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Study on genetic variability and correlation for floral traits and yield in *Heliconia* genotypes

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ABSTRACT

Exploration on genetic variability and diversity of Heliconia genotypes amongst yield and floral biology traits were executed being intended to investigate the prime floral parameters quite potential to enact vital role in breeding and also inflorescence productivity per annum. The study revealed noteworthy dissimilitude in flowering behavior of different varieties under West Bengal condition. Here, 'Golden Torch', a hybrid cultivar merely showcased perpetual flowering whereas other are considerably seasonal. Highest genotypic and phenotypic variabilities were observed for anthocyanin content. Likewise, PCV of 61.43% for duration of male phase and GCV of 58.34% for number of flowers/inflorescence were apparent as second highest. Here, characters days from first to last flower opening, days from emergence to male and female phase and duration of male and female phase recorded high heritability coupled with high genetic advance manifests possibility of genetic improvement through selection. Duration of male and female phase duo showed significant positive phenotypic and genotypic correlation with days from first to last flower opening and days from bud emergence to full unfurling of bracts. Furthermore, inflorescence productivity year^{-1} was found to be positively correlated with inflorescence length and number of open bracts at genotypic and phenotypic levels both.

Keywords**:** *Heliconia,* correlation, genotypic parameters, heritability and phenotypic parameters

Heliconia, a monophyletic genus familiar as 'Lobster-claws', 'Wild plantains' or 'False bird of paradise' resides to the family Heliconiaceae, formerly included in the family Musaceae. Approximately 200 to 250 species are distributed primarily in Neotropical areas from the North of Mexico to the South of Brazil (Urooj-Ul-Nissa *et al*., 2015). It is an herbaceous, rhizomatous, erect perennial having sympodial branching, posses pseudocaule formed by the juxtaposition of the petioles or leaf laminas. Their variable heights ranges from 1 to 7 m. It contains a group of excellent cut flowers due to their striking shape, attractive color, long vase life and prolific flower producing capacity. Vast morphological diversity at intra-specific, intra-population and varietal levels are observed in this genus (Janakiraman and Kumar, 2011). Owing to their desirable horticultural properties and postharvest characteristics they are gaining importance, much, though, remains to be known about this plant. So, the correct identification of the various species and cultivars are important.

For any crop improvement program, selection of superior parents is an essential prerequisite especially for the traits showing higher heritability and genetic advance for various traits. The adequate information on extent of variability parameters may be helpful to improve the yield by selecting the yield component traits because yield is a complex trait, whose manifestation depends on the component traits. Generally, the estimates of heritability (h^2) of traits are environment specific (Shimelis and Rhandzu, 2010). These estimates should be incorporated and specifically applied only to the population and environment sampled. Thus, selection of traits based on h^2 and genetic advance as per cent of mean is of great importance to the breeder for making criteria for improvement in a complex character. A positive genetic correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously.

In *Heliconia* sp., obvious problems in quest of new hybrids are the low rate of hybridization. With this consideration, the present study focuses on assessment of the genetic variability and correlation studies for yield and yield attributing traits in 'False-Bird-of-Paradise'.

MATERIALS AND METHODS

The present investigation was carried out at the Agricultural Experimental Farm, University of Calcutta, situated at Baruipur, South 24 Parganas, West Bengal, ($88^0$28' East longitude, $22^0$22' North latitude and 9.75m above sea level) during 2013 involving ten *Heliconia* genotypes namely *H. psittacorum* L.f. × *H. spathocircinata Aristeg*. cv. 'Golden torch', *H. psittacorum* L.f. var. 'Choconiana', *H. psittacorum* L.f. var. 'Lady di', *H. rostrata* Ruiz and Pavón, *H. humilis* (Aubl.) Jacq., *H. stricta* Huber var. 'Dwarf Jamaican Red', *H. wagneriana* Peterson, *H. stricta* Huber, *H. metallica* Planchon and Linden ex Hooker and *H. indica* Lam. var. 'Indica' summoned from Agri-Horticultural Society of India (AHSI) and Kamal Nursery, Andul, Howrah to find the nature and extent of genetic variability and correlation studies for flowering and yield parameters. Initially they were planted in black polyethylene bags followed by transplantation at a distance of 1 × 1m while attained 30cm height at main

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field at Baruipur during *Kharif* season of 2013. Main field was prepared by ploughing followed by mixing of 1 part of sand, 1part of dry cow-dung manure and 3 parts of vermi-compost. The variability was observed among the clones of this population. They were tagged and observations were documented to study the genetic variability existing among these population. Observations were recorded from the emergence of inflorescence and continued up to their senescence. Several traits were considered under this study such as –

Floral traits

Inflorescence length (cm), number of open bracts, number of inflorescence plant^{-1} year^{-1}, size of bract (cm^2), number of bracts, number of flowers per bract, number of flowers per inflorescence, days from bud emergence to full unfurling of bracts, days from first to last flower opening, days from bud emergence to male and female phase and duration of male and female phase.

Vegetative traits

Plant height (feet), plant spreading (sq. feet), leaf blade length (cm), stem length (cm), number of shoots per clump, number of leaves per stem, number of flowering stems clump^{-1}.

Biochemical Traits

Total Chlorophyll content of leaves (mg per g tissue), anthocyanin content of leaves (mg 100^{-1} g tissue).

Pigment estimations were done following the protocol of Sadasivam and Manickam (1996) and Mazumder and Mazumder (2003) at the laboratory of Department of Horticulture, Institute of Agricultural Science, University of Calcutta, Kolkata.

Genetic parameters like genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV) were estimated according to Burton (1952), heritability as suggested by Falconer (1981) and genetic advance as per cent over mean by Johnson *et al.* (1955). The correlations at genotypic and phenotypic levels between all the possible pairs of characters were calculated as proposed by Al Jibouri *et al*. (1958).

The experiments were conducted in Randomized Block Design (RBD) with factorial concept (Panse and Sukhatme, 1985) having two replications for each genotype. The data were subjected to ANOVA using SPSS 10.0 statistical package. The treatment means were compared by Duncan's New Multiple Range Test (DNMRT) at 5 per cent probability level.

RESULTS AND DISCUSSION

Estimation of mean, range, genotypic coefficient variation (GCV), phenotypic coefficient variation (PCV), heritability (broad sense), genetic advance (GA) as percent of mean of the assembled genotypes was pooled over years and are presented in the table 1. The range was highest for leaf blade length (27.80-56.45) followed by size of bracts (24.53-62.26), number of inflorescence/plant/year (23.61-98.17), stem length (20.39-49.49), number of flowers/inflorescence (19.97-76.65) and plant spread (19.56-30.11) while the lowest range perceived regarding pigment level *viz.* anthocyanin (0.30-39.84) and total chlorophyll (0.68-4.81) of leaves, days from first to last flower opening (0.18-48.33), days from emergence to male phase (0.64-26.63), duration of male phase (0.82-32.70), days from emergence to female phase (0.44-26.30) and duration of female phase (0.47-32.88).

The relative values for two types of coefficient of variation *viz.* phenotypic and genotypic gives an idea about the magnitude of genetic variability present in the population. There were narrow differences between corresponding PCV and GCV values for all characters under this study, with slightly higher values of the former highly influenced by environment. Similar results were obtained by Kumar (2016) in pearl millet, Suhel *et al*. (2013) in mung bean and Ravishanker *et al*. (2013) in ginger. Hence selection on phenotypic values of these characters would be effective. Srinivas *et al*., 2012 found slightly higher PCV values than GCV values, thus indicating negligible effect of environmental parameters on the characters studied in *Heliconia* sp.

Phenotypic and genotypic coefficients of variation were estimated based on the coefficient of variation and these parameters were used to compare the variability among the ten genotypes. The GCV provides a valid basis for comparing and accessing the range of genetic diversity for quantitative characters and PCV measures the extent of total variance. GCV and PCV are better indices for comparison of characters with different units of measurements, than estimates of quantitative variation like range and variation around mean (Sanjeev *et al*., 2010). For anthocyanin content of leaves combined high PCV and GCV of 245.997 and 245.983 were obtained. The difference among the phenotypic variance and genotypic variance were very low for leaf blade length, anthocyanin content, stem length, inflorescence length, number of open bracts, number of inflorescence/plant/year, number of flowers/inflorescence, days from bud emergence to full unfurling of bracts, days from first to last flower opening, days from emergence to male phase, duration of male phase, days from emergence to female phase (Table 1) indicating the low magnitude of variability *i.e*. less effect of environment on the expression of these characters or less genotype x environment interactions. Thus, evolution of these characters has only a limited scope. Whereas plant height, plant spread, number of shoots/clump, number of leaves/stem, number of flowering stems/clump, size of bracts, number of bracts, number of flowers/bract and duration of female phase manifested moderate to large differences between phenotypic variance and genotypic

variance (Table 1), indicating the role of environment in expression of these traits. So, careful selection may be practiced for improvement of characters. Akin findings were also obtained by Airadevi and Archana, 2014. It thus suggests that the selection for any character depends, not only on the extent of genetic variability but also in the extent to which it will be transferred from one generation to the other generation.

Table 1: Genetic variability of *Heliconia* sp.

Sl. No.	Characters	Grand mean	Range	GCV	PCV	ECV	Heritability (%)	GA as % of mean
1.	Plant height (feet)	4.208	1.48-7.43	47.4169	48.0771	7.9404	97.27	96.3373
2.	Plant spreading (sq.feet)	3.129	19.56-30.11	17.0227	18.3986	6.9812	85.60	32.4443
3.	Leaf blade length (cm)	41.469	27.80-56.45	24.1486	24.2066	1.6742	99.52	49.6270
4	Number of shoots clump^{-1}	7.648	6.12-10.08	22.5019	23.4706	6.6732	91.92	44.4409
5.	Number of leaves stem^{-1}	5.608	4.30-6.81	12.5341	15.5039	9.1251	65.36	20.8743
6.	Anthocyanin content of leaves(mg 100^{-1} g tissue)	5.273	0.30-39.84	245.983	245.997	2.7032	99.99	506.6944
7.	Total Chlorophyll content of leaves (mg g^{-1} tissue)	25.290	0.68-4.81	44.5238	44.6895	3.8453	99.26	91.3789
8.	Number of flowering stems/clump	4.915	3.69-6.85	17.7338	20.9495	11.1532	71.66	30.9242
9.	Stem length (cm)	36.215	20.39-49.49	30.5195	30.6268	2.5621	99.30	62.6497
10.	Inflorescence length(cm.)	35.636	16.59-58.40	35.1433	35.1696	1.3589	99.85	72.3411
11.	Number of open bracts	6.549	3.14-13.35	53.1902	53.9841	9.2241	97.08	107.9605
12.	Number of inflorescence/ plant/year	45.553	23.61-98.17	50.0001	50.0663	2.5744	99.74	102.8639
13.	Size of bracts (cm^2)	38.918	24.53-62.26	45.8461	30.9083	1.8110	99.66	63.4526
14.	Number of bracts	7.090	3.43-15.20	61.0607	45.9587	6.7108	99.51	125.0321
15.	Number of flowers/ bract	8.022	5.23-15.42	45.8109	46.0614	4.7973	98.92	94.2114
16.	Number of flowers/ inflorescence	40.660	19.97-76.65	58.3352	58.3816	3.2160	99.84	120.0752
17.	Days from bud emergence to full unfurling of bracts	27.324	16.78-41.02	28.4981	28.6465	2.9122	98.97	58.4020
18.	Days from 1st to last flower opening	30.509	0.18-48.33	46.0379	46.1494	3.2062	99.52	94.6090
19.	Days from bud emergence to male phase	16.094	0.64-26.63	49.3567	49.6187	5.0916	98.95	101.1381
20.	Duration of male phase	22.461	0.82-32.70	42.6725	42.8996	4.4084	98.94	87.4399
21.	Days from bud emergence to female phase	17.187	0.44-26.30	46.4018	46.5686	3.9380	99.28	95.2453
22.	Duration of female phase	22.332	0.47-32.88	30.8552	61.4283	2.3257	98.81	93.8573

Note: GCV – Genetic Co-efficient of Variation; PCV- Phenotypic Co-efficient of Variation; ECV- Environmental Co-efficient of Variation; GA- Genetic Advance

In the current study, heritability was high for most of the parameters under investigation demonstrating these parameters were less influenced by environmental impacts. The pooled data was utilized for estimation. Hence, selection would be more effective for up gradation of these parameters. Similar results were obtained by Soorianthasundaram and Nambisan (1991) and Bichoo *et al.* (2002) and Bhujabal *et al.* (2013) in *Gladiolus*.

In general, heritability specifies the proportion of the total variability that is due to genetic causes or the ratio of genotypic variance to the total variance. It is a good index of the transmission of characters from parents to their off spring (Falconer, 1981).

Improvement in the mean genotypic value of best selected plant over the parental population is known as genetic advance. It is the measure of genetic gain under selection. Heritability and genetic advance are important selection parameters. High heritability coupled with high genetic advance is important in predicting the genetic gain under selection than variability estimated alone (Jhonson *et al.*, 1955). In the present investigation,

preponderance yield correlated attributes and pigment intensity (h^2%- 99.99% and GAM- 506.69%@ anthocyanin of leaves, h^2%- 99.26% and GAM- 91.37%@ total chlorophyll of leaves) exhibited high heritability coupled with high genetic advance (GA) (Table 1). This indicates that most likely the heritability is due to additive gene effect or additive gene action predominant for controlling such characters under study. Therefore, there is an ample scope for selection in the variable population. But the character number of leaves/ stem revealed low heritability coupled with low GA. The characters days from first to last flower opening (Sanjeev *et al*., 2010), days from bud emergence to male phase, duration of male phase, days from bud emergence to female phase and duration of female phase recorded high heritability and genetic advance duo. Hence these features can be considered for further crop improvement program. Comparable consequences were found by Janakiram and Rao (1991) in African Marigold for total flower yield per plant, Misra and Saini (1997) in Dahlia and Katwate *et al*. (1990) in Gladiolus.

Greater part of characters under the present study showed high heritability as per the classification of Robinson (1965). So selection of phenotypically superior plants with respect to these features will result in significant improvement in the next generation.

Phenotypic and genotypic correlations were computed for all possible paired combinations among twenty two different characters over the years. Genotypic correlation in general was higher in magnitude (Table 3) than corresponding phenotypic correlation (Table 2), thus indicating that there was inherent association among various characters and phenotypic expressions or correlation was lessened under the influence of the environment.

It revealed from the table-2 and 3 that plant height exhibited positive correlation at both genotypic and phenotypic levels with all characters except number of shoots clump^{-1} (-0.179 and -0.181), number of leaves stem^{-1} (-0.030 and 0.032), anthocyanin content (-0.214 and -0.210), number of flowering stems clump^{-1} (-0.226 and -0.198), number of inflorescence plant^{-1} year^{-1} (-0.129 and -0.126) and duration of male phase (-0.019 and -0.022). Similar results were obtained by Raghava *et al*. (1992) in Chrysanthemum, Mathad *et al*., (2003) in Marigold, Misra and Saini (1997) in Dahlia, Barpande (1990) in Gladiolus and Radhakrishna *et al*. (2004) in Tuberose. In contrast, number of inflorescence plant^{-1} year^{-1} showed positive correlation (0.104) with plant height at environmental correlation level (Table 4). Here, annual yield of inflorescence was found to be positively correlated with number of leaves stem^{-1}, total chlorophyll content of leaves, inflorescence length and number of open bracts at genotypic and phenotypic levels duo (Table 2, 3). Few floral-biology attributes *viz.* days from first to last flower opening, duration of male phase and duration of female phase showed negative correlation with size of bracts at environmental correlation level (Table 4). So, the role of environment in the expression of these characters limits the chances of inheriting these characters through breeding. Significant positive correlation between the parameters at genotypic and phenotypic level revealed these features are vital for breeding programme.

The path analysis exhibited (Table 5) that the duration of female phase (hereby dependant variable) was largely influenced through the largest direct positive effect of days from bud emergence to full unfurling of bracts (0.4294), inflorescence length (0.3906), days from first to last flower opening (0.2763), number of inflorescence plant^{-1} year^{-1} (0.2108), duration of male phase (0.1711), leaf blade length (0.1172), size of bracts (0.0757), number of open bracts (0.0609), plant height (0.0568), number of leaves stem^{-1} (0.0517) and number of flowering stems/clump (0.0147). Similar trend was reported by Nazia (2007) in *Heliconia* sp.

Characters showing negative and direct effect on the depended character was highest in total chlorophyll content of leaves (-0.4923), stem length (-0.4404), anthocyanin content of leaves (-0.4394), number of bracts (-0.4374), number of flowers inflorescence^{-1} (-0.2636), number of flowers bract^{-1} (-0.2201), number of shoots clump^{-1} (-0.0809) and days from emergence to male phase (-0.0387).

It may be depicted from the above results that selection based on characters having highest positive and direct impacts on the duration of female phase might be accounted for crop improvement and shaping of potential genotypes.

Wide variation was observed among the 10 genotypes of *Heliconia* for vegetative and floral characteristics. The study revealed that under hot and humid situation prevailing over West Bengal there was no uniformity in flowering behavior of different species and varieties. Hybrid cultivar 'Golden Torch' only flowers profusely and exhibited perpetual blooming, hence ideal for the landscaping. Significant positive correlation b/w 'days from first to last flower opening', 'days from emergence to male' and 'female phase' and 'duration of male' and 'female phase' with 'days from bud emergence to full unfurling of bracts' at both genotypic and phenotypic levels revealing that these features are vital in breeding programs. As annual yield of inflorescences are reasonably an imperative parameter, it has found to be positively correlated with 'number of leaves/stem', 'total chlorophyll content of leaves', 'inflorescence length' and 'number of open bracts' at genotypic and phenotypic levels duo. It also showcased positive correlation with plant height at environmental correlation level.

Table 2: Phenotypic correlation coefficients between different characters of *Heliconia* sp. (pooled)

@	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.000	0.484	0.647	-0.181	-0.032	-0.210	0.561	-0.198	0.848**	0.700	0.800**	-0.126	0.670*	0.764*	0.680*	0.862**	0.706*	0.592	0.643	-0.022	0.635	0.016
2		1.000	0.695*	-0.120	0.060	0.403	-0.107	0.239	0.619	0.636	0.431	-0.261	-0.053	0.419	0.518	0.571	0.322	0.458	0.488	0.009	0.480	-0.039
3			1.000	-0.305	-0.076	0.570	-0.052	0.341	0.785*	0.606	0.491	-0.435	0.358	0.415	0.530	0.552	0.353	0.344	0.348	-0.145	0.421	-0.211
4				1.000	-0.221	-0.311	-0.377	-0.363	-0.345	-0.114	-0.080	-0.077	-0.228	0.114	-0.280	-0.026	-0.186	0.283	0.262	0.365	0.209	0.419
5					1.000	0.074	0.127	0.453	-0.116	0.453	0.102	0.118	0.010	0.028	0.194	-0.115	-0.157	-0.140	-0.222	0.011	-0.225	-0.015
6						1.000	-0.660	0.701*	0.144	0.149	-0.194	-0.328	-0.348	-0.219	-0.109	-0.243	-0.384	-0.234	-0.284	-0.219	-0.197	-0.348
7							1.000	-0.275	0.260	0.150	0.349	0.255	0.666*	0.179	0.515	0.392	0.665	0.146	0.205	0.025	0.175	0.085
8								1.000	-0.063	0.163	-0.217	-0.370	-0.075	-0.364	0.130	-0.278	-0.150	-0.176	-0.271	0.058	-0.169	-0.075
9									1.000	0.683*	0.801**	-0.042	0.400	0.769*	0.543	0.826**	0.453	0.391	0.462	-0.345	0.457	-0.340
10										1.000	0.761*	0.013	0.270	0.746*	0.508	0.614	0.171	0.334	0.317	-0.161	0.303	-0.167
11											1.000	0.134	0.528	0.903**	0.650	0.896**	0.374	0.341	0.390	-0.371	0.362	-0.309
12												1.000	-0.258	0.064	-0.220	-0.061	-0.432	-0.639	-0.544	-0.680*	-0.668*	-0.621
13													1.000	0.339	0.676*	0.531	0.685*	0.320	0.308	0.066	0.387	0.104
14														1.000	0.392	0.825**	0.294	0.514	0.551	-0.197	0.503	-0.123
15															1.000	0.767*	0.727*	0.380	0.405	-0.034	0.435	-0.026
16																1.000	0.650	0.570	0.645	-0.157	0.615	-0.100
17																	1.000	0.712*	0.749*	0.412	0.772*	0.442
18																		1.000	0.983**	0.675*	0.987**	0.702*
19																			1.000	0.591	0.982**	0.629
20																				1.000	0.623	0.987**
21																					1.000	0.647
22																						1.000

*Note: *Significant at 5% level, **Significant at 1% level*

Characters: 1. Plant height (feet), 2. Plant spread (sq. feet), 3. Leaf blade length (cm.), 4. Number of shoots per clump, 5. Number of leaves per stem, 6. Anthocyanin content of leaves (mg 100 $^{-1}$g tissue), 7. Total Chlorophyll content of leaves (mg g^{-1} tissue), 8. Number of flowering stems per clump, 9. Stem length (cm), 10. Inflorescence length (cm), 11. Number of open bracts, 12. Number of inflorescence per plant per year, 13. Size of bract (cm^2), 14. Number of bracts, 15. Number of flowers per bract, 16. Number of flowers per inflorescence, 17. Days from bud emergence to full unfurling of bracts, 18. Days from 1st to last flower opening, 19. Days from bud emergence to male phase, 20. Duration of male phase, 21. Days from bud emergence to female phase, 22. Duration of female phase.

Table 3: Genotypic correlation coefficients between different characters of *Heliconia* sp. (pooled)

@	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.000	0.547	0.665	-0.179	-0.030	-0.214	0.570	-0.226	0.865**	0.709*	0.823**	-0.129	0.685*	0.771*	0.699*	0.874**	0.718*	0.603	0.651	-0.019	0.647	0.017
2		1.000	0.749*	-0.137	0.143	0.436	-0.111	0.350	0.676*	0.690*	0.484	-0.281	-0.067	0.468	0.559	0.619	0.337	0.485	0.513	-0.009	0.494	-0.061
3			1.000	-0.325	-0.087	0.571	-0.049	0.414	0.790*	0.608	0.498	-0.437	0.358	0.419	0.532	0.553	0.358	0.346	0.352	-0.146	0.425	-0.211
4				1.000	-0.274	-0.324	-0.388	-0.538	-0.374	-0.121	-0.099	-0.088	-0.238	0.124	0.289	-0.033	-0.190	0.293	0.274	0.375	0.217	0.442
5					1.000	0.094	0.128	0.593	-0.141	0.564	0.160	0.146	0.039	0.036	0.212	-0.130	-0.211	-0.185	-0.289	0.002	-0.267	-0.035
6						1.000	-0.662	0.831**	0.144	0.149	-0.196	-0.329	-0.349	-0.221	-0.110	-0.243	-0.385	-0.234	-0.285	-0.220	-0.197	-0.348
7							1.000	-0.341	0.264	0.152	0.352	0.257	0.670*	0.181	0.522	0.395	0.668*	0.147	0.205	0.024	0.175	0.083
8								1.000	-0.100	0.196	-0.265	-0.454	-0.082	-0.405	0.172	-0.340	-0.170	-0.207	-0.317	0.050	-0.193	-0.082
9									1.000	0.685*	0.817**	-0.044	0.404	0.778*	0.550	0.828**	0.459	0.393	0.465	-0.352	0.460	-0.341
10										1.000	0.771*	0.013	0.271	0.749*	0.511	0.615	0.171	0.333	0.317	-0.162	0.305	-0.167
11											1.000	0.136	0.533	0.921**	0.669*	0.910**	0.385	0.346	0.396	-0.376	0.369	-0.314
12												1.000	-0.258	0.067	-0.220	-0.062	-0.432	-0.641	-0.548	-0.686*	-0.670*	-0.623
13													1.000	0.343	0.681*	0.533	0.690*	0.322	0.312	0.067	0.388	0.104
14														1.000	0.396	0.831**	0.293	0.517	0.557	-0.194	0.509	-0.122
15															1.000	0.773*	0.732*	0.384	0.410	-0.031	0.440	-0.027
16																1.000	0.655	0.573	0.650	-0.158	0.618	-0.099
17																	1.000	0.716*	0.755*	0.417	0.775*	0.443
18																		1.000	0.986**	0.675*	0.990**	0.703*
19																			1.000	0.591	0.986**	0.629
20																				1.000	0.624	0.991**
21																					1.000	0.647
22																						1.000

*Note: *Significant at 5% level, **Significant at 1% level*

Characters: 1. Plant height (feet), 2. Plant spread (sq. feet), 3. Leaf blade length (cm.), 4. Number of shoots per clump, 5. Number of leaves per stem, 6. Anthocyanin content of leaves (mg 100 $^{-1}$g tissue), 7. Total Chlorophyll content of leaves (mg g^{-1} tissue), 8. Number of flowering stems per clump, 9. Stem length (cm), 10. Inflorescence length (cm), 11. Number of open bracts, 12. Number of inflorescence per plant per year, 13. Size of bract (cm^2), 14. Number of bracts, 15. Number of flowers per bract, 16. Number of flowers per inflorescence, 17. Days from bud emergence to full unfurling of bracts, 18. Days from 1st to last flower opening, 19. Days from bud emergence to male phase, 20. Duration of male phase, 21. Days from bud emergence to female phase, 22. Duration of female phase.

Table 4: Environmental correlation coefficients between different characters of *Heliconia* sp. (pooled)

@	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.000	-0.239	-0.621	-0.255	-0.084	0.134	0.090	-0.104	-0.108	0.239	0.002	0.104	-0.427	0.463	-0.305	0.080	0.111	-0.119	0.271	-0.212	-0.083	-0.035
2		1.000	0.148	0.014	-0.211	-0.228	-0.130	-0.175	-0.139	-0.097	-0.158	-0.075	0.378	-0.272	0.096	-0.059	0.317	0.400	0.413	0.451	0.744*	0.622
3			1.000	0.303	-0.148	0.255	-0.475	-0.230	0.002	-0.025	0.150	0.094	0.495	-0.104	0.325	0.122	-0.292	-0.024	-0.171	-0.114	-0.147	-0.254
4				1.000	-0.050	0.053	-0.248	0.486	0.513	0.107	0.274	0.511	0.003	-0.155	-0.152	0.506	-0.153	0.180	0.018	0.260	0.054	-0.229
5					1.000	-0.310	0.470	0.151	-0.051	-0.106	-0.257	-0.006	-0.617	-0.007	0.386	-0.420	0.216	0.224	0.170	0.144	-0.201	0.308
6						1.000	-0.657	-0.368	0.178	0.015	-0.152	0.083	-0.026	0.174	-0.037	0.159	-0.468	-0.422	-0.338	-0.196	-0.212	-0.496
7							1.000	0.279	-0.309	-0.334	0.190	-0.249	-0.063	-0.026	-0.228	-0.295	0.371	0.124	0.116	0.121	0.067	0.339
8								1.000	0.475	-0.107	0.039	0.490	-0.183	-0.384	-0.262	0.457	-0.123	-0.028	-0.077	0.306	-0.129	-0.160
9									1.000	0.312	-0.083	0.375	-0.323	-0.244	-0.189	0.448	-0.183	0.159	0.109	0.486	0.011	-0.183
10										1.000	0.279	-0.066	-0.271	0.408	0.002	-0.061	0.013	0.487	0.454	0.023	-0.146	-0.010
11											1.000	0.033	0.318	0.031	-0.300	0.120	-0.172	0.078	0.159	-0.118	0.026	-0.029
12												1.000	-0.189	-0.478	-0.261	0.365	-0.571	-0.171	0.118	0.204	-0.135	-0.029
13													1.000	-0.173	-0.153	0.006	-0.022	-0.148	-0.296	-0.073	0.208	-0.048
14														1.000	0.049	-0.092	0.378	0.148	0.009	-0.420	-0.097	-0.223
15															1.000	-0.284	0.346	-0.098	-0.071	-0.300	-0.121	0.005
16																1.000	-0.215	-0.205	-0.208	-0.071	-0.027	-0.520
17																	1.000	0.228	0.122	-0.051	0.356	0.316
18																		1.000	0.743*	0.642	0.441	0.543
19																			1.000	0.573	0.453	0.638
20																				1.000	0.558	0.546
21																					1.000	0.678*
22																						1.000

*Note: *Significant at 5% level, **Significant at 1% level*

Characters: 1. Plant height (feet), 2. Plant spread (sq. feet), 3. Leaf blade length (cm.), 4. Number of shoots per clump, 5. Number of leaves per stem, 6. Anthocyanin content of leaves (mg 100 $^{-1}$g tissue), 7. Total Chlorophyll content of leaves (mg g^{-1} tissue), 8. Number of flowering stems per clump, 9. Stem length (cm), 10. Inflorescence length (cm), 11. Number of open bracts, 12. Number of inflorescence per plant per year, 13. Size of bract (cm^2), 14. Number of bracts, 15. Number of flowers per bract, 16. Number of flowers per inflorescence, 17. Days from bud emergence to full unfurling of bracts, 18. Days from 1st to last flower opening, 19. Days from bud emergence to male phase, 20. Duration of male phase, 21. Days from bud emergence to female phase, 22. Duration of female phase

Table 5: Direct (diagonal bold) and Indirect effects of different characters on 'Duration of Female Phase' (dependant variable)

@	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	**0.057**	-0.044	0.078	0.020	-0.002	0.094	-0.280	-0.003	-0.381	0.277	0.050	-0.027	0.052	-0.337	-0.154	-0.230	0.308	0.167	-0.025	-0.003	0.402
2	0.031	**-0.081**	0.088	0.015	0.007	-0.192	0.055	0.005	-0.298	0.269	0.030	-0.059	-0.005	-0.205	-0.123	-0.163	0.145	0.134	-0.020	-0.002	0.307
3	0.038	-0.061	**0.117**	0.037	-0.005	-0.251	0.024	0.006	-0.348	0.237	0.030	-0.092	0.027	-0.184	-0.117	-0.146	0.154	0.096	-0.014	-0.025	0.264
4	-0.010	0.011	-0.038	**-0.113**	-0.014	0.142	0.191	-0.008	0.165	-0.047	-0.006	-0.019	-0.018	-0.054	0.064	0.009	-0.082	0.081	-0.011	0.064	0.135
5	-0.002	-0.012	-0.010	0.031	**0.052**	-0.041	-0.063	0.009	0.062	0.220	0.010	0.031	0.003	-0.016	-0.047	0.034	-0.091	-0.051	0.011	0.000	-0.166
6	-0.012	-0.035	0.067	0.037	0.005	**-0.439**	0.326	0.012	-0.063	0.058	-0.012	-0.069	-0.026	0.097	0.024	0.064	-0.165	-0.065	0.011	-0.038	-0.123
7	0.032	0.009	-0.006	0.044	0.007	0.291	**-0.492**	-0.005	-0.116	0.059	0.021	0.054	0.051	-0.079	-0.115	-0.104	0.287	0.041	-0.008	0.004	0.109
8	-0.013	-0.028	0.049	0.061	0.031	-0.365	0.168	**0.015**	0.044	0.076	-0.016	-0.096	-0.006	0.177	-0.038	0.090	-0.073	-0.057	0.012	0.008	-0.120
9	0.049	-0.055	0.093	0.042	-0.007	-0.063	-0.130	-0.001	**-0.440**	0.268	0.050	-0.009	0.031	-0.341	-0.121	-0.218	0.197	0.109	-0.018	-0.060	0.286
10	0.040	-0.056	0.071	0.014	0.029	-0.065	-0.075	0.003	-0.302	**0.391**	0.047	0.003	0.021	-0.328	-0.113	-0.162	0.074	0.092	-0.012	-0.028	0.189
11	0.047	-0.039	0.058	0.011	0.008	0.086	-0.173	-0.004	-0.360	0.301	**0.061**	0.029	0.040	-0.403	-0.147	-0.240	0.165	0.096	-0.015	-0.064	0.229
12	-0.007	0.023	-0.051	0.010	0.008	0.144	-0.127	-0.007	0.019	0.005	0.008	**0.211**	-0.020	-0.029	0.048	0.016	-0.186	-0.177	0.021	-0.117	-0.417
13	0.039	0.005	0.042	0.027	0.002	0.153	-0.330	-0.001	-0.178	0.106	0.033	-0.054	**0.076**	-0.150	-0.150	-0.140	0.296	0.089	-0.012	0.011	0.241
14	0.044	-0.038	0.049	-0.014	0.002	0.097	-0.089	-0.006	-0.343	0.293	0.056	0.014	0.026	**-0.437**	-0.087	-0.219	0.126	0.143	-0.022	-0.033	0.316
15	0.040	-0.045	0.062	0.033	0.011	0.048	-0.257	0.003	-0.242	0.200	0.041	-0.046	0.052	-0.173	**-0.220**	-0.204	0.314	0.106	-0.016	-0.005	0.273
16	0.050	-0.050	0.065	0.004	-0.007	0.107	-0.194	-0.005	-0.365	0.240	0.055	-0.013	0.040	-0.364	-0.170	**-0.264**	0.281	0.158	-0.025	-0.027	0.384
17	0.041	-0.027	0.042	0.021	-0.011	0.169	-0.329	-0.003	-0.202	0.067	0.023	-0.091	0.052	-0.128	-0.161	-0.173	**0.429**	0.198	-0.029	0.071	0.482
18	0.034	-0.039	0.041	-0.033	-0.010	0.103	-0.072	-0.003	-0.173	0.130	0.021	-0.135	0.024	-0.226	-0.084	-0.151	0.308	**0.276**	-0.038	0.116	0.615
19	0.037	-0.042	0.041	-0.031	-0.015	0.125	-0.101	-0.005	-0.205	0.124	0.024	-0.116	0.024	-0.244	-0.090	-0.171	0.324	0.272	**-0.039**	0.101	0.613
20	-0.001	0.001	-0.017	-0.042	0.000	0.097	-0.012	0.001	0.155	-0.063	-0.023	-0.145	0.005	0.085	0.007	0.042	0.179	0.187	-0.023	**0.171**	0.388
21	0.037	-0.040	0.050	-0.024	-0.014	0.087	-0.086	-0.003	-0.203	0.119	0.022	-0.141	0.029	-0.223	-0.097	-0.163	0.333	0.274	-0.038	0.107	**0.621**

Residual effect – 0.886906

Characters: 1. Plant height (feet), 2. Plant spread (sq. feet), 3. Leaf blade length (cm.), 4. Number of shoots per clump, 5. Number of leaves per stem, 6. Anthocyanin content of leaves (mg 100 $^{-1}$g tissue), 7. Total Chlorophyll content of leaves (mg g^{-1} tissue), 8. Number of flowering stems per clump, 9. Stem length (cm), 10. Inflorescence length (cm), 11. Number of open bracts, 12. Number of inflorescence per plant per year, 13. Size of bract (cm^2), 14. Number of bracts, 15. Number of flowers per bract, 16. Number of flowers per inflorescence, 17. Days from bud emergence to full unfurling of bracts, 18. Days from 1st to last flower opening, 19. Days from bud emergence to male phase, 20. Duration of male phase, 21. Days from bud emergence to female phase, 22. Duration of female phase

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