# VARIABILITY STUDIES IN SEEDLINGS OF HELICONIA

## (*Heliconia spp.*).

by

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(2009-12-111)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

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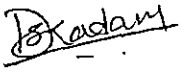
2011

## DECLARATION

I hereby declare that this thesis entitled **"Variability studies in seedlings of heliconia (*Heliconia spp.*)".** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.



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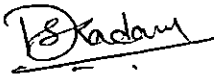

**Darshan S. K.**

**(2009-12-111)**

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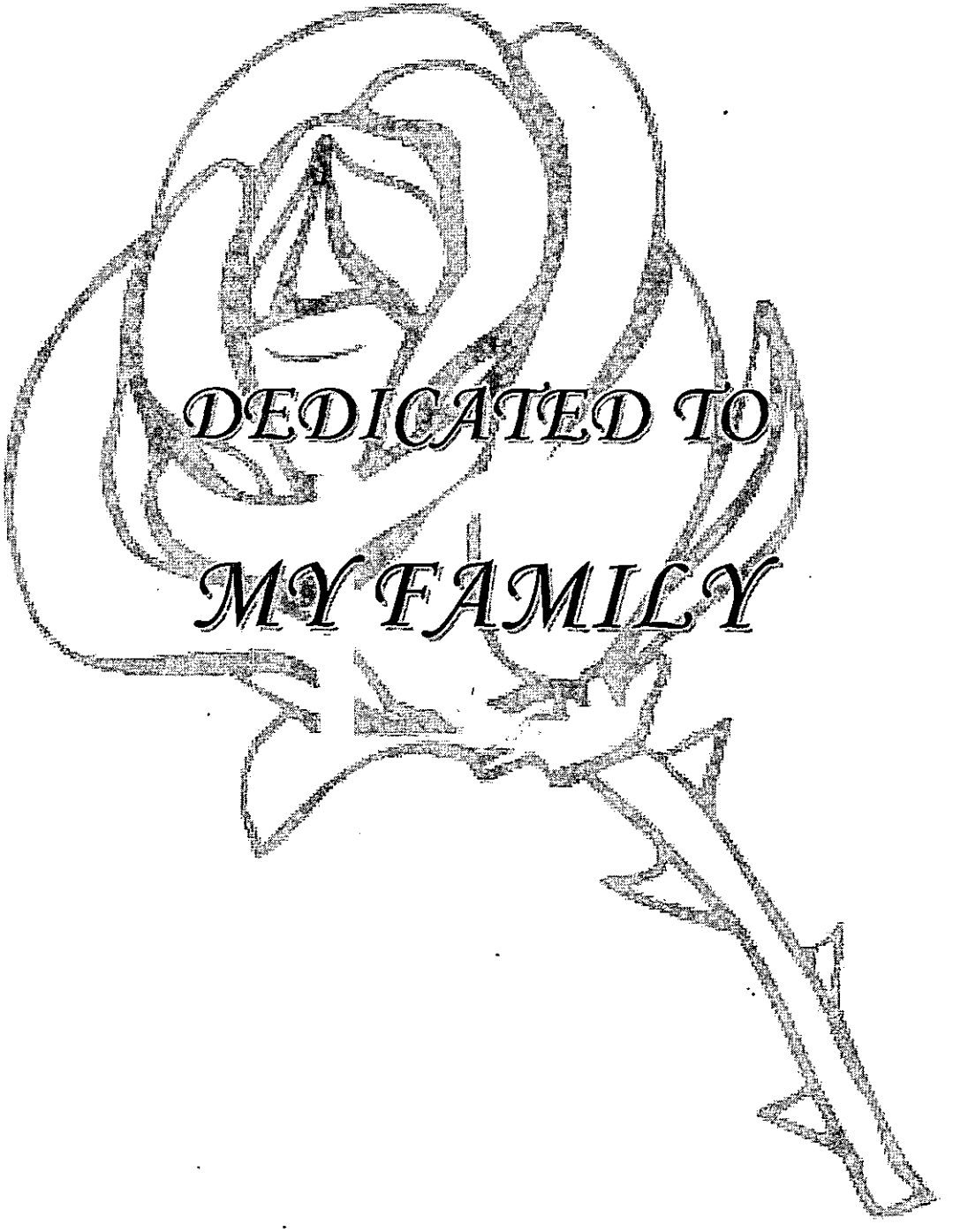
## LIST OF ABBREVATIONS

| | | |
|---|---|---|
| ANACOVA | – | Analysis of Covariance |
| ANOVA | – | Analysis of variance |
| *et. al.* | – | And others |
| cm | – | Centimeters |
| CRD | – | Completely Randomized Design |
| CD | – | Critical Difference |
| Cv. | – | Cultivar |
| DAE | – | Days after emergence |
| DMSO | – | Dimethyl sulfoxide |
| e. g. | – | Example |
| ' | – | Feet |
| Fig. | – | Figure |
| GA | – | Genetic advance |
| GCV | – | Genotypic coefficient of variation |
| g | – | Gram/s |
| $H^2$ | – | Heritability |

| LIST OF ABBREVATIONS CONTINUDE | | |
|---|---|---|
| LMA | – | Leaf mass area |
| LMD | – | Leaf mass density |
| LT | – | Leaf thickness |
| L | – | Length |
| lit. | – | Litre |
| M | – | Meter |
| $M^2$ | – | Meter square |
| Mm | – | Millimeter |
| NIR | – | Near Infrared |
| % | – | Percentage |
| PCV | – | Phenotypic coefficient of variation |
| St. Lucia | – | Saint Lucia |
| Spp./Sp. | – | Species |
| SE | – | Standard error |
| i.e. | – | That is |
| USSR | – | Union of Soviat Socalist Republic |

| LIST OF ABBREVATIONS CONTINUDE | | |
|---|---|---|
| UFRPE | – | Universidade Federal Rural de Pernambuco /Federal Rural University of Pernambuco |
| Vs. | – | Verses |
| W | – | Width |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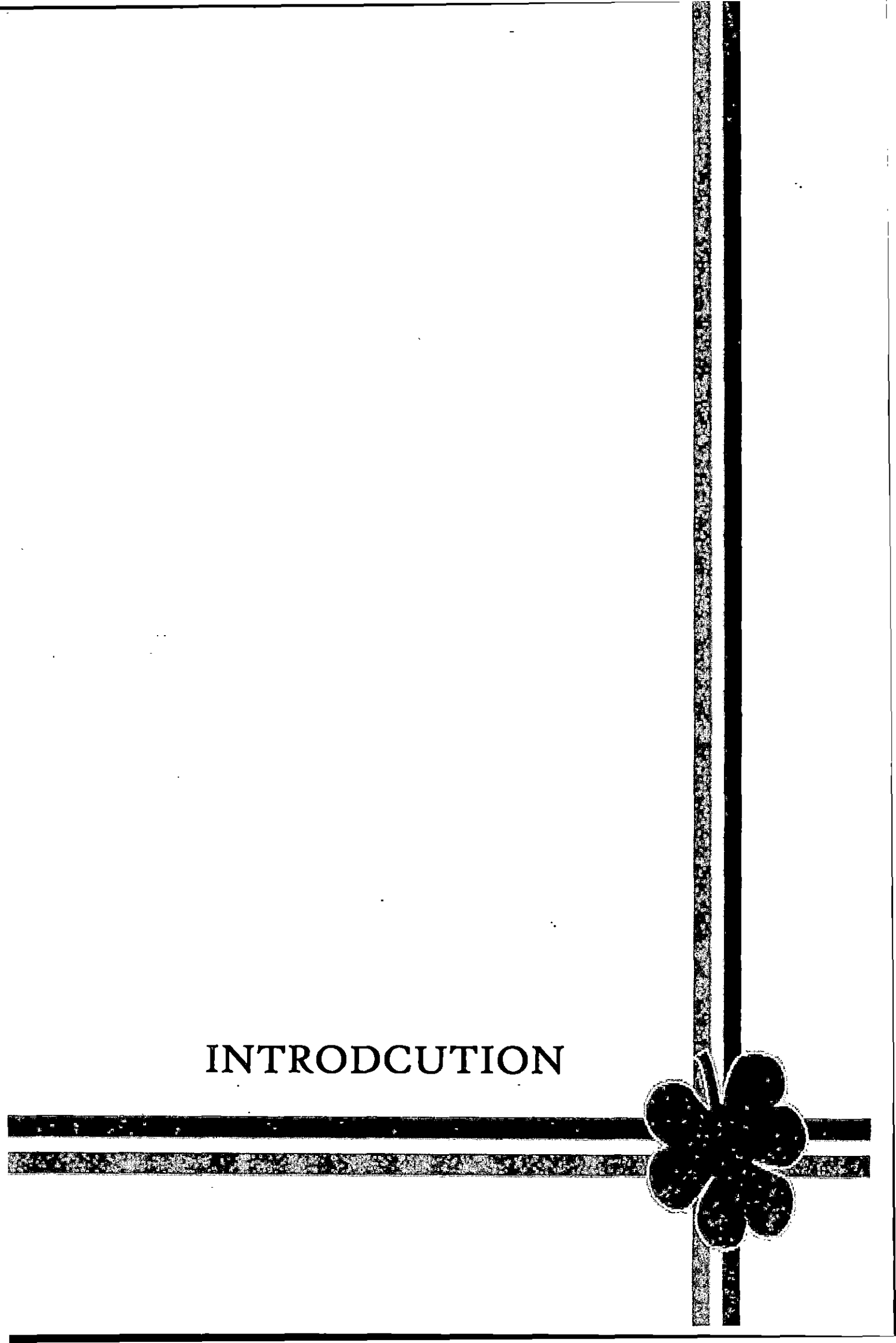


# 1. INTRODUCTION

Heliconia derives their name from the Mount Helicon in Greece, home to the Muses, goddesses of the arts and sciences in Greek mythology. The Muses were said to be eternally young and beautiful, thus the name "*Heliconia*" refers to the flower's long-lasting and attractive qualities. Common names for the genus include lobster-claws, wild plantains or false bird-of-paradise.

Heliconia are known for their beautiful, brilliant colorful flowering bracts. Breathtaking and unusual flowerheads (bracts) rise from clumps of banana like leaves, sometimes very large or slender. Heliconia flowers are actually highly modified leaves and bracts. Heliconias belonging to the family Heliconiaceae, are among the most provocative of all exotic tropical flowering plants. The family comprises of 250-300 species distributed mainly in Neotropical areas from the North of Mexico to the South of Brazil (Kress, 1990). They are native to Central and South America, the Caribbean Islands and some of the islands of the South Pacific.

Originally, heliconias were included in the family Musaceae, but the genus was always considered to be homogeneous and with its own characteristics, such as inverted flowers, the presence of a single staminode and drupe-type fruits. Nakai (1941) raised *Heliconia* to the family level (Heliconiaceae), and today, this family has only one genus (*Heliconia*), belonging to the order Zingiberales, which comprises eight families: Musaceae (bananas), Strelitziaceae (the birds of paradise), Lowiaceae (no common name), Heliconiaceae (heliconias), Zingiberaceae (the gingers), Costaceae (the costus), Cannaceae (the cannas), and Marantaceae (the prayer plants) (Berry and Kress, 1991). The growth habit of heliconias is similar to Canna, Strelitzia, and bananas, to which they are related.

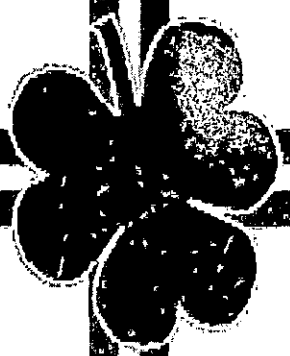
As most of the cultivated *Heliconia* species set few fruits or are sterile and the germination of the seed is low, the vegetative propagation by division of rhizomes is preferred in its commercial production (Criley, 1988; Lee *et al.*, 1994; Simao and

Scatena, 2003). It has been found that cross-fertilization between *Heliconia* species is generally unsuccessful due to problems of incompatibility. There is no evidence that any hybrids of heliconia have been artificially made (Berry and Kress, 1991). Existence of pre-fertilization crossability barrier *i.e.*, stigmatic, stylar or ovarian, act as the ultimate mechanism preventing hybridization (Kress, 1983a). Sanjeev (2005) also reported that cross incompatibility existed in heliconia leading to problems in seed set.

Seed set by transfer of pollen by pollinator is seen in heliconias (Berry and Kress, 1991). According to them small bird like the humming bird and some ants act as pollinating agents. Altshuler, (2003) has reported that pollination in heliconia is mainly ornithophilous. Lotens sunbird (*Nectarina lotentia)*, ants and stingless bees (*Melipona iridipennis*) were identified as pollinators of heliconia in Kerala (Sanjeev, 2005). A great number of new colours and shapes in inflorescences appear in cultivars of heliconias grown commercially. Differences in genetic expressions of traits were reported to be the causative factor of new colours and shapes in natural hybrid populations of heliconias. Naturally pollinated seedlings of H.carribea X H.bihai cv. Bubblegum showed colour variations widely differing from parents (Raymond, 2005). Similar variations have also been reported in *Heliconia atropurpurea* by Black (2009).

On the context of existence of pre-fertilization crossability barriers and ornithophilous pollination, utilization of naturally occurring variability is easiest way of crop improvement in heliconia. Also the identification of superior plants among population in early stage of growth is essential for research. Hence the present study was undertaken with the objective to assess the vegetative performance and extent of variability in heliconia population obtained from open pollinated seedlings.

# REVIEW OF LITERATURE



# 2. REVIEW OF LITERATURE

Heliconias are the most attractive among all exotic tropical flowering plants. They are known as lobster's claws, parrots flower, parrots plantain and false plantain. There are about 89 species under the genus Heliconia and more than 350 varieties. They are banana like plants with rhizomes or underground stems having distribution of nutrients and water like the true stems. They are propagated by bits of rhizomes as well as suckers or side shoots arising from the clumps and rarely from seeds (Tom, 1997).

When heliconias were first discovered, they were included in the Musaceae family along with bananas. But now they are included in the family Heliconiaceae. Heliconia is the only genus in the plant family Heliconiaceae, which is a member of a larger taxonomic order Zingiberales coming under the Monocots. There are two main types of heliconias, erect heliconia and pendent heliconia. Erect heliconias stand straight with bracts pointing up. Pendent heliconias hang with bracts pointing down. Their inflorescences have colourful bracts which curve upwards and downwards in alternate patterns along a thick stem (Endre, 1996). There are several characteristics by which they can be recognized, including large leaves and large colourful bracteaic inflorescences. Most taxonomists recognize eight separate families in the order Zingiberales which are Musaceae, Sterilitziceae, Lowiaceae, Heliconiaceae, Zingiberaceae, Costaceae, Cannaceae and Marantaceae.

This review highlights the research on the various aspects of evaluation, morphological, physiological and seed characterization of heliconias and extent of variability in heliconia and related crops.

## 2.1 SPECIES AND CULTIVARS

There are about 250-300 species of *Heliconia* distributed primarily in Neotropical areas from the North Mexico to the South of Brazil (Dehlgren *et*

*al.*, 1985; Kress, 1990). They are banana like plants with rhizomes or underground stems, propagated by bits of rhizomes as well as suckers. There are two types of heliconia erect and pendent with respect to the orientation of inflorescence.

Some of the important erect species of *Heliconia* are *Heliconia psittacorum, H. stricta, H. latispatha, H. bihai, H. distance, H. angustifolia, H. angusta, H. bourgeana, H. subulata, H. velloziana, H. hirsuta, H. rivularis* and *H. spathocircinata.* Pendent species of *Heliconia* include *Heliconia rostrata, H. collinsiana, H. chartacae, H. nutans* and *H. combinata.*

Other species of *Heliconia* include *H. solomenensis, H. orthotricha, H. magnifica, H. xanthovillosa, H. metallica, H. moriae, H. caribaea, H. secunda, H. clonophila, H. marginata, H. schiedeana, H. spissa, H. bourgeana, H. touruosa, H. irrasa, H. thomasiana* and *H. imbricata.*

In heliconia there are more than 500 cultivars (Berry and Kress, 1991). Among these *H. psittacorum* was considered the most useful for cut flower production because of its upright stem, moderately vigorous growth habit, long flowering season and long lasting flowers. Important cultivars of *H. psittacorum* are Andromeda, Lady Di, Sassy, Parakeet, St. Vincent Red, Pascal, Choconiana, Nikeriensis, Rosi and Blush.

Some of the most important species of heliconia are described below.

***Heliconia latispatha***

They are the native of Central and South America. The leaves are broad and oblong having 1m length and 30 cm width. It has erect inflorescence with well-separated boat shaped bract, 15 cm long and orange-yellow at base near axis and red towards the tip. They are tropical plants having green flowers (David, 1985).

***Heliconia collinsiana***

They are robust tropical perennial plants with lush growth. The inflorescence is pendent. The bracts are crimson-red and covered with waxy powder, yellowish towards tip. The flowers are cream in colour (David, 1985).

***Heliconia stricta***

The strictas have exotic inflorescence with colour ranging from red, gold, orange, maroon and green singly or in combination. These exotic tropicals are ideal for small arrangements as their inflorescence range from 5 to12 inches long and are not too heavy (Charleston, 1997).

***Heliconia bihai***

It is commonly known as Wild plantain or Fire bird. It is a large perennial herb having oblong smooth textured pointed green leaves. The bracts are crimson red with pointed tips and arranged in two rows on erect inflorescence (David, 1985).

***Heliconia magnifica***

It is a beautiful hanging heliconia of medium size, about 6-8 feet tall, and has solid dark red bracts with white hairs. Grows well in shade to partial shade. Blooms from May through September. (montosogardens, 2005)

***Heliconia latispatha* 'Orange Gyro'**

'Orange Gyro' has a beautiful solid orange spiral inflorescence with golden yellow true flowers. It is a large plant, about 8-10 feet tall, and is a spreading heliconia. Grows in partial shade to full sun. Blooms throughout the year, but primarily from May through August in Puerto Rico (montosogardens, 2005)

***Heliconia mariae***

A truly spectacular and bizarre heliconia. This one is very tall, reaching 15-20 feet, with a long lasting 3-4 foot inflorescence with tight, blood red bracts. It looks like something out of a prehistoric swamp! Blooms throughout the year. (montosogardens, 2005)

***Heliconia pogonantha***

*Heliconia pogonantha* is a hanging heliconia of medium size, about 6-8 feet tall, and has bright pink bracts, fading to light yellow at the base, with a golden yellow, hairy rachis. Grows well in shade to partial shade. Blooms from May through October. (montosogardens, 2005)

**Heliconia champneianana 'Maya Gold'**

'Maya Gold' is a close relative of 'Splash'. 'Maya Gold' has large, golden flowers with thick, chunky, open bracts. It has light to dark green along the edge and tip of the bracts, and some bracts have minute flecks of maroon. It can grow to be a large plant, up to about 15 feet tall in excellent conditions. It grows in partial shade to full sun. Blooms spring/summer.

**Heliconia Bihai 'Manoa Sunrise'**

Extra large red and yellow flowers (with shades of green and orange), having 6-12 bracts. Grows from 2-4 metres (6-12 feet) high, in full sun to 40% shade.

***Heliconia ramonensis***

*Heliconia ramonensis* is a hanging heliconia of medium size, about 6-8 feet tall, and has solid pale pink bracts with a darker pink border and a hairy

rachis. Grows well in shade to partial shade. Blooms from December through May. (montosogardens, 2005)

***Heliconia psittacorum***

They originated from the Coast of Guyana. The psittacorum (or parrot's beak) heliconias are small, dainty and exotically tropical. It resembles the plant commonly known as Bird-of-Paradise. They bloom throughout the year. The psittacorums rarely exceed 3'-6' in height. It grows well under tropical conditions (Juan, 1997).

***Heliconia psittacorum* cv. Andromeda**

It possesses very attractive reddish-orange to pink bracts. Flowers are very long lasting. It grows up to a height of 4 'to 6'. Broschat et al. (1984) had given the following description about Andromeda. Height ranges from 1.0 to 1.8 m, and it produce 5 leaves/shoot followed by a terminal inflorescence with 3 or 4 bracts. The bracts are red, fading to light orange at their bases. The lower half of each bract and the upper 2 to 3 cm of the peduncle are covered with a waxy white bloom. The florets are orange with black tips and the main axis of the inflorescence is orange.

***Heliconia psittacorum* cv. Lady Di**

Lady Di may be the most beautiful among the psiittacorums. It has dark rose red bracts and cream yellow sepals with dark green bands and white tips. Height of the plant ranges from 2'to 3' with an erect habit. It can grow well in up to 40 % shade. Peak flowering is during April to November (Juan, 1997).

***Heliconia psittacorum* cv. Choconiana**

They bloom throughout the year and produces 4 to 6 orange bracts and orange sepals with distal black bands and yellow white tips. It can grow well

in up to 50 % shade. Height ranges from 1' to 8'.Flowers are long lasting (Juan, 1997).

***Heliconia psittacorum* cv. Sassy**

It is a dwarf variety. Bracts are pale green or cream at base and reddish pink distally. Sepals are orange with distal green-black bands and white tips. It blooms from April to November. It grows up to a height of 3'- 6' and in full sun to 40 % shade (Juan, 1997).

***Heliconia psittacorum* X *Heliconia spathocircinata* cv. Golden Torch**

They have large golden boat-shaped bracts with golden yellow flower. It posses rigid flowers which were produced through the selective breeding for colour, longevity and durable texture. They are larger and sturdier than other psittacorums. Height ranges from 2.5' to 8'. It grows well in full sun to 40 % shade (Alan, 2004). Flower production peaked from July to September.

***Heliconia collinsiana X Heliconia bourgena* cv. Pedro Ortiz**

These are natural hybrids between the pendent *H. collinsiana* and the erect *H. bourgena*. It produces erect inflorescence, but have the tendency to twist and hang down like a pendent. Bracts are pinkish-red coloured. It grows well in partial shade to full sun. Height ranges from 6' to 8' (David, 1985).

***Heliconia rostrata***

They are beautiful tropical herbs with banana like leathery green leaves, commonly known as hanging lobster claws. It is a native of Peru and generally distributed in tropical America. They have pendent inflorescence of alternating bracts each 6-10 cm long, scarlet red tipped with cream to yellow colour. The bract has deep red colour with yellow green tips, boat shaped. Each inflorescence has 6 to 20 bracts. It grows well in up to 50 % shade. Height

ranges from 3' to 18'. It blooms throughout the year. It is one of the hardiest varieties (Goel, 2004).

***Heliconia humilis***

They are the native of Trinidad and Brazil. They have shiny green leaves, and erect flower heads. The bracts are boat shaped with salmon red colour changing to green towards tip. It has greenish yellow flowers (Timothy, 1996).

***Heliconia wagneriana***

These are erect heliconias, similar to *H. humilis*. But they are stouter than *H. humilis*. Their inflorescence is also stouter and paler in colour (Timothy, 1996).

***Heliconia wagneriana red***

The height of *H. wagneriana red* ranges from 3 to 4.5 m. They possess 5 to 10 red, yellow and green coloured bracts. It takes 10 months to flower and is having vase life of 15 days (Timothy, 1996).

***Heliconia wagneriana yellow* Peterson**

These are erect plants having a height of 3 to 4.5 m. Bracts are 5 to 10 in number and are yellow and green coloured. It takes 10 months to flower and has a vase life of 15 days (Timothy, 1996).

Heliconia subgenus *Taeniostrobus* is redefined by Anderson (1992). This includes three species plus one placed there provisionally. Four sections are recognized in Heliconia subgenus Heliconia : H. section Episcopales, H. section Heliconia, H. section Tenebria, and H. section Tortex. Two new species are described, *H. darienensis* and *H. nubigena*. Two new combinations are made: *H. albicosta* and *H. undulate* .

The new species of Heliconia *H. fredberryana, H. litana* and *H. lutheri* having colourful, pendent inflorescences are described by Kress (1991). All are herbaceous with Musa -like habit, reaching 6 -7, 2 and 4 m in height, respectively. Also described is the new subspecies *H. obscura* subsp. *dichroma* (4-4.5 m tall). Two new species of Heliconia *H. colgantea* and *H. xanthovillosa* are mentioned by Atehortua and Adams (1992).

## 2.2 MORPHOLOGICAL STUDIES

Detailed study of the morphological characteristics of heliconia helps in understanding the variability that exists among them. It also helps in the identification and classification of varieties.

### 2.2.1 PLANT HEIGHT

Tisdale *et al.* (1985) reported that plant height can be used as an index of plant growth and also distinguishing between varieties.

Reduced plant height is the desirable character in cut flower like Heliconia. As the plant height increases the weight of inflorescence also increases, thereby increasing the transportation charges and freight charges. For acceptance as garden plant also, reduced plant height is desirable. Increase in plant height will incur more cost of cultivation due to additional operations such as staking. Decrease in height also increases the suitability of the plant for container planting Smitha (2005).

Goel (2004) reported that *Heliconia rostrata* grew up to a height of 3.0 m tall and *Heliconia jacquinii* grew up to height of 1.5 to 2.0 m tall. According to him, Golden torch is the ideal choice for container.

Lalrinawmi and Talukdar (2000a) reported that *Heliconia psittacorum* grew up to height of 116.80 cm when rhizome of 40 g was used and 91.77 cm when rhizome of 10 g was used, at the planting time.

Variation in stem length of *Heliconia rauliniana* was reported by Ibiapaba *et al.* (1997).

Smitha (2005) investigated the 12 different species and varieties of heliconia for morphological and various other aspects. Among them, species *Heliconia latispatha* recorded highest plant height with mean height of 183.59 cm, 193.98 cm, 195.32 cm and 200.12 cm, respectively at three months, five months, seven months and nine months after planting which was significantly superior over all other 11 species and varieties. The variety Pedro Ortiz recorded the highest plant height at eleven months and one year after planting. The cultivar De Rooij recorded the lowest plant height during the whole observation period except five months after planting. It recorded a mean height of 62.39 cm, 75.26 cm, 75.77 cm, 80.88 cm, and 86.798 cm, respectively at three months, seven months, nine month, eleven months and one year after planting. These results confirmed that there is variation in the height among the different species and varieties of Heliconia.

Logas *et al.* (2007) evaluated ornamental attributes of clump of 26 genotypes of Heliconia Germplasm Collection of UFRPE at Pernambuco state, Brazil. They classified 26 genotypes in to three distinct classes on basis of clump height, short (<1.5m), medium (1.5m to 2.5m) and tall (< 2.5m.). Genotype classified as short were *H. psittacorum* 'Red Gold', *H. psittacorum* 'Strawberries', *H. psittacorum* 'Suriname Sassy', four hydrids of *H. psittacorum* x *H. Spathocircinata*, Heliconia x nickeriensis. The medium heighted cultivars were *H. episcopalis, H. latispatha* 'Distans', *H. latispatha* 'Red-Yellow Gyro', H. *orthotricha* 'She', H. *psittacorum* 'Red Opal', H. *pseudoaemygdiana, H. rostrata*, H. *rosrtata* (3 days), H. *stricta* 'Fire Bird', H. *wagneriana*. The tall genotypes identified in study were H. *bihai*, H.*bihai* 'Kamehameha', H.*bihai* 'Nappi Yellow', H. *caribaea* x H. *bihai* 'Carib Flame', *H. collinsiana, H. pendula, H. rauliniana, H. rostrata* (10 days) and *H. stricta.*

Sankari et al (2010) have introduced and evaluated the heliconia species in Shevory region of Tamil Nadu, India. Among different genotypes, the plant

height ranged from 36.0 cm in Black Cherry to 222.2 cm in Princess of Darkness.

Pawan Kumar P. (2010) has studied 18 heliconia genotypes for morphological and flowering parameters. The mean performance of varieties showed that variety Kawawuchi recorded highest plant height (302.50 cm) followed by the cultivar Pedro Ortiz (266.12 cm). Lowest plant height among cultivars studied was recorded by Golden Torch (94.68 cm).

### 2.2.2 NUMBER OF LEAVES

Smitha (2005) investigated the 12 different species and varieties of heliconia for morphological and various other aspects. The number of leaves per shoot showed significant difference three months after planting and five months after planting. The cultivar Lady Di recorded the highest number of leaves per shoot at three months after planting (6.25). The cultivar Guayana recorded the highest leaf number (6.13), nine months after planting.

Lalrinawmi and Talukdar (2000 b) reported 4-6 lance shaped leaves in *Heiconia psittacorum.* Higher variability in number of leaves per $m^2$ and number of leaves per clump was recorded by Lalrinawmi and Talukdar (2000 a).

### 2.2.3 LEAF CHARACTERS

The Heliconiaceae and Musaceae may be distinguished by characteristics of their lamina anatomy and by the fact that Musaceae blades have an irregular apex (Triplett and Kirchoff, 1991).

#### 2.2.3.1 LEAF LENGTH AND WIDTH

Pawan Kumar P. (2010) has studied 18 heliconia genotypes for morphological and flowering parameters. The mean performance of varieties showed that variety Kawawuchi recorded maximum values for leaf length and leaf width (166.25,33.97 cm respectively). The minimum value for leaf length

and leaf width (41.04,9.82 cm respectively) was recorded by variety Malas Pink.

According to Triplett and Kirchoff (1991) blade size in the family varies from small blades, of sizes similar to those typically found in the Zingiberaceae and related families, to sizes approximating the larger blades of the Musaceae. Typically, *Heliconia* blades are large. A common size, for instance in *Heliconia* platystachys, it is 114 cm long x 34 cm wide. *Heliconia caribaea* has distinctly larger than average leaves, with a blade size on the order of 182 x 46 cm. At the other extreme, the blades of *Heliconia psittacorum* are 45 x 11 cm, distinctly smaller than usual. Those plants having a musoid growth habit (Andersson 1981) tend to have larger blades, whereas those of the cannoid and zingiberoid habits (Andersson 1981) tend towards smaller sizes. However, growth habit is not a reliable indicator of blade size. The aforementioned *H. psittacorum* is a plant of musoid habit.

The shape and size of the lamina varies more in the Heliconiaceae than in the Musaceae. Lamina size in the Heliconiaceae ranges from 0.1 to 3-4 m (Andersson 1985a, 1985b). In the Musaceae, Cheesman (1947, 1948, 1949 and 1950) reports blades ranging in size from 1 m to longer than 3 m.

Although lamina size and shape cannot be used to distinguish the families, they may be of use at the generic or sub-generic levels. For example, the blades of *Heliconia* subgenus Griggsia are typically large compared with the other members of the genus (190-400 cm by 55-65 cm; Andersson 1985b), and those of section Zingiberastrum are much smaller than average (30-40 cm by 7.5-14 cm; (Andersson 1985a). Thus lamina size may aid in the placement of plants into species, sections, or subgenera.

Sultana (2008) have studied and recorded following variations in leaf characters of heliconia species,

*Heliconia aurantiaca*.- Leaves are simple, sheaths green to greenish-orange, petiolate, petioles 3.5 cm long, lamina 6-28 × 3-6 cm, linear to lanceolate, acute to acuminate, entire, midrib green.

*Heliconia bihai* - Leaves simple, petiolate, petioles 32 cm long, lamina 50-60 × 20-22 cm, ovate-oblong, shortly acuminate, entire, midrib green on the upper surface and reddish-green on the lower surface.

*Heliconia densiflora* - Leaves simple, petiolate, petioles 1 cm long, lamina 15-20 × 3-5 cm, linear-lanceolate, acute, entire, midrib green.

*Heliconia latispatha* Benth. cv. Distans - Leaves simple, petiolate, petioles 15-25 cm long, lamina 60-75 × 15-20 cm, oblong, acute, entire, midrib green on the upper surface and green with red spots on the lower surface.

*Heliconia latispatha* Benth. cv. Red-Yellow Gyro - Leaves simple, petiolate, petioles 20-25 cm long, lamina 70-80 × 20-25 cm, oblong, acute, entire, midrib green on the upper surface and green with red spots on the lower surface.

*Heliconia metallica* - Leaves simple, sheaths purplish maroon, petiolate, petioles 2-4 cm long, lamina 35-90 × 15-25 cm, lanceolate-ovate, acuminate, entire, upper surface green with light green midrib, lower surface purplishmaroon with purplish midrib.

*Heliconia psittacorum* L. f. cv. Black Cherry - Leaves simple, petiolate, petioles 7-10 cm long, lamina 30-45 × 7.5-11.0 cm, lanceolate, acuminate, entire, lower surface glossy, midrib green.

*Heliconia psittacorum* L. f. cv. Choconiana - Leaves simple, petiolate, petioles 16 cm long, lamina 20-37 × 6-9 cm, lanceolate, acute, entire, lower surface glossy, midrib green.

*Heliconia rostrata* - Leaves simple, petiolate, petioles up to 24 cm long, lamina 7-98 × 4-20 cm, oblong, acute, entire, midrib green, sometimes maroon beneath.

*Heliconia stricta* - Leaves simple, petiolate, petioles up to 19 cm long, lamina 25-35 × 10-12 cm, oblong, acuminate, entire, midrib green.

*Heliconia psittacorum* L. f. × *H. spathocircinata* Aristeguieta - Leaves simple, sheaths green, petiolate, petioles 4.5-6.0 cm long, lamina 17-30 × 7.5-9.5 cm, oblong-obovate, acuminate, entire, midrib green.

*Heliconia bourgaeana* Petersen × *H. collinsiana* Griggs - Leaves simple, sheaths green, petiolate, petioles 15 cm long, lamina 30-35 × 10-15 cm, oblong, acuminate, entire.

### 2.2.3.2 LEAF SHAPE

Triplett and Kirchoff (1991) observed that the leaf blades of the Heliconiaceae have a diversity of shapes and sizes. Most of the blades share a common morphology, but with a number of notable deviations from the standard. The typical lamina is oblong to more commonly narrowly oblong, with an asymmetrical, cordate base and an acute to slightly acuminate apex. However, oblong, elliptic, narrowly elliptic, ovate, and lanceolate blades are found in the genus. The lamina apex occasionally forms a right angle, as in *Heliconia stilesii*, or is obtuse as in *Heliconia* indica. The shape of the lamina base shows the greatest variability. In various species it is asymmetrically acute, decurrent obtuse, decurrent acute, symmetric and rounded, or asymmetric cuneate.

### 2.2.3.3 LEAF LENGTH AND WIDTH RATIO

The length (L) to width (W) ratio of the blade is variable across the Heliconiaceae, with no apparent correlation with other characteristics 'of the leaves. The range of L: W ratios in the study species is from 3:1 in *H. indica* to 6:1 in *Heliconia vaginalis* and *H. psittacorum*. (Triplett and Kirchoff, 1991)

### 2.2.3.4 LEAF AREA

Lalrinawmi and Talukdar (2000 a) reported the leaf area of *Heliconia psittacorum* varied from 700 to 860 $cm^2$ per leaf. Variability in leaf area among *Heliconia* cultivars was also reported by Lopez *et al.* (2001)

Smitha (2005) investigated the 12 different species and varieties of heliconia for morphological and various other aspects, among them leaf area had recorded significant variation during the period under study. The cultivar

Pedro Ortiz recorded highest leaf area with mean values of 2716.20 $cm^2$, 2734.39 $cm^2$, 2905.40 $cm^2$, 2944.54 $cm^2$, 2986.12 $cm^2$ and 2993.18 $cm^2$ at three months, five months, seven months, nine months, eleven months and one year after planting. The variety Lady Di recorded the lowest leaf area three months and eleven months after planting (671.94 $cm^2$ and 759.78 $cm^2$, respectively). The variety De Rooij recorded lower leaf area (699.54 $cm^2$) at five months after planting. The variety Deep Orange recorded the lowest leaf area seven months, nine months and one year after planting (724.73 $cm^2$, 747.75 $cm^2$, 782.62 $cm^2$, respectively).

In *H. acuminata*: total leaf area plays an important role in photosynthesis and the regulation of water loss in many tropical undestroyed species, while the number of vegetative shoots is strongly positively correlated with the probability the species will flower (Begg 1980).

Emilio (2002) have transplanted H. *accuminata* during the early part of the 1999 rainy season (7–28 February 1999), and counted the number of vegetative shoots on each plant and calculated its total leaf area using the regression equation:

$$\sqrt{\text{Leaf Area (cm}^2\text{)}} = 1.72 + 0.35 \times \text{leaf length (cm)}$$

($R^2 = 0.959$, $P < 0.0001$, based on $n = 144$ leaf tracings measured with a LI-COR Model 3000 A Leaf Area Meter).

### 2.2.3.5 LEAF THICKNESS

Skutch (1927) reported an increase in thickness from the margin to the costa in *Musa sapientum*. Triplett and Kirchoff (1991) confirmed this pattern in the Musaceae and Heliconiaceae and described several patterns of longitudinal variation in thickness. At the costa (midrib) it is more common for the thickest portion of the lamina to be at the center of the blade, whereas at the margin the thickest portion is most commonly at the base. These thickness relationships most likely play a role in supporting the blade. It would be

interesting to correlate thickness patterns with the degree of wind and heat stress to which a blade is exposed. At present, there is no evidence that these architectural features are associated with lamina tearing. The taxonomic value of lamina thickness is not clear from this preliminary study; however, the range of lamina thickness was greater in the Heliconiaceae than in the Musaceae.

Triplett and Kirchoff (1991) also observed that the thickness of the lamina is quite variable in the Heliconiaceae, both between species and within the blade of a single leaf. For instance, average thickness between the veins ranges from 0.167 mm in *Heliconia chartacea* to 0.303 mm in *H. caribaea*. The variation in thickness across a single lamina is also considerable. The following general statements describe the variability in lamina thickness observed in the family. Thickness increases across the lamina from the margin to the costa, at all locations, in all species. The thickness of the lamina varies longitudinally in different ways in different species. Near the margin, blade thickness increases from the apex to the base in *H. platystachys*, *H. indica*, *H. vaginalis*, *H. stilesii*, and *H. caribaea*; decreases from the apex to the base in *H. psittacorum*; increases from the apex to the middle of the lamina then decreases to the base in *Heliconia metallica*; or decreases from the apex to the middle of the lamina then increases to the base in *H. chartacea*. Near the costa, blade thickness increases from the apex to the base in *H. platystachys* and *H. vaginalis* or increases from the apex to the middle of the lamina then decreases to the base in *H. indica*, *H. chartacea*, *H. metallica*, *H. psittacorum*, *H. stilesii*, and *H. caribaea*.

Appreciable variation in vegetative and floral morphology was recorded in the population of single and double types of tuberose by Nambisan and Krishna (1983).

Nazarenko (1985) studied the floral morphology of oil- bearing rose types and observed greatest variation for number of flowers per plant. Slightly

less variation in flower weight, the frequency of double flowers and essential oil content was noticed.

Komarova and Shasilova (1988) studied the morphological diversity occurred in *Anethum graveolens* belonging to eleven geographical regions of USSR and observed specific variation in leaf size, length and number of terminal segments of the leaves and in the structure of the seed and inflorescence.

Baghdadi *et al.* (1989) recorded inter and intra specific variation in morphological characters of the leaves, spines, flowers and in plant height of *Lycium schweinfurthis* and *L. shawii.*

Jagadev *et al.* (2001) observed a lot of variation in relation to plant height, colour of stem and inflorescence, leaf sheath and node in palmarosa.

## 2.3 PHYSIOLOGICAL STUDIES:

Leaf pigment content can provide valuable insight into the physiological performance of leaves ( Sims and Gamon, 2002).

Pigments are integrally related to the physiological function of leaves. Chlorophylls absorb light energy and transfer it into the photosynthetic apparatus. Carotenoids (yellow pigments) can also contribute energy to the photosynthetic system. However, when incident light energy exceeds that needed for photosynthesis, the carotenoids that compose the xanthophyll cycle dissipate excess energy, thus avoiding damage to the photosynthetic system (Demmig-Adams & Adams, 1996).

Logas *et al.* (2007) evaluated ornamental attributes of clump of 26 genotypes of Heliconia Germplasm Collection of UFRPE at Pernambuco state, Brazile. They found variation in leaf colour and classified them under three distinct categories of green, light and dark. The cultivars with green coloured leaves were, *H. bihai*, *H.bihai* 'Kamehameha', *H. caribaea* x *H. bihai* 'Carib

Flame', *H. latispatha* 'Distans', *H. orthotricha* 'She', *H. pseudoaemygdiana*, *H. psittacorum* 'Red Gold', *H. psittacorum* 'Red Opal', *H. psittacorum* 'Strawberries', three hydrids of *H. psittacorum* x *H. Spathocircinata*, *H. rauliniana* and *H. rostata*. The cultivars with light coloured leaves were, *H. rostrata* (3 dys), *H. wagneriana*. The cultivars with dark coloured leaves were, *H. collinsiana*, *H. pendula*, *H. psittacorum* 'Suriname Sassy', one hydrids of *H. psittacorum* x *H. Spathocircinata*, *H. episcopalis*, *H. rostrata* (10 days), *H. stricta* 'Fire Bird' and Heliconia x nickeriensis.

Assessment of chlorophyll content is a valuable tool for agricultural and non-managed ecosystem studies, since it provides information on key vegetation properties that are, in turn, linked to net primary production. The effects of varying leaf structure (leaf thickness [LT], leaf mass area [LMA] and leaf mass density [LMD]) on reflectance-based chlorophyll indices were assessed using regression and correlation analyses for seven Mediterranean species. The chlorophyll indices used were: (1) corrected for differences in internal scattering, (2) corrected for differences in surface scattering and (3) based on first reflectance first derivatives. Within species, chlorophyll indices showed similar correlation with chlorophyll content ($r^2$ values larger than 0.80, $p<0.001$) while, across species, indices corrected for surface scattering and first reflectance derivative indices were more closely related to chlorophyll content ($r^2=0.78$ and $r^2=0.75$, respectively, $p<0.001$) than reflectance simple ratio indices ($r^2=0.70$, $p<0.001$). Nonetheless, species with thicker leaves showed lower index values at similar chlorophyll content than species with thinner leaves. In species with thicker leaves, the increases in chlorophyll content were associated with increases in LMD rather than to changes in LT and were accompanied by significant reductions in NIR radiation scattering at 800 nm. The contribution of LT and LMD to changes in LMA, and their effects on NIR scattering, might promote deviation from the relationship between reflectance based chlorophyll indices and chlorophyll content (Serrano 2008).

## 2.4 POLLINATION STUDIES

### 2.4.1 NATURE OF POLLINATION

Most species of Heliconia that have been tested so far are self-compatible; that is, a flower will produce seed following self-pollination. Seed set by transfer of pollen by pollinator is also seen (Berry and Kress, 1991). According to them small bird like the humming bird and some ants act as pollinating agents.

Altshuler, (2003) has reported that pollination in heliconia is mainly ornithophilous.

Lotens sunbird (*Nectarina lotentia)*, ants and stingless bees (*Melipona iridipennis*) were identified as pollinators of heliconia in Kerala (Sanjeev, 2005).

Schleuning et al. (2011) observed that in Heliconia metallica bagged flowers that were not hand pollinated did not produce fruits, indicating that flowers do not self-fertilize. Selfed flowers produced fruits and seeds, but fruit set, seed set, and mean individual seed mass were significantly lower than in outcrossed flowers.

### 2.4.2 AGENT OF POLLINATION

Berry and Kress (1991) reported that Bronzy Hermit, Crowned Wood Nymph Humming Birds and Bats are pollinators of heliconia, also some insects (e.g. Earwigs in Hawaii) and vertebrates (honey eater in Australia) are quite agile at transferring pollen especially within a heliconia flower.

Altshuler (2003) has reported that pollination in heliconia is mainly ornithophilous. Nectar feeding bat (*Melanycteris woodfordi*) are pollinator of green heliconia and 'The Bronzy Hermit'- Common Humming Bird (*Glaucis aenea*) and 'Crowned Wood Nymph Humming Bird '(*Thalurania colombica*) are the exclusive pollinators of red, yellow, pink and orange heliconia.

Because hummingbirds are the only known cross pollinators of heliconias in the Americas, the biology of hummingbirds greatly affect hybridization between heliconias. Some hummingbird species (or sexes) have long curved bills while others have short straight bills. For example, females of the purple throated Carib hummingbird of St. Lucia have long curved bills while males have short straight bills (Temeles *et al.*, 2000). In correspondence, the 'Emerald Forest' variety of *H. bihai* has long curved flowers while *H. caribaea* in St. Lucia has short straight flowers. Hybridization is thus prevented because female and male birds feed only on *H. bihai* and *H. caribaea,* respectively. The situation is even more complicated in areas of St. Lucia where only *H. bihai* occurs. In such areas another (unnamed) *H. bihai* variety with short straight flowers is found, and is pollinated by male hummingbirds (Temeles & Kress, 2003). A parallel situation occurs in Dominica where the red varieties of *H. caribea* (e.g., 'Black magic') have long curved flowers, while the yellow (e.g., 'Cream') varieties have short straight flowers. As a result, differences in flower shape may prevent cross pollination by hummingbirds even between varieties of the same heliconia species. Differences in hummingbird feeding behaviour can also affect hybridization. Some hummingbird species (or sexes) are territorial, feeding only on flowers of a single plant, while others are "trapliners" going from plant to plant (Stiles, 1979). Territorial and traplining hummingbirds would then decrease and increase chances for hybridization, respectively.

Pattanshetty and Prasad (1972) reported that honeybees are the principle agents of pollination. Bee free panicles had only 11 percent fruit set as against 50.66 percent in the case of panicles open to bee activity. Parameswar (1973) also reported that insects, especially honeybees, pollinate cardamom. Jose (1980) reported that giant rock bees (*Apis domestica*) are the primary agents of pollination in cardamom and the Indian honeybees (*Apis indica*) are the secondary agents.

Bingham (1897) has described Stingless bees (*Melipona iridipennis*) to be a pollinator in many plants.

Grewal (1993) and Neelakandan (1996) has described Loten's Sun bird (*Nectarina lotenia*) of Family Nectariniidae which is restricted to Western Ghats from South Gujarat to Kerala to be feeding on flower- nectar, insects, spiders etc. which may be a possible pollinator in many plants.

## 2.5 COMPATIBILITY STUDIES, ARTIFICIAL POLLINATION AND HYBRIDIZATION

A thorough understanding of the compatibility relationships of the genera under consideration is essential for successful varietal improvement programme.

Heliconia are propagated by rhizomes as well as suckers and rarely from seed. Most species of *Heliconia* have been self compatible on the other hand, it has been found that cross fertilization between species is generally unsuccessful due to pre-fertilization barrier (Kress, 1983a; Berry and Kress, 1991; Sanjeev, 2005). So far there is no solid evidence for any artificial *Heliconia* hybrid.

Conventional method of artificial hybridization is not possible in heliconia because of several pre-zygotic barriers (Dhanya, 2006).

Artificial hybridization among 14 species of neotropical heliconia was studied by Kress (1983a) at two sites in Costa Rica. At Las Cruces Tropical Botanical Garden, individuals in cultivation were used as parents in crosses primarily between species with pendent inflorescences that are normally distributed allopatrically. At Finca La Selva normally sympatric species with either pendent or erect inflorescences were crossed in their natural habitats. Observation of pollen tube growth by means of fluorescence microscopy and seed set were used to determine the extent of crossability. Crossability barriers

between the majority of species were strong and foreign pollen tubes were inhibited at the stigmatic surface, within the stylar tissue or within the ovary. The site of inhibition was consistent for each pair of species, and depended on the parentage and the direction of the cross. Although additional isolating mechanisms, such as pollinator specificity and phenological separation were present, pre-fertilization crossability barriers acted as the ultimate mechanism to prevent hybridization. The type of barrier (stigmatic, stylar or ovarian) that existed between two species was not dependent upon the geographical distribution of the parental species or the specific types of pollinators that visit them, but in some cases might indicate taxonomic relationships

Hybridization in *Heliconia* species is probably uncommon in nature. Most species of heliconia are self compatible but cross fertilization is unsuccessful due to biochemical incompatibility (Berry and Kress, 1991).

Kress (1983a) studied artificial hybridization among species of neotropical, heliconia. He reported that crossability barriers between the majority of species are strong and foreign pollen tubes are inhibited at the stigmatic surface, within the style or within the ovary.

Kress (1983b) also studied self incompatibility in 19 species of Central American heliconia reported that response ranged from total self rejection in one species to full self-incompatibility in the majority of taxa studied.

Lee *et al.* (1994) selected six cultivars of *Heliconia psittacorum* for studies on that natural fruit bearing ability, pollen formation and pollination under the tropical climatic conditions of Singapore. Three of them, namely Tay, Andromeda and Lady Di were partially fertile with a very low rate of fruit set, ranging from 2.8 to 4.7 per cent. The poor fruit set of these three cultivars was attributed to poor pollen germination on stigma rather than poor pollen formation. The other three cultivars namely Petra, Sassy and Iris were completely sterile.

Berry and Kress (1991) reported some of the natural hybrids of heliconia. E.g., *Heliconia* cv. Golden Torch is the natural hybrid between *H. psittacorum* and *H. spathocircinata* other hybrids between species include *H. caribaea* x *H. bihai*, *H. secunda* x *H. clinophila*, *H. psittacorum* x H. *marginata*.

Yoshioko (2003) also reported that heliconia hybrids are common in Puerto Rico due to several reasons such as environmental factors, flowering seasonality and difference in pollinators.

According to Atehortua (1997) future objectives in breeding of heliconia will include plants adapted to a wider range of environments, smaller size and weight to facilitate transport, different flowering times to allow a year- round market, and longer vase and transportation life.

Number of flowers per inflorescence is a character of prime importance in orchid breeding, as has been pointed out by Kamemoto(1983), McConnel and Kamemoto(1983), Singh (1986) and Mc Donald (1991).

Singh (1982) has pointed out that in orchids; higher order hybrids show increased number of flower per spike. Bobisud and Kamemoto (1982) arrived at the same conclusion that flower production in Dendrobium hybrids was primarily influenced by parental genotypes. Several scientists have reported the inheritance of the character, number of blooms per inflorescence.

Shankar *et al.* (1981) have reported that there are different sex forms in cardamom, which have been evolved through the years of evolution from the purely vegetatively propagated form to completely sexually propagated form. It ranges from partially incompatible to completely compatible form.

Johansen (1990) demonstrated a unique incompatibility system in Dendrobium which also showed high incompatibility in interspecific pollination in contrast to any other orchid genus. Incompatibility response was initiated by auxin content in pollinia. The compatibility substance was

specifically recognised by the eleutherocytes or eleutherosides produced in the stigmatic mucilage.

## 2.6 FLORAL BIOLOGY

A thorough understanding of the floral biology is an essential pre-requisite to any breeding programme. This background knowledge is of special significance in the breeding of heliconia.

Heliconias derive their beauty from highly modified leaves or bracts. The flowering bracts may be upright or pendulous depending on the variety and may exhibit the shape of a lobster claw, bird's beak or fan shape. Humming birds and bugs pollinates the flowers. However, some pollen may be carried from one flower to another by insects. These insects are not specialists, they feed from the flower for nectar and pollination rarely occurs. South East Asian heliconias are pollinated by bats (David, 1985).

Watson and Dallwitz (1991) had given the following descriptions about the floral biology of heliconia. Each inflorescence bract contains varying number of flowers up to 15 depending on the species. A small floral bract in turn subtends each flower. The floral bracts of some species are opaque and leathery and persist through fruit development to protect maturing ovaries. In other species they are plumby and translucent and quickly decompose after the flower close. Flowers are hermaphroditic possessing both male and female sexual parts. Perianth is made up of three outer sepals and three inner petals united at the base and to each other in various phases. When the flower opens, a single sepal become free from the outer perianth part and allows pollinators to enter the flower. The colour of the perianth is species specific. The flowers are open only for a single day after which the perianth falls from the ovary. The flower contains high fertile stamens that produce viable pollens. A sixth stamen is replaced by a sterile stamenoid that does not produce pollen but may function in some species as a guide leading the pollinators tongue to the floral nectaries situated at the base of the style. Anthers are basifixed,

tetrasporangiate. Ovary lies below the sepals and petals and can be variously coloured. It is usually smooth in most species, but is hairy in others. Gynoecium is three carpelled, carpels rhizomerous with the perianth. The pistil is three celled. Placentation is basal to exile and there is one ovule per locule, which is anatropous. The mature fruit of heliconia is a drupe with a hard inner layer enclosing each of the four seeds, which are triangular (1 – 3 per fruit). The outer layer of fruit is fleshy and at maturity the surface layer becomes blue in American species or red to orange in South Pacific species. The colourful fruits are very attractive to the birds and mammals that disperse the seeds.

In heliconia thread-like structures connecting the pollen grains are described by Rose and Barthlott (1995). These threads are decay products of the walls separating the pollen chambers, and products of the rupture of the mature anthers in the stomium region. The pliable cell threads mix with the pollen and entangle individual grains to form aggregates. This ensures that the pollen becomes embedded in the feathers or attached to the smooth, unsculptured beak of pollinating humming birds (Trochilidae).

Six cultivars of *H. psittacorum* were selected by Lee *et al.*(1994) for studies on their natural fruit-bearing ability, pollen formation and pollination under the tropical climatic conditions of Singapore. Three of them, namely Tay, Andromeda and Lady Di, were partially fertile with a very low rate of fruit set, ranging from 2.8 to 4.7 percent. They were found to be diploid with 2n = 24 chromosomes. The process of pollen formation (microsporogenesis) was normal, and pollen grains were all uniform in size and appeared normal. The poor fruit set of these 3 cultivars was attributed to poor pollen germination on stigmas rather than poor pollination or self-incompatibility. The other 3 cultivars, namely Petra, Sassy and Iris, were completely sterile. Their pollen grains were of variable sizes and appeared to be abnormally fragmented. Over 80 percent of the pollen grains aborted 1-2 days before pollination. These abnormal features were consistent with irregular distribution of chromosomes

during meiosis in microsporocytes. All 3 cultivars were confirmed to be triploid (2n = 3x = 36).

Length of inflorescence has been pointed out as a character of prime importance in any orchid-breeding programme (Mc Donald, 1991).

## 2.7 SEED CHARACTERS

Seed traits, including seed size, dormancy, germination, and dispersal, are central components of plant life histories (Harper, 1977; Fenner, 1983; Thompson, 1987), and their importance to plant fitness are widely appreciated (e.g., Leon, 1985; Venable, 1985, 1989; Foster, 1986; Lord, Westoby, and Leishman, 1995; Venable et al., 1998; Higgins and Richardson, 1999). Comparative analyses of seed size (e.g., Foster, 1986; Mazer, 1989; Leishman, Westoby, and Jurado, 1995; Lord, Westoby, and Leishman, 1995; Venable et al., 1998) and seed germination (e.g., Garwood, 1983, 1989; Leon, 1985) have been especially useful in illustrating not only the broad range of seed traits that occur within and among taxa, but also the environmental and phylogenetic constraints that limit variability in characters. Seed traits, including seed size, length of dormancy, germination requirements, and germination rate, often vary in parallel and are thought to comprise co-evolved complexes or life history strategies for many species

Growing heliconias from seed can be a very enjoyable experience. Seeds provide an inexpensive means of producing more plants without having to sacrifice clumps or dig rhizomes, and also increase the chance of producing a new cultivar or maybe even a hybrid. Plants grown from seed usually take longer to flower than those planted from rhizomes or chump divisions, but for those who are always on the lookout for something new, it's worth a try. Few heliconia hybrids have been found in nature and there still aren't any known man-made hybrids as in the case of orchids, roses, and other commercially grown flowers (Emilia, 2005). When pollinated, heliconias produce fruit, called a drupe which is generally bright blue in colour when fully ripe. When

the fleshy blue part is removed, it contains from one to three very hard, black seeds. These seeds can vary in size and shape among the different heliconia species. Some can be as large and round as a pea (*H. aemygdiana*), while others can be long and thin as a grain of rice (*H. rostrata*). They are all similar in colour and hardness.

Heliconia fruit is a 1 to 3 seeded drupe, blue or red to orange at maturity. Seed is surrounded by stony, roughened endocarp (pyrenes), embryo is straight and endosperm present copiously (Wagner *et al.*, 1999).

Dario et al. (2009) observed that, wild populations of *R. hypoglossum* were shown to vary more in seed traits than in fruit traits. It was the same with interannual variability. Fruit traits proved more stable than seed traits over the three-year period. Both between populations and between years, fruit and seed weight varied more than fruit and seed dimensions. Since seed weight is generally considered the least plastic of plant traits (Harper, 1970), the high variability of seed weight (CV = 35.34%) was unexpected. Turnbull et al. (2006) reported much lower (CV = 25%) average variability of seed weight for 63 species reviewed from the literature. Generative organs, including seeds, are organs with relatively constant features (Szkudlarz, 2003), but Dario et al. (2009) found variability in both fruit and seed characteristics, with seed traits demonstrating larger interpopulational and interannual variability.

### 2.7.1 SEED DEVELOPMENT IN HELICONIA

In Heliconiaceae there are very few reports about seed development studies. Humphrey (1896) described part of the ovule and seed development in 16 species of Zingiberales including *Heliconia psittacorum* and *Heliconia bihai.*

Mauritzon (1936) also described aspects of seed development in 17 species for Zingibrales including *Heliconia aurantiacea.*

Simao *et al.* (2006) studied the developmental anatomy and morphology of the seed in several species of *Heliconia.* They reported that the

zygote was round after syngamy and enveloped by a slightly thickened wall, with a prominent nucleus and nucleolus. The first transversal division resulted in the formation of the proembryo, with apical and basal cells, both of which had prominent nucleoli. The proembryo underwent several divisions and became globular and later reniform. In ripe and almost ripe fruit, the embryo was longitudinally elongated slightly curved on the apex. Most of the embryo formed by the cotyledon, especially the haustorial part at the apical and the endosperm started to develop in the zygote stage with successive nuclear division. In ripe seeds, the endosperm occupied a large part of the seeds and contained a substantial quantity of starch and numerous spherical bodies, probably lipid deposits. The drupaceous fruits usually had three seeds, with each one totally filling the ovule.

### 2.7.2 SEED GERMINATION

Most of the *Heliconia* species set few fruits or are sterile and the germination of the seed is slow, the vegetative propagation by division of rhizome, is preferred in its commercial production (Montgomery, 1986; Criley, 1988; Lee *et al.*, 1994; Simao and Scatena, 2003). In species of *Heliconia* there have been few detailed studies about seed and seedling morphology (Humphrey, 1986; Tillich, 1995; Simao and Scatena, 2003).

Germination of heliconia seed is erratic in nature. Seeds of the same species under close to identical conditions present different germination intervals (Simao and Scatena, 2003; Tejedor, 2005). Different species have different germination intervals which could vary from weeks to many months (Tejedor, 2005).

Some species of *Heliconia* took three years to germinate (Montgomery, 1986; Criley, 1988). Montgomery (1986) reported that the range in the germination period of Heliconia (from three months to three years), depended on the degree of the embryo development at the time of the fruit maturity.

Simao and Scatena (2003) observed that species from moist place usually took lesser time to germinate, while those from dry areas took longer, until environmental conditions were favourable. Although *H. velloziana* occurs in moist place and takes four to six months to germinate, suggest that other environmental factors, as e. g. temperature, or even other factors, such as the development of the embryo, could influence the beginning of germination period.

According to Criley (1988), the scarification did not hasten germination in species of Heliconia. Graven et. al. (1996) also reported that the removal of the operculum did not increase or accelerate the germination in species of Musaceae. They related that with removal, water reached the embryo but could not hydrate it, probably showing that both families (Heliconiaceae and Musaceae) the embryo had dormancy at the time of the fruit maturity.

As per the observation of Humphrey (1896) the operculum, which he named as sclerotic plug, was formed from the funiculus after the development of the seed and the endocarp. This structure served as protection, being pushed by the embryo growth, while the endocarp protected the remainder of the cotyledon.

Specified technique has been reported for inducing growth in seeds of heliconia. The fleshy part of the fruit removed and the seeds were sterilized in 10 per cent sodium hypochlorite for five minutes, then washed in distilled water. The seeds were stored in plastic bags with moist vermiculite in a greenhouse at 25-30°C, until germination was observed in some seeds (Criley, 1988; 1995; Simao and Scatena, 2003).

Some of these seeds have an aggressive start, while others seem to take forever to sprout. *Heliconia platystachys, H. imbricata* and *H. collinsiana*, all with very large round seeds, sprout quickly and it's not uncommon to find seedlings growing close to the mother clump. The tiny seeds of *H. mariae*, a robust plant, also sprout very fast. *Heliconia chartacea*, with large rectangular seeds, can take up to a year to emerge. Seedlings in a given batch will all be

very similar in size, but there might be slight differences in stem or leaf colour, absence or presence of powdery wax on the stems and underside of the leaves, and dark or light colour on the midrib of the leaves. Those seedlings with a slight difference should be tagged, separated from the rest, and planted. Seedlings can take up to 2 years (some even more) to flower. The probabilities that it may resemble its "mother" are very high. But those seedlings with some variation are worth the effortas there are chances of producing a new cultivar (Emilia, 2005).

Effects of seed size and seedling morphology on the establishment of six monocarpic perennials were examined in glasshouse experiments by Katherine (1984). Both within and between-species comparisons of seed-size effects were made as seed weight varied by more than two orders of magnitude among species and by 3 to 20-fold within a species. Relative growth rates of seedlings in non-competitive cover types were inversely related to seed size. In bare soil and litter, the small-seeded species had relative growth rates twice those of the large-seeded species.

Dario et al. (2009) observed that, in wild populations of *R. hypoglossum* seed length ranged from 4.72 mm in population K to 7.06 mm in population B, and seed width ranged from 4.74 mm in population VGD to 7.80 mm in population B. Seeds were heaviest (0.26 g) in population GD and lightest (0.10 g) in population VJ. Their results showed considerable variability of the analyzed morphological traits among wild populations of *R. hypoglossum* in Croatia. The high variability and interannual stability of fruit traits displayed by the populations will enable the most interesting populations to be selected for breeding of ornamental plants. Supporting that effort, the recorded variability of seed traits will provide the basis for future research on the influence of seed size on germination success in this endangered ornamental species.

## 2.8 VARIABILITY STUDIES

The magnitude of variability present in a population is of utmost importance as it provides the basis for effective selection. Since the observed variability in a population is the sum of variation arising due to the genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential.

Variability available in a population could be partitioned into heritable and non-heritable components with the aid of genetic parameters such as genetic and phenotypic coefficient of variation (GCV and PCV), heritability ($H^2$) and genetic advance (GA) which serves as basis for selection (Johnson *et. al.* 1955a).

## 2.9 HERITABILITY ($H^2$), COEFFICIENT OF VARIATION (CV) AND GENETIC ADVANCE (GA)

The magnitude of heritability is valuable in plant breeding programmes since it provides the basis for selection dependent on phenotypic performance. Heritability estimates the transmissibility of character from one generation to other and it provides a measure of the value of selection for different attributes. But high heritability does not necessarily mean a high genetic advance for a particular character (Allard, 1960). Heritability along with genetic advance is more useful than heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al*, 1955).

Heritability and genetic advance are important selection parameters. The ratio of genetic variance to phenotypic variance is known as heritability. Heritability (%) was categorized into low (0-30%), moderate (30-60%) and high (above 60%) as suggested by Robinson *et al* (1949). Higher $H^2$ indicates the least environmental influence on the characters. The difference between the mean phenotypic value of the progeny of selected plants and the base or parental population is called as the genetic advance. The genetic advance was categorized into low (<20%) and high (>20%) as suggested by Robinson *et al.* (1949). High GA indicates that additive genes govern the character and low

GA shows that non-additive gene action is involved. Heritability along with GA helps us in predicting the gene action and the method of breeding to be practiced.

In the study conducted by Smitha (2005) in heliconia, it was found that except for number of leaves (19.68%), all other characters under study recorded high heritability. The highest heritability was exhibited by the number of days taken for flowering (99.64%) followed by number of flowering shoots (99.48%) number of leaves (99.32%), plant height (97.95%) and bract size (97.06%). High heritability along with genetic gain was observed for petiole length (heritability 96.65%, GA 150.77%), number of flowering shoots (heritability 99.48, GA 121.73%), leaf area (heritability 93.78%, GA: 118.85%) and bract size (heritability 97.06%, GA 115.42%). These characters are genetically controlled by additive gene action and hence amendable to genetic improvement through selection (Panse, 1957).

In general PCV was slightly higher than GCV in most of the characters indicating the influence of environment. The apparent variation is not only due to genotypes but also due to the influence of environment (Smitha 2005).

High phenotypic (75.72%) and genotypic (59.25%), coefficients of variations were found for petiole length, followed by number of flowering shoots (PCV-59.40%), GCV-59.24%). This indicate a greater extend of variability for these characters thereby suggesting scope for improvement of these characters through selection. The difference between phenotypic and genotypic coefficient of variation was the lowest for the days to flowering (0.08238%) followed by number of flowering shoots (0.1542%). These small differences point out that the environmental influence on these characters is less (Smitha 2005).

## 2.10 CORRELATION STUDIES

The degree and direction of association between different characters could be better understood based on correlations. In a cut flower like *Heliconia*, the critical characters determining the economic value are length of spike, length of petiole, number of bracts, size of bracts, number of flowering

shoots and vase life. They are generally complex in nature and influenced by many factors. Characters genetically related to each other tends to move in the same direction under selection. Such a correlated response to selection is the basic property of qualitative traits under the control of polygenic system. The genotypic correlation between characters provides a reliable measure of genetic association between them and helps to differentiate the vital association useful in breeding (Falconer, 1981).

In the study conducted by Smitha (2005) in heliconia, it was found that, the plant height had significant positive correlation at phenotypic and genotypic levels with the leaf area, number of shoots, number of bracts, size of bract, spike length, petiole length, days to flowering, vase life and number of flowering shoots. The estimates of genotypic coefficient of correlation were much higher in magnitude than the corresponding estimates at phenotypic level. It indicates that though there was strong inherent association between the various characters studied, the phenotypic expression of correlation was lessened under the influence of environment. The number of flowering shoots had significant and positive genotypic correlation with number of leaves, number of shoots and petiole length. This is in accordance with the findings of Bruna *et al.* (2002).

A positive genotypic correlation between pairs of characters indicated that an improvement in one character would improve the other character also, thus enabling the breeder to select characters responsive to selection. The length of petiole is influenced by number of shoots and flowering shoots. The selection for more number of shoots and flowering shoots can thus result in higher petiole length. Number of bracts per spike is an important cut flower attribute. This character showed high positive and significant correlation both at phenotypic and genotypic levels with plant height, leaf area, bract size, spike length, days to flowering and vase life. Environment correlations are present only for a pairs of characters. Plant height had shown significant negative correlation with bract size and number of flowering shoots (Smitha 2005).

## 2.11 INSECT PESTS AND DISEASES

A few problems related to diseases or pests have been observed so far. However many disease causing organisms have been detected in heliconia plants which might be an indication that they may be acting as alternate hosts for the pathogens.

*Cercospora heliconiae* was isolated from *Heliconia caribaea* by Chowdhry *et al.* (1983). Bract liquid as a herbivore defense mechanism for *Heliconia wagneriana* inflorescences reducing the incidence of nectar robbing by chewing insects was reported by Wootton and Sun (1990). *Phyllosticta musae [P. musarum], Glomerella cingulata, Alternaria alternata, Gloeosporium musarum [Colletotrichum musae], Guignardia musae, Curvularia sp., Fusarium oxysporum, Mycosphaerella musicola, Drechslera musae-sapientum* and *Pestalotiopsis sp.* were isolated from lesions on leaves and inflorescences of *Heliconia sp.* grown in parks, gardens and indoors in Venezuela by Madriz *et al.* (1991). *Glomerularia heliconii* sp.nov. is described from *Heliconia sp.*, used primarily as an ornamental plant in Cuba by Herrera Isla (1994) .

Throughout the Neotropics the primary herbivores of *Heliconia* are Hispine beetles, which cause leaf scarring and readily identifiable perforations but remove little foliar tissue (Strong 1977).

Santos *et al.* (2011) reported that the interaction of plants with insect herbivores and fungal pathogens can affect community dynamics, but there is little information on how this antagonistic interaction may be altered in human-disturbed tropical systems. The overall insect damage in *H. latispatha* was similar between road edges and natural forest gaps (8.0% vs. 7.2% of leaf area). Damage by caterpillars, however, decreased from 4.2 percent in forest gaps to 0.5 percent on road edges, whereas damage by leaf-cutting ants increased from 0 to 5.8 percent. In secondary riparian vegetation, where none

of the leaves sampled were attacked by ants, overall herbivore damage in *H. collinsiana* was less than half that observed in forest gaps (3.0% vs. 6.7%), and driven mainly by differences in caterpillar damage (2.5% vs. 6.2%). By contrast, attack by leaf fungal pathogens was two to three times greater in both human-disturbed habitats than in gaps (8.2–9.6% vs. 3.7–4.2%). Potential mechanisms underlying these differences involved human-induced shifts in air and soil temperature driven by greater light availability, as well as changes in relative humidity, leaf toughness, foliar condensed tannins, and local abundance of herbivores. Their results indicate that the human disturbance alters insect herbivory and may increase proliferation of leaf disease.

Jankiram and P. Pawan Kumar (2011) reported that snail (*Achatina fullica)* occasionally, chews young leaves by scraping, making big irregular holes. Adult and young ones devour plant during nights. Handpicking and killing by dropping snails in 5% salt solution reduces population. Sprinkling of salt crystals in the path or around pots kills snails as they come in to contact. Spreading of snail kill (3% metaldehyde pellets) in the field effectively reduces snail population. Spray of neem oil 10 ml/lit. And soap nut extract 60 g/lit protects foliage from damage.

McConnell and Cruz, (1998) the most common pests are mealy bugs, scales and nematodes. The mealy bugs and scales can be controlled with an insecticidal soap. Nematodes are small worms that attack the roots. Due to nematode problems, heliconias require replanting every few years from healthy rhizomes. The roots must be removed to prevent the spread of nematodes.

Kelvin *et. al.* (1995) have done detailed study of diseases of heliconia in Hawaii. They have recorded those diseases as per causal organisms.

FOLIAGE DISEASES CAUSED BY FUNGI:

*Calonectria spathiphylli:*

Disease and symptoms: The most pronounced foliar symptoms on heliconia caused by *Calonectria spathiphylli* are leaf yellowing, "firing" or drying of leaf margins, sheath spots and petiole blights. The photosynthetic or food-producing capacity of the diseased plants is reduced by multiple sheath and petiole infections followed by leaf loss. Foliage loss and root rots cause large, vigorous plants with high productivity to decline in a few years and become small, weak plants with poor flower production. Severely diseased plants of susceptible cultivars are killed.

Biology and spread: *Calonectria spathiphylli* has been isolated from diseased heliconia throughout the state. This common pathogen attacks Heliconia species and cultivars such as H. angusta cv. Holiday (formerly 'Red Christmas'), H. bihai cv. Kamehameha and cv. Lobster Claw One (formerly H. jacquinii), H. caribaea cv. Purpurea (formerly 'Red Caribaea' or 'Red Caribe'), H. indica cv. Spectabilis (formerly H. illustris var. rubricaulis), H. mutisiana, H. psittacorum cv. Parakeet, H. psittacorum X H. spathocircinata cv. Golden Torch (known as 'Parrot' in Hawaii), H. stricta cv. Dwarf Jamaican and cv. Fire Bird, and H. wagneriana. In Hawaii, *Calonectria spathiphylli* is also a highly destructive pathogen of many cultivars of spathiphyllum. In Florida, besides heliconia and spathiphyllum, this pathogen has been found on Strelitzia nicolai (white bird-of-paradise tree) and Ludwigia palustris (water purslane) (El-Gholl *et al.* 1992).

A pathogenic (disease causing) fungus was discovered in Hawaii on rotting heliconia in the late 1980s (Uchida et al. 1989). Based on the characteristics of the asexual stage, the fungus was identified as Cylindrocladium spathiphylli. The shape and size of the asexual spores were similar to C. spathiphylli discovered on spathiphyllum in Hawaii during the early 1980s (Uchida 1989; Uchida and Aragaki 1992). Subsequently, mating studies showed that Cylindrocladium from spathiphyllum and heliconia would produce the sexual stage when certain pairs were grown together (El-Gholl *et al.* 1992).

Disease and symptoms: Leaf spots caused by Pyriculariopsis begin as very small yellow areas with brown centers and are concentrated on and along the midrib. A few to several hundred may occur along the midrib, enlarging to large brown spots and killing adjacent leaf tissue. Large apical sections of leaves are killed, and leaf loss occurs with heavy infections. One-half or more of the leaf blade is commonly killed by these fungal invasions of the midrib. Less commonly, brown leaf spots develop on the leaf blade and induce chlorotic streaking.

The first record of *Pyriculariopsis sp.*:as a pathogen of heliconia was made by Uchida and Kadooka (1994). The pathogen was isolated from Heliconia angusta cv. Yellow Christmas and also causes spots on H. mutisiana.

## RHIZOME AND ROOT DISEASES CAUSED BY FUNGI

### *Calonectria spathiphylli*

Disease and symptoms: This fungus is presently the most widely spread pathogen attacking roots and rhizomes of heliconia in Hawaii. Severe root and rhizome rots kill plants or cause rapid plant decline. Root and rhizome rots of field heliconia start at the center of clumps with old diseased stalks, which are dry and collapsed, and develop outward. New growth is the healthiest, and diseased clumps of heliconia have empty circles within the older diseased growth. Root rots prevent proper anchorage, and taller diseased heliconia cultivars are prone to toppling.

Biology and spread: Calonectria infects roots and rhizomes of heliconia and can be found deep within the rhizomes in infected root traces that originate from severe root rots.

Fungal spores and microsclerotia move into a field with water (e.g., run-off). The pathogen also moves in infested or contaminated soil, especially in

mud adhering to trucks, plows, other field equipment, tools, boots, etc. The fungus is also transported when infected rhizomes are moved to new fields.

*Pythium species*

Disease and Symptoms: Several Pythium species have been isolated from diseased heliconia roots and rhizomes. These include P. splendens, P. aphanidermatum, P. myriotylum, and others. The role of these organisms needs to be investigated further. To date, P. splendens appears to be pathogenic, with disease developing slowly over a three- to four-month period. Root rot and slow decline of the plants are primary symptoms

Biology and spread: Pythium species have been found on the cultivars 'Bengal', Heliconia indica cv. Spectabilis, and H. psittacorum. Pythium species have been isolated from many agricultural and landscape plants around the world. In Hawaii, important diseases caused by Pythium are root rots of taro, macadamia, papaya, orchids, vegetables, dracaena and other foliage plants, alfalfa and other legumes, turf, and more.

Moisture and poor drainage greatly favor diseases caused by Pythium. Like Phytophthora, most Pythium species produce motile spores which distribute the fungi over greater distances. Other spores, such as oospores, have thickened walls which enable the fungus to survive long periods within the dead plant tissue or in the soil. The pathogen is transported to new locations by the movement of contaminated soil and water or infected plants.

*Rhizoctonia solani-like fungi and Rhizoctonia solani*

Disease and symptoms: Rhizoctonia solani-like fungi have been recovered from rotting roots of H. bihai cv. Lobster Claw One and H. caribaea. Although frequently associated with diseased plants, these fungi are generally considered weak pathogens, and pathogenicity tests are needed to determine the role of these organisms on heliconia.

Rhizoctonia solani is one of the most common pathogens occurring throughout the world. Almost every crop is affected by R. solani or other Rhizoctonia species. In Hawaii, R. solani causes root rots of many legumes, papaya, alfalfa, and foliage plants; fruit and root rots of tomato, bean, and cucumber; and web blights (massive rots) of poinsettia cuttings, ornamentals, and herbs. World-wide, R. solani causes major losses in potato, vegetables, cereals, and numerous ornamentals.

## OTHER FUNGI ASSOCIATED WITH HELICONIA

Other fungi have been recovered from heliconia in addition to those described above. The ability of these fungi to cause disease on heliconia is not known, and continued research is needed. These fungi are listed here for documentation purposes and include Colletotrichum spp., Pestalotiopsis sp., Phyllosticta sp., Phomopsis sp., Acremonium sp., and Fusarium spp.

## DISEASE CAUSED BY BACTERIA

### *Pseudomonas solanacearum*

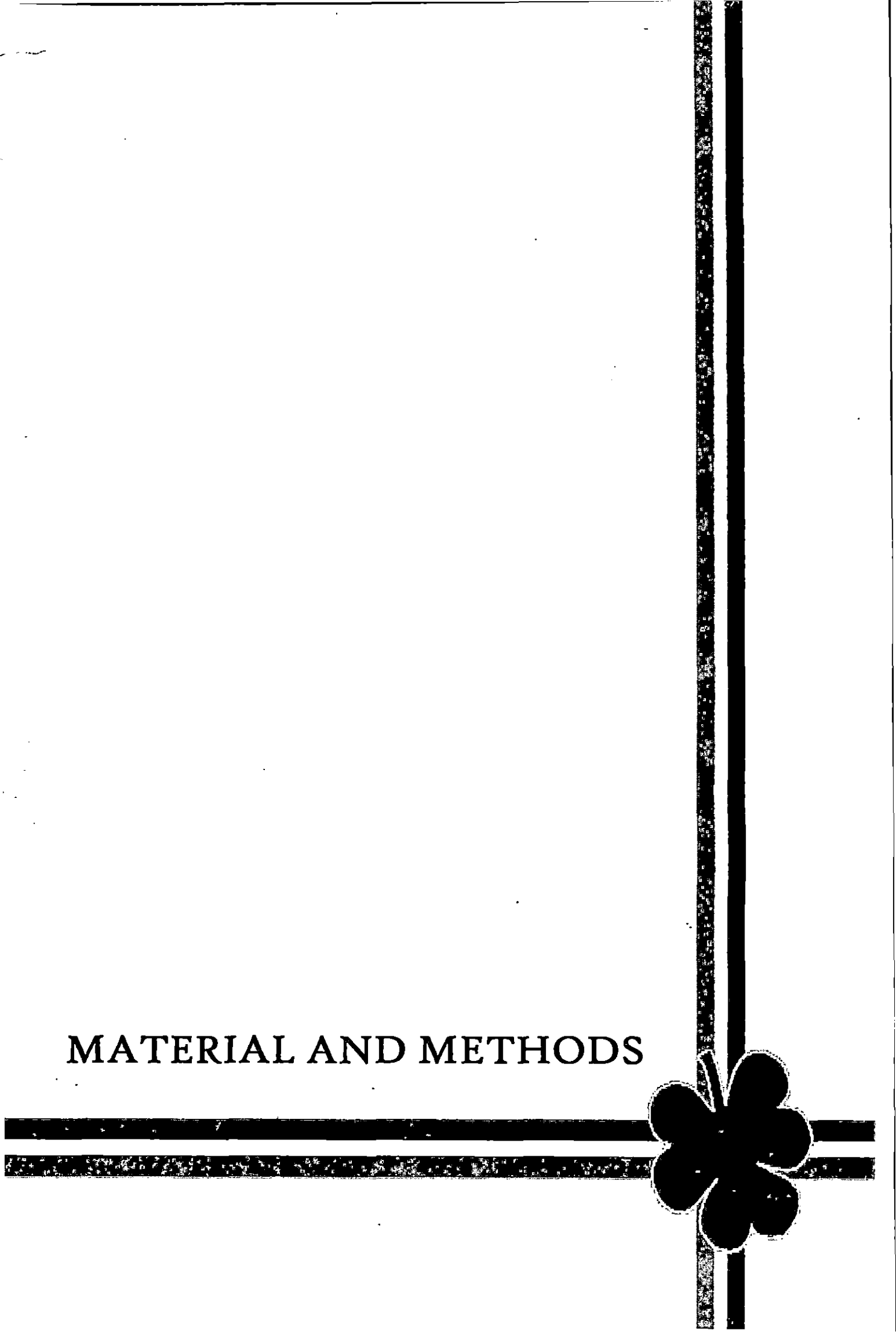
Disease and symptoms: The bacterial wilt pathogen *Pseudomonas solanacearum* causes foliar symptoms that include leaf rolling and wilting, leaf margin firing (browning of edges), and eventual dieback of the shoot. These symptoms are more pronounced on older leaves. Eventually, the entire leaf turns dark brown with an oily appearance, resulting in leaf loss. Within the rhizome, a dark brown discoloration of the vascular tissue runs longitudinally down the center. Often, milky ooze is associated with this brown vascular discoloration.

Biology and spread: Pseudomonas solanacearum survives in plant parts and many weed hosts. As diseased plants die and decompose, bacteria are released into the soil, where they can then spread by the movement of infested soil and water through fields. In Hawaii, Pseudomonas solanacearum has been identified on H. psittacorum and H. rostrata (Ferreira et al. 1991).

## ROOT DISEASES CAUSED BY NEMATODES

Nematodes recovered from heliconias include the burrowing nematode (Radopholus similis), a root-knot nematode (Meloidogyne sp.), a lesion nematode (Pratylenchus sp.), the reniform nematode Rotylenchus reniformis, and a spiral nematode (Helicotylenchus sp.). The burrowing, root-knot, and lesion nematodes are endoparasites that enter the host plant and feed within the roots. In the case of the root-knot nematode, the female becomes stationary in the plant and initiates gall formation. Other species move more freely within the plant or move about in the soil, feeding on roots without becoming attached to them. Nematodes have been recovered from roots of H. angusta cv. Yellow Christmas; H. farinosa cv. Rio; H. chartacea cv. Sexy Pink; H. stricta cv. Bucky; H. caribaea cv. Purpurea; H. psittacorum cv. Andromeda; H. rostrata; and more. They are spread greater distances by movement of soil on farm equipment and tools, surface water run-off, and infected plant propagation materials.

# MATERIAL AND METHODS



# 3 MATERIAL AND METHODS

The investigation on "Variability studies in seedlings of heliconia (Heliconia spp.)" was conducted in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during the period, 2010-2011. The details regarding the experimental material used, methodology adopted and analytical techniques followed are described in this chapter.

The experiment consisted of the following major studies.

- Seed characters
- Germination characters
- Morphological characters namely growth, shoot and leaf morphology, Suckering
- Physiological characters of the seedlings

## 3.1 Variability studies in seedlings of heliconia:

Seeds collected from at least 15 accessions of commercially grown heliconia species were utilized for the study. Seedlings were evaluated for their vegetative performance and variability under uniform cultural conditions. The experiment was conducted in the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram located at 8.5° N latitude and 76.9°E longitude and at an altitude of 29 m above mean sea level.

### 3.1.1 PLANT MATERIALS

Open pollinated seeds of fifteen promising heliconia accessions collected from growers.

Treatment details

| Treatment | Name Species / Variety |
|---|---|
| T1 | *Heliconia bihai* var. 'Monavo Sunrise' |
| T2 | *Heliconia magnifica* |
| T3 | *Heliconia mariae* |

*Heliconia champneiana*

*Heliconia latispatha* 'Orange Gyro'

*Heliconia lingulata* 'Red tip fan'

*Heliconia curtispatha*

*Heliconia bihai* 'Monavo Sunrise'

*Heliconia standleyi*

**Plate 1 :- Flowers of Heliconia species and varieties selected for study.**

*Heliconia imbricate*

*Heliconia magnifica*

*Heliconia ramonensis*

*Heliconia bourgaeana*

*Heliconia longa*

*Heliconia mariae*

**Plate 1 continued**

*Heliconia bihai var. 'Granda'*

*Heliconia caribaea Gold*

*Heliconia pogonantha*

**Plate 1 continued**

| | |
|---|---|
| T4 | *Heliconia champneiana* |
| T5 | *Heliconia curtispatha* |
| T6 | *Heliconia lingulata* var. 'Red tip fan' |
| T7 | *Heliconia bihai* var. 'Granda' |
| T8 | *Heliconia ramonensis* |
| T9 | *Heliconia pogonantha* var. 'Pogonantha' |
| T10 | *Heliconia standleryi* |
| T11 | *Heliconia longa* |
| T12 | *Heliconia bourgaeana* |
| T13 | *Heliconia latispatha* var. 'Orange Gyro' |
| T14 | *Heliconia imbricate* |
| T15 | *Heliconia caribaea* var. 'Gold' |

### 3.1.2 Method

The 15 genotypes were raised in a Completely Randomised Design with 4 replications during May 2010. In each replication 3 pots were placed. One seedling was maintained per pot.

### 3.1.3 SEED CHARACTERS

#### 3.1.3.1 Weight of 100 seeds

Weight of seeds was recorded at the beginning of pot culture experiment and their mean values were expressed in gm.

#### 3.1.3.2 Length of seeds

Length of seeds was recorded at the beginning of pot culture experimentation using vernier calliper and their mean values were expressed in the cm.

### 3.1.3.3 Width of seeds

Width of seeds was recorded at the beginning of pot culture experimentation using vernier calliper and their mean values were expressed in cm.

### 3.1.3.4 Seed shape

Seed shape was observed and recorded at the beginning of pot culture experimentation.

## 3.1.4 GERMINATION CHARACTERS

### 3.1.4.1 Percentage of germination:

Percent germination was observed and recorded.

### 3.1.4.2 Days required for 50 % germination

Days required for 50% germination were counted and recorded.

## 3.1.5 MORPHOLOGICAL CHARACTERS

Morphological characters were recorded from all the plants and replication means were calculated for statistical analysis.

### 3.1.5.1 Height of the plant

Height of the plant was recorded from base to the tip was measured at monthly interval and their mean values were expressed in the centimetres.

### 3.1.3.2 Shoot girth

Shoot girth was recorded using twine and scale at collar height at monthly interval and their mean values were expressed in the centimetres.

### 3.1.3.3 Rate of shoot elongation

Rate was calculated at the end of pot culture experiment using observations of plant height.

### 3.1.3.4 Number of leaves

Number of fully opened leaves was counted at monthly interval.

### 3.1.3.5 Length of leaves

Length of third fully opened leaf was measured form leaf base to the tip of leaf by using meter scale at monthly interval and their mean values were expressed in the centimetres.

### 3.1.3.6 Width of leaves

Width of third fully opened leaf was measured form leaf base to the tip of leaf by using meter scale at monthly interval and their mean values were expressed in the centimetres.

### 3.1.3.7 Leaf length: width ratio

Length and width ratio of leaf was calculated using the final values of leaf length and leaf width at the end of pot culture experiment.

### 3.1.3.8 Leaf shape

Shape of leaf was observed and was recorded at the end of pot culture experiment.

### 3.1.3.9 Leaf tip

Shape of leaf tip was observed and recorded at the end of pot culture experiment.

### 3.1.3.10 LEAF AREA

Leaf area was recorded from 3$^{rd}$ fully open leaf using graph paper tracings at monthly interval and their mean values were expressed in the $cm^2$.

**3.1.3.11Leaf thickness**

Using micrometer thickness of third leaf was recorded at monthly interval.

**3.1.3.12 Number of suckers**

Suckers produced were counted at monthly interval and their mean values were recorded.

### 3.1.4 Physiological characters

**3.1.4.1 Leaf sheath colour**

Leaf sheath colour was observed and recorded at the end of pot culture experimentation.

**3.1.4.2 Presence of powdery coating**

Presence of powdery coating was observed and recorded at the end of pot culture experimentation.

**3.1.4.3 Leaf colour**

Leaf colour was observed and recorded at the end of pot culture experimentation.

**3.1.4.4 Leaf margin colour**

Leaf colour was observed and recorded at the end of pot culture experimentation.

**3.1.4.5 PIGMENT CONTENT**

Using DMSO and Acetone method given by Arnons (1949) chlorophyll-a, chlorophyll-b, Total chlorophyll and Carotenoid content was recorded at the end of pot culture experimentation.

Estimation of chlorophyll by the DMSO method:

1. A known weight (500 mg) of the leaf material of each species and variety of heliconia was taken.
2. The leaf material was cut into small bits and takes them in a test tube.
3. 10 ml of DMSO: 80% acetone mixture (1:1) was poured into these test tubes and incubated over night at room temperature. All the pigments were extracted into the solution.
4. From the coloured solution supernatant liquid was decanted into a measuring cylinder and the volume made up to 25 ml with the DMSO-Acetone mixture.
5. Absorbance at 480, 510, 645, 652, and 663 nm using a spectrophotometer was recorded.
6. Pigment content was calculated by substituting the absorbance values in the formula given.

Chlorophyll a $= (12.7\ A_{663} - 2.69\ A_{645}) \times V/1000 \times 1/\text{Fresh wt.}$

Chlorophyll b $= (22.9\ A_{645} - 4.68\ A_{663}) \times V/1000 \times 1/\text{Fresh wt.}$

Chlorophyll a+ b $= (8.02\ A_{663} + 20.20\ A_{645}) \times V/1000 \times 1/\text{Fresh wt.}$

Carotenoids $= (7.6\ A_{480} - 1.49\ A_{510}) \times V/1000 \times 1/\text{Fresh wt.}$

Where, V is volume of extract.

### 3.1.6 Statistical Analysis

The data collected were subjected to the following statistical analysis for Completely Randomized Design after testing the homogeneity of error variances.

Analysis of Variance (ANOVA) technique was used to test the significance of genotypic differences among the selected heliconia varieties. Mean, variance, standard error and coefficient of variation were estimated. The character associations were estimated through correlation coefficients

using Analysis of Covariance (ANCOVA) technique (Panse and Sukhatme, 1967).

### *3*.1.6.1 Coefficient of Variation

Phenotypic and genotypic coefficient of variation (PCV and GCV) for a character X were estimated as

$$GCV = \frac{\sigma_{gx}}{\overline{X}} \times 100$$

$$PCV = \frac{\sigma_{px}}{\overline{X}} \times 100$$

Where,

$\sigma_{gx}$ = genotypic standard deviation

$\sigma_{px}$ = phenotypic standard deviation

$\overline{X}$ = mean of the character under study

### 3.1.6.2 Heritability coefficient and Genetic Advance

Heritability coefficient ($H^2$) in the broad sense was estimated as the proportion of heritability component of variation.

$$\text{Heritability coefficient, } (H^2) = \frac{\sigma_{gx}^2}{\sigma_{px}^2} \times 100$$

$$\text{Genetic advance as percentage of mean (GA)} = \frac{kH^2\sigma_{px}}{\overline{X}} \times 100$$

Where k is the selection differential whose value is 2.06 if five per cent selection is practiced (Miller *et al.*, 1958).

### 3.1.6.3 Correlation Analysis

The correlation coefficients (phenotypic, genotypic and environmental) between two characters denoted as X and Y were worked out as follows

$$\text{Genotypic correlation } (\gamma_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation } (\gamma_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation } (\gamma_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{ey}}$$

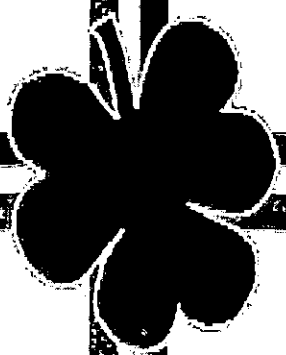
Where, $\sigma_{gxy}$, $\sigma_{pxy}$ and $\sigma_{exy}$ are the genotypic, phenotypic and environmental covariance. The $\sigma_{gx}$ is genotypic standard deviation and $\sigma_{px}$ is phenotypic standard deviation and $\sigma_{ex}$ is the environmental standard deviation for character X.

### 3.1.7 Mahanolobis ($D^2$) analysis

Mahanolobis ($D^2$) analysis (1936) was applied for classificatory studies by Murty and Aranachalam (1966) in crop plants. The same methodology was applied to cluster the fourteen genotypes of *Heliconia spp.* in the experiment.

The Tocher's method of clustering was utilized for grouping genotypes in to several clusters based on the $D^2$ values.

# RESULTS



# 4. RESULTS

The experimental data were collected on various aspects of morphology, physiology and seed characters of 15 selected species and varieties of Heliconia for the present study. The data were statistically analysed and the results obtained are presented here.

## 4.1 Evaluation of species and varieties for their performance

The mean performance of each of the fifteen varieties for the morphological, physiological and seed characters was studied.

### 4.1.1 SEED CHARACTERS

Data pertaining to seed characters of the species and varieties is presented in Table 1 and Plate 2.

#### 4.1.1.1 WEIGHT OF 100 SEEDS (SEED INDEX)

The species and varieties showed significant difference in weight of seeds. The variety T15 (*Heliconia caribaea* var. 'Gold') registered weight 15.03g/ 100 seeds. Followed by T10 (*Heliconia standleryi),* 14.12 g/ 100 seeds and T5 (*Heliconia curtispatha)* 13.88 g/ 100 seeds.

Minimum value for seed weight was registered by T3 (*Heliconia mariae),* 2.66 g/ 100 seeds. It was preceded by T11 (*Heliconia longa*), 5.18 / 100 seeds.

#### 4.1.1.2 LENGTH OF SEEDS

There was significant difference in the length of seeds between species and varieties utilized for study. The species T10 (*Heliconia standleryi),* registered longest seed of 1.17 cm length. It was followed by T5 (*Heliconia curtispatha ),*

**Table 1 Seed characters of 15 heliconia species and varieties**

| Treatment | Seed Characters | | | |
|---|---|---|---|---|
| | Seed Index (Seed Weight g/100 seeds) | Seed Length (cm.) | Seed Width (cm.) | Seed Shape |
| T1 | 8.79 | 0.80 | 0.51 | Rectangular |
| T2 | 7.98 | 0.78 | 0.47 | Rectangular |
| T3 | 2.66 | 0.58 | 0.31 | Slightly Conical |
| T4 | 12.20 | 0.96 | 0.61 | Rectangular |
| T5 | 13.88 | 1.10 | 0.50 | Rectangular |
| T6 | 10.34 | 0.88 | 0.49 | Rectangular |
| T7 | 12.28 | 0.94 | 0.55 | Rectangular |
| T8 | 8.20 | 0.75 | 0.48 | Rectangular |
| T9 | 10.66 | 0.94 | 0.59 | Rectangular |
| T10 | 14.12 | 1.17 | 0.61 | Rectangular |
| T11 | 5.18 | 0.68 | 0.39 | Rectangular |
| T12 | 13.45 | 1.07 | 0.56 | Rectangular |
| T13 | 7.32 | 0.70 | 0.44 | Rectangular |
| T14 | 13.77 | 0.80 | 0.74 | Round |
| T15 | 15.03 | 1.02 | 0.57 | Rectangular |
| SE | 0.25 | 0.05 | 0.03 | |
| CD | 0.74 | 0.14 | 0.9 | |

with mean value of 1.1 cm and T12 (*Heliconia bourgaeana)*, with mean value of 1.07 cm.

The species T3 (*Heliconia mariae)* recorded the lowest length of seeds with mean values of 0.58 cm. It was preceded by T11 (*Heliconia longa*) with mean values of 0.68 cm.

#### 4.1.1.3 WIDTH OF SEEDS

There was significant difference in the width of seeds between species and varieties utilized for study. The species T14 (*Heliconia imbricata)* registered widest seed with mean value of 0.74 cm. It was followed by the species T10 (*Heliconia standleryi),* and T4 (*Heliconia champneiana),* with mean value of 0.61 cm. each.

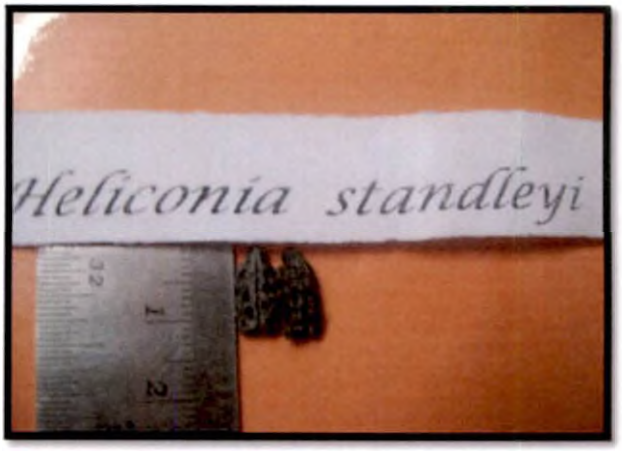
The species T3 (*Heliconia mariae)* recorded the lowest width of seeds with mean values of 0.31 cm. It was preceded by T11 (*Heliconia longa*) with mean values of 0.39 cm.

#### 4.1.1.4 SEED SHAPE

The shape of seed varied from rectangular to a rounded one. The species T14 (*Heliconia imbricata)* registered rounded seeds. In rest of the varieties seed shape was rectangular except T3 (*Heliconia mariae)* which observed to have slightly conical shaped.

### 4.1.2 GERMINATION CHARACTERS

Data pertaining to germination characters of the species and varieties is presented in Table 2



A: *Heliconia longa*

B: *Heliconia bihai* 'Granda'

C: *Heliconia curtispatha*


**Plate 2 :- Variability in seed characters of *Heliconia spp*.**

**Table 2 Germination characters of 15 heliconia species and varieties**

| Treatment | Percentage of germination | Days req. for 50% germination |
|---|---|---|
| T1 | 50 | 104 |
| T2 | 41.66 | - |
| T3 | 100 | 86 |
| T4 | 50 | 97 |
| T5 | 100 | 46 |
| T6 | 50 | 105 |
| T7 | 50 | 124 |
| T8 | 0 | - |
| T9 | 66.66 | 129 |
| T10 | 91.66 | 60 |
| T11 | 91.66 | 95 |
| T12 | 74.99 | 61 |
| T13 | 74.99 | 74 |
| T14 | 58.32 | 142 |
| T15 | 58.32 | 153 |
| SE | 11.98 | - |
| CD | 34.22 | - |

### 4.1.2.1 PERCENTAGE OF GERMINATION

The species and varieties showed significant difference percent germination. The species T5 (*Heliconia curtispatha* ), T3 (*Heliconia mariae)* recorded the highest germination percent(100%). It was followed by the species T10 (*Heliconia standleryi)* and T11 (*Heliconia longa*) (91.66%).

Among the species and for study species T8 (*Heliconia ramonensis)* failed to germinate during entire observation period. As a result T8 (*Heliconia ramonensis)* is not analyzed for any morphological and physiological character. The species T2 *(Heliconia magnifica),* recorded second lowest germination percentage of 41.66 percent.

### 4.1.2.2 DAYS REQUIRED FOR 50 % GERMINATION

In heliconia species and varieties studied the time taken for 50 percent germination is spread over wide range (46 – 153 days). The species T5 (*Heliconia curtispatha.),* registered less days required for 50% germination i.e. 46 days. . It was followed by the species T10 (*Heliconia standleryi),* with 60 days.

More number of days were required for 50% germination by variety T15 (*Heliconia caribaea* var. 'Gold') i.e. 153 days. It was preceded by the species T14 (*Heliconia imbricata)* which took 142 days for 50% germination.

## 4.1.3 MORPHOLOGICAL CHARACTERS

### 4.1.3.1 HEIGHT OF THE PLANT

Data pertaining to the height of the species and varieties is presented in Table 3 and Fig. 1.

The species and varieties varied significantly with respect to plant height throughout the observation period. The species T3 (*Heliconia mariae)* recorded the highest plant height with mean values of 154.8 cm, 175.3 cm, 194.1 cm, 202.6

**Table 3 Plant height of 14 Heliconia species and varieties**

| Treatment | Plant height (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAE | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 3.6 | 13.9 | 44.7 | 52.4 | 64.8 | 72.9 | 77.1 | 82.9 | 86.5 | 91.3 |
| T2 | 5.9 | 15.3 | 31.4 | 42.7 | 56.1 | 65.2 | 74 | 85.4 | 98.5 | 106.4 |
| T3 | 7.45 | 23.7 | 44.8 | 73.6 | 107.1 | 133.2 | 154.8 | 175.3 | 194.1 | 202.6 |
| T4 | 3.1 | 11.4 | 30.2 | 39.1 | 44.6 | 53.9 | 63.8 | 72.7 | 84.5 | 99.7 |
| T5 | 9.4 | 19.5 | 31 | 42.6 | 54.1 | 68.6 | 93.5 | 117.1 | 129.8 | 139.8 |
| T6 | 6.5 | 13.1 | 24.8 | 35.37 | 43.1 | 56.3 | 77.4 | 98.1 | 117 | 129.5 |
| T7 | 5.8 | 7.9 | 18.5 | 28.9 | 38.3 | 39.6 | 41.3 | 42.8 | 44.1 | 46.3 |
| T9 | 10.1 | 20.1 | 45.2 | 102.2 | 130.4 | 143.2 | 147.8 | 150.2 | 154.3 | 159.2 |
| T10 | 6.1 | 16.7 | 29.8 | 43.2 | 54.1 | 71.7 | 96.3 | 121.5 | 146.2 | 165.1 |
| T11 | 6.1 | 16.9 | 42.7 | 78.9 | 112.9 | 133.7 | 145.9 | 158.1 | 167.3 | 175.5 |
| T12 | 11.2 | 23.8 | 35.8 | 63.1 | 82.4 | 92.8 | 103.4 | 114.7 | 121.4 | 126.4 |
| T13 | 6.3 | 21.6 | 36.7 | 59.4 | 81.2 | 92.8 | 105.9 | 114.3 | 122.7 | 127.9 |
| T14 | 4.3 | 13.8 | 48.7 | 87.4 | 118.3 | 125.8 | 137.5 | 144.2 | 151.8 | 157.55 |
| T15 | 7.3 | 27.8 | 33.6 | 41.2 | 58.2 | 84.8 | 111.4 | 126.5 | 137.3 | 146.9 |
| SE | 0.33 | 0.16 | 0.17 | 0.15 | 0.11 | 0.11 | 0.13 | 0.13 | 0.16 | 0.23 |
| CD | 0.58 | 0.953 | 0.475 | 0.492 | 0.449 | 0.329 | 0.323 | 0.377 | 0.474 | 0.662 |

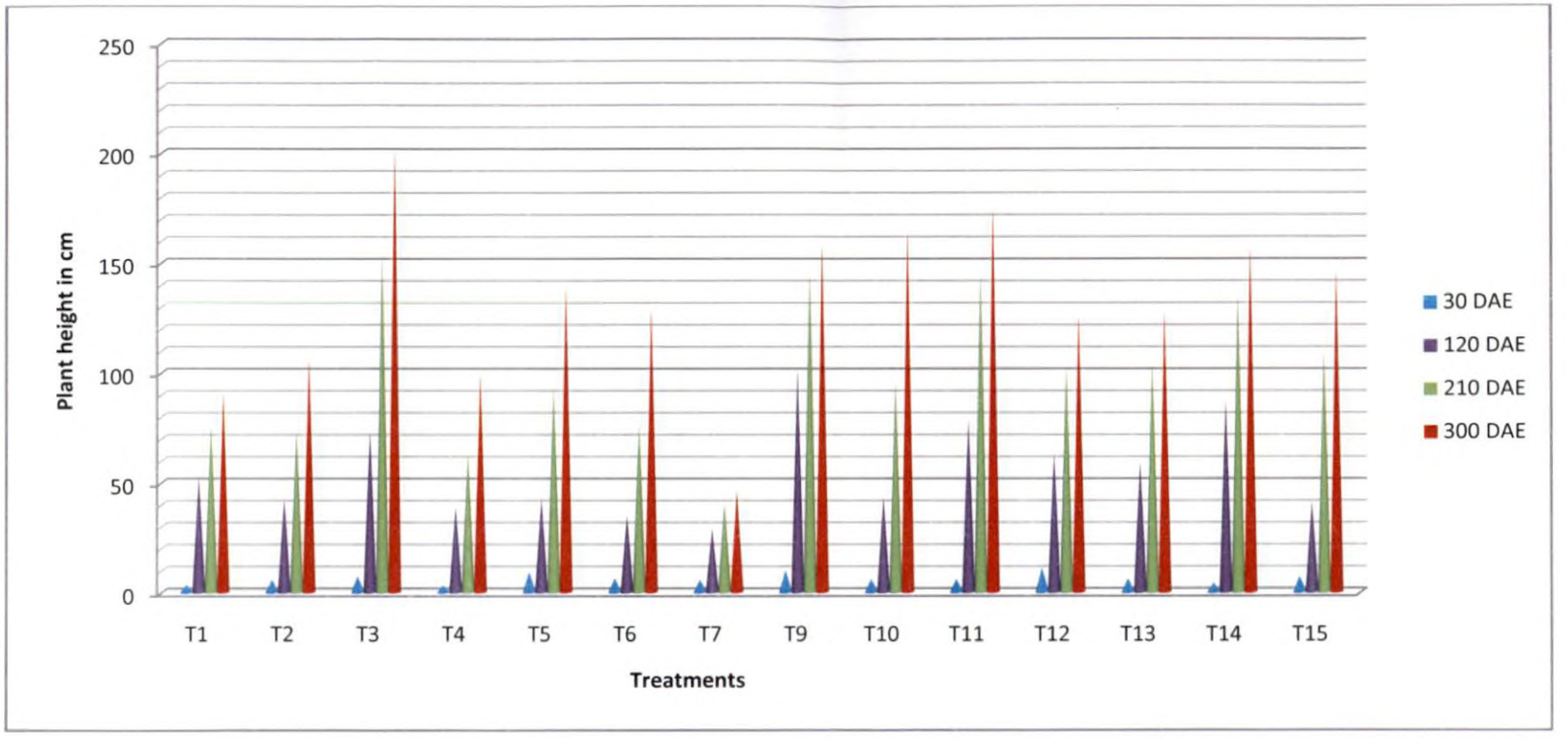



**Fig. 1 Plant height of 14 heliconia species and varieties**


**Plate 3:- Field view of Heliconia species and varieties**


**Plate 4 :- Variation in plant height of Heliconia species and varieties**

cm respectively at 210 DAE, 240 DAE, 270 DAE and 300 DAE which was significantly superior over other species and varieties. The variety T9 (*Heliconia pogonantha* var. 'Pogonantha') recorded highest plant height of 102.2 cm, 130.4 cm and 143.2 cm (respectively at 120 DAE, 150 DAE, 180 DAE). During early growth period species T12 (*Heliconia bourgaeana)* at 30 days after emergence (11.2 cm), variety T15 (*Heliconia caribaea* var. 'Gold') at 60 days after emergence (27.8 cm) and species T14 (*Heliconia imbricata*) at 90 days after emergence (48.7 cm) recorded highest plant height.

Among the species and varieties T7 (*Heliconia bihai* var. 'Granda') registered the lowest plant height during whole observation period except at 30 DAE. It recorded a mean height of 7.9 cm, 18.5 cm, 28.9 cm, 38.3 cm, 39.6 cm, 41.3 cm, 42.8 cm, 44.1 cm and 46.3 cm, respectively at 60 DAE, 90 DAE, 120 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence. The species T4 (*Heliconia champneiana*) recorded lowest plant height (3.1 cm) at 30 days after emergence.

### 4.1.3.2 SHOOT GIRTH

Data pertaining to the Shoot girth of the species and varieties is presented in Table 4.

There was significant difference in the shoot girth between species and varieties utilized for study. The species T3 (*Heliconia mariae)* recorded the highest shoot girth with mean values of 10.2 cm, 11.7 cm, 13.7 cm, 15.5 cm, 17.4 cm, 18.6 cm, respectively at 150 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE and 300 days after emergence which was significantly superior over other species and varieties. The variety T15 (*Heliconia caribaea* var. 'Gold') at 60 DAE, 90 DAE, 120 DAE, registered a highest shoot girth with mean values of 3.6 cm, 6.5 cm, 8.7 cm, respectively. The variety T13 (*Heliconia latispatha* var. 'Orange Gyro') have recorded highest shoot girth (2.6 cm) at 30 days after emergence.

The variety T13 (*Heliconia latispatha* var. 'Orange Gyro') have recorded lowest shoot girth at 240 DAE, 270 DAE and 300 days after emergence (6.5 cm,

**Table 4 Shoot girth of 14 Heliconia species and varieties**

| Treatment | Shoot girth (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAE | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 1.6 | 2.45 | 5.7 | 6.95 | 8.4 | 8.4 | 8.4 | 8.5 | 8.6 | 8.9 |
| T2 | 1.4 | 2.25 | 3.9 | 5.1 | 6.45 | 7.6 | 8.6 | 9.5 | 10 | 10.4 |
| T3 | 1.7 | 3.4 | 5.25 | 7.4 | 10.2 | 11.7 | 13.7 | 15.5 | 17.4 | 18.6 |
| T4 | 1.35 | 1.9 | 3.55 | 4.75 | 5.4 | 5.95 | 6.5 | 6.9 | 7.4 | 7.8 |
| T5 | 1.9 | 2.8 | 3.75 | 4.8 | 5.9 | 6.9 | 7.8 | 9.1 | 10 | 10.7 |
| T6 | 1.4 | 2.75 | 4.45 | 5.1 | 6.3 | 8.2 | 10.1 | 12.3 | 14.3 | 15.6 |
| T7 | 1.6 | 2.6 | 3.5 | 4.5 | 5.9 | 6.75 | 7.8 | 8.4 | 8.9 | 9.5 |
| T9 | 1.9 | 3.1 | 5.51 | 8.25 | 10.1 | 11 | 11.8 | 12.3 | 12.7 | 13.2 |
| T10 | 1.4 | 3.3 | 4.3 | 6.9 | 8.1 | 10.1 | 11.1 | 11.3 | 11.9 | 12.6 |
| T11 | 1.6 | 2.5 | 4.3 | 6.4 | 8.5 | 10.1 | 10.7 | 11.3 | 11.6 | 12 |
| T12 | 1.9 | 2.6 | 3.2 | 3.9 | 5.1 | 6.2 | 6.4 | 6.6 | 6.9 | 7.1 |
| T13 | 2.6 | 3.4 | 4.15 | 4.95 | 5.5 | 6.1 | 6.4 | 6.5 | 6.6 | 6.8 |
| T14 | 1.4 | 3.5 | 5.7 | 7.2 | 8.7 | 9.9 | 11.2 | 12.4 | 12.9 | 13.2 |
| T15 | 2.1 | 3.6 | 6.5 | 8.7 | 10.1 | 10.9 | 11.5 | 11.8 | 12.3 | 12.8 |
| SE | 0.075 | 0.076 | 0.06 | 0.058 | 0.071 | 0.047 | 0.069 | 0.069 | 0.06 | 0.061 |
| CD | 0.21 | 0.21 | 0.17 | 0.16 | 0.20 | 0.13 | 0.19 | 0.19 | 0.17 | 0.17 |

6.6 cm, 6.8 cm, respectively). Species T12 (*Heliconia bourgaeana)* registered lowest mean values of shoot girth at 90 DAE, 120 DAE, 150 DAE, 210 DAE, (3.2 cm, 3.9 cm, 5.1 cm and 6.4 cm, respectively). Species T14 (*Heliconia imbricata*) recorded lowest mean values for shoot girth at 30 DAE, 60 DAE and 180 days after emergence (1.35 cm, 1.9 cm and 5.95 cm, respectively).

### 4.1.3.3 RATE OF SHOOT ELONGATION

Data pertaining to rate of shoot elongation of the species and varieties is presented in Table 5 and Fig 2.

The species and varieties showed significant difference in rate of shoot elongation during observation period. At 30 days after emergence species T12 (*Heliconia bourgaeana)* registered highest rate of shoot elongation i.e. 11.2 cm/month. Followed by the variety T9 (*Heliconia pogonantha* var. 'Pogonantha') i.e. 10.1 cm/ month and T5 (*Heliconia curtispatha)* i.e. 9.4 cm/month. The lowest rate of shoot elongation (3.1 cm/month) was recorded by the species T4 (*Heliconia champneiana*) at 30 days after emergence.

At 150 days after emergence the variety T9 (*Heliconia pogonantha* var. 'Pogonantha') recorded highest mean value for rate of shoot elongation (26.08 cm/month) which was significantly superior over rest of the species and varieties. It was followed by species T14 (*Heliconia imbricata*) i.e. 23.66 cm/month. At 150 days after emergence the variety T6 *(Heliconia lingulata* 'Red tip fan'*)* recorded lowest rate of shoot elongation with mean value of 8.62 cm/month.

At 300 days after emergence the species T3 (*Heliconia mariae)* recorded the highest mean value for rate of shoot elongation (20.26 cm/month). Followed by species T11 (*Heliconia longa*) (17.55 cm/month). Varieties T7 (*Heliconia bihai* var. 'Granda') registered the lowest recorded lowest rate of shoot elongation with mean value of 7.63 cm/month.

**Table 5 Rate of shoot elongation of 14 heliconia species and varieties**

| Treatment No. | Rate of shoot elongation (cm/month) | | |
|---|---|---|---|
| | 30 DAE | 150 DAE | 300 DAE |
| T1 | 3.60 | 12.96 | 9.13 |
| T2 | 5.90 | 11.22 | 10.64 |
| T3 | 7.45 | 21.42 | 20.26 |
| T4 | 3.10 | 8.92 | 9.97 |
| T5 | 9.40 | 10.82 | 13.98 |
| T6 | 6.50 | 8.62 | 12.95 |
| T7 | 5.80 | 7.66 | 4.63 |
| T9 | 10.1 | 26.08 | 15.92 |
| T10 | 6.10 | 10.82 | 16.51 |
| T11 | 6.10 | 22.58 | 17.55 |
| T12 | 11.20 | 16.48 | 12.64 |
| T13 | 6.30 | 16.24 | 12.79 |
| T14 | 4.30 | 23.66 | 15.75 |
| T15 | 7.30 | 11.64 | 14.69 |
| SE | 0.33 | 0.03 | 0.23 |
| CD | 0.58 | 0.80 | 0.662 |

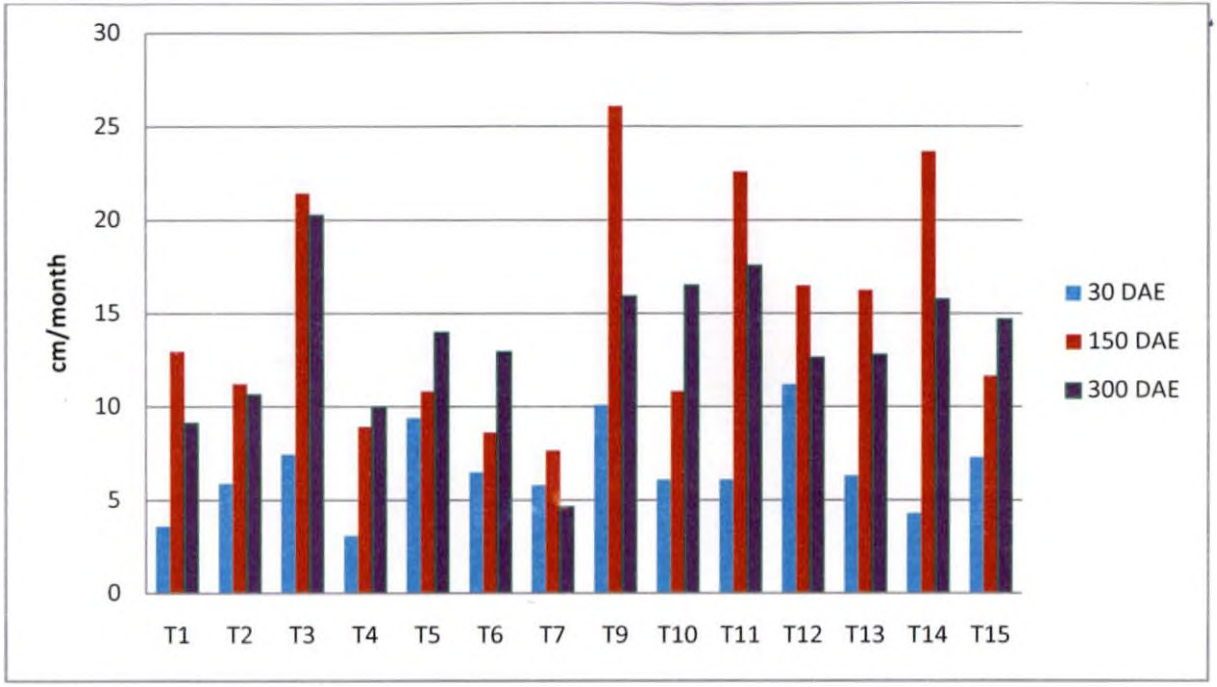



**Fig. 2 Rate of shoot elongation of 14 heliconia species and varieties**

### 4.1.3.4 NUMBER OF LEAVES

Data pertaining to number of leafs of the species and varieties are presented in Table 6.

The species and varieties showed significant difference in number of leaves per plant. At initial growth period 30 DAE variety T1 *Heliconia bihai* 'Manova Sunrise' and T10 (*Heliconia standleryi)* registered the highest number of leaves with mean value of 6. Among the species and varieties T7 (*Heliconia bihai* var. 'Granda') registered the highest number of leaves with mean value of 9, 10 and 10 at 240 DAE, 270 DAE and 300 days after emergence. Followed by variety T15 (*Heliconia caribaea* var. 'Gold') and the species T10 (*Heliconia standleryi)* i.e. 9 leaves per plant at 300 days after emergence.

The species T2 *(Heliconia magnifica)* and variety T6 *(Heliconia lingulata* 'Red tip fan'*)* recorded lowest number of leaves per plant i.e. 6 leaves per plant at 300 days after emergence.

### 4.1.3.5 LENGTH OF LEAVES

Data pertaining to length of leaves of the species and varieties is presented in Table 7.

There was significant difference in the length of leaves between species and varieties utilized for study. The species T3 (*Heliconia mariae)* recorded the highest length of leaves except 150 DAE with mean values of 8.4 cm, 21.1 cm, 29.6 cm, 46.7 cm, 48.6 cm, 50.7 cm, 52.8 cm and 54.1, respectively at 60 DAE, 90 DAE, 120 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence. The species T11 (*Heliconia longa*) have recorded highest length of leave at 150 DAE (38.2 cm).

Among the species and varieties T7 (*Heliconia bihai* var. 'Granda') registered the lowest length of leaves during whole observation period except at 60 DAE, 90 DAE; with mean values of 13.3 cm, 16.9 cm, 20.5 cm, 20.5 cm, 26.3

**Table 6 Number of leaves of 14 Heliconia species and varieties**

| Treatment | Number of leaves | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAE | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| T2 | 3 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| T3 | 5 | 5 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| T4 | 4 | 4 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| T5 | 4 | 4 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 |
| T6 | 2 | 2 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| T7 | 2 | 2 | 4 | 6 | 8 | 9 | 9 | 9 | 10 | 10 |
| T9 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 |
| T10 | 6 | 6 | 7 | 8 | 8 | 8 | 8 | 8 | 9 | 9 |
| T11 | 5 | 5 | 6 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| T12 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 7 | 7 |
| T13 | 4 | 4 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 8 |
| T14 | 5 | 5 | 6 | 7 | 7 | 7 | 8 | 8 | 8 | 8 |
| T15 | 5 | 5 | 6 | 7 | 8 | 8 | 8 | 9 | 9 | 9 |
| SE | 0.3 | 0.3 | 0.3 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| CD | 0.88 | 0.88 | 0.88 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |

**Table 7 Length of leaf of 14 Heliconia species and varieties**

| Treatment | Length Of leaf (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 4.2 | 18.5 | 22.8 | 26.5 | 30.4 | 33.9 | 36.7 | 41 | 42.2 |
| T2 | 4.9 | 8.4 | 15.9 | 24.4 | 29.6 | 32.7 | 34.9 | 36.1 | 39.7 |
| T3 | 8.4 | 21.1 | 29.6 | 38.1 | 46.7 | 48.6 | 50.7 | 52.8 | 54.1 |
| T4 | 0 | 10.3 | 18.3 | 24.3 | 31.2 | 32.3 | 32.9 | 34.5 | 35.9 |
| T5 | 7.5 | 10.4 | 15.1 | 19.3 | 24.9 | 28.2 | 33.7 | 38.1 | 43.6 |
| T6 | 5.1 | 11.6 | 15.3 | 18.6 | 23.1 | 28.6 | 35.2 | 42 | 47.3 |
| T7 | 2.6 | 9.75 | 13.3 | 16.9 | 20.5 | 20.5 | 26.3 | 28.4 | 30.2 |
| T9 | 0 | 10.4 | 16.3 | 30.2 | 36.7 | 40.1 | 41.2 | 42.1 | 42.9 |
| T10 | 5.2 | 13.1 | 21.4 | 27.4 | 34.4 | 46.5 | 47.3 | 49.7 | 51.9 |
| T11 | 0 | 14.3 | 27.1 | 38.2 | 45.6 | 46.3 | 47.3 | 47.7 | 48.4 |
| T12 | 7.9 | 14.7 | 21.3 | 30.5 | 35.2 | 38.1 | 25.425 | 45.5 | 47 |
| T13 | 0 | 10.5 | 18.1 | 25.6 | 32.9 | 39.5 | 42.1 | 44.9 | 46.1 |
| T14 | 6.7 | 20.1 | 29.7 | 33.4 | 35.2 | 37.1 | 39 | 40.1 | 40.8 |
| T15 | 5.8 | 19.3 | 22.4 | 26.1 | 33.1 | 39.4 | 41.8 | 42.9 | 43.8 |
| SE | 0.05 | 0.07 | 0.05 | 0.05 | 0.04 | 0.04 | 0.08 | 0.04 | 0.05 |
| CV | 0.14 | 12.36 | 0.16 | 0.17 | 0.13 | 0.13 | 0.22 | 0.13 | 0.14 |

cm, 28.4 cm and 30.2, respectively at 120 DAE, 150 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence.

### 4.1.3.6 WIDTH OF LEAVES

Data pertaining to width of leaves of the species and varieties is presented in Table 8.

There was significant difference in the width of leaves between species and varieties utilized for study. The species T3 (*Heliconia mariae)* recorded the highest width of leave with mean values of 3.5 cm, 18.3 cm, 22.3 cm, 24.5 cm, respectively at 60 DAE, 150 DAE, 180 DAE and 300 days after emergence. The species T10 (*Heliconia standleryi)* recorded the highest width of leave with mean values of 23.4 cm, 23.7 cm, 24 cm, respectively at 210 DAE, 240 DAE, 270 days after emergence. At 90 DAE and 120 DAE species T14 (*Heliconia imbricata*) recorded the highest width of leave with mean values of 9.7 cm, 13.6 cm, respectively.

Among the species and varieties T7 (*Heliconia bihai* var. 'Granda') registered the lowest width of leaves during whole observation period except at 60 DAE; with mean values of 4.1 cm, 5.3 cm, 6.5 cm, 7.8 cm, 9.1 cm, 10.2 cm, 11.8 cm and 12.6 cm, respectively at 60 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence.

### 4.1.3.7 LEAF LENGTH: WIDTH RATIO

Data pertaining to leaf length: width ratio of the species and varieties is presented in Table 9.

There was significant difference in the leaf length: width ratio between species and varieties utilized for study. The variety T13 (*Heliconia latispatha* var. 'Orange Gyro') have recorded highest leaf length: width ratio of 3:1. Followed by variety T1 (*Heliconia bihai* 'Manova Sunrise') i.e. 2.7: 1.

**Table 8 Width of leaf of 14 Heliconia species and varieties**

| Treatment | Width Of leaf (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 2.3 | 7.2 | 9.1 | 10.4 | 11.9 | 12.7 | 12.7 | 13.6 | 14.7 |
| T2 | 2.1 | 5.2 | 8 | 11.9 | 14.9 | 16.3 | 16.3 | 17.1 | 18.6 |
| T3 | 3.5 | 6.75 | 11.5 | 18.3 | 22.3 | 22.7 | 22.7 | 23.2 | 23.8 |
| T4 | 0 | 4.2 | 8.1 | 9.3 | 11.7 | 12.1 | 12.1 | 12.7 | 14.5 |
| T5 | 2.7 | 5.2 | 8.6 | 11.5 | 13.8 | 16.1 | 16.1 | 19.7 | 22.2 |
| T6 | 2.4 | 6.45 | 7.1 | 8.2 | 10.5 | 14.1 | 14.1 | 17.7 | 20.5 |
| T7 | 1.9 | 4.1 | 5.3 | 6.5 | 7.8 | 9.1 | 9.1 | 10.2 | 11.8 |
| T9 | 0 | 5.8 | 9.1 | 12.2 | 16.6 | 18.5 | 18.5 | 20.1 | 21.8 |
| T10 | 3.15 | 8.3 | 10.7 | 14.375 | 19.3 | 23.4 | 23.4 | 23.7 | 24 |
| T11 | 0 | 4.1 | 8.8 | 14.7 | 20.7 | 21.4 | 21.4 | 22.7 | 23.7 |
| T12 | 2.95 | 4.7 | 8.1 | 14.1 | 18.6 | 20.2 | 20.2 | 21.2 | 22 |
| T13 | 0 | 4.9 | 6.7 | 8.7 | 10.8 | 11.95 | 11.95 | 13 | 14 |
| T14 | 3.2 | 9.7 | 13.6 | 16.8 | 19.9 | 20 | 20 | 20.2 | 20.3 |
| T15 | 2.7 | 8.2 | 9.1 | 10.6 | 13.1 | 15.3 | 15.3 | 16.9 | 17.4 |
| SE | 0.03 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.04 | 0.05 |
| CD | 0.112 | 0.146 | 0.135 | 0.118 | 0.132 | 0.16 | 0.199 | 0.116 | 0.158 |

**Table 9 Length: width ratio of leaves of 14 heliconia species and varieties**

| Treatment No. | Length: Width ratio |
|---|---|
| T1 | 2.7 : 1 |
| T2 | 1.9 : 1 |
| T3 | 2.2 : 1 |
| T4 | 2.2 : 1 |
| T5 | 1.8 : 1 |
| T6 | 2 : 1 |
| T7 | 2.3 : 1 |
| T9 | 1.8 : 1 |
| T10 | 2.1 : 1 |
| T11 | 1.9 : 1 |
| T12 | 2.1 : 1 |
| T13 | 3 : 1 |
| T14 | 2 : 1 |
| T15 | 2.4 : 1 |

Among the species and varieties species T5 (*Heliconia curtispatha)* and variety T9 (*Heliconia pogonantha* var. 'Pogonantha') recorded lowest leaf length: width ratio of 1.8:1.

### 4.1.3.8 LEAF AREA

Data pertaining to rate of leaf area of the species and varieties is presented in Table 10 and fig 3.

The species and varieties showed significant difference in leaf area during observation period. The species T3 (*Heliconia mariae)* recorded the highest leaf area with mean values of 22.335 $cm^2$, 529.888 $cm^2$, 91.473 $cm^2$, 791.473 $cm^2$, 838.452 $cm^2$, 893.948 $cm^2$, 955.045 $cm^2$, and 1007.35 $cm^2$, respectively at 60 DAE, 150 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence. At 90 DAE and 120 DAE species T14 (*Heliconia imbricata*) recorded the highest leaf area with mean values of 148.178 $cm^2$, 306.981 $cm^2$, respectively.

Among the species and varieties T7 (*Heliconia bihai* var. 'Granda') registered the lowest leaf area during whole observation period 3.755 $cm^2$, 30.3784 $cm^2$, 53.5737 $cm^2$, 83.4832 $cm^2$, 121.519 $cm^2$, 141.782 $cm^2$, 203.88 $cm^2$, 254.693 $cm^2$ and 289.2 $cm^2$, respectively at 60 DAE, 90 DAE, 120 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence.

### 4.1.3.9 LEAF SHAPE

Among the species and varieties utilized for study two type leaf shapes were observed viz. lanceolate and oblong (Plate 5). Variety T1 (*Heliconia bihai* 'Manova Sunrise'), species T4 (*Heliconia champneiana)*, T9 (*Heliconia pogonantha* var. 'Pogonantha'), T13 (*Heliconia latispatha* var. 'Orange Gyro'), registered the 'lanceolate' leaf shape.

Species T2 *(Heliconia magnifica)*, T3 (*Heliconia mariae)*, T5 (*Heliconia curtispatha)*, T10 (*Heliconia standleryi),* T11 (*Heliconia longa*), T14 (*Heliconia*

**Table 10 Leaf area of 14 Heliconia species and varieties**

| Treatment | Leaf area ($cm^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 7.34 | 101.23 | 157.68 | 209.45 | 274.93 | 327.19 | 379.32 | 458.05 | 484.29 |
| T2 | 7.82 | 33.19 | 96.67 | 220.68 | 335.18 | 405.09 | 453.56 | 510.30 | 615.51 |
| T3 | 22.33 | 108.24 | 258.70 | 529.88 | 791.47 | 838.45 | 893.94 | 955.04 | 1007.35 |
| T4 | 0 | 32.88 | 112.65 | 171.75 | 277.42 | 297.02 | 317.55 | 380.19 | 428.35 |
| T5 | 15.39 | 41.10 | 98.69 | 168.68 | 261.14 | 345.06 | 504.55 | 642.819 | 798.57 |
| T6 | 9.29 | 56.86 | 82.55 | 115.91 | 184.34 | 306.48 | 473.51 | 654.36 | 812.42 |
| T7 | 3.75 | 30.37 | 53.57 | 83.48 | 121.51 | 141.78 | 203.88 | 254.69 | 289.2 |
| T9 | 0 | 45.84 | 112.72 | 280.01 | 463.01 | 563.81 | 629.37 | 697.51 | 736.85 |
| T10 | 12.45 | 82.63 | 174.01 | 299.35 | 504.57 | 826.96 | 851.96 | 832.27 | 958.47 |
| T11 | 0 | 44.56 | 181.23 | 426.76 | 717.38 | 753.01 | 816.02 | 859.16 | 901.20 |
| T12 | 17.712 | 52.51 | 131.12 | 326.84 | 497.58 | 584.91 | 669.92 | 760.75 | 796.56 |
| T13 | 0 | 39.09 | 92.16 | 169.27 | 270.04 | 433.73 | 415.95 | 477.74 | 532.54 |
| T14 | 16.3 | 148.17 | 306.98 | 426.45 | 532.36 | 563.91 | 598.72 | 618.66 | 629.46 |
| T15 | 13.90 | 120.28 | 154.91 | 210.26 | 329.54 | 458.14 | 536.89 | 567.30 | 602.51 |
| SE | 0.57 | 0.79 | 0.79 | 1.13 | 1.38 | 20.25 | 402.23 | 19.89 | 2.11 |
| CD | 1.652 | 2.282 | 2.261 | 3.231 | 3.955 | 57.863 | 1149.06 | 56.833 | 6.048 |

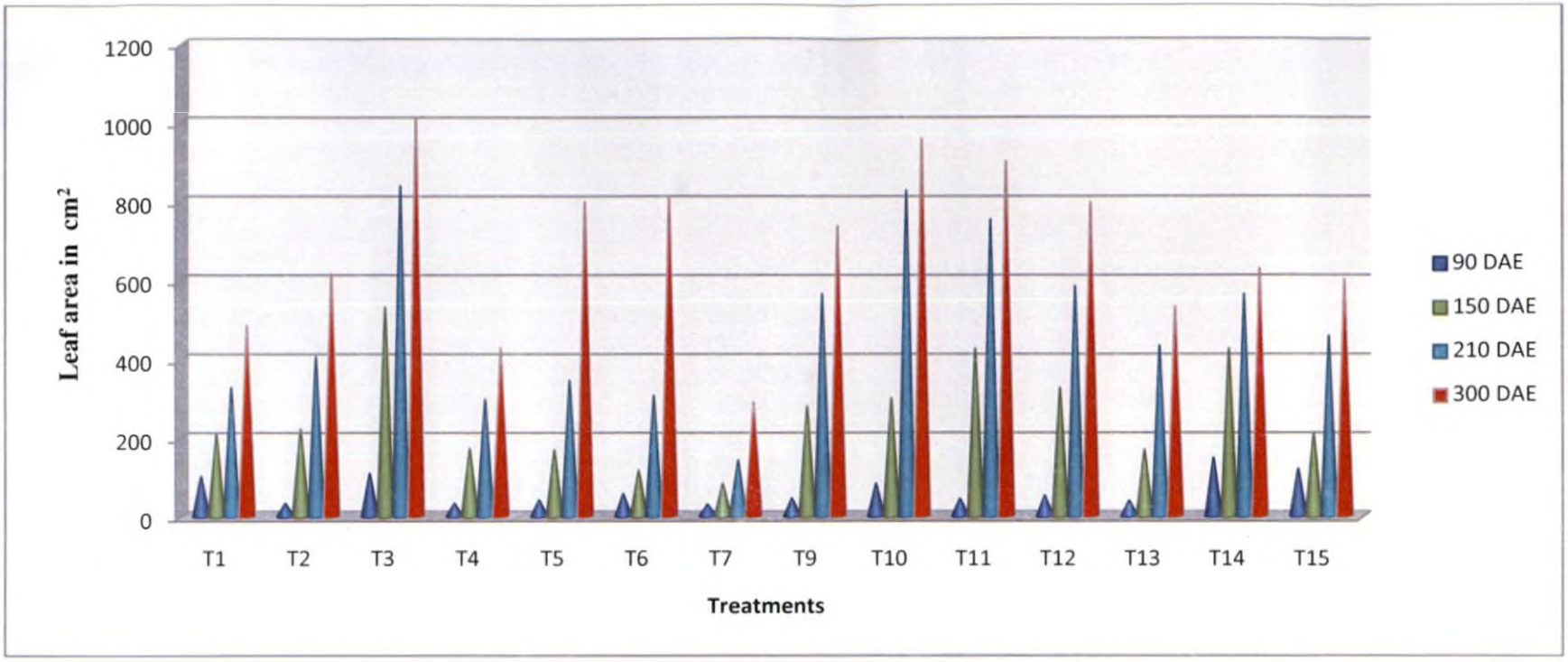



**Fig. 3 Leaf area of 14 Heliconia species and varieties**

Typical 'Lanceolet' shaped leaf T 13.

Typical 'Oblong' shaped leaf T 4

**Plate 5 :- Variation in leaf shape of Heliconia species and varieties**

*imbricata),* T12 (*Heliconia bourgaeana)*, varietiy T6 *(Heliconia lingulata* 'Red tip fan'*)*, T15 (*Heliconia caribaea* var. 'Gold'), registered 'oblong' leaf shape.

#### 4.1.3.10 LEAF MARGIN

Among the species and varieties utilized for study leaf margin variation is observed within the T3 (*Heliconia mariae)*, leaf margin was serrated in one plant while it was plane in other (Plate 6).

#### 4.1.3.11 LEAF TIP

Among the species and varieties utilized for study shape of leaf tip was observed to be 'acute' in all the species and varieties except in T3 (*Heliconia mariae)* i.e. 'obtuse'.

#### 4.1.3.12 LEAF BASE

Among the species and varieties utilized for study T1 (*Heliconia bihai* 'Manova Sunrise'), species T4 (*Heliconia champneiana)*, T9 (*Heliconia pogonantha* var. 'Pogonantha'), T13 (*Heliconia latispatha* var. 'Orange Gyro'), T2 *(Heliconia magnifica),* T3 (*Heliconia mariae)*, T5 (*Heliconia curtispatha)*, registered 'oblique' leaf base (Plate 7).

T10 (*Heliconia standleryi),* T6 *(Heliconia lingulata* 'Red tip fan'*)*, registered 'cordat' leaf base. T15 (*Heliconia caribaea* var. 'Gold') and T7 (*Heliconia bihai* var. 'Granda') registered 'cuneate' leaf base. T11 (*Heliconia longa*) and T12 (*Heliconia bourgaeana)*, registered 'obtuse' leaf base.

In T14 (*Heliconia imbricata)* variation among leaf base structure was observed, both 'oblique' and 'obtuse' shapes were observed.

#### 4.1.3.13 LEAF THICKNESS

Data pertaining to leaf thickness of the species and varieties is presented in Table 12.

The species and varieties showed wide variation in leaf thickness during observation period.

**Table 11 Morphological leaf characters of 14 Heliconia species and varieties**

| Treatment | Leaf tip | Leaf base | Leaf shape |
|---|---|---|---|
| T1 | Acute | Oblique | Lanceolate |
| T2 | Acute | Oblique | Lanceolate |
| T3 | obtuse | Oblique | oblong |
| T4 | Acute | Oblique | Lanceolate |
| T5 | Acute | Oblique | oblong |
| T6 | Acute | Cordet | oblong |
| T7 | Acute | Cuneate | oblong |
| T9 | Acute | Oblique | Lanceolate |
| T10 | Acute | Cordet | oblong |
| T11 | Acute | Obtuse | oblong |
| T12 | Acute | Obtuse | oblong |
| T13 | Acute | Oblique | Lanceolate |
| T14 | Acute | Oblique/Obtuse | oblong |
| T15 | Acute | Cuneate | oblong |

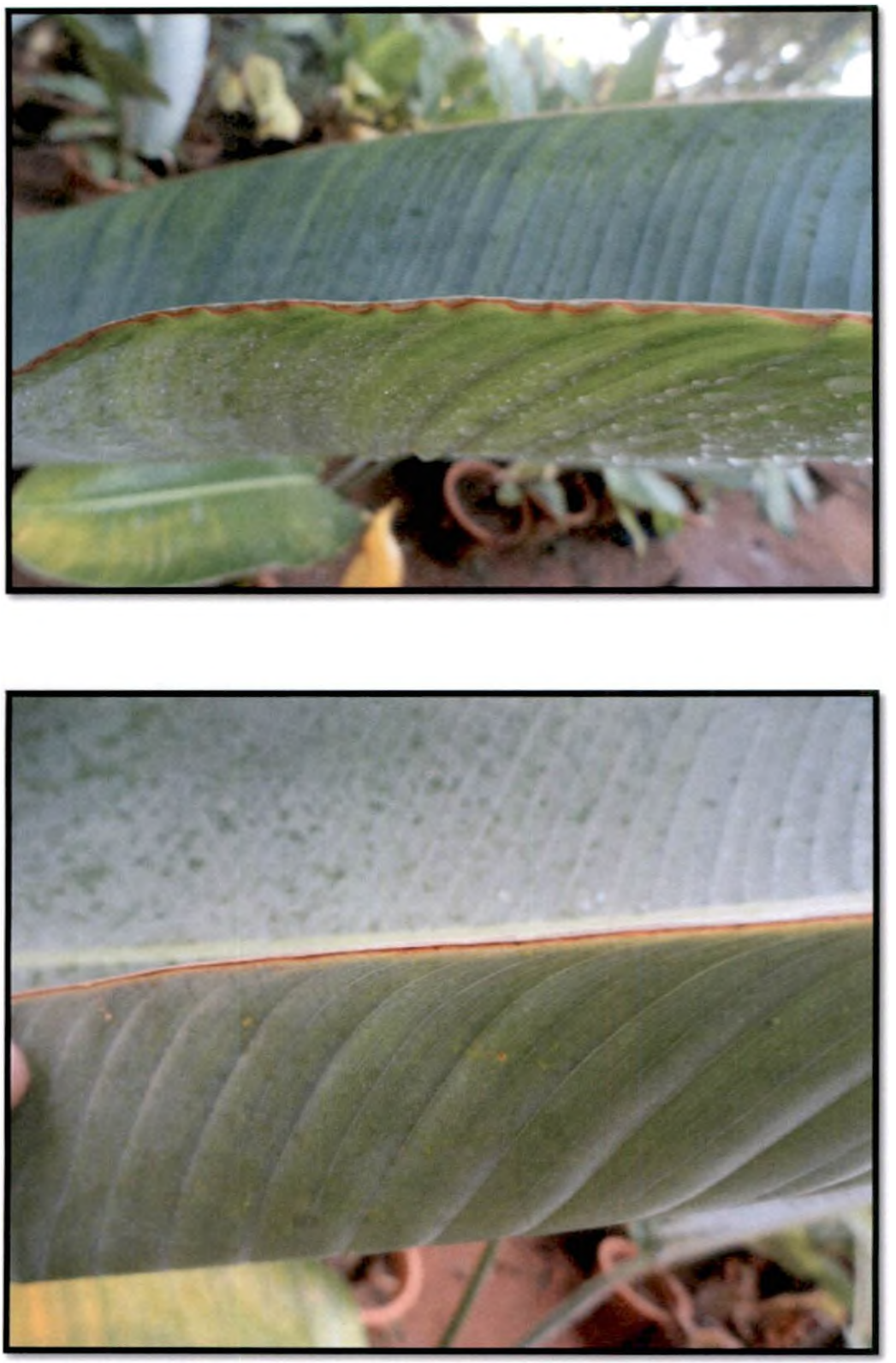


**Plate 6:- Variation in leaf margin structure within *Heliconia mariae* seedlings.**

T1

T2

T3

T4

T5

T6

**Plate 7 :- Variation in leaf base structure of Heliconia species and varieties**

T7

T9

T10

T11

T12

T13

**Plate 7 continued**

T14 a

T14 b

T15

**Plate 7 continued**

**Table 12 Leaf thickness of 14 heliconia species and varieties**

| Treatment No. | Leaf thickness (mm) |
|---|---|
| T1 | 0.17 |
| T2 | 0.14 |
| T3 | 0.18 |
| T4 | 0.17 |
| T5 | 0.16 |
| T6 | 0.14 |
| T7 | 0.15 |
| T9 | 0.19 |
| T10 | 0.17 |
| T11 | 0.15 |
| T12 | 0.08 |
| T13 | 0.09 |
| T14 | 0.2 |
| T15 | 0.16 |

At 300 days after emergence the species T14 (*Heliconia imbricata)* recorded the highest leaf thickness with mean value of 0.20 mm. Followed by T9 (*Heliconia pogonantha* var. 'Pogonantha') and T3 (*Heliconia mariae)*, with mean value of 0.19 mm and 0.18 mm, respectively.

The species T12 (*Heliconia bourgaeana)*, registered lowest leaf thickness with mean value of 0.08 mm. Variety T13 (*Heliconia latispatha* var. 'Orange Gyro'), registered second lowest leaf thickness with mean value of 0.09 mm.

#### 4.1.3.14 NUMBER OF SUCKERS

Data pertaining to number of suckers of the species and varieties is presented in Table 13.

Earlier suckers production (at 60 DAE) was recorded in variety T13 (*Heliconia latispatha* var. 'Orange Gyro'), with mean value of 1 sucker per plant. The species T3 (*Heliconia mariae)* and T10 (*Heliconia standleryi),* registered late sucker production, starting at 270 DAE with mean value of 1 sucker per plant.

At 300 days after emergence the variety T13 (*Heliconia latispatha* var. 'Orange Gyro') and T15 (*Heliconia caribaea* var. 'Gold') registered highest mean value for number of suckers per plant i.e. 3 sucker per plant.

### 4.1.4 PHYSIOLOGICAL CHARACTERS

#### 4.1.4.1 LEAF SHEATH COLOUR

Data pertaining to sheath colour of the species and varieties are presented in Table 14 and Plate 8.

The species and varieties showed significant difference in leaf sheath colour. In T1 (*Heliconia bihai* 'Manova Sunrise'), colour of leaf sheath was green with couple of red spots. In T2 *(Heliconia magnifica),* greenish brown coloured leaf sheath was observed. In T3 (*Heliconia mariae)*, colour of leaf sheath was green with reddish tinge. In species T4 (*Heliconia champneiana)*, colour of leaf sheath was green. In T5 (*Heliconia curtispatha)* greenish brown coloured leaf sheath was observed.

**Table 13 Number of Suckers of 14 Heliconia species and varieties**

| Treatment | Number of Suckers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 60 DAE | 90 DAE | 120 DAE | 150 DAE | 180 DAE | 210 DAE | 240 DAE | 270 DAE | 300 DAE |
| T1 | 0 | 0 | 1 | 1 | 1 | 2 | 2.5 | 2.5 | 2.5 |
| T2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| T3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| T4 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| T5 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| T6 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 |
| T7 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| T9 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| T10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| T11 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| T12 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| T13 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| T14 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 |
| T15 | 0 | 0 | 1 | 2 | 2 | 3 | 3 | 3 | 3 |

T1

T2

T3

T4

T5

T6

**Plate 8:- Variation in leaf sheath colour of Heliconia species and varieties**

T7

T9

T10

T11

T12

T13

**Plate 8 continued**

T14

T15

Plate 8 continued

In T6 *(Heliconia lingulata* 'Red tip fan'*)*, leaf sheath was intensely red pigented. In T7 (*Heliconia bihai* var. 'Granda'), deep green colourd leaf sheath was observed. In T9 (*Heliconia pogonantha* var. 'Pogonantha'), mosaic pattern of green and brown colour was seen. In T10 (*Heliconia standleryi),* leaf sheath was green with brown tinge. T11 (*Heliconia longa*), it was green with minor traces of brown colour. T12 (*Heliconia bourgaeana)*, was observed to have green with medium tinge of red pigentation. In T13 (*Heliconia latispatha* var. 'Orange Gyro'), green leaf sheath with brown circular patches was observed. In T14 (*Heliconia imbricata)* leaf sheath was predominantly green with brown patches. T15 (*Heliconia caribaea* var. 'Gold'), green leaf sheath with red strakes was observed.

#### 4.1.4.12 PRESENCE OF POWDERY COATING

Among the species and varieties utilized for study presence of powdery coating on back surface of leaves was observed in T3 (*Heliconia mariae)*, T5 (*Heliconia curtispatha)* and T9 (*Heliconia pogonantha* var. 'Pogonantha'). In T11 (*Heliconia longa*). Along with back surface of leaves, powdery coating was observed on leaf sheath of young as well as on older plants.

#### 4.1.4.13 LEAF COLOUR

Data pertaining to leaf colour of the species and varieties are presented in Table 14.

Species and varieties utilized for study showed significant difference in leaf colour. They are categorized in three classes of 'light', 'green' and 'dark' coloure. T2 *(Heliconia magnifica),* T10 (*Heliconia standleryi),* T13 (*Heliconia latispatha* var. 'Orange Gyro'), and T15 (*Heliconia caribaea* var. 'Gold') observed to have 'light' coloured leaves.

In T1 (*Heliconia bihai* 'Manova Sunrise'), T3 (*Heliconia mariae)*, T6 *(Heliconia lingulata* 'Red tip fan'*)*, T12 (*Heliconia bourgaeana)*, leaf colour was 'green'.

In T4 (*Heliconia champneiana)*, T5 (*Heliconia curtispatha),* T7 (*Heliconia bihai* var. 'Granda'), T11 (*Heliconia longa*) and T14 (*Heliconia imbricata)* leaf colour was 'dark'.

#### 4.1.4.14 MIDRIB COLOUR

Data pertaining to midrib colour of the species and varieties are presented in Table 14 and Plate 9.

The species and varieties showed significant difference in leaf midrib colour. In T1 (*Heliconia bihai* 'Manova Sunrise'), colour of midrib was green. In T2 *(Heliconia magnifica),* dark green coloured midrib was observed. In T3 (*Heliconia mariae)*, colour of midrib was green with gray tinge. In species T4 (*Heliconia champneiana)*, colour of midrib was green. In T5 (*Heliconia curtispatha)* dark green coloured midrib with red edges was observed. In T6 *(Heliconia lingulata* 'Red tip fan'*)*, midrib was green with red spots. In T7 (*Heliconia bihai* var. 'Granda'), deep green colourd midrib was observed.

In T9 (*Heliconia pogonantha* var. 'Pogonantha'), bottom portion of midrib was having red edge and radish green middle portion (Plate 4.' T9 a') the top portion was green coloured (Plate 4. 'T9 b'). In T10 (*Heliconia standleryi),* midrib was green coloured. T11 (*Heliconia longa*), it was deep green colourd. T12 (*Heliconia bourgaeana)*, was also observed to deep green colour. In T13 (*Heliconia latispatha* var. 'Orange Gyro'), green midrib was observed. In T14 (*Heliconia imbricata)* midrib was predominantly red in colour. In T15 (*Heliconia caribaea* var. 'Gold'), green midrib was observed.

#### 4.1.4.15 PIGENT CONTENT

Data pertaining to pigent content of the species and varieties is presented in Table 14 and Fig 4.

There was significant difference in the pigent content between species and varieties utilized for study. The variety T1 (*Heliconia bihai* 'Manova Sunrise'), recorded the highest leaf chlorophyll-a content of 1.529 mg/g of leaf sample. Followed by T5 (*Heliconia curtispatha ),* with mean value of 1.30783 mg/g of

T1

T2

T3

T4

T5

T6

T7

T9 a

T9 b

**Plate 9:- Variation in midrib colour of Heliconia species and**

T10

T11

T12

T13

T14

T15

**Plate 9 continued**

**Table 14 Physiological characters of 14 Heliconia species and varieties**

| Treatment | Pigment characters | | | | | |
|---|---|---|---|---|---|---|
| | Chlorophyll A (mg/g of sample) | Chlorophyll B (mg/g of sample) | Total Chlorophyll (mg/g of sample) | Carotenoid (mg/g of sample) | Midrib colour | Leaf colour |
| T1 | 1.52 | 0.56 | 1.70 | 0.095 | Green | Green |
| T2 | 0.77 | 0.29 | 0.96 | 0.058 | Dark green | Light |
| T3 | 0.78 | 0.32 | 1.11 | 0.080 | Green with gray ting | Green |
| T4 | 1.08 | 0.52 | 1.60 | 0.095 | Green | Dark |
| T5 | 1.30 | 0.74 | 2.04 | 0.099 | Dark green | Dark |
| T6 | 0.86 | 0.62 | 1.48 | 0.088 | Green with red spots | Green |
| T7 | 1.08 | 0.59 | 1.68 | 0.098 | Deep green | Dark |
| T9 | 0.77 | 0.30 | 1.08 | 0.065 | Red and Green | Green |
| T10 | 0.73 | 0.27 | 1.00 | 0.065 | Green | Light |
| T11 | 1.10 | 0.54 | 1.65 | 0.090 | Deep green | Dark |
| T12 | 1.01 | 0.43 | 1.45 | 0.087 | Deep green | Green |
| T13 | 0.76 | 0.30 | 1.06 | 0.076 | Green | Light |
| T14 | 0.77 | 0.37 | 1.15 | 0.063 | Red | Dark |
| T15 | 0.38 | 0.14 | 0.53 | 0.035 | Green | Light |
| SE | 0.16 | 0.06 | 0.19 | 0.009 | | |
| CD | 0.47 | 0.19 | 0.54 | 0.025 | | |

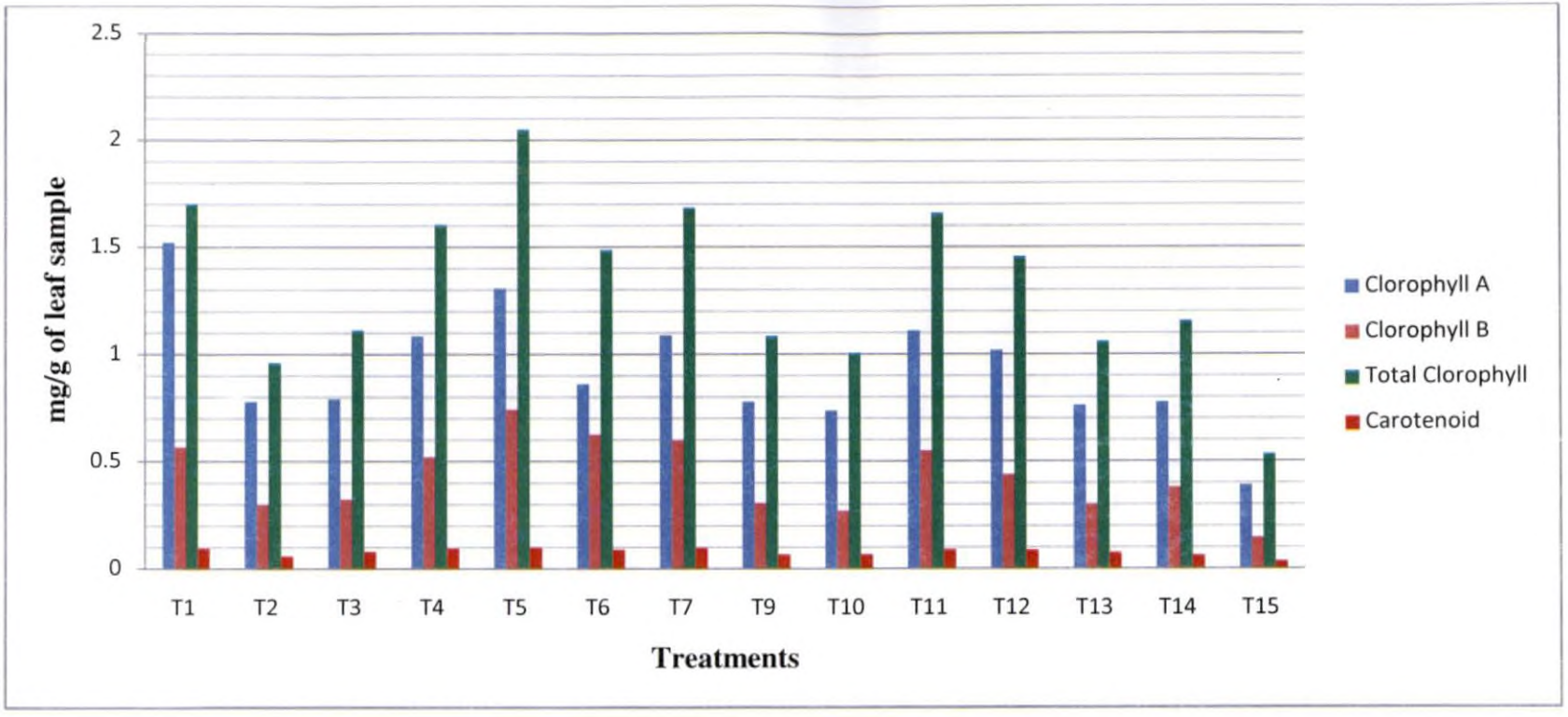



**Fig. 4 Pigment content of 14 heliconia species and varieties**

leaf sample. Chlorophyll-b, total chlorophyll and carotenoid content was higher in T5 (*Heliconia curtispatha* ), 0.74212 mg/g, 2.049 mg/g and 0.09944 mg/g of leaf sample respectively.

The variety T15 (*Heliconia caribaea* var. 'Gold') registered lowest mean values for all the pigents i.e. chlorophyll-a (0.388 mg/g), Chlorophyll-b (0.146 mg/g), total chlorophyll (0.534 mg/g) and carotenoids (0.035 mg/g) which appeared to be most 'light' coloured variety among the species and varieties utilized for study.

### 4.1.5 VARIABILITY STUDIES

The phenotypic and genotypic variance and the genotypic and phenotypic coefficient of variation (GCV and PCV) are presented in Table 15 and Fig 5.

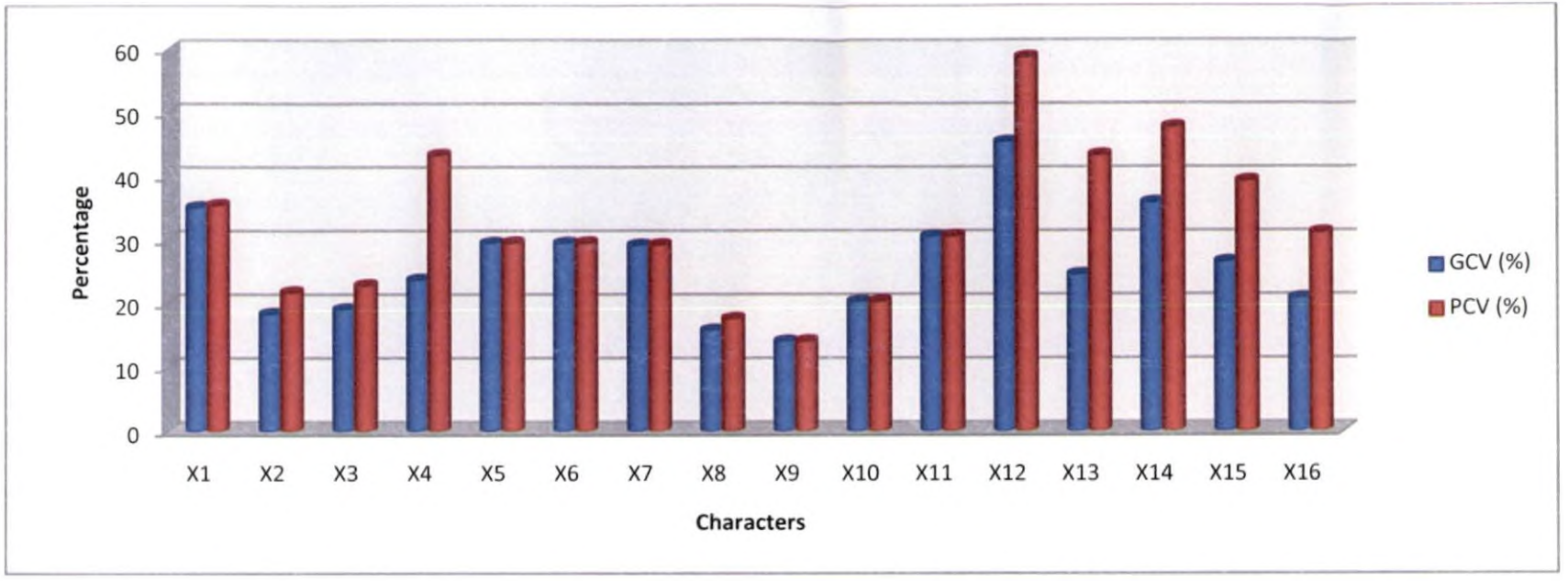
The number of suckers (45.42 %) showed highest value for GCV, followed by chlorophyll-b (35.86%), seed weight (35.16 %), leaf area (30.56 %), plant height (29.55 %) and rate of shoot elongation (29.55 %).The GCV was lowest for length of leaf (14.1%).

The highest PCV was observed for number of suckers (58.7 %) followed by chlorophyll-b (47.71 %), percent germination (43.33 %). PCV was lowest for length of leaf (14.1 %).

The difference between phenotypic and genotypic coefficient of variation (GCV and PCV) was lowest for length of leaf, plant height, rate of shoot elongation (0 %) succeeded by leaf width and leaf area (0.01 %). The difference between phenotypic and genotypic coefficient of variation was relatively higher for percent germination (19.56 %).

### 4.1.6 ESTIMATE OF HERITABILITY ($H^2$) AND GENETIC ADVANCE (GA)

The estimate of Heritability ($H^2$) and Genetic Advance (GA) are presented in Table 15 and Fig. 6.




X1 Seed weight X2 Seed length X3 Seed weight X4 Percentage of germination

X5 Plant height X6 Rate of shoot elongation X7 Shoot girth X8 Number of leaves

X9 Length of leaf X10 Width of leaf X11 Leaf area X12 Number of suckers

X13 Chlorophyll a X14 Chlorophyll b X15 Total chlorophyll X16 Carotenoids

**Fig. 5 Coefficient of variation of characters of 14 heliconia species and varieties.**

**Table 15 Estimates of genetic parameters for various characters in heliconia species and varieties.**

| SR. No. | Character | Range | Mean | GCV (%) | PCV (%) | Heritability (%) | Genetic advance (as percentage of mean) |
|---|---|---|---|---|---|---|---|
| 1 | Seed wt (g) | 5.18-15.03 | 10.39 | 35.16 | 35.5 | 98.05 | 71.72 |
| 2 | Seed length (cm) | 0.58-1.175 | 0.88 | 18.39 | 21.75 | 71.5 | 32.04 |
| 3 | Seed width (cm) | 0.31-0.74 | 0.52 | 19.11 | 22.84 | 70.01 | 32.95 |
| 4 | Percentage of germination | 0-100 | 63.88 | 23.77 | 43.33 | 30.1 | 26.86 |
| 5 | Plant height (cm) | 46.3-202.6 | 133.86 | 29.55 | 29.55 | 99.99 | 60.88 |
| 6 | Rate of shoot elongation cm/ month | 7.63-20.26 | 13.38 | 29.55 | 29.55 | 99.99 | 60.88 |
| 7 | Shoot girth (cm) | 6.8-18.6 | 11.37 | 29.22 | 29.24 | 99.86 | 60.17 |
| 8 | Number of leaves | 6.0-10.0 | 7.5 | 15.86 | 17.63 | 80.95 | 29.41 |
| 9 | Length Of leaf (cm) | 30.2-54.1 | 43.85 | 14.1 | 14.1 | 99.97 | 29.04 |
| 10 | Width Of leaf (cm) | 12.6-24.5 | 20.16 | 20.32 | 20.33 | 99.93 | 41.85 |
| 11 | Leaf area ($cm^2$) | 289.2-1007.35 | 685.23 | 30.56 | 30.57 | 99.96 | 62.95 |
| 12 | Number of Sucker | 1.0-3.0 | 1.6 | 45.42 | 58.7 | 59.88 | 72.4 |
| 13 | Clorophyll A (mg/g) | 0.388-1.529 | 0.92 | 24.61 | 43.3 | 32.31 | 28.82 |
| 14 | Clorophyll B (mg/g) | 0.146-0.742 | 0.43 | 35.86 | 47.71 | 56.49 | 55.52 |
| 15 | Total Clorophyll (mg/g) | 0.534-2.049 | 1.32 | 26.58 | 39.25 | 45.88 | 37.09 |
| 16 | Carotenoid (mg/g) | 0.035-0.099 | 0.078 | 20.82 | 31.11 | 44.81 | 28.72 |

Heritability value were classified as per Robinson (1965) as low (less than 30 per cent), medium (30-60 per cent) and high (greater than 60 per cent).Accordingly the characters plant height (99.99 %), rate of shoot elongation(99.99 %), length of leaf (99.97 %), leaf area (99.96 %), width of leaf (99.93 %), shoot girth (99.86 %), seed weight (98.05 %), number of leaves (80.95 %), seed length (71.5 %) and seed length (70.01 %) recorded higher heritability values. The lower heritability value was recorded for percentage of germination (30.1%).

Expected genetic advance as percentage of mean was used for comparison among characters. Highest genetic advance was observed for number of suckers (72.4) followed by seed weight (71.72). The percentage of germination exhibited the lowest value of genetic advance (26.86).

### 4.1.7 CORRELATION ANALYSIS

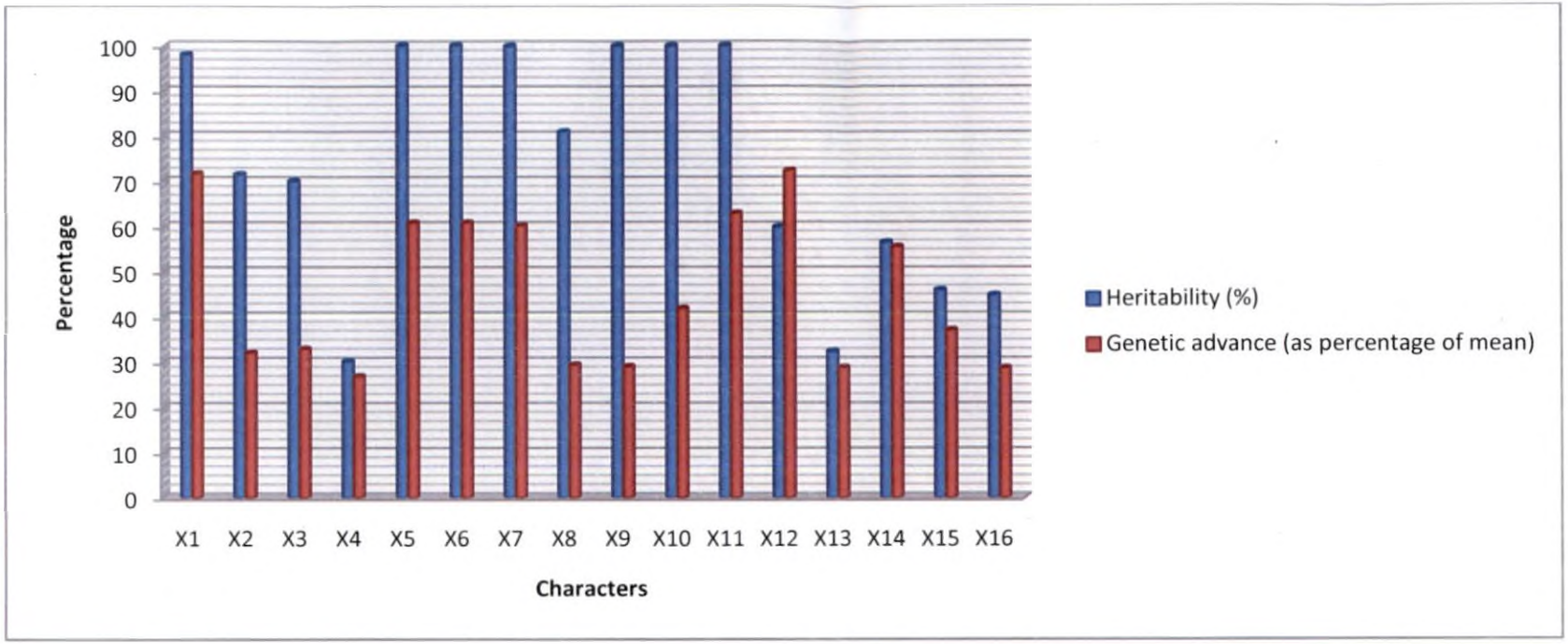
The phenotypic, genotypic and environmental correlations were presented in Table 16, 17, 18 and fig 7, 8, 9 respectively.

#### 4.1.6.1PHENOTYPIC CORRELATION

The character seed weight was found to have significant positive correlation with seed length, seed width. It had significant negative correlation with leaf length. The character seed length was found to have significant positive correlation with seed width, plant height, shoot girth, leaf length, leaf width and leaf area. The character seed width had significant negative correlation with leaf length and leaf area.

The character percentage of germination was found to have significant positive correlation with plant height, rate of shoot elongation, leaf length, leaf width and leaf area.

The character plant height was found to have significant positive correlation with rate of shoot elongation, shoot girth, leaf length, leaf width and leaf area. It had significant negative correlation with chlorophyll-b.




X1 Seed weight X2 Seed length X3 Seed weight X4 Percentage of germination

X5 Plant height X6 Rate of shoot elongation X7 Shoot girth X8 Number of leaves

X9 Length of leaf X10 Width of leaf X11 Leaf area X12 Number of suckers

X13 Chlorophyll a X14 Chlorophyll b X15 Total chlorophyll X16 Carotenoids

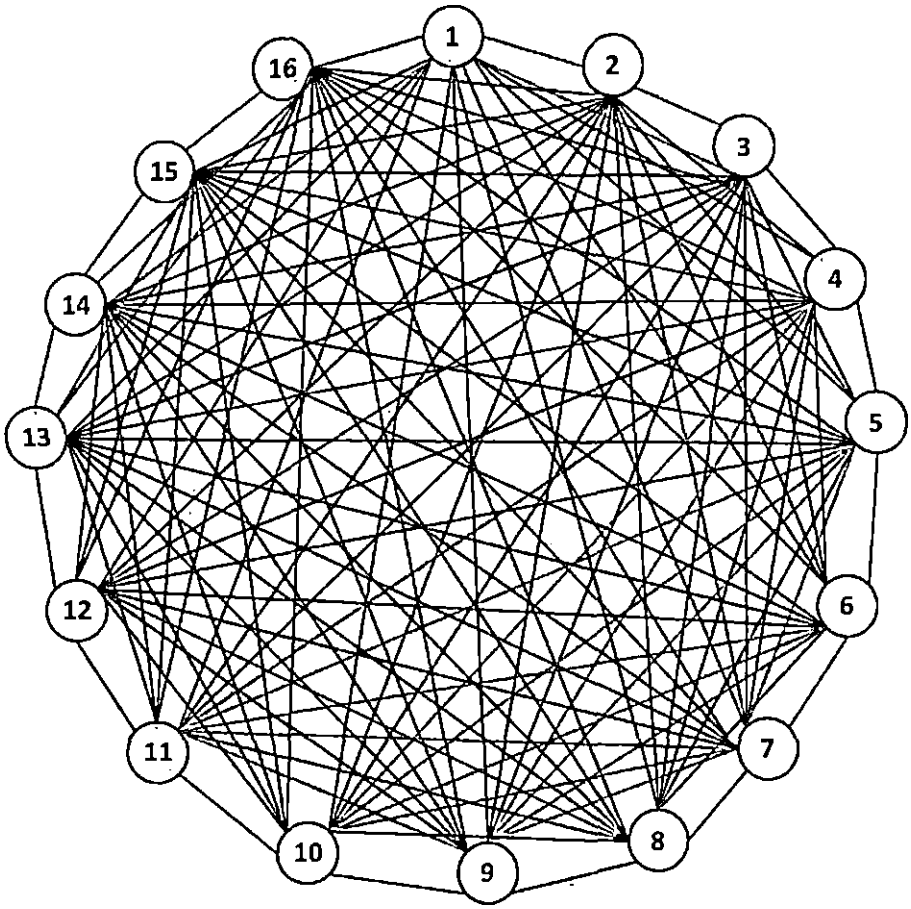
**Fig. 6 Heritability and Genetic Advance of characters of 14 heliconia species and varieties**

**Table 16: Phenotypic correlation coefficient for the characters of 14 Heliconia species and varieties**

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | 1 | | | | | | | | | | | | | | | |
| X2 | 0.7848** | 1 | | | | | | | | | | | | | | |
| X3 | 0.7167** | 0.5049** | 1 | | | | | | | | | | | | | |
| X4 | -0.1566 | -0.0016 | -0.243 | 1 | | | | | | | | | | | | |
| X5 | -0.291 | -0.1939 | -0.2139 | 0.4839** | 1 | | | | | | | | | | | |
| X6 | -0.291 | -0.1939 | -0.2139 | 0.4839** | 1 | 1 | | | | | | | | | | |
| X7 | -0.2878 | -0.2405 | -0.2177 | 0.196 | 0.657** | 0.657** | 1 | | | | | | | | | |
| X8 | 0.2941 | 0.1919 | 0.1522 | 0.1038 | -0.1591 | -0.1591 | -0.1327 | 1 | | | | | | | | |
| X9 | -0.3634* | -0.1404 | -0.3953** | 0.4857** | 0.8317** | 0.8317** | 0.4955** | -0.1821 | 1 | | | | | | | |
| X10 | -0.1434 | 0.058 | -0.2049 | 0.4534** | 0.8042** | 0.8042** | 0.5895** | -0.3415* | 0.74** | 1 | | | | | | |
| X11 | -0.2626 | -0.0229 | -0.3209* | 0.5124** | 0.86** | 0.86** | 0.616** | -0.2509 | 0.8962** | 0.9539** | 1 | | | | | |
| X12 | 0.1009 | -0.0787 | 0.1067 | -0.1186 | -0.243 | -0.243 | -0.1424 | 0.2928 | -0.1496 | -0.530** | -0.4278** | 1 | | | | |
| X13 | -0.088 | 0.0084 | -0.0318 | 0.236 | -0.29 | -0.29 | -0.273 | -0.0537 | -0.1736 | -0.1158 | -0.1404 | -0.072 | 1 | | | |
| X14 | 0.0346* | 0.1071 | -0.0375 | 0.0901 | -0.3167* | -0.3167* | -0.1448 | -0.0916 | -0.2335 | -0.035 | -0.1064 | -0.1299 | 0.7488** | 1 | | |
| X15 | -0.0014 | 0.0993 | -0.0182 | 0.1662 | -0.2759 | -0.2759 | -0.2202 | -0.0366* | -0.2001 | -0.0336* | -0.09 | -0.1786 | 0.8324** | 0.9525** | 1 | |
| X16 | -0.1441 | -0.0039 | -0.0978 | 0.1592 | -0.2759 | -0.2759 | -0.2133 | -0.034 | -0.1338 | -0.0915 | -0.0878 | -0.1704 | 0.7668** | 0.8547** | 0.9285** | 1 |

* : significant at 5%
** : significant at 1 %

X1 Seed wt
X2 Seed length
X3 Seed width
X4 Percentage of germination
X5 Plant height
X6 Rate of shoot elongation cm/ month
X7 Shoot girth
X8 Number of leaves
X9 Length of leaf
X10 Width of leaf
X11 leaf area
X12 Number of Sucker
X13 Clorophyll A
X14 Clorophyll B
X15 Total Clorophyll
X16 Carotenoid




| | | | |
|---|---|---|---|
| X1 | Seed wt | X9 | Length of leaf |
| X2 | Seed length | X10 | Width of leaf |
| X3 | Seed width | X11 | leaf area |
| X4 | Percentage of germination | X12 | Number of Sucker |
| X5 | Plant height | X13 | Clorophyll A |
| X6 | Rate of shoot elongation cm/ month | X14 | Clorophyll B |
| X7 | Shoot girth | X15 | Total Clorophyll |
| X8 | Number of leaves | X16 | Carotenoid |

**Fig 7: Phenotypic correlation coefficient among the characters in Heliconia**

The character rate of shoot elongation was found to have significant positive correlation with shoot girth, leaf length, leaf width and leaf area. It had significant negative correlation with chlorophyll-b.

The character shoot girth was found to have significant positive correlation with leaf length, leaf width and leaf area.

The character number of leaves had significant negative correlation with leaf width.

The character leaf length was found to have significant positive correlation with leaf width and leaf area.

The character leaf width was found to have significant positive correlation with leaf area. It had significant negative correlation with number of suckers.

The character leaf area had significant negative correlation with number of suckers.

The character chlorophyll-a, was found to have significant positive correlation with chlorophyll-b, total chlorophyll and carotenoids. The character chlorophyll-b was found to have significant positive correlation with total chlorophyll and carotenoids. Total chlorophyll was found to have significant positive correlation with carotenoids

### 4.1.6.2 GENOTYPIC CORRELATION

The character seed weight was found to have significant positive correlation with seed length, seed width and number of leaves. It had significant negative correlation with length of leaf.

The character seed length was found to have significant positive correlation with seed width.

The character seed width had significant negative correlation with percentage of germination, leaf length, leaf area and carotenoid content.

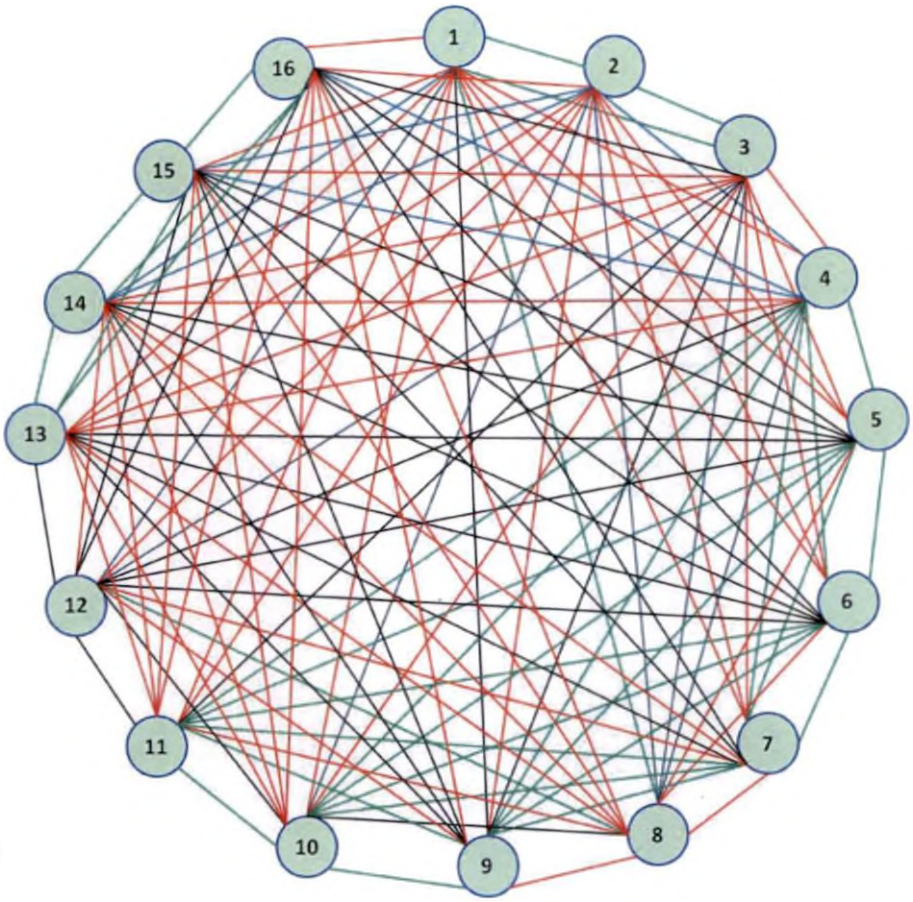
The character percentage of germination was found to have significant positive correlation with plant height, rate of shoot elongation, shoot girth, leaf

**Table 17 : Genotypic correlation coefficient for the characters of 14 Heliconia species and varieties**

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | 1 | | | | | | | | | | | | | | | |
| X2 | 0.9207** | 1 | | | | | | | | | | | | | | |
| X3 | 0.886** | 0.6268** | 1 | | | | | | | | | | | | | |
| X4 | -0.2831 | 0.0151 | -0.5525 | 1 | | | | | | | | | | | | |
| X5 | -0.2942 | -0.23 | -0.2559 | 0.8832** | 1 | | | | | | | | | | | |
| X6 | -0.2942 | -0.23 | -0.2559 | 0.8832** | 1** | 1 | | | | | | | | | | |
| X7 | -0.2905 | -0.2832 | -0.2606 | 0.3546* | 0.6575** | 0.6575** | 1 | | | | | | | | | |
| X8 | 0.3222* | 0.2082 | 0.238 | 0.1284 | -0.177 | -0.177 | -0.1452 | 1 | | | | | | | | |
| X9 | -0.3677* | -0.1671 | -0.4736** | 0.8799** | 0.8319** | 0.8319** | 0.4959** | -0.205 | 1 | | | | | | | |
| X10 | -0.1446 | 0.0705 | -0.2448 | 0.8292** | 0.8046** | 0.8046** | 0.5902** | -0.3812* | 0.7404** | 1 | | | | | | |
| X11 | -0.2654 | -0.0262 | -0.3832* | 0.9346** | 0.8603** | 0.8603** | 0.6166** | -0.2808 | 0.8964** | 0.9539** | 1 | | | | | |
| X12 | 0.1313 | -0.203 | 0.1161 | -0.6135** | -0.3142* | -0.3142* | -0.1841 | 0.4205** | -0.1928 | -0.6847** | -0.5513** | 1 | | | | |
| X13 | -0.1351 | -0.0193 | -0.2134 | -0.1808 | -0.5091** | -0.5091** | -0.4842** | -0.2524 | -0.312* | -0.2017 | -0.2483 | -0.3059* | 1 | | | |
| X14 | 0.0134 | 0.0654 | -0.1563 | -0.0346 | -0.4218** | -0.4218** | -0.1938 | -0.1813 | -0.3143* | -0.0436 | -0.1412 | -0.2289 | 0.909** | 1 | | |
| X15 | -0.0309 | 0.0684 | -0.1895 | 0.0981 | -0.4075** | -0.4075** | -0.3294* | -0.1759 | -0.3012* | -0.0469 | -0.1336 | -0.3637* | 0.9846** | 0.9772** | 1 | |
| X16 | -0.2428 | -0.1011 | -0.3761* | 0.13 | -0.4119** | -0.4118** | -0.3217* | -0.1738 | -0.2058 | -0.1353 | -0.1327 | -0.332* | 0.9478** | 0.9039** | 0.9421** | 1 |

* : significant at 5%
** : significant at 1 %

X1 Seed wt
X2 Seed length
X3 Seed width
X4 Percentage of germination
X5 Plant height
X6 Rate of shoot elongation cm/ month
X7 Shoot girth
X8 Number of leaves
X9 Length of leaf
X10 Width of leaf
X11 leaf area
X12 Number of Sucker
X13 Clorophyll A
X14 Clorophyll B
X15 Total Clorophyll
X16 Carotenoid




| | | | |
|---|---|---|---|
| X1 | Seed wt | X9 | Length of leaf |
| X2 | Seed length | X10 | Width of leaf |
| X3 | Seed width | X11 | leaf area |
| X4 | Percentage of germination | X12 | Number of Sucker |
| X5 | Plant height | X13 | Clorophyll A |
| X6 | Rate of shoot elongation cm/ month | X14 | Clorophyll B |
| X7 | Shoot girth | X15 | Total Clorophyll |
| X8 | Number of leaves | X16 | Carotenoid |

**Fig 8: Genotypic correlation coefficient among the characters in Heliconia**

length, leaf width and leaf area. It had significant negative correlation with number of suckers.

The character plant height was found to have significant positive correlation with rate of shoot elongation, shoot girth, leaf length, leaf width and leaf area. It had significant negative correlation with number of suckers, chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoid content.

The character rate of shoot elongation was found to have significant positive correlation with shoot girth, leaf length, leaf width and leaf area. It had significant negative correlation with number of suckers, chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoid content.

The character shoot girth was found to have significant positive correlation with leaf length, leaf width and leaf area. It had significant negative correlation with chlorophyll-a, total chlorophyll and carotenoid content.

The character number of leaves was found to have significant positive correlation with number of suckers. It had significant negative correlation with leaf width.

The character leaf width was found to have significant positive correlation with leaf area. It had significant negative correlation with number of suckers.

The character leaf length was found to have significant positive correlation with leaf width and leaf area. It had significant negative correlation with chlorophyll-a, total chlorophyll.

The character leaf width was found to have significant positive correlation with leaf area. It had significant negative correlation with number of suckers.

The character leaf area had significant negative correlation with number of suckers.

The character number of suckers had significant negative correlation with chlorophyll-a and total chlorophyll.

The character chlorophyll-a, was found to have significant positive correlation with chlorophyll-b, total chlorophyll and carotenoids. The character chlorophyll-b was found to have significant positive correlation with total

chlorophyll and carotenoids. Total chlorophyll was found to have significant positive correlation with carotenoids.

#### 4.1.6.3 ENVIRONMENTAL CORRELATION

Low values of correlation coefficients due to environmental effect were obtained for most of the characters studied.

The plant height has shown significant positive correlation with rate of shoot elongation. It had significant negative correlation with leaf area.

The character leaf length was found to have significant positive correlation with leaf area, total chlorophyll and carotenoids.

The character leaf width was found to have significant positive correlation with leaf area.

The character chlorophyll-a, was found to have significant positive correlation with chlorophyll-b, total chlorophyll and carotenoids. The character chlorophyll-b was found to have significant positive correlation with total chlorophyll and carotenoids. Total chlorophyll was found to have significant positive correlation with carotenoids.

### 4.1.8 GENETIC DIVERGENCE ANALYSIS

Following Mahalanoblis statistic, the 14 species and varieties of heliconia were subjected to $D^2$ analysis based on eight characters, viz., seed weight, percentage of germination, plant height, number of leaves, leaf area, number of suckers, chlorophyll-a and total chlorophyll.

The 14 accessions were grouped into five clusters. The clustering pattern is furnished in Table 19.

Cluster I was the largest with five accessions, closely followed by cluster II with four genotypes. Cluster III had three genotypes. Cluster V and cluster IV had one accession each.

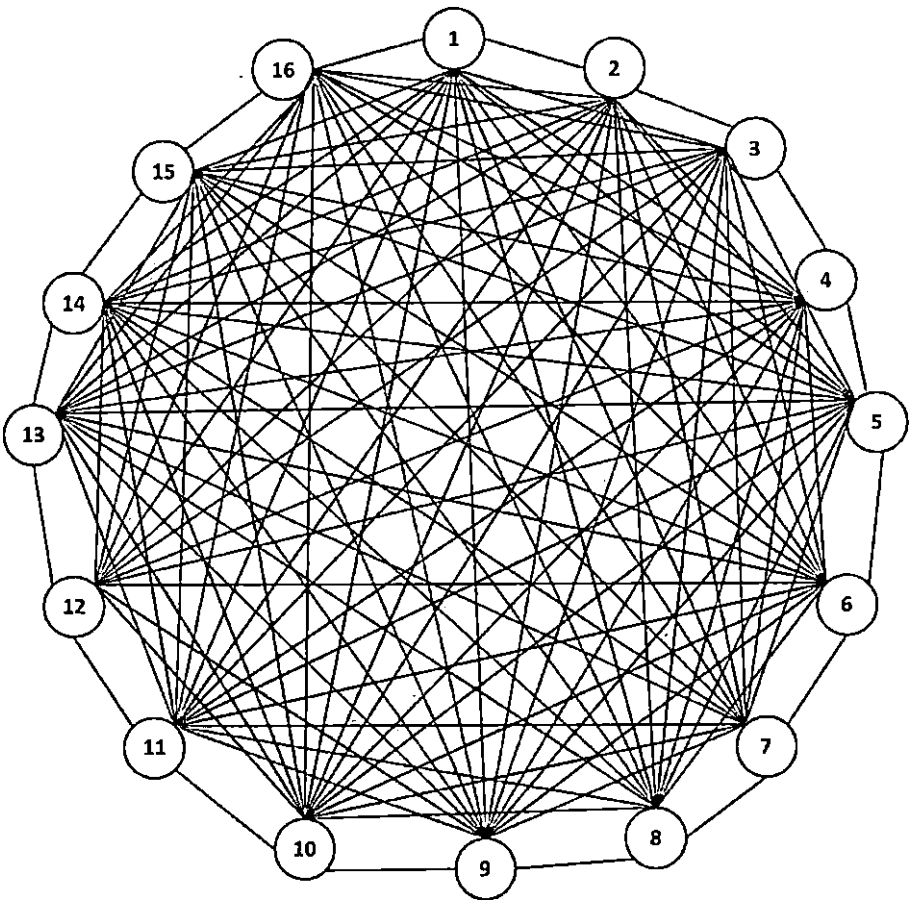
**Table 18 : Environmental correlation coefficient for the characters of 14 Heliconia species and varieties**

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | 1 | | | | | | | | | | | | | | | |
| X2 | 0.187 | 1 | | | | | | | | | | | | | | |
| X3 | -0.2267 | 0.21 | 1 | | | | | | | | | | | | | |
| X4 | -0.0239 | -0.0193 | 0.0231 | 1 | | | | | | | | | | | | |
| X5 | 0.1683 | 0.0863 | 0.0321 | -0.0586 | 1 | | | | | | | | | | | |
| X6 | 0.1659 | 0.0867 | 0.0322 | -0.0588 | 0.9991** | 1 | | | | | | | | | | |
| X7 | -0.0735 | -0.0616 | 0.0088 | 0.0519 | 0.0033 | 0.0163 | 1 | | | | | | | | | |
| X8 | 0.1159 | 0.1437 | -0.1128 | 0.1108 | 0.0188 | 0.0174 | -0.1335 | 1 | | | | | | | | |
| X9 | 0.2412 | 0.0993 | 0.0902 | 0.2141 | -0.0614 | -0.0768 | 0.0359 | -0.205 | 1 | | | | | | | |
| X10 | -0.0747 | -0.1102 | -0.0096 | -0.0577 | -0.2901 | -0.2677 | -0.1053 | 0.1119 | 0.0641 | 1 | | | | | | |
| X11 | 0.033 | -0.0677 | -0.0259 | -0.0141 | -0.3651 | -0.3655* | -0.0642 | 0.1979 | 0.3967** | 0.9376** | 1 | | | | | |
| X12 | 0.003 | 0.16 | 0.0908 | 0.2677 | 0.0087 | 0.0086 | 0 | 0 | -0.0382 | -0.0718 | -0.0986 | 1 | | | | |
| X13 | -0.1039 | 0.0402 | 0.1547 | 0.425 | -0.0653 | -0.0655 | 0.0675 | 0.2098 | 0.2629 | -0.0522 | 0.0449 | 0.1201 | 1 | | | |
| X14 | 0.2677 | 0.1862 | 0.1683 | 0.1892 | 0.0478 | 0.048 | 0.0325 | 0.1075 | 0.2402 | -0.1265 | -0.0248 | 0.0076 | 0.6642** | 1 | | |
| X15 | 0.1885 | 0.1531 | 0.2212 | 0.2109 | 0.0085 | 0.0082 | 0.101 | 0.2197 | 0.3126* | -0.0901 | 0.0301 | 0.0258 | 0.749** | 0.9378** | 1 | |
| X16 | 0.163 | 0.1345 | 0.2774 | 0.1794 | -0.0311 | -0.0314 | 0.0662 | 0.2197 | 0.3131* | -0.045 | 0.0641 | 0.0033 | 0.6645** | 0.8162** | 0.9173** | 1 |

* : significant at 5%

** : significant at 1 %

X1 Seed wt
X2 Seed length
X3 Seed width
X4 Percentage of germination
X5 Plant height
X6 Rate of shoot elongation cm/ month
X7 Shoot girth
X8 Number of leaves
X9 Length of leaf
X10 Width of leaf
X11 leaf area
X12 Number of Sucker
X13 Clorophyll A
X14 Clorophyll B
X15 Total Clorophyll
X16 Carotenoid




Positive

Positive significant

Negative

Negative significant

| | | | |
|---|---|---|---|
| X1 | Seed wt | X9 | Length of leaf |
| X2 | Seed length | X10 | Width of leaf |
| X3 | Seed width | X11 | leaf area |
| X4 | Percentage of germination | X12 | Number of Sucker |
| X5 | Plant height | X13 | Clorophyll A |
| X6 | Rate of shoot elongation cm/ month | X14 | Clorophyll B |
| X7 | Shoot girth | X15 | Total Clorophyll |
| X8 | Number of leaves | X16 | Carotenoid |

**Fig 9: Environmental correlation coefficient among the characters in Heliconia**

**Table 19 Clustering of heliconia species and varieties based on $D^2$ analysis**

| Clusters | Species and varieties |
|---|---|
| I | T6, T5, T9, T12, T13 |
| II | T10, T11, T14, T15 |
| III | T1, T2, T4 |
| IV | T7 |
| V | T3 |

**Table 20 Cluster means for eight characters in heliconia**

| Character | Clusters | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| Seed weight (g/ 100 seeds) | 12.42 | 12.05 | 9.65 | 12.28 | 2.66 |
| Percentage of germination | 63.33 | 74.99 | 47.22 | 50 | 100 |
| Plant height (cm) | 136.65 | 161.26 | 99.13 | 46.3 | 202.6 |
| Number of leaves | 6.8 | 8.5 | 6.6 | 10 | 7 |
| Leaf area ($cm^2$) | 735.39 | 772.91 | 510.18 | 289.20 | 1007.34 |
| Number of suckers | 1.6 | 1.75 | 1.5 | 2 | 1 |
| Chlorophyll-a (mg/g) | 0.94 | 0.75 | 1.12 | 1.08 | 0.78 |
| Total chlorophyll. (mg/g) | 1.42 | 1.08 | 1.42 | 1.68 | 1.11 |

**Table 21 Average intra and inter cluster distances ($D^2$ values)**

| Clusters | I | II | III | IV | V |
|---|---|---|---|---|---|
| I | 4266.64 | 8833.9 | 17995.7 | 81923.1 | 41720.3 |
| II | | 8525.6 | 38187.62 | 121537 | 22785.3 |
| III | | | 2484.7 | 26245.8 | 105402.1 |
| IV | | | | 0.00 | 232932.23 |
| V | | | | | 0.00 |

Cluster means of the eight characters are presented in Table 20.

Cluster I had the maximum cluster mean for seed weight (12.42) and cluster V had the minimum value of (2.66).

The highest mean for percentage of germination (100) was shown by cluster V, and cluster III had the minimum value of (47.22).

The highest mean for plant height (202.6 cm) was shown by cluster V, while lowest was seen in cluster IV (46.3 cm).

Cluster mean for number of leaves was highest in cluster IV (10) and lowest in cluster III (6.6).

Cluster V exhibited the maximum values for leaf area, (1007.34) while cluster IV had minimum value (289.20).

Cluster mean for number of suckers was highest in cluster IV (2) and lowest in cluster V (1). The maximum value for chlorophyll-a was seen in cluster III (1.12) and minimum value in cluster II (0.75).

The maximum value for total chlorophyll was seen in cluster III and cluster I (1.42) and minimum value in cluster II (1.08).

The average intra and inter cluster distances are furnished in Table 21.

The average inter and intra cluster distances were estimated based on total $D^2$ values. The intra cluster (D value) distances varied from 0 to 8525.6. Whereas the inter-cluster (D value) distances ranged from 848.39 to 5911.80. The intra-cluster distances seen to be lower than inter-cluster distances. The maximum intra-cluster distance was observed in cluster II (8525.6). Clusters IV and V had only one genotype each and hence intra cluster distance was 0. The maximum inter-cluster distance was noticed between cluster IV and V (232932.2) while the minimum distance was between cluster I and II (8833.9).

Using eucedian distance measures dendrogram was constructed to represent inter and intra specific relationships among the species and varieties. Clustering shown slightly different grouping than grouping by $D^2$ analysis. On drawing a vertical line in the dendrogram along the point corresponding to the similarity coefficient value of 110.12, the 14 species and varieties got divided in to five clusters. The varieties *Heliconia lingulata* var. 'Red tip fan', *Heliconia*

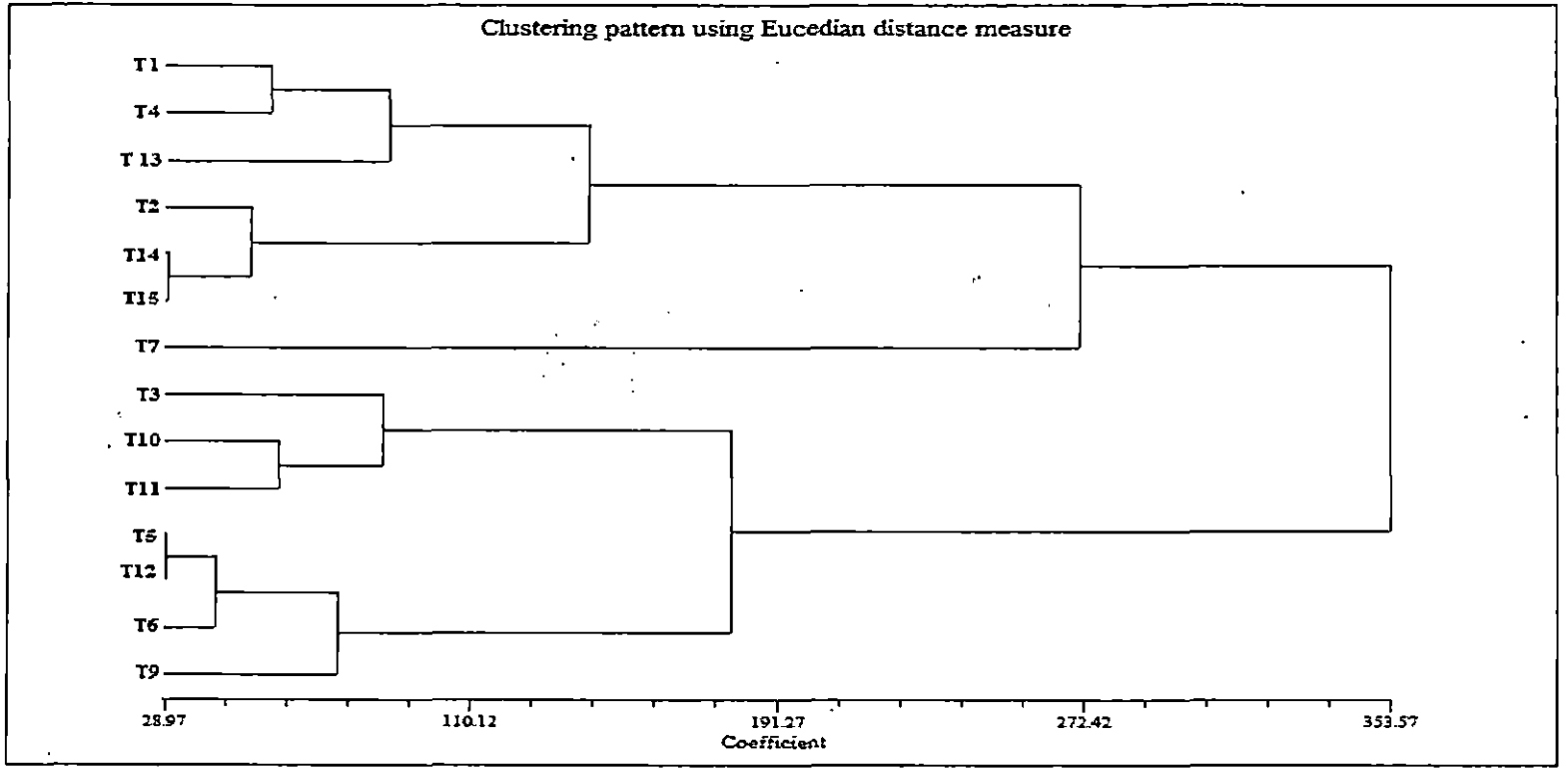



**Fig 10: Clustering pattern of 14 heliconia species and varieties using Eucedian distance measure**

*pogonantha* var. 'Pogonantha' and species *Heliconia curtispatha, Heliconia bourgaeana* formed the largest cluster. The variety *Heliconia bihai* var. 'Granda' formed separate cluster as like in $D^2$ analysis.

### 4.1.9 INSECTS PESTS AND DISEASES

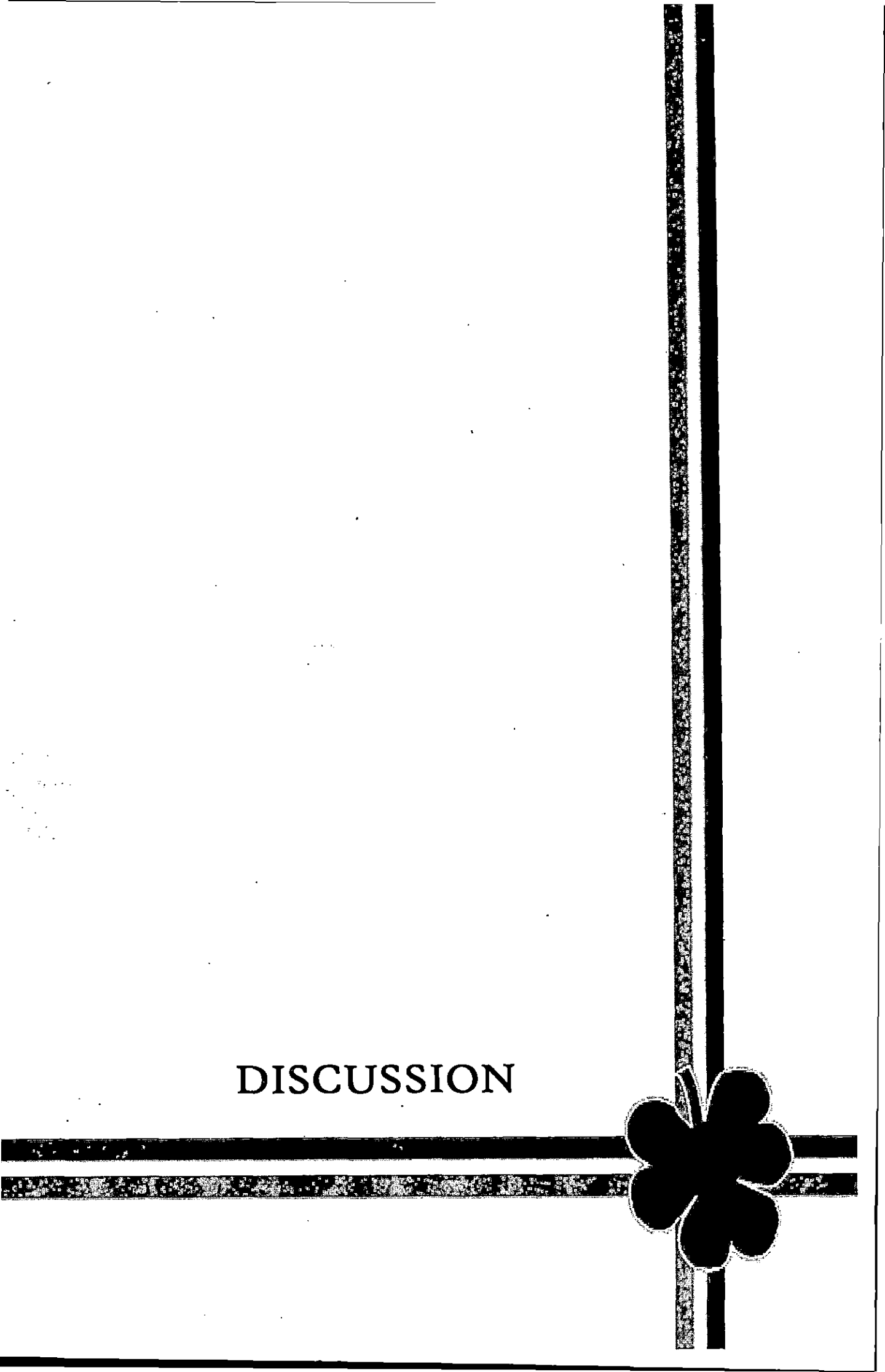
Very few insect pest and diseases were observed in the heliconia accessions utilized for the study. Irrespective of difference in growth habit of species and varieties the Gray Field Slug (*Deroceras reticulatum*) was seen to be attacking all the 14 heliconia accessions during rainy period. The grass hoppers were found to be making shoot and leaf damage in early growth stages of the plants. A very few incidences of Leaf spot and leaf blight diseases were observed throughout the research period during humid and rainy periods.

**Gray Field Slug**
***(Deroceras reticulatum)***

**Grasshopper**

**Plate 10 :- Insect Pest attacking on *Heliconia spp.***

# DISCUSSION



# 5. DISCUSSION

Heliconias are one of the important cut flower of tropics and versatile landscape plants due to their variation in the growth habit and flower characters. Regarding the number of species and cultivars it has outnumbered several ornamental plants. In their natural habitat crosspollination occurs and many species sets seed freely. Even though there is no man made hybrid reported in heliconia; natural hybrids does exists. Several such natural hybrids have subsequently developed in to superior cultivars. With this background it was decided to study the extent of variability among open pollinated seedlings collected from 15 different species and varieties; which sets seed freely in nature. It is essential to have an understanding of natural variability among different species for cleaver utilization and for evolving novel varieties.

## 5.1 Evaluation of species and varieties for their performance

Evaluation of open pollinated seedlings of 15 heliconia species and varieties in vegetative phase was carried out for seed characters, germination characters i.e. percent germination and days require for fifty percent germination; morphological characters such as plant height, shoot girth and leaf morphology, leaf area, suckering habit. Also physiological characters such as chlorophyll content, leaf sheath colour variation of the seedlings were evaluated.

The 15 heliconia genotypes studied comes under fourteen diverse species. There is significant difference in the seed, germination, morphological and physiological characters.

### 5.1.1 SEED CHARACTERS

Many of the heliconia species and varieties reported to produce seed in their natural habitat. There are very few studies done regarding seed aspects of heliconia species. Though not for commercial production purpose, seed character studies are of vital importance for crop improvement purpose. There is

considerable variation in the weight, seed length and seed width. Influence of these seed characters on the other economically important characters needed to be investigated. Size of seeds may be a pointer towards aspects like early germination and vigor of plants.

In the present study, the species and varieties showed significant difference in weight of seeds. The variety *Heliconia caribaea* var. 'Gold' registered highest seed weight. Followed by *Heliconia standleryi* and *Heliconia curtispatha.* Minimum value for seed weight was registered by *Heliconia mariae.* It was preceded by *Heliconia longa.*

Interestingly *Heliconia mariae* which have registered lowest seed weight have observed to have highest value of plant height. Similarly *Heliconia longa* which also recorded minimum value for seed weight also developed in to taller plants.

Similarly there was significant difference in the length of seeds between species and varieties utilized for study. The species *Heliconia standleryi,* registered longest seed length. It was followed by *Heliconia curtispatha and Heliconia bourgaeana.* The species *Heliconia mariae* recorded the lowest length of seeds. It was preceded by *Heliconia longa.*

There was significant difference in the width of seeds between species and varieties utilized for study. The species *Heliconia imbricata* registered widest seed. It was followed by the species *Heliconia standleryi* and *Heliconia champneiana.* The species *Heliconia mariae* recorded the lowest width of seeds. It was preceded by *Heliconia longa.*

The shape of seed varied from rectangular to a rounded one. There was no variation in seed colour and hardness. These results are similar to the observations recorded by Emilia in 2005.

Emilia, (2005) reported that, in heliconia seeds can vary in size and shape among the different heliconia species. Some can be as large and round as a pea (*H. aemygdiana*), while others can be long and thin as a grain of rice (*H. rostrata*). They are all similar in colour and hardness.

## 5.1.2 GERMINATION CHARACTERS

In heliconia species and varieties studied the time taken for germination is spread over considerable period of time. Also species and varieties showed significant difference in percent germination. The species *Heliconia curtispatha, Heliconia mariae* recorded the highest germination percent (100%). It was followed by the species *Heliconia standleryi* and *Heliconia longa*. Among the species and varieties utilized for study species *Heliconia ramonensis* failed to germinate during entire observation period. The species *Heliconia magnifica,* recorded second lowest germination percentage. Interestingly the varieties with smaller seed weight recorded higher germination percent as compare to varieties with higher seed weight, reiterating the concept that in smaller seeds it is easier for water to reach embryo and ultimately facilitating the quicker germination.

There was significant difference in the days required for 50% germination among species and varieties utilized for study. The species *Heliconia curtispatha,* registered less days required for 50% germination. It was followed by the species *Heliconia standleryi*. More number of days were required for 50% germination by variety *Heliconia caribaea* var. 'Gold'. It was preceded by the species *Heliconia imbricata*. Variation in time taken for germination can be attributed to factors like difference in environmental conditions in areas from where seeds were collected. As per Simao and Scatena (2003) observed that species from moist place usually took lesser time to germinate, while those from dry areas took longer, until environmental conditions were favourable. Although H. velloziana occurs in moist place and takes four to six months to germinate, suggest that other environmental factors, as e. g. temperature, or even other factors, such as the development of the embryo, could influence the beginning of germination period.

Similar observations have been recorded by Montgomery (1986) that the range in the germination period of Heliconia (from three months to three years).

Germination of heliconia seed is erratic in nature. Seeds of the same species under close to identical conditions present different germination intervals (Simao and Scatena, 2003; Tejedor, 2005). Different species have different germination intervals which could vary from weeks to many months (Tejedor, 2005).

Some species of *Heliconia* took three years to germinate (Montgomery, 1986; Criley, 1988), depended on the degree of the embryo development at the time of the fruit maturity.

### 5.1.3 MORPHOLOGICAL CHARACTERS

#### 5.1.3.1 HEIGHT OF THE PLANT

Plant height is one of the important characters for any ornamental and cut flower plant species. It decides its position in the landscape design. The variation in the plant height of various heliconia species and varieties can facilitate garden designers to fit a range of species at different location as per utility. Dwarf species can be used as borders, tall species for screening etc. Increase in the length of flower stalk is desirable in cut flowers as it increases the flexibility in use of flower for different purpose. But in heliconia it holds true to a certain limits as taller plants produce inflorescence with more length for flower and flower stalk, which in turn increases weight of inflorescence considerably.

In the present study, the species and varieties showed significant difference in the plant height. The species *Heliconia mariae* recorded the highest plant height at 210 DAE, 240 DAE, 270 DAE and 300 DAE which was significantly superior over other species and varieties. Among the species and varieties *Heliconia bihai* var. 'Granda' registered the lowest plant height during whole observation period except at 30 DAE. These results confirm the variation in the plant height of heliconia species and varieties.

The dwarf nature exhibited by varieties like *Heliconia bihai* var. 'Granda' can be effectively utilized for using them as potted plants, in borders or even in urban landscape for planting in roadside besides of their value as cut flowers. Tall

varieties like *Heliconia mariae* capable of producing long and big inflorescence which can be utilized for large flower arrangements e.g. halls and stages etc. Also these tall species can be effectively utilized at end of lawn in big gardens. Tall species with dense canopy are also useful for screening in garden.

Logas *et al.* (2007) evaluated ornamental attributes of clump of 26 genotypes of Heliconia germplasm collection of UFRPE at Pernambuco state, Brazile. They classified 26 genotypes in to three distinct classes on basis of clump height, short (< 1.5m), medium (1.5m to 2.5m) and tall (< 2.5m.).

Smitha (2005) reported that reduced plant height is the desirable character in cut flower like Heliconia. As the plant height increases the weight of inflorescence also increases, thereby increasing the transportation charges and freight charges. For acceptance as garden plant also, reduced plant height is desirable. Increase in plant height will incur more cost of cultivation due to additional operations such as staking. Decrease in height also increases the suitability of the plant for container planting.

### 5.1.3.2 SHOOT GIRTH

Shoot girth is important character in the crops like heliconia and banana as ultimately it affects the performance of plants. There are no studies have been done on the effect of shoot girth on other morphological and floral characters of plant. The more shoot girth can help in the additional support to plants against high wind velocity.

The present study reveals that there was significant difference in the shoot girth between species and varieties utilized for study. The species *Heliconia mariae* recorded the highest shoot girth at 150 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE and 300 days after emergence which was significantly superior over other species and varieties. The variety *Heliconia caribaea* var. 'Gold' at 60 DAE, 90 DAE, 120 DAE, registered a highest shoot girth. The variety *Heliconia latispatha* var. 'Orange Gyro' has recorded lowest shoot girth at 240 DAE, 270

DAE and 300 days after emergence. Species *Heliconia bourgaeana* registered lowest mean values of shoot girth at 90 DAE, 120 DAE, 150 DAE, and 210 DAE.

### 5.1.3.3 RATE OF SHOOT ELONGATION

Plants with faster rate of shoot elongation may flower earlier thus reducing gap between planting and collection of flowers for growers, which is beneficial to them. However timely application of the nutrients is critical for attending potential rate of shoot girth and ultimately flowering.

In present study the species and varieties showed significant difference in rate of shoot elongation during observation period. At 30 days after emergence species *Heliconia bourgaeana* registered highest rate of shoot elongation followed by the variety *Heliconia pogonantha* var. 'Pogonantha' and *Heliconia curtispatha*. The lowest rate of shoot elongation was recorded by the species *Heliconia champneiana* at 30 days after emergence. At 150 days after emergence the variety *Heliconia pogonantha* var. 'Pogonantha' recorded highest mean value for rate of shoot which was significantly superior over rest of the species and varieties. It was followed by species *Heliconia imbricata*. At 150 days after emergence the variety *Heliconia lingulata* 'Red tip fan' recorded lowest rate of shoot elongation.

At 300 days after emergence the species *Heliconia mariae* recorded the highest mean value for rate of shoot elongation. Followed by species *Heliconia longa*. Variety *Heliconia bihai* var. 'Granda' registered the lowest rate of shoot elongation.

According to Emilia (2005), rate of shoot elongation differs in seedlings of heliconia species. Some of these seeds have an aggressive start, while others seem to take forever to sprout. *Heliconia platystachys, H. imbricata* and *H. collinsiana*, all with very large round seeds, sprout quickly and it's not uncommon to find seedlings growing close to the mother clump. The tiny seeds of *H. mariae*, a robust plant, also sprout very fast. *Heliconia chartacea*, with large rectangular seeds, can take up to a year to emerge.

### 5.1.3.4 NUMBER OF LEAVES

In the present study, the species and varieties showed significant difference in number of leaves per plant. At initial growth period 30 DAE variety *Heliconia bihai* 'Manova Sunrise' and *Heliconia standleryi* registered the highest number of leaves with mean value of 6. Among the species and varieties *Heliconia bihai* var. 'Granda' registered the highest number of leaves with mean value of 9, 10 and 10 at 240 DAE, 270 DAE and 300 days after emergence. The leaf production was rapid in early stages of growth. Also the interval between apparent and successive leaves increases as plant grows.

Smitha (2005) investigated the 12 different species and varieties of heliconia for morphological and various other aspects. The number of leaves per shoot showed significant difference three months after planting and five months after planting. The cultivar Lady Di recorded the highest number of leaves per shoot at three months after planting (6.25). The cultivar Guayana recorded the highest leaf number (6.13), nine months after planting.

Lalrinawmi and Talukdar (2000 b) reported 4-6 lance shaped leaves in *Heiconia psittacorum.* Higher variability in number of leaves per $m^2$ and number of leaves per clump was recorded by Lalrinawmi and Talukdar (2000 a).

### 5.1.3.5 LEAF LENGTH AND WIDTH

There was significant difference in the length of leaves between species and varieties utilized for present study. The species *Heliconia mariae* recorded the highest length of leaves 54.1cm, at 300 days after emergence. Among the species and varieties *Heliconia bihai* var. 'Granda' registered the lowest length of leaves during whole observation period.

Similarly there was significant difference in the width of leaves between species and varieties utilized for present study. The species *Heliconia mariae* recorded the highest width of leave at 60 DAE, 150 DAE, 180 DAE and 300 days after emergence. The species *Heliconia standleryi* recorded the highest width of

leaf at 210 DAE, 240 DAE, 270 days after emergence. At 90 DAE and 120 DAE species *Heliconia imbricata* recorded the highest width of leave. Among the species and varieties *Heliconia bihai* var. 'Granda' registered the lowest width of leaves at 60 DAE, 180 DAE, 210 DAE, 240 DAE, 270 DAE, 300 days after emergence. It has been observed that leaf shape and leaf area are more dependent on leaf width than that of leaf length. Similar variations in length and width of leaf are observed by different scientist in heliconia, which are discribed below.

Pawan Kumar P. (2010) has studied 18 heliconia genotypes for morphological and flowering parameters. The mean performance of varieties showed that variety Kawawuchi recorded maximum values for leaf length and leaf width (166.25, 33.97 cm respectively). The minimum value for leaf length and leaf width (41.04, 9.82 cm respectively) was recorded by variety Malas Pink.

Triplett and Kirchoff (1991) reported that blade size in the family varies from small blades, of sizes similar to those typically found in the Zingiberaceae and related families, to sizes approximating the larger blades of the Musaceae. Typically, *Heliconia* blades are large. A common size, for instance in *Heliconia* platystachys, is 114 cm long x 34 cm wide. *Heliconia caribaea* has distinctly larger than average leaves, with a blade size on the order of 182 x 46 cm. At the other extreme, the blades of *Heliconia psittacorum* are 45 x 11 cm, distinctly smaller than usual.

### 5.1.3.6 LEAF LENGTH: WIDTH RATIO

The leaf length: width ratio gives in general idea about leaf shape. More the length: width ratio leaf has a propensity of lanceolate shaped. The present study revealed that there is significant difference in the leaf length: width ratio between species and varieties utilized for study. The variety *Heliconia latispatha* var. 'Orange Gyro' has recorded highest leaf length: width ratio of 3:1 followed by variety *Heliconia bihai* 'Manova Sunrise' i.e. 2.7: 1. Among the species and

varieties species *Heliconia curtispatha* and variety *Heliconia pogonantha* var. 'Pogonantha' recorded lowest leaf length: width ratio of 1.8:1.

The length (L) to width (W) ratio of the blade is variable across the Heliconiaceae, with no apparent correlation with other characteristics 'of the leaves. The range of L: W ratios in the study species is from 3:1 in *H. indica* to 6:1 in *Heliconia vaginalis* and *H. psittacorum.* (Triplett and Kirchoff, 1991)

### 5.1.3.7 LEAF SHAPE, LEAF TIP, LEAF BASE AND LEAF MARGIN

Assessment of leaf shape, leaf tip and leaf base was done to know whether there is variation for these characters among the open pollinated seedlings of species and varieties.

Among the species and varieties utilized for the study, two type leaf shapes were observed viz. lanceolate and oblong. These results are parallel to results of Triplett and Kirchoff (1991) who observed that the leaf blades of the Heliconiaceae have a diversity of shapes and sizes. Most of the blades share a common morphology, but with a number of notable deviations from the standard. The typical lamina is oblong to more commonly narrowly oblong, with an asymmetrical, cordate base and an acute to slightly acuminate apex.

There are no much reports on the leaf tip variation in heliconia. But among the species and varieties utilized in present study shape of leaf tip was observed to be 'acute' in all the species and varieties except in *Heliconia mariae* which was 'obtuse'.

There are no reports on the leaf base variation in heliconia till now. But among the species and varieties utilized in present study *Heliconia bihai* 'Manova Sunrise', species *Heliconia champneiana, Heliconia pogonantha* var. 'Pogonantha', *Heliconia latispatha* var. 'Orange Gyro', *Heliconia magnifica, Heliconia mariae, Heliconia curtispatha,* registered 'oblique' leaf base.

*Heliconia standleryi and Heliconia lingulata* 'Red tip fan', registered 'cordate' leaf base. The *Heliconia caribaea* var. 'Gold' and *Heliconia bihai* var.

'Granda' registered 'cuneate' leaf base. *Heliconia longa* and *Heliconia bourgaeana*, registered 'obtuse' leaf base. In *Heliconia imbricata* variation among leaf base structure was observed, both 'oblique' and 'obtuse' shapes were observed. These variations are indication of occurrence of variability among the seedlings.

Among the species and varieties utilized for study leaf margin variation is observed within the T3 (*Heliconia mariae)*, leaf margin was serrated in one seedling while it was plane in other (Plate 6.).

**5.1.3.10 LEAF AREA**

Leaf area is one of the important characters as it has significant effect on the physiological processes of the plant. Among the species and varieties utilized for present study the species and varieties showed significant difference in leaf area during the observation period. The species *Heliconia mariae* recorded the highest leaf area with mean value of 1007.35 $cm^2$, at 300 days after emergence.

Among the species and varieties *Heliconia bihai* var. 'Granda' registered the lowest leaf area during whole observation period with mean value of 289.2 $cm^2$, at 300 days after emergence. These results conforms the variation in leaf area within heliconia species and varieties and are in line with the findings of previous heliconia researchers as can be seen below.

Lalrinawmi and Talukdar (2000 a) reported the leaf area of *Heliconia psittacorum* varied from 700 to 860 $cm^2$ per leaf. Variability in leaf area among *Heliconia* cultivars was also reported by Lopez *et al.* (2001)

Smitha (2005) investigated the 12 different species and varieties of heliconia for morphological and various other aspects, among them leaf area had recorded significant variation during the period under study. The cultivar Pedro Ortiz recorded highest leaf area. The variety Lady Di recorded the lowest leaf area.

### 5.1.3.11 LEAF THICKNESS

Leaf thickness play important role in avoiding damage of leaf lamina by tearing due to high wind velocity. In the present study the species and varieties showed significant difference in leaf thickness during observation period. At 300 days after emergence the species *Heliconia imbricata* recorded the highest leaf thickness with mean value of 0.20 mm followed by *Heliconia pogonantha* var. 'Pogonantha' and *Heliconia mariae*, with mean value of 0.19 mm and 0.18 mm, respectively. The species *Heliconia bourgaeana*, registered lowest leaf thickness with mean value of 0.08 mm. Variety *Heliconia latispatha* var. 'Orange Gyro', registered second lowest leaf thickness with mean value of 0.09 mm.

The variety *Heliconia bourgaeana*, having thinner leaves observed to have more leaf lamina tearing due to high velocity winds. But in species *Heliconia latispatha* var. 'Orange Gyro', though having thinner leaves due to lanceolate leaf shape it do not experience leaf lamina tearing by wind. Also leaf thickness may be factor determining degree to which leaf minor favours a particular leaf. In present study *Heliconia bourgaeana* having lowest leaf thickness is observed to have incidence of leaf minor in spite of being planted at more distance from wild population with leaf minor infestation. *Heliconia imbricata* having highest leaf thickness is found to have no leaf minor attack in spite of being close to wild population with leaf minor infestation.

Triplett and Kirchoff (1991) also observed that the thickness of the lamina is quite variable in the Heliconiaceae, both between species and within the blade of a single leaf. For instance, average thickness between the veins ranges from 0.167 mm in *Heliconia chartacea* to 0.303 mm in *H. caribaea*. The variation in thickness across a single lamina is also considerable.

### 5.1.3.12 NUMBER OF SUCKERS

In rhizomatous flower crops like heliconia sucker production is one of the economically important characters for having faster multiplication rate. Usually exorbitant prices are charged for suckers of heliconia varieties. Hence rate of

sucker production is crucial in getting early returns and to get favourable benefit cost ratio in first year of planting itself. In present study as planting material was a seed so there was delay in production of suckers. When suckers are the planting material the production of suckers from mother plant occurs much earlier. A seedling with variation can be multiplied faster only if it has good suckering habit.

In the present study among the species and varieties earlier suckers production (at 60 DAE) was recorded in variety *Heliconia latispatha* var. 'Orange Gyro', with mean value of 1 sucker per plant. The species *Heliconia mariae* and *Heliconia standleryi,* registered late sucker production, starting at 270 DAE with mean value of 1 sucker per plant. At 300 days after emergence the variety *Heliconia latispatha* var. 'Orange Gyro' and *Heliconia caribaea* var. 'Gold' registered highest mean value for number of suckers per plant i.e. 3 sucker per plant.

### 5.1.4 PHYSIOLOGICAL CHARACTERS

#### 5.1.4.1 LEAF SHEATH COLOUR

Leaf sheath colour is one of the important characters used in varietal identification. This is standard practice in bananas in which family heliconias were included previously. In heliconia also this is a crucial character for distinguishing the varieties in non flowering stage. Most of the species have distinctive leaf sheath colour pattern. Apart from attractive flowers and lush green foliage the unique leaf sheath colour also add beauty to plant. Until now this character remained neglected by researchers in heliconia across the world.

The species and varieties showed significant difference in leaf sheath colour. In *Heliconia bihai* 'Manova Sunrise', colour of leaf sheath was green with couple of red spots. In *Heliconia magnifica,* greenish brown coloured leaf sheath was observed. *Heliconia mariae*, colour of leaf sheath was green with reddish tinge. In species *Heliconia champneiana*, colour of leaf sheath was green. In *Heliconia curtispatha* greenish brown coloured leaf sheath was observed. In

*Heliconia lingulata* 'Red tip fan', leaf sheath was intensely red pigmented. In *Heliconia bihai* var. 'Granda', deep green colourd leaf sheath was observed.

In *Heliconia pogonantha* var. 'Pogonantha', mosaic pattern of green and brown colour was seen. In *Heliconia standleryi,* leaf sheath was green with brown tinge. *Heliconia longa,* it was green with minor traces of brown colour. In Heliconia *bourgaeana,* it was observed to have green with medium tinge of red pigentation. In *Heliconia latispatha* var. 'Orange Gyro', green leaf sheath with brown circular patches was observed. In *Heliconia imbricata* leaf sheath was predominantly green with brown patches. *Heliconia caribaea* var. 'Gold', green leaf sheath with red strakes was observed.

### 5.1.4.2 PRESENCE OF POWDERY COATING

There are very few reports on the presence of powdery coating on the back surface of leaf and leaf sheath. The presence of powdery coating is considered as unwanted character as during flower harvest it sticks to body of harvester or any other trespasser from field. At the same time presence of powdery coating may act as deterrent to leaf pests and diseases. Also it plays important role in reducing transpiration rate.

Among the species and varieties utilized for study presence of powdery coating on back surface of leaves was observed in *Heliconia mariae, Heliconia curtispatha* and *Heliconia pogonantha* var. 'Pogonantha'. In *Heliconia longa* presence of powdery coating on back surface of leaves, also on leaf sheath of young as well as on older plants was observed.

### 5.1.4.3 LEAF COLOUR

Difference in leaf colour reflects the difference in chlorophyll content of leaf and in turn difference in photosynthetic efficiency. In present study species and varieties showed significant difference in leaf colour. They are categorized in three classes of 'light', 'green' and 'dark' colour. This classification is in line with classification given by Logas *et al.* (2007). *Heliconia magnifica, Heliconia*

*standleryi, Heliconia latispatha* var. 'Orange Gyro', and *Heliconia caribaea* var. 'Gold' observed to have 'light' coloured leaves. In *Heliconia bihai* 'Manova Sunrise', *Heliconia mariae*, *Heliconia lingulata* 'Red tip fan', *Heliconia bourgaeana*, leaf colour was 'green'. In *Heliconia champneiana*, *Heliconia curtispatha, Heliconia bihai* var. 'Granda', *Heliconia longa* and *Heliconia imbricata* leaf colour was 'dark'.

### 5.1.4.4 MIDRIB COLOUR

Colour of midrib has not been studied previously thought this might be identifying feature of a varieties. The species and varieties showed significant difference in leaf midrib colour. In *Heliconia bihai* 'Manova Sunrise', colour of midrib was green. In *Heliconia magnifica,* dark green coloured midrib was observed. In *Heliconia mariae*, colour of midrib was green with gray tinge. In species *Heliconia champneiana*, colour of midrib was green. In *Heliconia curtispatha* dark green coloured midrib with red edges was observed. In *Heliconia lingulata* 'Red tip fan', midrib was green with red spots. In *Heliconia bihai* var. 'Granda', deep green colourd midrib was observed.

In *Heliconia pogonantha* var. 'Pogonantha', bottom portion of midrib was having red edge and radish green middle portion the top portion was green coloured. In *Heliconia standleryi,* midrib was green coloured. *Heliconia longa*, it was deep green colourd. *Heliconia bourgaeana*, was also observed to deep green colour. In *Heliconia latispatha* var. 'Orange Gyro', green midrib was observed. In *Heliconia imbricata* midrib was predominantly red in colour. In *Heliconia caribaea* var. 'Gold', green midrib was observed.

### 5.1.4.5 PIGMENT CONTENT

Over all pigment content of the leaf gives ultimate leaf colour. In heliconia leaf colour variants have been observed via somaclonal variation by Rodrigues (2008) in '*Heliconia Bihai* cv. Lobster Claw I'. Hence it is probable that variation in the pigment content may be indication of variation in seedlings.

In present study there was significant difference in the pigment content between species and varieties. The variety *Heliconia bihai* 'Manova Sunrise', recorded the highest leaf chlorophyll-a content of 1.52 mg/g of leaf sample. Followed by *Heliconia curtispatha,* with mean value of 1.30 mg/g of leaf sample. Chlorophyll-b, total chlorophyll and carotenoid content was higher in *Heliconia curtispatha,* 0.74 mg/g, 2.04 mg/g and 0.099 mg/g of leaf sample respectively.

The variety *Heliconia caribaea* var. 'Gold' registered lowest mean values for all the pigments i.e. chlorophyll-a (0.388 mg/g), Chlorophyll-b (0.146 mg/g), total chlorophyll (0.53 mg/g) and carotenoid (0.035 mg/g) which appeared to be most 'light' coloured variety among the species and varieties utilized for study.

### 5.1.6 INSECT PESTS AND DISEASES

Heliconia is a hardy tropical flower plant. It can tolerate various insect and pest attack up to higher limit as compared to other crops. In the present study very few insect pest and diseases were observed. Irrespective of difference in growth habit of species and varieties the Gray Field Slug (*Deroceras reticulatum*) was seen to be attacking all the 14 heliconia accessions during rainy period. The grass hoppers were found to be making shoot and leaf damage in early growth stages of the plants. A very few incidences of leaf spot and leaf blight diseases were observed during humid and rainy periods. Mites, nematodes and mealy bugs are also reported on heliconia by McConnell and Cruz, (1998). Jankiram and P. Pawan Kumar (2011) observed that Snail (*Achatina fullica)* occasionally, chews young leaves by scraping, making big irregular holes. Adult and young ones devour plant during nights.

### 5.1.7 VARIABILITY ESTIMATE

Planning and execution of a breeding programme for the improvement of any crop depends to great extent on the magnitude of genetic variability present in a germplasm. Information on a genetic variability among the existing stock provides an opportunity for selecting the divergent parents for the breeding

programme. The existence of high variability in respect of many vegetative and floral characters was observed by many researchers in heliconia.

In general PCV was slightly higher than GCV in most of the characters indicating the influence of environment. The apparent variation is not only due to genotypes but also due to the influence of environment.

In present study, high phenotypic (58.7 %) and genotypic (45.42 %), coefficient of variation was found for number of suckers, followed by chlorophyll-b (PCV 47.71 %, GCV 35.86%) and seed weight (PCV 35.05 %, GCV 35.16%).

The difference between phenotypic and genotypic coefficient of variation (GCV and PCV) was lowest for length of leaf, plant height, rate of shoot elongation (0 %) succeeded by leaf width and leaf area (0.01 %). These smaller differences between phenotypic and genotypic coefficient of variation point out that the environmental influence on these characters is less. Whereas the high difference in phenotypic and genotypic coefficient of variation for percent germination (19.56 %) point out higher environmental influence over it.

### 5.1.8 HERITABILITY ($H^2$) AND GENETIC ADVANCE (GA)

Heritability estimates the transmissibility of characters from one generation to other and it provides a measure of the value of selection for different attributes. But heritability does not necessarily mean a high genetic advance for a particular character (Allard, 1960). Heritability along with genetic advance is more useful than heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955).

In present study except for percent of germination and pigment content rest of the characters under study recorded high heritability. The highest heritability was exhibited by the plant height (99.99 %), rate of shoot elongation(99.99 %), length of leaf (99.97 %), leaf area (99.96 %), width of leaf (99.93 %), shoot girth (99.86 %) and seed weight (98.05 %).

High heritability along with high genetic advance was observed for seed weight (heritability 98.05 %, GA 71.72%) and leaf area (heritability 99.96 %, GA 62.95%). High heritability and genetic advance indicates that the character is controlled by additive gene action suggesting the possibility of genetic improvement of those characters through selection (Panse and Sukhatme, 1967).

### 5.1.8 CORRELATION STUDIES

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Correlation provides information on the nature and extent of relationship between all pairs of characters. So when the breeder applies selection for a particular character, not only it improves that trait, but also those characters provides a reliable measure of genetic association between them, which is useful in the breeding programmes.

In present study seed weight was found to have significant positive correlation at genotypic and phenotypic level with seed length, seed width. The character percentage of germination was found to have significant positive correlation at genotypic and phenotypic level with plant height, rate of shoot elongation, leaf length, leaf width and leaf area.

The estimates of genotypic coefficient of correlation were much higher in magnitude than that of corresponding estimates of phenotypic level. It indicates that though there was strong inherent association between the various characters studied, the phenotypic expression of correlation was lessened under the influence of environment.

As per previous findings of Bruna *et. al.* (2002) and smitha (2005) important flower characters like number of bracts per spike, number of flowering shoots had significant and positive correlation with number of leaves, plant height and leaf area. Positive genotypic correlation between pairs of characters indicates that improvement in one character would improve the other character also, thus enabling breeder to select characters responsive to selection.

### 5.1.9 GENETIC DIVERGENCE

Importance of genetic diversity of parents in hybridisation programme has been emphasised by many workers. The more diverse the parents within a reasonable range, higher would be the chances of improving the characters in question. Mahalanobis $D^2$ statistic has been found to be a powerful tool in the hands of plant breeders to assess the degree of relationship among the genotypes and group them based on their phenotypic expression.

14 species and varieties of heliconia were subjected to $D^2$ analysis based on eight characters, viz., seed weight, percentage of germination, plant height, number of leaves, leaf area, number of suckers, chlorophyll-a and total chlorophyll. They were grouped into five clusters on the basis of relative magnitude of $D^2$ values. The greater the distance between two clusters, greater is the divergence between the accessions belonging to the two clusters and vice versa. The maximum number of genotypes (5) were included in cluster I, followed by 4 genotypes in cluster II. Three genotypes were included in cluster III. Cluster IV and Cluster V consisted of only one genotype each.

Cluster V was superior in percentage of germination, plant height and leaf area. Cluster IV was superior in number of leaves, number of suckers and total chlorophyll content.

The maximum intra-cluster distance was observed in cluster II (8525.6). Clusters IV and V had only one genotype each and hence intra cluster distance was 0. The maximum inter-cluster distance was noticed between cluster IV and V (232932.2) meaning that these two clusters show the maximum genetic divergence which can be utilized in hybridization programmes to get heterotic advantage. While the minimum distance was between cluster I and II (8833.9). The intra-cluster distances were seen to be lower than inter-cluster distances thereby suggesting homogeneity among the genotypes within a cluster and heterogeneity between clusters.

$D^2$ analysis has also been effectively employed for identification of traits contributing to genetic divergence and grouping of cultivars in vegetatively propagated crops like banana (Valsala Kumari *et al.*, 1985; Marcy and George 1987, 1988) and sugarcane (Punia et al., 1983; Santhi, 1989).

Using eucedian distance measures dendrogram was constructed to represent inter and intra specific relationships among the species and varieties. Clustering shown slightly different grouping than grouping by $D^2$ analysis. On drawing a vertical line in the dendrogram along the point corresponding to the similarity coefficient value of 110.12, the 14 species and varieties got divided in to five clusters. The varieties *Heliconia lingulata* var. 'Red tip fan', *Heliconia pogonantha* var. 'Pogonantha' and species *Heliconia curtispatha, Heliconia bourgaeana* formed the largest cluster. The variety *Heliconia bihai* var. 'Granda' formed separate cluster as like in $D^2$ analysis.

The natural variation present in the population of heliconia can be utilized for the breeding of new desired cultivars and varieties suitable for our climate. Also the evaluation of cultivars for different ornamental purposes such as garden display, landscaping and cut flower purpose must be done in future.

# SUMMERY

# 6. SUMMARY

The present investigation 'Variability studies in seedlings of heliconia (*Heliconia* spp.).' was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2010-2011 with the aims to assess the vegetative performance and extent of variability in open pollinated heliconia seedlings.

For the study open pollinated seedlings of 15 Heliconia species and varieties were selected. It includes species such as *Heliconia magnifica, Heliconia mariae, Heliconia champneiana, Heliconia curtispatha, Heliconia ramonensis, Heliconia standleryi, Heliconia longa, Heliconia bourgaeana, Heliconia imbricate,* varieties such as *Heliconia bihai* var. 'Monavo Sunrise', *Heliconia lingulata* var. 'Red tip fan', *Heliconia bihai* var. 'Granda', *Heliconia pogonantha* var. 'Pogonantha', *Heliconia latispatha* var. 'Orange Gyro', *Heliconia caribaea* var. 'Gold'. Evaluation of seed, germination, morphological and physiological characters showed significant variation.

- The species *Heliconia mariae* which has lowest seed weight, registered taller and vigorous seedlings. Similarly *Heliconia longa* which also recorded second lowest value for seed weight also developed in to seedlings with taller stature. The shape of seed varied from rectangular to a rounded one (*Heliconia imbricata*). The shape of seed varied from rectangular to a rounded one. There was no variation in seed colour and hardness.
- In heliconia species and varieties studied, the time taken for germination is spread over considerable period of time. Also species and varieties showed significant difference in percent germination. The species *Heliconia curtispatha, Heliconia mariae* recorded the highest germination percent (100%).

- Interestingly the varieties with smaller seed weight recorded higher germination percent as compare to varieties with higher seed weight, reiterating the concept that in smaller seeds it is easier for water to reach the embryo and ultimately facilitate quicker germination.
- In the present study the species *Heliconia mariae* recorded the highest plant height and variety *Heliconia bihai* var. 'Granda' registered the lowest plant height during whole observation period except at 30 DAE.
- The present study revealed that there was significant difference in the shoot girth between species and varieties utilized for study. The species *Heliconia mariae* recorded the highest shoot girth most of the times in observation period which was significantly superior over other species and varieties. The variety *Heliconia latispatha* var. 'Orange Gyro' has recorded lowest shoot girth at end of observation period.
- At end of pot culture experiment the species *Heliconia mariae* recorded the highest mean value for rate of shoot elongation. Followed by species *Heliconia longa*. Variety *Heliconia bihai* var. 'Granda' registered the lowest recorded lowest rate of shoot elongation.
- The leaf production was rapid in early stages of growth. Also the interval between apparent and successive leaves increases as seedling grows. Among the species and varieties *Heliconia bihai* var. 'Granda' registered the highest number of leaves.
- There was significant difference in the length and width of leaves between species and varieties utilized for present study. The species *Heliconia mariae* recorded the highest length and width of leaves, ultimately registering the highest leaf area. Whereas variety *Heliconia bihai* var. 'Granda' registered the lowest length and width of leaves during whole observation period, ultimately registering the lowest leaf area.
- The present study revealed that there is significant difference in the leaf length: width ratio between species and varieties utilized for study. The variety *Heliconia latispatha* var. 'Orange Gyro' has recorded highest leaf length: width ratio of 3:1. Followed by variety *Heliconia bihai* 'Manova

Sunrise' i.e. 2.7: 1. Among the species and varieties species *Heliconia curtispatha* and variety *Heliconia pogonantha* var. 'Pogonantha' recorded lowest leaf length: width ratio of 1.8:1.

- Among the species and varieties utilized for study two type leaf shapes were observed viz. lanceolate and oblong. Among the species and varieties utilized in present study shape of leaf tip was observed to be 'acute' in all the species and varieties except in *Heliconia mariae* which was 'obtuse'. The present study revealed that there is considerable variation in the leaf base structure of heliconias. In species and varieties utilized for study 'oblique', 'cordate', 'cuneate' and 'obtuse' type of leaf bases were observed.
- Among the species and varieties utilized for study leaf margin variation is observed within the T3 *(Heliconia mariae)*, leaf margin was serrated in one seedling while it was plane in other.
- In present study as planting material was a seed so there was overall delay in production of suckers. Among the species and varieties earlier suckers production (at 60 DAE) was recorded in variety *Heliconia latispatha* var. 'Orange Gyro'.
- In heliconia most of the species have distinctive leaf sheath colour pattern. Also presence of powdery coating on back surface of leaves was observed in *Heliconia mariae, Heliconia curtispatha, Heliconia pogonantha* var. 'Pogonantha' and *Heliconia longa.* The species and varieties showed significant difference in leaf midrib colour. These characters might be identifying feature in some of the varieties.
- *Heliconia bihai* 'Manova Sunrise' recorded the highest leaf chlorophyll-content. Chlorophyll-b, total chlorophyll and carotenoid content were higher in *Heliconia curtispatha.* The variety *Heliconia caribaea* var. 'Gold' registered lowest mean values for all the pigments i.e. chlorophyll-a, Chlorophyll-b, total chlorophyll and carotenoids.
- Heliconia is a hardy tropical flower plant. It can tolerate various insect and pest attack up to higher limit as compare to other crops. Irrespective of

difference in growth habit of species and varieties the Gray Field Slug (*Deroceras reticulatum*) was seen to be attacking all the 14 heliconia accessions during rainy period.

- The magnitude of variation was calculated. PCV was slightly higher than GCV in most of the characters studied, indicating the influence of environment. High phenotypic (58.7 %) and genotypic (45.42 %), coefficient of variation was found for number of suckers.
- High heritability was recorded for all characters except for percent of germination and pigment content. High heritability along with high genetic advance was observed for followed by seed weight (heritability 98.05 %, GA 71.72%) and leaf area (heritability 99.96 %, GA 62.95%). Hence these characters can be improved through selection.
- The character percentage of germination was found to have significant positive correlation at genotypic and phenotypic level with plant height, rate of shoot elongation, leaf length, leaf width and leaf area. The estimates of genotypic coefficient of correlation were much higher in magnitude than that of corresponding estimates of phenotypic level. It indicates that though there was strong inherent association between the various characters studied, the phenotypic expression of correlation was lessened under the influence of environment.
- 14 species and varieties of heliconia were subjected to $D^2$ analysis based on eight characters and they were grouped into five clusters on the basis of relative magnitude of $D^2$ values. The maximum intra-cluster distance was observed in cluster II. The maximum inter-cluster distance was noticed between cluster IV and V.

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* Original not seen

# APPENDIX

## APPENDIX I

Technical and scientific terms:

| Technical/ scientific Term | Meaning |
|---|---|
| Ornithophilous | Pollinated by Birds |
| Trapliners | Birds with relatively feed on flower of more than two plant. |
| Acute | Slightly pointed |
| Obtuse | Rounded |
| Acuminate | Sharply pointed |
| Cuneate | Waged shaped |
| Tuncate | Squared or abruptly cut off |
| Oblique | Asymmetrical, unequal |
| Cordate | Heart shaped |
| Serrate | A leaf margin that has pointed teeth |

# ABSTRACT

# VARIABILITY STUDIES IN SEEDLINGS OF HELICONIA

(*Heliconia spp.*).

by

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# ABSTRACT

Heliconias are one of the important cut flowers of tropics and versatile landscape plants due to their variation in the growth habit and flower characters. The objective of study was to assess the extent of variability among open pollinated seedlings collected from 15 different species and varieties.

There was wide variation in the seed characters, germination characters, and morphological characters such as plant height, shoot girth and leaf morphology, leaf area, suckering habit. Also variation in physiological characters such as chlorophyll content, leaf sheath colour of the seedlings was observed.

The species *Heliconia mariae* which registered lowest seed weight was observed to have highest value of plant height. Similarly *Heliconia longa* which recorded minimum value for seed weight developed in to taller plants. The varieties with smaller seed weight recorded higher germination percent as compared to varieties with higher seed weight.

The species *Heliconia mariae* which recorded the highest plant height, also recorded higher values for leaf length, leaf width and leaf area. The variety *Heliconia bihai* var. 'Granda' registered the lowest plant height, also recorded higher values for leaf length, leaf width and leaf area during the whole observation period. The variety *Heliconia latispatha* var. 'Orange Gyro' recorded highest leaf length: width ratio of 3:1. Among the species and varieties *Heliconia bihai* var. 'Granda' registered the highest number of leaves.

Among other leaf characters leaf base was found to have more variation. In species and varieties utilized for study 'oblique', 'cordate', 'cuneate' and 'obtuse' type of leaf bases were observed.

In heliconia most of the species have distinctive leaf sheath colour pattern. Also presence of powdery coating on back surface of leaves was observed in *Heliconia mariae*, *Heliconia curtispatha*, *Heliconia pogonantha* var. 'Pogonantha' and *Heliconia longa*. The species and varieties showed significant

difference in leaf midrib colour. These characters might be identifying feature in some of the varieties. Variation in pigment content was also observed among the species and varieties utilized for study.

The variability was high both at phenotypic and genotypic level for most of the characters. PCV was slightly higher than GCV in most of the characters studied. High phenotypic (58.7 %) and genotypic (45.42 %), coefficient of variation was found for number of suckers. High heritability along with high genetic advance was observed for seed weight (heritability 98.05 %, GA 71.72%) and leaf area (heritability 99.96 %, GA 62.95%). The low heritability was recorded for percent of germination and pigment content. The character percentage of germination was found to have significant positive correlation at genotypic and phenotypic level with plant height, rate of shoot elongation, leaf length, leaf width and leaf area.

Fourteen species and varieties of heliconia were subjected to $D^2$ analysis based on eight characters. They were grouped into five clusters on the basis of relative magnitude of $D^2$ values. The greater the distance between two clusters, greater is the divergence between the accessions belonging to the two clusters and vice versa. The maximum number of genotypes (5) were included in cluster I, followed by 4 genotypes in cluster II. Three genotypes were included in cluster III. Cluster IV and Cluster V consisted of only one genotype each.

Using eucedian distance measures dendrogram was constructed to represent inter and intra specific relationships among the species and varieties. Clustering showed slightly different grouping than grouping by $D^2$ analysis. On drawing a vertical line in the dendrogram along the point corresponding to the similarity coefficient value of 110.12, the 14 species and varieties got divided in to five clusters. The varieties *Heliconia lingulata* var. 'Red tip fan', *Heliconia pogonantha* var. 'Pogonantha' and species *Heliconia curtispatha*, *Heliconia bourgaeana* formed the largest cluster. The variety *Heliconia bihai* var. 'Granda' formed separate cluster as like in $D^2$ analysis.