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# Morphological Characterization in Wild Species of *Heliconias* (*Heliconia* spp) in Mexico

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## Abstract

In Mexico, the utilization of native *heliconias* germplasm for preservation and genetic improvement purposes, has been limited partly because of the unawareness between their population similarities and differences, and because of the degree of genetic divergence that exists among the interspecific and intraspecific ecotypes originated from different regions of the humid tropics. The objective of the present study was to morphological characterization wild species of the genus *Heliconias* in Mexico through some qualitative and quantitative morphological descriptors. Fifty-five qualitative and quantitative morphological characters were studied in 25 accessions from 11 native species. Characters of plant, leaf, inflorescence, flower, fruit, and seed were taken into account. Data was analyzed by Principal Component Analysis (PCA) and Hierarchical Cluster Analysis. Two analyses were carried out: the first one was for the 25 accessions that included characters of flower (55 variables), whereas the second was for only 19 accessions (66 variables) concluded until seed. The first six components explained a 69.4% of the total variation based on PCA. The variables which contributed most significantly were: leaf length ($p < 0.001$), limb width ($p < 0.001$), limb's petiole length ($p < 0.001$), pseudostem thickness ($p < 0.05$)/width at 60 cm ($p < 0.05$), rachis width ($p < 0.05$)/thickness ($p < 0.001$), second bract width ($p < 0.001$), growth ($p < 0.001$) and type of inflorescence ($p < 0.05$), petiole ($p < 0.05$) and peduncle length ($p < 0.05$), rachis color ($p < 0.05$), and wax in limb ($p < 0.05$) and in pseudostem ($p < 0.05$). Thirty-eight descriptors were suggested to differentiate wild species of *heliconias* in Mexico.

**Keywords**

*Heliconia*, Morphological Descriptors, Principal Components

## 1. Introduction

The *Heliconia* genera are a group of plants integrated by 200 to 220 species which inhabit in the tropical and subtropical forests of America [1]. In Colombia, there were 93 species recognized until the year of 1993 [2], but in Mexico, there is mention of 14 to 16 different species [3], with three endemic species [4].

*Heliconias* are plants with inflorescences that can be present throughout the year or during seasons, as in most species. The terminal inflorescence is formed by bracts colorful, with variable size and shape to be cultivated as an ornamental plant by farmers [3]. These characteristics make them exotic flowers with a growing demand in the market. In Mexico, Veracruz and Chiapas states are the main producers of these flowers [5]. In the plants of this genus, a high phenotypic variation has been observed, this represent a good possibility to form varieties or hybrids with high quality, but up to now, research studies have focused mainly on taxonomic studies [6] [7] [8], and regeneration and *in vitro* propagation [9] rather than on morphological diversity characterization.

Varietal characterization is meant by the description of an existing variation in one germplasm collection. Its main objective is the identification and differentiation of the accessions in one specie [10]. For this, the use of varietal descriptors is essentially important, where one descriptor is a characteristic or a quality which expression is easy to measure, register or evaluate, and it refers to the accession shape, structure and behavior [11]. Descriptors can take values of numerical, scale, code, and qualifying adjective types [10].

Characterization can be made through some morphological markers which are observed primarily when identifying, classifying and distinguishing phenotypes. It can also be made by molecular markers of DNA or proteins, where in either case, heredity can be traced out and detected variation (polymorphism) is useful for the genetic diversity characterization and classification [12].

In the molecular characterization of one species, the existing variability is estimated within the genome of the individuals that make up the population [12].

Within the *Heliconia* genera, morphological characterization has been used to differentiate interspecific cultivars and hybrids [1] [13]. Guimaraes *et al.* [13] for example, utilized 45 qualitative morphological descriptors of pseudostem, leaf, inflorescence, and flower to differentiate interspecific species and hybrids of *heliconias* from Brazil.

In Mexico, the utilization of native *heliconias* germplasm for preservation and genetic improvement purposes has been limited partly because of the unawareness between their population similarities and differences, and because of the degree of genetic divergence that exists among the interspecific and intraspecific ecotypes originated from different regions of the humid tropics.

In order to carry out morphological characterization of a native germplasm collection in Mexico, Ortiz *et al.* [14] used only inflorescence morphological characters such as color and shape, whereas Avendaño *et al.* [15] only used leaf and inflorescence characters.

The goal of the present study was to morphologically characterize wild species of the genus *Heliconias* in Mexico, through some qualitative and quantitative morphological descriptors.

## 2. Material and Methods

This current work was carried out at Rosario Izapa Experimental Station of the National Forestry, Crops and Livestock Research Institute (INIFAP) wich is located at 15˚16'16.1''LN, 92˚42'59.1''LW, and at 435 m altitude in Tuxtla Chico, Chiapas, Mexico.

Twenty-five accessions were studied comprising 11 native species of *heliconia*, that were collected from the south-east region of Mexico (covering the states of Oaxaca, Puebla, Veracruz, and Chiapas); these accession are currently conserved at the Genebank of *Heliconia*, in the Rosario Izapa Experimental Station-INIFAP (**Table 1**). The accessions were chosen based on their morphological characteristics of plant, bracts and flower.

### 2.1. Morphological Characterization

Each accession was characterized based on 66 varietal descriptors (**Table 2**): From these descriptors, 34 and 32 were quantitative and qualitative descriptors respectively, for plant, leaf, inflorescence (bract), flower, fruit, and seed (**Table 2**).

### 2.2. Statistical Analysis

We evaluated 66 descriptors, qualitative characters were taken based on visual parameters, except for color that was taken as reference the Pantone® color chart; For the registration of the quantitative characters was used rule and electronic vernier mark Mitutoyo, Model No. CD-6 CS. For each character, 20 repetitions per accession were evaluated, considering a repetition to a leaf, a fruit or a seed according to the case.

The principal components analysis (PC) was applied to the data obtained using the PRINCOMP procedure of SAS Ver.6.12 [16] using the correlation matrix; (Eigenvalues), eigenvectors and pearson correlation coefficient between the original variables and the principal components [17]. The PCs were plotted on a Cartesian plane, to observe the distribution of the characterized accessions.

Hierarchical clusters were also analyzed by the PROC CLUSTER procedure of SAS Ver. 6.12 [16] and the algorithm was performed by hierarchical clustering, which generated a dendrogram that allowed to distinguish the groups conformed by the characterized accessions [17] [18].

**Table 1.** Accessions of wild species of *heliconias* in Mexico studied.

| Code | Specie | Location | State | Latitude (N) | Longitude (O) | Altitude (m) |
|---|---|---|---|---|---|---|
| L1 | *H. latispatha Benth* | Acapetahua | Chiapas | 15˚16'16.3" | 92˚42'57.3" | 36 |
| L2 | *H. latispatha Benth* | Acapetahua | Chiapas | 15˚16'16.1" | 92˚42'57.1 | 36 |
| Li1 | *H. librata Griggs* | Ejido A. Obregón | Veracruz | 17˚17'46.7" | 94˚35'34.7 | 74 |
| S1 | *H. spissa Griggs* | Villa corzo, Nueva Independencia | Chiapas | 16˚13'05.30 | 93˚35'09.38" | 1270 |
| U1 | *H. uxpanapensis* | Uxpanapa Loc. 12 | Veracruz | 17˚13'13.2" | 94˚8'40.6" | 90 |
| V1 | *H. vaginalis Benth. Subsp. Mathiasiae* (*G. S. Daniels & F. G. Stiles*) *L. Anders.* | Palenque | Chiapas | 17˚23'48.4" | 91˚59'23.2" | 309 |
| S2 | *H. spissa Griggs* | Ocosingo | Chiapas | 16˚58'02.9" | 92˚6'09.4" | 1193 |
| B1 | *H. bourgaeana Petersen* | Cuetzalan | Puebla | 20˚2'52.3" | 97˚32'26.8" | 705 |
| B2 | *H. bourgaeana Petersen* | Cuetzalan | Puebla | 20˚3'18.28 | 97˚32'02.03" | 602 |
| L3 | *H. latispatha Benth* | Rosario Izapa | Chiapas | 15˚16'16.1" | 92˚42'57.1 | 419 |
| U2 | *H. uxpanapensis Gutiérrez Báez* | Uxpanapa Loc. 10 | Veracruz | 17˚15'03.4" | 94˚22'39.3" | 82 |
| U3 | *H. uxpanapensis Gutiérrez Báez* | Uxpanapa | Veracruz | 17˚15'06.2" | 94˚23'16.4" | 73 |
| H2 | *H. bihai* | Cuetzalan | Puebla | 20˚3'33.8" | 97˚31'36.4" | 514 |
| L4 | *H. latispatha Benth* | Tuzantan | Chiapas | 15˚16'16.1" | 92˚42'57.1 | 35.6 |
| S3 | *H. spissa* (*Griggs*) *Standl.* | Matias Romero | Oaxaca | 17˚ 5' 46.5" | 94˚ 57' 12.83" | 126 |
| S4 | *H. spissa* (*Griggs*) *Standl.* | Matias Romero | Oaxaca | 17˚ 5' 55.5" | 94˚ 56' 42.9" | 161 |
| C1 | *H. collinsiana, Var. Velutina* | Villa corzo, Nueva Independencia | Chiapas | 16˚13'4.89" | 93˚35'11.45" | 1264 |
| C2 | *H. collinsiana Griggs var. Collinsiana* | El triunfo | Chiapas | 15˚21'30.29 | 92˚31'55.94" | 596 |
| B3 | *H. bourgaeana Petersen* | La Joya, Tezonapa | Veracruz | 18˚38'06.14" | 96˚47'13.52" | 635 |
| U4 | *H. uxpanapensis Gutiérrez Báez* | Uxpanapa | Veracruz | 17˚15'13.2" | 94˚22'31.9" | 101 |
| P1 | *H. champneiana* | Palenque | Chiapas | 17˚23'42.1" | 91˚59'38.8" | 50 |
| P2 | *H. champneiana* | Palenque | Chiapas | 17˚23'42.1" | 91˚59'38.8" | 309 |
| H4 | *H. bihai* | Aguapan | Puebla | 20˚3'07.0" | 97˚31'54.3" | 590 |
| C3 | *H. collinsiana ver. collinsiana* | Rosario Izapa | Chiapas | 14˚57'45.20" | 92˚9'17.94" | 402 |
| C4 | *H. collinsiana Griggs var. collinsiana* | Tezonapa | Veracruz | 18˚37'36.2" | 96˚42'22.6" | 250 |

**Table 2.** Morphological evaluated characters for the characterisation of wild species of *heliconias* in Mexico.

| | Character | Scale | Acronym |
|---|---|---|---|
| | | **Plant** | |
| 1. | Culm growth | 1: Extended 2: somewhat extended 3: Compact | CW |
| 2. | Type of rhizome | 1: Leptomorph 2: Mesomorphs 3: Pachymorph | TR |
| 3. | Plant growth | 1: Musoide 2: Canoide 3: Zingiberoide | PG |
| 4. | Plant length | cm | PL |

**Continued**

| | | | |
|---|---|---|---|
| **5.** | Pseudostem length | cm | PSLE |
| **6.** | Pseudostem' petiole width | mm | PPW |
| **7.** | Pseudostem' petiole thickness | mm | PPT |
| **8.** | Pseudostem width 60 cm | mm | PSW |
| **9.** | Pseudostem thickness 60 cm | mm | PST |
| **10.** | Pseudostem colour | 1: Green 2: Yellow 3: Red | PCO |
| **11.** | Pseudostem shape | 1: Tubular 2: Ribbed 3: Oval | PS |
| **12.** | Pseudostem pubescence | 1: Pubescent 2: Setosa 3: Glabrous | PPB |
| **13.** | Pseudostem length ratio and leaf length | cm | PLRLEL |
| **14.** | Wax in pseudostem | 1: Presence 2: Absence | WAP |
| | | **Leaf** | |
| **15.** | Limb edge | 1: Entire 2: Dentate 3: Serrate 4: Crenate | LE |
| **16.** | Limb ondulation | 1: Undulate 2: Fuzzy 3: Absence | LON |
| **17.** | Limb's base shape | 1: Acute 2: Obtuse 3: Alternate 4: Trucate 5: Cordate | LBS |
| **18.** | Limb's apices shape | 1: Acute 2: Obtuse 3: Acuminate | LAS |
| **19.** | Limb length | cm | LLE |
| **20.** | Limb width | cm | LW |
| **21.** | Limb length-to-width ratio | 1: Too elongated 2: Moderately elongated 3: Medium. 4: Moderately compressed 5: Highly compressed | LLEWR |
| **22.** | Limb color | 1: Bright green 2: Green 3: Light green | LCO |
| **23.** | Leaves arrangement | 1: Rosette 2: Distichous 3: Alternate | LA |
| **24.** | Leaves present | Number | LNo |
| **25.** | Limb's petiole length | cm | LPLE |
| **26.** | Petiole consistency | 1: Full 2: Hollow | PEC |
| **27.** | Leaf length | cm | LELE |
| **28.** | Wax in limb | 1: Presence 2: Absence | WL |
| **29.** | Type of leaf venation | 1: Highly visible 2: Visible 3: Barely visible | TLV |
| **30.** | Leaf growth | 1: Erected 2: Outwards (salient) 3: Downward | LG |
| **31.** | Leaf symmetry | 1: Symmetric 2: Moderately asymmetric 3: Asymmetric | LS |
| | | **Inflorescence** | |
| **32.** | Inflorescence growth | 1: Erected 2: Pendular 3: Between 0 & 45˚ 4: Between 45 & 90˚ | IG |
| **33.** | Inflorescence length | cm | ILE |
| **34.** | Inflorescence width | cm | IW |
| **35.** | inflorescence length-to-width ratio | cm | ILEWR |
| **36.** | Rachis shape | 1: Lineal 2: Undulate | RS |
| **37.** | Rachis width | mm | RW |
| **38.** | Rachis thickness | mm | RT |
| **39.** | Presence of pubescence | 1: Pubescent 2: Setosa 3: Glabrous | PPB |

Continued

| | | | |
|---|---|---|---|
| **40.** | Open bracts | Number | BNo |
| **41.** | Second bract length | cm | SNBLE |
| **42.** | Second bract width | mm | SNBW |
| **43.** | Second bract thickness | mm | SNBT |
| **44.** | Bracts arrangement | 1: One level 2: Helicoid | BA |
| **45.** | Bracts color | 1: Red 2: Pink 3: Yellow 4: Orange 5: Dotted | BCO |
| **46.** | Bract shape | 1: Keel-like. 2: Boat-like | BS |
| **47.** | Rachis colouring | 1: Red 2: Orange 3: Yellow 4: Pink 5: Green | RCO |
| **48.** | Type of inflorescence | 1: Erected: in only one level 2: Erected: in one more level<br>3: Pendular: in only one level 4: Pendular: in one more level | TOI |
| | | **Flower** | |
| **49.** | Sepals colour | 1: Light green 2: Yellow 3: Orange | SCO |
| **50.** | Peduncle color | 1: Yellow 2: Green 3: White | PCO |
| **51.** | Sepal length of the most flourished flower | mm | SLEMFF |
| **52.** | Most flourished flower width | mm | MFFW |
| **53.** | Most flourished flower thickness | mm | MFFT |
| **54.** | Peduncle length | mm | PLE |
| **55.** | Peduncle width | mm | PW |
| | | **Fruit** | |
| **56** | Ovary color | 1: Light green 2: Yellow 3: Orange 4: Purple 5: Blue | VCO |
| **57.** | Fruit in second bract | Number | FSB |
| **58.** | Ovary length | mm | OLE |
| **59.** | Ovary width | mm | OW |
| **60.** | loculos in fruit | Number | NOLC |
| **61.** | Seeds in fruit | Number | SNo |
| | | **Seed** | |
| **62.** | Seed length | mm | SELE |
| **63.** | Seed thickness | mm | SET |
| **64.** | Seed color | 1: Dark grey 2: Brown 3: Beige 4: Yellow | SECO |
| **65.** | Seed shape | 1: Oval 2: Elliptical 3: Ovobade | SES |
| **66.** | Seed width | mm | SEW |

## 3. Results and Discussion

### 3.1. Analysis with 55 Variables and 25 Accesions Were Included.

For the initial analysis, 25 accessions as well as 55 descriptors were used without including fruit and seed variables (Table 2). The PCA indicated that the first six components explained 69.4% of the total variability, with 26.1%, 14.0%, 9.0%, 7.8%, 6.5% and 5.9% respectively (Table 3). These results are very similar to those reported by Sosof *et al.* [19] with 43 cultivars of *Heliconia* but using only

**Table 3.** Eigenvalues and the total variance amount are explained by each of the principal components, based on the 55 morphological characters of *Heliconia* spp.

| PC | Eigenvalores | Difference | Proportion | Acumulate |
|---|---|---|---|---|
| 1 | 14.396 | 6.678 | 0.261 | 0.261 |
| 2 | 7.717 | 2.768 | 0.140 | 0.402 |
| 3 | 4.949 | 0.640 | 0.09 | 0.492 |
| 4 | 4.308 | 0.716 | 0.078 | 0.570 |
| 5 | 3.592 | 0.345 | 0.065 | 0.635 |
| 6 | 3.247 | 0.713 | 0.059 | 0.694 |

PC = Principal Component.

three components (69.94).

The variables which contributed significantly were: for PC1: limb length (LLE, $p < 0.001$), limb width (LW, $p < 0.001$), limb petiole length (LPLE, $p < 0.001$), pseudostem petiole width (PPW, $p < 0.001$), pseudostem thickness at 60 cm (PPT, $p < 0.001$), pseudostem width at 60 cm (PSW, $p < 0.001$), rachis width (RW, $p < 0.001$), rachis thickness (RT, $p < 0.001$), second bract width (SNBW, $p < 0.001$), plant length (PL, $p < 0.05$), inflorescence length (ILE, $p < 0.05$), second bract thickness (SNBT, $p < 0.05$), pseudostem petiole thickness (PPT, $p < 0.05$), plant growth (PG, $p < 0.05$), pseudostem and leaf length ratio (PLRLEL, $p < 0.05$), bracts arrangement (BA, $p < 0.05$), and leaves growth (LG, $p < 0.05$). For PC2: inflorescence growth (IG, $p < 0.001$), type of inflorescence (TOI, $p < 0.05$), peduncle length (PLE, $p < 0.05$), rachis color (RCO, $p < 0.05$), wax in limb (WL, $p < 0.05$), pseudostem shape (PS, $p < 0.05$), and bracts color (BCO, $p < 0.05$). PC3: presence of pubescence on inflorescence (PPB, $p < 0.001$), open bracts (BNo, $p < 0.05$), inflorescence length-to-width ratio (ILEWR, $p < 0.05$), limb color (LCO, $p < 0.05$), rachis shape (RS, $p < 0.05$), leaves present (LNo, $p < 0.05$), and type of rhizome (TR, $p < 0.05$). All of the above suggested that 33 of 55 analyzed variables contributed significantly to explain the total variation within the 25 *heliconia* characterized accessions (Table 4).

According to PC1 and PC2, the distribution of the accessions within Cartesian axis permitted to observe the great variation among the *Heliconia* species (Figure 1). Likewise, Figure 2 shows that the clustering pattern of the accessions is consistent with their corresponding species, but inflorescence is now related to it.

### 3.2. Hierarchical Cluster Analysis

With 55 variables (plant, leaf, inflorescence, and flower), a hierarchical cluster analysis (HCA) was carried out. According to a 0.05 semipartial correlation coefficient, six groups were determined and divided into different sub-groups, for example: group I was divided into IA and IB, group III into IIIA and IIIB, group V into VA and VB, and group VI into VI and VIB (Figure 3).

**Table 4.** Eigenvectors and Pearson's coefficient correlation of each original variable, is accordingly to its principal component of 55 characters.

| Variable | Eigenvectors | | | Pearson's coefficient correlation | | |
|---|---|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC1 | PC2 | PC3 |
| CW | 0.099 | 0.179 | −0.184 | 0.378 | 0.498 | −0.409 |
| TR | 0.105 | 0.158 | **−0.231** | 0.399 | 0.441 | **−0.514*** |
| PG | **−0.182** | 0.068 | −0.012 | **−0.690*** | 0.190 | −0.027 |
| PL | **0.200** | 0.158 | 0.135 | **0.759*** | 0.439 | 0.300 |
| PSLE | 0.049 | **0.274** | 0.066 | 0.187 | **0.763*** | 0.148 |
| PPW | **0.229** | 0.042 | 0.079 | **0.869**** | 0.116 | 0.176 |
| PPT | **0.184** | 0.028 | 0.138 | **0.699*** | 0.078 | 0.308 |
| PSW | **0.226** | 0.083 | 0.089 | **0.860**** | 0.232 | 0.198 |
| PST | **0.229** | 0.126 | 0.071 | **0.869**** | 0.352 | 0.159 |
| PCO | 0.065 | 0.019 | −0.100 | 0.248 | 0.054 | −0.224 |
| PS | 0.113 | **−0.187** | 0.133 | 0.432 | **−0.521*** | 0.297 |
| PPB | −0.114 | 0.173 | 0.108 | −0.433 | 0.480 | 0.240 |
| PLRLEL | **−0.175** | 0.091 | 0.002 | **−0.664*** | 0.254 | 0.004 |
| WAP | 0.090 | **−0.199** | 0.072 | 0.344 | **−0.553*** | 0.161 |
| LE | −0.012 | −0.001 | −0.117 | −0.048 | −0.003 | −0.260 |
| LON | 0.111 | −0.066 | 0.032 | 0.424 | −0.185 | 0.073 |
| LBS | 0.011 | −0.033 | 0.067 | 0.045 | −0.091 | 0.150 |
| LAS | 0.063 | 0.041 | 0.004 | 0.241 | 0.114 | 0.009 |
| LLE | **0.229** | 0.073 | 0.125 | **0.869**** | 0.205 | 0.279 |
| LW | **0.235** | 0.088 | 0.025 | **0.892**** | 0.246 | 0.056 |
| LLEWR | −0.063 | 0.086 | −0.215 | −0.239 | 0.239 | −0.479 |
| LCO | −0.052 | 0.070 | **−0.267** | −0.199 | 0.194 | **−0.596*** |
| LA | 0.064 | 0.097 | −0.071 | 0.245 | 0.271 | −0.159 |
| LNo | −0.125 | 0.017 | **0.234** | −0.474 | 0.047 | **0.522*** |
| LPLE | **0.234** | −0.001 | 0.056 | **0.891**** | −0.003 | 0.126 |
| PEC | 0.006 | −0.072 | −0.103 | 0.024 | −0.201 | −0.231 |
| LELE | **0.242** | 0.038 | 0.082 | **0.921**** | 0.107 | 0.183 |
| WL | **0.015** | −0.225 | −0.122 | **0.059** | −0.627* | −0.272 |
| TLV | **−0.082** | −0.101 | 0.164 | **−0.312** | −0.281 | 0.366 |
| LG | **−0.149** | 0.036 | −0.101 | **−0.568*** | 0.102 | −0.225 |
| LS | **0.013** | 0.034 | 0.002 | **0.052** | 0.096 | 0.005 |
| IG | −0.001 | **0.293** | 0.049 | −0.005 | **0.814**** | 0.110 |
| ILE | 0.198 | 0.101 | −0.113 | **0.752*** | 0.283 | −0.253 |
| IW | 0.083 | 0.107 | 0.174 | 0.315 | 0.299 | 0.388 |
| ILEWR | 0.135 | −0.002 | **−0.268** | 0.512 | −0.008 | **−0.597*** |

**Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| RS | −0.059 | −0.006 | **0.243** | −0.226 | −0.018 | **0.541*** |
| RW | **0.225** | −0.136 | −0.076 | **0.854**** | −0.379 | −0.169 |
| RT | **0.219** | −0.137 | −0.095 | **0.831**** | −0.383 | −0.212 |
| PPB | −0.029 | 0.047 | **0.378** | −0.112 | 0.132 | **0.841**** |
| BNo | 0.057 | 0.088 | **−0.305** | 0.218 | 0.244 | **−0.680*** |
| SNBLE | −0.084 | 0.037 | 0.174 | −0.318 | 0.104 | 0.387 |
| SNBW | **0.211** | −0.116 | 0.073 | **0.802**** | −0.323 | 0.164 |
| SNBT | **0.184** | −0.137 | −0.024 | **0.701*** | −0.382 | −0.053 |
| BA | **−0.167** | 0.172 | −0.069 | **−0.634*** | 0.480 | −0.154 |
| BCO | −0.081 | **−0.186** | 0.079 | −0.309 | **−0.518*** | 0.176 |
| BS | 0.102 | −0.168 | −0.044 | 0.388 | −0.468 | −0.098 |
| RCO | −0.097 | **−0.234** | −0.010 | −0.368 | **−0.652*** | −0.022 |
| TOI | −0.059 | **0.285** | 0.020 | −0.226 | **0.793*** | 0.045 |
| SCO | 0.114 | 0.171 | −0.090 | 0.433 | 0.475 | −0.202 |
| PCO | 0.086 | −0.174 | −0.057 | 0.326 | −0.484 | −0.128 |
| SLEMFF | 0.095 | 0.111 | 0.047 | 0.362 | 0.309 | 0.105 |
| MFFW | 0.017 | 0.116 | 0.154 | 0.067 | 0.323 | 0.344 |
| MFFT | 0.026 | 0.100 | −0.030 | 0.100 | 0.278 | −0.068 |
| PLE | −0.032 | **0.252** | 0.024 | −0.121 | **0.702*** | 0.053 |
| PW | 0.039 | 0.073 | −0.027 | 0.151 | 0.204 | −0.062 |

PC1: Principal Component 1, PC2: Principal Component 2; PC3: Principal Component 3. *. **= Significant with alpha = 0.05 and alpha = 0.01 respectively.

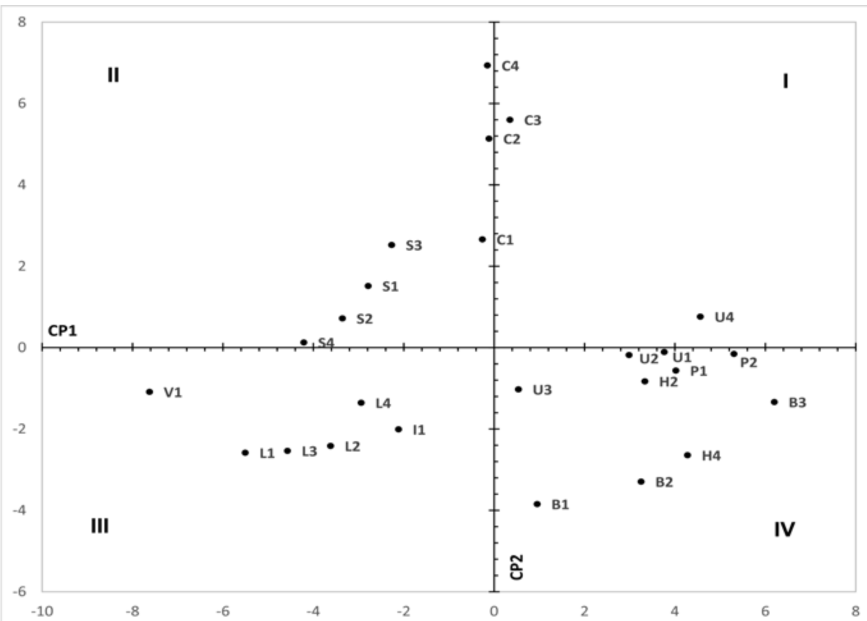


**Figure 1.** Distribution of 25 accesions of *heliconias*, in funtion of principals components I and II (CP1 = principal component 1, CP2 = principal component 2).

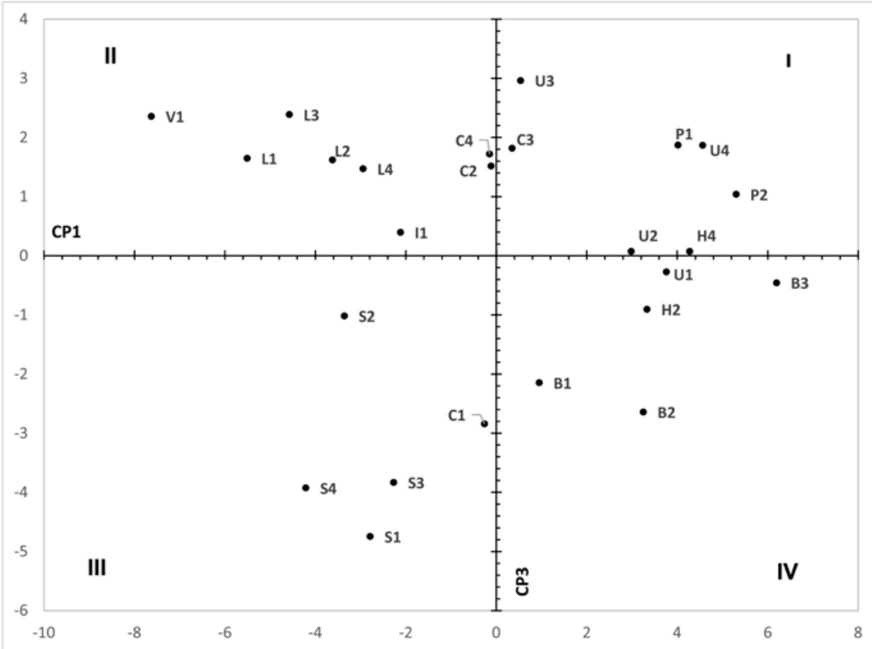


Figure 2. Distribution of 25 accesions of *heliconias*, in funtion of principals components I and III (PC1 = principal component 1, PC3 = principal component 3).

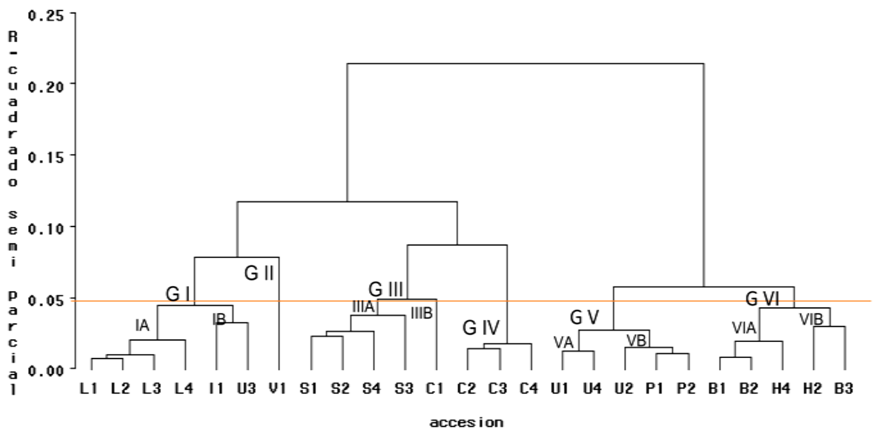


Figure 3. Dendrogram generated by qualitative (29) as well as quantitative (26) characters for 25 accessions of *Heliconias* spp. Cutting distance for group formation.

### 3.3. Phenotypic Diversity

Group I (GI) was formed by six accessions, which can be easily distinguished by the oblique position of their leaves and short petiole, and the medium plant height. Accessions from group IA are separated from IB primarily because of the lack of wax in the limb. Although L3 is a tall-size plant, it is considered to be a hybrid between *H. uxpanapensis* and *H latisphata*, since it presents some morphological characteristics closer to *H. latisphata* [14], for example: an erected growth of inflorescence and an absence of pubescence on inflorescence (glabrous).

Group II (GII) was made up by only one accession from *H. vaginalis* Benth. Subsp. Besides being *Mathiasiae* a-1 85.31 cm height short-size plant and having a-3 13 stem/leaf ratio, erected inflorescence, undulate rachis, bracts in distichous position, and an orange color; it is the only species that presents a growing zingiberidae-like shape.

Group III (GIII) was integrated by five accessions, which are easily distinguishable for presenting wax in the limb [13], leaf growth in an oblique position, pubescence on inflorescence, undulated rachis, and a helicoidal arrangement in the bracts. Accession C1 was associated to this group due to the short size of the plant, which is probably in response to where the characterization was carried out [20]. However, as this accession comes from an altitude higher than 1200 m, it presents a pubescence just like the *H. spisa* species, which belong to GIII.

Group IV (GIV) was integrated by three accessions C2, C3, and C4 belonging to *H. collinsiana Griggs* var. *Collinsiana*. These samples were collected in Chiapas (C2, C3) and in Veracruz (C4) at an altitude of 596, 402, and 250 m respectively and present a greatest inflorescence length [21].

Group V (GV) included five accessions, which are easily distinguishable for being tall-size plants (>400 cm), their growth in plant is of a musoide type, have an oval-shape stem, presence of wax in the limb, an erected growth of the inflorescence, absence of pubescence on the inflorescence, the bracts are in distichous position, and an erected growth. In the sub-group VA, two accessions of *H. uxpanapensis* are clustered, a third one was associated to *H. champaneana* because of its similarity in shape, bracts of short length and orange color.

Group VI (GVI) clustered five accessions that are characterized for being plants with a growing musoide habit, have an oval-shape stem, absence of wax in the pseudostem, number of leaves from 2 to 3, absence of wax in the limb, an erected growth of the inflorescence, pubescent, and bracts arrangement in one level. Accessions belonging to *H. bourgaena* and *H. bihai* clustered within subgroup VIA abide by the similarity in their inflorescence, while in the sub-group VIB two other accessions were clustered based on the size of the plant.

Guimarães *et al.* [13] registered the presence of wax in pseudostem on *H. bihai* whilst Costa *et al.* [21] reported a bigger length in the inflorescence. This variation can be highly influenced by the environment since temperature conditions and rainfalls vary from 26˚C to 1, 968 mm [20]. According to Robles [22], limitations in water affect plants morphology, physiology, and metabolism. Among the physiological and metabolic changes that occur within these plants, there is an increase of wax in leaves' surface.

Accessions clustering of *H. bourgaena* and *H. bihai* within sub-group VIA abide by the similarity in their inflorescence, while in sub-group VIB; two other accessions are clustering by the plant's size.

In general, the groups reflect an association among the individuals that belong to the same species; this tendency has been observed by Londoño [23] who reported the association of samples from different *in vitro* cultures through AFLP markers into *H. caribaea* and *H. orthotricha* especies. Pereira *et al.* [24] using 16 morphological markers in *heliconias* found variation between the studied species, but these did not allow a clear differentiation between species.

### 3.4. Analysis with 66 Variables (Chart 2) and 19 Accessions Were Included

It was found that in the most grown flower width (MDFW), in the most flourished flower thickness (MFFT), in limb's apice shape (LAS), limb undulation (LUN), leaf nervation type (LNT), bract shape (BS), and sepals colouring (SCO) contribute significantly to groups formation (Data no show).

Ovary coloring (OCO) and width (OW) were the characters that presented the greatest variability regarding the fruit size. For seed, the most relevant characters were: seed thickness (SET), seed color (SECO), and seed width (SEW) (Data no show)

When including fruit and seed variables, a better clustering could be observed. The groups did not change on the first analysis, therefore; it indicates that fruit and seed are important variables to include when making a distinction among species accessions (Figure 4).

The great phenotypic diversity found on the 25 studied accessions, which are maintained in the Rosario Izapa genebank, will be a very useful strategy in programs of genetic improvement just as it is carried out in other countries of Central [19] and South America [3].

## 4. Conclusions

With the use of 39 varietal descriptors (16 qualitative and 23 quantitative), it was possible to differentiate the species of *Heliconia* analyzed in the present study. Fourteen inflorescence descriptors (bract) were the most important, followed by plant (11), leaf (8), seed (3), fruit (2), and flower (1) descriptors.

The results of this work indicate that there is a great morphological diversity in the native *heliconias* from Mexico. This source of germplasm is important forts genetic heritage for preservation and propagation purposes, since it might

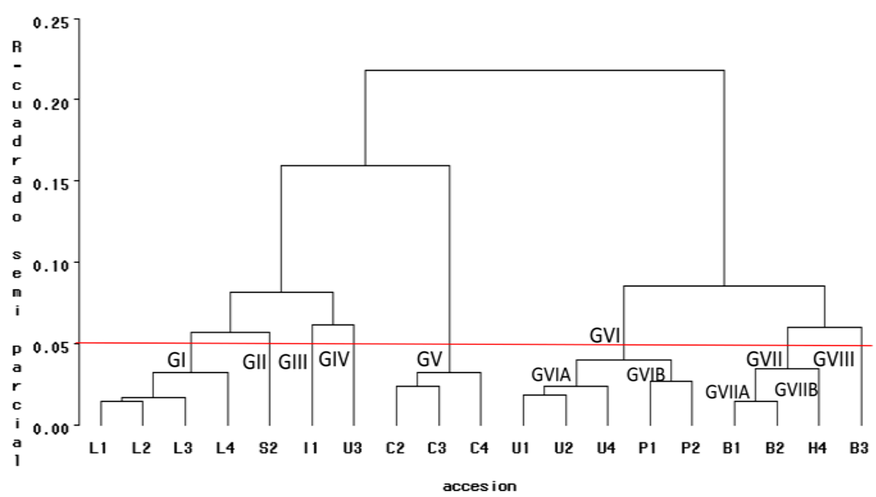


Figure 4. Dendrogram generated by qualitative (34) as well as quantitative (32) characters for 19 accessions of *Heliconias spp.* Cutting distance for group formation

constitute a source for producing new materials with desirable characteristics for commercial purposes.

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