, muri smooth, 2 sets of bacula.

**Lilac Perfection:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.3 $\mu$  (27-36) and ED 36.4 $\mu$  (32-41), P/A 87.91, pollen shape sub oblate, ambs round, reticulation angular, exine thickness 3.0 $\mu$ , top of muri not smooth, double set of bacula.

**Louis Wathena:** Aperture 3-colpate, pollen size uniform, normal grain size PA 38.4 $\mu$  (35-48) and ED 31.2 $\mu$  (28-40), P/A 123.07, pollen shape polar view + round, 3.5+1.5 $\mu$ , pollen shape sub prolate in equatorial view, exine normal reticulation, not angular, exine thickness 4.0-5.0 $\mu$  lateral view, 2 sets of bacula (resembles A lick Lancaster), bacula heads are free, smaller sets within the Lumina, mini grains rarely noticed, top of muri not smooth.

**Louis Wathena Intermediate:** Aperture 3-colpate, pollen size variations, mini grain size PA 15 $\mu$  and ED 16 $\mu$ , P/A 93.75, big grain size PA 49-58 $\mu$  and ED 54-68 $\mu$ , P/A 88.70, normal grain size PA 30.9 $\mu$  (27-35) and ED 37.4 $\mu$  (35-44), P/A 82.62, pollen shape sub oblate, exine reticulate, exine thickness 4.0 $\mu$ , 2-sets of bacula, most of the grains in regular range, abnormal grains present, top of muri not smooth, normal grains similar to Louis Wathena.

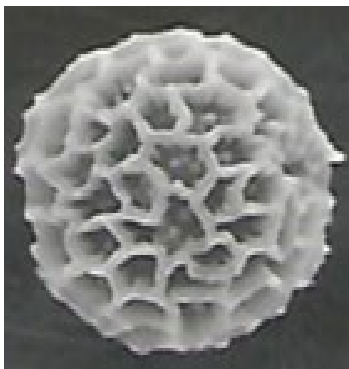
**Lucifer Red:** Aperture 3-(4) colpate, pollen size variations, big grain size PA 63.3 (50-75) and ED 50.0 (40-60), P/A 126.6, normal grain size PA 37.4 $\mu$  (32-50) and ED 28.9 $\mu$  (25-40), P/A 129.41, pollen shape sub prolate in equatorial view, exine densely reticulate, exine thickness 4.2 $\mu$ , smaller baculi are present inside the muri.

**Magenta Queen (syn. Mrs. Butt Magenta, Purple green):** Aperture 3- colpate, pollen size uniform, normal grain size PA 37.7 $\mu$  (30-44) and ED 31.7 $\mu$  (28-38), P/A 118.92, pollen shape sub prolate, exine reticulate, angular, exine thickness 4.0 $\mu$ , few bigger grains found, 2-sets of bacula, top of muri smooth, resembling Enid Lancaster.

**Manohar Chandra Variegate:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.1 $\mu$  (26-36) and ED 24.3 $\mu$  (20-30), P/A 132.09, , pollen shape sub prolate in lateral view, exine densely reticulate, exine thickness 2.94 $\mu$ , colpa is not visible, and some small baculi are observed inside the muri.

**Mary Palmer:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.0 $\mu$  (28-35) and ED 26.8 $\mu$  (23-30), P/A 123.13, pollen shape sub prolate in equatorial view, exine densely

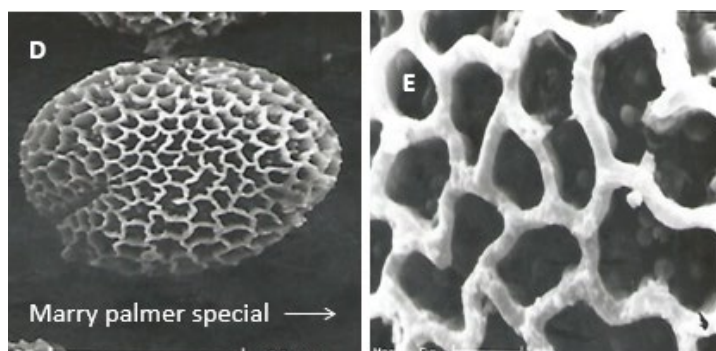
reticulate, exine thickness 3.4 $\mu$ , some bacula are present inside the muri (Figure 4C).



**Figure 4C: Cultivar 'Mary Palmer' – Pollen Grain in Equatorial View with 3 Colpate**

**Mary Palmer Special:** Aperture 3-(4) colpate, pollen size variations, big grain size PA 39.2 $\mu$  (26-43) and ED 30.1 $\mu$  (22-35), P/A 130.23, small grain size PA 16.6 $\mu$  (10-22) and ED 13.9 $\mu$  (9-20), P/A 119.42, pollen shape sub prolate in equatorial view, exine

reticulate, exine thickness 1.5 $\mu$  in small grain, 3.2 $\mu$  bigger grain, two distinct size bigger grains dark stained comparison to small grains, small bacula are visible inside the muri, highly reticulation (Figure 4D & E).



**Figure 4D and 4E: Cultivar 'Mary Palmer Special' – D. Polar View Showing 3 Colpate. E. Muri with Irregular Shape. 2 Nd Set of Bacula Very Small.**

**Mrs. Fraser:** Aperture not distinct, pollen size variations, big grain size PA 59.3 $\mu$  (45-73) and ED 64.6 $\mu$  (55-75), P/A 91.79, normal grain size PA 30.9 $\mu$  (27-37) and ED 38.7 $\mu$  (35-45), P/A 79.84, pollen shape sub oblate, exine reticulate, rug uloid, normal grain exine thickness 4.0 $\mu$  and bigger grain 5.0-6.0 $\mu$ , few diads noted, double set of bacula, ornamentation like Turley's special.

grain size PA 36.8 $\mu$  (32-46) and ED 32.1 $\mu$  (28-40), P/A 114.64, big grain size PA 70 $\mu$  and ED 60 $\mu$ , P/A 116.67, bigger grain present but not frequent, pollen shape prolate spheroidal. in equatorial view, exine normal reticulate, exine thickness 3.5-4.0 $\mu$ , tetrads noted frequently in normal grains, 2-sets of bacula present, top of bacula not fused, few grains with gemmate type projections noted.

**Mrs. Mclean:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.3 $\mu$  (28-40) and ED 38.0 $\mu$  (34-44), P/A 85.0, pollen shape sub oblate, regular reticulation, not angular, exine thickness 4.0 $\mu$ , double set of bacula, top of muri scab rate, not smooth.

**Padmi:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 39.2 $\mu$  (34-50) and ED 32.9 $\mu$  (26-43), P/A 119.14, pollen shape sub prolate, exine reticulate, reticulation mostly angular, exine thickness +4.0 $\mu$ , angular muri, 4-colpate condition mostly found in bigger grains, 2-sets of bacula, top of muri scab rate (not smooth).

**Machaka's:** Aperture 3- colpate, pollen size uniform, normal grain size PA 39.0 $\mu$  (30-35) and ED 26.2 $\mu$  (24-28), P/A 148.85, pollen shape sub prolate in equatorial view, exine densely reticulate, exine thickness 3.1 $\mu$ , colpa not clear, smaller baculi inside the muri.

**Palekar:** Aperture 3-colpate, pollen size uniform, normal pollen size PA 40.5 $\mu$  (38-43) and ED 34.7 $\mu$  (32-37), P/A 116.71, pollen round in polar view, exine densely reticulate, exine thickness 4.0 $\mu$ , ornamentation regular reticulate, Lumina not angular, top of muri not very smooth.

**New Red:** Aperture 3-(4) colpate, pollen size variations, normal

**Partha:** Aperture 3-colpate, pollen size variations, big grain size PA 77.8 $\mu$  (70-85) and ED 70.6 $\mu$  (55-78), P/A 110.20, normal grain size PA 49.4 $\mu$  (45-54) and ED 42.6 $\mu$  (40-45), P/A 115.96, small grain size PA 33.6 $\mu$  (30-37) and ED 28.0 $\mu$  (25-32), P/A 120.0, pollen shape sub prolate, exine reticulate, exine thickness giant grain 5.0 $\mu$  and normal grain 4.0-5.0 $\mu$ , normal grains with 2 sets of bacula, diads and tetrads found, abnormal grains present with different exine ornamentation.

**Parthasarathy:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.5 $\mu$  (29-35) and ED 37.2 $\mu$  (31-43), P/A 88.16, pollen shape suboblate, exine reticulate, reticulation not angular, exine thickness 4.0 $\mu$ , top of muri not smooth, double set of bacula.

**Pisil:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.3 $\mu$  (28-44) and ED 38.0 $\mu$  (32-45), P/A 85.0, pollen shape sub oblate, exine thickness 3.0-4.0 $\mu$ , reticulation angular, Lumina almost angular, muri top smooth, 2-sets of bacula.

**Poultonii:** Aperture 3-colpate, pollen size uniform, normal grain size PA 26.8 $\mu$  (23-30) and ED 31.5 $\mu$  (32-38), P/A 85.08, pollen shape sub oblate, exine reticulate, not angular, exine thickness 3.0 $\mu$  (2.0+1.0), rare mini grains noted, 2 sets of bacula, number of luminary bacula numerous, top of muri not smooth.

**Poultonii Special:** Aperture 3-colpate, Grains smaller than Poulton, 2 sets of bacula, all characters same as Poultonii.

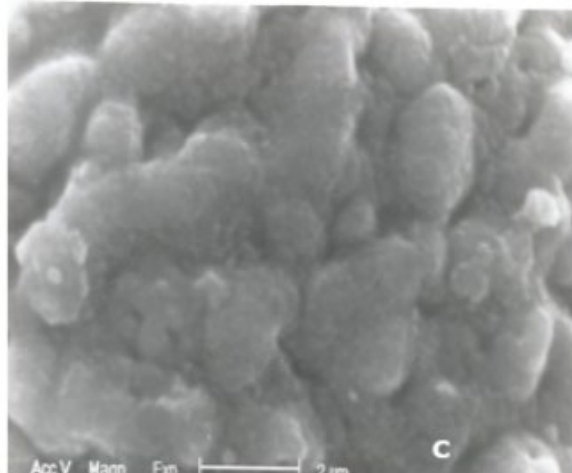
**President Roosevelt:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 32.5 $\mu$  (27-41) and ED 38.5 $\mu$  (33-47), P/A 84.41, pollen shape sub oblate, exine rugulo-reticulate, exine thickness 3.0 $\mu$ , grains more or less in single size range, single set

of bacula, grains with regular reticulation, top of muri smooth.

**Princess Margaret Rose:** Aperture 3-(4) colpate, pollen size variations, bigger grains lighter stained, smaller grains dark brown, 4 colpate conditions found in bigger grains, normal grain size PA 30.4 $\mu$  (27-32) and ED 37.2 $\mu$  (36-41), P/A 81.72, big grain size PA 38.6 $\mu$  (35-41) and ED 44.5 $\mu$  (40-50), P/A 86.74, pollen shape sub oblate, exine reticulate, exine thickness 3.5 $\mu$  in lateral view, 3.0 $\mu$  in prox. view, muri angular, muri heads joined on top view, colpa broad + 4.0 $\mu$  (in bigger grain), a single set of bacula (in L.M.), number of bacula within Lumina (2nd set) 2-3 (as in X10000 mag in SEM).

**Profusion:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 31.5 $\mu$  (27-37) and ED 37.9 $\mu$  (36-41), P/A 83.11, pollen shape oblate spheroidal in equatorial view, exine reticulate, exine thickness 4.0 $\mu$ , ornamentation not always forming regular reticulation, rugulate in many grains, rugulate formed by bigger bacula joined at the top, 2nd set of bacula shorter, within lamina, or the luminoid space, in normal regular reticulation Lumina is not angular, top of muri not smooth.

**Refulgent:** Aperture not distinct, pollen size variations, big grain size PA 46 $\mu$  and ED 53 $\mu$ , P/A 86.79, normal grain size PA 30.0 $\mu$  (27-36) and ED 36.0 $\mu$  (32-41), P/A 83.33, pollen shape sub oblate, exine reticulate, exine thickness 3.5-4.0 $\mu$ , a single set of bacula, normal grains with regular reticulation (luminary bacula present), in some grains reticulation is different with solid wall like muri, regulate exine with irregular projections were found in some grains, bigger grains very few (Figure 6C).



**Figure 6: C. Cultivar 'Refulgens' – Rugulate Exine Showing Irregular Projections.**

**Rhodamine:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 31.8 $\mu$  (28-39) and ED 35.9 $\mu$  (34-42), P/A 88.58, pollen shape oblate spheroidal, exine rugulo-reticulate, exine thickness 3.0 $\mu$ , single set of bacula, Lumina not angular, luminary baculi not distinct (ill-formed), muri top not smooth, grains are very similar to those of Rose Queen.

**Roseau Fuchsea:** Aperture 3-colpate, pollen size variations, big pollen size PA 61.4 $\mu$  (62-65) and ED 59.5 $\mu$  (50-60), P/A 103.19, normal grain size PA 44.6 $\mu$  (35-55) and ED 34.5 $\mu$  (27-49), P/A 129.27, pollen grain almost spheroid in proximal view and prolate to prolate spheroid in equatorial view, exine reticulate, exine thickness 3.0-3.5 $\mu$ , diads present, tetrad noticed, single set of bacula, abnormal exine ornamentation, gemmate in some grains.

**Rose Queen:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.8 $\mu$  (29-38) and ED 39.8 $\mu$  (33-42), P/A 84.92, pollen shape sub oblate, exine normal reticulation, exine thickness 4.0 $\mu$ , Lumina angular, muri almost smooth, 1 set of bacula, grains bigger- 4 colpate.

**Roseau (syn. Thomasi):** Aperture 3-colpate, pollen size variations, big grain size PA 65.0 $\mu$  (54-66) and ED 56.2 $\mu$  (44-72), P/A 115.66, normal grain size PA 38.8 $\mu$  (35-43) and ED 31.3 $\mu$  (29-34), P/A 123.96, pollen shape sub prolate, exine thickness 4.0-5.0 $\mu$ , diads and tetrads noticed frequently, few mini grains noticed, double set of bacula, ornamentation abnormal in some grains resembling cv. Profusion.

**Rurarka:** Aperture 3(-4) colpate, pollen size variations, normal grain size PA 37.8 $\mu$  (35-41) and ED 32.4 $\mu$  (28-34), P/A 116.67, mini pollen size PA 24 $\mu$  and ED 20 $\mu$ , P/A 120.0, pollen shape sub prolate, exine reticulate, reticulation not angular, exine thickness +5.0 $\mu$ , 4 colpate rarely found, mini grains sparsely found, top of muri not smooth.

**Scarlet Queen:** Aperture 3-colpate, pollen size uniform, normal grain size PA 39.5 $\mu$  (35-47) and ED 31.5 $\mu$  (27-38), P/A 125.39, pollen shape prolate spheroidal in equatorial view, exine reticulate, angular, exine thickness 4.0-4.5 $\mu$ , bacula single set (LM), second set of bacula in lower level of the muri head (SEM), muri top almost not smooth, Lumina not angular.

**Scarlet Glory:** Aperture 3(-4) colpate, colpa narrow, pollen size uniform, normal grain size PA 30.8 $\mu$  (28-33) and ED 37.9 $\mu$  (33-40), P/A 81.27, pollen shape oblate spheroidal in equatorial view, exine reticulate, angular, exine thickness 3.0 $\mu$ , (2.0+1.0 prox. view), amb convex, less variation in grain size, shape, and reticulation, top of muri smooth, unusual ornamentation found in some grains (SEM).

**Shubhra:** Aperture 3- colpate, pollen size uniform, normal grain size PA 32.5 (30-35) and ED 34.5 (34-41), P/A 94.20, pollen shape oblate spheroidal in lateral view, exine reticulate, + homobrochate, exine thickness 4.0 $\mu$  (lateral view) and 3.0 $\mu$  + 1.0 $\mu$  (Prox. View), normal reticulation with 2 sets of bacula, while forming muri the 1st set of bacula join and form column-like structure in the lower surface of exine, Lumina angular, not much variation in grain size, very few big grains found.

**Singapore Dark Red:** Aperture 3(-4) colpate, pollen size uniform, normal grain size PA 33.9 $\mu$  (30-44) and Ed 39.4 $\mu$  (36-51), P/A 86.04, pollen shape sub oblate, regular reticulation, exine thickness 5.0 $\mu$  (4.0+1.0), regular two sets of bacula.

**Spring Festival:** Aperture 3-colpate, pollen size uniform, normal grain size PA 44.3 $\mu$  (35-50) and ED 35.9 $\mu$  (30-40), P/A 123.40, pollen shape round, reticulation incomplete, (not closed), exine rugulo-reticulate, exine thickness 3.0 $\mu$ , bacula head not swollen, single set of bacula (2nd set of bacula ill-formed), muri not continuous, reticulation not regular type.

**Srinivasa:** Aperture 3-colpate, pollen size uniform, normal grain size PA 34.6 $\mu$  (30-44) and ED 39.3 $\mu$  (32-47), P/A 88.04, pollen shape oblate in equatorial view, exine reticulate, not angular, exine thickness 3.0 $\mu$ , (2.0+1.0 proximal view), heterobrochate, Lumina angular, separated distinctly from one another, bacula free, straight, top of muri intermediate (not smooth), in some places scab rate in other places smooth.

**Stanza:** Aperture 3-colpate, pollen size uniform, normal grain size PA 42.2 $\mu$  (30-37) and ED 26.1 $\mu$  (22-30), P/A 161.68, pollen shape sub prolate in equatorial view, exine densely reticulate, exine thickness 2.94 $\mu$ , colpa are not clearly visible, small bacula are present inside the muri.

**Star:** Aperture 3-colpate, pollen size variations, big grain size PA 43 $\mu$  and ED 50 $\mu$ , P/A 86.0, medium grain size PA 42 $\mu$  and ED 40 $\mu$ , P/A 105.0, pollen shape prolate spheroidal, exine reticulate, reticulation normal i.e. 2 sets of bacula present, lateral view bigger exine thickness 2.5-3.0 $\mu$  at mesocolpium and 4.0 $\mu$  at pole, Lumina size varies, muri head free, 2 sets of bacula present, bigger one forms muri, two types of reticulation - in most cases the baculi are free, occasionally united at the top, tetrads (tetragonal) found.

**Sumatra:** Aperture 3-colpate, pollen size uniform, normal grain size PA 33.7 $\mu$  (28-37) and ED 27.6 $\mu$  (23-34), P/A 122.10, pollen shape convex at amb and prolate spheroidal at equatorial view, exine reticulate, exine thickness 3.0-4.0 $\mu$ , heterobrochate, bacula of two sizes- bigger +4.0 $\mu$  and smaller +2.0 $\mu$ , Lumina not angular, top of muri smooth.

**Summer Time:** Aperture 3-colpate, pollen size uniform, normal grain size PA 31.5 $\mu$  (30-36) and ED 26.9 $\mu$  (25-30), P/A 117.10, pollen shape sub prolate in equatorial view, exine densely reticulate, exine thickness 3.0 $\mu$ , colpa is not clearly visible, smaller baculi is present inside the muri.

**Summer Queen:** Aperture 3-colpate, pollen size uniform, normal grain size PA 30.9 $\mu$  (28-35) and ED 38.0 $\mu$  (32-43), P/A 81.31, pollen shape round convex at Amb and + spheroid at proximal view and oblate spheroidal at equatorial view, exine thickness 4.0-5.0 $\mu$ , abnormal exine ornamentation in some grains found in SEM, double set of bacula.

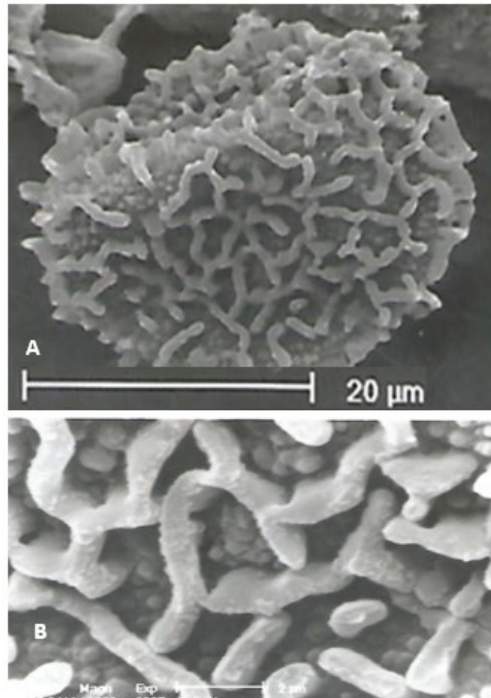
**Sundari:** Aperture 3(-4)-colpate, pollen size variations, big pollen size PA 56.5 $\mu$  (50-68) and ED 43.8 $\mu$  (38-47), P/A 128.99, medium grain size PA 39.6 $\mu$  (37-44) and ED 29.8 $\mu$  (27-32), P/A 132.89, small grain size PA 26.3 $\mu$  (25-28) and ED 20.6 $\mu$  (18-24), P/A 132.89, pollen shape prolate, exine reticulate, in some grains Pilate without forming Lumina, reticulation not angular, top of muri not smooth, exine thickness in big grain 3.0-4.0 $\mu$  and small grain 1.0-3.0 $\mu$ , height of pila +3 $\mu$ , shape and ornamentation, diads and more frequently tetrads are found.

**Surekha:** Aperture 3(-4) colpate, pollen size uniform, normal grain size PA 30.0 $\mu$  (28-34) and ED 36.8 $\mu$  (31-42), P/A 81.52, shape round in polar view, exine reticulate, reticulation not

angular, exine thickness 4.0-5.0 $\mu$ , few mini gains noted rarely, tetrads present, lumina not angular, muri top not smooth, double set of bacula.

**Swetha:** Aperture 3-colpate, pollen size variations, small grain size PA 16 $\mu$  and ED 19 $\mu$ , P/A 84.21, smaller grains rare, normal

grain size PA 29.8 $\mu$  (25-36) and ED 36.7 $\mu$  (30-42), P/A 81.20, pollen shape sub oblate, exiles regular reticulation (angular), exine thickness 3.0 $\mu$ , single or 2 sets of bacula, muri heads at angle point of reticulation (longer) visible [grains similar to Dream], top of muri smooth (Figure 6A & B).



**Figure 6A and 6B: Cultivar 'Swetha'. A. Pollen Grain in Equatorial View Showing Irregular Muri. B. Enlarged View of Exine Showing Muri and Inner Bacula Heads.**

**Sydney:** Aperture not distinct, pollen size uniform, normal pollen size PA 31.2  $\mu$  and ED 36.6 $\mu$ , P/A 85.24, pollen shape rounded triangular, regular reticulation, 2 sets of bacula.

**Tetra Mrs. McClean:** Aperture 4- colpate, (3-colpate rare), pollen size uniform, normal grain size PA 57.1 $\mu$  (46-67) and ED 56.7 $\mu$  (45-61), P/A 97.40, pollen shape oblate spheroidal, exine reticulate, angular reticulation, exine thickness 4.0-5.0 $\mu$ , mostly 4-colpate, a few abnormal aperturate grains e.g. Spiraperturate like noted, mini grains rare, angular reticulation, top of muri smooth.

**Theresa Jacobs:** Aperture 3-colpate, colpa not much prominent in equatorial view, pollen size uniform, normal pollen size PA 37.5 $\mu$  (31-40) and ED 38.5 $\mu$  (31-37), P/A 97.40, shape round convex, exine reticulate, thickness 4.0-4.5 $\mu$  in lateral view and 3.5+1.0 $\mu$  in equatorial view, Lumina angular, muri is formed by pila type bacula, top of muri smooth, in some grains there are gaps in muri thus the two adjacent Lumina are not always well separated, few grains were big size (68 x 58 $\mu$ ), muri formed by bacula, two sets of bacula were observed, Lumina well demarcated.

**Thimma:** Aperture 3-(4) colpate, pollen size uniform, normal grain size PA 27.10 (25-30) and ED 35.2 (32-38), P/A 77.0, pollen shape oblate spheroidal in equatorial view, exine reticulate,

angular but not sharp angle, exine thickness 3.0 $\mu$ , in some grain's large reticulation with numerous baculi in Lumina are present, top of muri not smooth, abnormal grains with very different exine structure is found.

**Turly's Special:** Aperture 3-colpate, pollen size uniform, normal grain size PA 38.5 $\mu$  (28-53) and ED 33.1 $\mu$  (25-45), P/A 116.31, pollen shape sub prolate, exine reticulate, exine thickness 4.0 $\mu$ , few double grains and mini grains noted, reticulation not angular, top of muri not smooth.

**Zakeriana:** Aperture 3-colpate, pollen size uniform, normal grain size PA 32.9 $\mu$  (27-38) and ED 39.1 $\mu$  (30-42), P/A 84.14, pollen shape 3-lobed in proximal view and oblong spheroidal in equatorial view, exine thickness 4.0 $\mu$ , exine reticulate (Lumina) not angular, top of muri smooth.

**Zulu Queen:** Aperture 3-colpate, pollen size variations, small grain size PA 14.0 $\mu$ (11-17) and ED 10.5 $\mu$  (9-13), P/A 133.33, normal grain size PA 29.30 $\mu$  (25-35) and ED 25.1 $\mu$  (22-30), P/A 116.73, pollen shape sub prolate in equatorial view, exine reticulate, exine thickness 3.5 $\mu$ , two distinct size pollen, both sizes are equal, reticulation is very dense, smaller bacula are present inside the muri.

Pollen types observed in different varieties have been shown in Table 2. Size variations of pollen grains in different category have been mentioned in Table 3. Attempt has been made to focus on some specific varieties which exhibit noticeable pollen characteristics (Table 3).

|   |
|---|
| <b>Normal pollen grains:</b> Abraham Konoor, Aida, Arjun, Cleopatra, Dog Star, Dream, Dwarf Gem,                |
| Ecstasy, Eisha, Enid Lancaster, Glabra, Glabra Magnificat, Glabra Magnificat Trails, Glabra                     |
| Sanderanea, Gillian Green Smith, Golden Glory, Happiness, Harbhajan Singh, Isabel Green Smith,                  |
| Jaya, Killer Campbell, Krumbiegal, Lady Hydson of Ceylon, Lady Mary Baring, Leopaldi, Lilac                     |
| Perfection, Louis Wathena, Magenta Queen, Manohar Chandra Variegata, Mary Palmer, Mrs.                          |
| Mclean, Machaka's, Pad mi, Palekar, Parthasarathy, Pisil, Poulton, Poultonii Special, President                 |
| Roosevelt, Profusion, Rhodamine, Rose Queen, Scarlet Queen, Scarlet Glory, Singapore Dark                       |
| Red, Spring Festival, Srinivasa, Stanza, Sum antra, Summer Time, Summer Queen, Surekha,                         |
| Sydney, Tetra Mrs. McClean, Thimma Thurley's Special, Zakeriana.  |
|   |
| <b>Normal + Big pollen grains:</b> Floribunda, Gopal, Joede Livers, Jubilee, Lucifer Red, Mrs. Fraser, New Red, |
| Princes Margaret Rose, Refulgent, Rosea Fuchsea, Rosea, Shubhra, Star, Theresa Jacops.                          |
|   |
| <b>Normal + Big + Small pollen grains :</b> Charles William, Flame, Golden Glow, Louis Wathen Intermediate,     |
| Paratha, Sundar.  |
|   |
| <b>Normal + Big + Small + Mini pollen grains:</b> A lick Lancaster  |
| <b>Normal + Mini pollen grains:</b> Garnet Glory, Rurarka, Swetha, Zulu Queen                                   |
| <b>Big + Small pollen grains:</b> Mary Palmer Special   |

**Table 2: Pollen Grain Types in Some Notable Varieties of Bougainvillea**



|  |   |
|--|---|
| Normal pollen grain size ( $\mu$ ):  | PA 27.1 – 39.5, ED 24.3 – 39.8                                |
| Big pollen grain size ( $\mu$ ):   | PA 39.6 – 65.0, ED 30.1 – 70.6                                |
| Medium pollen grain size ( $\mu$ ):  | PA 42.0 -39.6, ED 40.0 – 29.8                                 |
| Small pollen grain size ( $\mu$ ):   | PA 23.0 – 26.2, ED 30.0 - 28.0                                |
| Mini pollen grain size ( $\mu$ ):  | PA 14.0 – 26.3, ED 10.5 – 20.6                                |
| Varieties with normal size pollen grains (%):  | 68.67   |
| Varieties with normal + Big pollen grains (%):   | 16.87   |
| Varieties with normal + big + small pollen grains (%):   | 7.22  |
| Varieties with normal + big + small + mini pollen grains (%):  | 1.20  |
| Varieties with normal + mini pollen grains (%):  | 4.81  |
| Varieties with big + small pollen grains (%):  | 1.20  |
| Eisha : Number of pollen grains scanty   |   |
| Charles Williams, Floribunda, Glabra, Gopal,   | Diads and Tetrads found                                       |
| Mrs. Fraser, New Red, Paratha, Rosea Fuchsea,  |   |
| Rosea, Star, Sundari, Thurley's Special  |   |
| Magenta Queen, Shubhra, Theresa Jacobs: Sometimes few big pollen grains noted  |   |
| Poultonii, Rurarka, Surekha, Thurley's Special: Sometimes few mini pollen grains noted   |   |
| Louis Wathena, Tetra Mrs. McClean: Mini grains rarely noted  |   |
| Eisha: exine ornamentation much different baculate or retaliate, bacula straight, free forming rugulo-reticulusis type pattern |   |
| Glabra:  | exine ornamentation gemmate, verrucate                        |
| Gillian Green Smith:   | exine regulo-reticulate                                       |
| Isabel Green smith:  | abnormal exine ornamentation found–Verrucate type             |
| Sumatra:   | exine heterobrochate  |
| Tetra Mrs. McClean:  | few abnormal aperturate grains e.g. Spiraperturate like noted |
| A lick Lancaster, Arjun, Dream, Dwarf gem, : Two sets of bacula noted  |   |
| Flame, Floribunda, Garnet Glory, Glabra  |   |
| Magnificat, Glabra manifesto Trails, Gopal,  |   |
| Jaya, Joede Livers, Lady Mary Baring,  |   |
| Leopaldi, Lilac Perfection, Louis Wathena,   |   |
| Louis Wathena Intermediate, Magenta Queen,   |   |
| Mrs. Fraser, Mrs. Mclean, New Red, Pad mi,   |   |
| Paratha, Parthasarathy, Pisil, Poultonii, Poultonii  |   |
| Special, President Roosevelt, Profusion, Rosea,  |   |
| Scarlet Queen, Singapore Dark Red, Star,   |   |
| Summer Queen, Surekha, Theresa Jacobs  |   |

**Table 3: Pollen Types and Their Size Variations, and Few Special Features in Some Varieties of Bougainvillea**

#### 4. Discussion

Pollen morphological characters have been used for identification and in solving many taxonomical problems of interrelationships between various taxa of families, genera and species. Studies on Pollen characters earned considerable interest in solving many taxonomical problems and has been considered as useful tool in many plant species. However, pollen grain morphological characters have not been applied much to solve taxonomic disputes at varietal level in different commercially important ornamental crops. As the classifications of the species and the cultivars of ornamental genus is not well understood detailed pollen morphological investigation of the cultivars of *Bougainvillea* has been taken with objective of micromorphological characterization of the cultivars through pollen features which may provide some important information for consideration in cultivar taxonomy and may indicate interrelationship and origin of many cultivars. The pollen morphological studies will yield the maximum return to systematics, evolution and for correct identification of horticultural/floriculture varieties. The present study highlights the pollen morphological characters of 83 *Bougainvillea* varieties and discusses the role of pollen morphology for characterization at the variety level. *Bougainvillea* pollen grains are basically 3(-4) colpate, prolate spheroidal to oblate spheroidal in shape with prominently reticulate exine. In most cultivars 2 sets of bacula are present, the 1st outer and bigger set forms the muri, and the second inner set is shorter and present in the Lumina. The shape and size of the Lumina are variable among the cultivars. Pollen grain size ranges are observed – mini grains to giant-sized grains in some cultivars. In addition to monads, diads, and tetrads are found probably as a result of incomplete cytokinesis. Varietal differences were noticed in reticulation. Reticulation angular and muri top almost smooth ('Scarlet Queen', 'Scarlet Glory', 'Magenta Queen', 'President Roosevelt', 'Enid Lancaster', 'Lady Mary Baring', 'Tetra Mrs. Mclean'), and reticulation not angular and muri top not smooth ('Srinivasan', 'Padma', 'Poultonii', 'Poulton Special', 'Louis Wathena', 'Louis Wathena Intermediate', 'A lick Lancaster', 'Mrs. Mclean').

Variation in aperture (colpa) was noticed in different varieties. Majority of varieties (52) are 3- colpate ('Abraham Konnor', 'A lick Lancaster', 'Arjun', 'Cleopatra', 'Dog Star', 'Dream', 'Ecstasy', 'Eisha', 'Glabra', 'Glabra Magnificat', 'Glabra Sanderanea', 'Gillam Green Smith', 'Golden glow', 'Golden glory', 'Gopal', 'Harbhajan Singh', 'Joede Liversa', 'Jubilee', 'Killer Campbell', 'Lady Hydson of Ceylon', 'Lady Mary Baring', 'Lilac Perfection', 'Louis Wathena', 'Louis Wathena Intermediate', 'Magenta Queen', 'Manohar Chandra variegata', 'Mary Palmer', 'Mrs. Mclean', 'Machaka's', 'Palekar', 'Partha', 'Parthasarathy', 'Pisil', 'Poultonii', 'Poultonii Special', 'Roseau Fuchsia', 'Rose Queen', 'Roseau' (syn. Thomasi), 'Scarlet Queen', 'Shubhra', 'Spring Festival', 'Srinivasa', 'Stanza', 'Star', 'Sumatra', 'Summer Time', 'Summer Queen', 'Swetha', 'Theresa Jacobs', 'Turly's special', 'Zakeriana', 'Zulu Queen') and 23 varieties had 3- (-4) colpate ('Aida', 'Dwarf Gem', 'Enid Lancaster' (syn. Golden Glow?), 'Glabra manifesto Trails', 'Golden Glow', 'Happiness', 'Jaya', 'Krumbiegel', 'Leopaldi', 'Lucifer Red', 'Mary Palmer special',

'New Red', 'Padmi', 'President Roosevelt', 'Princess Margaret Rose', 'Profusion', 'Rhodamine', 'Rurarka', 'Scarlet Glory', 'Singapore Dark Red', 'Sundari', 'Surekha', 'Thimma'); 'Tetra Mrs. McClean' showed 4-colpate (rarely 3-colpate). Pollen grains in few varieties (8) are not normal as the aperture is not distinct ('Charles William', 'Flame', 'Floribunda', 'Garnet Glory', 'Isabel Greens MTh', 'Mrs. Fraser', 'Refulgent', 'Sydney'). Variations in exinal pollen surface ultrastructural ornamentation pattern were observed in different cultivars like 'Eisha' (exine ornamentation much different baculate, Pilate or retipilate), Floribunda (ruguloreticuloid, gemmate and Pilate, the bacula are verrucate in such grains), 'Glabra' (gemmate, verrucate), 'Glabra Sanderanea' (reticulation is very big and fine), 'Gillam Green Smith' (exine rugulo-reticulate), 'Golden Glow' (giant grains mostly 4-colpate), 'Isabel Greens MTh' (exine verrucate type), 'Jaya' (muri formed by pilata baculi), 'Leopaldi' (grains with rounded amb -polar view), 'Lilac Perfection' (ambs round), 'Mrs. Fraser' (exine reticulate, rug uloid, few diads noted), 'Mrs. Mclean' (top of muri scab rate), 'New Red' (few grains with gamete type projections), 'President Roosevelt' (exine rugulo-reticulate), 'Profusion' (ornamentation not always forming regular reticulation, regulate in many grains), 'Roseau Fuchsia' (gemmate in some grains), 'Scarlet Glory' (amb convex), 'Shubhra' (reticulate, + homobrochate), 'Spring Festival' (rugulo-reticulate), 'Srinivasa' (heterobrochate, muri intermediate (not smooth), in some places scabrata in other places smooth, reticulation not angular), 'Sumatra' (pollen shape convex at amb), 'Summer Queen' (pollen shape round convex at amb), 'Tetra Mrs. McClean' (aperture 4- colpate, abnormal aperturate grains e.g. Spiraperturate like), 'Theresa Jacobs' (muri is formed by pila type bacula), 'Charles William' (tetrads found).

Diversity in pollen morphological and structural polymorphism (apertures, shape, size, pollen surface, pollen units, pollen symmetry, polarity, number of pores, number and position of colpa, pollen orientation pattern, exine sculpturing etc.) have been reported earlier in the varietal analysis and highlighted the importance of pollen characters in solving problems of interrelationships in different ornamental groups particularly concerning the families, subfamilies, tribes, genera, species, and subspecies [21,23,24,58-71]. The present analysis indicates that pollen grain characters have been changed and diversified along with other morphological characters due to natural processes (geographical movement of elemental species, adaptation, spontaneous mutation, natural selection, etc.) and manmade processes (human selection pressure, intentional indiscriminate hybridization, chromosomal manipulations, induced mutation, etc.). The present authors explored how pollen grain characters are changed through induced mutations using gamma irradiation in different ornamentals. Chrysanthemum cultivars had pollen grains mostly regular in size, but few cultivars and their mutants had dimorphic pollen grains. The endocolpium shape was variable; the lalongate type was most common but Lolo gate, circular, square, and indiscernible types were noticed in some mutant varieties. Noteworthy changes in exine surface pattern have been observed. Exine spine shape was changeable about the base and tip. The exine surface of the original cv. 'D-5' having a fossa-reticulate

pattern with narrow muri and irregularly shaped Lumina, changed to reticulate exine with broad muri and uniformly circular Lumina in the mutants 'Alankar' and 'Agnisikha.' The tips of the spines also changed from straight to bent. The reticulate undulated exine surface of the original cv. 'Kings form Smith' changed to a scrobiculate wrinkled surface in the mutant CV.

'Rohit.' The punctate exine surface pattern of the original cv. 'Him ani' transformed into a scrobiculate pattern in the mutant CV. 'Sheela' [72]. Gamma radiation made noticeable changes in the pollen exine ornamentation pattern in *Narcissus*. The exine ornamentation pattern in control was reticulate where the brocholi consisted of large circular Lumina interspersed with smaller Lumina and the top of the muri was flat. The number of Lumina per  $2\mu\text{m}^2$  was 8 to 9. 250 rad gamma-ray treated plants showed larger and elongated Lumina mixed with some in between smaller and round Lumina. The muri were raised and the number of Lumina per  $2\mu\text{m}^2$  was 6 to 7 due to the increase in size. 500 rad treated plants showed significant change in exiles ornamentation where the brochi became compact consisting of small angular Lumina and narrow muri. The number of Lumina per  $2\mu\text{m}^2$  has been increased to 13-14 due to a size reduction. 1000 rad gamma ray developed a very prominent change in the exine pattern. A loose brochi comprising large Lumina of various shapes was found. The muri were raised and varied in width from narrow to considerably wide at the joints and the number of Lumina per  $2\text{mm}^2$  was 4-5 due to larger size [73]. The pollen morphology of control *Mesembryanthemum* was studied after exposure to gamma rays and found that the exine ornamentation of 10 Krad treated plants was completely changed showing a 'microverrucate' pattern as against the 'spin lose' pattern of control. There are no puncta in the exine. A few dyads with similar patterns of exine also occurred among the monads. The basic apertural character in these grains remained the same as in the controls, being 3-colpate (colporoidata) [74]. A large pool of genes is involved in a complex system of pollen grain development. About 20,000 gametophytic genes have been detected, at least 2000 of which are specifically expressed in the mature pollen grain. Molecular studies have demonstrated that a large number of genes are expressed in pollen [75-78]. The structural diversity renders important taxonomic value for variety differentiation in *Bougainvillea*. In floriculture, such study is very important for better management, identification of accessions, and varieties, and also in avoiding duplications or mislabeling of the genotypes. Pollen exine is made up of sporopollenin, which protects the male gametes from natural stresses. Pollen structural characteristics of pollution-tolerant plants have been studied which may be utilized as a significant protection parameter against adverse conditions. *Bougainvillea* under industrial pollution environment stress developed morphological permutation in both vegetative and reproductive features. A kind of holistic structural resistance has been acquired by some *bougainvillea* varieties through selective pressure of environmental changes and can survive successfully under polluted conditions. The author (K. Datta) reported true reticulate exine comprising a network-like arrangement where the width of the perforation was greater than the width of the surrounding exinous muri in *Bougainvillea*. There

were the perforated areas or Lumina occupied by some solid projections (second set of columellae) so that the open exposed surface area was virtually reduced [1].

In the present studies, a good number of varieties conform to similar pollen micromorphology characteristics supporting the pollutant-tolerant nature of *Bougainvillea*. The present pollen-based characterization will help to develop a pollen database for horticultural crops [82]. In the present study, variations in pollen grain size, pollen shape, pollen type, apertures number etc. were the most distinguished characters in the circumscription of the *Bougainvillea* cultivars. Present pollen morphological studies (differences and similarities) indicate that variations have taxonomic significance and could be considered as of horto-taxonomic value in the differentiation among the closely related varieties of *Bougainvillea*. This will provide added knowledge on pollen micromorphology at a varietal level in addition to other characteristics. The variation and similarities, observed in the pollen characters of the present varietal studies will give a clue of the importance of application of palynological studies on floriculture crops. All ornamental varieties need to be studied horto-taxonomically to arrange all variations systematically before commercialization.

#### Acknowledgment

Both authors thank the Director of CSIR-National Botanical Research Institute, Lucknow, India for providing the working facilities. We especially thank and convey our deepest feelings to our professional colleagues at the floriculture and palynology laboratory, NBRI from where we have greatly benefited in our research activities. We sincerely acknowledge all scientists and internet sources from where we collected information for the preparation of the manuscript.

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