FLOWERING AND POST HARVEST DYNAMICS OF HELICONIAS (*Heliconia spp*).

By

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(2009-12-106)

THESIS

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DECLARATION

I, **Liju Abraham** (2009-12-106) hereby declare that this thesis entitled **"Flowering and post harvest dynamics of heliconias (*Heliconia spp*)"** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Flowering and post harvest dynamics of heliconias (*Heliconia spp*)"** is a record of research work done independently by **Mr. Liju Abraham** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Liju Abraham

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INTRODUCTION

1. INTRODUCTION

Floriculture is increasingly regarded as a viable diversification from the traditional field crops due to increased per unit returns and the increased habit of 'saying it with flowers' during all occasions. Enormous genetic diversity, varied agroclimatic conditions and versatile human resources offer India unique scope for diversification into new avenues which have not been explored to greater extent. India has better scope in floriculture in the future as there is a shift in trend towards tropical flowers and this can be gainfully exploited (Singh, 2009).

Heliconias are wonderful tropical plants with multi-coloured bracts and varied flower structure and long shelf life. Each inflorescence is made up of several colorful bracts which enclose the true flowers. Its demand for cut flower trade is increasing day-by-day. Heliconias are also valued as garden plants as their long lasting flowers stand out with striking visual effect on plants. Easiness in cultivation and hardy nature with tolerance to major pests and diseases make this crop more appealing for widespread cultivation.

It is the only genus in the plant family Heliconiaceae, coming under the larger order Zingiberales. Heliconias are native to Central and South America, the Carribean Island and some of the islands of the South Pacific. Castro and Graziano (1997) have described the distribution of the heliconia species in Brazil. Their easy cultivation and spectacular presence have made them favourite garden plants throughout the world. Heliconias are mostly grown for cut flower and as garden adornments. As the flowers last in the field for several days without losing their visual appeal, the harvesting time can be accordingly adjusted (Criley, 1998).

Major heliconia producing nations include Barbados, Hawaii, Brazil and Venezuela. It is reported that India has an annual production of one lakh stems which forms only less than one per cent of the total floral production of the country and the major portion is from Andhra Pradesh. Heliconias are well adapted to all major agroclimatic zones of our country. About 50 per cent of India's production comes from the coconut farms located in the West Godavari district in Andhra Pradesh, where it is grown as an intercrop.

Heliconias are hailed as '*The flower of tomorrow* '. In most other flower crops of global importance, many new varieties are being released every year in all major growing countries. Novelty is a key factor to maintain persistent higher competition value in national and international markets for which demands efforts to improve the existing varieties by releasing new varieties. The adaptation of new potential crops normally requires studying the growth, flowering and post harvest physiology and developing practical methods for post harvest handling, transportation and storage.

Taking these factors into consideration the present study on flowering and post harvest dynamics of heliconias (*Heliconia spp.)* was undertaken with the objective of studying the flowering behaviour of heliconia varieties and to develop a protocol for the post harvest handling of cut flowers, so as to promote the indigenous cut flower industry.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Heliconias (*Heliconia* spp.) are attractive tropical plants with banana-like leaves and beautiful, long lasting inflorescences. Each inflorescence is made up of several colorful bracts which enclose the true flowers. Its demand for cut flower trade is increasing day-by-day because of the long vase life, attractive colour and exotic shape. Heliconias are also valued as garden plants as their long lasting flowers stand out with striking visual effect on plants. Easiness in cultivation and hardy nature with tolerance to major pests and diseases make this crop more appealing for widespread cultivation (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 about 89 species under the genus *Heliconia* and more than 350 varieties.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 bracteatic inflorescences.

The literature on growth, flowering and post harvest handling of heliconia and other ornamental gingers which can be used as cut flower has been reviewed.

2.1 Field evaluation

A large number of diverse genotypes are grown in different parts of the country. But systematic studies regarding their quality traits are negligible. The various species studied in greenhouse trials, *Heliconia psittacorum* was considered the most useful for cut flower production because of its upright stems, moderately vigorous growth habit, long flowering season and long lasting flowers Geertsen (1988). The natural variability in heliconia plant and population is high (Berry and Kress, 1991) and can be exploited for breeding purposes.

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, viz., Tay, Andromeda and Lady Di, were partially fertile with very low rates of fruit set, ranging from 2.8 to 4.7 per cent.

Lady Di is the most beautiful among the *psittacorums*. 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 feet with an erect habit. It can grow well in full sun and up to 40 per cent shade. Peak flowering is during April to November (Juan, 1997).

Heliconia spathocircinata x *Heliconia psittacorum* cv. Golden Torch plants ranges the height from 1.0 to 1.8 m, and produce 4 or 5 leaves/shoot followed by a terminal inflorescence with 3 or 4 bracts. The entire inflorescence is uniformly orange-yellow in colour. Trials conducted in South-Eastern Florida revealed that under higher dose of NPK application (3.6 kg of 18:6:12 NPK m^{-2} $year^{-1}$) flower production was increased up to an average of 84 flowers/plant/year. The optimum temperature range for flower production was 21° to 35ºC. Growing plants under 63 per cent shade reduced flower production by about 50 per cent (Broschat *et al.* 1984)

According to Alan (2004) Golden Torch plants are larger and sturdier than other *psittacorums*. Height ranges from 2.5 to 8.0 feet. It grows well in full sun to 40 per cent shade. Flower production peaked from July to September. Flowers have large golden boat-shaped bracts with golden yellow flower.

Heliconias grow well at a temperature range of 21 to 35ºC. Plants grown in full sun produce much more flowers than in partial shade. The influence of irradiance on photosynthesis under natural conditions was studied by Jie He *et al.* (l996) using *Heliconia rostrata, H. psittacorum* x *H. spathocircinata* cv. Golden Torch and *H. psittacorum* cv. Tay. When grown under full sunlight, all three taxa exhibited reduced photosynthetic capacities and chlorophyll content per leaf area compared with those grown under intermediate and high shade.

Growth and development of *H. bihai* cv. Lobster Claw and *H. latispatha* were studied under 3 shade levels (0, 40 and 60 per cent) for 20 months, during which 5 generations of shoots were developed. Plants without shade produced the maximum pseudostems. The number of shoots per clump was greater in *H. bihai* than in *H. latispatha*. In *H. bihai* the first 3 generations flowered simultaneously, when the clump reached the age of 12 months. This flowering period lasted 6 months with a peak during March to June, when 95 per cent of the flowers developed. In *H. latispatha* flowering began when plants were 10 months old and showed an irregular pattern during the cycle, with the peak (82 per cent) occurring in July and August (Maciel and Rojas 1994).

According to Charleston (1997) 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 to 12 inches long and are not too heavy. *Heliconia stricta* cv. Dwarf Jamican bloom through out the year. Peak flowering is observed in winter, whereas in *Heliconia stricta* cv. Sharonii flowering starts from late July to February

Criley *et al*. (1999) reported that although heliconia is a tropical genus, many species exhibit seasonal patterns of flowering. Some cases have been attributed to seasonal rainfall, but research has demonstrated that *H. wagneriana* and *H. stricta* cv. Dwarf Jamaican are short day (SD) species while *H. angusta* initiates its flowers during long days (LD). *H. stricta* cv. Dwarf Jamaican initiates its flowers when its pseudostem has 3 unfurled leaf blades.

Janakiram and Kumar (2011) reported that in Heliconia the growth and yield are greatly affected by light intensity. Plants grown in full sun produced four times as many inflorescences as those grown under more than 50 per cent shade. Shade grown plants were taller, but substantially weaker. The bract colour may be slightly more intense under light shade than full sun for some *H. psittacorum* selections.

2.2 Phenology of flowering

A thorough understanding of the floral biology is an essential for the pre-requisite to any post harvest studies.

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).

A seasonal pattern of flowering was observed in field production of *Heliconia stricta* cv. Dwarf Jamaican by Criley and Kawabata (1986). This seasonality could be photoperiod-related because greater yields for plants were obtained when grown under 8 hour day lengths for 6 weeks than those plants grown under natural day lengths (about 13.5 h). Depending on the capacity of the plant to respond to photoperiod, 3 or 4 weeks of short day length (SD) were sufficient for flower initiation. Geertsen (1990) observed that by exposing plants to a photoperiod of 8 hours, flowering was more advanced and more abundant.

Raising the temperature from 15 to 21ºC flowering percentage increased by 20 per cent. The flowering stems were 40 cm longer and the number of leaves subtending the inflorescence increased by 2.5 cm.

Criley (2000) reported that the natural flowering season for heliconia species in their natural habitat may be influenced locally by rainfall, drought periods as well as by photoperiod. Strong seasonal flowering patterns were reported in *H. angusta, H. bihai, H. caribaea* x *H. bihai, H. collinsiana, H. lingulata, H. rostrata, H. stricta* and *H. wagneriana.* It has previously been reported that *Heliconia psittacorum* cv. Golden Torch leaves grown in full sunlight exhibit a sustained decrease in PS II efficiency as compared to those grown under shade conditions (Jie He *et al*., 1996).

The peak flowering period is from September to December in the first year of planting when planted in January. In the subsequent years it flowers in April and continues upto December. However flowers are produced almost throughout rest of the year. During winter partial shading of leaves occurs and flowering is arrested. The natural flowering season for heliconia species in their natural habitats may be influenced locally by rainfall and drought periods as well as by photoperiod and may not be reliable in indicating production periods elsewhere. With more than three dozen species of heliconia grown and exported in international trade, the seasonality of flowering is important to the supply and marketing of this bold tropical flower (Criley, 2000).

According to Sanjeev *et al.* (2010) there was no uniformity in the flowering behaviour of different varieties of heliconia under South Kerala condition. Considering the flowering pattern, some of the varieties like Ladi Di, GoldenTorch etc. showed continuous flowering through out the year, whereas some others (eg: Distans) were significantly seasonal.

Kumar *et al.* (2011) evaluated 18 genotypes of Heliconia keeping in view of their ability in further breeding programmes. A wide range of variation was observed among the genotypes for sexual, morphological and flowering characters.

Results show that overall superior performance for salient characters was for variety Kawauchi which excelled in all the vegetative parameters like plant height, leaf length, leaf width, leaves per sucker and leaves per stem. Cultivar Guyana (spike length and overall stalk length) and Golden torch (flower per bract) was also found to be promising cutivars.

2.3 Post harvest handling

The cut flower is an intricate organ, composed of different morphological units including sepals, petals, androecium, gynoecium, stem and leaves, which differ in their physiology and functions with each other ultimately decide the longevity of the flower (Bhattacharjee and De, 2003).

Cut flowers are metabolically active and carry on all life processes at the expense of stored reserved food in the form of carbohydrates, proteins and fats, extending their longevity to a few more days even after detaching from the mother plant. In general, longevity of the flower is determined by senescence and wilting of petals (Halevy and Mayak, 1979). Wide differences in post harvest behaviour and lasting quality have been observed amongst different species of flowers and ornamental crops and ornamental cultivars of the same species.

Heliconia flowers have to be harvested at the correct stage of maturity. Stage of harvest, pre harvest and post harvest handling are the factors which determine the life of cut flower. Various preservatives and growth regulators are increasingly used in heliconia to extend their vase life by means of pulsing and holding.

2.4 Stage of harvest

The heliconia flowers are harvested 8-9 weeks after emergence of shoot. Opening of bracts on the inflorescence is also used as a criterion for harvesting the flower. According to Broschat *et al*. (1983) heliconia flowers can be cut when 2-3 bracts are open, but tighter flowers can also be used effectively in flower arrangement.

Heliconia inflorescences are normally harvested in the morning by pulling the stem from the plant clump at mature stage, characterized by the bract being split at the top, allowing the sepals inside the inflorescence boat to be seen. Inflorescences do not open further after they are harvested. Heliconia flower stalks should be cut early in the day while still turgid. It is important to minimize desiccation after harvest as heliconias do not take up water well, and flowers harvested at midday can have as much as a week poorer post harvest life than those harvested in the morning. Inflorescences last longer if cut from well-irrigated plants than from plants under water stress (Donselman and Broschat, 1986; Criley and Paull, 1993).

According to Criley and Broschat (1991) harvested heliconia flower stalk length range from 0.5 to 1.3 m, and inflorescence size from 10 to 50 cm increases the post harvest life

Criley and Paull (1993) recommended that for *H. psittacorum* the harvest should be done when one to two bracts are open and for larger heliconias one-half to two-thirds fully open.

Immature inflorescences had a shorter post harvest life and this was more pronounced in the warm season than the cool season. Inflorescences harvested in the cool season tend to have a slightly longer post harvest life than inflorescences harvested in the warm season (Jaroenkit and Paull, 2003).

According to Bahybalid *et al.* (2011) harvest stage significantly influenced overall quality (visual basis) and vase life of heliconia inflorescence cv. Golden Torch. Inflorescence harvested at 3 bracts opened stage exhibits excellent quality score (4.23) on the basis of freshness, turgidity and overall acceptability as compared to other stages, although vase life was limited (7.43 days). Maximum vase life was recorded in unopened bract stage inflorescence (15.4 days), however it failed to exhibit further bract opening that reduced the visual appeal.

2.5 Pre cooling

Pre cooling is a practice done for quick reduction of the temperature of packed material to keep them fresh in storage and transport.

Plant material should be cooled as soon as possible after harvest to minimize deterioration. Rudnick *et al.* (1991) observed that pre cooling of cut flowers maintained an appropriate low temperature level inside the package during the entire cold storage and shipping period.

Rapid cooling of packaged cut flowers and foliage reduces the time and they would otherwise pick up higher temperature and therefore helps to prolong the quality and vase life. High respiratory activity not only generates further heat around the product but also uses up stored reserves within the flowers and foliage (Elgar, 1998). He also reported that a low temperature treatment of cut flowers and foliage after harvest reduced the rate of ethylene production and depleted stored carbohydrates from the leaves.

Marcsik (2003) reported that heliconia flowers are pre cooled at 13^{0}C to remove field heat for at least one hour before packing improves vase life.

2.6 Pulsing

Pulsing refers to short duration pre-shipment or pre-storage treatment and the effect lasts throughout the entire vaselife of a flower or foliage.

Cytokinins have been identified as the growth regulator that delay leaf senescence by slowing chlorophyll degradation and maintaining protein and RNA levels (Arteca, 1996). When cytokinins are supplied at correct time and dosage, flower longevity of many species can be extended. Cytokinins are effective in delaying bract darkening and abscission of *H. psittacorum* regardless if they were dipped or sprayed with 200 mg l^{-1} Benzyl Adenine increasing by three fold the vase life (Paull and Chantrachit, 2001).

According to Moraes *et al.* (2005), in an experiment to determine the response of *Heliconia latispatha* flower to treatment with Benzyl Adenine applied immediately after harvesting at two stages showing one or two fully opened bracts (Stage 1) and from three to four fully opened bracts (Stage 2) improved flower longevity. The growth regulator was sprayed twice within the first hour after harvest until the stalks are completely wet. Spraying the flower with 100, 200 and 300 mg l^{-1} Benzyl Adenine, longevity was increased by 1.29, 1.57 and 1.85 fold, respectively compared to untreated flowers.

Bird-of-Paradise inflorescence post harvest life is increased by placing the stems in a pulsing solution of 10 per cent sucrose + 250 ppm 8-hydroxyquinoline citrate and 150 ppm citric acid for 48 hr at 22 ºC prior to packing and vase holding solutions (Halevy et al., 1978). The Society of American Florists manual (Klink, 1990), recommends only 24 hours in the pulsing solution.

According to Bayogan *et al.* (2008) overnight treatment of Bird-of-Paradise inflorescences prior to packing with 20 or 40 per cent sucrose + 250 or 500 mg l^{-1} 8-hydroxyquinoline citrate (8-HQC) + 150 or

300 mg l^{-1} citric acid or silver thiosulfate for 10 min. and gibberellic acid overnight increased post harvest life from 10 to about 13 days.

Paull *et al.* (1985) reported that the rate of increase in respiration rate of silver treated flower was just half of that in the controls. Silver pulsing of stem reduced the amount plugging and reduced the rate of change of all senescence processes.

The individual florets of species such as *H. angusta, H. chartacea,* and *H. psittacorum* abscise within a day or two of opening, but this does not mean the inflorescence is old. Silver thiosulfate pulse treatment has failed to prevent abscission (Tjia and Sheehan, 1984) due possibly to a failure of the silver to reach the florets in sufficient concentration. Florists pick off mature florets before selling the inflorescence. Bract abscission sometimes occurs on *H. chartacea* and may be due to stress-induced ethylene.

El-Saka *et al.* (1995) reported that the best post harvest treatment for Bird-of Paradise was a dip in silver thiosulfate (STS) for 10 min and holding in 25 mg l^{-1} gibberellic acid overnight and then in a vase solution containing 10 per cent sucrose + 200 mg l^{-1} 8-HQS + 150 mg l^{-1} citric acid. This regime was reported to extend post harvest life from 15.5 to 38.5 days.

The suggested treatment to extend the red ginger (*Alpinia purpurata*) inflorescence vase life was a preconditioning at 40 ºC for 15 min., standing in bucket of water at room temperature (22 ± 1 ºC) for 1 hour, and then a hot water treatment at 50 ºC for 12-15 minutes (Paull and Chantrachit , 1993).

2.7 Holding

Various holding solutions are used for long term storage of cut flowers.

In Heliconia floral preservatives do not improve vaselife (Broschat and Donselman, 1983; Powell, 1991; Tjia and Sheehan, 1984), but anti-transpirants improve postharvest life slightly (Broschat and Donselman, 1987; Ka-ipo et al., 1989; Paull, 1991). The lack of response to preservatives may be associated with poor vascular development of the base of the flower stem, while antitranspirants and waxes provide limited response due to a failure to completely coat the bract surface.

According to Broschat and Donselman (1983) flowers of recommended cultivars ('Golden Torch', 'Andromeda', 'St. Vincent Red', etc.) maintain their bract color and shape for 14-15 days in tap or deionized water at 23°C. Uptake of water or floral preservatives is minimal, hence silver or 8-hydroxyquinoline citrate-containing solutions have no effect on post harvest life of the cut flowers.

Bredmose (1987) reported that inflorescence lasted in water for 2-4 weeks, with no additives. Vase life was shorter in winter than at other times.

Among *H. psittacorum* cultivars, 'Lady Di' is reported to last 7 to 10 days while 'Andromeda' lasts 10 to 15 days (Powell, 1991) or up to 21 days (Donselman and Broschat, 1986). Among the large heliconia, *H. latispatha* and *H. rostrata* are regarded as poor keepers with only 3 to 5 days vase life, while *H. caribaea* and *H. wagneriana* can last 15 days or more (Criley, 1990; Powell, 1991).

Paull and Chantrachit (2001) reported that the vase life of *Heliconia psittacorum* c.v. Andromeda, *Heliconia chartacea* c.v. Sexy Pink and Red was increased by BA 100ppm applied as a dip or as a spray.

According to Goel (2011) the vase life of different varieties of heliconias ranges from 3 to 4 days (in *Heliconia psittacorum* cv. Rubra Red); 10-14 days in several large erect varieties and about 28 days in *H. humilis*.

2.8 Storage

Heliconias are sensitive to temperatures below 13ºC and should not be placed in cold storage. Cold injury develops as black spots at the base of the bracts. As desiccation reduces post-harvest life, storage conditions should maintain 90-95 per cent humid conditions (Donselman and Broschat, 1983).

Among the large heliconia flowers, *Heliconia latispatha* is considered as the species with the shortest longevity (3 - 5 days) in vase, compared with species like *H. caribaea* and *H. wagneriana* where the longevity may reach up to 15 days considering similar conditions of temperature and humidity (Criley and Paull, 1993).

According to Reid (2004) heliconia flowers cannot be stored at a temperature below 10-12ºC. Flowers can be stored in moist shredded newsprint or in water at 12.5ºC. Temperature below 10-12ºC develops black spot on the bracts.

2.9 Packing

Packing of flowers is done in three strages. Bunching, wrapping and packing. Each operation must be carried out with utmost care. Most flowers are bunched, usually containing 5, 10 or 20 (generally multiples of 5) flower to a bunch. Different flowers require different methods of wrapping using different materials. The wrap should always be protruding above the bunch, to protect them from pushing up against the box ends. Thus, the success of the cut flowers production technique will heavily depend on the choice of a rational and functional packaging, which is adapted to the product to be protected, as well as to the method of transport, handling and storage. In view of the growing environmental concerns the packaging material should be ecofriendly and easy to dispose.

The large heliconias are usually cut to fit a 150 cm long box, while the *H. psittacorum* types are trimmed to lengths of 60 to 90 cm. In packing, shippers often mix heliconia types. *H. psittacorum* is often packed in a "metric" bunch of 10, and sleeved in plastic film or open weave netting. Up to 25 such bunches may be packed in a 150 x 50 x 25 cm box. Medium sized heliconias such as *H. bihai*, and *H.stricta* may be packed 20 to 50 per box while the large *H. caribaea* are packed as 10 to 15 pieces. Moist or dry shredded newspaper is use as well as layers of newspaper to reduce damage due to shifting during shipment (Donselman and Broschat, 1986).

Small heliconias such as *H. psittacorum* and *H. angusta* are bunched (5s, 10s) and may be sleeved in plastic film or netting. Some shippers use plastic sleeves over the inflorescences of large heliconias to prevent bruising. Packing strategies vary, but the large, heavy heliconias are usually packed with moist shredded news paper or between layers of news paper to prevent shifting. Bunches of the smaller heliconias are packed on top of the heavier heliconias (Criley and Paull, 1993).

According to Criley and Paull, (1993) few days prior to harvest, the Bird-of-Paradise inflorescences are often covered by a paper or wax paper bag, wrapped with electrical tape, a wide elastic band or a plastic net sleeve installed to prevent inflorescences from opening during transportation, and to reduce mechanical injury to the floret. Gingers are packed singly or bunched by fives, and bunches are wrapped in a polyethylene film or moistened shredded newspaper is packed around the bunches to prevent drying. Single stems are layered in rows in the boxes achieving counts of 100 to 400 per box (150 x 40 x 25 cm) depending upon the stem length and amount of cushioning material.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Investigations on the "Flowering and post harvest dynamics of heliconias (*Heliconia spp.*) were conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during 2009 - 2011. The objective was to study the flowering behaviour of heliconia varieties and to develop a protocol for post harvest handling. Details regarding the materials used and the methods adopted are presented in this chapter.

3.1 Location

Vellanikkara is situated at a latitude of 10º 31' N and longitude of 76º 13' E. The area lies 22.25 m above MSL and enjoys the typical warm humid tropical climate of Kerala.

3.2 Materials

The following varieties of heliconia were used for the study

1. *Heliconia bihai* (L.) L. cv. Banana Split
2. *Heliconia caribaea* Lamarck x *Heliconia bihai* (L.) L. cv. Kawauchi
3. *Heliconia psittacorum* L.f. cv. Lady Di
4. *Heliconia psittacorum* L.f. cv. Rubra Red
5. *Heliconia psittacorum* L.f. x *H. spathocircinata* Aristeguieta cv. Golden Torch
6. *Heliconia psittacorum* L.f. x *H.spathocircinata* Aristeguieta cv. Golden Torch Adrian
7. *Heliconia stricta* Huber cv. Firebird

A complete randomized block design with three replication was laid out. The varieties were grown under uniform crop management condition and developmental characters of the flower and post harvest behaviour were recorded.

3.3 Evaluation of heliconias

Observations on the flowering phenology and floral characters of heliconia were recorded.

3.3.1 Observations

In each variety three plants were used for recording biometric observations. The parameters recorded are the following.

3.3.1.1 Quantitative characters

3.3.1.1.1 Number of inflorescence per plant / year

Monthly counts were made for estimating number of flowering shoots for a period of one calendar year. Total number of flowering shoots produced by each plant for one year was recorded and the mean value calculated.

3.3.1.1.2 Flowering nature / Blooming period

Average flower production per month, the non-flowering months if any and the seasonality of flowering were recorded.

3.3.1.1.3 Length of inflorescence

Inflorescence length was measured from the junction of pedicel of the top most leaf to the tip of the axis of a fully opened inflorescence. The average of the inflorescence length was recorded.

3.3.1.1.4 Length of rachis

Length of rachis was measured from the junction of the basal bract (Ist bract) to the tip of the axis of the fully opened inflorescence. The average of the length of rachis was recorded.

3.3.1.1.5 Length of peduncle (cm)

Peduncle length was measured from the junction of pedicel of the top most leaf to the tip junction of the basal bract (Ist bract). The average of the peduncle length was recorded.

3.3.1.1.6 Number of bracts

Number of bracts in each spike was counted and the mean value calculated.

3.3.1.1.7 Length of bract (cm)

The length of the second bract from base was recorded and the mean calculated.

3.3.1.1.8 Number of days from emergence to fully opening of basal bract

The numbers of days taken from the emergence of the inflorescence to full opening of the basal bract were noted and their average recorded for each of the inflorescence.

3.3.1.1.9 Number of days for full unfurling of bracts

The number of days taken from the first bract to last bract opening was recorded.

3.3.1.1.10 Number of flowers / bract

Second bract from below was selected as standard for counting the number of flowers / bract.

3.3.1.1.11 Interval between opening of successive flowers in a bract

Number of days taken from the first flower to next flower opening was recorded.

3.3.1.1.12 Longevity of flower on the plant

Longevity was recorded by counting the days from basal bract opening till it become unfit for use (as indicated by drying, wilting, drooping, yellowing, blackening etc.)

3.3.1.2 Qualitative characters

This included primarily the inflorescence characters, which directly contributed towards their use as cut flower.

3.3.1.2.1 Nature of inflorescence - erect / pendent / spiraling with bracts

3.3.1.2.2 Arrangement of bracts – Spiral / distichous

3.3.1.2.3 Bract colour

3.3.1.2.4 Bract margin- straight / revolute / involute near the rachis

3.3.1.2.5 Colour of flower

3.3.1.2.6 Colour of sepals

3.3.1.2.7 Colour of rachis

3.3.1.2.8 Colour of pedicel

3.3.2 Evaluation of morphological characters of inflorescence

Morphological characters of inflorescence were evaluated based on methodology adapted from Castro (1993) for their suitability as cut flower.

- Fresh weight of stem (FWS): Light (< 100 g); Medium (between 101 and 200 g) and Heavy (> 200 g)
- Stem diameter(SD); 20 cm below the rachis: Thin (< 10.0 mm); Medium (between 10.1 and 30.0 mm) and Thick (> 30.0 mm)
- Length of inflorescence (LF): Short (< 50.0 cm); Medium (between 50.1 and 150.0 cm) and Long (> 150.0 cm)
- Length of rachis (LR): Short (< 10.0 cm); Medium (between 10.1 and 30.0 cm); Long (between 30.1 and 50.0 cm) and Very Long (> 50.0 cm)
- Bract arrangement (BA): One plane or Spiraled
- Wax on inflorescence (WAX): Present or Absent

3.4 Development of post harvest management practices

3.4.1 Standardization of stage of harvest

Inflorescences at following different stages of development (Plate 1) were harvested from each varieties and kept in water and tested their longevity.

Stage 1 (S_1)- Bud stage (no bracts open)

Stage 2 (S_2)- 1-2 fully opened bracts

Stage 3 (S_3)- 3-4 fully opened bracts

Stage 4 (S_4)- All bracts opened

3.4.2 Pre-cooling

The harvested inflorescences were kept at temperature of 10^0C, 15^0C and 20^0C in a cold chamber for 4 hours and under ambient condition at a temperature of 27^0C. After pre-cooling the inflorescences were transferred to water to compare the effect of various pre-cooling temperatures on their longevity.

3.4.3 Pulsing treatments

After harvesting the inflorescences at the correct stage of maturity the base was re-cut under water and kept in the following pulsing solutions.

P_0 - Control (no pulsing treatment)

P_1 - Sucrose 5% + HQ 200ppm for 6 hours

P_2 - Sucrose 5% + HQ 400ppm for 6 hours

P_3 - BA 100ppm for 6 hours

P_4 - BA 200ppm for 6 hours

P_5 - BA 100ppm as spray within 1 h. after harvest

P_6 - BA 200ppm as spray within 1 h. after harvest

P_7 - Hot water dip at 60^0C for 5 seconds

S_1 - Bud stage (no bracts open)

S_2 - 1-2 fully opened bracts

S_3 - 3-4 fully opened bracts

S_4 - All bracts opened

Plate 1. Heliconia inflorescences harvested at different sages of development

The pH of the solution was maintained as 3.5 except in control and hot water dip treatment. After pulsing, the inflorescences were transferred to water for comparing the effect of various pulsing treatments.

3.4.4 Holding treatments

The inflorescences of different varieties were subjected to following holding treatments after best pulsing treatment.

H_0 - Acidified water (3.5 pH)

H_1 - Sucrose 5% + HQ 100 ppm

H_2 - Sucrose 5% + HQ 200 ppm

H_3 - BA 100 ppm

H_4 - BA 200 ppm

H_5 - Sucrose 5% + $Al_2(SO_4)_3$ 200 ppm

H_6 - Control (distilled water)

3.4.5 Storage studies

The harvested inflorescences of different varieties were kept at a temperature of 8^0C, 11^0C, 14^0C and 17^0C in a cold chamber and under ambient condition at a room temperature of 27^0C.

3.4.6 Packing

The inflorescences of different varieties were treated with the best pulsing solution and packed (both dry without any cotton plug and wet with a cotton plug at the base) in cartons of size 75 x 30 x 10 cm. Ten inflorescences were kept in each carton. Sachets of $KMnO_4$ was also placed in the cartons before packing. The following lining materials were used along with a control (without lining).

1. Butter paper
2. Polythene sheet
3. Newspaper
4. Brown kraft paper

After keeping the cartons for three days, the inflorescences were transferred to best holding solution. The effect of different packing materials was compared with a control and the vase life was noted.

3.4.7 Observations

3.4.7.1 Fresh weight of inflorescence (g)

Initial weight of the inflorescence was taken immediately after harvest and recorded.

3.4.7.2 Physiological loss in weight (PLW)

Initial and final weight of inflorescence was noted at the beginning and end of the experiment, respectively, and by working out the difference PLW was arrived at and expressed in g.

3.4.7.3 Water uptake (ml)

The quantity of vase solution remaining at the end of the experiment was recorded and by finding the difference between the initial and final volumes of the vase solution, total uptake was worked out and expressed in ml.

3.4.7.4 Days taken for the appearance of shriveling / blackening of bracts

Time taken from the harvest of the inflorescence to shriveling/ blackening of bracts was recorded and expressed in days.

3.4.7.5 Changes under storage

3.4.7.6 Quality (turgor, browning and curvature)

3.4.7.7 Vase life (days)

Life of each inflorescence in vase was recorded in days and average value worked out. Vase life was calculated by noting the time taken to develop the symptoms like bract / flower drop, shriveling or blackening of bracts which made the flower unfit for arrangements.

3.5 Statistical analysis

The data from the study was subjected to statistical analysis using SPSS software (SPSS16,2007)

4. RESULTS

The results of the studies on the flowering and post harvest dynamics of heliconias (*Heliconia spp.*) are presented under two heads.

1. Field evaluation
2. Development of protocol for post harvest handling practices of heliconias

4.1. Field evaluation of heliconias

Data on the flowering behaviour and floral characters of heliconia varieties are presented in Tables 1 and 2.

4.1.1. Quantitative characters

Analysis of variance revealed significant differences in the floral characters of heliconia varieties (Table 1).

4.1.1.1 Pattern of flowering

There was no uniformity in the flowering behaviour of different varieties evaluated. Considering the flowering pattern, some of the varieties showed free flowering, whereas others were seasonal. Flower production was seen throughout the year in all the varieties, except in Kawauchi, Golden Torch Adrian and Firebird.

4.1.1.2 Blooming period

Even though the varieties Banana Split, Lady Di, Rubra Red and Golden Torch showed free flowering, flower production was low in the months of January to March. There was no flower production during the months of November to May in Kawauchi, December to May in Golden Torch Adrian and October to January in Firebird. The variety Golden Torch Adrian and Lady Di recorded the highest flower production in the months of June and July.

4.1.1.3 Inflorescence length

The different varieties showed marked difference in the length of the inflorescence (Table 1). Inflorescence length observed was maximum in Banana Split (117.1 cm) and was significantly superior to other varieties. This was followed by

Kawauchi (108.2 cm) and Golden Torch (96.3 cm) which were on par. Minimum length was recorded in Rubra Red (73.2 cm) and was on par with Firebird (74.3 cm) and Lady Di (74.9 cm).

4.1.1.4 Stalk length

Significant differences in the stalk length of the different heliconia varieties were recorded (Table 1). The variety Banana Split recorded maximum stalk length (99.1 cm) and was significantly superior to all others, except Kawauchi (91.9 cm), which was followed by Golden Torch (81.8 cm) and Golden Torch Adrian (70.7 cm), whereas all the other varieties were statistically comparable.

4.1.1.5 Length of rachis

The variety Banana Split recorded maximum length of rachis (18.0 cm), followed by Kawauchi (16.3 cm) and were significantly superior to other varieties. This was followed by variety Golden Torch (14.5 cm) and Firebird (13.3 cm), which were on par. Minimum length was observed in variety Rubra Red (9.3 cm), whereas varieties Golden Torch Adrian (12.0 cm) and Lady Di (10.3 cm) were comparable.

4.1.1.6 Bract length

Significant differences were observed on the bract length of heliconia varieties (Table 1). The variety Kawauchi recorded maximum bract length (16.7 cm) and was comparable with Banana Split (15.8 cm). This was closely followed by Golden Torch Adrian (15.1 cm) and Golden Torch (14.7 cm), which were on par. Minimum bract length (11.7 cm) was recorded in Rubra Red.

4.1.1.7 Days from bud emergence to opening of basal bract

The shortest duration from bud emergence to opening of basal bract was shown by the variety Firebird (19.5 days) which was on par with Lady Di (20.0 days) and Golden Torch Adrian (21.0 days). The variety Banana Split (23.8 days) recorded the longest duration and was on par with Golden Torch (22.8 days), Kawauchi and Rubra Red (22.3 days, each)

Table 1. Flowering behaviour and floral characters of selected varieties of Heliconia

Varieties	Pattern of flowering	Blooming period	Inflorescence length (cm)	Stalk length (cm)	Length of rachis (cm)	Bract length (cm)	Days from bud emergence to opening of basal bract	Days for full unfurling of bract	Number of flowers / bract	Interval between opening of successive flowers in a bract	Number of inflorescences/plant / year	Inflorescence longevity (days)
Banana Split	Year Round	Continuous Jan - Mar less	117.1^{a}	99.1^{a}	18.0^{a}	15.8^{a}	23.8^{a}	19.5^{a}	9.6^{b}	3.8^{a}	82.3^{b}	40.1^{a}
Kawauchi	Seasonal	May - Nov	108.2^{b}	91.9^{a}	16.3^{a}	16.7^{a}	22.3^{a}	12.8^{c}	10.8^{ab}	2.4^{b}	54.3^{c}	42.0^{a}
Lady Di	Year Round	Continuous June - July highest Jan - Mar less	74.9^{d}	61.6^{d}	10.3^{c}	13.9^{b}	20.0^{b}	14.5^{b}	8.7^{c}	1.8^{c}	102.0^{a}	15.8^{c}
Rubra Red	Year Round	Continuous Mar - April less	73.2^{d}	63.9^{d}	9.3^{d}	11.7^{c}	22.3^{a}	12.3^{c}	9.4^{b}	2.0^{b}	87.3^{b}	16.3^{c}
Golden Torch	Year Round	Continuous Jan - Mar less	96.3^{bc}	81.8^{b}	14.5^{b}	14.7^{ab}	22.8^{a}	12.0^{c}	12.2^{a}	2.3^{b}	80.1^{b}	40.2^{a}
Golden Torch Adrian	Seasonal	May - Dec June - July highest	82.7^{c}	70.7^{c}	12.0^{c}	15.1^{ab}	21.0^{b}	11.0^{cd}	9.2^{b}	3.2^{a}	61.0^{c}	26.8^{b}
Fire bird	Seasonal	Jan - Oct	74.3^{d}	61.0^{c}	13.3^{b}	13.8^{b}	19.5^{b}	13.0^{c}	7.3^{c}	3.5^{a}	22.8^{d}	37.1^{a}

4.1.1.8 Days for full unfurling of all bracts

Lowest number of days for complete unfurling of all bracts was shown by the variety Golden Torch Adrian (11.0 days), followed by Golden Torch (12.0 days), Rubra Red (12.3 days), Kawauchi (12.8 days), and Firebird (13.0 days), which were on par. The highest value was recorded by the variety Banana Split (19.5 days), followed by Lady Di (14.5 days).

4.1.1.9 Number of flowers/bract

Significantly highest number of flowers/bract was observed on Golden Torch (12.2), closely followed by Kawauchi (10.8). Minimum number of flowers/bract (7.3) was observed in Firebird and was on par with Lady Di (8.7). The number of flowers/bract of the variety Banana Split (9.6) was comparable with Rubra Red (9.4) and Golden Torch Adrian (9.2).

4.1.1.10 Interval between the openings of successive flowers in a bract

The interval between the opening of successive flowers in a bract ranged from 1.8 days (Lady Di) to 3.8 days (Banana Split). The varieties Golden Torch Adrian and Firebird were comparable with Banana Split.

4.1.1.11 Number of inflorescences/plant/year

Significantly highest number of inflorescences was observed in Lady Di (102.0). This was followed by Rubra Red (87.3), Banana Split (82.3) and Golden Torch (80.1) and were comparable. Minimum production of inflorescence (22.8) was observed in Firebird. The varieties Golden Torch Adrian (61.0) and Kawauchi (54.3) were on par.

4.1.1.12 Inflorescence longevity

Marked differences were recorded in the longevity of the inflorescence on the plant (Table 1). Maximum number of days (42.0) was observed for the variety Kawauchi, followed by Golden Torch (40.2 days), Banana Split (40.1 days) longevity of Firebird (37.1 days) and were comparable. The lowest value was shown by the variety Lady Di (15.8 days) which was on par with Rubra Red (16.3 days).

4.1.2 Qualitative Characters

The heliconia varieties exhibited wide variation in all qualitative morphological characters of flowering stems (Table 2-3 and Plates 2-8). All the evaluated varieties were vegetation musoid (banana like leaves) and with erect inflorescence.

A wide range of variation was observed among the varieties for several qualitative morphological characters of flowering stems. The nature of inflorescence was erect in all the varieties. The bracts were either distichous or spiral. The heliconia variety Kawauchi had waxy bracts. Wide range of pigmentation was observed in the bract, rachis, sepals, ovary and pedicel.

4.1.3 Evaluation of heliconia varieties for use as cut flower

Mean data of the morphological inflorescence characters of the varieties evaluated are given in Table 4.

Based on the fresh weight of stem (FWS), the varieties were classified as lights (Golden Torch, Golden Torch Adrian, Lady Di, Rubra Red and Firebird) and heavy (Banana Split and Kawauchi).

Considering the stem diameter (SD) the varieties were classified as thin (Lady Di and Rubra Red) and medium (Banana Split, Kawauchi, Golden Torch, Golden Torch Adrian and Firebird).

All the varieties had inflorescence length between 63.3 and 117.1 cm (medium length). Most of the varieties evaluated in the study fit to the standard for inflorescence length, except Lady Di, Rubra Red, Golden Torch Adrian and Firebird.

Reduced length of rachis (LR) was observed in Rubra Red. In other varieties, the length of rachis varied from 10.3 cm (Lady Di) to 18.0 cm (Banana Split) and belonged to the category with medium length.

Among the varieties evaluated, wax on the inflorescence was presented only in Kawauchi.

Considering the bract arrangement, wax on inflorescence and fresh weight of stem, the varieties were classified as follows:

Table 2. Qualitative morphological characters of flowering stems of selected varieties of Heliconia

Varieties	Nature of inflorescence	Bract	Rachis	Sepals	Ovary	Pedicel
Banana Split	Erect	6-9 distichous bracts, chocolate (burnt sienna) on cheek of upper bracts with a thick yellow band along the lip. Lip green distally, less chocolate on basal bracts	Chocolate to greenish yellow	Green distally and white below	Yellow	Yellow
Kawauchi	Erect	7-8 distichous bracts, red with narrow golden yellow lip proximally, extending distally on younger bracts tip green. Basal bract green over most of keel, waxy coating present	Red becoming yellow between upper bracts	Green on distal half and white below	Cream	White
Lady Di	Erect	5-7 spiraled bracts, dark red becoming paler towards the cheek	Red or Pink	Cream yellow with dark green bands and white tip	Yellow proximally cream	Light yellow or cream
Rubra Red	Erect	4-6 spiraled bracts , red with dark orange or paler red infusion ,waxy coating present	Red with dark orange infusion	Orange yellow with red infusion	Dark orange distally and light orange below	Orange
Golden Torch	Erect	4-5 boat shaped distichous bracts. Golden yellow basal bracts with green keel and lip	Golden, often with small red areas at base	Golden with green tip	Golden on distel 1/3 and top, yellow below	Yellow with green tint
Golden Torch Adrian	Erect	5-8 spiraled bracts, maroon and dark red at base, distal half of upper bracts with yellow and splashes of red, lower bracts faint green keel	Maroon to dark red	Golden with faint green/dull green below	Bright yellow in tip and yellow flush of green or dull green below	Green yellow
Fire bird	Erect	5-8 distichous bracts, red to bright red over most of the bracts with a green line along lip on maroon background	Red	Green with white tip	Creamy or yellow with light green	Cream

Table 3. Comparison of the qualitative characters of the inflorescence of selected varieties of Heliconia

Inflorescence character	Banana Split	Kawauchi	Lady Di	Rubra Red	Golden Torch	Golden Torch Adrian	Firebird
Nature of inflorescence	Erect	Erect	Erect	Erect	Erect	Erect	Erect
Bract colour	Chocolate (burnt sienna)	Red - golden yellow	Dark red	Red - paler red	Golden yellow	Maroon - dark red	Blood red to bright red
Fading of colour on the bract base	Homogenous	Homogenous	Paler towards the cheek	Homogenous	Homogenous	Paler towards the distal half	Homogenous
Wax on the bract	Absent	Present	Absent	Absent	Absent	Absent	Absent
Colour of rachis	Chocolate - greenish yellow	Red - yellow	Red - pink	Red - dark orange	Golden yellow	Maroon - dark red	Red
Colour of sepals	Green	Green - white	Cream yellow	Red - dark orange	Golden yellow	Golden with faint green	Green with white tip

Plate 2. ***Heliconia bihai*** **(L.) L. cv. Banana Split**

Plate 3. ***Heliconia caribaea*** **Lamarck x** ***Heliconia bihai*** **(L.) L. cv. Kawauchi**

Plate 4. *Heliconia psittacorum* L.f. cv. Lady Di

Plate 5. *Heliconia psittacorum* L.f. cv. Rubra Red

Plate 6. ***Heliconia psittacorum*** **L.f. x** ***H. spathocircinata*** **Aristeguieta cv. Golden Torch**

Plate 7. ***Heliconia psittacorum*** **L.f. x** ***H.spathocircinata*** **Aristeguieta cv. Golden Torch Adrian**

Plate 8. ***Heliconia stricta*** **Huber cv. Firebird**

Table 4. Evaluation of morphological characters of inflorescence of selected varieties of heliconia as cut flower

Varieties	FWS (g)	SD (mm)	IL (cm)	LR (cm)	BA	WAX
Banana Split	220.0 Heavy	21.0 Medium	117.1 Medium	18.0 Medium	Distichous	Absent
Kawauchi	218.0 Heavy	23.0 Medium	108.2 Medium	16.3 Medium	Spiraled	Present
Lady Di	45.2 Light	8.0 Medium	74.9 Medium	10.3 Medium	Spiraled	Absent
Rubra Red	52.7 Light	9.0 Medium	73.2 Medium	9.3 Medium	Spiraled	Absent
Golden Torch	98.4 Light	15.0 Medium	96.3 Medium	14.5 Medium	Distichous	Absent
Golden Torch Adrian	75.3 Light	14.0 Medium	63.3 Medium	12.0 Medium	Spiraled	Absent
Firebird	62.3 Light	13.0 Medium	74.3 Medium	13.3 Medium	Distichous	Absent

FWS = Fresh weight of stem: Light (< 100 g); Medium (between 101 and 200 g); Heavy (> 200 g)

SD = Stem diameter 20 cm below the floral display: Thin (< 10.0 mm); Medium (between 10.1 and 30.0 mm); Thick (> 30.0 mm)

IL = Inflorescence length: Short (< 50.0 cm); Medium (between 50.1 and 150.0 cm); Long (> 150.0 cm)

LR = Length of rachis: Short (< 10.0 cm); Medium (between 10.1 and 30.0 cm); Long (between 30.1 and 50.0 cm);Too long (> 50.1 cm)

BA = Bract arrangement: Distichous or Spiraled

WAX= Wax on inflorescence: Present or Absent

Mean data of 10 inflorescence/variety is given

- High performance (fresh weight of stem < 100 g, wax absence and one plane/spiraled arrangement of bract)

  eg:- Golden Torch, Firebird (one plane arrangement)

  Lady Di, Rubra Red, Golden Torch Adrian (spiraled arrangement)

- Regular performance (fresh weight of stem between 101 and 200 g), wax absent, one plane/spiraled arrangement of bract)

  None of the evaluated varieties belonged to this group

- Low performance (fresh weight of stem > 200g, one plane/spiraled arrangement of bract)

  eg:- Banana Split (one plane arrangement of bract)

  Kawauchi (spiraled arrangement of bract)

Based on the evaluation, the varieties Golden Torch, Firebird, Lady Di, Rubra Red and Golden Torch Adrian were classified as cut flowers of high performance and Banana Split and Kawauchi as low performance.

Results reveal the superiority of the variety Golden Torch, which excelled in all quantitative and qualitative morphological characters of flowering stems like, duration of flowering, number of inflorescence produced/year, low fresh weight of stem, absence of wax and single plane arrangement of bracts. Hence it is ideal as cut flower and for landscape. Firebird was also found to be promising as cut flower and landscape plant, though flowering was seasonal.

Overall performance of Lady Di, Rubra Red and Golden Torch Adrian were observed to be ideal for the landscape, and as a cut flower for local markets. The varieties Banana Split and Kawauchi with heavy flowering stem were suitable for planting in landscapes.

4.2 Development of protocol for post harvest handling practices of heliconias

Data pertaining to the development of protocol for post harvest handling are presented in (Table 5 to 23).

4.2.1 Stage of harvest

Stage of harvest significantly influenced the vase life of heliconia inflorescence. The varietal differences were also significant (Table 5).

4.2.1.1 Banana split

Inflorescence harvested at 3-4 bracts open stage (stage 3) recorded the maximum vase life (6.0 days) and was significantly superior as compared to other stages. This was closely followed by 1-2 bracts open stage (stage 2). Remarkable variation could not be observed in the physiological loss of weight (PLW) of inflorescence at different harvest stages.

4.2.1.2 Kawauchi

Maximum vase life (6.0 days) was recorded at 3-4 bracts open stage (stage 3) and was significantly superior to other stages. The unopened bract stage (stage 1) recorded minimum vase life (3.5 days) whereas 1-2 bract open stage (stage 2) and all bracts open stage (stage 4) were on par. No significant changes in the PLW and water uptake were noted in different stage of harvest.

4.2.1.3 Lady Di

Inflorescence harvested at 1-2 bract open stage (stage 2) recorded maximum vase life (5.0 days) and was significantly superior to other stage of harvest. All the other stages of harvest were on par. The PLW was minimum (3.18 g) in stage 2 and was on par with unopened bract stage (stage 1). Maximum (7.02 g) PLW was recorded in all bracts open stage (stage 4). Water uptake was also minimum (13.75 ml) in stage 2, whereas that at all the other stages were on par.

4.2.1.4 Rubra Red

One to two bract open stage (stage 2) exhibited maximum vase life (4.0 days) and was on par with unopened bract stage (stage 1). Minimum vase life

Table 5. Vase life of heliconia inflorescences harvested at different stages of development

Varieties	Stage of harvest	Vase life (days)	PLW (g)	Water uptake (ml)	Symptoms of wilting
Banana Split	Stage 1	4.2[bc] (2.1706)	6.53[a]	15.00[ab]	Bract did not open, > 50% of the tip of bract turned black, sign of wilting
	Stage 2	4.7[b] (2.2892)	7.80[a]	18.75[a]	Dropping of flowers, blackening of bract started
	Stage 3	6.0[a] (2.5495)	7.77[a]	13.75[ab]	Dropping of bract and flowers, discolouration
	Stage 4	3.7[c] (2.0587)	8.72[a]	12.50[b]	Bract and flower drop, blackening of bracts
Kawauchi	Stage 1	3.5[c] (1.9961)	1.87[a]	4.75[a]	Bracts did not open, turned black
	Stage 2	4.7[b] (2.2892)	1.50[a]	5.00[a]	Darkening and discolouration, spots on bract, flower drop
	Stage 3	6.0[a] (2.5495)	2.70[a]	5.00[a]	Bract and flower drop, loss of brightness and discolouration of bracts
	Stage 4	4.7[b] (2.2892)	2.67[a]	5.00[a]	Bract and flower drop, loss of brightness and wilting
Lady Di	Stage 1	3.5[b] (1.9894)	3.42[c]	18.75[a]	Unopened bracts, blackened and loss of brightness
	Stage 2	5.0[a] (2.3452)	3.17[c]	13.75[b]	Flower drop, loss of brightness and discolouration of bract
	Stage 3	3.2[b] (1.9335)	5.10[b]	18.75[a]	Bract and flower drop, loss of brightness and blackening

Vase life of heliconia inflorescences harvested at different stages of development (contd…..)

Rubra Red	Stage 1	3.5^{ab} (1.9961)	2.25^{b}	5.00^{a}	Unopened bracts, blackened and loss of brightness
	Stage 2	4.0^{a} (2.1213)	1.90^{b}	2.75^{b}	Flower drop, loss of brightness and discolouration of bract
	Stage 3	3.2^{b} (1.9335)	2.65^{ab}	2.00^{b}	Bract and flower drop, loss of brightness and blackening
	Stage 4	3.0^{b} (1.8708)	3.37^{a}	2.75^{b}	Bract and flower drop, loss of brightness and blackening
Golden Torch	Stage 1	3.0^{b} (1.8708)	3.83^{a}	23.75^{a}	Unopened bract, loss of brightness, discolouration
	Stage 2	5.0^{a} (2.3452)	4.75^{a}	25.00^{a}	Flower drop, discolouration of bracts, loss of brightness
	Stage 3	2.5^{bc} (1.7260)	4.03^{a}	27.50^{a}	Bract discolouration, blackening, flower and bract drop, loss of brightness
	Stage 4	2.2^{c} (1.6536)	3.90^{a}	30.00^{a}	Loss of brightness flower and bract drop, blackening of bracts sign of senescence

Vase life of heliconia inflorescences harvested at different stages of development (Contd…)

Golden Torch Adrian	Stage 1	7.5^{a} (2.8270)	2.35^{c}	22.50^{b}	Bracts did not open, turned black
	Stage 2	8.0^{a} (2.9129)	5.78^{bc}	25.00^{b}	Darkening and discolouration, spots on bract, flower drop
	Stage 3	5.0^{b} (2.3452)	9.68^{a}	30.00^{ab}	Bract and flower drop, loss of brightness and discolouration of bracts
	Stage 4	4.0^{c} (2.1147)	9.23^{ab}	38.75^{a}	Bract and flower drop, loss of brightness and wilting
Firebird	Stage 1	4.2^{c} (2.1773)	2.17^{a}	5.25^{a}	Unopened bracts, blackened and loss of brightness
	Stage 2	5.0^{b} (2.3452)	2.07^{a}	5.00^{a}	Flower drop, loss of brightness and discolouration of bract
	Stage 3	5.7^{a} (2.4984)	2.10^{a}	4.50^{a}	Bract and flower drop, loss of brightness and blackening
	Stage 4	5.2^{ab} (2.3963)	2.00^{a}	4.75^{a}	Bract and flower drop, loss of brightness and blackening

Values in parenthesis are square root transformations

Stage 1 - Bud stage (no bracts open)
Stage 2 - 1-2 fully opened bracts
Stage 3 - 3-4 fully opened bracts
Stage 4 - All bracts opened
PLW – Physiological loss in weight

(3.0 days) was recorded by all bract open stage (stage 4) which also recorded minimum PLW (1.90 g).

4.2.1.5 Golden Torch

The different stages of harvest influenced the vase life significantly. The inflorescences when harvested at 1-2 bracts open stage (stage 2) remained for a longer period (5.0 days) and were significantly superior to other stages. This was followed by no bract open stage (stage 1). Minimum vase life (2.2 days) was recorded by all bracts open stage (stage 4). Remarkable variation could not be observed in PLW and water uptake for different stages of harvest.

4.2.1.6 Golden Torch Adrian

Among the different stages of harvest of the inflorescence tried, maximum vase life (8.0 days) was recorded in 1-2 bract open stage (stage 2), which was on par with no bract open stage i.e., stage 1 (7.5 days). They were significantly superior to other stages of harvest. Minimum vase life (4.0 days) was recorded in all bract open stage (stage 4). PLW and water uptake was significantly less in no bract open stage (stage 1) and was on par with 1-2 bract open stage (stage 2)

4.2.1.7 Firebird

Different stages of harvest showed marked differences in the vase life. Maximum vase life (5.8 days) was observed in inflorescence harvested at 3-4 bract opened stage (stage 3) which was on par with all bract open stage (stage 4). Appreciable difference could not be observed in physiological loss in weight and water uptake of the inflorescence belonging to different stage of harvest.

4.2.2 Effect of pre cooling

Data on the effect of pre cooling on the vase life of heliconia inflorescence are given in Table 6 and Fig. 2.

The influence of pre cooling temperature on the vase life of cut flowers of heliconia was significant. Maximum vase life was observed in all the varieties of heliconia when pre cooled at 20°C for 4 hours. The vase life ranged from 6.7 days (Lady Di) to 9.0 days (Golden Torch). This was followed by keeping at 15°C for 4 hours and at ambient condition (27°C). The cut flowers recorded minimum vase life (2.0 to 3.0 days) when pre cooled at 10°C for 4 hours.

4.2.3 Effect of pulsing treatments

Data pertaining to the effect of different pulsing treatments on the vase life of cut flowers of heliconia are presented in Table 7 to 13.

4.2.3.1 Banana Split

The different pulsing treatments significantly influenced the vase life of inflorescences of heliconia cv. Banana Split. The flowers remained for longer period of 8.0 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours which was on par (7.8 days) with 5 per cent sucrose and HQ 400 ppm. Remarkable variation could be observed in the vase life of cut flowers when pulsed with Benzyl Adenine (200 ppm and 400 ppm). It was effective in prolonging the vase life regardless if they were dipped or sprayed with 200 ppm and 400 ppm Benzyl adenine (6.0 and 5.0 days respectively). A hot water dip at 60°C for 5 seconds recorded minimum vase life (4.0 days) which was on par with control (Table 7).

4.2.3.2 Kawauchi

Kawauchi flowers remained for longer period of 8.7 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours and was

Table 6. Effect of Pre-cooling on the vase life of heliconia

Sl. No.	Varieties	Vase life (days) at different storage temperatures			
		10^0C	**15^0C**	**20^0C**	**Control**
1	Banana Split	2.7^d (1.7984)	5.7^b (2.4984)	8.0^a (2.9155)	4.0^c (2.1213)
2	Kawauchi	3.0^d (1.8708)	6.5^b (2.6441)	8.7^a (3.0405)	4.7^c (2.2892)
3	Lady Di	2.0^d (1.5811)	5.0^b (2.3452)	6.7^a (2.6913)	3.5^c (1.9961)
4	Rubra Red	2.2^c (1.6536)	4.7^b (2.2892)	7.0^a (2.7386)	4.5^b (2.2333)
5	Golden Torch	2.7^d (1.7984)	6.5^b (2.6441)	9.0^a (3.0822)	5.7^c (2.4984)
6	Golden Torch-Adrian	2.7^d (1.7984)	5.7^b (2.4984)	7.7^a (2.8713)	4.7^c (2.2892)
7	Firebird	3.0^d (1.8708)	5.5^b (2.4474)	8.7^a (3.0405)	4.7^c (2.2892)

Values in parenthesis are square root transformations

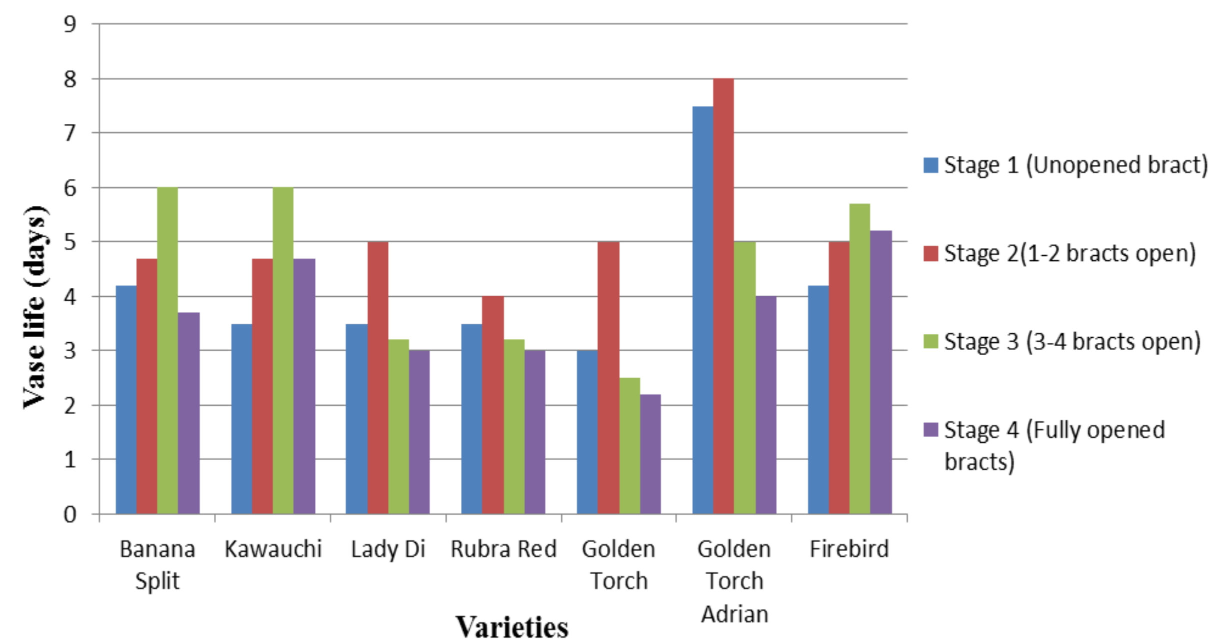

Fig. 1. Vase life of heliconia inflorescences harvested at different stages of development

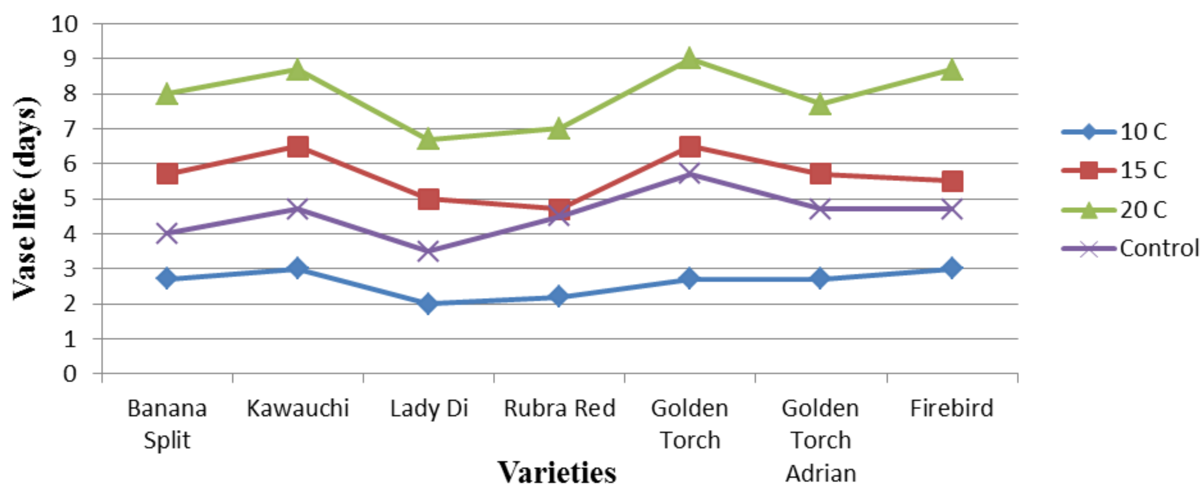

Fig. 2. Effect of pre cooling on the vase life of heliconia

Table 7. Effect of pulsing treatments on the vase life of heliconia cv. Banana Split

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	4.0[d] (2.1213)	5.20[b]	15.00
P1	8.0[a] (2.9155)	8.25[a]	13.75
P2	7.7[a] (2.8713)	8.65[a]	16.25
P3	6.0[b] (2.5495)	8.30[a]	16.25
P4	6.0[b] (2.5495)	8.85[a]	16.25
P5	5.0[c] (2.3452)	4.95[b]	12.50
P6	5.0[c] (2.3452)	5.67[b]	15.00
P7	4.0[d] (2.1213)	4.60[b]	15.00

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^0C for 5 seconds
PLW – Physiological loss in weight

significantly superior to other treatments. This was followed by 5 per cent sucrose and HQ 400 ppm (7.2 days). Benzyl adenine 100 ppm as spray within 1 hour after harvest recorded minimum vase life (4.5 days). This was on par with Benzyl adenine as 200 ppm spray, hot water dip at 60°C for 5 seconds and control (Table 8).

4.2.3.3 Lady Di

Different pulsing treatments significantly influenced the vase life of cut flowers of heliconia cv. Lady Di (Table 9). Flowers remained fresh for longer period of 5.7 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours. This was followed by a solution containing 5 per cent sucrose and HQ 400 ppm (5.0 days), BA 100 ppm for 6 hour (5.0 days), BA 100 ppm as spray within 1 hour after harvest (4.7 days) and hot water dip at 60°C for 5 seconds (4.5 days). Minimum vase life (3.0 days) was recorded under control (no pulsing).

4.2.3.4 Rubra Red

Pulsing treatments significantly influenced the vase life of cut flowers of heliconia cv. Rubra Red (Table 10). The flowers remained fresh for longer period of 5.5 days when pulsed with a solution containing 5 per cent Sucrose and HQ 200 ppm for 6 hours which was on par with all the pulsing treatments, except hot water dip at 60°C for 5 seconds and control. Hot water dip at 60°C for 5 second recorded minimum vase life (4.2 days).

4.2.3.5 Golden Torch

Appreciable differences were observed in vase life of cut flowers of heliconia cv. Golden Torch in various pulsing treatments (Table 11). The flowers remained for 8.5 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours, which was on par with 5 per cent sucrose and HQ 400 ppm (8.2 days). Remarkable variation could not be observed in the vase life

Table 8. Effect of pulsing treatments on the vase life of heliconia cv. Kawauchi

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	5.0^{de} (2.3452)	1.92^{b}	4.75^{a}
P1	8.7^{a} (3.0405)	2.30^{ab}	4.50^{ab}
P2	7.2^{b} (2.7828)	2.62^{a}	3.50^{b}
P3	6.0^{c} (2.5457)	2.22^{ab}	5.00^{a}
P4	5.5^{cd} (2.4474)	2.47^{ab}	4.75^{a}
P5	4.5^{e} (2.2333)	2.22^{ab}	4.75^{a}
P6	4.7^{de} (2.2892)	2.30^{ab}	4.75^{a}
P7	4.7^{de} (2.2892)	2.27^{ab}	5.00^{a}

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^{0}C for 5 seconds
PLW – Physiological loss in weight

Table 9. Effect of pulsing treatments on the vase life of heliconia cv. Lady Di

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	3.0[d] (1.8708)	2.75[b]	12.50
P1	5.7[a] (2.4984)	2.65[b]	13.75
P2	5.0[b] (2.3452)	3.00[b]	16.25
P3	5.0[b] (2.3452)	4.77[a]	15.00
P4	4.0[c] (2.1213)	4.65[a]	11.25
P5	4.7[b] (2.2892)	2.32[b]	15.00
P6	4.0[c] (2.1213)	2.32[b]	16.25
P7	4.5[b] (2.2333)	3.00[b]	11.25

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^0C for 5 seconds
PLW – Physiological loss in weight

Table 10. Effect of pulsing treatments on the vase life of heliconia cv. Rubra Red

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	4.5^{bc} (2.2333)	3.00	5.75^{ab}
P1	5.5^{a} (2.4474)	2.60	5.25^{ab}
P2	5.0^{ab} (2.3452)	2.67	5.25^{ab}
P3	5.0^{ab} (2.3452)	3.32	6.00^{a}
P4	5.0^{ab} (2.3452)	3.35	5.25^{ab}
P5	5.2^{a} (2.3963)	2.72	5.00^{b}
P6	5.0^{ab} (2.3452)	2.42	5.25^{ab}
P7	4.2^{c} (2.1773)	2.60	5.25^{ab}

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^{0}C for 5 seconds
PLW – Physiological loss in weight

Table 11. Effect of pulsing treatments on the vase life of heliconia cv. Golden Torch

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	6.0[c] (2.5495)	2.85	5.00
P1	8.5[a] (2.9988)	3.02	5.00
P2	8.2[a] (2.9572)	3.27	6.25
P3	7.0[b] (2.7386)	3.17	7.50
P4	7.0[b] (2.7386)	3.20	6.25
P5	7.0[b] (2.7386)	3.50	5.00
P6	7.2[b] (2.7828)	2.65	5.00
P7	7.0[b] (2.7386)	2.82	5.00

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^0C for 5 seconds
PLW – Physiological loss in weight

of cut flowers when pulsed with Benzyl Adenine solution (200 ppm and 400 ppm), Benzyl adenine (100 ppm and 200 ppm) as spray within 1 hour after harvest and hot water dip at 60°C for 5 seconds of 7.0 days. Minimum vase life (6.0 days) was recorded under control (no pulsing treatment).

4.2.3.6 Golden Torch Adrian

The different pulsing treatments significantly influenced the vase life of cut flowers of heliconia cv. Golden Torch Adrian (Table 12). Maximum vase life (7.2 days) was recorded when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours, followed by five per cent sucrose and HQ 400 ppm (6.7 days) and were on par. Minimum vase life (3.7 days) was recorded under control (no pulsing treatment).

4.2.3.7 Firebird

Among the pulsing solutions tried, maximum vase life (8.5 days) was when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours and was significantly superior(Table 13). This is followed by a solution containing 5 per cent sucrose and HQ 400 ppm (7.5 days). The other pulsing treatments, Benzyl Adenine (100 ppm and 200 ppm) as spray within 1 hour after harvest and hot water dip at 60°C for 5 seconds treatments were on par with control, which recorded the minimum vase life (5.0 days).

4.2.4 Effect of holding treatments

Data pertaining to the effect of holding treatments on the vase life of heliconia inflorescences are furnished in Table 14 to 20.

4.2.4.1 Banana Split

Holding treatments significantly influenced the vase life of cut flowers of heliconia cv. Banana Split (Table 14). Among the different treatments tried, maximum vase life (12.0 days) was recorded in a solution containing 5 per cent sucrose and HQ 100 ppm and was significantly superior. This was followed by a solution containing sucrose 5 per cent and HQ 200 ppm (11.0 days),

Table 12. Effect of pulsing treatments on the vase life of heliconia cv. Golden Torch Adrian

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	3.7^{d} (2.0587)	2.75^{ab}	5.00^{a}
P1	7.2^{a} (2.7772)	3.20^{ab}	4.25^{a}
P2	6.7^{ab} (2.6913)	3.32^{ab}	3.50^{ab}
P3	6.2^{b} (2.5968)	2.47^{b}	5.00^{a}
P4	6.0^{b} (2.5495)	2.50^{b}	2.00^{b}
P5	5.0^{c} (2.3452)	3.07^{ab}	5.00^{a}
P6	5.0^{c} (2.3452)	3.72^{a}	3.50^{ab}
P7	4.7^{c} (2.2892)	3.50^{ab}	5.00^{a}

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^{0}C for 5 seconds
PLW – Physiological loss in weight

Table 13. Effect of pulsing treatments on the vase life of heliconia cv. Firebird

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
P0	5.0[d] (2.3452)	2.52	4.75[a]
P1	8.5[a] (2.9988)	2.35	5.00[a]
P2	7.5[b] (2.8270)	2.25	4.50[ab]
P3	6.2[c] (2.5968)	2.15	3.75[b]
P4	6.2[c] (2.5968)	2.37	5.00[a]
P5	5.2[d] (2.3963)	2.65	5.00[a]
P6	5.0[d] (2.3452)	2.30	4.75[a]
P7	5.0[d] (2.3452)	2.77	5.00[a]

Values in parenthesis are square root transformations

P0- . Control (no pulsing treatment)
P1- Sucrose 5% + HQ 200ppm for 6 hours
P2- Sucrose 5% + HQ 400ppm for 6 hours
P3- BA 100ppm for 6 hours
P4- BA 200ppm for 6 hours
P5- BA 100ppm as spray within 1 h. after harvest
P6- BA 200ppm as spray within 1 h. after harvest
P7- Hot water dip at 60^0C for 5 seconds
PLW – Physiological loss in weight

Table 14. Effect of holding treatments on the vase life of heliconia cv. Banana Split

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	4.2[d] (2.1773)	6.27[ab]	11.25[b]
H1	12.0[a] (3.5355)	7.55[a]	20.00[a]
H2	11.0[b] (3.3896)	6.40[ab]	16.25[a]
H3	11.0[b] (3.3912)	6.07[ab]	18.75[a]
H4	11.2[b] (3.4273)	6.10[ab]	20.00[a]
H5	5.0[c] (2.3452)	4.92[b]	10.00[b]
H6	4.0[d] (2.1213)	5.27[b]	11.25[b]

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2 (SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

BA 100 ppm (11.0 days) and BA 200 ppm (11.2 days) and were on par. Minimum vase life was recorded in control (4.0 days) and was comparable with acidified water (4.3 days).

4.2.4.2 Kawauchi

Different holding treatments showed marked difference in the vase life of cut flowers of heliconia cv. Kawauchi (Table 15). Among the treatments, maximum vase life (11.0 days) was recorded in a solution containing 5 per cent sucrose and HQ 100 ppm, and was significantly superior. This was followed by a solution containing sucrose 5 per cent and HQ 200 ppm (9.7 days), BA 100 ppm (6.5 days), BA 200 ppm (6.2 days), Acidified water at 3.5 ppm (6.2 days) and 5 per cent sucrose and 200 ppm Aluminium Sulphate (6.7 days) and was on par. Minimum vase life was recorded in control (5.2 days).

4.2.4.3 Lady Di

Among the different holding solutions used in Lady Di flowers (Table 16) maximum vase life (10.0 days) was recorded in a solution containing 5 per cent sucrose and HQ 100 ppm and was significantly superior. This was followed by a solution containing sucrose 5 per cent and HQ 200 ppm (7.2 days) and BA 100 ppm (7.2 days) and were on par. Minimum vase life was recorded in control (4.0 days) which was on par with acidified water (4.5days).

4.2.4.4 Rubra Red

Significantly maximum vase life (6.5 days) was recorded in a solution containing 5 cent sucrose and HQ 100 ppm , and was on par with solution containing sucrose 5 per cent + HQ 200 ppm (6.2 days), BA 100 and BA 200 ppm (6.0 days, each). Minimum vase life (4.5 days) was recorded in control and acidified water (4.2 days) (Table 17).

Table 15. Effect of holding treatments on the vase life of heliconia cv. Kawauchi

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	6.2c (2.5968)	3.02	4.25
H1	11.0a (3.3896)	3.00	4.50
H2	9.7b (3.2008)	2.72	5.00
H3	6.5c (2.6441)	2.47	5.00
H4	6.2c (2.5968)	2.47	4.50
H5	6.7c (2.6913)	2.30	4.25
H6	5.2d (2.3963)	2.47	3.50

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2 (SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

Table 16. Effect of holding treatments on the vase life of heliconia cv. Lady Di

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	4.5[d] (2.2333)	3.32[a]	8.75[abc]
H1	10.0[a] (3.2404)	2.50[ab]	6.25[bcd]
H2	7.2[b] (2.7729)	2.00[b]	5.00[cd]
H3	7.2[b] (2.7729)	2.27[ab]	2.50[d]
H4	6.0[bc] (2.5495)	2.25[ab]	3.50[d]
H5	5.0[cd] (2.3452)	2.40[ab]	10.00[ab]
H6	4.0[d] (2.1213)	2.87[ab]	11.75[a]

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2 (SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

Table 17. Effect of holding treatments on the vase life of heliconia cv. Rubra Red

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	4.2[c] (2.1773)	3.60[ab]	2.00[b]
H1	6.5[a] (2.6441)	3.20[ab]	5.00[a]
H2	6.2[a] (2.5968)	2.62[ab]	5.00[a]
H3	6.0[ab] (2.5495)	3.72[a]	5.00[a]
H4	6.0[ab] (2.5495)	2.60[b]	5.00[a]
H5	5.5[b] (2.4474)	2.72[ab]	2.75[b]
H6	4.5[c] (2.2333)	3.02[ab]	2.00[b]

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2 (SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

4.2.4.5 Golden Torch

Among the different holding solutions tried in cut flowers of heliconia cv. Golden Torch, maximum vase life (14.5 days) was recorded in a solution containing 5 per cent sucrose and HQ 200 ppm, and was on par with solution containing sucrose 5 per cent and HQ 100 ppm (14.2 days). Minimum vase life was recorded in control (4.0 days) and acidified water (4.2 days) which were on par (Table 18).

4.2.4.6 Golden Torch Adrian

Holding treatments significantly influenced the vase life of cut flowers of heliconia cv. Golden Torch Adrian (Table 19). Maximum vase life (8.2 days) was recorded in a solution containing 5 per cent sucrose and HQ 100 ppm, and on par with solution containing sucrose 5 per cent and HQ 100 ppm (7.7 days). Minimum vase life was recorded in control (4.0 days) and was on par with acidified water (4.2 days).

4.2.4.7 Firebird

The influence of holding treatments on the vase life of cut flowers of heliconia cv. Firebird was remarkable. Maximum vase life (12.2 days) was recorded in a solution containing 5 per cent sucrose and HQ 100 ppm and was significantly superior to others (Table 20). This was followed by a holding solution containing sucrose 5 per cent and HQ 200 ppm (11.0 days). Minimum vase life was recorded in control (6.5 days) and was on par with acidified water (7.0 days).

4.2.5 Storage studies

Appreciable differences were observed in the storage life of heliconia inflorescences under five storage conditions (Table 21 and Fig. 3).

Table 18. Effect of holding treatments on the vase life of heliconia cv. Golden Torch

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	4.2[e] (2.1773)	2.92[b]	4.25[ab]
H1	14.2[a] (3.8402)	3.35[a]	6.25[a]
H2	14.5[a] (3.8724)	3.27a	4.25[ab]
H3	11.2[b] (3.4273)	2.87[bc]	2.00[b]
H4	10.2[c] (3.2781)	3.52[a]	4.25[ab]
H5	5.5[d] (2.4474)	2.65[c]	4.25[ab]
H6	4.0[e] (2.1147)	3.55[a]	2.75[b]

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2(SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

Table 19. Effect of holding treatments on the vase life of heliconia cv. Golden Torch Adrian

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	4.2[c] (2.1773)	2.50	2.00[c]
H1	8.2[a] (2.9572)	3.00	5.00[b]
H2	7.7[a] (2.8687)	2.65	5.00[b]
H3	6.5[b] (2.6441)	2.82	6.25[b]
H4	6.0[b] (2.5457)	2.35	8.75[a]
H5	4.5[c] (2.2333)	3.32	5.00[b]
H6	4.0[c] (2.1213)	3.55	5.00[b]

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2 (SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

Table 20. Effect of holding treatments on the vase life of heliconia cv. Firebird

Treatments	Vase life (days)	PLW (g)	Water uptake (ml)
H0	7.0^{de} (2.7386)	1.82^{c}	4.00
H1	12.2^{a} (3.5702)	2.45^{ab}	4.75
H2	11.0^{b} (3.3912)	2.37^{ab}	4.75
H3	7.7^{c} (2.8713)	2.15^{abc}	3.75
H4	7.5^{cd} (2.8270)	2.60^{a}	4.75
H5	8.0^{c} (2.9155)	2.07^{bc}	4.75
H6	6.5^{e} (2.6441)	2.15^{abc}	4.00

Values in parenthesis are square root transformations

H0- Acidified water (3.5 pH)
H1- Sucrose 5% + HQ 100 ppm
H2- Sucrose 5% + HQ 200ppm
H3- BA 100ppm
H4- BA 200ppm
H5- Sucrose 5% + $Al_2(SO_4)_3$ 200ppm
H6- Control (distilled water)
PLW – Physiological loss in weight

Table 21. Effect of Storage temperature on the post harvest life (days) of heliconia

Sl. No.	Varieties	Storage temperatures				
		8^0C	11^0C	14^0C	17^0C	27^0C
1	Banana Split	2.2^d (1.6391)	2.8^d (1.8129)	6.8^b (2.7008)	8.6^a (3.0155)	4.6^c (2.2557)
2	Kawauchi	3.0^e (1.8708)	3.8^d (2.0712)	8.4^b (2.9801)	11.4^a (3.4489)	4.6^c (2.2557)
3	Lady Di	2.0^e (1.5811)	3.6^c (2.0211)	6.6^b (2.6630)	9.0^a (3.0805)	2.8^d (1.8129)
4	Rubra Red	2.2^d (1.6391)	3.2^c (2.0712)	6.4^b (2.6252)	8.4^a (2.9822)	3.8^c (2.0712)
5	Golden torch	3.0^e (1.8708)	3.8^d (2.0712)	8.6^b (3.0155)	11.8^a (3.5067)	5.8^c (2.5086)
6	Golden Torch Adrian	2.8^e (1.8129)	5.0^c (2.3452)	7.8^b (2.8801)	11.2^a (3.4200)	4.4^d (2.2109)
7	Firebird	2.6^e (2.3452)	3.6^d (2.0211)	7.8^b (2.8801)	11.6^a (3.4778)	5.0^c (2.3452)

Values in parenthesis are square root transformations

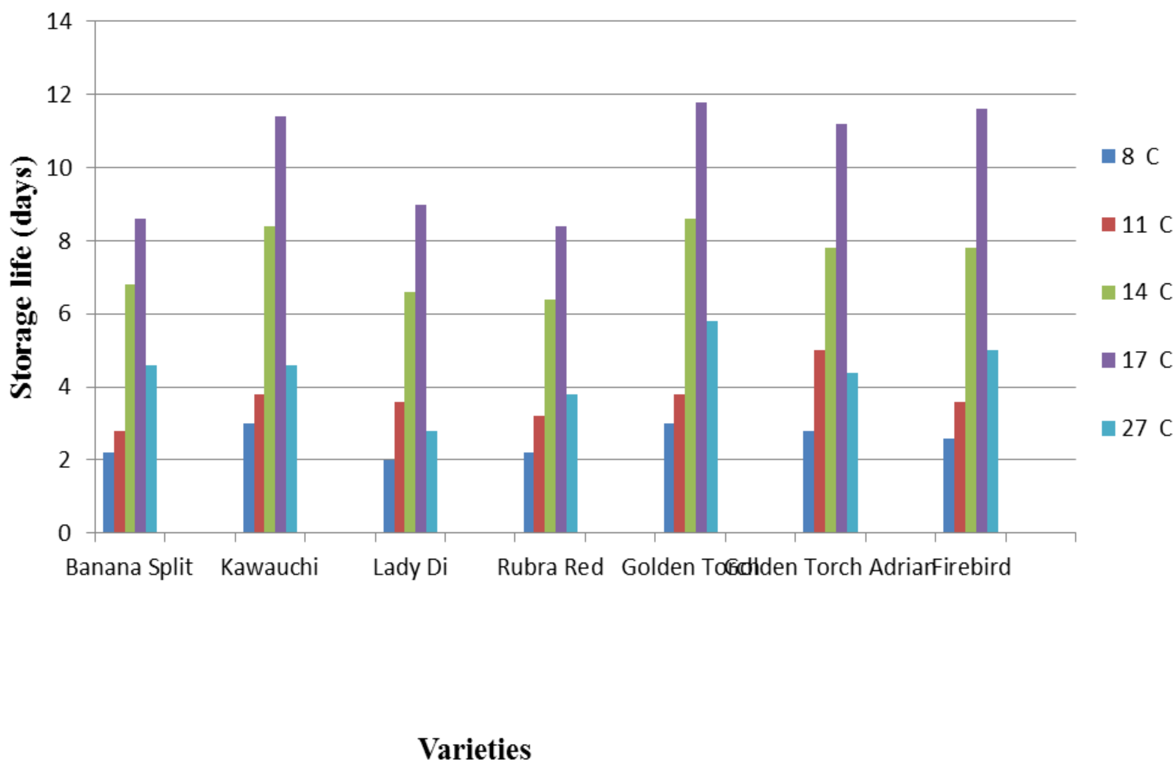

Fig. 3. Effect of storage temperature on the storage life of heliconia

Storage life of heliconia varieties was significantly superior (8.6 to 11.6 days) when stored under a temperature of 17^0C than either at the lower temperatures of 8^0C, 11^0C and 14^0C nor at the ambient conditions (27^0C). Storage temperature of 14^0C was the second best treatment (6.4 to 8.6 days).

The cut flowers when stored under cold storage at 11^0C or less developed black spots at the base of the bract.

4.2.6 Packing

Data pertaining to the effect of different packing methods on the inflorescences of heliconia are furnished in Table 22.

Different conditions of packing (wet and dry) significantly influenced the vase life in all the varieties of heliconia. The cut flowers remained for a longer period in the vase when plugged with wet cotton at the peduncle end.

In heliconia var. Banana Split, lining materials like polythene sheet (11.8 days) newspaper (9.6 days) brown kraft paper (7.4days) and butter paper (5.4 days) influenced the vase life positively when plugged, than when packed dry. Influence of lining material was evident when packed dry. The vase life ranged from 4.6 days (butter paper) to 7.6 (polythene sheet) when packed dry. The cut flowers remained for a period of 2.8 and 3.8 days in vase after being packed for 3 days without any lining material under dry and wet condition respectively.

Vase life of heliconia cv. Kawauchi, Lady Di, Rubra Red, Golden Torch, Golden Torch Adrian and Firebird was significantly the highest when polythene sheet was used as the lining material under both dry and wet conditions. The vase life ranged from 4.6 days (Rubra Red) to 8.8 days (Golden Torch) when packed dry and 7.0 days (Rubra Red) to 14.8 days (Golden Torch) when plugged with wet cotton. The lining materials like newspaper and brown kraft paper also influenced the vase life positively. All the heliconia varieties remained in the vase for a lesser

Table 22. Effect of Packing condition and lining materials on the vase life of heliconia

Sl. No	Varieties	Condition of packing	Vase life (Days)				
			Butter paper	Polythene sheet	News paper	Brown kraft paper	Control (without lining)
1	Banana Split	D	4.6[d] (2.2557)	7.6[a] (2.8447)	6.6[b] (2.6630)	5.6[c] (2.4678)	2.8[e] (1.8129)
		W	5.4[d] (2.4269)	11.8[a] (3.5067)	9.6[b] (3.1771)	7.4[c] (2.8094)	3.8[e] (2.0712)
2	Kawauchi	D	3.6[e] (2.0211)	6.6[a] (2.6630)	5.4[b] (2.4269)	4.4[c] (2.2109)	2.8[e] (1.8129)
		W	5.6[d] (2.4678)	10.8[a] (3.3610)	8.6[b] (3.0155)	6.6[c] (2.6630)	4.0[e] (2.1213)
3	Lady Di	D	3.6[d] (2.0211)	7.8[a] (2.8801)	6.6[b] (2.6630)	4.8[c] (2.3004)	2.8[e] (1.8129
		W	5.8[b] (2.5086)	9.8[a] (3.2087)	7.6[b] (2.8447)	6.8[c] (2.7008)	4.8[e] (2.3004)
4	Rubra Red	D	2.8[c] (1.8129)	4.6[a] (2.2557)	3.6[b] (2.0211)	2.6[c] (1.7550)	2.2[c] (1.6391)
		W	3.6[d] (2.0211)	7.0[a] (2.7386)	5.6[b] (2.4678)	4.6[c] (2.2557)	2.8[e] (1.8129)
5	Golden Torch	D	2.8[e] (1.8129)	8.8[a] (3.0489)	7.6[b] (2.8447)	5.6[c] (2.4678)	3.8[d] (2.0712)
		W	3.4[e] (1.9710)	14.8[a] (3.9112)	12.6[b] (3.6188)	8.8[c] (3.0489)	4.6[d] (2.2557)
6	Golden Torch Adrian	D	3.8[d] (2.0712)	6.6[a] (2.6630)	5.8[b] (2.5086)	4.6[c] (2.2557)	2.8[e] (1.8129)
		W	4.6[d] (2.2557)	8.8[a] (3.0489)	7.6[b] (2.8447)	6.6[c] (2.6630)	4.0[d] (2.1213)
7	Firebird	D	3.6[c] (2.0211)	7.4[a] (2.8094)	5.4[b] (2.4269)	4.2[c] (2.1608)	3.8[c] (2.0712)
		W	4.4[e] (2.2109)	11.6[a] (3.4778)	9.4[b] (3.1455)	6.8[c] (2.7008)	5.2[d] (2.3861)

Values in parenthesis are square root transformations
D - Packed without plugging the peduncle ends
W - Packed after plugging the peduncle ends with wet cotton

period (2.2 to 5.2 days) only when packed without lining material under both the conditions.

Based on the results obtained from the studies conducted on post harvest handling of seven heliconia varieties, the protocol for post harvest management of heliconia has been developed (Table 23).

Table 23. Protocol for Post harvest management of Heliconia

Stage of harvest
One to two fully opened bracts

↓

Pre cooling
20^0C for 4 hours

↓

Pulsing
HQ 200 ppm, Sucrose 5 % for 6 hours

↓

Plugging
Plugging the end of stem with wet cotton

↓

Covering
Covering with polythene sheet

↓

Packing
Cardboard boxes with $KMnO_4$

↓

Storage
Storage at 17^0C

↓

Holding
Holding 100 ppm + Sucrose 5 %

DISCUSSION

5. DISCUSSION

Heliconias are wonderful tropical plants with multi-colour bracts and varied flower structure and long shelf life. It is the only genus in the family Heliconiaceae, which is a member of a largest taxonomical category called order Zingiberales. Its demand for cut flower trade is increasing day-by-day because of the long vase life, attractive colour and exotic shape. The results from the study conducted to evaluate the flowering and post harvest dynamics of heliconias are discussed below.

In the present study seven varieties of *Heliconia* belonging to different species were evaluated. They were *Heliconia bihai* (L.) L. cv. Banana Split, *Heliconia caribaea* Lamarck x *Heliconia bihai* (L.) L. cv. Kawauchi, *Heliconia psittacorum* L.f. cv. Lady Di, *Heliconia psittacorum* L.f. cv. Rubra Red, *Heliconia psittacorum* L.f. x *H. spathocircinata* Aristeguieta cv. Golden Torch, *Heliconia psittacorum* L.f. x *H.spathocircinata* Aristeguieta cv. Golden Torch Adrian and *Heliconia stricta* Huber cv. Firebird.

5.1 Field performance of heliconias

The performance of any plant depends upon its inherent genetic characters as influenced by growing environmental conditions. Differences in flower longevity and quality among varieties may be due to the difference in anatomical, physiological, physical, biochemical and genetic makeup.

The present study reveals that under South Kerala condition, there was no uniformity in flowering behavior of different varieties. Considering the flowering pattern, some of the varieties showed free flowering, whereas some others were significantly seasonal. Free flowering was observed in *H. psittacorum* varieties Lady Di, Rubra Red and the hybrid Golden Torch and also in *Heliconia bihai* (L.) L. cv. Banana Split. The results obtained is in confirmity with the findings of Juan (1997) and Sanjeev *et al.* (2010) that the heliconias especially the *H. psittacorum* varieties bloom throughout the year.

Many species exhibit seasonal pattern of flowering (Criely *et. al.,* 1999). *H. latispatha* showed an irregular pattern of flowering during the cycle of growth with the peak occurring in July to August (Maciel and Rojas (1994). Climatic variables such as wind, rain, relative humidity, temperature, light intensity and spectral quality are the triggers for the time of flowering in plants. Continuity if flowering can be due to constancy of environmental conditions or adaptability to environmental fluctuations.

The heliconia varieties exhibited wide variation in all quantitative and qualitative morphological characters of flowering stems. Significantly maximum number of flowering stems were recorded in Lady Di (102.0) followed by Rubra Red (87.3), Banana Split (82.3), and Golden Torch (80.1). This variability may be associated with the genetic characteristics of the genotypes or adaptability to the climatic conditions (Costa *et.al*. 2009 and Sreenivas *et. al.* 2012).

Significant variation was observed among the varieties for flowering traits such as fresh weight of stem, inflorescence length, length of rachis, bract length, etc. The morphological characters of the inflorescence were evaluated according to Castro (1993) for use as cut flower. Based on the fresh weight of stem (FWS), the varieties were classified as Light (< 100 g): Golden Torch, Golden Torch Adrian, Lady Di, Rubra Red and Firebird; Heavy (> 200 g) Banana Split and Kawauchi. The fresh weight of stem is directly related to the transportation costs. Lighter heliconia stems are more adequate for commercialization as cut flower.

Considering the stem diameter (SD) the varieties were classified as: Thin (< 10.0 mm): Lady Di and Rubra Red; Medium (between 10.1 and 30.0 mm): Banana Split, Kawauchi, Golden Torch, Golden Torch Adrian and Firebird. All the varieties had inflorescence length between 63.3 and 117.1 cm and thus classified as medium length (between 50.1 and 150.0 cm). In

Pernambuco State, inflorescence with 80 cm is the commercialization standard for heliconia (Lalrinawmi and Talukadar, 2000). Based on inflorescence length most of the varieties evaluated in the study fit to the commercialization standard, except Lady Di, Rubra Red, Golden Torch Adrian and Firebird.

All the varieties tested except Rubra Red, the length of rachis varied from 10.3 cm (Lady Di) to 18.0 cm (Banana Split) and belonged to the category with medium length (between 10.1 and 30.0 cm). Wide variation in inflorescence length and rachis in 10 species (Lalrinawmi and Talukadar, 2000) and 7 cultivars of *Heliconia psittacorum* and inter specific hybrids have been reported (Rocha *et. al*., 2010). This study also confirm with their observations.

The bract arrangement on the inflorescence has an important influence on handling and packing of inflorescences. Based on the bract arrangement the varieties (Banana Split, Golden Torch and Firebird) are classified as distichous *ie.* bract arrangement in one plane; and (Kawauchi, Lady Di, Rubra Red and Golden Torch Adrian) as spiraled. Inflorescences with bract arrangement in one plane allow easier handling and packing and also more number of stems per box than that of spirally arranged bracts. Among the varieties evaluated, wax on the inflorescence was presented only in Kawauchi. According to Loges *et al.* (2005) inflorescences with waxy bracts should not be immersed in water during cleaning to avoid stains on the bract. Post harvest handling and transportation may move the wax from the surface of the bract.

Considering the bract arrangement, wax on inflorescence and fresh weight of stem, the varieties having fresh weight of stem up to 100 g, absence of wax and one plane/spiral arrangement of bract were classified as High performance, fresh weight of stem between 101 to 200 g, wax absent and one plane /spiral arrangement of bract as Regular performance and the fresh weight of stem >200g, spiraled/one plane arrangement of bract as Low performance (Castro, 1993).

Based on the evaluation, the heliconia varieties Golden Torch, Lady Di, Rubra Red, Golden Torch Adrian and Firebird were classified as high performance and Banana Split and Kawauchi as low performance.

For heliconia cut flower industry, production inflorescence during the whole year, light flowering stem for lower transportation costs, flowering stems less than 80 cm, stems with diameter thick enough for better handling and lighter weight of inflorescence, inflorescence with no wax and no hairs, and bract arranged in one plane for easier handling and packing are the characteristic to be taken into consideration.

Results reveal the superiority of the variety Golden Torch, which excelled in all qualitative and quantitative morphological characters of flowering stems viz., continuous flowering, number of inflorescence produced/year, fresh weight of stem less than 100 g, wax absence and one plane arrangement of bracts. Hence, it is ideal as cut flower and for landscaping. Sreenivas *et al.* (2012) also observed profused flowering and prolonged blooming in the cultivar Golden Torch and hence ideal for the landscape. Firebird was also found to be promising as landscape plant and cut flower, though flowering was seasonal. Overall performance of Lady Di, Rubra Red and Golden Torch Adrian were observed to be ideal for the landscaping, and as a cut flower for local markets. Presence of spiraled bracts make handling and packing difficult in these varieties.

The varieties Banana Split and Kawauchi with heavy flowering stems would have higher influence on transportation costs as cut flower. They were also observed to be ideal as landscape plant and recommended for commercial cultivation.

5.2 Post harvest studies

Cut flowers in general, are considered as highly perishable commodities and vulnerable to large post harvest losses. Once severed from the plant, they are deprived of their natural resources of water and nutrients and wilt rapidly and the cut flowers carry on all life processes at the expense of stored food in the form of carbohydrates, proteins and fats for a few more days. The vase life of cut flowers varies with the variety. The environment which has supported the growth of the crop also has a role to play. The season, time and stage of harvest, post harvest treatments and ethylene production and several other factors influence the keeping quality of cut flowers. It is claimed that 70 per cent of the potential lasting of cut flowers are predetermined by maturity of inflorescence at the time of harvest, while rest by post harvest factors. Post harvest behaviour and lasting quality of flower species and cultivars vary considerably.

The optimum stage at which flowers are to be harvested varies with plant species. The heliconia inflorescences are harvested 8-9 weeks after emergence of shoot. Opening of bracts on the inflorescence is also used as a criterion for harvesting the flower. Broschat and Donselman (1983) reported that heliconia flowers can be cut when 2-3 bracts are open, but tighter flowers can also be used effectively in flower arrangement. They are normally harvested in the morning by pulling the stem from the plant clump at mature stage, characterized by the bract being split at the top, allowing the sepals inside the inflorescence boat to be seen.

In the present study also maturity of the inflorescence at the time of harvest significantly influenced the vase life of heliconia. *Heliconia* varieties Banana Split, Firebird and Kawauchi inflorescences harvested at 3-4 bracts open stage (stage 3) recorded the maximum vase life (7.0 days). *Heliconia psittacorum* varieties was best at 1-2 bracts open stage (stage 2). This is in confirmity with the findings of Criley and Paull (1993) that for *H. psittacorum* the harvest should be done when one to two bracts are open and for larger heliconias one-half to two-thirds fully open. According to Bahybalid *et al.* (2011) Golden Torch inflorescences harvested at unopened bract stage recorded maximum vase life, however it failed to exhibit further bract opening that reduced visual appeal. Similar visual effect was observed in the present study also in all heliconia varieties when harvested at unopened bract stage.

Plant material should be cooled as soon as possible after harvest to minimize deterioration. Rudnick *et al.* (1991) observed that pre cooling of cut flowers maintained an appropriate low temperature level inside the package during the entire cold storage and shipping period. Significantly maximum vase life was observed in all the varieties of heliconia when pre cooled at 20°C for 4 hours. According to Marcsik (2003) heliconia flowers are pre cooled at 13^0C to remove field heat for at least one hour before packing.

Rapid cooling of packaged cut flowers and foliage reduces the time and they would otherwise pick up higher temperature and therefore helps to prolong the quality and vase life. High respiratory activity not only generates further heat around the product but also uses up stored reserves within the flowers and foliage (Elgar, 1998). He also reported that a low temperature treatment of cut flowers and foliage after harvest reduced the rate of ethylene production and depleted stored carbohydrates from the leaves.

Pulsing treatment significantly influenced the vase life of heliconia inflorescences. Pulsing refers to a short duration pre treatment or pre storage treatment and the effect lasts throughout the vase life of a cut flower and foliage. The increase in vase life (1.2 to 2.0 fold) of heliconia inflorescences pulsed with HQ 200 ppm + sucrose five per cent for 6 hours was evident over the untreated control. There was 1.4 and 1.8 fold greater vase life of Golden Torch and Golden Torch Adrian inflorescences following treatment with sucrose 5 per cent + HQ 400 ppm (Table 24 and Fig. 4). Influence 8HQ in extending post harvest life of cut flowers has been reported. Halevy *et al.* (1978) could increase the post harvest longevity of Bird-of-Paradise inflorescences by placing the stems in a pulsing solution of 10 per cent sucrose + 250 ppm HQC + 150 ppm Citric acid for 48 hours prior to packing. Swapna (2000) compared different pulsing solutions and reported a 6 hour pulse with a solution containing 500 ppm HQ and 5 per cent sucrose as the best to increase the vase life of *Dendrobium* cv. Sonia

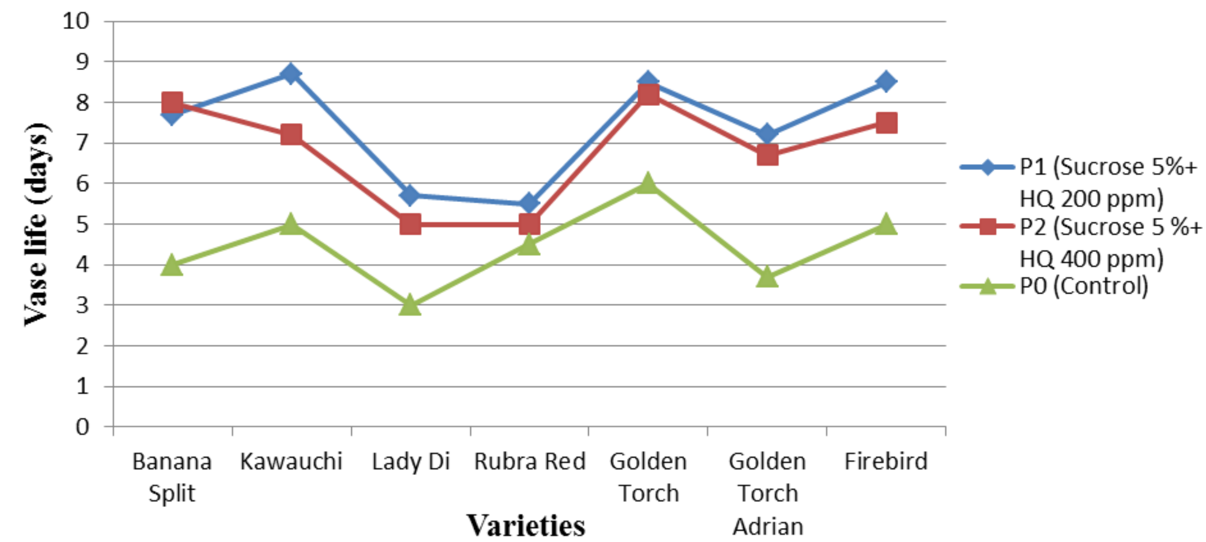

Fig. 4. Effect of pulsing treatments (HQ) on the vase life of heliconia

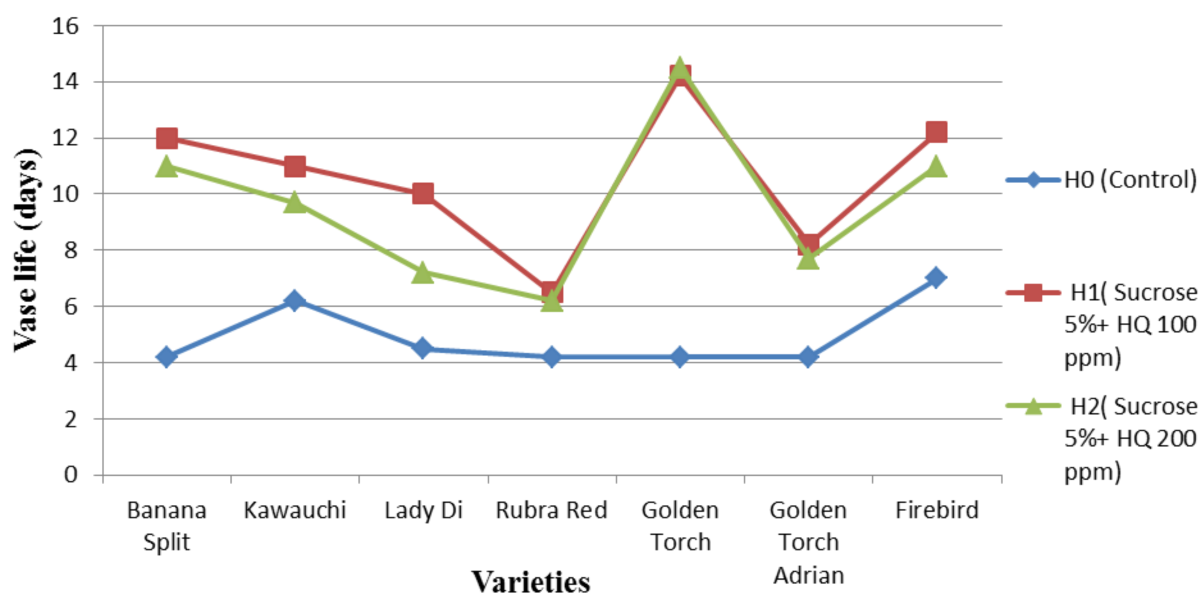

Fig. 5. Effect of holding treatments (HQ) on the vase life of heliconia

Table 24. Effect of pulsing treatments on the vase life and the increase in vase life of heliconia inflorescences

Varieties	Vase life (days)								Increase vase life times (%)						
	P0	P1	P2	P3	P4	P5	P6	P7	P1	P2	P3	P4	P5	P6	P7
Banana Split	4.0^{d}	8.0^{a}	7.7^{a}	6.0^{b}	6.0^{b}	5.0^{c}	5.0^{c}	4.0^{d}	2.0	1.7	1.5	1.5	1.3	1.3	1.0
Lady Di	5.0^{d}	8.7^{a}	7.2^{b}	6.0^{c}	5.5^{cd}	4.5^{e}	4.7^{de}	4.7^{de}	1.7	1.4	1.2	1.1	0.9	0.9	0.9
Kawauchi	3.0^{d}	5.7^{a}	5.0^{b}	5.0^{b}	4.0^{c}	4.7^{b}	4.0^{c}	4.5^{b}	1.9	1.7	1.7	1.7	1.6	1.3	1.5
Rubra Red	4.5^{bc}	5.5^{a}	5.0^{ab}	5.0^{ab}	5.0^{ab}	5.2^{a}	5.0^{ab}	4.2^{c}	1.2	1.1	1.1	1.1	1.2	1.1	0.9
Golden Torch	6.0^{c}	8.5^{a}	8.2^{a}	7.0^{b}	7.0^{b}	7.0^{b}	7.2^{b}	7.0^{b}	1.4	1.4	1.2	1.2	1.2	1.2	1.2
Golden Torch Adrian	3.7^{d}	7.2^{a}	6.7^{ab}	6.2^{b}	6.0^{b}	5.0^{c}	5.0^{c}	4.7^{c}	1.9	1.8	1.7	1.6	1.4	1.4	1.3
Fire bird	5.0^{d}	8.5^{a}	7.5^{b}	6.2^{c}	6.2^{c}	5.2^{d}	5.0^{d}	5.0^{d}	1.7	1.5	1.2	1.2	1.0	1.0	1.0

Means in the same row followed by same letter are not significantly different by Ducan - Walter multiple range test at $P \leq 0.05$

P0 - Control (no pulsing)
P1 - Sucrose 5% + HQ 200ppm for 6 hours
P2 - Sucrose 5% + HQ 400ppm for 6 hours
P3 - BA 100ppm for 6 hours
P4 - BA 200ppm for 6 hours
P5 - BA 100ppm as spray within 1 h. after harvest
P6 - BA 200ppm as spray within 1 h. after harvest
P7 - Hot water dip at 60^{0}C for 5 seconds

Cytokinins have been identified as the growth regulator that delay leaf senescence by slowing chlorophyll degradation and maintaining protein and RNA levels (Arteca, 1996). When cytokinins are supplied at correct time and dosage, flower longevity of many species can be extended. Cytokinins are effective in delaying bract darkening and abscission of *H. psittacorum* regardless of whether if they were dipped or sprayed with 200 mg l^{-1} Benzyl Adenine, increasing by three fold the vase life (Paull and Chantrachit, 2001).

According to Moraes *et al.* (2005), treatment with Benzyl Adenine applied immediately after harvesting at two stages showing one or two fully opened bracts (Stage 1) and from three to four fully opened bracts (Stage 2) improved flower longevity (*Heliconia latispatha*). The growth regulator was sprayed twice within the first hour after harvest until the stalks are completely wet. Spraying the flower with 100, 200 and 300 mg l^{-1} Benzyl Adenine, longevity was increased by 1.29, 1.57 and 1.85 fold, respectively compared to untreated flowers. In the present study also 100 ppm and 200 ppm Benzyl Adenine spray increased (1.2 fold) the vase life over the control in Golden Torch also (Table 24).

Among the holding solutions used, maximum vase life recorded in a solution containing 5 per cent sucrose and HQ 100 ppm. In heliconia varieties 1.5 to 3.4 fold increase in vase life was evident over the untreated control. There is 3.5 fold greater vase life of Golden Torch inflorescence in the solution containing 5 per cent sucrose and HQ 200 ppm (Table 25 and Fig. 5).

The results obtained is not in confirmity with the findings of Broschat and Donselman (1983). They reported that flowers of recommended cultivars (Golden Torch, Andromeda, St. Vincent Red, etc.) maintain their bract color and shape for 14-15 days in tap or deionized water at 23°C. Uptake of water or floral preservatives is minimal, hence silver or 8-hydroxyquinoline citrate-containing solutions have no effect on post harvest life of the cut flowers.

Table 25. Effect of holding treatments on the vase life and the increase in vase life of heliconia inflorescences

Varieties	Vase life (days)							Increase vase life times (%)					
	H0	H1	H2	H3	H4	H5	H6	H1	H2	H3	H4	H5	H6
Banana Split	4.2[d]	12.0[a]	11.0[b]	11.0[b]	11.2[b]	5.0[c]	4.0[d]	2.9	2.6	2.6	2.7	1.2	1.0
Kawauchi	6.2[c]	11.0[a]	9.7[b]	6.5[c]	6.2[c]	6.7[c]	5.2[d]	1.8	1.6	1.0	1.0	1.1	0.8
Lady Di	4.5[d]	10.0[a]	7.2[b]	7.2[b]	6.0[bc]	5.0[cd]	4.0[d]	2.2	1.6	1.6	1.3	1.1	0.9
Rubra Red	4.2[c]	6.5[a]	6.2[a]	6.0[bc]	6.0[ab]	5.5[b]	4.5[e]	1.5	1.4	1.4	1.4	1.3	1.1
Golden Torch	4.2[c]	14.2[a]	14.5[a]	11.2[b]	10.2[c]	5.5[d]	4.0[e]	3.4	3.5	2.7	2.4	1.3	1.0
Golden Torch Adrian	4.2[c]	8.2[a]	7.7[a]	6.5[b]	6.0[b]	4.5[c]	4.0[c]	2.0	1.8	1.5	1.4	1.1	1.0
Fire bird	7.0[de]	12.2[a]	11.0[b]	7.7[c]	7.5[cd]	8.0[c]	6.5[e]	1.7	1.6	1.1	1.1	1.1	0.9

Means in the same row followed by same letter are not significantly different by Ducan - Walter multiple range test at $P \leq 0.05$

H0 - Acidified water (3.5 pH)
H1 - Sucrose 5% + HQ 100 ppm
H2 - Sucrose 5% + HQ 200ppm
H3 - BA 100ppm
H4 - BA 200ppm
H5 - Sucrose 5% + Al2 (SO4)3 200ppm
H6 - Control (distilled water)

Storage under different temperatures showed drastic effect on the storage life of heliconias. Maximum storage life was recorded when stored at 17^0C and minimum at 8^0C. The inflorescences also developed black spots at the base of bracts when stored at 11^0C or less. This observation is similar to the findings of Donselman and Broschat (1983) and Reid (2004). They opined that heliconia inflorescences cannot be stored at a temperature below 10 - 12^0C. Temperature below 10 - 12^0C develops black spots on the bracts.

Packing should protect the cut flowers from physical damage, water loss and detrimental external conditions during transport. Packing the flowers with wet cotton plug at the peduncle end with polythene lining was found to be good. Other lining materials like news paper, brown kraft paper and butter paper also influenced the vase life positively. This keeps the inflorescences spikes from rubbing and bruising each other. The results are in confirmity with the findings of Donselman and Broschat (1986), that medium sized heliconias such as *Heliconia bihai* and *H eliconia stricta* are packed as 10 to 15 pieces using moist or dry shredded news paper as well as layers of news paper to reduce damage due to shifting during shipment. There are reports that small heliconia such as *Heliconia psittacorum* and H. angusta are bunched (5s, 10s) and wrapped in polythene film or moistened shredded news paper is packed around the bunches to prevent drying (Criley and Paull, 1993).

The foregoing discussions on the results generated from the present study suggest that there were consistent differences in the performance of different heliconia varieties. Considering the quantitative and qualitative morphological inflorescence characters *Heliconia psittacorum* L.f. x *Heliconia spathocircinata* Aristeguieta cv. Golden Torch has immense potential for use as cut flower and landscape plant. *Heliconia stricta* Huber cv. Firebird was equally good, though flowering was seasonal. Overall performance of *Heliconia psittacorum* varieties Ladi Di, Rubra Red and the hybrid Golden Torch Adrian were ideal for the landscape and as cut flower for local markets. *Heliconia bihai* (L.) L. cv. Banana

Split and *Heliconi caribaea* Lamarck x *Heliconia bihai* (L.) L. cv. Kawauchi had heavy flowering stems, hence used for planting in landscapes only.

Post harvest studies were undertaken to determine the effect of inflorescence maturity, post harvest chemical treatments and packing on post harvest longevity of heliconia inflorescences. The results were aimed at providing to local growers and shipper's optimum harvest and handling procedures to assist in shipping to consumers a consistent supply of long lived high quality product. Based on the results obtained from the studies conducted on post harvest handling of seven heliconia varieties, the protocol was developed.

The present investigations on flowering and post harvest dynamics of heliconias were conducted under uniform conditions. Useful information has been obtained on the flowering pattern and post harvest behaviour. It is necessary to conduct further studies to evaluate more heliconia varieties to improve yield and quality of flowers both under open and shade conditions for assessing the suitability for planting in landscape and as cut flower.

SUMMARY

6. SUMMARY

The results of the studies on the flowering and post harvest dynamics of heliconias (*Heliconia spp*.) are summarized below.

- There were significant differences in the flowering behaviour of heliconia varieties. Certain varieties were free flowering, whereas others were seasonal. Flower production was seen throughout the year in all the varieties, except in Kawauchi, Golden Torch Adrian and Firebird.
- Even though the varieties Banana Split, Lady Di, Rubra Red and Golden Torch showed free flowering, flower production was low in the months of January to March. There was no flower production during the months of November to May in Kawauchi, December to May in Golden Torch Adrian and October to January in Firebird. Golden Torch Adrian and Lady Di recorded the highest flower production in the months of June and July.
- Inflorescence length was maximum in Banana Split (117.1 cm) and was significantly superior to other varieties. Minimum length was recorded in Rubra Red (73.2 cm) and was on par with Firebird (75.3 cm) and Lady Di (75.9 cm).
- Banana Split recorded maximum stalk length (99.1 cm) and was significantly superior to all others, except Kawauchi (91.9 cm).
- The variety Banana Split recorded maximum length of rachis (18.0 cm), followed by Kawauchi (16.3 cm) and were significantly superior to others. Minimum length was observed in variety Rubra Red (9.3 cm).
- Significant differences were observed on the bract length also. The variety Kawauchi recorded maximum bract length (16.7 cm) and was comparable with Banana Split (15.8 cm). Minimum bract length (11.7 cm) was recorded in Rubra Red.
- The shortest duration from bud emergence to opening of basal bract was shown by Firebird (19.5 days), which was on par with Lady Di (20.0 days) and Golden Torch Adrian (21.0 days). Variety Banana Split

(23.8 days) recorded the longest duration and was on par with Golden Torch (22.8 days), Kawauchi and Rubra Red (22.3 days, each).

- Lowest duration for complete unfurling of all bracts was shown by the variety Golden Torch Adrian (11.0 days), followed by Golden Torch (12.0 days), Rubra Red (12.3 days), Kawauchi (12.8 days), and Firebird (13.0 days), which were on par. The highest value was recorded by the variety Banana Split (19.5 days).
- Highest number of flowers/bract was observed on Golden Torch (12.2), closely followed by Kawauchi (10.8). The interval between the opening of successive flowers in a bract ranged from 1.8 days (Lady Di) to 3.8 days (Banana Split).
- Highest number of inflorescences was observed in Lady Di (102.0). This was followed by Rubra Red (87.3), Banana Split (82.3) and Golden Torch (80.1).
- Maximum longevity of the inflorescence (42.0 days) was observed in the variety Kawauchi, followed by Golden Torch (40.2 days) and Banana Split (40.1 days).
- All the evaluated varieties were vegetation musoid (banana like leaves) and with erect inflorescence. The bracts were either distichous or spiral. The variety Kawauchi had waxy bracts. Wide range of pigmentation was observed in the bract, rachis, sepals, ovary and pedicel.
- Based on the fresh weight of stem, the varieties were classified as light (Golden Torch, Golden Torch Adrian, Lady Di, Rubra Red and Firebird) and heavy (Banana Split and Kawauchi).
- Based on the stem diameter the varieties were classified as thin (Lady Di and Rubra Red) and medium (all others).
- All the varieties had medium length (63.3 and 117.1 cm) of inflorescence. Most of the varieties evaluated in the study fit to the standard for inflorescence length of cut flowers, except Lady Di, Rubra Red, Golden Torch Adrian and Firebird.

- Reduced length (9.3 cm) of rachis was observed in Rubra Red. In other varieties, the length of rachis varied from 10.3 cm (Lady Di) to 18.0 cm (Banana Split) and belonged to the category with medium length.
- Considering the bract arrangement, wax on inflorescence and fresh weight of stem, the varieties were classified as cut flower of high performance (Golden Torch, Firebird, Lady Di, Rubra Red and Golden Torch Adrian and low performance Kawauchi and Banana Split.
- Golden Torch was significantly superior in all quantitative and qualitative morphological characters of flowering stems, like, duration of flowering, number of inflorescence produced/year, low fresh weight of stem, absence of wax and single plane arrangement of bracts and is ideal as cut flower and for landscape use. Firebird was promising as cut flower and landscape plant, though flowering was seasonal. Lady Di, Rubra Red and Golden Torch Adrian were ideal for the landscape, and as a cut flower for local markets.
- Stage of harvest significantly influenced the vase life of heliconia inflorescence. The varietal differences were also significant.
- In Banana split, the inflorescence harvested at 3-4 bracts open stage (stage 3) recorded the maximum vase life (6.0 days) and was significantly superior to other stages. Remarkable variation could not be observed in the physiological loss of weight (PLW) of inflorescence at different harvest stages.
- The vase life of Kawauchi was similar to that of Banana split (6.0 days) at 3-4 bracts open stage (stage 3) and was significantly superior to other stages. The unopened bract stage (stage 1) recorded minimum vase life (3.5 days). No significant changes in the physiological loss in weight and water uptake were noted in different stage of harvest.
- In Lady Di inflorescence harvested at 1-2 bract open stage (stage 2) recorded maximum vase life (5.0 days) and was significantly superior to other stages of harvest. The physiological loss in weight was minimum

(3.18 g) in stage 2 and was on par with unopened bract stage (stage 1). Water uptake was also minimum (13.75 ml) in stage 2.

- One to two bract open stage (stage 2) in Rubra Red exhibited maximum vase life (5.0 days) and was on par with unopened bract stage (stage 1).
- In Golden Torch, the inflorescences harvested at 1-2 bracts open stage (stage 2) remained for a longer period (5.0 days) and were significantly superior to other stages.
- Golden Torch Adrian recorded significantly longest vase life of 8.0 days when harvested at 1-2 bract open stage (stage 2), and no bract open stage i.e., stage 1 (7.5 days). Minimum vase life (5.0 days) was in all bract open stage (stage 4). Physiological loss in weight and water uptake was significantly less in both the no bract open stage (stage 1) and 1-2 bract open stage (stage 2).
- Different stages of harvest in Firebird maximum vase life (5.8 days) when harvested at 3-4 bract opened stage (stage 3) which was on par with all bract open stage (stage 4). Physiological loss in weight and water uptake were not influenced by the stage of harvest of the bract.
- Maximum vase life was observed in all the varieties when pre cooled at 20°C for 4 hours. The vase life ranged from 6.7 days (Lady Di) to 9.0 days (Golden Torch). This was followed by keeping at 15°C for 4 hours at ambient condition (27°C). The cut flowers recorded minimum vase life (2.0 to 3.0 days) when pre cooled at 10°C for 4 hours.
- The different pulsing treatments significantly influenced the vase life of Banana Split. The flowers remained for longer period of 8.0 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours which was on par (7.8 days) with 5 per cent sucrose and HQ 400 ppm.
- Kawauchi flowers remained for longer period of 8.7 days when pulsed with 5 per cent sucrose and HQ 200 ppm for 6 hours and was significantly superior to other treatments.

- Flowers remained fresh for longer period of 5.7 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours in Lady Di.
- The flowers of Rubra Red remained fresh for longer period of 5.5 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours which was on par with all the pulsing treatments, except hot water dip at 60°C for 5 seconds and control.
- In Golden Torch, the flowers remained fresh for 8.5 days when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours, which was similar to that in 5 per cent sucrose and HQ 400 ppm (8.2 days).
- Maximum vase life (7.2 days) was recorded in Golden Torch Adrian when pulsed with a solution containing 5 per cent sucrose and HQ 200 ppm for 6 hours, which was similar to that by 5 per cent sucrose and HQ 400 ppm (6.7 days) and were on par.
- Pulsing with 5 per cent sucrose and HQ 200 ppm for 6 hours and was a significantly superior treatment in Firebird.
- In Banana Split, maximum vase life (12.0 days) was recorded in a vase solution containing 5 per cent sucrose and HQ 100 ppm.
- Kawauchi recorded maximum vase life (11.0 days) in 5 per cent sucrose and HQ 100 ppm.
- Among the different holding solutions used in Lady Di, maximum vase life (10.0 days) was recorded in 5 per cent sucrose + HQ 100 ppm.
- In Rubra Red, significantly longest vase life of 6.5 days was recorded in a solution containing 5 per cent sucrose and HQ 100 ppm , and was similar to that solution containing sucrose 5 per cent + HQ 200 ppm (6.2 days), BA 100 and BA 200 ppm (6.0 days, each).
- Among the different holding solutions tried in Golden Torch, maximum vase life (15.5 days) was recorded in 5 per cent sucrose and HQ 200 ppm,

and was similar with the solution containing sucrose 5 per cent and HQ 100 ppm (15.2 days).

- Golden Torch Adrian recorded maximum vase life (8.2 days) in 5 per cent sucrose + HQ 100 ppm solution and was on par with sucrose 5 per cent and HQ 100 ppm (7.7 days).
- Longest vase life of 12.2 days was recorded in Firebird in a solution containing 5 per cent sucrose and HQ 100 ppm.
- Storage life of heliconia varieties was significantly superior (8.6 to 11.6 days) when kept at a temperature of 17^0C. At the storage temperature of 11^0C or less, the flowers developed black spots at the base of the bract.
- In the variety Banana Split, lining materials like polythene sheet (11.8 days) newspaper (9.6 days), brown kraft paper (7.4days) and butter paper (5.4 days) influenced the vase life positively when plugged with wet cotton. The vase life ranged from 5.6 days (butter paper) to 7.6 days (polythene sheet) when packed dry

- Vase life of heliconia cv. Kawauchi, Lady Di, Rubra Red, Golden Torch, Golden Torch Adrian and Firebird was significantly the longest when polythene sheet was used as the lining material, both under dry and wet conditions. The vase life ranged from 5.6 days (Rubra Red) to 8.8 days (Golden Torch) when packed dry and 7.0 days (Rubra Red) to 15.8 days (Golden Torch) when plugged with wet cotton.
- Based on the results obtained from the studies conducted on seven heliconia varieties, a protocol for post harvest handling was developed.

REFERENCES

REFERENCES

Alan,M. A. 2004. Plant information [online]. Available: http://www.hortcopia.com/heliconia-psittacorum-spathocircinata [21-5-2011].

Arteca, R. N. 1996. *Plant Growth Substances: Principles and Application*. Chapman & Hall: New York. 268p.

Bahybalid, M., Singh, A., Chawla, S. L. and Dhaduk, B.K. 2011. Effect of harvesting stage and post harvest handling on quality and vase life of heliconia inflorescences. *J. Orn. Hortic*. 14(12): 48-52

Bayogan, E. R. V., Jaroenkit, T., and Paull, R. E. 2008. Post harvest life of Bird-of-paradise inflorescences. *Post Harvest Biol. Technol.* 48: 259–263.

Berry and Kress, F. W. J. 1991. Heliconia: An indentification Guide, Smithsonia institution press, Washington, 334p.

Bhattacharjee S.K. and De L.C. 2006. Postharvest technology of flowers and ornamental plants, Pointer publishers, Jaipur, 440p.

Bredmose, N. 1987. Keeping quality of some new flowers for cutting. Nogle nye snitblomsters holdharhed. *Gartner Tidende* 103(6): 146-147.

Broschat, T. K. and Donselman, H. M. 1983. Heliconias: A promising new cut flower crop. *HortScience* 18:1-2.

Broschat, T. K. and Donselman. H. M. 1988. Production and post harvest culture of red ginger in southern Florida. *Proc. Fla. State Hort. Soc*. 1011:326-327.

Broschat, T.K. and Donselman, H. M. 1983. Production and post harvest culture of *Heliconia psittacorum* flowers in South Florida. *Proc. Fla. State Hort. Soc.* 96:272-273.

Broschat. T. K., Donselman. H. M., and Will, A. A. 1984. Golden Torch, an orange heliconia for cut flower use. *Circ. Agric. Exp. Stn. Univ. Fla.* 308: 4.

Castro, C. E. F. 1993. *Helicônias como flores de corte: adequação de espécies e tecnologia pós-colheita*. Tese de Doutorado. ESALQ, Piracicaba, 191p.

Castro, C.E.F. and Graziano, T. T 1997. Espécies do Gênero Heliconia (Heliconiaceae). *R. Bras. Hortic. Ornam.* 3:15-18

Charleston, W. V. 1997. *Heliconia stricta* general description[online]. http://www.heliconia-amazon.com/heliconia-stricta [21-5-2011]

Costa A. S., Loges V., Castro A. C. R., and Nogueira 2009. Genotypes under partial shade: Evaluation of flowering stems. *Acta Hortic.* 813: 23-24.

Criley, R. A. 1990. Production of Heliconia as cut flower.and their potential as new potted plants. *Hortic Digest*, 92:1-7

Criley, R. A. 1998. A review of floriculture production research in Hawaii. *Inter. Amer. Soc. for Tropical Hortic.*9682: 1-20

Criley, R. A. 2000. Seasonal flowering pattern for Heliconia shown by grower records. *Acta Hortic.* 486: 159- 165.

Criley, R. A. and Broschat, T. K. 1991. Heliconia: botany and horticulture of a new floral crop. *Hortic. Rev.* 83: 34- 38.

Criley, R. A. and Kawabata, O. 1986. Evidence for short day flowering response in *Heliconia stricta* 'Dwarf Jamaican'. *Hortic. Sci.* 21: 605- 607.

Criley, R. A. and Paull, R. E. 1993. Review: postharvest handling of bold tropical cut flowers – *Anthurium*, *Alpinia purpurata*, *Heliconia*, *and Strelitzia*. *Acta Hortic*. 337: 201-212.

Criley, R. A., Sakai, W. S., Lekawatana, S., and Kwon, E. 1999. Photoperiodism in the genus Heliconia and its effect upon seasonal flowering. *Acta Hortic.* 486: 323- 327.

David, B. Z. 1985. Notes on Heliconia [online]. Available: http://www.fairchildtropicalgardens.com/heliconia-latispata.[21-5-2011].

Dolselman, H. and Broschat T. K. 1986. Production of Heliconia psittacorum for cut flower in South Florida. *Heliconia Soc. Intern.* 1(4): 4-6.

Donselman, H. and Broschat, T. K. 1983. Heliconias: A promising new cut flower crop. *HortScience* 18:1-2.

Elgar, J. 1998. Cut flower and foliage – cooling requirements and temperature management.[online].Available:http://www.hortnet.co.nz/publications/hortfacts/ nf305004.htm[21-5-2013].

El-Saka, M., Awad, A. E., Fahmy, B., and Dowh, A. K. 1995. Trials to improve the quality of bird-of-paradise flowers after cutting. In: Ah-Oubahao, A. and El-Osmari, M.

(eds.), *Post Harvest Physiology, Pathology and Technology for Horticultural Commodities: Recent Advances.* Institute Agronomique and Veterianaire Hassan 2, Morocco, pp. 480- 485.

Endre, G. 1996. Heliconias and gingers [online]. Available: http://www.tciendre@coqui.net/heliconia-types.[21-5-2011].

Geertsen, V. 1988. Effect of photoperiod and temperature on the growth and flower production of *Heliconia psittacorum* 'Tay'. *Acta Hortic.* 252: 117- 122.

Geertsen, V. 1990. Influence of photoperiod and temperature on the growth and flowering of *Heliconia aurantiaca. Hortic. Sci.* 25: 646- 648.

Goel A.K. 2011. Heliconias: nature wonder from neotropical regions. Indian Horticulture, vol. 49,no. 1 : 20-21

Halevy, A.H., Kofranek A.M., and Besemer S.T. 1978. Postharvest handling methods for bird of paradise flowers (*Sterlitzia reginae* Ait.). *J. Am. Soc. Hortic. Sci.* 103: 165-169

Halevy, A. H. and Mayak, S. 1979. Senescence and post harvest physiology of cut flowers. Part I. *Hortic. Rev.* 1: 204- 236.

Janakiram, T. and Kumar, P. P. 2011. Enhancing flower potential of Heliconia. *Indian Hortic.* 56(1): 22- 24.

Jaroenkit, T. and Paull, R. E. 2003. Post harvest handling of Heliconia, Red ginger and Bird-of-paradise. *Hortic. Tech.*13(2): 259- 266.

Jie He, S., Chee, C. W., and Goh, C. J. l996. Photo inhibition of Heliconia under natural tropical condition: the importance of leaf orientation for light interception and leaf temperature. *Plant Cell Environ.* 19: 1238- 1248.

Juan, A. R. 1997. Notes on Heliconias [online]. Available: http://www.gardenweb.com/heliconia-psittacorum. [21-5-2011].

Ka-ipo, R., Sakai, W. S., Furutai, S. C., and Collins, M. 1989. Effect of post harvest anti transpirants on the shelf life of *Heliconia psittacorum* cv. Parakeet cut flowers. *Bull. Heliconia Soc. Int.* 4(3): 13- 14.

Klink, C. H. 1990. Supplement to SAF's care and handling of flowers and plants manual. *Trop. Flowers Trop. Foliage* 23: 1- 17.

Kress, W. J. l99l. New taxa of Heliconia (Heliconiaceae) from Ecudor. *Brittonia* 43: 253- 260.

Kumar, P.P. Janakiram, T., Kumar, D. P. Ans Venugopalan, R. 2011. Correlation studies in heliconia genotypes. *J. Orn. Hortic.* 14 (142):21-23.

Lalrinawmi and Talukadar M. C. 2000. Effect of spacing and size of rhizome on the flower production of Heliconia (Heliconia psittacorum L.). *J. Agri. Sci. N. E. India* 13: 48-51

Lee, W. H., Nig, N. Y., and Goh, C. J. 1994. Pollen formation and fruit set in some cultivars of *Heliconia psittacorum. Scientia Hortic.* 60: 167- 172.

Loges, V., Teixeira, M. C. R., Castro, A. C. R. and Costa, A. S. 2005. Colheita e pós-colheita de flores tropicais no estado de Pernambuco. *Revista de Hortic. Brasileira* 23: 699-672.

Maciel, N. and Rojas, C. 1994. Growth and development of *Heliconia bihai* and *H. latispatha* under different levels of shade. *Proc. Interam. Soc. Trop. Hortic.* 38: 257- 263.

Marcsik, D. 2003. Heliconia[online]. Available: http://www.horticulture.net.gov.au.[13-7-2011].

Moraes, P. J., Finger, F. L., Barbosa, J. G., and Cecon, P. R. 2005. Influence of benzyladenine on longevity of *Heliconia latispatha* Benth. *Acta Hortic.* 683: 369-376.

Paull, R. E. 1991. Season and fertilization affects the post harvest flower life of anthurium. *Scientia Hortic.*(in press).

Paull, R. E. and Chantrachit, T. 2001. Benzyladenine and vase life of tropical ornamentals. *Postharvest Biol. Technol*. 21: 303-310.

Paull, R. E. and Chantrachit, T. L. 1993. Benzyl adenine and vase life of tropical ornamentals. *Post-harvest Biol. Technol.* 21(3):303-310.

Paull, R. E. and Goo, T. 1985. Ethylene and water stress in the senescence of cut anthurium flowers. *J. Am. Soc. Hortic. Sci.* 110: 84- 88.

Powell, J. 1991. *Growing Heliconias for Cut Flowers*. North Terrestrial Australian Department of Primary Industries and Fisheries, 442p.

Reid, M. S. 2004. Heliconia, Parrot Flower: Recommendations for Maintaining Post Harvest Quality. Post harvest technology and information center, University of California, Davis, 175p.

Rocha, F. H. A. and Loges, V. 2010. Genetic study with *Heliconia psittacorum* and interspecific hybrids. *Brazillian Soc. Of Plant Breeding*.10: 282-286.

Rudnick, R. M., Nowak, J., and Goszczynska, D. M. 1991. Cold storage and transportation conditions for cut flowers, cuttings and potted plants. *Acta Hor tic.* 298(1): 225-236.

Sanjeev, S.J., Sheela, V. L. and Geetha Lekshmi, P. K. 2010. Floral Biology and correlation studies in heliconia. *J. Orn. Hortic.* 13(1): 6-19

Singh, H. P. 2009. Floriculture industry in India: the bright future ahead. *Indian Hort*. 54(1): 3-9.

Sreenivas, M., Kumar, R. and Janakiram, T. 2012. Evaluation of *Heliconia* genotypes for vegetative and flowering traits. *Indian J. Genet*., 72(3): 397-399.

Swapna, S. 2000. Regulation of growth and flowering in Dendrobium var. Sonia 17, Phd. Thesis, Kerala Agricultural University, 226p.

Tjia, B. and Sheehan, T. J. 1984. Preserving profits and beauty. *Greenhouse Manager* 2(11): 94- 100.

Tom, W. 1997. Stokes tropical: A source of Heliconia plants [online]. Available: http://www.heliconia-amazon.com/heliconia-gen-des.[21-5-2011].

FLOWERING AND POST HARVEST DYNAMICS OF HELICONIAS (*Heliconia spp*).

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Floriculture has become an important business sector all over the world. In India, it has been associated with culture and heritage since very ancient times. Apart from the growing domestic demand in the last few years, export has also shown an upward trend. In the increasingly competitive international cut flower and pot plant market, new and indigenous ornamental plants play a major role. Hence it is imperative that the potential new ornamentals are evaluated so as to create further diversity in flori-businesss.

Heliconias are wonderful tropical plants with multi-colour bracts, varied flower structure and long shelf life. It is the only genus in the family Heliconiaceae, which is a member of a largest taxonomical category, the order Zingiberales. Its demand for cut flower trade is increasing day-by-day because of the long vase life, attractive colour, massive appearance and exotic shape.

Seven varieties of heliconia, viz., *Heliconia bihai* (L.) L. cv. Banana Split, *H. caribaea* Lamarck x *H.bihai* (L.) L. cv. Kawauchi, *H. psittacorum* L.f cv. Lady Di, *H. psittacorum* L.f. cv. Rubra Red, *H. psittacorum* L.f. x *H. spathocircinata* Aristeguieta cv. Golden Torch, *H. psittacorum* L.f. x *H.spathocircinata* Aristeguieta cv. Golden Torch Adrian and *H. stricta* Huber cv. Firebird, were evaluated for suitability for planting in landscapes and as cut flower, based on various quantitative and qualitative characters.

There were significant differences in the flowering behaviour of heliconia varieties. Certain varieties were free flowering, whereas others were seasonal. Flower production was seen in all the varieties, except in Kawauchi, Golden Torch Adrian and Firebird.

The varieties exhibited significant variation in all the quantitative and qualitative characters studied. Considering the bract arrangement, wax on

inflorescence and fresh weight of stem, the varieties were classified as cut flowers of high performance (Golden Torch, Firebird, Lady Di, Rubra Red and Golden Torch Adrian) and low performance (Banana Split and Kawauchi).

The variety Golden Torch excelled in all quantitative and qualitative characters of flowering stems, like, continuous flowering, number of spikes produced/year, fresh weight of stem less than 100 g, absence of wax and one plane arrangement of bracts. These characters have made it more ideal as cut flower and for landscape use. Firebird was promising as cut flower and landscape plant, though flowering was seasonal. Lady Di, Rubra Red and Golden Torch Adrian were ideal for the landscape, and as a cut flower for the local markets.

Stage of harvest significantly influenced the vase life of heliconia flowers. At the stage when 1-2 bracts opened, the post harvest life was the best. Maximum vase life was observed in all the varieties when pre cooled at 20^0C for 4 hours. The flowers remained for a longer period, when pulsed with a solution containing sucrose 5 per cent + HQ 200ppm for 6 hours. Among the different holding solutions used, maximum vase life was recorded in sucrose 5 per cent + HQ 100 ppm.

A storage temperature of 17^0C was the best for all the heliconia varieties tried, recording a life of 8.6 to 11.6 days. Packing the flowers with wet cotton plug at the peduncle end and with polythene lining was found to be the best. Based on the results obtained from the studies, a protocol for post harvest handling has been developed.