

CHAPTER 20

Morphometric Analysis of Twenty *Hibiscus Rosa-Sinensis* L. Cultivars

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Abstract

This study explores the phenetic similarity among 20 *Hibiscus* cultivars through morphological analysis of vegetative and floral parts. Each cultivar is treated as an Operational Taxonomic Unit (OTU) in a morphometric (multivariate) analysis. All characters were coded numerically, with qualitative traits represented as binary attributes. A character-taxon matrix was constructed, and cluster analysis using UPGMA was conducted with PAST 3.0. The resulting phenogram grouped cultivars based on 40 phenotypic characters, including qualitative traits like flower color and quantitative traits such as bloom

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size and leaf dimensions. The dendrogram, generated using complete clustering and Gower distance, reveals distinct groupings among the cultivars.

Keywords: Cluster analysis, Dendrogram, Gower distance, *Hibiscus*, Multivariate

Introduction

Assessing the phenetic similarity and dissimilarity among plant cultivars is crucial for taxonomy, breeding, and conservation efforts. The genus *Hibiscus* Medik. of family Malvaceae exhibits extensive taxonomic complexity. Numerical approaches have not been utilized for taxonomic purposes among other taxa of this family even though there seems to be ample scope for an examination of the applicability of these techniques to consider the taxonomic relatedness of the taxa (Alam et al., 2006). In this study, we focus on twenty (20) hibiscus cultivars, treating each as an Operational Taxonomic Unit (OTU). Morphological analysis of floral parts serves as the basis for evaluating phenetic relationships. To facilitate statistical analysis, all characters were numerically coded, with qualitative traits represented as binary attributes and multistate coding for some traits. The resulting character-taxon matrix allowed for cluster analysis using the Unweighted pair-group method with arithmetic average (UPGMA) (Sneath and Sokal, 1973). Through the utilization of PAST 3.0, a statistical package, the authors constructed a phenogram illustrating the clustering patterns among the cultivars (Anantha Lakshmi et al., 2019). This dendrogram, derived from a combination of qualitative and quantitative traits, sheds light on the phenetic relationships within the hibiscus cultivars, aiding in their classification and further research endeavors.

Materials and Methods

1. Sample Collection

Twenty hibiscus cultivars were selected for analysis and both vegetative and floral parts from each cultivar were collected for morphological examination (Fig. 1).

2. Morphological Characterization

Plant parts, including flowers, leaves, petioles, and pedicels, were examined for morphological traits. Qualitative traits such as flower color, eye color, and staminal column color and quantitative traits including bloom size, corolla length and width, style length, leaf width and length, petiole length, and pedicel length were measured (Table 1).

3. Character Coding

All characters were coded numerically for statistical analysis. For qualitative traits were represented as binary attributes and Multistate coding was applied where necessary. The diagnostic morphological characters of floral parts of plants were examined for assessing the degree of overall phenetic similarity between the 20 hibiscus cultivars (Table 2).

4. Character-Taxon Matrix Construction

A character-taxon matrix was constructed, with characters as rows and cultivars as columns, following the guidelines by Radford (1986). The characters states of qualitative characters were coded as binary attributes. In cases, multistate coding has been used and the details are given in table 3.

5. Principal Component Analysis and Cluster Analysis

The phenetic similarity among cultivars was assessed using the Unweighted pair-group method with arithmetic average (UPGMA) and PCA (Cabarrubias et al., 2017). Cluster analysis was performed using the statistical package PAST 3.0 (Hammer et al., 2001). With the help of this correlation coefficient matrix.

6. Dendrogram Construction

The resulting correlation coefficient matrix was used to generate a dendrogram. The dendrogram illustrated the clustering patterns among cultivars based on selected qualitative and quantitative traits. Complete clustering method and Gower distance were employed as measures of dissimilarity.

7. Visualization

The phenogram was visualized to depict the hierarchical clustering of hibiscus cultivars based on their morphological characteristics, using Discriminative statistical tools.



Fig. 1. Flowers of twenty *Hibiscus rosa-sinensis* L. cultivars

Table 1: Morphological Character of 20 *Hibiscus* cultivars

| Characters | A. A. Mao | A J C Bose | Apolion | Bengal Dancing Queen | Bengal Sunrise | Bengal Sunset | City of Joy | Countdown | Cream Dream | Dark Mother of Bengal | Janaki Ammal | Krishna's Radiance | Mothers Touch Singur | Queen of Winter | Republic Day | RN Tagore | Shining Blue | Spiritual of Madhubati | Vivekanda | Swamy |
|--------------------------------|------------|------------|-----------|----------------------|----------------|---------------|-------------|-----------|-------------|-----------------------|--------------|--------------------|----------------------|-----------------|--------------|-----------|--------------|------------------------|-----------|---------|
| Plant height (cm) | 100 | 60 | 150 | 150 | 150 | 150 | 120 | 200 | 100 | 90 | 200 | 200 | 100 | 100 | 150 | 150 | 100 | 150 | 150 | 100 |
| Branch attitude | upright | spreading | Spreading | upright | Spreading | Spreading | upright | Upright | Spreading | Upright | Spreading | upright | upright | Spreading | upright | Spreading | upright | Upright | Upright | Upright |
| Internodal portion length (cm) | 1.4-2.8 cm | 2-3 cm | 1-1.5 | 1.7-3 | 3.5-4.5 | 2-5.5 | 1.5-3 | 2.5-4.5 | 1.5-3.5 | 1.4-4.5 | 1-2 | 2.5-4.5 | 2.5-3 | 1.2-2.2 | 0.6-1.6 | 2-2.5 | 2.5-3.5 | 2.2-3 | 1.2-3 | 1.3-2 |
| Petiole length (cm) | 4.2-4.5 | 4.8-5 | 3.9-4 | 3-3.2 | 3.5-4 | 1.8-2.1 | 5-6 | 5.5-5.9 | 2.5-2.7 | 3.9-4 | 2-3 | 4-4.5 | 3.5-4 | 4.3-4.5 | 2.5-2.8 | 3.5-4 | 3.5-3.8 | 4-4.5 | 2.5-3 | 4.3 |
| Leaf length (cm) | 10-11.3 | 8-9 | 11-11.5 | 11-11.2 | 8.3-8.5 | 8-8.5 | 11-11.5 | 13.7-14 | 6.1-6.2 | 11.2-12 | 9-10 | 11.7-12 | 9.5-10.5 | 12.4-13 | 8.5-9.1 | 10-10.6 | 7-7.5 | 17.2-17.5 | 12.5-13 | 7-7.2 |
| Leaf width (cm) | 9.5-10.1 | 8-8.5 | 10.5-11 | 9.8-10 | 9.5-10 | 8-8.5 | 10-10.5 | 14.7-15 | 3.9-4 | 8-10.5 | 8-9 | 8-10 | 7.3-7.6 | 11.5-12 | 7-7.2 | 8-8.2 | 6-6.8 | 14-14.5 | 8.7-9 | 5-5.5 |
| Lateral nerves from the base | 6-7 | 6-7 | 6-7 | 5-6 | 5-6 | 3-6 | 5 | 5-6 | 4-5 | 5-6 | 5-7 | 5 | 5-7 | 4-5 | 5-6 | 9-10 | 5-7 | 7 | 5-6 | 6-7 |
| Pedicle length (cm) | 0.3-0.4 | 1.4-1.7 | 0.2-0.3 | 0.6-0.9 | 0.8-1 | 0.4-0.5 | 0.3 | 1 | 0.5 | 1 | 0.4-0.7 | 0.5-0.7 | 0.4-0.5 | 0.6-0.8 | 0.5-0.7 | 0.6-0.8 | 0.7-0.9 | 1.1 | 0.5-0.6 | 0.7-0.8 |
| Peduncle length (cm) | 2-2.2 | 5-5.3 | 3.1-3.3 | 4.6-4.8 | 3.5-3.7 | 4.9-7.8 | 3-3.5 | 4.5-4.7 | 3-3.2 | 5.5 | 3.5-3.7 | 3.8-4.1 | 4.3-4.5 | 1.1 | 6-6.5 | 9-10 | 3.5-4.2 | 7-7.5 | 4-4.2 | 6.6-6.8 |
| Flower type | Single | Single | Single | Single | Single | Single | Single | Single | single | single | Single | Single | Single | Single | Single | Single | Single | Single | Double | Single |
| Flower color | Red | Red | Orange | Pink | Red | Red | purple | pink | pink | brown | Pinkish | Blue | Brown | pink | lavender | Pink | purple | brown | Orange | Orange |

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|------------------------------------------------|------------|--------------------|------------|--------------------|---------|-----------|----------|------------|---------|--------------------|------------|--------------------|--------------------|------------|----------|---------|------------|--------------------|---------|-----------------------|---------|
| group | | | | | | | | | | | | | | | | | | | | | |
| Flower size in diameter (cm) | 14-15 | 16.5-17 | 16-16.5 | 19-20 | 15-16 | 15-15.5 | 14.5-15 | 19-19.5 | 19-20 | 18-19 | 10-15 | 15.5-16 | 15-15.5 | 20-21 | 18-20 | 17-18 | 14-15 | 15-16.6 | 15-15.5 | 16-16.5 | |
| Face of the flower | Horizontal | Downward | Horizontal | Horizontal | Upright | Upright | Upright | Horizontal | Upright | Horizontal | Horizontal | Upright | Downward | Horizontal | Upright | Upright | Horizontal | Horizontal | Upright | Horizontal | |
| Bloom type | Regular | Cartwheel | Cartwheel | Regular | Regular | Cartwheel | Regular | Regular | Regular | Single & Regular | Regular | Regular | Regular | Regular | Regular | Regular | Regular | Regular | Regular | Semi double & regular | Regular |
| Bloom features | Ruffled | Ruffled and tufted | Ruffled | Ruffled and tufted | Ruffled | Ruffled | Ruffled | Ruffled | Ruffled | Ruffled and tufted | Ruffled | Ruffled and tufted | Ruffled and tufted | Ruffled | Ruffled | Ruffled | Ruffled | Ruffled and tufted | Ruffled | Ruffled | |
| Color of veining upper surface of petal | Red | White | White | Lavender | Red | Red | Lavender | White | red | White | Silver | White | White | Pink | Lavender | Pink | Lavender | White | Pink | White | |
| Number of Colors | Two | Three | Three | Three | Three | Two | Three | Three | Two | Three | Four | Three | Two | One | Two | Two | Two | Three | Three | Two | |
| Spots and splashes | No | White | No | No | No | No | Purple | No | No | No | No | No | No | No | No | Pink | Purple | None | Yellow | Yellow | |
| Color of eye zone | Red | Red | White | Lavender | red | Blackish | Red | Red | pink | Red | Red | white | Red | Pink | Lavender | Pink | pink | Red | Red | Pink | |
| Eye zone size | Big | Medium | Medium | Absent | Big | Small | Small | Medium | Absent | Small | Small | Big | Medium | Absent | Absent | Small | Small | Small | Small | Small | |
| Epicalyx lobes | 5 | 10 | 6 | 5 | 5-8 | 8 | 6-7 | 6 | 6 | 9 | 6 | 7 | 7 | 6 | 8 | 8 | 6 | 10 | 7 | 7 | |
| Epicalyx length (cm) | 1.2-1.4 | 1-1.3 | 1.3-1.6 | 1.5-1.6 | 1-1.4 | 1.1-1.5 | 1.4-1.5 | 0.5-0.7 | 1.5-1.6 | 1.3-1.7 | 1.2-1.3 | 0.8-0.9 | 1.2-1.5 | 0.8-1 | 1-1.2 | 1.1-1.8 | 0.8-1.3 | 1.1-1.6 | 1-1.5 | 1.2-1.3 | |

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|----------------------------------|----------|----------|----------|---------------|----------|---------|---------------|-------------|------------|------------|------------|--------------|------------|---------|----------|------------|----------|----------|----------|---------|
| Epicalyx width (cm) | 0.2-0.3 | 0.2-0.4 | 0.1-0.2 | 0.4-0.5 | 0.1-0.2 | 0.2-0.3 | 0.3 | 0.2-0.3 | 0.3-0.4 | 0.2-0.3 | 0.2-0.3 | 0.2-0.3 | 0.2-0.3 | 0.2-0.3 | 0.2-0.3 | 0.2-0.3 | 0.1-0.2 | 0.2-0.3 | 0.2-0.4 | 0.1-0.4 |
| Calyx lobe length (cm) | 1.6-1.8 | 1.2-1.5 | 1-1.3 | 1.5-1.6 | 1.6-1.8 | 1-1.1 | 1.4-1.5 | 1.2-1.3 | 1-1.2 | 1.4-1.6 | 1.4 | 1.7-2 | 1.4-1.5 | 1.5-1.7 | 1-1.2 | 1.3-1.4 | 1 | 1.5-1.6 | 1.5-1.6 | 1.4-1.5 |
| Calyx lobe width (cm) | 1-1.2 | 0.8-0.9 | 0.8-1 | 1.1-1.2 | 1.4-1.5 | 1.1 | 1.2-1.3 | 1.2 | 1.2-1.4 | 1 | 1.2 | 0.9-1 | 1-1.1 | 1.1-1.2 | 1-1.2 | 0.8-1 | 0.8 | 0.8-1 | 1.1-1.2 | 1.2-1.3 |
| Form of Bloom | Recurved | Recurved | Recurved | Recurved | Recurved | Flat | Recurved | Recurved | Flat | Recurved | Flat | | Recurve | Recurve | Recurved | Flat | Recurved | Recurved | Recurved | Flat |
| Petal's length (cm) | 7-7.5 | 8.5-9 | 7-8 | 10-10.5 | 7-7.5 | 7.5-8 | 7-7.5 | 9.5-9.8 | 6-6.2 | 7.5-8 | 10-10.5 | 8-8.2 | 7.5-8 | 9-10 | 9-10 | 8.5-8.6 | 7-8 | 8-8.5 | 8-9 | 9-9.2 |
| Petal's width (cm) | 6-6.5 | 8.6-7 | 7.8-8 | 9.5-10 | 6-6.2 | 7.9-8.2 | 6-6.2 | 9-9.2 | 4.2-4.3 | 7.2-7.8 | 9.5-10 | 6-8 | 7.5-8 | 8.5-9 | 9-9.5 | 7-7.5 | 6-7 | 7-7.8 | 6-6.3 | 8.4-8.5 |
| Fading of color in scorching sun | Light | NO | NO | Medium | Strong | NO | Medium | Strong | NO | Strong | Medium | Medium | No | No | Light | Strong | Medium | Strong | No | Strong |
| Staminal column color | Red | Red | Creamy | pinkish-white | Red | Red | pinkish white | Creamy pink | Creamy red | Creamy red | Creamy red | Creamy white | creamypink | Pink | Red | creamypink | creamy | creamy | Red | creamy |
| Staminal column length (cm) | 4-4.3 | 7-7.3 | 7-7.4 | 7.5-8 | 7.5-7.7 | 6-6.3 | 7.2-7.8 | 7-8 | 5-5.5 | 7.2-7.6 | 9-9.5 | 7.5-7.8 | 5.3-5.5 | 6-6.5 | 8-8.3 | 9.5-10.5 | 3-3.2 | 6-6.7 | 3-3.3 | 9 |
| Anther zone length (cm) | 1-1.4 | 1.6-1.7 | 2-2.1 | 3.2-3.4 | 2.5-2.6 | 1.8-2.1 | 3-3.2 | 2-2.2 | 1.7-1.9 | 2-2.2 | 3-3.2 | 1.5-1.7 | 2-2.2 | 1.8-2.1 | 2-2.8 | 3.5-4 | 0.9-1.2 | 2-2.3 | 1 | 3-3.2 |
| Anther zone width (cm) | 1-1.4 | 1-1.1 | 1-1.1 | 1.2-1.3 | 1.2-1.3 | 1.2-1.4 | 1.6-1.8 | 1.6-1.8 | 1.1-1.3 | 2.1-2.3 | 1.5-1.6 | 1-1.3 | 2-2.3 | 1-1.3 | 1.5-1.8 | 2-2.3 | 1-1.2 | 1.1 | 1.5-2 | 2-2.2 |

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|-------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--------|
| Naked zone length (cm) | 2-3 | 5-5.5 | 4.6-4.8 | 4.2-4.5 | 5-5.3 | 4-4.2 | 4.5-4.7 | 5-5.5 | 3.2-3.6 | 5-5.6 | 5-6 | 4.5-4.9 | 3.4-3.5 | 4-4.5 | 5-5.7 | 6.1-6.5 | 3 | 3-.3.9 | 2 | 6 | |
| Pistil length (cm) | 5-5.3 | 7-7.5 | 8-8.3 | 9-9.5 | 7.5-8 | 6-6.3 | 7.5-8 | 7.5-7.9 | 5.2-5.7 | 8-9 | 9-10 | 6-6.7 | 7.5-8 | 7-7.2 | 8-8.6 | 10.5-11.2 | 5-5.5 | 7-8 | 4.5 | 8 | |
| Ovary length (cm) | 0.6-0.8 | 0.8-0.9 | 0.8-0.9 | 1 | 1 | 0.6-0.9 | 1 | 0.5-0.7 | 0.5-0.7 | 1.1-1.2 | 1 | 1.1 | 1 | 0.8-1 | 0.6-0.8 | 1 | 0.5-0.6 | 0.8-1 | 0.3 | 1.1-1.2 | |
| Style length (cm) | 4.5-4.7 | 4.5-5 | 6-7 | 6-7 | 4-4.2 | 4-4.5 | 5.5-6 | 7-8 | 4.2 | 6-6.5 | 7-7.8 | 4-5 | 3.7-3.8 | 5-5.3 | 6.5-7.1 | 9-9.7 | 3-3.5 | 5-6 | 3 | 7-7.2 | |
| Seeder traits | Average | Average | Reluctant | Average | Average | Good | Reluctant | Average | Good | Good | Good | Good | Good | Good | Good | Good | Good | Reluctant | Reluctant | Average | |
| Bush | Medium | High | High | Medium | High | High | Medium | High | High | High | High | High | High | Medium | High | High | High | Medium | Medium | High | Medium |
| Flowering season | Throughout the year | Throughout the year | Throughout the year | Prominent in winter | Prominent in winter | Throughout the year | Very prominent in winter | Throughout the year | Throughout the year | Prominent in winter | Throughout the year | Prominent in winter | Throughout the year | Throughout the year | Throughout the year | Throughout the year | Prominent in winter | Prominent in winter | Throughout the year | Prominent in winter | |

Table 2: Coding characters states of qualitative characters of OTUS

| OTU | UNIT CHARACTER | CHARACTER STATES |
|-----|-----------------------------------------|-------------------------------------------------------------------------------|
| 1 | Plant height (cm) | 50-100(0)/101-150(1)/151-200(2) |
| 2 | Branch attitude | Spreading (0)/ upright (1) |
| 3 | Inter nodal portion length (cm) | 1-3.5(0)/ <5.5(1) |
| 4 | Leaf petiole length (cm) | 1-3(0)/ 3.1-4(1)/ <=6(2) |
| 5 | Leaf length (cm) | 1-6.4 (0)/ 6.5-10 (1) / < = 17.5 (2) |
| 6 | Leaf width (cm) | 1-4.9 (0)/ 5-10 (1)/ < = 15 (2) |
| 7 | Lateral nerves from the base | 1-5 (0)/ 5-10 (1) |
| 8 | Pedicle length (cm) | 0.1-1 (0)/ < = 2 (2) |
| 9 | Peduncle length (cm) | 1-2.2 (0)/ 2.3-4.6 (1)/ < = 10 (2) |
| 10 | Flower type | Single (0)/ Double (1) |
| 11 | Flower color group | Red (0)/ Pink (1)/ Orange (2)/ Purple (3) / Lavender (4)/ Brown (5)/ Blue (6) |
| 12 | Flower size in diameter (cm) | 10-16 (0)/ < 16.1-20 (1)/ < = 22 (2) |
| 13 | Face of the flower | Horizontal (0)/ Upright (1)/ Downward (2) |
| 14 | Bloom type | Regular (0)/ Cartwheel (1)/ Semi double regular (2) |
| 15 | Bloom features | Ruffled (0)/ Ruffled and Tufted (1) |
| 16 | Color of veining upper surface of petal | White (0)/ Red (1)/ Lavender (2)/ Silver (3)/ Pink (4) |
| 17 | Number of colors | One (0)/ Two (1)/ Three (2)/ Four (3) |
| 18 | Spots and splashes | Absent (0)/ White (1)/ Purple (2)/ Yellow (3)/ pink (4) |
| 19 | Color of eye zone | Red (0)/pink (1)/ White (2)/ Lavender (3)/ Blackish (4)/ white 20 (5) |
| 20 | Eye zone size | Absent (0)/ Small (1)/ Medium (2)/ Big (3) |
| 21 | Epicalyx lobes | 5-8 (0)/ < = 10 (1) |
| 22 | Epicalyx length (cm) | 0.5-1 (0)/ < 1.6 (1)/ < = 1.8 (2) |
| 23 | Epicalyx width (cm) | 0.1-0.3 (0)/ < = 0.5 (1) |
| 24 | Calyx lobe length (cm) | 1-1.5 (0)/ < = 2 (1) |
| 25 | Calyx lobe width (cm) | 0.8-1 (0)/ < = 1.5 (1) |
| 26 | Form of Bloom | Recurved (0)/ Flat (1) |
| 27 | Petal's length (cm) | 6-8 (0)/ 8.1-10 (1)/ < = 10.5 (2) |
| 28 | Petal's width (cm) | 4-8 (0)/ 8.1-10.5 (1) |

| OTU | UNIT CHARACTER | CHARACTER STATES |
|-----|----------------------------------|---------------------------------------------------------------------------------------------------|
| 29 | Fading of color in scorching sun | No (0)/ Light (1)/ Medium (2)/ Strong (3) |
| 30 | Staminal column color | Red (0)/ Creamy (1)/ Pink (2)/Pinkish-white (3)/ Creamy pink (4)/ Creamy red (5)/Creamy white (6) |
| 31 | Staminal column length (cm) | 3-5.9(0)/6-9(1)/9.1-10.5(2) |
| 32 | Anther zone length (cm) | 0.5-1.4(0)/1.5-2.4(1)/2.5-3.4(2)/3.5-4(3) |
| 33 | Anther zone width (cm) | 1-1.4(0)/1.5-3(1) |
| 34 | Naked zone length (cm) | 2-3.9(0)/4-4.9(1)/5-6(2)/6.1-7(3) |
| 35 | Pistil length (cm) | 4.5-5.9(0)/6-6.9(1)/7-12(2) |
| 36 | Ovary length (cm) | 0.1-0.4(0)/0.5-1(1)/1.1-1.5(2) |
| 37 | Style length (cm) | 3-5(0)/5.1-8(1)/8.1-10(2) |
| 38 | Seeder traits | Average (0)/ Good (1)/ Reluctant (2) |
| 39 | Bush | Medium (0)/ High (1) |
| 40 | Flowering | Throughout the year (0) /Prominent in winter (1) |

Result and Discussion

Vegetative and reproductive characteristics have been used for analysis. Various traits such as (1) Plant height (cm), (2) Branch attitude, (3) Inter nodal portion length (cm), (4) Petiole length (cm), (5) Leaf length (cm), (6) Leaf width (cm), (7) Lateral nerves from the base, (8) Pedicel length (cm), (9) Peduncle length (cm), (10) Flower type, (11) Flower color group, (12) Flower size in diameter (cm), (13) Face of the flower, (14) Bloom type, (15) Bloom features, (16) Color of veining upper surface of petal, (17) Number of colors in flower, (18) Spots and splashes, (19) Color of eye zone, (20) Eye zone size, (21) Epicalyx lobes, (22) Epicalyx length (cm), (23) Epicalyx width (cm), (24) Calyx lobe length (cm), (25) Calyx lobe width (cm), (26) Form of bloom, (27) Petals length (cm), (28) Petals width (cm), (29) Fading of color in scorching sun, (30) Staminal column color, (31) Staminal column length (cm), (32) Anther zone length (cm), (33) Anther zone width (cm), (34) Naked zone length (cm), (35) Pistil length (cm), (36) Ovary length (cm), (37) Style length (cm), (38) Seeder traits, (39) Bush, (40) Flowering were examined across for 20 hibiscus cultivars.

A total of 40-unit characters and 125-character states were evaluated and coded into a matrix for statistical analysis. PCA is a multivariate analysis technique used to determine the relative significance of different variables, finding patterns in data of high dimension, prior to cluster analysis (Jackson., 1991). Principal Component Analysis (PCA) was conducted to identify key factors, with the first 8 PCA values showing Eigen values greater than 1 along with their percentage of variance (Table 4, Fig. 2). The cultivars were clustered based on similarities and dissimilarities in 40 phenotypic characters, resulting in distinct groupings. The dendrogram, constructed using complete clustering method and Gower distance, integrated qualitative traits like flower and eye color with quantitative traits such as bloom and leaf

dimensions, facilitating a comprehensive classification and identification of individual cultivars (Fig. 3 and Fig. 4).

Principal Component Analysis

The results of the Principal Component Analysis (PCA) demonstrate that a significant proportion of the variability in the dataset can be explained by a relatively small number of principal components (Table 4). Specifically, 8 out of 19 components were identified as having Eigenvalues greater than one, collectively capturing 82.7% of the total cumulative variation (4). This indicates that these components are crucial for discriminating between the lines or cultivars under study.

Principal Component (PC) 1, contributing the highest variability at 24.01% with an eigen value of 6.64%, appears to be particularly influential in differentiating the observations. Conversely, PC 18 and PC 19 exhibit minimal variability, as evidenced by their declining eigen values. In conclusion, the PCA results suggest that the selected set of variables effectively captures the variation present among the hibiscus cultivars studied. These findings provide valuable insights into the key factors driving the observed differences and can inform further research or breeding efforts aimed at understanding and improving hibiscus cultivars.

Table 3: Coding character states of OTUS

| OTUs Character | A. A. Ma o | A J C Bos e | Apoli on | Benga l Danci ng Queen | Beng al Sunri se | Beng al Sunse t | Cit y of Jo y | Countdo wn | Crea m Drea m | Dark Moth er of Beng al | Jana ki Ammal | Krishn a's Radian ce | Mothe rs Touch Singur | Quee n of Wint er | Repub lic Day | RN Tago re | Shini ng Blue | Spiritual of Madhub ati | Vivekana nda | Swamy |
|--------------------------------|------------|-------------|----------|------------------------|------------------|-----------------|---------------|------------|---------------|-------------------------|---------------|----------------------|-----------------------|-------------------|---------------|------------|---------------|-------------------------|--------------|-------|
| Plant height (cm) | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| Branch attitude | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| Internodal portion length (cm) | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Petiole length (cm) | 2 | 2 | 1 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 0 | 2 | 1 | 2 | 0 | 2 | 1 | 2 | 0 | 2 |
| Leaf length (cm) | 2 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 1 |
| Leaf width (cm) | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 0 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| Lateral nerves from the base | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Pedicel length (cm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Peduncle length (cm) | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 2 | 1 | 2 |

Morphometric Analysis of Twenty *Hibiscus Rosa-Sinensis* L. Cultivars

| | | | | | | | | | | | | | | | | | | | | |
|-----------------------------------------|---|------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flower type | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Flower color group | 0 | 0 | 2 | 1 | 0 | 0 | 3 | 1 | 1 | 5 | 1 | 6 | 5 | 1 | 4 | 1 | 3 | 5 | 2 | 2 |
| Flower size in diameter (cm) | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 1 | 0 | 1 |
| Face of the flower | 0 | 2 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| Bloom type | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Bloom features | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Color of veining upper surface of petal | 1 | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 1 | 0 | 3 | 0 | 0 | 4 | 2 | 4 | 2 | 0 | 4 | 0 |
| Number of colors | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 1 | 1 | 2 | 2 | 1 |
| Spots and splashes | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 3 | 3 |
| Color of eye zone | 0 | 0 | 2 | 3 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 3 | 1 | 1 | 0 | 0 | 1 |
| Eye zone size | 3 | 2 | 2 | 0 | 3 | 1 | 1 | 2 | 0 | 1 | 1 | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Epicalyx lobes | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Epicalyx length (cm) | 1 | 1.00 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 1 | 1 |

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|--------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Epicaly x width (cm) | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Calyx lobe length (cm) | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| Calyx lobe width (cm) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| Form of bloom | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| Petals length (cm) | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| Petals width (cm) | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| Fading of color in scoring sun | 1 | 0 | 0 | 2 | 3 | 0 | 2 | 3 | 0 | 3 | 2 | 2 | 0 | 0 | 1 | 3 | 2 | 3 | 0 | 3 |
| Stamina l column color | 0 | 0 | 1 | 3 | 0 | 0 | 3 | 4 | 5 | 5 | 5 | 6 | 4 | 2 | 0 | 5 | 1 | 1 | 0 | 1 |
| Stamina l Column length (cm) | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 1 |
| Anther zone length (cm) | 0 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 0 | 0 | 0 | 2 |

Morphometric Analysis of Twenty *Hibiscus Rosa-Sinensis* L. Cultivars

| | | | | | | | | | | | | | | | | | | | | |
|------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anther zone width (cm) | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| Naked zone length (cm) | 0 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 0 | 2 | 2 | 1 | 0 | 1 | 2 | 3 | 3 | 0 | 0 | 2 |
| Pistil length (cm) | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 0 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 0 | 2 | 0 | 2 |
| Ovary length (cm) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 2 |
| Style length (cm) | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 1 |
| Seeder traits | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 0 |
| Bush | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Flowering season | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |

Table 4: Eigenvalue and Variance of 8 PCA Components

| PC | Eigen value | % variance |
|----|-------------|------------|
| 1 | 6.64013 | 24.013 |
| 2 | 4.37691 | 15.828 |
| 3 | 2.99031 | 10.814 |
| 4 | 2.69738 | 9.7545 |
| 5 | 2.2904 | 8.2828 |
| 6 | 1.54133 | 5.5739 |

| | | |
|---|---------|--------|
| 7 | 1.22502 | 4.43 |
| 8 | 1.11666 | 4.0382 |

Morphometric Analysis of Twenty *Hibiscus Rosa-Sinensis* L. Cultivars

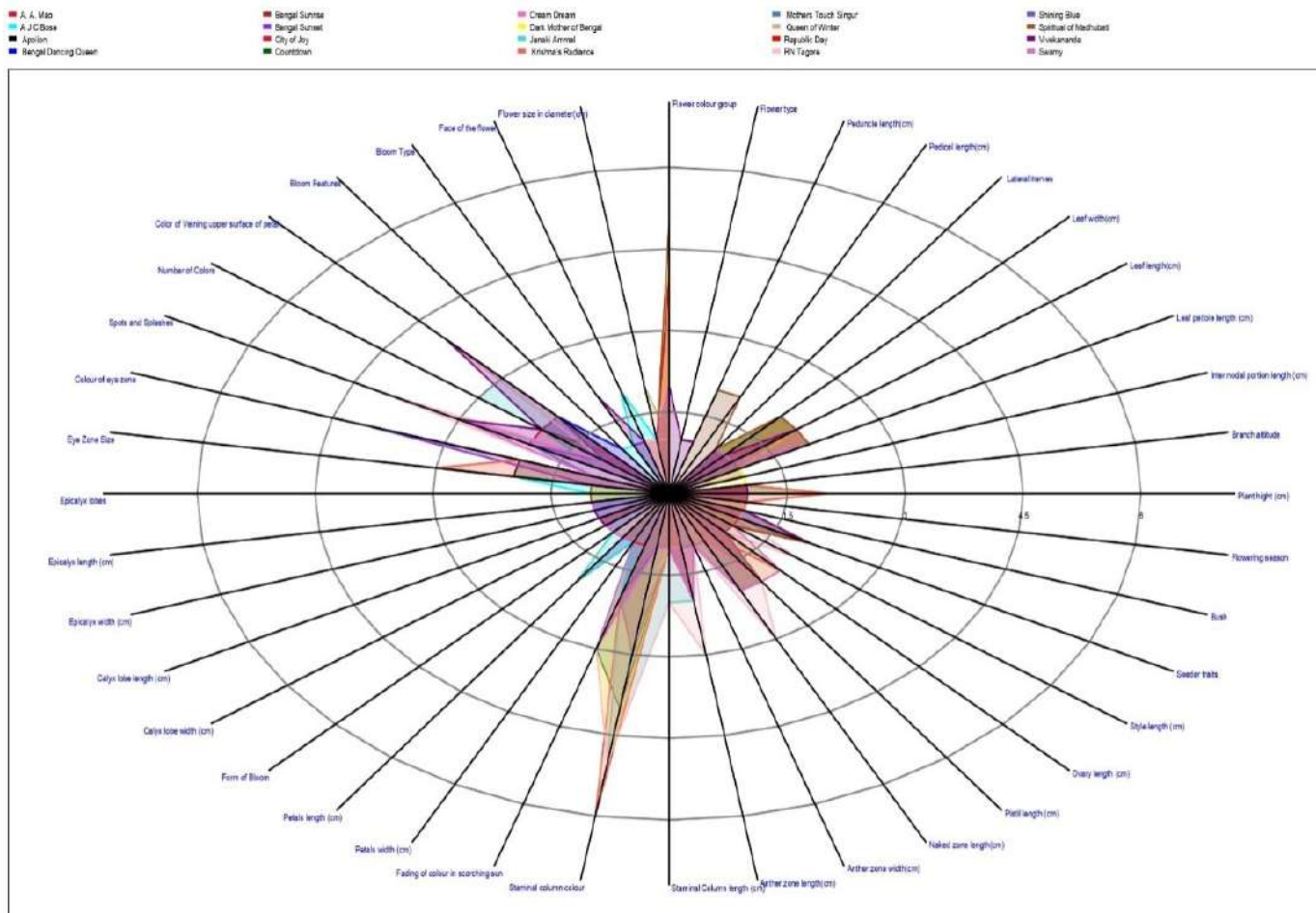


Fig. 2. Influence of characters in cultivar differentiation

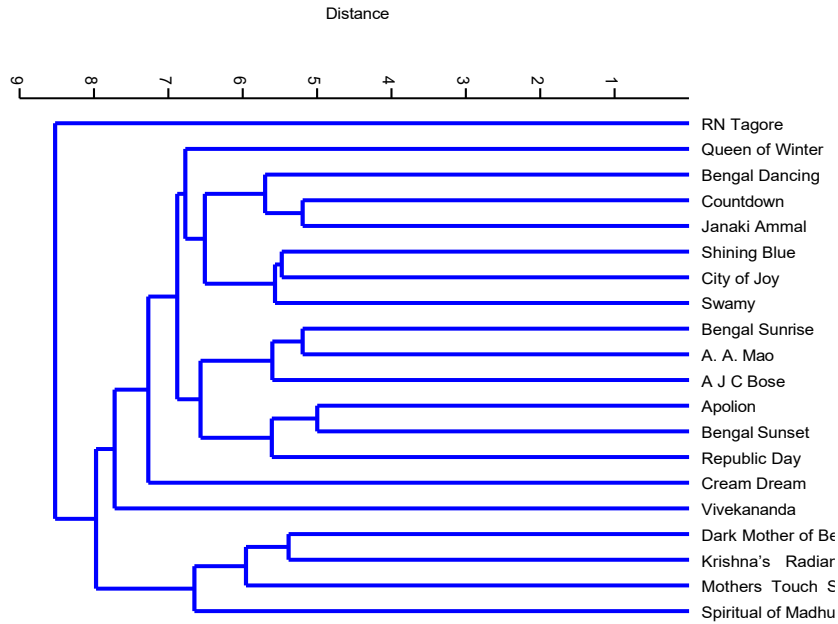


Fig. 3: Dendrogram of the 20 hibiscus cultivars

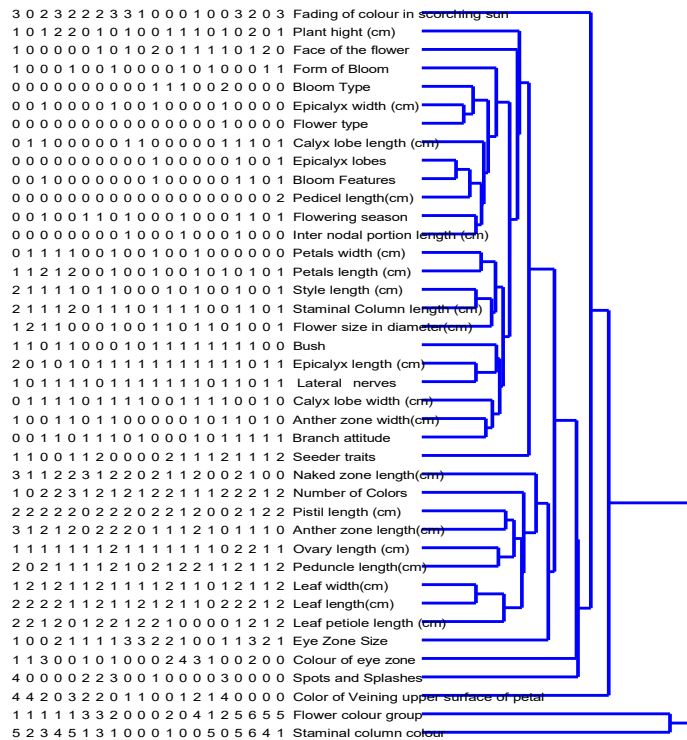


Fig. 4. The clustering of the 20 cultivars

Conclusion

This morphometric analysis showed a wide range of variation in qualitative and quantitative characters among 20 hibiscus cultivars. The dendrogram showed a highly branched structure, suggesting a high degree of variability among the various hibiscus hybrid progenies. PAST is a user friendly and comprehensive package of statistical and graphical algorithms which developed for the scientific investigation of paleontological material. It provides a window on current and future developments in this rapidly evolving research area with a simple manual and linked case histories and datasets, this package is an ideal educational aid and first-hand research tool. Planned future developments include enhanced functionality for morphometric analysis, further quantitative characterization, cladistics and expansion of algorithms available within the single association module. This high variability suggests that there is a wide window for selection of unique genotypes among different hybrid progeny as assessed by both PCA and cluster analysis. This information can be used as a basis for selecting specific hybrid progenies for the development into cultivars.

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