GMR Genetics and Molecular Research
Online Journal
ISSN:1676-5680

Heliconia phenotypic diversity based on qualitative descriptors

W.N.R. Guimarães[1], L.S.S. Martins[1], C.E.F. Castro[2], J.L.S. Carvalho Filho[3] and V. Loges[3]

[1]Departamento de Biologia, Área de Genética,
Universidade Federal Rural de Pernambuco, Recife, PE, Brasil
[2]Instituto Agronômico de Campinas, Campinas, SP, Brasil
[3]Departamento de Agronomia, Área de Fitotecnia,
Universidade Federal Rural de Pernambuco, Recife, PE, Brasil

Corresponding author: W.N.R. Guimarães
E-mail: walmalamo@gmail.com

Genet. Mol. Res. 13 (2): 3128-3142 (2014)
Received March 26, 2013
Accepted December 4, 2013
Published April 17, 2014
DOI http://dx.doi.org/10.4238/2014.April.17.9

ABSTRACT. The aim of this study was to characterize *Heliconia* genotypes phenotypically using 26 qualitative descriptors. The evaluations were conducted in five flowering stems per clump in three replicates of 22 *Heliconia* genotypes. Data were subjected to multivariate analysis, the Mahalanobis dissimilarity measure was estimated, and the dendrogram was generated using the nearest neighbor method. From the values generated by the dissimilarity matrix and the clusters formed among the *Heliconia* genotypes studied, the phenotypic characterizations that best differentiated the genotypes were: pseudostem and wax green tone (light or dark green), leaf-wax petiole, the petiole hair, cleft margin at the base of the petiole, midrib underside shade of green, wax midrib underside, color sheet (light or dark green), unequal lamina base, torn limb, inflorescence-wax, position of inflorescence, bract leaf in apex, twisting of the rachis, and type of bloom. These results will be applied in the preparation of a catalog for *Heliconia* descriptors, in the selection of different genotypes with most

promising characteristics for crosses, and for the characterization of new genotypes to be introduced in germplasm collections.

Key words: Phenotypic characterization; Germplasm collections; Plant morphology; Heliconiaceae; Dendrogram

INTRODUCTION

Heliconia plants are found in all tropical regions around the world. The economic importance of the *Heliconia* genus relies on its cultivation as an ornamental plant, which is used either as cut flowers or as garden and potted plants. In northeast Brazil, especially under the rainforest conditions in the State of Pernambuco, these plants have increased their production and most genotypes bloom throughout the year (Costa et al., 2007). This genus has great potential to be exploited in the international flower market by adjusting the quality of its products to international requirements, which can be achieved through genetic breeding programs.

In this context, germplasm characterization is a fundamental, quick, and affordable tool in the study of genetic diversity. Characterization consists of obtaining data that can be used to describe, identify, and differentiate genotypes within species, classes, or categories (de Vicente et al., 2005). In genetic terms, characterization can also refer to the detection of variation that results from differences in DNA sequences or specific genes. In phenotypic terms, characterization refers to describing the genetic diversity that is under environmental influence.

A germplasm represents the collection of genotypes, composed of any material that constitutes the physical basis of inheritance of a species, that are transmitted from one generation to another (IPGRI, 2001). Thus, germplasm characterization can be conducted using different methods, ranging from practices that involve the use of a list of morphological and agronomic descriptors to biochemical applications for detecting differences between isozymes, proteins, and molecular markers (de Vicente et al., 2005).

A descriptor is the term used to refer to an attribute or character that is observed or measured within genotypes of a germplasm collection (Cruz and Carneiro, 2003). Descriptors related to plant morphology have been employed in these collections for the determination of phenotypic diversity; i.e., the genetic diversity under the influence of the environment. The nature of these descriptors is usually multi-categorical and qualitative, related to plant structural features and morphology, or even qualitative binary when referring to the absence or presence of a certain characteristic.

Morphological descriptions have been used to differentiate some *Heliconia* cultivars and interspecific hybrids (Berry and Kress, 1991). Since the *Heliconia* genus was originally included in the Musaceae family (Cronquist, 1981), qualitative descriptors used in *Musa* spp germplasm (Silva et al., 1999) can be adapted to describe *Heliconia* genotypes. Some studies have been developed with the use of botanical, morphological, and agronomic descriptors of both quantitative and qualitative natures, or through the estimation of genetic parameters, which has contributed knowledge of the *Heliconia* germplasm (Criley, 2000; Castro et al., 2006, 2007; Loges et al., 2007; Costa et al., 2009a,b; Rocha et al., 2010).

The establishment and maintenance of a *Heliconia* germplasm collection is important for science and technology as well as for social and economic development, because it

extends the possibilities of genotype exchanges between researchers (Castro, 2010). Furthermore, many genotypes are not under the protection of germplasm collection, which indicates a need to increase efforts to conserve *Heliconia* diversity. However, germplasm collections often store a large number of genotypes that need to be characterized.

The aim of this study was to phenotypically characterize *Heliconia* genotypes using 26 qualitative descriptors.

MATERIAL AND METHODS

Experimental design

The 22 genotypes evaluated were obtained through exchanges with research institutions and farmers from the States of Pernambuco (PE), Alagoas (AL), and São Paulo (SP) in Brazil (Table 1). Genotypes were planted in January 2007 in the Federal Rural University of Pernambuco's *Heliconia* Germplasm Collection (UFRPE-HCG) located in Camaragibe-PE at 8°1'19" S, 34°59'33" W, and 100 m above sea level, in a 0.3-ha experimental area. The average annual temperature of the region is 25.1°C, and monthly rainfall is 176 mm, with a maximum of 377 mm and a minimum of 37 mm (ITEP, 2008).

Soil management and NPK fertilization were undertaken in the experimental area, according to the soil analysis, by using 72 g/clump ammonium sulfate, 12 g/clump simple superphosphate, and 16 g/clump potassium chloride. Every three months, fertilization was complemented with 72 g/clump ammonium sulfate, 16 g/clump potassium chloride, and 13 kg/clump cattle manure. Mechanical weeding was performed in the period before flowering. A randomized block design was used with three replications per genotype. The plant spacing was 3.0 m between plants in the row and 4.0 m between rows. Irrigation was applied when needed by a sprinkling irrigation system using 2.5 m high gun sprinklers.

Qualitative descriptors

The evaluation started three months after planting the rhizomes. Five shoots of each of the three clumps per genotype were marked when they reached up to 15 cm tall. In the period from 2007 to 2008, five flowering stems per genotype were evaluated for the descriptors of the pseudostem, leaves, and inflorescences. These descriptors were elaborated according to previous *Heliconia* studies (Loges et al., 2007; Costa et al., 2009b), and were also based on the catalog of *Musa* spp descriptors (Silva et al., 1999), with modifications to accommodate the typical *Heliconia* morphological features observed, as described below:

Pseudostem

1 - pseudostem surface (shade of green): 1 ( ) pale; 2 ( ) yellow; 3 ( ) clear; 4 ( ) dark

2 - wax: 1 ( ) presence; 2 ( ) absence

3 - hair: 1 ( ) presence; 2 ( ) absence

4 - plant height: 1 ( ) short, less than 1.50 m; 2 ( ) medium, 1.51 to 2.50 m mean; 3 ( ) tall, more than 2.50 m

Table 1. Genotypes evaluated in the Federal Rural University of Pernambuco *Heliconia* Germplasm Collection (UFRPE-HCG).

Genotypes[1]	Subgenus e ection[2]	Description[3]
H. bihai (L.) L.	*Heliconia* *Heliconia*	Large, upright inflorescences in a single plane; Bract color Red
H. bihai (L.) L. cv. Kamehameha	*Heliconia* *Heliconia*	Large, upright inflorescences in a single plane; Bract color Red Yellow
H. caribaea Lamark x *H. bihai* (L.) L. cv. Carib Flame	-	Large, pendant inflorescence single plane; Bract color Red
H. collinsiana Griggs	*Griggsia* *Pendulae*	Large; Inflorescence pending in more than one plan; Bract color Red
H. episcopalis Vellozo	*Heliconia* *Episcopales*	Medium-size erect inflorescences; Bract color Orange-Yellow
H. latispatha Benth. cv. Red-Yellow Gyro	*Heliconia* *Tortex*	Medium-size Inflorescence erect more than one plan; Bract color Orange
Heliconia x nickeriensis Maas and deRooij	*Heliconia* *Pendulae*	Small, erect inflorescences; Bract color Orange-Yellow
H. psittacorum L.f x *H. spathocircinata* cv. Golden Torch Adrian	*Heliconia*	Small, erect inflorescences in a single plane; Bract color Yellow-Red
H. psittacorum L. x *H. spathocircinata* cv. Golden Torch	*Heliconia*	Small, erect inflorescences in a single plane; Bract color Yellow
H. psittacorum L.f x *H. spathocircinata* cv. Alan Carle	*Heliconia*	Small, erect inflorescences in a single plane; Bract color Yellow-Orange
H. psittacorum L. x *H. spathocircinata* cv. Red Opal	*Stenochlamys* *Stenochlamys*	Small, erect inflorescences in a single plane; Bract color Orange
H. psittacorum L. cv. Red Gold	*Stenochlamys* *Stenochlamys*	Small, erect inflorescences in a single plane; Bract color Yellow-Orange
H. psittacorum L. cv. Strawberries and Cream	*Stenochlamys* *Stenochlamys*	Small, erect inflorescences in a single plane; Bract color Rose-Yellow
H. psittacorum L. cv. Suriname Sassy	*Stenochlamys* *Stenochlamys*	Small, erect inflorescences in a single plane; Pink Bract color green with wax
H. pseudoaemygdiana Emygdio and Santos	*Stenochlamys* *Lanea*	Medium-size erect inflorescences; Bract color Yellow
H. rostrata Ruiz and Pavón (10 days postharvest)	*Griggsia* *Rostratae*	Medium-size pendant inflorescence single plane; Bract color Red; seasonal
H. rostrata Ruiz and Pavón (3 days postharvest)	*Griggsia* *Rostratae*	Medium-size; pendant inflorescence single plane; Bract color Red; annual
H. rostrata Ruiz and Pavón	*Griggsia* *Rostratae*	Medium-size pendant inflorescence single plane; Bract color Red; annual
H. orthotricha Andersson cv. She	*Heliconia* *Heliconia*	Small, erect inflorescences in a single plane; Bract color Red
H. stricta Huber	*Heliconia* *Heliconia*	Large, upright inflorescences in a single plane; Bract color Red-Orange
H. stricta Huber cv. Fire Bird	*Heliconia* *Heliconia*	Large, upright inflorescences in a single plane; Bract color Red
H. wagneriana Peter	*Heliconia* *Heliconia*	Large, upright inflorescences in a single plane; Bract color Yellow-Orange

[1]Identification of genotypes based on Berry and Kress (1991); [2]Based on Kress et al. (1993); [3]Description proposed by Loges et al. (2007) and Costa et al. (2009a).

Leaf

5 - leaf underside green color: 1 ( ) pale; 2 ( ) yellow; 3 ( ) clear; 4 ( ) dark

6 - leaf upper side green color: 1 ( ) pale; 2 ( ) yellow; 3 ( ) clear; 4 ( ) dark

7 - reddish main vein leaf underside green color (antocianin presence): 1 ( ) very colorful; 2 ( ) rather colorful, average; 3 ( ) not colored

8 - reddish main vein leaf upper side green color (antocianin presence): 1 ( ) very colorful; 2 ( ) rather colorful, average; 3 ( ) not colored

9 - leaf margin color: 1 ( ) dark purple; 2 ( ) light purple; 3 ( ) absence

10 - leaf position: 1 ( ) erect; 2 ( ) pending; 3 ( ) arcade

11- dorsal wax: 1 ( ) a lot; 2 ( ) average; 3 ( ) low; 4 ( ) missing

12 - ventral wax: 1 ( ) a lot; 2 ( ) average; 3 ( ) low; 4 ( ) missing

13 - dorsal hair: 1 ( ) a lot; 2 ( ) average; 3 ( ) low; 4 ( ) missing

14 - ventral hair: 1 ( ) a lot; 2 ( ) average; 3 ( ) low; 4 ( ) missing

15 - leaf margins width (aid of calipers or tape measure)

16 - presence of leafblade stain: 1 ( ) spots rare; 2 ( ) a few spots; 3 ( ) unstained

17 - comparison of the base of the leafblade dimensions: (1) equal; 2 ( ) unequal; 3 ( ) variable in the same plant

18 - leafblade base form: 1 ( ) both bases abrupt; 2 ( ) both bases tapered; 3 ( ) abrupt and tapered base

19 - leafblade: 1 ( ) ripped (in genotype *H. rostrata*), 2 ( ) not ripped

20 - base of the petiole form: 1 ( ) winged with wrinkles; 2 ( ) winged without wrinkles; 3 ( ) not winged; 4 ( ) closed

21 - margins base: 1 ( ) very cleft; 2 ( ) cleft bit; 3 ( ) not cleft

22 - petiole margin shape: 1 ( ) wide open; 2 ( ) slightly open; 3 ( ) somewhat closed; 4 ( ) closed

23 - leaf arrangement (field assessment): 1 ( ) musoide; 2 ( ) zingiberoide; 3 ( ) canoide.

Peduncle and inflorescence

24 - angle of first bract in relation to peduncle: 1 ( ) > 90°; 2 ( ) 75-90°; 3 ( ) 45-60°; 4 ( ) 15-30°; 5 ( ) 0°

25 - angle of 1st bract in relation to rachis: 1 ( ) > 90°; 2 ( ) 75-90°; 3 ( ) 45-60°; 4 ( ) 15-30°; 5 ( ) 0°

26 - bract with leaf at the end: 1 ( ) presence; 2 ( ) absence

27 - bract apex shape: 1 ( ) large (bowed); 2 ( ) narrow; 3 ( ) tapered

28 - wax: 1 ( ) a lot; 2 ( ) average; 3 ( ) low; 4 ( ) absent

29 - hair: 1 ( ) a lot; 2 ( ) average; 3 ( ) low; 4 ( ) absent

30 - inflorescence position in relation to stem: 1 ( ) erect; 2 ( ) pending

31 - length of the second bract (aid of calipers)

32 - width of the second bract (aid of calipers)

33 - number of bracts: inflorescence mature, i.e., pointer with two bracts open

34 - bracts outer color: different among cultivars

35 - bracts inner color: different among cultivars

36 - rachis color: different among cultivars
37 - rachis twist: 1 ( ) presence; 2 ( ) absence
38 - rachis stiffness: 1 ( ) presence; 2 ( ) absence
39 - perianth base color: 1 ( ) white; 2 ( ) cream; 3 ( ) yellow
40 - presence of anthocyanin on perianth: 1 ( ) at the baseline; 2 ( ) presence of stripes; 3 ( ) uniform color; 4 ( ) missing
41 - sepal color
42 - petal color
43 - ovary color, immature fruit
44 - presence of pollen: 1 ( ) presence; 2 ( ) absence
45 - blooming period: 1 ( ) short (< 5 months); 2 ( ) average (5 < months < 8); 3 ( ) long (> 8 months)

From this list, 26 qualitative descriptors were selected to phenotypically characterize the *Heliconia* genotypes. For these descriptors, classes were assigned as absence (0) and presence (1), or other contrasting classes, such as light green and dark green, annual and seasonal, upright and pendent, or equal and unequal (Table 2).

Table 2. Qualitative descriptors related to the pseudostem, leaf and inflorescence from genotypes of the Federal Rural University of Pernambuco *Heliconia* Germplasm Collection (UFRPE-HCG).

Descriptors	Code	Categories	
		0	1
Pseudostem			
Pseudostem of dark green color**	PDG	Absence	Presence
Wax*	PW	Absence	Presence
Hair*	PH	Absence	Presence
Leaf		Absence	Presence
Wax in the petiole**	WP	Absence	Presence
Hair on petiole**	HP	Absence	Presence
Base of the petiole winged**	BPW	Absence	Presence
Basal margin of the petiole cleft**	BMP	Absence	Presence
Open edge of the petiole**	OEP	Absence	Presence
Midrib underside shade of green**	MUG	Absence	Presence
Midrib upper shade of green**	MUSG	Absence	Presence
Wax midrib underside**	WMU	Absence	Presence
Midrib underside hair**	MUH	Absence	Presence
Leaf hair*	LH	Absence	Presence
Wax leaves*	WH	Absence	Presence
Dark green leaf color	DGC	Absence	Presence
Margin of leaves shade of purple**	MLP	Absence	Presence
Leafblade dark**	LD	Absence	Presence
Leafblade uneven bases**	LUB	Absence	Presence
Cut leafblade**	CLB	Absence	Presence
Inflorescence		Absence	Presence
Wax*	WI	Absence	Presence
Inflorescence position pending*	IP	Absence	Presence
Bract leaf at the apex	BLA	Absence	Presence
Hair in the bracts**	HB	Absence	Presence
Torsion of the rachis	TR	Absence	Presence
Stiffness of the rachis	SR	Absence	Presence
Type of seasonal blooming*	TSB	Absence	Presence

*Description proposed by Loges et al. (2007) and Costa et al. (2009b). **Description based on the catalog of *Musa* spp descriptors, with modifications.

Data analysis

Multivariate analyses were performed to estimate the Mahalanobis dissimilarity measure, and a dendrogram was generated using the nearest neighbor method with the program Genes, 2004 version (Cruz, 2006).

RESULTS AND DISCUSSION

Qualitative descriptors

Differences were observed in most of the 26 qualitative descriptors used among the UFRPE-HCG genotypes sampled.

Pseudostem

With respect to the descriptors related to the pseudostem, the vegetative part of the plant that is usually cylindrical and is formed by numerous overlapping leaf sheaths, the shade of dark green varied among genotypes in the outer pseudostem. This variation was classified as a shade of dark green (PDG), being present in *H. rostrata* (Figure 1A), *H. collinsiana*, *H. psittacorum* x *H. spathorcircinata* cv. Alan Carle, *H. bihai* cv. Kamehameha, *H. bihai*, *H. stricta*, *H. stricta* cv. Fire Bird, and *H. caribaea* x *H. bihai* cv. Carib Flame. With respect to the pseudostem wax (PW), *H. psittacorum* cv. Suriname Sassy (Figure 1B) was the only genotype among all cultivars and interspecific hybrids of *H. psittacorum* to present this descriptor. In other genotypes (*H. wagneriana*, *H. collinsiana*, *H. bihai*, *H. latispatha* cv. Red Yellow, and *H. caribaea* x *H. bihai* cv. Carib Flame), the presence of PW was remarkable. Hair in pseudostem (PH) was observed only in *H. orthotricha* cv. She (Figure 1C).

A B C

Figure 1. Descriptors evaluated in *Heliconia* pseudostem. **A.** Pseudostem of dark green color - PDG (*H. rostrata*). **B.** Pseudostem wax - PW (*H. psittacorum* cv. Suriname Sassy). **C.** Pseudostem hair - PH (*H. orthotricha* cv. She).

Leaf

With respect to the leaves, the combinations of the petiole, leafblade, and appendices

were considered. The presence of wax was verified in the petiole (WP) (Figure 2A) in *H. wagneriana*, *H. collinsiana*, *H. bihai*, *H. caribaea* x *H. bihai* cv. Carib Flame, and *H. latispatha* cv. Red Yellow. Purple was observed in the margin of leaves (MLP) in all genotypes (Figure 2B), with the exception of *H.* x *nickeriensis* (Figure 2C). This result corroborated with the fact that its likely parent, *H. marginata*, also did not present this descriptor (Figure 2C). Wax on leaves (WH) was observed in *H. collinsiana* (Figure 2D) and the dark green leaf color (DGC) was observed in *H. rostrata* (Figure 2E).

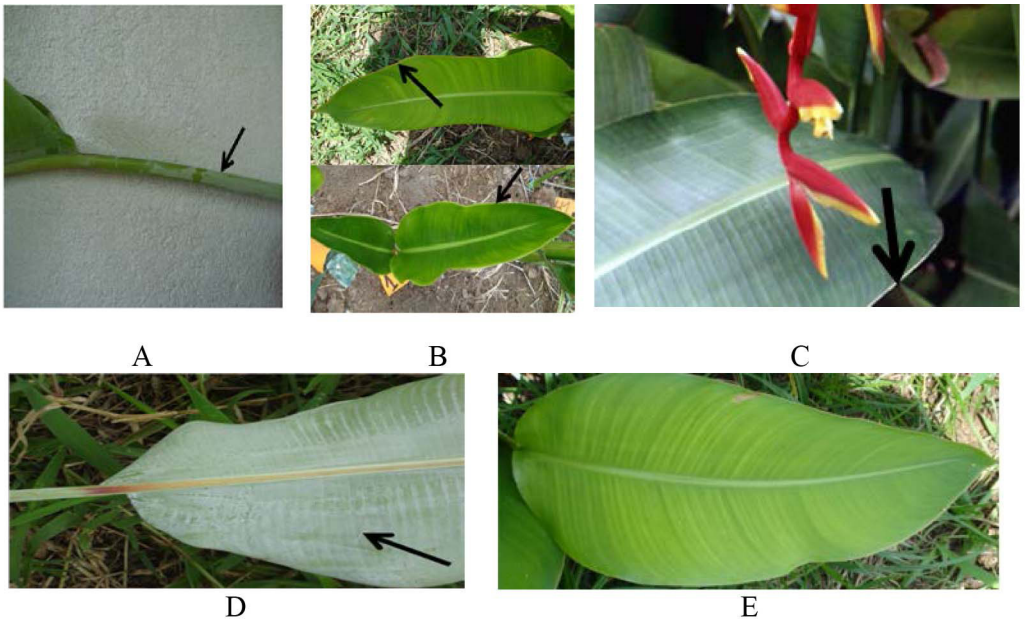

Figure 2. Descriptors evaluated in *Heliconia* leaf. **A.** Wax on the petiole - CEP (*H. collinsiana*). **B.** Presence of the margin of leaves shade of purple - COM, top arrow (*H. psittacorum* cv. Red Gold) and absence of the margin of leaves shade of purple (*H.* x *nickeriensis*), lower arrow. **C.** Absence of the margin of leaves shade of purple (*H. marginata*). **D.** Wax leaves - CEF (*H. collinsiana*). **E.** Dark green leaf color - COF (*H. rostrata*).

The base of the petiole near the pseudostem may have a membranous expansion in its upper part, called the base of the petiole winged (BPW) (Figure 3A). With respect to the descriptor hair on petiole (HP), it was observed that most of the genotypes did not show this character, except for *H. wagneriana*, *H. collinsiana*, *H. orthotricha* cv. She, and *H. latispatha* cv. Red-Yellow Gyro. The outside of the basal margin of the petiole cleft (BMP) (Figure 3B) was observed in *H. rostrata*, *H. bihai*, *H. stricta*, *H. bihai* cv. Kamehameha, *H. stricta* cv. Fire Bird, *H. psittacorum* x *H. spathocircinata* cv. Red Opal, and *H. orthotricha* cv. She. Remarkably, *H. orthotricha* cv. She and *H. latispatha* cv. Red-Yellow Gyro were the only genotypes to present hair on the underside of the midrib (MUH). *H. latispatha* cv. Red-Yellow Gyro was the only genotype to present leaf hair (LH) (Figure 3C).

The external deposition of anthocyanin on the top surface of the leaf is typical in some species, although the distribution of this substance is not uniform. As for the descriptors midrib underside shade of green (MUG) and the midrib upper shade of green (MUSG), it was

observed that the genotypes *H. episcopalis*, *H. bihai*, and *H. stricta* showed the former descriptor, while only *H. wagneriana* (Figure 4A) did not show the latter descriptor. *H. collinsiana* and *H. caribaea* x *H. bihai* cv. Carib Flame presented the wax midrib underside descriptor (WMU). The descriptor leafblade uneven base (LUB) was observed in most genotypes (Figure 4B), except for *H. wagneriana*, *H. collinsiana*, *H. bihai*, *H. stricta*, *H. stricta* cv. Fire Bird, and *H. psittacorum* x *H. spathocircinata* cv. Red Opal. The descriptor cut leafblade (CLB) was observed in *H. wagneriana*, *H. collinsiana*, and *H. latispatha* cv. Red-Yellow Gyro (Figure 4C).

A B C

Figure 3. Descriptors evaluated in *Heliconia* leaf. **A.** Base of the petiole winged - BPA (*H. collinsiana*). **B.** Basal margin of the petiole cleft - MPE (*H. stricta* cv. Fire Bird). **C.** Leaf hair - PIF (*H. latispatha* cv. Red-Yellow Gyro).

A B C

Figure 4. Descriptors evaluated in *Heliconia* leaf. **A.** Midrib upper shade of green - NFS (*H. wagneriana*). **B.** Leafblade uneven bases - BLB (*H. psittacorum* x *H. spathocircinata* cv. Red Opal). **C.** Cut leafblade - LIB (*H. collinsiana*).

None of the genotypes showed either open edge of the petiole (OEP) or leafblade dark (LD), indicating that these descriptors are not useful for differentiating the *Heliconia* genotypes evaluated, although these descriptors do occur in other species of the genus (Loges et al., 2007).

Inflorescence

Heliconia inflorescences are composed of arranged bracts on an axis called the rachis,

and its flowers are inserted inside these bracts. The descriptor wax on inflorescences (WI) (Figure 5A) was only evident in *H. collinsiana* and *H. psittacorum* cv. Suriname Sassy. *H. orthotricha* cv. She stood out in group II as the only genotype to show hair on the bracts (HB) (Figure 5B). *H. episcopalis*, *H. psittacorum* cv. Red Gold, *H. latispatha* cv. Red-Yellow Gyro, and *H. orthotricha* cv. She presented bract leaf at the apex (BLA) (Figure 5C and D). Regarding the descriptor seasonal blooming (TSB), most of the genotypes presented the annual type, which means that they bloom throughout the year. The genotypes *H. wagneriana*, *H. bihai* cv. Kamehameha, *H. rostrata* '10 days', *H. collinsiana, H. orthotricha* cv. She, and *H. caribaea* x *H. bihai* cv. Carib Flame presented seasonal blooming. Four genotypes, *H. rostrata*, *H. rostrata* '3 days', *H. rostrata* '10 days', and *H. collinsiana* had the descriptor inflorescence position pending (IP). Finally, with respect to torsion of the rachis (TR), four genotypes, *H. pseudoaemygdiana*, *H. bihai* cv. Kamehameha, *H. psittacorum* cv. Red Gold, and *H. latispatha* cv. Red-Yellow Gyro, presented this descriptor. It was observed that all genotypes presented stiffness of the rachis (SR).

A B C D

Figure 5. Descriptors evaluated for *Heliconia* inflorescence. **A.** Wax inflorescence - CEI (*H. psittacorum* cv. Suriname Sassy). **B.** Hair in the bracts (PIB) (*H. orthotricha* cv. She). **C.** Bract leaf at the appex (*H. episcopalis*). **D.** Bract leaf at the appex (*H. latispatha* cv. Red-Yellow Gyro).

Qualitative descriptors of the flowering stem that best differentiated the genotypes were: pseudostem dark green color (PDG) and wax (PW); wax in the petiole (WP), petiole hair (HP), basal margin of the petiole cleft (BMP); midrib underside shade of green (MUG), wax midrib underside (WMU), dark green leaf color (DGC), leafblade uneven bases (LUB), and cut leafblade (CLB); inflorescence wax (WI), inflorescence position pending (IP), bract leaf at the apex (BLA), torsion of the rachis (TR), and type of seasonal blooming (TSB).

Although other qualitative descriptors related to the leaf were not relevant in differentiating the 22 evaluated *Heliconia* genotypes, such as midrib upper shade of green (MUSG), midrib underside hair (MUH), leaf hair (LH), wax leaves (WH), margin of leaves shade of purple (MLP), open edge of the petiole (OEP), leafblade dark (LD), and stiffness of the rachis (SR), these can nonetheless be suggested for an extended list of *Heliconia* descriptors because they are known to occur in other species.

In general, qualitative descriptors of the flowering stem are an important tool in measuring the variability of the genus *Heliconia*, since the results can be applied in the preparation of a catalog that may promote the best understanding of the economic potential of *Heliconia* germplasm collections, saving time, and providing research material, as well as contributing valuable information for the conservation and breeding of this genus.

Phenotypic diversity

A dissimilarity matrix was generated from the values attributed (Table 3) to contrasting classes of *Heliconia* qualitative descriptors (Table 4). The greatest dissimilarity rate was 90% between the most genetically distant genotypes *H. pseudoaemygdiana* and *H. psittacorum* cv. Red Gold. The lowest dissimilarity rate was 17% for genotypes *H. wagneriana* and *H. rostrata*, indicating that they are genetically the closest among the studied genotypes.

Based on this matrix data and using the hierarchical nearest neighbor method, the dendrogram was generated, in which the x-axis depicts the percentage of the distance between the genotypes and the y-axis depicts the 22 genotypes (Figure 6). The dendrogram revealed two main groups (GI and GII). Group GI was composed only by *H. psittacorum* cv. Suriname Sassy. Group GII, the most representative, was formed by the other genotypes. GII was further divided into three subgroups (SG1, SG2, and SG3). The other genotypes that appeared to be isolated in the tree were: *H. psittacorum* cv. Strawberries and Cream, *H. stricta* cv. Fire Bird, *H. orthotricha* cv. She, *H. caribaea* x *H. bihai* cv. Carib Flame, and *H. latispatha* cv. Red-Yellow Gyro.

In group GII, *H. orthotricha* cv. She formed an isolated group in the dendrogram, and it was also the only genotype to show hair in pseudostem (PH) and hair in the bracts (HB).

In subgroup SG1, genotypes *H. wagneriana*, *H. rostrata*, *H. rostrata* '10 days', *H. rostrata* '3 days', *H. psittacorum* x *H. spathocircinata* cv. Alan Carle, and *H. bihai* cv. Kamehameha all showed erect inflorescences on the same plane, predominant red color in the bracts (Loges et al., 2007; Costa et al., 2009b), and belong to the *Heliconia* subgenus and *Heliconia* section (Kress et al., 1993). It is noteworthy that the presence of the following qualitative descriptors were observed in these genotypes: hair in pseudostem (PH); midrib underside shade of green (MUG), hair on the underside of the midrib (MUH), margin of the leaves shade of purple (MLP), leaf hair (LH), and wax leaves (WH); bract leaf at the apex (BLA), and wax (CIS).

In subgroup SG2, the genotypes *H. collinsiana*, *H. episcopalis*, *H. pseudoaemygdiana*, and *H. psittacorum* formed a group, along with cultivars and interspecific hybrids such as cv. Golden Torch, cv. Golden Torch Adrian, cv. Red Gold, cv. Red Opal and *H.* x *nickeriensis*, which were all characterized by predominant yellow in their bracts (Loges et al., 2007). These genotypes showed the following qualitative descriptors: hair in pseudostem (PH); base of the petiole winged (BPW), midrib upper shade of green (MUSG), midrib underside hair (MUH), and leaf hair (LH).

Subgroup SG3 was composed of *H. bihai* and *H. stricta*, which were both characterized by large, upright inflorescence on a single plane and red color bracts (Loges et al., 2007; Costa et al., 2009b), and they both belong to the *Heliconia* subgenus and *Heliconia* section (Kress et al., 1993). Only two qualitative descriptors were not common between these two genotypes: wax pseudostem (PW) and dark green leaf color (DGC).

The results showed that the use of qualitative descriptors with the application of multicategorical variables assessed by the hierarchical nearest neighbor method was adequate to study the phenotypic diversity among *Heliconia* genotypes. These results will be applied for the preparation of a catalog for this culture, for the selection of different genotypes with characteristics most promising for crosses, and for characterization of new genotypes introduced in germplasm collections.

Table 3. Values of the qualitative descriptors for genotypes of the Federal Rural University of Pernambuco *Heliconia* Germplasm Collection (UFRPE-HCG).

	Descriptors																								
	Pseudostem			Leaf															Inflorescence						
	PDG	PW	PH	WP	HP	BPW	BMP	OEP	MUG	MUSG	WMU	MUH	MLP	LD	DGC	LH	WH	LUB	CLB	BLA	TSB	WI	IP	HB	TR
H. wagneriana	0	1	0	1	1	1	0	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	0	0	0
H. rostrata	1	0	0	1	0	0	1	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0
H. rostrata (3 days)	0	0	0	1	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0
H. psittacorum x *H. spathorcircinata* cv. Alan Carle	1	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
H. bihai cv. Kamehameha	1	0	0	0	0	1	1	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1
H. rostrata (10 days)	0	0	0	0	0	1	0	0	1	1	0	0	1	0	1	0	0	1	0	0	1	0	1	1	0
H. collinsiana	1	1	0	1	1	1	0	0	1	1	1	0	1	0	1	0	1	0	1	0	1	1	1	1	0
H. psittacorum x *H. spathorcircinata* cv. Golden Torch	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Heliconia x *nickeriensis*	0	0	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
H. psittacorum cv. Red Gold	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1
H. episcopalis	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0
H. pseudoaemygdiana	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1
H. psittacorum x *H. spathorcircinata* cv. Red Opal	0	0	0	0	0	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
H. psittacorum x *H. spathorcircinata* cv. Golden Torch Adrian	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
H. bihai	1	1	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
H. stricta	1	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
H. psittacorum cv. Strawberries and Cream	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0
H. stricta cv. Fire Bird	1	0	0	0	0	1	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
H. orthotricha cv. She	0	0	1	0	1	1	1	0	1	1	0	1	1	0	0	1	0	1	0	1	1	0	0	1	0
H. caribaea x *H. bihai* cv. Carib Flame	1	1	0	1	0	1	0	0	1	1	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0
H. latispatha cv. Red-Yellow Gyro	0	1	0	1	1	1	1	0	1	1	0	1	1	0	1	0	0	1	1	1	0	1	0	0	1
H. psittacorum cv. Suriname Sassy	0	1	0	1	0	1	0	0	1	1	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0

For abbreviations, see Table 2.

Table 4. Matrix of genetic dissimilarity among 22 genotypes of the Federal Rural University of Pernambuco *Heliconia* Germplasm Collection (UFRPE-HCG).

Genotypes	cv. GoAd	cv. Alan	cv. Straw	cv. Surin	cv. RedOp	*H. pseu*	cv. RedG	*H.* x *nick*	cv. RedYe	*H. ortho*	*H. rost10*	*H. rost3*	*H. wagne*	cv. Kame	cv. FireBi	*H. episco*	*H. collin*	*H. rost*	cv. Carib	*H. stricH*	cv. GolT	*H. bihai*
cv. GoAd																						
cv. Alan	0.818																					
cv. Straw	0.909	0.750																				
cv. Surin	0.692	0.571	0.642																			
cv. RedOp	0.666	0.538	0.615	0.571																		
H. pseu	0.909	0.750	0.833	0.642	0.615																	
cv. RedG	0.833	0.692	0.769	0.600	0.571	0.916																
H. x *nick*	0.727	0.583	0.666	0.750	0.583	0.666	0.615															
cv. RedYe	0.473	0.400	0.450	0.578	0.400	0.526	0.578	0.421														
H. ortho	0.555	0.473	0.611	0.428	0.473	0.526	0.578	0.421	0.565													
H. rost10	0.500	0.500	0.562	0.444	0.333	0.470	0.444	0.437	0.333	0.454												
H. rost3	0.571	0.571	0.642	0.500	0.375	0.533	0.500	0.400	0.363	0.428	0.733											
H. wagne	0.333	0.263	0.315	0.529	0.411	0.315	0.300	0.352	0.523	0.333	0.272	0.238										
cv. Kame	0.600	0.714	0.562	0.444	0.500	0.666	0.625	0.437	0.454	0.523	0.555	0.444	0.272									
cv. FireBi	0.500	0.615	0.466	0.437	0.615	0.466	0.437	0.428	0.380	0.380	0.470	0.437	0.315	0.562								
H. episco	0.750	0.615	0.692	0.642	0.500	0.692	0.769	0.666	0.526	0.526	0.470	0.437	0.315	0.470	0.466							
H. collin	0.260	0.318	0.304	0.347	0.260	0.250	0.240	0.217	0.423	0.321	0.500	0.409	0.571	0.375	0.428	0.250						
H. rost	0.437	0.533	0.500	0.388	0.352	0.411	0.388	0.294	0.347	0.409	0.588	0.785	0.173	0.500	0.500	0.333	0.391					
cv. Carib	0.500	0.600	0.470	0.529	0.333	0.470	0.444	0.352	0.391	0.391	0.555	0.529	0.400	0.647	0.470	0.388	0.571	0.500				
H. stricH	0.466	0.571	0.437	0.411	0.571	0.437	0.411	0.400	0.363	0.363	0.444	0.333	0.300	0.625	0.769	0.533	0.409	0.388	0.444			
cv. GolT	0.900	0.727	0.818	0.750	0.727	0.818	0.750	0.800	0.421	0.500	0.437	0.500	0.352	0.533	0.428	0.666	0.217	0.375	0.437	0.400		
H. bihai	0.466	0.571	0.437	0.411	0.571	0.437	0.411	0.312	0.363	0.363	0.368	0.333	0.300	0.625	0.642	0.437	0.409	0.388	0.529	0.846	0.400	

For the complete names of genotypes, see Table 3.

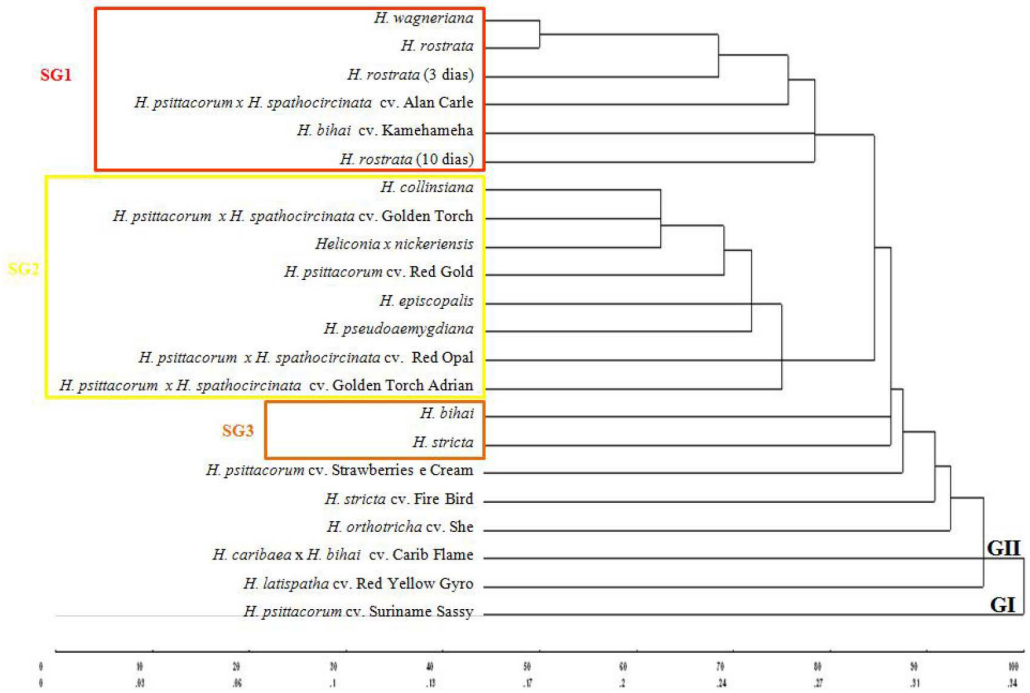

Figure 6. Dendrogram of genetic dissimilarity among the 22 genotypes of the Federal Rural University of Pernambuco Heliconia Germplasm Collection (UFRPE-HCG), using hierarchical method of the nearest neighbor. SG1 = subgroup 1; SG2 = subgroup 2; SG3 = subgroup 3.

ACKNOWLEDGMENTS

The authors thank the National Council of Scientific and Technological Development (CNPq) and the Coordination for the Improvement of Higher Education (CAPES) for a scholarship granted to W.N.R. Guimarães, the BNB for financial support, the Bem-Te-Vi Farm, the RECIFLORA association, and trainees of the UFRPE Floriculture Laboratory.

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