SCIENCE DILIMAN (JULY-DECEMBER 2017) 29:2, 51-81

Morphological Characterization, Evaluation and Selection of Hibiscus (*Hibiscus rosa-sinensis* L) Hybrids

Elena May N. Cabarrubias
University of the Philippines Los Baños

Pablito M. Magdalita*
University of the Philippines Los Baños

Antonio G. Lalusin
University of the Philippines Los Baños

Norma G. Medina
University of the Philippines Los Baños

ABSTRACT

Fifty-seven hibiscus hybrid progenies from different crosses were characterized and evaluated for morphological traits to select hybrids with unique color and form. A total of 14 progenies with the following pedigrees were selected: 22xDT-9, (LLxEFA)xGC-2, (LLxEFA)xGC-8, DSxGC-7, 20xGC-5, (GCxBGB)xHP-4, GCxDS-4, ABAxMDM-1, ABAxMDM-3, 23xGC-2, CVxNB-1, CVxNB-2, CVxMP-4 and CVxNB-6. Phenotypic data were analyzed for principal component analysis (PCA) and agglomerative cluster analysis. Correlation using PCA revealed significant positive association between flower size and leaf size, and between petiole length and leaf size. PCA depicted three major PCs with eigenvalue >1 contributing 78% of the total cumulative variability among different hybrids. The PC-I showed positive factor loadings for all the traits. The contribution of flower size, leaf size and style length was highest in PC-I. Cluster analysis grouped the 57 hybrids into five clusters. Cluster-I had the highest number of members (16), consisting of yellow-orange and purple flowers with a mean size of 131.09 mm. Cluster-II had 15 members, possessing white and red-purple hybrids with a mean size of 140.54 mm. Cluster-III was composed of five yellow members with a mean size of 131.12 mm. Cluster-IV had 13 members, comprising yellow and yellow-orange hybrids whose flowers are small and have a mean size of 115.20 mm. Cluster-V consists of eight red- and red-purple-colored hybrids with mean size of 130.21 mm. The study revealed that hybrids with large flowers and longer petioles tend to have wider leaves, and these results were in agreement with the dendrogram groupings of the 57 hybrids.

Keywords: Agglomerate cluster analysis, *Hibiscus rosa-sinensis* L., hybrids, principal component analysis

____
**Corresponding Author*

ISSN 0115-7809 Print / ISSN 2012-0818 Online

INTRODUCTION

Hibiscus is a genus of the family Malvaceae or mallow family composed of more than 400 species of flowering plants (Edmonds 1991). It is a native of the tropical and sub-tropical regions of the world, and exists as a small tree, shrub, or herb (McMullen 1999). The double red *Hibiscus rosa-sinensis* had a broad distribution in China, India, South-East Asia and the Pacific Islands in pre-European discovery days. The other forms from Asia and the islands of the South Indian Ocean were introduced into the green houses of Europe in early decades of the 19th century (Howie 1980). It is thought that hibiscus was first introduced to the Philippines by the Chinese traders. New forms and cultivars were introduced into the country by the American colonizers in the 1890s (Magdalita et al. 2016; Magdalita and Pimentel 2010a).

In the Philippines, hibiscus has become a popular ornamental plant because of its attractive flowers. In addition, some varieties are used as food, medicine, feed, ingredients of industrial products, symbol for religious purposes and national emblem in some countries (Magdalita et al. 2011).

To date, various new varieties have been developed through cross breeding, and these new varieties are getting popular with home gardeners, landscapers and other hibiscus enthusiasts. Cross breeding in hibiscus aid in the creation of new varieties with improved traits, especially color, form, size, number of flowers, longevity, continued blooming, disease resistance and growth habit (Magdalita and Pimentel 2013). Various hibiscus hybrids between local and foreign varieties were developed, resulting in 44 varieties that were named after Filipina achievers (Magdalita and Pimentel 2010b).

Traditionally, plant breeders have selected plants based on their visible or measurable traits, such as flower color, seed color, leaf shape, fruit shape, stem length, etc. (Jiang 2013). Characterization descriptors pertain to those traits that tend to be highly heritable, ranging from morphological to molecular markers, and are expressed in all environments, in order to establish differences or similarities in phenotypic traits of each accession. Characterization and evaluation based on phenotypic traits is a quick, easy and practical guide in selection of parents for use in hybridization (Brown and Caligari 2008). This plant selection technique can be enhanced by utilizing principal component analysis (PCA) and cluster 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). Furthermore, PCA is used to reduce the dimension of the data set and leads to the understanding of variables by determining how much of the total variance is contributed by each data set. On the other hand, cluster analysis is used to determine patterns and relationship between objects in the data set, and to group objects into homogenous and well-defined groups, wherein observations within each cluster are similar to one another and the complete set of clusters contain all individuals (Everitt et al. 2010). For this study, determination of the relationship between the different hybrid progenies is an important factor for the selection of parents in the hybridization program.

The objectives of the study were as follows: (1) characterize, evaluate, and select promising progenies from the 57 hybrids based on qualitative and quantitative traits; (2) categorize or group the hybrid progenies into five major clusters; and, (3) determine the correlation of the different quantitative characters of the hybrids.

MATERIALS AND METHODS

Plant Materials

Hibiscus hybrids developed by the breeder-scientists of the Institute of Crop Science and Institute of Plant Breeding, College of Agriculture and Food Science, University of the Philippines Los Baños were used in the study. Fifty-seven hibiscus hybrid progenies from 10 different crosses established in 2013 were characterized and evaluated phenotypically. The hibiscus hybrids were planted in single rows in the hibiscus breeding block and given the standard cultural practices. Five to ten progeny plants per cross were characterized and evaluated based on their growth habit, and leaf and flower traits.

Plant Characters

The height and width of 5-10 progenies of every cross were measured using a meterstick from the base to the top of the plant, and across the widest portion of the canopy, respectively.

Leaf Characteristics

Ten leaves from each plant of the 57 hybrid progenies were used for evaluation. The following qualitative leaf traits of each of the hybrid progenies were characterized: leaf arrangement, type, form or outline, margin, apex, base, attachment and color. The descriptions of most leaf characteristics were based from Simpson (2006). The quantitative traits, such as leaf length, width and petiole length were measured using a ruler.

Flower Characteristics

Characterization and evaluation of 10 fully opened flowers from each hybrid progeny was performed in the morning. The qualitative traits evaluated included inflorescence type, bloom type, flower color, stigma color, style and stigma type and calyx color. The flower and leaf colors were determined using the Royal Horticultural Society Color Chart (RHS) of London 5th ed. (RHS 2007) and were matched with the RHS color coordinate. Descriptions of the flower characteristics were based on the standards of the Australian Hibiscus Society (2007). The quantitative traits evaluated were bloom size/diameter, length and width of each corolla, angle of display of flower, pedicel length, receptacle diameter, ovary length and width, calyx lobe length and width, stigma length and width, and style length.

Selection

Selection of the hybrid progenies with potential for variety development was conducted in 10 different crosses. Identification of selections was primarily based on new flower color and form. The other traits considered in selection were non-folding of the petals, retention of flower color for the day, prolificacy of blooming, bushiness, and plant vigor. In each cross, one to three hybrid progenies possessing good flower characteristics and plant growth habit were selected.This study was conducted at the Institute of Plant Breeding, College of Agriculture and Food Science, University of the Philippines Los Baños from April 2013 to May 2015.

Statistical Design and Analysis

The experimental hybrid progenies were planted in single rows in the hibiscus breeding blocks. In each cross, five to eight hybrid progenies were used for evaluation. Thirty-two morphological characters consisting of nine qualitative and three quantitative traits for leaves, and six qualitative and 13 quantitative traits for flowers were gathered. They were analyzed using the Statistical Tool for Agricultural Research (STAR) software (IRRI 2014). Nine selected quantitative traits were subjected to Principal Component Analysis (PCA), in order to reduce the number of variables in the dataset while maintaining the variability in the data. Eigen values and eigen vectors plus relative and cumulative proportion of the total variance were calculated to identify the significant traits that will be used for cluster analysis. Traits with a correlation value of $e \geq 0.3$ were considered relevant for the component to be used for clustering of hybrid progenies. Agglomerative cluster analysis was performed using the complete clustering method and Gower value as the distance determinant method to assess the level of similarity between the hybrid progenies for the dendrogram grouping.

RESULTS AND DISCUSSION

Morphological Characterization, Evaluation and Selection

Characterization and evaluation of the morphological traits of hibiscus hybrids prior to selection and variety release was performed. This strategy has been implemented to identify elite progenies from different crosses of hibiscus whose parents are genetically diverse (Pimentel 1999, San Pascual 2015, Magdalita et al. 2016). Parallel to this study is the characterization of *Hibiscus sabdariffa*, locally known as roselle, to identify varieties with good bast fiber qualities (Mwasiagi et al. 2014). In the present study, the morphological characteristics of the 13 crosses and the selections identified from these crosses were presented as follows:

22xDT is a cross between *Hibiscus rosa-sinensis* 'accession 22' (yellow) and *Hibiscus rosa-sinensis* 'Domini M. Torrevillas' (dark orange). Six hybrid progenies of this cross with pedigrees 22xDT-1, 22xDT-2, 22xDT-5, 22xDT-6, 22xDT-9 and 22xDT-10 had different flower colors ranging from different shades of yellow and orange. 22xDT-1 is persimmon orange (RHCC 28 A) with an orange-red (RHCC N 34 B) eye zone surrounded by grayed orange (RHCC 163 C) halo, and yellow-orange (RHCC 21 C) edges with yellow vein markings radiating from the center to the petal. 22xDT-2 is canary yellow (RHCC 9 A) with a red (RHCC 47 B) eye zone and Saturn red (RHCC 30 B) vein markings radiating from the center to the petal. 22xDT-5 is Indian yellow (RHCC 17 A) with a scarlet red (RHCC 46 B) eye zone. 22xDT-6 had two color forms: orange-red and yellow-orange. The orange-red corolla (RHCC N30 A) had a scarlet red (RHCC 46 B) eye zone surrounded by grayed orange (RHCC N 170 B) halo and yellow vein markings radiating from the center to the petal. The yellow-orange or Indian yellow (RHCC 17 A) corolla had a scarlet red (RHCC 46 B) eye zone. 22xDT-9 is China rose (RHCC 58 D) with a currant red (RHCC 46 A) eye zone and white (RHCC 155 A) edges. 22xDT-10 is straw yellow (RHCC 13 C) with yellow and orange (RHCC 28 C) eye zone. The red eye expressed in each hybrid progeny was inherited from the male parent, *H. rosa-sinensis* 'Domini Torrevillas'. This suggests that the red color for the eye could be dominant to yellow.

Based on the criteria for selection, 22xDT-9 (Figure 1F) was selected. It expressed a unique flower color: red-purple or china rose (RHCC 58 D) and white petal edges, which are not observed in other hybrid progenies of the cross (Table 1). It has good quality blooms and the white edges of the petals are undulating. This selection has a similar flower color to *Hibiscus rosa-sinensis* 'Arlene B. Arcillas' (Magdalita and Pimentel 2013) and *H. rosa-sinensis* 'Obdulia F. Sison' (Magdalita and Pimentel 2010b). In addition, its tufted petal edges are similar to the foreign variety *H. rosa-sinensis* 'Lillian Amy' whose parents are *H. rosa-sinensis* 'Miss Liberty' and 'Inspiration' (Australian Hibiscus Society 2007).

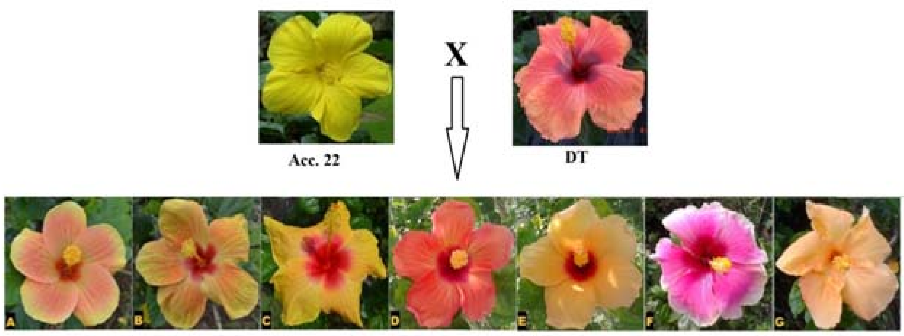

Figure 1. Hybrids of accession 22 x *Hibiscus rosa-sinensis* 'Domini Torrevillas'. (A) 22xDT-1; (B) 22xDT-2; (C) 22xDT-5; (D-E) 22xDT-6; (F) 22xDT-9; and, (G) 22xDT-10.

(LLxEFA)xGC is a cross between *Hibiscus rosa-sinensis* 'Loren Legarda', *Hibiscus rosa-sinensis* 'Estrella F. Alabastro' (light whitish pink), and *Hibiscus rosa-sinensis* 'Gelia Castillo' (golden yellow). Five hybrid progenies of this cross with pedigrees (LLxEFA)xGC-2, (LLxEFA)xGC-3, (LLxEFA)xGC-5, (LLxEFA)xGC-7 and (LLxEFA)xGC-8 had flower colors with different shades of yellow, orange and red-purple. (LLxEFA)xGC-2 is orange-red (RHCC N 30 B) with a red (RHCC 46 B) eye zone. (LLxEFA)xGC-3 is lemon yellow (RHCC 14 C) with a claret rose (RHCC 50 A) eye surrounded by two layers of grayed purple (RHCC 186 C) and persimmon orange (RHCC 28 A) halos. (LLxEFA)xGC-5 is spinel red (RHCC 54 C) with a neyron rose (RHCC 55 A) eye radiating from the center to the petal. (LLxEFA)xGC-7 is Chinese yellow (RHCC 16 A) with a white (RHCC N 155 B) eye and orpiment orange (RHCC 25 A) vein markings on the petals. (LLxEFA)xGC-8 is roseine purple (RHCC 68 C) with white spots. Its eye is spinel red (RHCC 54 A) surrounded with a purple (RHCC 76 C) halo.

Table 1. Selected hybrids and their important characteristics

Selected Hybrids	Flower Characteristics	Foliation	Growth Habit
 22xDT-9	Solitary, simple, regular, 146.8 mm in diameter and the angle of display of the flower on the plant is 74 degrees. Red purple or China rose (RHCC 58 D) petals with currant red (RHCC 46 A) eye and white (RHCC 155 A) petal edges.	Arranged alternately, simple and ovate leaf form. Margin is entire, base is obtuse and leaf tip is acute. Leaf is 71.6 mm long and 53.2 mm wide.	1.31 tall and 0.53 m wide, semi-erect growth habit and fast grower on its own root.
 (LLxEFA)xGC-2	Solitary, simple, regular, 130.1 mm in diameter and the angle of display of flower on the plant is 74 degrees. Orange red (RHCC N 30 B) petals with red (RHCC 46 B) eye.	Arranged alternately, simple and cordate/cordiform leaf form. Margin is crenate, base is cordate and leaf tip is obtuse. Leaf is 80.7 mm long and 82.6 mm wide.	2.07 m tall and 0.79 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
 (LLxEFA)xGC-8	Solitary, simple, regular, 131.6 mm in diameter and the angle of display of flower on the plant is 80 degrees. Red purple or roseine purple (RHCC 68 C) petals with white and pink splashes on the petals. Eye is spinel red (RHCC 54 A) surrounded by purple (RHCC 76 C) halo.	Arranged alternately, simple and cordate/cordiform leaf form. Margin is crenate, base is cordate and the leaf tip is acute. Leaf is 71.1 mm long and 59.1 mm wide.	1.92 m tall and 0.86 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
 DSXGC-7	Solitary, simple, regular, 141.9 mm in diameter and the angle of display of flower on the plant is 83 degrees. Grayed purple (RHCC 186 B) petals with red/neyron rose (RHCC 55 B) eye. It has bluish white vein markings radiating from the eye to the petals.	Arranged alternately, simple and cordate/cordiform leaf form. Margin is serrate, base is cordate, and leaf tip is acute. Leaf is 110.1 mm long and 94.1 mm wide.	1.19 m tall and 0.51 m wide, semi-erect growth habit and fast grower on its own root.

Table 1. Selected hybrids and their important characteristics (cont'n.)

Selected Hybrids	Flower Characteristics	Foliation	Growth Habit
 20xGC-5	Solitary, simple, regular, 136 mm in diameter and the angle of display of flower on the plant is 80 degrees. Pastel pink or red purple (RHCC 69 C) with red purple or ruby red (RHCC 59 A) eye surrounded by red purple or spiraea red (RHCC 63 C) halo that extends to the petals.	Arranged alternately, simple and cordate/ cordiform leaf form. Margin is crenate, base is cordate and leaf tip is acute. Leaf is 101.4 mm long and 85.6 mm wide.	1.71 m tall and 1.30 m wide, semi-erect growth habit and fast grower on its own root.
 GCxDS-4	Solitary, simple, regular, 142.9 mm in diameter and the angle of display of flower on the plant is 88 degrees. Yellow orange (RHCC 14 B) petals with red purple (RHCC N 57 A) eye surrounded by red purple or spiraea (RHCC 63 C) halo that extends to the petals.	Arranged alternately, simple and cordate/ cordiform leaf form. Margin is serrate, base is cordate and leaf tip is acute. Leaf is 72.8 mm long and 68 mm wide.	1.55 m tall and 1.50 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
 ABAxMDM-1	Solitary, simple, regular, 131.4 mm in diameter and the angle of display of flower on the plant is 81 degrees. Neyron rose (RHCC 56 A) petals with cardinal red (RHCC 53 A) eye and light neyron rose (RHCC 55 B) vein markings.	Arranged alternately, simple and cordate/ cordiform leaf form. Margin is crenate, base is cordate and leaf tip is acute. Leaf is 83.6 mm long and 85.1 mm wide.	1.88 m tall and 1.24 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
 ABAxMDM-3	Solitary, simple, regular, 114 mm in diameter and the angle of display of flower on the plant is 69 degrees. Orange (RHCC N 25 C) petals with neyron rose (RHCCF 55 A) eye surrounded by white halo.	Arranged alternately, simple and cordate/ cordiform leaf form. Margin is crenate, base is cordate and leaf tip is rounded. Leaf is 89.1 mm long and 78 mm wide.	1.58 m tall and 1.09 m wide, semi-erect growth habit and fast grower on its own root.

Table 1. Selected hybrids and their important characteristics (cont'n.)

Selected Hybrids	Flower Characteristics	Foliation	Growth Habit
 23xGC-2	Solitary, simple, regular, 113.4 mm in diameter and the angle of display of flower on the plant is 80 degrees. Buttercup yellow (RHCC 15 A) petals with red/ carmine rose (RHCC 52 C) eye surrounded by two layers of grayed purple or magenta rose (RHCC 186 D) and red purple (RHCC 62 C) halos that extend to the petals.	Arranged alternately, simple and cordate/ cordiform leaf form. Margin is entire, base is cordate and leaf tip is retuse. Leaf is 66.7 mm long and 58.2 mm wide.	1.91 m tall and 1.09 m wide, semi-erect growth habit and fast grower on its own root.
 CVxNB-1	Solitary, simple, regular, 117.9 mm in diameter and the angle of display of flower on the plant is 67 degrees. Scarlet red (RHCC 43 C) petals with orange red or saturn red (RHCC 30 C) petal edges and cardinal red (RHCC 53 A) eye.	Arranged alternately, simple and cordiform/ cordate leaf form. Margin is serrate, base is cordate and leaf tip is acute. Leaf is 69.4 mm long and 66.7 mm wide.	2.87 m tall and 0.91 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
 ABAxMDM-1	Solitary, simple, regular, 131.4 mm in diameter and the angle of display of flower on the plant is 81 degrees. Neyron rose (RHCC 56 A) petals with cardinal red (RHCC 53 A) eye and light neyron rose (RHCC 55 B) vein markings.	Arranged alternately, simple and cordate/ cordiform leaf form. Margin is crenate, base is cordate and leaf tip is acute. Leaf is 83.6 mm long and 85.1 mm wide.	1.88 m tall and 1.24 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
 CVxNB-2	Solitary, simple, regular, 137.4 mm in diameter and the angle of display of flower on the plant is 78 degrees. Spinel red (RHCC 54 C) petal with yellow orange/ cadmium orange (RHCC 23 C) edges and red (RHCC 46 B) eye.	Arranged alternately, simple and cordiform/ cordate leaf form. Margin is crenate, base is cordate and leaf tip is acute. Leaf is 97.6 mm long and 88.1 mm wide.	1.58 m tall and 1.02 m wide, shrubby, semi-erect growth habit and fast grower on its own root.

Table 1. Selected hybrids and their important characteristics (cont'n.)

Selected Hybrids	Flower Characteristics	Foliation	Growth Habit
 CVxMP-4	Solitary, simple, regular, 140.7 mm in diameter and the angle of display of flower on the plant is 81 degrees. Neyron rose (RHCC 55 B) petals with rhodonite red (RHCC 51A) eye and white vein markings radiating from the eye to the petals.	Arranged alternately, simple and ovate leaf form. Margin is crenate, leaf base is obtuse and leaf tip is acute. Leaf is 80.8 mm long and 57.3 mm wide.	1.12 m tall and 0.97 m wide, shrubby, semi-erect growth habit and fast grower on its own root.
	Solitary, simple, regular, 135.6 mm in diameter and the angle of display of the flower on the plant is 75 degrees. Carmine rose (RHCC 52 C) petals with Spanish orange (RHCC 26 B) petal edges and currant red (RHCC 46 A) eye.	Arranged alternately, simple and cordiform/ cordate leaf form. Margin is serrate, base is cordate and leaf tip is acute. Leaf is 77.8 mm long and 73.8 mm wide.	1.58 m tall and 1.20 m wide, shrubby, semi-erect growth habit and fast grower on its own root.

Based on the criteria for selection, two progenies were identified as candidates, namely (LLxEFA)xGC-2 and (LLxEFA)xGC-8 (Figures 2A and 2E). (LLxEFA)xGC-2, which is orange-red (RHCC N 30B), had a similar flower color to *H. rosa-sinensis* 'Ledivina V. Cariño' (Magdalita et al. 2016) 'Cynthia A. Villar' (Magdalita and Pimentel 2013) including 'Loren B. Legarda' (Magdalita et al. 2011). (LLxEFA)xGC-2 inherited the deep red eye from GC and (LLxEFA)xGC-8 inherited its color from LLxEFA. (LLxEFA)xGC-8 had splashes of white and pink on its petals (Table 1). On the other hand, the red eye of GC was expressed in different shades in all progenies except for (LLxEFA)xGC-7. This suggests that the red eye could be dominant to white and pink.

DSxGC is a cross between *Hibiscus rosa-sinensis* 'Diamond Star', a creamy white hybrid, and the golden yellow *H. rosa-sinensis* 'Gelia Castillo'. Six hybrid progenies of this cross with pedigrees DSxGC-1, DSxGC-2, DSxGC-3, DSxGC-6, DSxGC-7 and DSxGC-8 had flower colors with different shades of white, yellow, yellow-orange, and grayed purple. DSxGC-1 is aureolin (RHCC 12 A) with a cardinal red (RHCC 53 A) eye surrounded by a white halo extending to the petals. DSxGC-2 is white (155 A) with a red/rhodonite red (RHCC 51 A) eye. DSxGC-3 is nasturtium orange (RHCC 25 B) with a red (RHCC 44 B) eye surrounded by a grayed orange (RHCC 165 B) halo. DSxGC-6 is white (RHCC NN155 D) with a neyron rose (RHCC 55 A) eye. DSxGC-7 is grayed purple (RHCC 186 B) with a neyron rose (RHCC 55 B) eye and bluish white vein markings radiating from the eye to the petals. DSxGC-8 is aureolin (RHCC 12 A) with a cardinal red (RHCC 53 A) eye surrounded by a white halo extending to the petals.

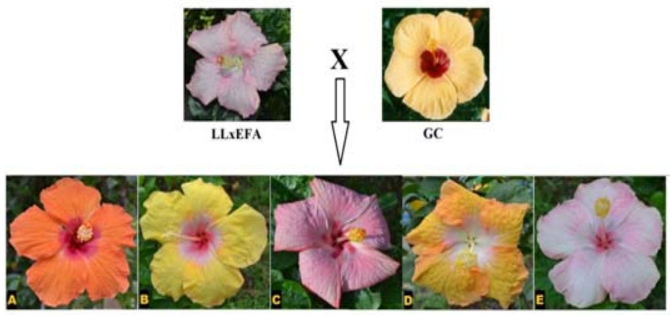

Figure 2. Hybrids of [*Hibiscus rosa-sinensis* 'Loren Legarda' x *Hibiscus rosa-sinensis* 'Estrella F. Alabastro'] x *Hibiscus rosa-sinensis* 'Gelia Castillo'. (A) (LLxEFA)xGC-2; (B) (LLxEFA)xGC-3; (C) (LLxEFA)xGC-5; (D) (LLxEFA)xGC-7; and, (E) (LLxEFA)xGC-8.

The selected hybrid progeny in this cross was DSxGC-7 (Figure 3E). This selected hybrid has traits different from the parents, such as the grayed purple petals (Table 1). It has a flower color similar to *H. rosa-sinensis* 'Patricia B. Licuanan' (Magdalita et al. 2016) and 'Kristie Anne Kenney' (Magdalita et al. 2011). In this cross, the red eye of both parents was expressed in different shades in five out of six (83.33%) progenies, namely DSxGC-1, DSxGC-2, DSxGC-3, DSxGC-6 and DSxGC-8. This suggests that the red eye is dominant to white and yellow.

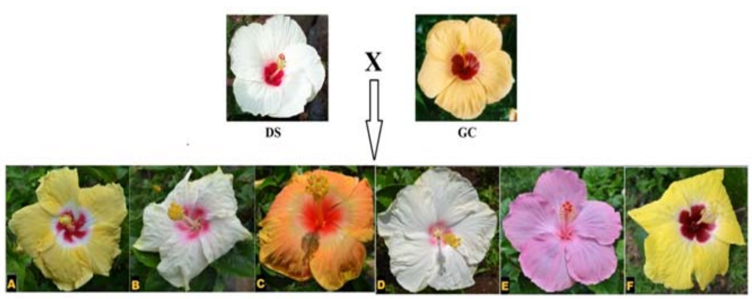

Figure 3. Hybrids of *Hibiscus rosa-sinensis* 'Diamond Star' x *H. rosa-sinensis* 'Gelia Castillo'. (A) DSxGC-1; (B) DSxGC-2; (C) DSxGC-3; (D) DSxGC-6; (E) DSxGC-7; and, (F) DSxGC-8.

20xGC is a cross between the red-purple *Hibiscus rosa-sinensis* 'Accession 20' and the golden yellow *H. rosa-sinensis* 'Gelia Castillo'. Five hybrid progenies in this cross with pedigrees 20xGC-3, 20xGC-4, 20xGC-5, 20xGC-6 and 20xGC-9 had flower colors with different shades of purple and orange.The progeny 20xGC-6 was red-purple (RHCC 58 C) with a red-purple (RHCC 59 A) eye extending to the petals. 20xGC-3 is grayed purple (RHCC 186 B) to spiraea red (RHCC 63 B) with a ruby red (59 A) eye and pink vein markings extending to the petals. 20xGC-4 is grayed orange (RHCC 169 A) with a cardinal red (RHCC 53 A) eye surrounded by a neyron rose (RHCC 55 C) halo extending to the petal. 20xGC-5 is red-purple (RHCC 69 C) with a ruby red (RHCC 59 A) eye zone surrounded by a spiraea red (RHCC 63 C) halo that extends to the petals. 20xGC-9 is phlox pink (RHCC 62 B) with pink blushes on the edges of the petals and light pink vein markings radiating from the eye to the petals.

Based on the criteria for selection, 20xGC-5 (Figure 4D) was selected out of the five progenies. Its unique properties include semi-overlapping pastel pink petals and striking cartwheel red-purple eye (Table 1). In addition, the dark red eye of GC was inherited by three out of five (60%) hybrid progenies, suggesting again that the red eye is dominant to yellow and purple, while the purple petal is dominant to yellow.

(GCxBGB)xHP is a cross between the yellow hybrid *Hibiscus rosa-sinensis* 'Gelia Castillo' x *Hibiscus rosa-sinensis* 'Betty Go Belmonte' and the red-purple variety *Hibiscus rosa-sinensis* 'Hot Pink'. Six hybrid progenies generated in this cross with pedigrees (GCxBGB)xHP-1, (GCxBGB)xHP-2, (GCxBGB)xHP-4, (GCxBGB)xHP-7, (GCxBGB)xHP-8 and (GCxBGB)xHP-9 had flowers with different hues of red-purple. (GCxBGB)xHP-1 is red-purple (RHCC 61 B) with a red-purple (RHCC N 57 A) eye

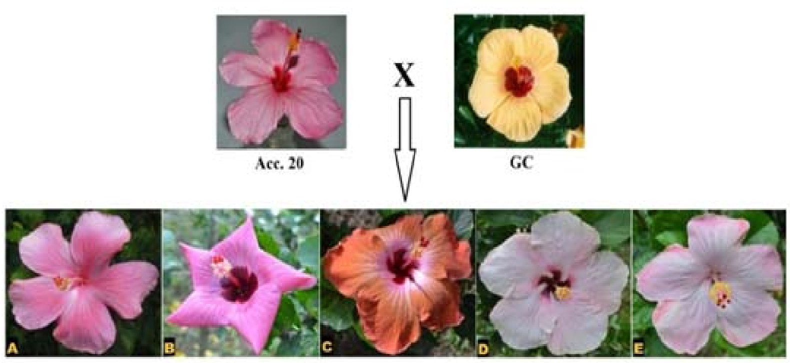

Figure 4. Hybrids of *Hibiscus rosa-sinensis* 'accession 20' and *H. rosa-sinensis* 'Gelia Castillo'. (A)20xGC-6; (B) 20xGC-3; (C) 20xGC-4; (D)20xGC-5; and, (E) 20xGC-9.

zone. (GCxBGB)xHP-2 is amaranth rose (RHCC 65 A) with a tyrian purple (RHCC N 57 A) eye. (GCxBGB)xHP-4 is rhodamine pink (RHCC 62 A) with a currant red (RHCC 46 A) eye and pink vein markings extending to the petals. (GCxBGB)xHP-7 is amaranth rose (RHCC 65 A) with a rose red (RHCC 58 B) eye and pink vein markings radiating from the eye to the petals. (GCxBGB)xHP-8 is red-purple (RHCC 61 B) with a strong red purple eye. (GCxBGB)xHP-9 is a light red purple hybrid (RHCC N 57 B) with a dark red purple (RHCC N 57 A) eye.

Out of the six progenies in this cross, only one hybrid progeny plant, (GCxBGB)xHP-4, (Figure 5C) was selected. The hybrid has a unique combination of pastel pink or rhodamine pink petals and a dark red eye (Table 1).The pastel pink or red purple or rhodamine pink (RHCC 62 A) flower color of this selection is similar to *H. rosa-sinensis* 'Pia S. Cayetano' (Magdalita et al. 2016). In this cross, the red eye from the female parent GCxBGB was inherited by four out of six (66.6%), namely (GCxBGB)xHP-1, (GCxBGB)xHP-2, (GCxBGB)xHP-4 and (GCxBGB)xHP-7. This suggests that the red eye is dominant to yellow in this particular cross.

GCxDS is a cross between *Hibiscus rosa-sinensis* 'Gelia Castillo' (golden yellow) and *Hibiscus rosa-sinensis* 'Diamond Star' (creamy white). Five hybrid progenies generated in this cross with pedigrees GCxDS-1, GCxDS-2, GCxDS-4, GCxDS-5 and GCxDS-6 had flower colors with different shades of yellow (3), red (1), and white (1). GCxDS-1 is white (RHCC N 155 A) with a red (RHCC 55 D) eye. GCxDS-2 is Turkey red (RHCC 46 C) with a red (RHCC N 34 A) eye. GCxDS-4 is yellow-orange (RHCC 14 B) with a red purple (RHCC N 57 A) eye surrounded by a spiraea (RHCC 63 C) halo extending to the petals. GCxDS-5 is yellow-orange (RHCC 16 B) with a neyron rose (RHCC55 C)

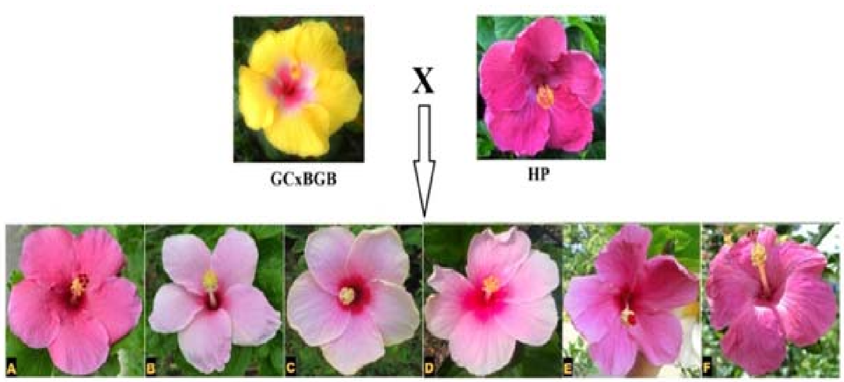

Figure 5. Hybrids of *Hibiscus rosa-sinensis* 'Gelia Castillo' by *H. rosa-sinensis* 'Betty Go Belmonte' and *H. rosa-sinensis* 'Hot pink'. (A) (GCxBGB)xHP-1; (B) (GCxBGB)xHP-2; (C) (GCxBGB)xHP-4; (D) (GCxBGB)xHP-7; (E) (GCxBGB)xHP-8; and, (F) (GCxBGB)xHP-9.

eye surrounded by white streaks that extend to the petals. GCxDS-6 is buttercup yellow (RHCC 15 A) with a neyron rose (RHCC 55 A) eye surrounded by white streaks that extend to the petals.

Out of the five progenies, only GCxDS-4 (Figure 6C) was selected because of its unique cartwheel eye pattern surrounded by a white halo and its yellow-orange ruffled semi-overlapping petals. The dark red eye from both parents was inherited by four out of five progenies (80%). Again in this cross, the red eye is dominant to yellow and white. This hybrid is a prolific bloomer with good quality of blooms. In addition, this yellow-orange flower (RHCC 14 B) is similar to *H. rosa-sinensis* 'Vilma Abaya-Dimacuha' (Magdalita et al. 2016), 'Marilyn D. Marañon' (Magdalita and Pimentel 2013), 'Mercedes B. Concepcion', and 'Betty Go-Belmonte (Magdalita et al. 2009).

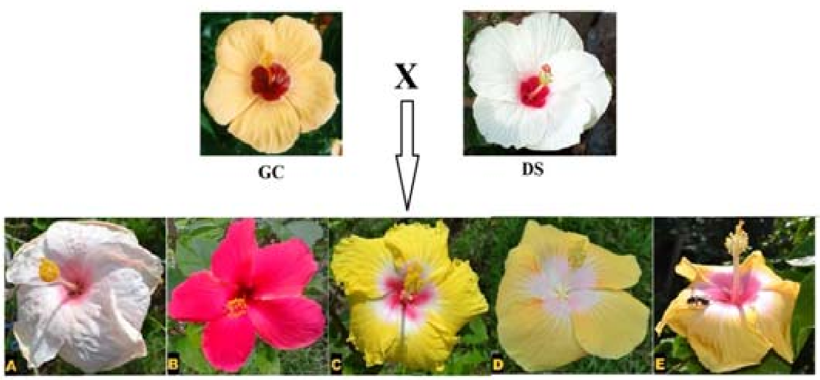

Figure 6. Hybrids of *Hibiscus rosa-sinensis* 'Gelia Castillo' and *Hibiscus rosa-sinensis* 'Diamond star'. (A) GCxDS-1; (B) GCxDS-2; (C) GCxDS-4; (D) GCxDS-5; and, (E) GCxDS-6.

ABAxMDM is a cross between *Hibiscus rosa-sinensis* 'Arlene B. Arcillas' (carmine rose) and *Hibiscus rosa-sinensis* 'Marilyn D. Marañon' (lemon yellow). Seven hybrid progenies in this cross with pedigrees ABAxMDM-1, ABAxMDM-2, ABAxMDM-3, ABAxMDM-4, ABAxMDM-5, ABAxMDM-6 and ABAxMDM-7 had flower colors with different shades of orange, red, yellow and white. ABAxMDM-1 is neyron rose (RHCC 56 A) with a cardinal red (RHCC 53 A) eye and neyron (RHCC 55 B) vein markings. ABAxMDM-2 is fire red (RHCC 33 B) with a spinel red (RHCC 54 A) eye and orange (RHCC 32 C) petal edges. ABAxMDM-3 is orange (RHCC N 25 C) with a neyron rose (RHCC 55 A) eye surrounded by a white halo. ABAxMDM-4 is persimmon orange (RHCC 28 A) with a neyron rose (RHCC 55 A) eye. ABAxMDM-5 is buttercup yellow (RHCC 15 A) with a red purple (RHCC N 57 A) eye. ABAxMDM-6 is white (RHCC N155 C) with a red-purple (RHCC N 57 A) eye and red-purple (RHCC 62 D) vein markings extending from the eye to the petals. ABAxMDM-7 is neyron rose (RHCC 56 A) with a cardinal red (RHCC 53 A) eye and neyron (RHCC 55 B) vein markings extending from the eye to the petals.

Out of the seven progenies, two were selected, namely ABAxMDM-1 and ABAxMDM-3 (Figures 7A and 7C). ABAxMDM-1 was selected for its pastel pink or neyron rose petals with distinct cardinal red eye and semi-ruffled petal edges, while ABAxMDM-3 was selected because of its attractive light orange petals with semi-ruffled edges (Table 1). Three progenies out of seven (42.86%) inherited the pink color of the maternal parent ABA, while four (57.1%) possessed the orange color not present in either parents. The ruffled edges of the female parent MDM was inherited by five (71.43%) out of seven progenies. Six out of seven (85.71%) progenies had the red eye inherited from the female parent ABA. This suggests that the red eye is dominant to yellow in this cross.

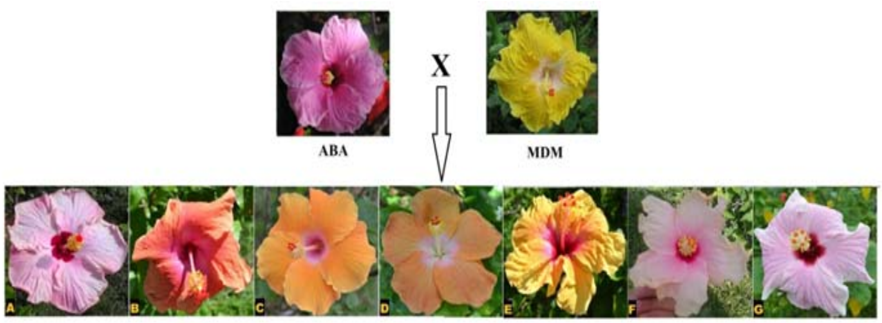

Figure 7. Hybrids of *Hibiscus rosa-sinensis* 'Arlene B. Arcillas' and *Hibiscus rosa-sinensis* 'Marilyn D. Marañon'. (A) ABAxMDM-1; (B) ABAxMDM-2; (C) ABAxMDM-3; (D) ABAxMDM-4; (E) ABAxMDM-5; (F) ABAxMDM-6; and, (G) ABAxMDM-7.

23xGC is a cross between the light yellow *Hibiscus rosa-sinensis* 'Accession 23' and the golden yellow *Hibiscus rosa-sinensis* 'Gelia Castillo'. Five hybrid progenies generated in this cross with pedigrees 23xGC-2, 23xGC-5, 23xGC-6, 23xGC-8 and 23xGC-10 had flower colors with different shades of yellow. 23xGC-2 is buttercup yellow (RHCC 15 A) with a carmine rose (RHCC 52 C) eye surrounded by two layers of magenta rose (RHCC 186 D) and red purple (RHCC 62 C) halos that extend to the petals. 23xGC-5 is lemon yellow (RHCC 13 B) with a red (RHCC 45 B) eye inherited from GC and surrounded by a white halo that extends to the petals. 23xGC-6 is saffron yellow (RHCC 21 A) with a neyron rose (RHCC 55 A) eye and persimmon orange (RHCC 28 A) vein markings extending from the eye to the petals. 23xGC-8 is buttercup yellow (RHCC 15 A) with a dawn pink (RHCC 49 A) eye surrounded by a white halo that extends to the petals. 23xGC-10 is buttercup yellow (RHCC 15 A) with a carmine rose (RHCC 52 C) eye surrounded by two layers of magenta rose (RHCC 186 D) and red purple (RHCC 62 C) halos that extend to the petals. Four out of five (80.0%) progenies inherited the dark red eye from GC. In this cross, the dark red eye was dominant to the yellow. Based on the criteria for selection, 23xGC-2 (Figure 8A) was selected out of the five progenies because of its bright and striking red eye surrounded by a white halo.

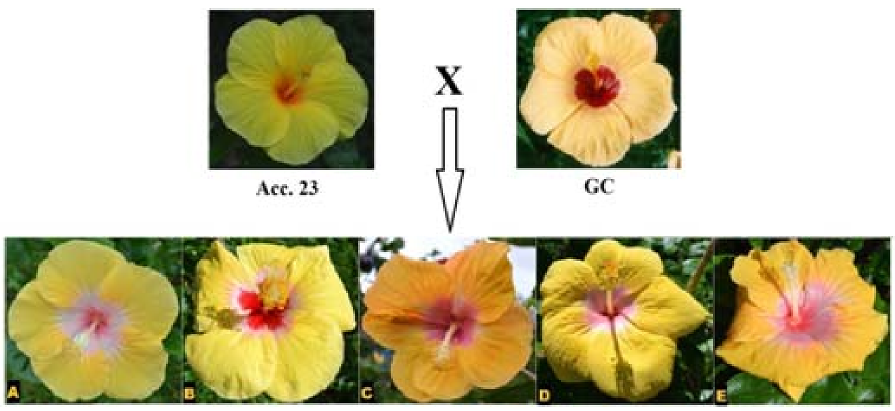

Figure 8. Hybrids of *Hibiscus rosa-sinensis* 'Accession 23' and *H. rosa-sinensis* 'Gelia Castillo'. (A) 23xGC-2; (B) 23xGC-5; (C) 23xGC-6; (D) 23xGC-8; and, (E) 23xGC-10.

CVxNB is a cross between the orange *Hibiscus rosa-sinensis* 'Cynthia Villar' and the white *Hibiscus rosa-sinensis* 'New Bangkok'. Six hybrid progenies generated in this cross with pedigrees CVxNB-1, CVxNB-2, CVxNB-3, CVxNB-4, CVxNB-5 and CVxNB-6 had flower colors ranging from red-orange to yellow (Figure 9). CVxNB-1 is scarlet (RHCC 43 C) with saturn red (RHCC 30 C) petal edges and a cardinal red (RHCC 53 A) eye. CVxNB-2 is spinel red (RHCC 54 C) with cadmium orange (RHCC 23 C) petal edges and a red (RHCC 46 B) eye. CVxNB-3 is cadmium orange (RHCC 23 B). CVxNB-4 is buttercup yellow (RHCC 15 A) with a cardinal red (RHCC 53 A) eye surrounded by a white halo extending to the petals. CVxNB-5 is carmine red (RHCC 52 B) with jasper red (RHCC 39 A) petal edges and a cardinal red (RHCC 53 A) eye.CVxNB-6 is carmine rose (RHCC 52 C) with Spanish orange (RHCC 26 B) petal edges and a currant red (RHCC 46 A) eye.

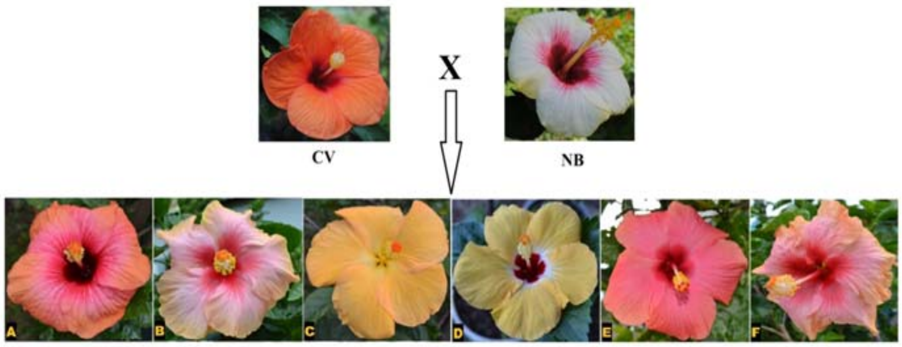

Figure 9. Hybrids of *Hibiscus rosa-sinensis* 'Cynthia Villar' and *H. rosa-sinensis* 'New Bangkok'. (A) CVxNB-1; (B) CVxNB-2; (C) CVxNB-3; (D) CVxNB-4; (E) CVxNB-5; and, (F) CVxNB-6.

Out of the six hybrid progenies, three hybrid progenies, namely CVxNB-1, CVxNB-2, and CVxNB-6, were selected (Figure 9) because of their unique red eye that radiates to the scarlet red petals inherited from the male parent 'New Bangkok' (Table 1). CVxNB-6, which has carmine rose (RHCC 52 C) petals with Spanish orange (RHCC 26 B) petal edges and currant red (RHCC 46 A) eye (Table 1), is similar to the foreign variety *H. rosa-sinensis* 'Erin Rachel' (Australian Hibiscus Society 2004). Four hybrid progenies out of six (66.6%) inherited the red eye, which is dominant to white and orange in this cross.

CVxMP is a cross between *Hibiscus rosa-sinensis* 'Cynthia Villar' (orange) and *Hibiscus rosa-sinensis* 'Marjorie Pink' (pink). Five hybrid progenies generated from this cross with pedigrees CVxMP-1, CVxMP-2, CVxMP-3, CVxMP-4 and CVxMP-5 had flower colors ranging from orange, light pink, yellow to light purple (Figure 10). CVxMP-1 is vermilion (RHCC 41 A) with a rhodonite red (RHCC 51 A) eye.CVxMP-2 is buttercup yellow (RHCC 15 A) with a cardinal red (RHCC 53 A) eye surrounded by neyron rose (RHCC 55 B) vein markings that extend to the petals. CVxMP-3 is crimson (RHCC 52 A) to azalea pink (RHCC 41 C) with a currant red (RHCC 46 A) eye. CVxMP-4 is neyron rose (RHCC 55 B) with a rhodonite red (RHCC 51 A) eye and white vein markings radiating from the eye to the petals. CVxMP-5 is neyron rose (RHCC 55 B) with a rhodonite red (RHCC 51 A) eye.

Out of the five progenies, only the CVxMP-4 (20%) was selected (Figure 10D). It has a unique rhodonite red eye with a light purple halo radiating to the neyron rose petals and ruffled edges (Table 1). The red eye from both parents was inherited by the five hybrid progenies, indicating that the red eye is dominant to orange and light pink. One progeny, CVxMP-2, had a crest which is a unique trait not present in both parents (Figure 10B).

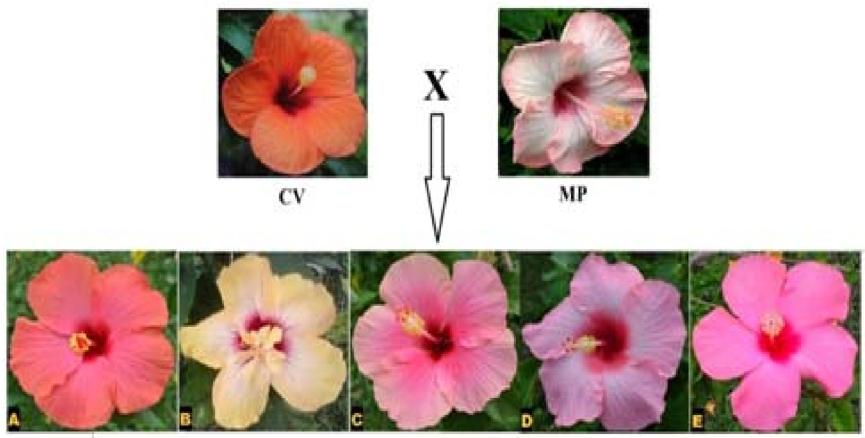

Figure 10. Hybrids of *Hibiscus rosa-sinensis* 'Cynthia Villar' and *H. rosa-sinensis* 'Marjorie Pink'. (A) CVxMP-1; (B) CVxMP-2; (C) CVxMP-3; (D) CVxMP-4; and, (E) CVxMP-5.

Principal Component and Agglomerative Cluster Analyses of Phenotypic Traits

The Principal Component Analysis (PCA) and Agglomerative Cluster Analysis (ACA) are two multivariate approaches that can be utilized to analyze relationships within and between samples. Each can be used to complement each other to generate more precise information. PCA is known to be less sensitive to distances between clusters, while cluster analysis generally reproduces distances between close neighbors faithfully but shows distortion among members of large clusters (Sneath and Sokal 1973). To study the patterns of variation within the data matrix, the PCA based on the correlation matrix of the sample means for the nine floral traits was carried out using the EIGEN program (Jacob and Guennebaud 2016).

PCA is also a tool for selection of variables according to the degree of their variances in each principal component generated. PCA generates principal components, eigenvalues, proportion of variance, cumulative proportion and eigenvectors. The variation shown in the nine floral traits of the 57 hybrids can be explained using PCA which grouped these traits into nine PCs (Table 2).The principal components generated were ranked by importance through variances. In this study, out of nine principal components (PCs), three PCs, namely: PC-I; PC-II; and PC-III had eigenvalues >1, accounting for 78% of total cumulative variability of the various traits among the 57 different hybrid progenies (Table 2). This suggests medium correlation among the floral traits studied. Similarly, in jackfruit (*Artocarpus heterophyllus* Lam.), an eigenvalue greater than 1 was obtained using 41 morphological traits in 88 trees studied, subsequently generating 12 PCs. These 12 PCs accounted for 72.5% of the total variability of the jackfruit genotypes studied (Dayap 2000), which is not distant to the variability (78%) obtained for the hibiscus hybrids.

Table 2. Eigenvalues, proportion of the variability, and the characters represented by the nine principal components of 57 hibiscus experimental hybrid progenies

Principal Components (PCs)	Eigenvalues	Proportion of Variance	Cumulative Proportion	Principal Characters Represented
I	3.93	0.44	0.44	Bloom size, corolla length, corolla width, style length, leaf length, leaf width
II	1.85	0.21	0.64	Style length, petiole length, leaf length, leaf width
III	1.24	0.14	0.79	Pedicel length, receptacle length
IV	0.69	0.08	0.86	Pedicel length, receptacle length
V	0.50	0.06	0.91	Petiole length, leaf width
VI	0.41	0.05	0.96	Bloom size, corolla with, style length
VII	0.18	0.02	0.98	Corolla length, corolla width, leaf length
VIII	0.13	0.02	0.99	Corolla length, leaf length, leaf width
IX	0.07	0.01	1.00	Bloom size, corolla length

The contribution of PC-I to the variability in the data set was highest (43.69%), followed by PC-II at 20.56% and PC-III at 13.72%. PCA results revealed patterns of correlation through the eigenvectors. Traits with eigenvectors of ≥0.3 were considered relevant for the component (Table 3). The first principal component (PC-I) showed positive variable loadings for all the traits, including bloom size (ev=0.45), corolla length (ev=0.44), corolla width (ev=0.42), pedicel length (ev=0.15), style length (ev=0.31), petiole length (ev=0.30), leaf length (ev=0.35), leaf width (ev=0.32), and receptacle diameter (ev=0.087). The characteristics that had positive significant eigenvectors in PC-I were bloom size, corolla length, corolla width, style length, leaf length, and leaf width. This suggests that hybrids with larger flower size tend to have longer and wider leaves. PC-II indicated positive variable loadings for petiole length (ev=0.38), leaf length (ev=0.45) and leaf width (ev=0.47) except for style length (ev=-0.40). Petiole length had a significant positive correlation with leaf length and leaf width. However, it had significant negative association with style length, suggesting that flowers with longer petiole tend to have shorter style. In the third principal component (PC-III), receptacle length (ev=0.70) had a significant negative correlation with pedicel length (ev=-0.66), suggesting that flowers with larger receptacle tend to have shorter pedicel.

Table 3. Eigenvectors of the characters in each Principal Component (PC)

Variables	PC-I	PC-II	PC-III	PC-IV	PC-V	PC-VI	PC-VII	PC-VIII	PC-IX
Bloom Size	0.45*	-0.25	0.06	-0.03	0.03	-0.32*	0.28	-0.09	0.74*
Corolla Length	0.44*	-0.28	-0.001	0.02	0.02	-0.05	0.50*	-0.31*	-0.61*
Corolla Width	0.42*	-0.25	0.17	0.09	0.09	-0.39*	-0.67*	0.27	-0.23
Pedicel Length	0.15	0.23	-0.62*	-0.66*	-0.16	-0.27	-0.08	0.005	-0.07
Style Length	0.31*	-0.40*	-0.21	-0.13	-0.16	0.77*	-0.19	0.12	0.12
Petiole Length	0.29	0.38*	-0.18	0.07	0.82*	0.22	-0.06	-0.08	0.04
Leaf Length	0.35*	0.45*	0.01	0.24	-0.28	0.06	0.30*	0.67*	-0.05
Leaf Width	0.32*	0.47*	0.14	0.19	-0.42*	0.11	-0.30	-0.59*	0.06
Receptacle Length	0.09	0.16	0.70*	-0.67*	0.08	0.15	0.06	0.07	-0.03

*significant eigenvector (≥0.3)

The PCA reduced the 16 quantitative traits to nine that still contain important information about the data set. Bloom size, corolla length, corolla width, style length, leaf width, leaf length, petiole length, pedicel length, and receptacle diameter obtained high variances, were considered important traits in the first three principal components, namely: PC-I; PC-2; and, PC-3. The same characteristics had the largest contribution to the total variation in the data set. They were used to group the 57 hibiscus hybrid progenies into five distinct clusters, thus providing a better clustering of the hybrid progenies in a dendrogram (Figure 11).

As a whole, while PCA and cluster analysis are both useful in analyzing the relationships across and among the 57 hibiscus hybrids, they both complemented each other in generating more precise information in the selection of 14 hybrid progenies out of the 57. Clustering generated a highly branched structure (Figure 11), suggesting the existence of a highly variable group, wherein selection of desirable hibiscus hybrid progenies can be performed effectively. In addition, clustering was able to optimally capture the representative progenies of the different crosses having similar floral traits like petal color and bloom size, thereby facilitating the selection of the 14 desirable hybrid progenies from the various crosses. On the other hand, PCA effectively showed the patterns of variation in the data matrix of the various floral traits studied and separated the nine distinct principal components based on the derived eigenvalues of the primary characters represented in each component (Table 2). For instance, PC-I with eigenvalue of 3.93 accounted for 78.0% of the variability of different hybrid progenies in terms of bloom size, corolla length, corolla width, style length, leaf length and leaf width. Since many of the useful traits are included in this principal component, particularly bloom size, corolla length and width, and style length, which are indeed necessary in the rigorous selection of the 14 desirable hybrid progenies (Table 1), the process of selection was implemented effectively and efficiently in this set of hibiscus hybrids. Selection was executed through the combined information derived from both cluster analysis and PCA.

Agglomerative Cluster Analysis and Correlation among Phenotypic Traits

Based on a priori knowledge, five clusters were arbitrarily selected to form the dendrogram, which was automatically cut at a Gower distance between 0.3 and 0.4 using the Statistical Tool for Agricultural Research (STAR) software (IRRI 2014). The 57 hibiscus hybrids clustered into five groupings (Table 4) based on the clustering analysis of 16 phenotypic characters (Figure 11).The dendrogram was based on selected qualitative traits, including flower color, eye color, stigma color, leaf form, leaf margin, leaf apices, and leaf base and quantitative traits, namely: bloom size; corolla length; corolla width; style length; leaf width; leaf length;

Table 4. Distribution of Hibiscus hybrids in different clusters

Cluster	Pedigree of Experimental Hybrids	No. of Experimental Hybrids in a Cluster
I	22xDT-1, 22xDT-10, (LLxEFA)xGC-2, (LLxEFA)xGC-3, (LLxEFA)xGC-5, (LLxEFA)xGC-8, GCxDS-2, GCxDS-4 ABAxMDM-1, ABAxMDM-2, ABAxMDM-4, ABAxMDM-5, ABAxMDM-7, 23xGC-10, CVxNB-3, CVxNB-6	16
II	22xDT-2, 22xDT-5, DSxGC-1, DSxGC-2, DSxGC-6, DSxGC-7, DSxGC-8, 20xGC-3, 20xGC-4, 20xGC-5, 20xGC-9, GCxBGB)xHP-1, GCxDS-1, GCxDS-6, CVxNB-2	15
III	22xDT-6, 22xDT-9, (LLxEFA)xGC-7, 23xGC-6, 23xGC-8	5
IV	DSxGC-3, 20xGC-7, (GCxBGB)xHP-8, (GCxBGB)xHP-9, ABAxMDM-3, ABAxMDM-6, 23xGC-2, CVxNB-1, CVxNB-4, CVxNB-5, CVxMP-1, CVxMP-2, CVxMP-3	13
V	20xGC-6, (GCxBGB)xHP-2, (GCxBGB)xHP-4, (GCxBGB)xHP-7, GCxDS-5, 23xGC-5, CVxMP-4, CVxMP-5	8

petiole length; pedicel length; and, receptacle diameter of the progenies. It was constructed by employing the complete clustering method and Gower distance as a measure of dissimilarity.

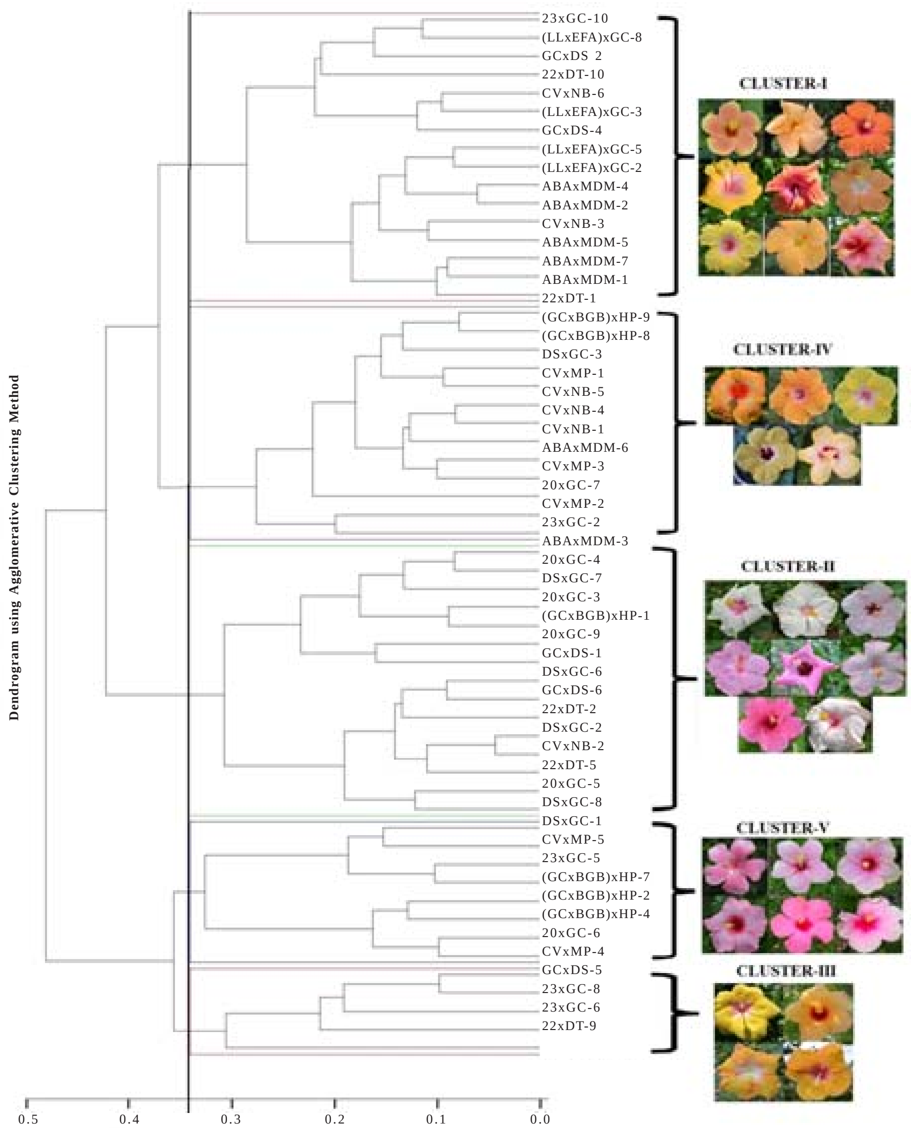

Figure 11. The clustering of the 57 hibiscus hybrids.

The 57 hybrid progenies grouped into five clusters based on agglomerate clustering (Figure 11). The cluster number, specific hybrid progenies and number of progenies in each cluster are indicated in Table 4.

The hybrids in Cluster-I were from six different crosses, namely 22xDT, (LLxEFA)xGC, GCxDS, ABAxMDM, 23xGC and CVxNB, which consist of 16 hybrid progenies (Table 4). The hybrid progenies in this cluster have flower sizes that ranged from 115.10 mm to 143.30 mm, with a mean of 131.09 mm. The flowers of hybrids in this group had an average style length of 61.38 mm, petiole length of 27.22 mm and pedicel length of 37.90 mm (Table 4). Cluster-I comprises yellow to orange-red hybrids, most of which have red eye (Figure 11).

The 15 members of Cluster-II were from the crosses of 22xDT, DSxGC, 20xGC, (GCxBGB)xHP, GCxDS, and CVxNB. The progenies had flower sizes that ranged from 118.40 mm to 152.30 mm, with a mean of 140.54 mm. In this group, the flowers of the hybrid progenies had an average style length of 61.57 mm, petiole length of 39.53 mm and pedicel length of 39.79 mm. Cluster-II was represented by white and red-purple hybrids mostly with red eye (Figure 11).

Cluster-III contained five yellow hybrids from the crosses of 22xDT, (LLxEFA)xGC, and 23xGC. Their flowers had sizes ranging from 125.0 mm to 146.80 mm, with a mean of 131.12 mm. Flowers of hybrids in this group had an average style length of 58.08 mm, petiole length of 22.80 mm and pedicel length of 24.86 mm.

Thirteen hybrid progenies from the crosses of DSxGC, 20xGC, (GCxBGB)xHP, ABAxMDM, 23xGC, CVxNB and CVxMP formed Cluster-IV. Flowers of hybrids in this cluster were small compared to other hybrids belonging to Clusters-I, II, III and V. The bloom size ranged from 95 mm to 126.00 mm, with a mean of 115.20 mm. Flowers of hybrids belonging to this cluster had an average style length of 52.76 mm, petiole length of 24.07 mm and pedicel length of 29.44 mm. Cluster-IV contained yellow and yellow-orange hybrid progenies with red eye.

The members of Cluster-V are 8 hybrid progenies from the crosses of 20xGC, (GCxBGB)xHP, GCxDS, 23xGC and CVxMP. Their flowers had sizes ranging from 105.70 mm to 160.80 mm, with a mean of 130.21 mm. Flowers of the hybrids in this group had an average style length of 52.71 mm, petiole length of 27.80 mm and pedicel length of 39.82 mm. The hybrids in Cluster-V had pinkish flowers with red eye (Figure 11).

The mean and standard deviation of the quantitative traits of the hibiscus hybrid progenies belonging to the different clusters are presented in Table 5.

Table 5. Mean and standard deviation (SD) of quantitative characters of hibiscus hybrids belonging to the five clusters

			MORPHOLOGICAL CHARACTERS								
CLUSTER NUMBER	n	Statistics	Bloom Size	Corolla Length	Corolla Width	Style Length	Petiole Length	Leaf Length	Leaf Width	Pedical Length	Receptacle Length
CLUSTER	16	Mean	131.09	150.76	112.30	61.38	27.22	80.40	71.33	37.90	9.47
I		SD	7.58	8.26	6.62	7.43	7.43	9.53	10.79	9.63	1.53
CLUSTER	15	Mean	140.54	159.77	117.93	61.57	39.53	106.42	86.35	39.79	9.37
II		SD	8.67	7.89	8.56	5.92	7.39	8.78	9.28	10.60	0.81
CLUSTER	5	Mean	131.12	148.24	109.42	58.08	22.80	68.92	58.54	24.86	9.63
III		SD	8.87	11.81	7.20	10.42	6.57	6.42	8.02	10.03	1.18
CLUSTER	13	Mean	115.20	138.56	101.65	52.76	24.07	77.59	64.45	29.44	9.07
IV		SD	7.88	11.58	6.49	11.42	7.95	14.54	10.46	7.44	0.86
CLUSTER	8	Mean	130.21	146.91	108.13	52.71	27.80	83.15	62.98	39.82	8.84
V		SD	21.75	18.48	16.47	12.52	5.08	10.79	11.07	11.71	0.76

The correlation matrix showed different levels of relationship among the traits (Table 6). Bloom size is moderately correlated with corolla length (r=0.91) and width (r=0.86) and style length (r= 0.60), suggesting that the size of the bloom or flower is associated with its overall length and width, and the length of the style. Similarly, correlation studies conducted in other hibiscus varieties with one- and two-day retention on the plant indicated that peduncle diameter, length and petal thickness correlated strongly with the retention of the flower in planta (Valdoz et al 2017). In addition, the length of the style is correlated with the length of the corolla (r=0.70) and leaf width is correlated with leaf length (r=0.84).

Table 6. Correlation matrix of nine qualitative characters of hibiscus hybrids

	Bloom Size	Corolla Length	Corolla Width	Style Length	Petiole Length	Leaf Length	Leaf Width	Pedicel Length	Receptacle Length
Bloom Size	1.00								
Corolla Length	0.91**	1.00							
Corolla Width	0.86**	0.80**	1.00						
Style Length	0.60*	0.70*	0.53*	1.00					
Petiole Length	0.31	0.31	0.28	0.11	1.00				
Leaf Length	0.40	0.37	0.35	0.10	0.60*	1.00			
Leaf Width	0.33	0.30	0.33	0.05	0.52*	0.84**	1.00		
Pedicel Length	0.15	0.13	0.01	0.16	0.34	0.28	0.22	1.00	
Receptacle Length	0.13	0.06	0.16	-0.09	0.07	0.15	0.26	-0.14	1.00

** high correlation

*medium correlation

The results also show that bloom size had low correlation with petiole length (r= 0.31), leaf size (r=0.40), pedicel length (r=0.15), and receptacle length (r=0.13). A similar pattern was also observed in corolla length, corolla width, and style length. Petiole length had moderate correlation with leaf length (r=0.60) and leaf width (r=0.52). Pedicel length had low positive correlation with flower size (r=0.15), leaf length (r=0.28), leaf width (r=0.22), style length (r=0.16) and petiole length (r=0.34). However, pedicel length had low negative correlation with receptacle length (r=-0.14). Receptacle length had low negative correlation with style length (r=-0.09) and had low positive correlation with flower size (r=0.13), leaf length (r= 0.15), leaf width (r= 0.26) and petiole length (r= 0.07).

A dendrogram with a cophenetic correlation value of 1 gives a perfect picture of the pattern of dis/similarities of the data. Low values indicate low correlation between the dendrogram and the original similarities or dissimilarities. The cophenetic coefficient gives a measure of how well the original data match the hierarchical clustering through comparisons of the resemblance values from the similarity or dissimilarity matrix with those implied from the dendrogram. For a dendrogram to be a reasonably good reflection of a matrix of association, values of 0.85 or higher are desirable (Stuessy 2009). The cophenetic correlation coefficient obtained in this study was 0.667, which is relatively lower than the desirable value, indicating that the dis/similarities of the data may not be well presented in the dendrogram generated. A similar cophenetic correlation coefficient of 0.766 was also obtained in clustering 88 genotypes of jackfruit, another highly heterozygous species (Dayap 2000). However, a low cophenetic correlation coefficient does not necessarily mean that the dendrogram is not acceptable or that the relationships expressed are lacking in taxonomic value; instead, it may indicate that distortion has taken place during clustering (Stuessy 2009).

The dendrogram showed a highly branched structure, suggesting a considerable degree of variability and divergence within the 57 hibiscus hybrid progenies studied. This observed variability can be attributed to the genetic differences of the hybrid progenies. These differences are expected because the parents used for hybridization are highly heterozygous. A similar dendrogram also suggesting high genetic variability of samples for different horticultural traits was generated for 22 pineapple hybrids and cultivars (Ines et al. 2009), whose parents were also heterozygous. Morphological and RAPD markers effectively revealed this high degree of variability in pineapple (Ines et al. 2009). However, the variability observed among the 57 hybrid progenies cannot be solely attributed to genetic differences but also to environmental conditions. Therefore, the interaction of the genotype and the environment can contribute to the total variability among the 57 hybrid progenies.

As exhibited by the dendrogram, the agglomerative clustering method demonstrated its efficiency in clustering the 57 hybrid progenies. However, a decision has to be made on how many variables will be used to group the hybrid progenies. In this study, quantitative and qualitative characters, including bloom size, corolla length, corolla width, style length, leaf width, leaf length, petiole length, pedicel length and receptacle length, were used to group the hybrid progenies into five clusters.

However, classifying the 57 hybrid progenies into groups is a subjective procedure because there is no definite algorithm that can be used in deciding at what specific coefficient distance the dendrogram should be cut (Brown 1991).

In some cases, a priori knowledge can facilitate the determination of the number of clusters to be formed. For instance, Cena (1995) used the three populations of cacao, namely Ferastero, Criollo, and Trinitario, as the basis for grouping the University of Southern Mindanao Agricultural Research Center (USMARC) cacao collections. The study found out that most of the studied clones with known varietal group fall in the same cluster.

One common practice in clustering is to examine the tree generated and then designate similarity and difference levels above which the individuals are considered grouped. Representative flower samples for each of the clusters are shown in Figure 11.

CONCLUSION

This characterization study showed a wide range of variation in both qualitative and quantitative characters between the crosses. For some characters like flower color and flower size, variation was also observed among hybrid progenies within a specific cross. Based from the evaluation of morphological traits, 14 hybrid progenies were selected from the 10 different crosses. The 14 hybrid progenies are as follows: 22xDT-9; (LLxEFA)xGC-2; (LLxEFA)xGC-7; (LLxEFA)xGC-8; DSxGC-7; 20xGC-5; (GCxBGB)xHP-4; GCxDS-4; ABAxMDM-1; ABAxMDM-3; 23xGC-2; CVxNB-1; CVxNB-2; CVxNB-6; and, CVxMP-4. 22xDT-9 is China rose with a currant red eye zone and white edges. (LLxEFA)xGC-2 is orange-red with a red eye zone. (LLxEFA)xGC-7 is Chinese yellow with a white eye zone and orpiment orange vein markings. (LLxEFA)xGC-8 is roseine purple with white spots and spinel red eye color surrounded by purple halo. DSxGC-7 is grayed purple with a neyron rose eye and bluish white vein markings radiating from the center to the petal. 20xGC-5 is red-purple with a ruby red eye zone surrounded by a spiraea red halo extending to the petal. (GCxBGB)xHP-4 is rhodamine pink with a currant red eye zone and pink vein markings extending to the petal. GCxDS-4 is yellow-orange with a red-purple eye zone surrounded by a spiraea halo extending to the petal. ABAxMDM-1 is neyron rose with a cardinal red eye zone and neyron vein markings. ABAxMDM-3 is orange with a neyron rose eye zone surrounded by a white halo. 23xGC-2 is buttercup yellow with a carmine rose eye zone surrounded by two layers of magenta rose and red-purple halo extending to the petals. CVxNB-1 is scarlet with saturn red edges and a cardinal red eye. CVxNB-2 is spinel red with cadmium orange edges and a red eye zone. CVxNB-6 is carmine rose with Spanish orange edges and a currant red eye zone. CVxMP-4 is neyron rose with a rhodonite red eye zone and white vein markings radiating from the center to the petal.

The height of the hybrids ranged from 1.17-2.87 m, while their width or canopy spread of 0.53-1.50 m classified them as semi-dwarf plants. In addition to the hybrids' desirable floral traits, plant height and width are equally important since they are useful traits for consideration in maintaining a good architecture of the varieties as a potted ornament and a landscaping material. These selected hybrid progenies could be used for variety release. Moreover, the selected hybrids were propagated asexually either by marcotting or air-layering and cleft grafting, propagation methods that will make them breed true-to-type. These methods guarantee the genetic stability of their desirable floral characteristics in succeeding asexual generations.

Results of present study suggest that red could be dominant to yellow as observed in the hybrids of 20xGC, (GCxBGB)xHP, and CVxMP. Majority of the hybrids expressed different hues of red. The study also revealed that yellow could be dominant to white, as observed in the hybrids of GCxDS.

Cluster analysis based on PCA using the first three components, namely PC-I, PC-II and PC-III, grouped the 57 hibiscus hybrid progenies into five different clusters. The dendrogram showed a highly branched structure, suggesting the high degree of variability among the different hibiscus hybrid progenies studied. This high variability suggests that there is a wide window for selection of unique genotypes in the different hybrid progenies evaluated both by PCA and cluster analysis. This information can be used as a basis for selecting specific hybrid progenies for the development into varieties. In addition, for future studies of similar type of research, it is recommended that further quantitative characterization should be performed using morphometric analysis.

ACKNOWLEDGEMENTS

The Hibiscus Breeding Programme is supported by the Office of the former UPLB Chancellor Luis Rey I. Velasco, and the Crop Science Cluster-Institute of Plant Breeding, College of Agriculture and Food Science, University of the Philippines Los Baños. This research paper was based from the project "Mass Production and Propagation of the *Hibiscus rosa-sinensis* 'St. Bridget College' for Beautification Purposes" funded by St. Bridget College, Batangas City (January 2012-June 2013).The authors would like to thank Mr. Marcelino T. Gregorio, Mr. Jessie V. Silverio, Mr. Renato Pabalate, Ms. Maria Fe H. Cayaban and Ms. Juliana A. Balogo for the assistance they provided to this study.

REFERENCES

[AHS] Australian Hibiscus Society. 2004. Hibiscus Growing Guide. 2nd ed. Queensland, Australia: The Australian Hibiscus Society Inc. p. 40.

[AHS] Australian Hibiscus Society. 2007. Hibiscus Growing Guide. 4thed. Queensland, Australia: The Australian Hibiscus Society Inc. p. 42.

Brown JS. 1991. Principal component and cluster analyses of cotton cultivar variability across the US cotton belt. Crop Science. 31(4):915-922.

Brown J, Caligari DS. 2008. An Introduction to Plant Breeding. Oxford: Blackwell Publishing Ltd. p. 209.

Cena RL. 1995. Classification of Cacao Germplasm Using Morphological Characters and Isozyme Analysis [dissertation]. Los Baños, Laguna: University of the Philippines Los Baños.

Dayap FT. 2000. Morphological and isozyme characterization of jackfruit (*Artocarpus heterophyllus* Lam.) collections [dissertation]. Los Baños, Laguna: University of the Philippines Los Baños. p. 118.

Edmonds JM. 1991. The distribution of *Hibiscus* L. section Furcaria in Tropical East Africa. In: Systematic and ecogeographic studies on crop gene pools 6. Rome: International Board for Plant Genetic Resources. p. 60.

Everitt BS, Landau S, Leese M, Stahl D. 2011. Cluster analysis. 5th ed. Oxford: John Wiley and Sons. p. 348.

Howie J. 1980. Hibiscus- Queen of the flowers. 1st ed. Brisbane, Australia.

Ines MBC, Magdalita PM, Dela Viña CD, Dela Cruz Jr FS, Villegas VN. 2009.Randomly Amplified Polymorphic DNA (RAPD) analysis to reveal genetic relationships among pineapple (*Ananas comosus* (L.) Merr.) genotypes. Philippine Journal of Crop Science. 34(3):1-10.

[IRRI] International Rice Research Institute. 2014. Statistical Tool for Agricultural Research Software. Los Baños, Laguna: International Rice Research Institute.

Jackson EJ. 1991. A User's Guide to Principal Components. New York: John Wiley and Sons, Inc. p. 563.

Jacob B, Guennebaud G. [Internet]. 2016. Eigen is a C++ template library for linear algebra: matrices, vectors, numerical solvers, and related algorithms. [updated 2017 Jun 16; cited 2017 Jun 23]. Available from: http://eigen.tuxfamily.org/index.php?title=Main_Page.

Jiang GL. 2013. Molecular markers and marker-assisted breeding in plants. In: Anderson SB, editor. Plant Breeding from Laboratories to Fields. Croatia: InTech. p. 45-83.

Magdalita PM, Gonzales-Lee VRC, Pimentel RB. 2009. *Hibiscus* hybrids Oblation Series: A tribute to outstanding University of the Philippines alumnae for the University Centennial Year. Philippine Journal of Crop Science. 34(1):113-118.

Magdalita PM, Pimentel RB. 2010a. *Hibiscus* Hybrids and Philippines' Women Achievers. National Academy of Science and Technology Philippines. Taguig, Metro Manila: National Academy of Science and Technology Philippines. p. 55.

Magdalita PM, Pimentel RB. 2010b. The Philippine *Hibiscus* hybrids. Los Baños, Laguna: Crop Science Cluster-Institute of Plant Breeding (CSC-IPB), College of Agriculture, University of the Philippines Los Banos (UPLB). p. 71.

Magdalita PM, Gonzales-Lee VRC, Pimentel RB. 2011. Development and horticultural characteristics of *Hibiscus* hybrids "Women in Public Service Series". Philippine Journal of Crop Science. 36(2):56-62.

Magdalita PM, Pimentel RB. 2013. Development of *Hibiscus* hybrids 'Women in Public Service Series II' and propagation studies on *Hibiscus rosa-sinensis* 'Cynthia A. Villar'. Philippine Science Letters. 6(1):39-55.

Magdalita PM, Cayaban MFH, Gregorio MT, Silverio JV. 2016. Development and characterization of nine new *Hibiscus* hybrids. Philippine Journal of Crop Science. 41(2):31-45.

McMullen CK. 1999. Flowering Plants of the Galápagos. New York: Cornell University Press. p. 370.

Mwasiagi JI, Yu CW, Phologolo T, Waithaka A, Kamalha E and Ochola Jr. 2014. Characterization of the Kenyan *Hibiscus sabdariffa* L. (Roselle) bast fibre. Fibres and Textiles in Eastern Europe. 3(105):31-34.

Pimentel RB. 1999. New cultivars and germplasm *Hibiscus* (*Hibiscus rosa-sinensis* L.) Centennial Series. Philippine Agricultural Scientist. 82(2):238-244.

[RHS] Royal Horticultural Society of London. 2007. RHS Colour Chart. 5th ed. Unpublished Standard Reference for Colours. London: Flower Council of Holland.

San Pascual AO. 2015.Phenotypic evaluation and propagation of *Hibiscus* hybrids (*Hibiscus rosa-sinensis* L.) [BS Thesis]. Los Baños, Laguna: Crop Science Cluster, College of Agriculture, University of the Philippines Los Baños. p. 65.

Simpson MG. 2006. Plant Systematics. Netherlands: Elsevier Inc. p. 579.

Sneath PHA, Sokal RR. 1973.Numerical Taxonomy. California: W.H. Freeman.

Stuessy TF. 2009. Plant Taxonomy: The systematic evaluation of comparative data. New York: Columbia University Press. p. 568.

Valdoz JC, Magdalita PM, Absulio WL, Sotto RC. 2017. Morpho-anatomical characters and ethylene production in *Hibiscus rosa-sinensis* L in relation to two-day floral retention. Philippine Agricultural Scientist. 100(2):168-177.

____

Elena May N. Cabarrubias holds a Bachelor of Science in Agriculture (Agronomy) from the University of Philippines Los Baños. She is a former University Research Associate at the Institute of Plant Breeding and at present she is a Research Assistant at the Ecosystems Research and Development Bureau-Department of Environment and Natural Resources. She is an active member of the UP Painters' Club where she participates in various art exhibitions.

Pablito M. Magdalita <pabsmagdalita@gmail.com> holds a PhD degree in Agricultural Science (Plant Breeding and Biotechnology) and a Post-Doctoral training (Plant Genetic Engineering) from the University of Queensland in Brisbane, Australia. He is a Professor I of plant breeding and plant biotechnology and UP Scientist I at the Institute of Crop Science, and project leader of fruit (papaya, banana, avocado, soursop, chico, rambutan, pummelo, etc.) and ornamental (hibiscus, croton, bougainvilla, sampaguita, ixora, etc.) breeding at the Institute of Plant Breeding, College of Agriculture and Food Science, University of the Philippines Los Baños. He was an Outstanding Young Scientist (Plant Breeding) of the National Academy of Science and Technology in the year 2000, the FCSSP Achievement Award for Research in 2011 and Gawad Saka Outstanding Agricultural Scientist-Finalist in 2011, among others.

Norma G. Medina holds a Master of Science degree from the University of Philippines Los Baños. She is an Assistant Professor 2 of ornamental horticulture and Division Head at the Crop Production and Management Division at the Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños. Also, she is involved as project staff in various projects such as edible landscaping, utilization of landscape organic waste materials and commercialization of indigenous and endemic plants.

Antonio G. Lalusin holds a PhD degree in Bioresource Engineering from the University of Tsukuba in Japan. He is an Associate Professor 5 in conventional and molecular plant breeding at the Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños. Also, he is a project leader in the varietal improvement of feeds and industrial crops (cassava, abaca, sugarcane, coconut and sweet potato) using conventional and biotechnology-assisted techniques. He was a recipient of the Outstanding Young Scientist Award (Genetics and Plant Breeding) of the National Academy of Science and Technology in 2009 and, the FCSSP Achievement Award for Teaching in 2007, among others.