NUTRIENT MANAGEMENT PRACTICES FOR HELICONIA UNDER OPEN CONDITION AND AS INTERCROP IN COCONUT GARDEN

by

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(2007-22-101)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Nutrient management practices for Heliconia under open condition and as intercrop in coconut garden."** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

°C	–	Degree Celsius
@	–	At the rate of
BCR	–	Benefit cost ratio
Ca	–	Calcium
CD	–	Critical difference
CF	–	Chemical Fertilizer
cm	–	Centimetre
CPCRI	–	Central Plantation Crops Research Institute
Cu	–	Copper
et al.	–	And others
Exp	–	Experiment
Fe	–	Iron
FW	–	Fresh weight
FYM	–	Farm yard manure
g	–	Gram
ha	–	Hectare
K	–	Potassium
KAU	–	Kerala Agricultural University
kg	–	Kilogram
l	–	Length
LAI	–	Leaf area index
m	–	Metre
MAP	–	Months After Planting
Mg	–	Magnesium
mi	–	Microbial inoculants
min	–	Minute

LIST OF ABBREVIATIONS CONTINUED

ml	–	Millilitre
mm	–	Millimetre
Mn	–	Manganese
MSL	–	Mean Sea Level
N	–	Nitrogen
NC	–	Neem cake
nm	–	Nanometer
NUE	–	Nitrogen use efficiency
P	–	Phosphorus
PSB	–	Phosphate solublising bacteria
POP	–	Package of practice
RGR	–	Relative growth rate
S	–	Sulphur
SE	–	Standard Error
t	–	Tonnes
TDM	–	Total dry matter production
VAM	–	Vescicular Arbuscular Mycorrhizal
VC	–	Vermicompost
Zn	–	Zinc

Introduction

1. INTRODUCTION

Heliconia is a large genus of attractive monocots, mostly indigenous to the Neotropics (the North of Mexico to the South of Brazil). Heliconia takes its name from Mount Helicon, the home of the ancient Greek gods. The genus is made up of about 100 species along with a large number of hybrids and cultivars. Heliconias produce rhizomes and erect shoots. The rhizomes branch off and produce new shoots. New branches and shoots develop from buds or eyes on the rhizomes. The shoots are composed of overlapping leaf sheaths which make up the above ground pseudostem and support the large leaf blades and inflorescences. Some Heliconias have erect leaves with long petioles like bananas (musoid), others have horizontal leaves with short petioles resembling gingers (zingiberoid), some are intermediate with short to medium petioles supporting leaves at about a forty degree angle, like cannas (cannoid). The growth habit of Heliconias is of two types: spreading or clumping. The spreading types fill and colonize quickly and are capable of covering a substantial area of land in a few years. The clumping types grow more slowly and new pseudostems develop on the edge of the clump and the centre of the clump hollows out.

The inflorescences are either erect or pendent with showy bracts containing varying number of bracts. The bracts are joined by axis (rachis) that is either straight or spiraling. Depending on the variety it takes from 60 to 100 days for a shoot to develop a mature inflorescence. They produce tubular flowers with inferior ovaries. The floral tubes are made up of six variably fused tepals. Within the flowers are the pollen-producing stamens and the stigma on a long style. The flowers are mostly hidden by large, colourful bracts. The bracts vary in colouration, size, shape, arrangement, degree of crowding, texture, number, and other details. Flower production in Heliconia is related to rate of vegetative growth as well as plant density. At optimal temperatures of 21-35°C, a flower can be harvested 8-9 weeks after emergence of the shoot. At temperatures below

21°C, growth rate is reduced proportionally until 10°C is reached. At this temperature all growth stops and cold damage symptoms appear, first as small black spots on the floral rachis near the point of bract attachment, and eventually as blackening of the entire inflorescence and necrosis of the foliage.

The cut flowers export has risen from Rs.4 million to Rs.180 million during the past decade. Heliconias are well adapted to all major agro climatic zones of our country. These plants come up well in full sunlight to partial shade making them as an ideal choice for intercropping in coconut gardens. About 50% of Indian production of cut flower Heliconia comes from the coconut farms located in the West Godavari districts of Andhra Pradesh. In Kerala, where open areas are scarce and the cropping pattern is dominated by coconut palms, there is immense potential for exploiting this flower crop.

For Heliconia cut flower industry, the characteristics of interest are: production of inflorescences during the whole year; short flowering cycle; light flowering stems for lower transportation costs; stems longer than 80 cm; stems with diameter thick enough for better resistance to handling and for lighter total weight of inflorescence; inflorescences with no wax and no hair; and bracts arranged in one plane for easier handling and packing .In addition, other characteristics that must be observed include: inflorescence width; length and rachis diameter mainly in erect inflorescences for reducing the possibility of rupture; firmness of bracts; bracts not too deep and with a few or no flower inside (which will reduce time and cost of cleaning and minimize occurrence of insects, odors from water accumulation and organic matter deterioration); and post-harvesting durability longer than seven days. Considering all these factors, *Heliconia stricta* cv. Iris Red has been selected for the present investigation.

Inflorescence characters of *Heliconia stricta* Huber var. Iris Red (Berry and Kress, 1991)

Bracts : Red over most of bract, green along distal lip, some yellow along keel

Rachis : Red

Tepals : Dark green distally with green-white tip, white proximally

Ovary : White

Pedicel : White

Heliconias need plenty of water and rich composting during active growing period. Little is known about its performance under sandy soils with low organic manure and water holding capacity. In this context the present study was undertaken using *Heliconia stricta* cv. Iris Red with the following objectives:

1. To standardize a cost-effective manurial schedule for *Heliconia stricta* for better flower yield and quality when grown as an intercrop in coconut garden and as a monocrop in open condition.

2. To analyze the effect of substituting chemical fertilizers with vermicompost, neem cake and biofertilizers in flower quality and yield.

3. To evaluate the performance of Heliconia under the two cropping systems; as monocrop and as intercrop in coconut gardens.

Review of Literature

2. REVIEW OF LITERATURE

Heliconias are newly identified cut flowers in our country and becoming popular in all metropolitan cities (Ramachandrudu and Thangam, 2012). Among the tropical flowers, Heliconia is outstanding for its diversity in form, colour, size and particularly, its durability (Rodrigues, 2008). Heliconia flowers are actually highly modified leaves called bracts, which may be erect, pendulous or spiraling in the shapes of bird's beaks, lobster claws or fan shaped and colors of reds, pinks, gold, oranges and splashes of a mixture of colours (Castro *et al*, 2007). Currently, the demand for ornamental Heliconias has increased, both in national and international markets, and its cultivation has become a major factor in the agricultural economy of many countries (Jerez, 2007).

A single inflorescence of *Heliconia stricta* variety Iris Red can fetch up to Rs.25 in the national market. Large flowers fetch $2 each in International markets (HSPR Newsletter, 2003). The main criteria used by the farmers for marketing Heliconia inflorescence are the number of open bracts and the length of the inflorescence stem (Costa *et al.*, 2006b).Among the Heliconias, *Heliconia stricta* cv. Iris Red is a commercial variety with high market value due to its unique crimson colored bracts with a definite shape. According to Costa *et al.*(2009b), this species is grouped under the High performance group and the inflorescence and morphological characters come in the medium range with fresh weight of stems (101 -200 g), stem diameter (10.1-30.0mm), stem length (50.1-150.0cm) and spike length (10.1-30.0cm). The global cut flower export has risen from Rs.4 million to Rs.180 million during 1999 -2009 (Janakiram, 2009). There is great potential for floriculture in coconut gardens especially shade loving Heliconias, ornamental gingers and foliage plants in a commercial scale in coastal belts of India as there is ample scope for intercropping in coconut garden.

Heliconia stricta (Family: Heliconiaceae) is a clumping type tropical ornamental plant grown for its beautiful, brilliant colorful flowering bracts. It is a short day plant (Kress *et al.*, 2002) attaining a height of 1.2 to 2.4m producing erect inflorescence in one plane with straight rachis. They grow well in soils rich in organic matter, but little is known about its nutrient management practices when grown under open or intercropped conditions especially in low fertile soils with less water holding capacity. Nutritional deficiency affects Heliconia cut flower production and the success of its commercialization (Castro *et al.*, 2011).

This review highlights the various aspects of growth, flower yield and quality parameters of Heliconias when grown in open as well as shaded conditions under different nutrition regimes.

2.1 CROPPING SITUATION

In general, Heliconia flowers under a wide range of light intensity (Broschat and Svenson, 1994).But subsequent studies revealed that the light requirement varies from species to species (Bruna and Kress 2002). Even geographically widespread or abundant species of Heliconia can be detrimentally affected by the environmental changes associated with light intensity (Bruna *et al.*, 2002). Light is an essential prerequisite factor for plant growth and development. It has long been known that photoperiodic conditions bring around the transition from vegetative to reproductive development as distinguished from condition that influences the subsequent development of flower buds (Wurr *et al.*, 2000). In addition, physiologically, light has both direct and indirect effects. It affects metabolism directly through photosynthesis and indirectly in growth and development (Dai *et al.*, 2009). In this study, two experiments were conducted under two levels of natural light intensity. The first experiment was laid out as an intercrop in coconut garden with an average light intensity of 26.2% and the second experiment in open condition (full sunlight) as a monocrop and providing artificial life-saving shade during summer months. The literature pertaining to the two conditions of cropping systems are presented below.

2.1.1 Intercropping

Broschat *et al.*, *(*1984a) reported that the growth and flowering of some Heliconias such as *H. psittacorum* were known to be limited by light-intensity. Yet some other species appear better adapted to slightly shaded conditions and were easily injured under full sunlight in the tropics (Criley,1995). *Heliconia stricta* can be grown from open to 40% shade (Berry and Kress, 1991). Under 50% shade, *H. stricta* plants produced fewer number of flowers (Broschat and Svenson, 1994). Eventhough, *Heliconia psittacorum* plants grown under 30% shade cloth had a lower total yield of flowers they produced longer stems, bigger flowers of better quality and a higher marketable yield (Powell, 1991). *H. angusta* was found mainly in shaded places, forming smaller shoots, about 0.70 m in height inside the forest, while those found at the border of the forest reach about 1.75 m (Simao and Scatena,2001). Plant height, leaf number, leaf area, number of suckers, number of spikes, no.of flowers/ bract and vase life were the highest in 25% shade followed by 50% shade in shade loving Heliconias (Sheela,2008).

2.1.2 Monocropped Condition

Flower production in *Heliconia psittacorum* increased as fertilizer rate increased and was substantially greater under full sunlight than 63% shade (Broschat and Donselman, 1983b;Manarangi *et al.*, 1988).According to Kress (1990), Heliconia species found in open areas achieve a larger size than those species restricted to shaded areas. This fact probably was due to the difference in the light intensity and to the degree of vegetative competition that occured among the different species in these habitats (Stiles,1975). *Heliconia stricta* 'Dwarf Jamaican' grown under open condition produced more inflorescences than those grown under 50%

shade. According to Broschat and Svenson (1994), plants grown in open condition had more inflorescences than those in shaded condition, possibly due to abortion of flower buds under suboptimal light intensity.

2.2 EFFECT OF NUTRITION AND CROPPING SYSTEM ON PLANT GROWTH PARAMETERS

2.2.1 Plant Height

Light intensity significantly affected plant height in *H. stricta* 'Dwarf Jamaican'. *H. stricta* was taller under shade than in full sunlight (Broschat and Svenson, 1994). *H. velloziana* produces larger shoots with up to 3.50 m in height in open areas (Simao and Scatena, 2001). The mean maximum height of species growing within 15 ^{0} of the equator (7.8 m) was 29 times greater than the height of species between 60and 75 ^{0}N (27 cm), and 31 times greater than the height of species between 45and 60 ^{0}S (25 cm). There was no evidence that the latitudinal gradient in plant height was different in the northern hemisphere than in the southern hemisphere ($P = 0.29$). A 2.4 fold drop in plant height at the edge of the tropics ($P = 0.006$) supported the idea that there might be a switch in plant strategy between temperate and tropical zones (Moles *et al.*,2009).

2.2.2 Sucker Production

Temperature had no significant effect on new shoot production with an average of 9.3 shoots per planting in Heliconia 'Golden Torch'. More shoots, however, were produced at the higher photosynthetic photon flux (PPF) level (10.1 compared with 8.3 shoots). The duration from emergence of shoot to the appearance of inflorescence was significantly less at 32 ^{0}C day/20 ^{0}C night than at 24 ^{0}C day/20 ^{0}C night (140 and 146 days, respectively) and was unaffected by PPF. This duration also was significantly affected by the interaction effects of order of shoot appearance and the number of leaves subtending the inflorescence. The second shoot to emerge had the shortest duration from shoot emergence to inflorescence emergence (Catley and Brooking, 1996). The hybrid Golden Torch presented better shoot production in 18 months with 20.4 shoots per clump on an average. The genotypes *H. pendula, H. episcopalis* and *H. bihai* cv. Nappi Yellow produced the smallest number of shoots and inflorescence per clump (7 to 13.7 on average) which explained the correlation between these two factors (Costa *et al*, 2006c). Number of shoots per clump varied from 1.00 to 4.00 at 108 DAP (Days after planting) and from 9.40 to 69.25 at 365 DAP (Loges *et al.*, 2011).

2.2.3 Leaf Thickness

According to Syvertsen *et al.,* (1995), the amount of light absorbed by a leaf, and the diffusion pathway of CO_2 through its tissues depended, at least partially, on its thickness. Negative relationships between leaf thickness and growth rates (Poorter, 1990) and photosynthetic rates (Enriquez *et al.*, 1996) have been observed and thicker leaves were associated with increased longevity (Mediavilla *et al.*, 2001). White and Montes (2005) reported that leaf thickness was often used as a tool to screen species and/or cultivars for productivity.

2.2.4 Leaf Number

The number of leaves subtending the inflorescence increased at higher temperature and decreased as rate of shoot production increased but was unaffected by PPF (Catley and Brooking, 1996). The number of leaves observed at the time of inflorescence emergence may be a useful indicator for producers to quantify the plants expected to bloom for market planning. The number of leaves on the pseudostem at inflorescence emergence ranged from 5.13 to 6.29 in *Heliconia psittacorum* (Rocha *et al.*,2010) and four to five leaves per shoot in *Heliconia stricta* (Cabral and Benedetto,2010).

2.2.5 Leaf Area

Temperature and PPF levels influenced total leaf area at flowering, with the highest leaf area being achieved in the high temperature–low PPF combination (Catley and Brooking, 1996). Specific leaf area (SLA) of Heliconia is negatively correlated with leaf life span and assimilation rates (Reich *et al.* 1997).According to Rundel *et al.* (1998), leaf blade areas were the largest in open sites, and leaf specific mass was also significantly higher, but leaf support efficiency was the highest in understorey species. Species in open sites had thicker leaves with more chlorenchyma, whereas, deep-shade species had very thin leaves and low stomatal densities. As leaf size and SLA usually change in parallel, it was suggested that these traits represented two facets of a functional strategy associated with low water and/or nutrient availability (Grubb 1998; Cunningham *et al.*, 1999). Fonseca *et al.* (2000) reported that SLA declined along with the gradients of decreasing moisture and/or nutrient availability. Leaf area of *H.acuminata* increased more than twice as much in continuous forest as in forest fragments (Bruna *et al.*, 2002).

According to Bruna *et al.* (2002), there was considerable difference in growth by Heliconia plants in both open and under storey condition. During the second rainy season, plants grown in open condition never recovered from initial dry season losses of leaf area and shoots. The asymmetrical losses of leaf area and shoots during the dry seasons, as well as final differences in growth rates, suggested that the normal abiotic stresses to which these understorey plants were exposed were greatly exhibited in open condition. Vile *et al.* (2005) reported that SLA is inversely proportional to leaf thickness which played an important role in leaf and plant functioning and resource acquisition and use.

2.3 EFFECT OF NUTRITION AND CROPPING SYSTEM ON DURATION OF THE CROP

Broschat *et al.* (1984a) studied in detail about the flowering of Heliconias. According to them, growth and flowering of *H· psittacorum* 'Parrot' occurred throughout the year. However, shoot and flower production appeared to be greater in the summer. Mean shoot and flower production reached a yearly high of 8.1 shoots/ plant/month (s/p/m) and 5.5 flowers/ plant/month (f/p/m) in the third quarter (July-Aug-Sept). Mean shoot and flower production during the first quarter (Jan-Feb-March) were 3.5 s/p/m and 2.9 f/p/m; second quarter (April-May-June), 4.1 s/p/m and 2.3 f/p/m and fourth quarter (Oct.-Nov.-Dec.), 2.4 s/p/m and 1. 8 f/ p/m. This greater shoot and flower production in the summer months appeared to be a factor of both higher temperature and greater total sunlight. The recorded average maximum and minimum temperatures respectively in January were 25.9^0 C and 17.5^0 C, and in August 29.8^0 C and 21.8^0 C. Total sunshine hours were 13 hours and 20 minutes during June, and 10 hours and 56 minutes during December. Later their researches with Heliconia 'Golden Torch', also reported a peak in production from July to September.

2.3.1 Growth Pattern

The optimum temperature for growth of 'Golden Torch' was between 32 ^{0}C and 21^0C . Reduced growth occurred at low temperatures and growth stopped at 10^0 C (Donselman and Broschat, 1986). Broschat *et al.* (1984b) reported a decrease in flower production under lower light conditions. In the study conducted by Skillman *et al.* (1999) with patterns of wet- and dry-season, vegetative growth in Heliconia and other understorey monocots indicated that they were relatively intolerant of dry-season water stress.

2.3.2 Flowering Pattern

According to Dobkin (1984), the interval between opening of bracts in Heliconia inflorescence increased with more soil moisture retention. In *H. psittacorum*, it was reported that the main factors influencing flowering were irradiance and temperature (Broschat *et al.*, 1984b), but photoperiod also appeared to have a slight influence (Geertsen, 1989). Criley and Kawabata(1986) studied seasonal pattern of flowering in *H. stricta*. Yields were greater for plants grown at eight hour photoperiods than under natural daylength. *H. stricta* flowered within one year after emergence of pseudostem. According to Geertsen (1990), the studies on the effect of photoperiod (8, 12, or 16 hr) and temperature (15, 18, or 21 ^{0}C) on *Heliconia aurantiaca* showed that at a photoperiod of eight hour, flowering was more advanced and more abundant, fewer leaves subtended the inflorescence, and the length of the flowering stems was shorter than at 16 hr photoperiod. A raise in the temperature from 15 to 21 ^{0}C increased the flowering percentage by 20; the flowering stems were 40 cm longer and the number of leaves subtending the inflorescence was increased by 2.5. No flowering occurred in long days. According to Powell and Neilson (1991), flowering of Heliconia started from 5 to 12 months after planting depending on the variety. Criley and Lekawatana (1995) observed that year-round flowering of *H. chartacea* was potentially possible as new shoots developed regularly. Flowering was low in the period of late March to early June. Heliconia species of commercial interest with strong seasonal flowering periods were noted by Criley(1999). They were *H.angusta, H.bihai, H.caribaea, H.caribaea X H.bihai, H.collinsiana, H.lingulata, H.rostrata, H.stricta, H.wagneriana* whereas the *H.psittacorum* cultivars and hybrids were observed as species with longer periods of bloom. In another study by Costa *et al.* (2006b), the number of days between the shoot emission and the inflorescence emission (DBSI) was observed in 10 genotypes of Heliconia. The shortest was 105 and 45 days and the longest was 126 and 93 days respectively. The average harvesting interval (interval between emission of inflorescence bud and the harvesting day) varied from 14 and 4 days (Hybrid Golden Torch) to 27 and 9 days (*H. bihai* cv. Nappi Yellow) (Costa *et al.*, 2009a).

2.3.3 Stages Of Flower Opening

The developmental stages of *Heliconia hirstutella* inflorescence has been documented (Ballah and Starr, 2010). The opening characters were classified into six stages. Each of these can be further subdivided into two sub-stages, which varied in their distinctness among the stages.

Stage 1 . Emergence: Inflorescence emerged from terminal end of pseudostem. Peduncle was not visible, bracts still closed without nectar secretion. Inflorescence was reddish-orange.

1A. Tip of bract one was visible.

1B. Bract one fully emerged.

Stage 2. Elongation: Peduncle emerged and elongated. Inflorescence rotated relative to axis of pseudostem. Bracts remained closed and were bright reddish-orange. Nectar droplets appeared on cheek of basal bracts.

2A. Peduncle began to appear and elongate, elevating inflorescence away from pseudostem. Inflorescence orientation was parallel to axis of peduncle.

2B. Inflorescence rotated to angle of 45-90° from axis of peduncle. Bract two starts to emerge.

Stage 3. Opening of first bracts: Nectar droplets appeared on all bracts. Flowers and fruits appeared. Inflorescence had bright reddish-orange with some yellow.

3A. Bracts began to open, bracts one and two unfurled, each with droplets of nectar. At least one flower was present in either or both of these bracts. Immature fruit was present in bract one only.

3B. Bracts three and four unfurled, with nectar droplets. Flowers were present in all bracts with immature fruit. Mature fruit were seen only in bracts one and two.

Stage 4. Inflorescence opened completely: Flowers and fruits were visible in all bracts, with dried pedicels in bracts one to four. No nectar secretion was seen on bracts one and two. Bracts were brick red-orange.

4A. Bracts five to six unfurled. Flowers were visible in all bracts, with fruits at all stages of maturity. Pedicels were seen only in bracts one to four. Nectar droplets were seen in bracts three to six.

4B. All bracts fully unfurled.

Stage 5. Early senescence: New-flower production reduced, darkening of bracts and cessation of nectar secretion occurred.

5A. Bracts darken, immature and mature fruit were present in all bracts together with dried pedicels.

5B. Further darkening of bracts was observed which led to development of dull red to pale orange in parts. The ratio of dried pedicels to flowers and fruits increased.

Stage 6. Full senescence: Flower production stopped entirely, with clear decay in all parts of inflorescence. There was distinct loss of color, with bracts going from dark red to blackish.

6A. Only mature fruit was present in some bracts.

6B. Inflorescence dried and became lifeless and its parts disintegrated.

2.4 EFFECT OF NUTRITION AND CROPPING SYSTEM ON FLORAL TRAITS AND YIELD

Rodrigues (2008) stated that among the tropical flowers, Heliconia was outstanding for its diversity in form, color, size and particularly, its durability. Fertilization rates strongly affect growth and flowering of Heliconia under high light intensities (full sunlight) (Broschat and Donselman, 1983a).

Ferreira and Pires (2005) studied in detail about the growth and flowering of Heliconia. Increased vegetative growth delayed flowering in Heliconia. Delay in floral initiation resulted in the development of additional leaves. According to them, the effect of nutrition on the number of leaves subtending the inflorescence might not have resulted a delay in floral initiation because no nutrient factor had an effect on the length of time from shoot emergence to flowering. Heliconias responded satisfactorily to application of fertilizers resulted in vigorous plants with increased size of inflorescences. Application of nitrogen, potassium, phosphorus, magnesium, iron and manganese and the fragmentation of fertilization of two to three times a year at a ratio of 3:1:2 of N, P and K resulted in rapid growth and flowering. Phosphorus and potassium positively influenced increase in the length of buds in *H.psittacorum* "St. Vincent Red."Increasing doses of N, P and K increased linearly in the production of flowers of that variety.

2.4.1 Flower Production

According to Broschat and Donselman (1987), temperature had a greater effect on flower production than inflorescence quality and postharvest vase life. Inflorescence production of *H. psittacorum* types was reduced at air temperature below 10^{o} to 12.5 ^{o}C. Criley and Kawabata (1986) reported that in *H. stricta* shoots had to have four leaves or more before flowering was initiated. Flowering in Heliconia was controlled by photoperiod (Criley and Kawabata, 1986;Criley,1990; Sakai *et al.*, 1990), leaf number (Criley and Kawabata, 1986; Kwon, 1992), and failure of an inflorescence to develop or flower abortion (Criley, 1989). Flower production of 'Golden Torch' was higher at 20 ^{0}C (Catley and Brooking, 1996). Heliconia flower production was probably limited by declining solar radiation and by within-plant competition for rooting space. Flowering occurred only in the first three shoots to emerge, the proportion of shoots producing flowers declined sharply with order of shoot emergence (57%, 26%, and 7% overall treatments, respectively) (Clemens and Morton, 1999).

2.4.2 Inflorescence Characters

Plant and flower size and postharvest life were not affected by light intensity in *Heliconia psittacorum*. (Broschat and Donselman, 1983a) Effect of light intensity on *H. stricta* 'Dwarf Jamaican', was highly significant for number of inflorescences (Broschat and Svenson, 1994). Loges *et al.*(2006) studied in detail the floral traits of 18 Heliconia genotypes from the Heliconia Germplasm Collection of Federal Rural

University of Pernambuco State. The genotypes were *H. psittacorum* L.f. *x H. spathocircinata* Aristeguieta cv. Golden Torch Adrian; *H. psittacorum* L.f. x *H.spathocircinata* Aristeguieta cv. Alan Carle; *H. psittacorum* L.f. cv. Strawberries & Cream; *H. psittacorum* L.f. cv. SurinameSassy; *H. psittacorum* Red Opol; *H.pseudoaemygdiana* L. Em. & Em; *H. psittacorum* Red Gold; *Heliconia x nickeriensis* Maas &de Rooij; *H. latispatha* Benth (orange); *H. latispatha* Bentham cv Yellow Gyro; *H. rauliniana*; *H. latispatha* Benth cv. Distans; *H.rostrata.*; *H. rostrata*; *H. wagneriana* Peters; *H. bihai* (L.) L. cv. Kamehameha; *H. psittacorumx H. spathocircinata* Aristeguieta cv. Golden Torch and *H. bihai.* Number of days from inflorescence emission to harvesting (DIH), fresh weight of stem (FWS), number of leaves in the stem at inflorescence emission (NLI), diameter of stem at 20 cm under the inflorescence (DI), stem length (SL) and inflorescence length (IL) are some important traits to be considered for genotype selection. The inflorescences were harvested when they had two to four open bracts. Significant (5%) difference was observed for all the traits among genotypes. The DIH ranged from 14 to 23 days. This information was important to help the growers on planning the harvesting program according to the species cultivated. The FWS varied from 40 to 360 g and the DI 18 to 34mm. The SL ranged from 56to 125cm, and the IL from 15 to 87 cm.

The main criteria used by the farmers for Heliconia inflorescence are the number of open bracts and the length of the inflorescence stem (Costa *et al*, 2006b). In 2007 Costa *et al* reported that the inflorescence stem length of *H.stricta* grown under partial shade was 71.6cm. Ballah and Starr (2010) observed that the stem diameters tended to be thinner at the lower PPF level. Overall, temperature was more dominant than light in influencing production and quality of flowers, but developmental factors associated with the order of shoot appearance also played a significant role. Bracts decreased in size from the base to the tip of the inflorescence.

2.4.3 Flower Quality

According to Powell (1991), Heliconia flowers could be cut when two or three bracts are open, but tighter flowers could also be used effectively in floral arrangements. The marketable yield of Heliconia flowers varied with nutrient content of the growing medium and light intensity; ranging from 59.5 to 74.7 %. Catley and Brooking (1996) reported that acceptable quality flowers had at least two, opened, well-formed, well coloured bracts. Flower stems were taller and thicker at 32 ^{0}C day/20 ^{0}C night and these dimensions increased further with increasing order of shoot appearance. The period of flowering varied between species but was also affected by environmental conditions. The peak usually occurred in early summer, declined in autumn and stoped when the average temperature approached 10 °C (Geertsen, 1989; Catley and Brooking, 1996).It was observed by Criley and Lekawatana(1991) that the period from planting to flowering of each cultivar varied markedly depending on environmental conditions.

2.4.4 Vase Life Of Flowers

Broschat and Donselman (1983a,b) reported that postharvest life of *Heliconia* flowers varied with variety and ranged from 7-14 days in deionized water, with or without floral preservatives. Flowers were damaged when stored at temperatures below 10° C. No varietal difference was reported. Growth and flower production of *H. psittacorum* types were greatly affected by light intensity, though inflorescence quality and postharvest vase life were not significantly affected. It was observed by Bredmose (1987) that the shortest vase life of Heliconia flowers grown in Denmark and held in tap water was 2 weeks when harvested during the winter compared to 4 weeks during the summer. Potassium fertilization from 0 to 600 gm^{-2} per year did not significantly affect *H.psittacorum* inflorescence quality was reported by Broschat and Donselman (1983a). Their studies in red ginger in 1988 showed that if nitrogen fertilizer rate is increased from 142 to 568 g per plant per year the number of saleable red ginger inflorescence increased nearly by 70%, without affecting postharvest vase life. Tija (1988) expressed the end of vase life in red plume ginger (*Alpinia purpurata*) when the inflorescence and stem had lost 10% of their fresh weight. Later, Criley and Paull (1993) studied in detail about the vase life of Heliconia. According to them, the end point was reached when 20% to 30% of total bracts showed browning or when the bract tip bends away from the axis $>90^0$. Stem length was not reported as a major factor contributing to the vase life. When stem lengths of 35cm and 70 cm were compared no significant difference in vase life (14 to 16 days) was found between younger or mature inflorescences. But the inflorescences harvested in the cool season recorded a slightly longer vase life than warm season inflorescence.

Broschat and Donselman (1983a) observed that generally, Heliconia inflorescences did not continue to open once cut. Hence Heliconia flowers must be cut at the desired stage of opening since further opening of the bracts does not occur after cutting, even if sucrose solutions were used (Criley and Lekawatana, 1995). It was also observed that *H.psittacorum* inflorescences could be cut at the tight flower stage or when one to three bracts were open (Criley, 1995; Donselman and Broschat, 1986). However, Tija and Sheehan (1984) reported that those inflorescences harvested at a younger stage (no open bract) lasted 42% longer than those harvested at a mature stage (three to four bracts open).The common practice for Hawaiian growers was to harvest Heliconia by cutting the inflorescence stalks near the soil line in the early morning (Criley and Paull, 1993;Criley,1996). Postharvest quality of tropical cut flowers depended on both preharvest and postharvest factors. Preharvest factors included environmental factors such as rainfall and temperature, cultivar, fertilizer levels, stage of flower development at harvest and time of day when harvested; whereas postharvest factors included all the steps in the handling system until the flowers reached the consumer (Jaroenkit and Paull, 2003).

2.5 EFFECT OF NUTRITION AND CROPPING SYSTEM ON LEAF CHLOROPHYLL CONTENT

Leaf chlorophyll content was well established as a common reference system when physiological reactions were quantified. Assessment of chlorophyll content was a valuable tool for agricultural and non-managed ecosystem studies, since it provided information on key vegetative properties that were, in turn, linked to net primary production. Osmond (1994) reported that in shade loving plants high light intensity inhibited photosynthesis and led to photosynthetic apparatus (chloroplast) damage. Middleton (2001) observed that under shaded condition, ornamental plants in general produced thinner leaves with higher chlorophyll content. Light provided the leaf with more photochemical energy that could be utilized by photosynthesis. Excessive light intensity resulted in lower quantum utilization and a lower assimilation yield (photoinhibition).Goltsev *et al.* (2003) reported that extremely high irradiation destroyed photosynthetic pigments. Decreases in chlorophyll b content was suggested to be an indication of chlorophyll destruction by excess irradiance by Jason *et al.*(2004).

He *et al.*(1996)observed that in several species of Heliconia, photosynthetic efficiency and chlorophyll content of leaves were lower when plants were grown under full sun light, than when they were under light shade. The increases in Heliconia leaf chlorophyll content were associated with increased leaf mass density rather than to changes in leaf thickness according to Rundel *et al* (1998). However, later found that lower chlorophyll content occurred when the nutrient supply to plants was limited and photoinhibition of plants grown under full sun disappeared when applying nutrients particularly, nitrogen (He *et al.*,2003).

2.6 EFFECT OF NUTRITION AND CROPPING SYSTEM ON PLANT NUTRIENT CONTENT

Nutritional deficiency affects Heliconia cut flower production and the success of its commercialization. Castro *et al.* (2011) studied in detail about the macro nutrient content in various parts of Heliconia in different stages of growth. They found that the nutrient contents differed significantly between different growth phases of Heliconia. The greatest nitrogen amount was observed at the reproductive phase. P and K contents were the highest at the vegetative phase. The highest N content was found in the mix of leaves and in the third leaf. The superior N content at the mix of leaves indicated that other leaves may have a N content even higher than the third leaf. The rhizome showed a higher P and K content than leaves. There was an interaction between the development phase and plant parts for all the macronutrients studied. For the elements P and K, the same result for each factor separately could be observed at the interaction of these factors, where rhizome showed the highest contents at the vegetative phase which characterized a simple interaction.

According to Clemens and Morton (1999), the use of different NPK formulation was very common without considering development phase (whether vegetative or reproductive), species, seasonality or flowering period. The number of shoots and flowers produced per rhizome were maximum at low N to K ratio (1:1). Flower yield could therefore be optimized with appropriate fertilization, provided attention was paid to the N to K ratio so that the size of plants and their flowers was not compromised by efforts to increase shoot and flower number. The probability of shoots flowering declined markedly with order of shoot emergence, although this could be increased with appropriate mineral nutrition. The maximum number of leaves subtending the inflorescence (seven) was obtained at high N and P rates. The number of shoots that emerged per plant was strongly influenced by mineral nutrition, with significant positive linear effects of N, P, and K, and quadratic effects of N and P. There were no significant mineral nutrient interactions. Maximum number of shoots to emerge per plant was predicted at N and P rates of 1.16 and 0.67 kgm^{-2}, respectively, by the following equation: Number of Shoots = 0.95 + 8.54N+5.95P – 3.67N2 – 4.5 P2 (standard error of the estimate ± 1.7 shoots). Increasing K from zero to one kgm^{-2} increased the predicted maximum by 0.34 shoots per plant for each 0.25 kg m^{-3} K increase from 7.85 shoots per plant with no addition of K), but did not alter the location of the maximum with respect to N or P.

Studies by Criley and Broschat (1992) showed that *Heliconia* sp. in cultivation generally required high rates of macroelements, particularly N. An 18:6:12 NPK fertilizer applied at 3 kgm^{-2} $year^{-1}$ was recommended for *H. psittacorum* 'Andromeda'and *H.* sp. x 'Golden Torch' (Broschat and Donselman, 1983a;Broschat *et al.*, 1984b). These authors found that lower fertilizer rates resulted in reduced flower yield under full sun conditions. There was no effect of fertilizer rate under low irradiance (63%shade), when yield was reduced substantially. *Heliconia* sp. were reported to be grown commercially using ratios of N, P, and K that include 1:1:1, 1:2:2, 3:1:2, and 3:1:5 (Criley, 1985; Ball, 1986; Criley, 1990). Broschat and Donselman (1987) investigated N to K ratios in *H. psittacorum* and reported that K was not a limiting factor at K application rates in the range 0.0 to 0.65 kg $m^{-2}year^{-1}$.The effects that individual rates and ratios of N, P, and K had on specific aspects of growth and flowering in Heliconia have not been studied comprehensively. In addition, little published research is available on fertilizer requirements of potted *Heliconia* sp. (Criley and Broschat, 1992). Investigation by Clemens and Morton(1999) further revealed that high N and a high N:K ratio favoured biomass production (reflected in vegetative growth and size of flowers), a more moderate N and low N:K ratio favoured flower production. There were significant linear and negative quadratic terms for N, P, and K, as well as N–P and P–K interactions, for the number of leaves subtending each inflorescence on the first shoot to emerge. A *maximum of* 6.7to 7.0 leaves was predicted at high rates of N and P (>0.9 and 0.6 kgm^{-2}, respectively). At lower and higher rates of N and P application, the number of subtending leaves was predicted to drop to 5 to 6, especially in response to low N.

The critical nutrient level in leaves of Heliconia var.Parrot and var. Pink lobster claw was estimated from University of Hawaii (Uchida,2000) is listed below

N	P	K	Ca	Mg	S	B	Fe	Mn
(%)						(ppm)		
1.67-1.79	0.27-0.38	1.72-2.13	0.75-0.81	0.33-0.38	0.36-0.39	10-15	30-40	26 -93
2.34	0.27	1.77	1.34	0.75	0.3	09	3.8	142

2.7 EFFECT OF NUTRITION AND CROPPING SYSTEM ON SOIL PROPERTIES

According to Janakiram (2009), Heliconias thrived in soils rich in organic material. However, a slightly acidic soil with well- drained medium with high fertility is preferred. Chlorosis developed readily on plants grown in soils with a high pH. Higher incident solar radiation resulted in higher air and soil temperature leading to lower soil moisture and nutrient retention (Nobel and Linton, 1997). Studies showed that intercrops use soil-nutrients more efficiently than sole crops by Zhang and Li (2003). Presence of a specific nutrient in the soil did not necessarily suggest availability to the plant. The key component to nutrient uptake was the chemical solubility of the ion that the plant required and that solubility was highly dependent on soil solution pH. In general, many plants did well in a soil pH range of 5.5 to 7.5.The EC of the soil had little direct detrimental effect on sandy soils (Hanlon, 2012).

2.8 EFFECT OF INTERCROPPING ON COCONUT YIELD AND YIELD PARAMETERS

Coconut palms grown under coastal sandy soil conditions generally produced only 20-40 nuts/palm/year (George *et al*, 2010).According to Khan (2003), in several coconut growing countries, coconut as a monocrop was only marginally productive and profitable. Many investigators showed that when coconut is grown as monoculture, as little as 25% of land was effectively used for its growth and productivity (Braconie *et al*, 1998).Intercropping in coconut plantations was an important subject of many investigations (Mapa,1995; Braconie *et al*,1998; Reddy and Biddappa,2000). But there are only a few reports on ornamental plants as intercrops in coconut plantations (Sudha and Subramanyam, 1992). Heliconia, Anthurium and *Jasminum* spp. could be grown as coconut intercrops. (CPCRI, 2003; Arunachalam and Reddy,2007). The economic analysis of coconut based cropping system under coastal sandy soil realized higher returns as compared to monocrop (George *et al*, 2010). The net returns had ranged from Rs.45,771/ha/year in the case of coconut monocrop to Rs.1,03,010/ha/year in the case of coconut+pineapple intercropping system. (Subramanian *et al*., 2009).

Materials and Methods

3. MATERIALS AND METHODS

Two experiments on *Heliconia stricta* cv. Iris Red as monocrop and intercrop in coconut garden were laid out in RBD for a period of two years during 2010- 2012 with five treatments and four replications in Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State. The present investigation was to standardize a manurial schedule for enhancing production and quality of Heliconia flowers when grown under same nutrient management practice in two cropping systems. This also aims at comparing the flower quality and vase life of flowers grown under different conditions and thereby standardising an integrated nutrient recommendation suitable for each system of planting. The present study is based on the information available regarding the nutrient requirement of the crop and also the management practices adopted by Heliconia growers of Kerala. According to the information received from the growers in Kerala, they adopt an integrated approach of nutrient management ie; 1kg FYM/plant + 250g bonemeal applied basally and complex fertilizers such as 17:17:17 NPK applied @ 5g/plant at quarterly intervals. Heliconia fertilizer mixture developed by Green culture, Singapore for top dressing the plants is 13:5:13 NPK @ 5g/plant as slow-release fertilizer (Ken, 2007). Details of the materials and methods used for the experiments are described in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The field experiment was conducted at Block III of Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State, India. The area is located in coastal humid tropics (9^0 8' North latitude, $76^0$30' East longitude and 3.05 m above mean sea level).

3.1.2 Soil

The soil of the experimental site is sandy loam of the order Entisol with pH of 5.7, 0.15% organic carbon,397.3kg/ha of available N, 53.1 kg/ha P_2O_5, 122.3kg/ha K, 0.022 % Ca, 24.6 ppm Mg, 1.12 ppm Mn, 13.4 ppm Fe, 1.39 ppm Cu and 2.2 ppm Zn.

3.1.3 Nature And Cropping History Of The Site

Two sites were selected for the experiments in Block III of Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State, India. The site for monocropping was under various crops such as tapioca, banana and elephant foot yam in rotation since 2005. The site selected for intercropping study during May 2010 was coconut garden with palms spaced at 7.5m and aged 25 years. There was no history of intercropping in that location. The gross cropped area of the experimental plot was 1100 m^2 with a net cropped area of 320 m^2.The average shade intensity of the plot was 26.2%.

The PAR (Photosynthetically active radiation), total illumination and total radiation of the site was estimated using Light meter Model LI-250, Li-COR serial no.LMA 2505. The average values during peak hours (11 am to 2pm) are as follows.

Parameter	Cropping system	
	Monocropping (Open condition)	Intercropping
PAR(μ mol $s^{-1}m^{-2}$)	1253.15	937.5
Total illumination(Wm^{-2} μA)	4981	2278
Total radiation(Wm^{-2})	13184	8068

3.2 SEASON

The field experiment was conducted from June 2010 to May 2012.

3.3 WEATHER

Data on weather conditions during the experimental period (June 2010 to May 2012) were obtained from the Meteorological Observatory, Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State, India and is given in Appendix I.

The average maximum and minimum temperature experienced during the period of present study (June 2010 to May 2012) was 32.3^{0}C and 23.1^{0}C, respectively. The mean evaporation was 2.97 mm/day with RH of 94.9% (FN) and 64.5% (AN).

3.4 MATERIALS

3.4.1 Planting Material

Uniform sized good quality *Heliconia stricta* Iris Red stumps collected from an authorized Heliconia nursery of Kerala state (Saubhagya orchid, Nalanchira, Thiruvandapuram, Kerala,India) were used for the study.

3.4.2 Manures And Biofertilizers

Bonemeal and dried cowdung were applied uniformly to all the plots at the time of planting. Two complex fertilizers (17:17:17 and 13:05:13 NPK), two organic manures (vermicompost and neemcake) and two biofertilizers (Azospirillum and phosphobacteria) were used for the study. Urea (46 % N), rock phosphate (16 % P_2O_5) and muriate of potash (60 % K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively. The nutrients supplied to each treatment was calculated based on the analytical report of the

NPK contained in the organic manures used for the experiment and is given in Appendix.II .The biofertilizers, vermicompost and neemcake were purchased from authorized dealers (Uppoottil Agencies, Kottayam, Kerala,India).

3.5 METHODS

The variety selected for study is *Heliconia stricta* cv. Iris red

3.5.1 Experiment I

Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

3.5.2 Experiment II

Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

3.5.3 Design And Layout Of The Experiment

Design	:	RBD
Treatments	:	5
Replications	:	4
Spacing	:	1m x 1m
Plot size	:	4 m x 4 m
Number of plants per plot	:	16

3.5.4 Land Preparation And Planting

The field was ploughed to a fine tilth during second fortnight of May 2010 and plots of size 4 m x 4 m were taken in the open condition as well as in the

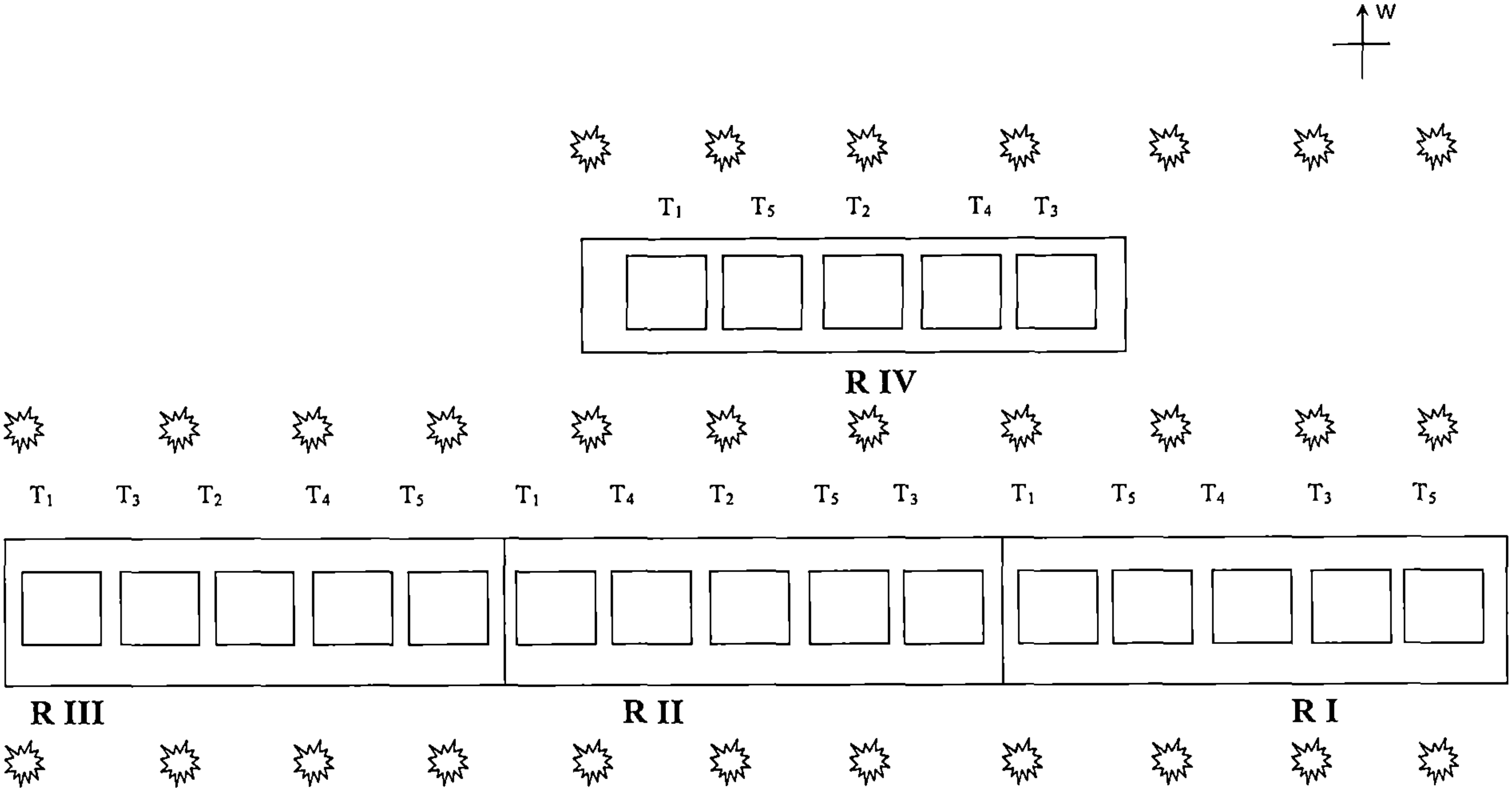


Figure.1. Field lay-out of Experiment I

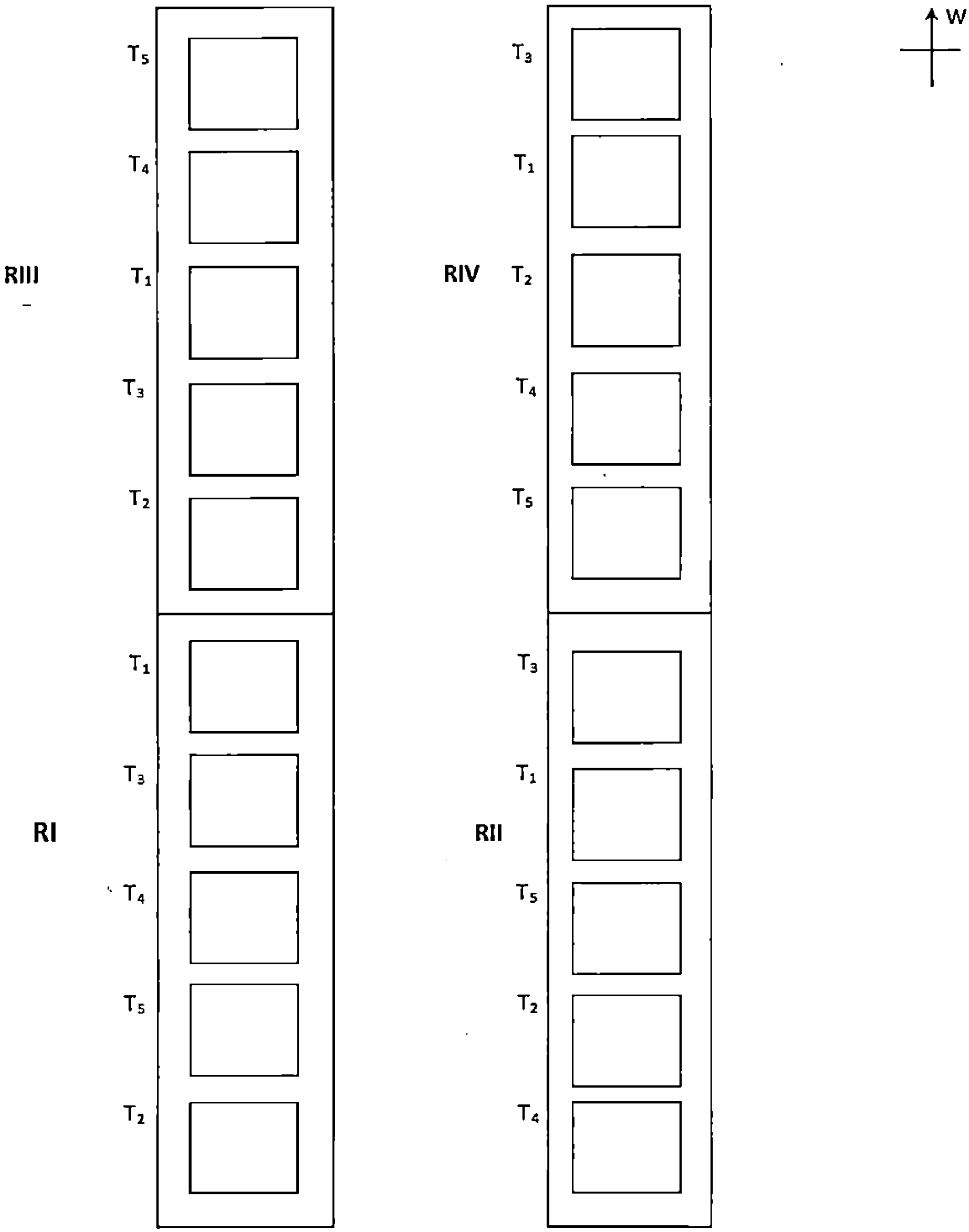
- Coconut palm

R - Replication

T - Treatment

Fig. 2. Field lay-out of Experiment II

Standardisation of nutrient management for *Heliconia stricta* grown as monocrop



interspaces of coconut garden leaving an area of two meter radius from the base of the palms. Heliconia stumps were planted during first week of June 2010 in beds at 1m x1 m spacing with a plant density of 16 plants/plot. Between plots, a spacing of 50 cm was maintained (Fig. 1 and 2).

3.5.5 Treatment Details

The same treatments were repeated at quarterly interval for the two experiments laid out for the study. A uniform dose of 1kg FYM + 250 g bonemeal/plant was applied basally for all the treatments. All the treatments as per the technical programme were given as top dressing at quarterly intervals. The same set of treatments was applied for both Experiment 1 and Experiment 2. Biofertilisers in the treatment were applied at the time of planting. All the nutrients in the treatment combinations were supplied in full dose at quarterly intervals from three months after planting (September 2010 onwards).

T_1 : 17:17:17 NPK complex fertilizer @5g/plant (Farmers' practice)

T_2 : 13:05:13 NPK @ 5g/plant (Ken, 2007)

T_3 : Vermicompost @ 200 g/plant + Neem cake @100g/plant

T_4 : Vermicompost @ 100 g/plant + Neem cake @50g/plant + Biofertilisers (*Azospirillum* and Phosphate Solublising Bacteria each @1g/plant)

T_5 : 13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant + Neem cake @50g/plant

Plate Ia. Before planting

Plate Ib. After planting

Plate 1: Closer view of the experimental field

3.5.6 After Cultivation

The crop was grown as an irrigated crop. Irrigation was given at four days interval during non rainy days. Periodical hand weeding and earthing up were done depending upon the intensity of weed growth. Old shoots and flowers were removed periodically. Thinning of slender shoots was also done at monthly intrevals. Shade net was erected during January to May for the second experiment.

3.5.7 Plant Protection

The plants were observed frequently for any pest /disease occurrence and remedial measures were taken as and when needed.

3.6 OBSERVATIONS

For each treatment combination, four replications were maintained. Three plants in each replication and treatment were tagged for taking biometric observations at monthly intervals from Dec.2010 till Nov.2011.The inflorescence characters were taken at quarterly intervals for a period of one year. Leaf nutrient content was analyzed one year after planting at the time of flowering. Plant nutrient content and final soil analysis were conducted during May 2012. The observations of coconut palms in the intercropped area for leaf nutrient content and yield parameters were taken at six monthly interval from June 2010 to December 2011.

3.6.1 Plant Characters

3.6.1.1 Growth Characters

The observations on growth characters were taken from randomly selected three sample plants in each plot at monthly intervals after six months of planting for a period of one year and the mean values were worked out.

3.6.1.2 Plant Height (cm)

The height of the plant was measured from the base of the plant to the tip of the longest leaf and the mean value was recorded.

3.6.1.3 Number Of Suckers

The number of suckers per clump was counted and the mean value was recorded.

3.6.1.4 Number Of Leaves

The number of fully opened leaves in a clump was counted and the mean value was recorded.

3.6.1.5 Collar Girth (cm)

The circumference of the collar region at 5cm height from base of the longest stump was measured and the mean value was recorded.

3.6.2 Physiological Characters

3.6.2.1 Leaf Area

Leaf area of the plants was calculated using the formula given below and the mean value was recorded.

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

(Bruna *et al.*, 2002)

3.6.2.2 Leaf Area Index (LAI)

The LAI is computed by using the equation and the mean value was recorded.

a, General view at 2 MAP

b, General view at 4 MAP

c, General view at 8MAP

d, General view at 12MAP

Plate 2.General view of the experimental field at different growth stages – Exp I

a, General view at 2 MAP

b, General view at 4 MAP

c, General view at 8MAP

d, General view at 12MAP

Plate 3.General view of the experimental field at different growth stages - Exp II

a,Experiment I

b,Experiment II

Plate 4.General view of the experimental fields at 24 MAP

a, Exp I and b, Exp II

$$LAI = \text{Leaf area (cm}^2\text{)} \; / \; \text{Land area (cm}^2\text{)}$$

3.6.2.3 Specific Leaf Area (SLA)

SLA is calculated instead of Leaf area ratio (LAR).

The SLA is computed using the equation and the mean value was recorded.

$$SLA \text{ (cm}^2 \text{ g}^{-1}\text{)} = \text{Leaf area (cm}^2\text{)} \; / \; \text{Dry weight of leaf (g)}$$

3.6.2.4 Leaf Area Duration (cm² / 30 days)

It is the average difference in leaf area in 30 days interval and the mean value was recorded using the equation given below.

$$LAD = \frac{\text{(Leaf area at 30 days + Leaf area at 60 days) / 2}}{30}$$

3.6.2.5 Leaf Area Density (g/cm²)

The Leaf Area Density is computed by using the equation and the mean value was recorded.

$$\text{Leaf Area Density (g/cm}^2\text{)} = \frac{\text{Dry weight of leaf (g)}}{\text{Leaf area (cm}^2\text{)}}$$

3.6.3 Duration Of The Crop

3.6.3.1 Days Taken For First Flowering

It is the number of days taken from planting to commencement of flowering.

3.6.3.2 Days Taken For fifty Percent Flowering

It is the number of days taken by fifty percent of plants in a plot to flower

3.6.4 Life Of Flower In The Plant

The life of the flower in plant is categorized into different stages.

3.6.4.1 Just Emerged To Just Opened (Stage I to II)

The days taken for the inflorescence from just emerged from terminal end of pseudostem (Stage I) to just opened stage (Stage II). The inflorescence is deep red in colour.

3.6.4.2 Just Opened To Fully Opened (Stage II to III)

The days taken for the inflorescence peduncle to emerge and elongate resulting in complete opening of inflorescence (Stage III).

3.6.4.3 Longevity Of Flower (Stage III to IV)

The days taken for fully opened flower to senescence (Distinct loss of color, with bracts going from dark red to blackish).It is taken as the time taken for the inflorescence to shift to senescence (Stage IV) from Stage III.

3.6.4.4 Interval Between Opening Of Bracts

Number of days taken for opening of bracts is taken and the mean value is recorded.

3.6.5 Inflorescence Characters

Observations on inflorescence and spike parameters were taken from selected plants at quarterly interval from nine months after planting (March 2011) up to 24 months (May 2012). The quality parameters were studied during May to Nov.2011 and Feb.2012.The flower opening patterns were studied on alternate days during April-May 2011 and Sep.-Oct.2011.

3.6.5.1 Inflorescence Length (cm)

The length of the inflorescence was taken from the base of the inflorescence stalk to the tip of the axis of fully opened inflorescence.

3.6.5.2 Length And Width Of Spike

a. Size of just opened spike

The length and width of the just opened (peduncle not visible, bracts still closed, no nectar secretion) inflorescence was taken and the mean values were recorded.

b. Size of fully opened spike

The length and width of the fully opened (all bracts fully unfurled) flower was taken and the mean values recorded.

3.6.5.3 Length Of Inflorescence Stalk (cm)

The length of the inflorescence peduncle was taken from the point of emergence from the shoot to the base of the first bract and the mean value was calculated and expressed in cm.

3.6.5.4 Number Of Flower Bracts

The number of bracts in fully opened inflorescence was counted and the mean value was recorded.

3.6.5.5 Girth Of Inflorescence (cm)

The inflorescence stem diameter 20cm under the spike was taken and the mean value was recorded (Loges *et al*, 2006).

3.6.5.6 Average Width Of Bract (cm)

The width of all the bracts at the broadest point in an inflorescence was taken and the mean value was recorded.

3.6.5.7 Number Of Flowering Shoots Per Year

Monthly counts were made for estimating number of flowering shoots during April 2011 to May2012. Total number of flowering shoots produced by each clump of plant for one year was recorded and the mean value was calculated.

3.6.5.8 Fresh Weight Of Inflorescence (g)

Form each experiment, five fully opened inflorescences from every treatment were selected during June, Sep. and Dec. 2011 and March 2012. The fresh weight was recorded and the mean value was calculated.

3.6.6 Visual Appeal Of Flowers

The visual appeal of fully opened flowers was assessed by a panel of 20 judges. Score sheet was prepared with a score range from 1 to 10 (low to high) with four parameters. Three flowers were selected from each treatment and were assessed visually for the following characters.

Flowers were categorized into three groups; Average (1 to 5), Good (6-8) and Very good (9 to 10) on a 10 point basis.

The model score sheet for visual appeal of inflorescence:

SCORE CARD

Visual appeal of *Heliconia stricta* cv. Iris Red flowers

Range : 1 to 10 (low to high)

Sl.no	General Appearance	Bract arrangement	Glossiness	Colour development	Total score
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

3.6.6.1 General Appearance

The compactness of the flowers was visually assessed by each judge and the score was given according to their perception.

3.6.6.2 Bract Arrangement

The arrangement of bracts in one plane and the uniformity of arrangement were assessed by each judge and the score was given according to their perception.

3.6.6.3 Glossiness

The smoothness and glossiness of the inflorescence was visually assessed by each judge and the score was given according to their perception.

3.6.6.4 Colour Development

The uniform colour development of the bracts was visually assessed by each judge and the score was given according to their perception.

3.6.7 Plant Analysis

3.6.7.1 Leaf Chlorophyll Content (%)

The leaf chlorophyll content was estimated by Acetone method (Saini *et al.*, 2001) and estimated chlorophyll a, chlorophyll b and total chlorophyll.

3.6.7.2 Leaf Wax Content

Leaf bits of $5cm^2$ were taken from upper most fully opened leaves of flowered shoots and dipped in 10 ml of cholorform for 10 seconds. The difference in weight of the chloroform content was calculated as the wax content and expressed in mg/cm^2.

3.6.7.3 Leaf And Whole Plant Nutrient Content

Leaf samples were taken from the top most fully opened leaves (Uchida,2000) of flowered shoots during Sep.2011 and dried and powdered. The whole plant was taken during June 2012, chopped and dried in hot air oven at 70^0 C till constant weights were obtained. It was then powdered and the composite sample for each treatment was taken for analysis. The plant and leaf samples were analyzed for nitrogen, phosphorus , potassium, calcium, magnesium, iron, manganese and zinc content.

The methods adopted were:

a) Total N

Modified Microkjeldhal Method (Jackson, 1973).

b) Total P

Plant digest was taken in diacid (Nitric and Perchloric acid in 2:1) (Baruah and Barthakur,1998) and estimated by Vanadomolybdophosphoric yellow colour method and read in spectrophotometer at wavelength 660 nm (Jackson, 1973).

c) Total K

Plant digest was taken in diacid (Nitric and Perchloric acid in 2:1) (Baruah and Barthakur,1998) and estimated by Flame photometric method in Systronics Flame Photometer (Jackson, 1973).

d) Ca, Mg, Fe, Mn and Zn

Plant digest was taken in diacid (Nitric and Perchloric acid in 2:1) using standard procedure (Baruah and Barthakur,1998) and estimated using AAS.

3.6.8 Nutrient Status Of Organic Manures

Organic manures	N (%)	P (%)	K (%)
Cowdung	1.0	0.5	1.0
Bonemeal	3.5	21.0	-
Vermicompost	1.2	0.4	0.6
Neemcake	0.9	0.5	1.2

3.6.9 Soil Nutrient Status

The soil samples(before and after the experiment) were taken from four soil cores adjacent to a randomly selected point along each transect from uppermost 10 cm of soil where the roots of Heliconia are generally found (Bruna *et al.*, 2002).These soil samples were then mixed and composite sample was taken for analysis.

a) Soil pH

The soil was dried in the shade, sieved and pH was measured at 1: 2.5 soil–water ratio using a pH meter with glass electrode (Jackson,1973).

b) Electrical conductivity (dSm^{-1})

The clear supernatant of 1:2.5 soil water suspension prepared for pH measurement was used for estimation of EC using conductivity meter (Jackson,1973).

c) Organic carbon

Wet Digestion method (Walkley, 1947)

d) Available P_2O_5

Bray colorimetric method (Jackson, 1973).

e) Available K_2O

Ammonium acetate method (Jackson, 1973).

f) Exchangeable Ca and Mg

Ammonium acetate extract was taken using standard procedure and the elements were estimated using AAS (Baruah and Barthakur,1998).

g) Fe, Mn and Zn

DTPA extract was taken using standard procedure and the elements were estimated using AAS (Lindsay and Norvell, 1978).

3.6.10 Flower Quality Parameters

The following flower quality parameters were analyzed at quarterly intervals during May to Nov.2011 and Feb.2012 and the mean values were recorded.

3.6.10.1 Wax Content Of Flowers (mg/cm²)

Bract- slices of 5cm^2 were taken from either sides of the 2nd and 3rd bracts and dipped in 10 ml of cholorform for 10 seconds. The difference in weight of the chloroform content was calculated as the wax content.

3.6.10.2. Flower Carotenoid And Chlorophyll Content

The flower carotenoid and chlorophyll content were estimated by Acetone method (Saini *et al.*, 2001) and the ratio of carotenoid to chlorophyll a, chlorophyll b and total chlorophyll was calculated.

3.6.10.3 Vase Life Of Flowers

Fully opened flowers were immersed in distilled water and the seasonal variation on vase life was recorded during June 2011, Sep.2011, Dec.2011 and March 2012. The end point of the flower is noted with the distinct loss of color, with bracts going from dark red to blackish. The data was pooled and average vase life of flowers was statistically analysed.

3.6.11 Economics Of Cultivation

3.6.11.1 Number Of Saleable Suckers

The number of saleable suckers with collar girth more than nine centimetres was counted monthly from 8MAP for a period of one year and the mean was recorded.

3.6.11.2 Number Of Marketable Flowers

Inflorescences with at least two, opened, well-formed, well coloured bracts with around one meter length and more than nine centimetres peduncle girth were taken as marketable flowers. The number of flowers produced from 10 MAP was recorded monthly during April.2011 to May2012.

3.6.11.3 Benefit Cost Ratio (BCR)

BC ratio was worked out based on cost of cultivation and economic returns (in terms of flowers).

3.6.12 Nutrient Balance Sheet

The nutrient content of soil after the experiment and the whole plant nutrient content were estimated from the samples taken during June 2012 and nutrient balance sheet for N, P and K was prepared. It is estimated using the equation.

{Initial nutrient content in soil (kg/ha) + Nutrient supplied through fertilizer (kg/ha)} - {Plant uptake (kg/ha) + soil nutrient content after the experiment (kg/ha)}

3.6.13 Effect Of Heliconia Intercropping On Fruit Setting Percentage Of Coconut

Six coconut palms were selected in Heliconia intercropped area and the following parameters were recorded at six monthly intervals during May and December of 2010 and 2011.

3.6.13.1 Number Of Leaves

Total number of leaves in the coconut palms was counted and the mean was recorded.

3.6.13.2 Number Of Bunches

The total number of fruit bunches was counted and the mean was recorded.

3.6.13.3 Number Of Barren Bunches

The number of bunches without nuts was counted and the mean was recorded.

3.6.13.4 Average Number Of Buttons Per Bunch

The total number of buttons per bunch was recorded and the average was worked out.

3.6.13.5 Average Number Of Nuts per Bunch

The total number of nuts per bunch was recorded and the average was worked out.

3.6.13.6 Coconut Leaf Nutrient Content

The leaf N, P, K,Ca, Mg, Fe, Mn and Zn content were analysed. The leaf samples were collected from the index leaf as per the standard procedure.

3.6.13.7 Fruit Setting Percentage

The fruit setting percentage was calculated based on the predicted yield. The predicted yield of palm was calculated using the equation

(Mathew *et al.*,1991)

Sept. to Feb. $Y= 1.09\, X1 + 0.44X2\ (R^2 = 0.92)$

Mar. to May $Y= 1.02\, X1 + 0.52\, X2\ (R^2 = 0.88)$

Where,

Y= forecast yield

X1= total count of nuts above fist size

X2= total count of nuts below fist size

3.6.14 Land Efficiency Ratio (LER)

It is the relative land area required as sole crop to produce the same yield as intercrop and computed using the equation;

$$LER = L_A + L_B = Y_A / S_A + Y_B / S_B$$

(Mead and Willey, 1980)

Where, L_A and L_B are the LER for individual crops, Y_A and S_A are individual crop yields in intercropping system and Y_B and S_B are crop yield when grown as sole crop.

The LER was calculated in terms of marketable flowers.

3.6.15 Statistical Analysis

The data collected on different treatments in two cropping systems were analysed by applying the technique of analysis of variance (ANOVA) for randomized block design (RBD) (Panse and Sukhatme, 1985).

Results

4. RESULTS

Two experiments were conducted on *Heliconia stricta* cv. Iris Red in Block III of Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State, India during 2010-2012.The experiments aimed at the following objectives.

1. To standardize a cost-effective manurial schedule for *Heliconia stricta* for better flower yield and quality when grown as an intercrop in coconut garden and as a monocrop in monocropped condition.

2. To analyze the effect of substituting chemical fertilizers with vermicompost, neem cake and biofertilizers in flower quality and yield.

3. To evaluate the performance of Heliconia under two cropping systems.

The results of the study as two experiments are presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Effect Of Nutrition And Cropping System On Plant Height (cm)

Height of the heliconia plants was recorded from six Months After Planting (MAP) at monthly intervals. The height of the plants were found to have significant difference only after 8MAP and the data is presented in Table 1a and 1b.The plants supplied with NPK @ 13:5:13kg/ha (T_2) recorded the highest value under both the experimental conditions which was followed by Vermicompost (VC) @ 200g/plant +Neemcake (NC) @ 100g/plant (T_3).

In the intercropped plants, T_2 was on par with T_3 throughout the period of observation except in the 14^{th} and 15^{th} MAP (Table 1a).The plants supplied with VC@ 100g/plant + NC @50g/plant+ 13:5:13 @ 5g/plant (T_5) recorded superior height from 12 MAP. By 17^{th} MAP, the height of plants in all the treatments except the ones supplied with NPK @ 17:17:17 @ 5g/plant (T_1) were found to be on par.

In monocropped plants the highest values were recorded for T_3 which was on par with T_2 and significantly different from other treatments throughout the growth period (Table 1b).

4.1.2 Effect Of Nutrition And Cropping System On Number Of Suckers

Number of suckers produced per plant was recorded from 6MAP. It was found that nutrition significantly influenced sucker production under both the cropping systems throughout the growth period. Sucker production was more in plants grown under intercropped condition. The data is presented in Table 2a and 2b.

In the intercropped area there was significant difference among the treatments (Table 2a) in sucker production except at 13MAP. The plants in T_2 and T_3 produced significantly higher number of suckers throughout the year which was followed by T_5 plants. At 12 MAP, significantly higher number of suckers was produced in all the treatments except T_1.

The sucker production of plants grown under monocropped condition is presented in Table 2b.The number of suckers produced in T_2 plants was significantly higher and was on par with T_3 plants. At 12 MAP, T_5 (plants supplied with 2.5 g/ plant NPK @ 13:5:13 and Vermicompost @ 100g/plant +Neemcake @ 50g/plant) was also on par with T_1 and T_2. From 14MAP onwards, there was no significant difference among the treatments in the total number of suckers produced.

4.1.3 Effect Of Nutrition And Cropping System On Number Of Leaves

The data on number of leaves per clump is presented in Table 3a and 3b. The influence of treatments on leaf number in the intercropped condition (Table 3a) was significant throughout the growth period except at nine MAP. The plants supplied with Vermicompost @ 200g/plant +Neemcake @ 100g/plant (T_3) recorded significantly the highest leaf production. It was on par with T_2 on

Table 1 a. Effect of nutrition and cropping system on plant height (cm)-Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP	16MAP	17MAP
T_1 : 17:17:17	103.9	106.2	123.9	125.7	139.7	141.5	142.5	142.9	149.5	158.7
T_2 :13:05:13	122.1	136.2	149.1	162.3	187.2	204.2	208.1	216.7	217.1	218.7
T_3 :VC+NC	124.0	130.1	146.1	154.2	167.6	192.4	193.3	193.9	197.7	199.3
T_4:VC+NC+BF	108.7	120.6	128.2	132.4	150.8	154.7	166.5	171.1	171.9	201.2
T_5:VC+NC+CF	109.3	121.5	128.5	131.0	162.6	171.8	172.9	178.9	192.8	205.0
F	1.8	5.8**	6.0**	4.7**	5.2*	19.1**	31.3**	36.5**	14.4*	4.8*
SE	**6.7**	**4.7**	**4.7**	**7.4**	**7.9**	**5.9**	**4.5**	**4.5**	**6.8**	**10.2**
CD (p=0.05)	**NS**	**14.6**	**14.5**	**22.9**	**24.3**	**18.3**	**13.9**	**13.9**	**21.0**	**31.6**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 1 b. Effect of nutrition and cropping system on plant height (cm)- Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP	16MAP	17MAP
T_1 : 17:17:17	95.5	118.2	120.8	124.4	133.4	136.1	137.8	139.8	144.3	152.0
T_2 :13:05:13	117.3	125.5	138.3	157.3	159.2	160.7	166.9	170.6	175.7	181.2
T_3 :VC+NC	108.8	137.4	145.6	154.6	163.8	170.7	173.8	176.8	180.0	187.7
T_4:VC+NC+BF	99.3	115.1	122.9	128.4	136.4	142.7	144.2	147.3	147.8	162.8
T_5:VC+NC+CF	114.8	116.0	134.3	145.6	150.2	151.3	153.0	154.3	175.9	178.9
F	3.1	6.6**	4.5*	14.8**	7.0**	5.3*	6.8**	3.9**	13.3**	6.1*
SE	5.4	3.6	4.9	3.9	5.1	6.0	5.8	7.9	4.7	5.9
CD (p=0.05)	NS	11.1	15.1	12.0	15.7	18.6	17.7	24.3	14.5	18.2

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 2 a. Effect of nutrition and cropping system on number of suckers –Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	6.75	8.50	9.50	11.75	13.75	15.25	15.50	21.00	24.75	24.81
T_2 :13:05:13	8.00	9.25	11.25	13.75	16.75	16.75	21.75	21.75	24.25	24.62
T_3 :VC+NC	7.25	8.50	11.25	13.50	15.00	18.25	19.75	25.50	29.25	30.20
T_4 :VC+NC+BF	6.25	6.50	10.00	10.25	10.50	15.75	18.75	22.00	23.75	26.46
T_5 :VC+NC+CF	5.25	6.25	7.25	14.00	14.25	17.25	17.50	23.25	23.75	27.87
F	5.86**	10.13**	10.56**	12.02**	22.62**	5.34**	4.44*	2.18	9.30**	0.97
SE	0.43	0.42	0.51	0.46	0.48	0.52	1.11	1.19	0.76	0.67
CD (p=0.05)	1.32	1.29	1.56	1.43	1.48	1.6	3.44	NS	2.35	NS

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 2 b. Effect of nutrition and cropping system on number of sucker –Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	4.50	6.75	8.50	9.50	11.75	13.75	15.25	15.50	21.00	23.25
T_2 :13:05:13	6.25	8.00	9.25	11.25	13.75	16.75	16.75	21.75	21.75	24.50
T_3 :VC+NC	4.75	7.25	8.50	11.25	13.50	15.00	18.25	19.75	25.50	24.75
T_4 :VC+NC+BF	3.50	6.25	6.50	10.00	10.25	10.50	15.75	18.75	22.00	21.75
T_5:VC+NC+CF	3.75	5.25	6.25	7.25	14.00	14.25	17.25	17.50	23.25	20.00
F	8.13*	5.86**	10.12**	10.56**	12.03**	22.62**	5.34*	4.43*	2.18	0.53
SE	0.38	0.43	0.42	0.51	0.46	0.48	0.52	1.12	1.19	0.62
CD (p=0.05)	1.17	1.32	1.30	1.56	1.43	1.48	1.59	3.44	NS	NS

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

seven, eight, ten and twelve MAP.

The number of leaves produced per clump of plant when grown under monocropped condition is presented in Table.3.b. The plants supplied with 13:5:13 (T_2) recorded the highest leaf production throughout the period and was on par with Vermicompost @ 200g/plant +Neemcake @ 100g/plant (T_3) on six and nine MAP. T_1 (17:17:17) was on par with T_2 during 10, 11 and 12 MAP. The effect of nutrition on leaf production was significant only upto 12MAP.

4.1.4 Effect Of Nutrition And Cropping System On Collar Girth (cm)

The collar girth of plants was recorded at monthly intervals and the effect of treatment was found to be significant only during certain months of observation and is presented in Table 4a and 4b. The collar girth from 10MAP showed a higher value in monocropped condition.

The plants grown under coconut canopy (Table 4a) showed significant difference in collar girth only in 10, 11 and 13 MAP. All the plants attained more than 10cm collar girth in 12MAP. Higher collar girth was observed in VC+NC treatment (T_3) followed by T_5.

In monocropped condition (Table 4b) the collar girth was found to be not significantly affected by the treatments throughout the period except at 8 and 11 MAP. The lowest girth was recorded in plants supplied with biofertilizer and Vermicompost @ 100g/plant +Neemcake @ 50g/plant (T_4).All other treatments were found to be on par and significantly superior to T_4.

4.2 PHYSIOLOGICAL PARAMETERS

4.2.1 Effect Of Nutrition And Cropping System On Leaf Area (cm^2)

The leaf area of the plants grown under different nutritional trials was recorded at monthly intervals. It was found to be significantly different throughout the period of growth. The data is presented in Table 5a and 5b.

Table 3 a. Effect of nutrition and cropping system on number of leaves- Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	18.50	20.50	27.50	37.25	37.25	47.75	48.25	50.50	54.50	56.50
T_2 :13:05:13	20.50	25.75	31.25	33.00	49.25	50.25	54.50	60.25	74.75	78.00
T_3 :VC+NC	16.25	23.75	33.00	41.25	46.25	57.50	58.75	69.25	88.75	94.25
T_4:VC+NC+BF	16.50	16.50	20.75	33.50	41.75	49.75	55.50	58.75	61.75	64.00
T_5:VC+NC+CF	16.50	21.25	25.75	32.00	45.00	55.25	57.00	58.50	59.00	63.75
F	3.82*	13.50**	7.29**	1.24	5.22*	10.16**	7.03**	5.90**	65.07**	75.55**
SE	0.94	0.95	1.78	3.44	2.01	1.28	1.51	2.75	1.73	1.73
CD (p=0.05)	2.89	2.94	5.50	NS	6.19	3.95	4.65	8.47	5.33	5.32

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 3 b. Effect of nutrition and cropping system on number of leaves- Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	15.25	23.25	29.75	36.00	52.50	60.75	62.00	71.00	80.25	92.25
T_2 :13:05:13	22.75	31.00	34.00	44.50	60.00	62.00	67.50	85.75	90.50	104.75
T_3 :VC+NC	19.75	22.50	30.00	41.50	48.00	49.25	56.00	68.50	76.50	105.75
T_4 :VC+NC+BF	16.00	19.25	26.50	38.25	40.75	45.25	47.25	55.00	76.00	85.75
T_5:VC+NC+CF	17.75	19.75	28.00	30.00	40.25	48.75	49.75	51.75	59.00	71.25
F	5.21*	2.88	2.77	4.13*	6.26**	4.06*	4.48*	1.65	3.05	0.98
SE	**1.33**	**2.78**	**1.69**	**2.72**	**3.32**	**3.79**	**4.00**	**10.64**	**6.51**	**14.43**
CD (p=0.05)	**4.10**	**NS**	**NS**	**8.39**	**10.23**	**11.68**	**12.24**	**NS**	**NS**	**NS**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 4 a. Effect of nutrition and cropping system on collar girth(cm)- Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	9.02	9.10	9.35	9.80	9.80	9.85	10.08	10.45	11.00	12.63
T_2 :13:05:13	8.52	9.08	9.63	10.35	11.00	10.88	11.53	11.68	11.80	12.68
T_3 :VC+NC	9.23	9.75	10.30	10.68	11.73	12.48	12.85	13.00	13.60	14.43
T_4 :VC+NC+BF	9.33	9.65	10.10	10.28	10.35	10.40	10.80	12.33	12.33	12.73
T_5 :VC+NC+CF	9.05	9.13	10.65	11.08	11.93	12.38	12.18	13.98	13.43	13.63
F	0.34	0.46	0.52	0.54	4.74*	5.03*	2.29	3.41*	1.80	1.22
SE	**0.53**	**0.49**	**0.72**	**0.54**	**0.41**	**0.49**	**0.72**	**0.72**	**0.82**	**0.72**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**1.27**	**1.51**	**NS**	**2.23**	**NS**	**NS**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

Table 4 b. Effect of nutrition and cropping system on collar girth (cm)- Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	4.50	6.75	9.13	9.50	12.80	16.93	17.25	17.50	23.25	24.75
T_2 :13:05:13	6.00	8.00	9.31	11.75	14.25	16.00	21.75	20.25	24.00	26.25
T_3 :VC+NC	4.75	7.25	7.50	11.25	13.50	15.50	15.25	19.75	24.75	29.25
T_4:VC+NC+BF	3.75	6.25	6.88	10.00	10.25	10.50	15.75	18.75	21.75	27.00
T_5:VC+NC+CF	3.75	6.75	7.00	7.25	13.45	14.75	15.00	16.25	20.00	23.50
F	1.99	0.61	3.88*	2.98	1.46	3.42*	2.45	0.61	1.49	2.13
SE	**0.66**	**0.84**	**0.59**	**1.02**	**1.28**	**1.35**	**1.78**	**2.05**	**1.55**	**1.51**
CD (p=0.05)	**NS**	**NS**	**1.83**	**NS**	**NS**	**4.15**	**NS**	**NS**	**NS**	**NS**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

Intercropped Heliconia plants significantly differed in their leaf area except in 12 and 14MAP.The leaf area of T_2 and T_3 plants recorded significantly higher values throughout the period of observation (Table 5a).

Plants grown under full sunlight recorded significant difference in their leaf area except in 8 and 11 MAP. The plants in T_2 and T_3 recorded significantly the highest leaf area. This trend was observed throughout the period of observation (Table 5b).

4.2.2 Effect Of Nutrition And Cropping System On Leaf Area Index

The plants grown under the two experiments differed significantly in their leaf area index. The values are presented in Table 6a and 6b.

The plants grown as coconut intercrop varied significantly throughout the year except in 12 and 14 MAP. The value was significantly higher in T_3 and T_2 plants. T_1 had significantly lower LAI during the later stages (13 and 15 MAP) of growth (Table 6a).

The LAI of plants grown under monocropped condition were significantly different between the treatments except at 8MAP.The plants under T_3 treatment recorded the highest LAI and was found to be on par with the T_2 plants during 6^{th},7^{th} and 9^{th} to 12MAP.During the rest of the period (13 MAP onwards), T_3 recorded the highest LAI followed by T_2 plants. The lowest LAI was recorded in T_4 plants from 12MAP.

4.2.3 Effect Of Nutrition And Cropping System On Specific Leaf Area (cm^2 g^{-1})

Specific leaf area was calculated at monthly intervals from 6MAP. The data showed that effect of nutrition on SLA was significant throughout the period of observation and is given in Table 7a and 7b.

The specific leaf area of the intercropped plants varied significantly throughout the period except at 14MAP. The plants supplied with VC + NC (T_3)

Table 5 a. Effect of nutrition and cropping system on leaf area (cm^2) - Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	295.8	372.5	390.4	408.2	475.9	561.0	593.7	731.2	785.6	794.0
T_2 :13:05:13	376.3	488.2	566.9	575.8	788.1	905.5	931.7	986.4	1075.9	1122.8
T_3 :VC+NC	414.4	479.2	674.7	591.9	710.7	831.1	863.3	1045.5	1059.6	1149.8
T_4:VC+NC+BF	286.5	370.4	432.3	508.2	526.6	673.8	813.0	851.4	876.8	931.0
T_5:VC+NC+CF	327.8	362.0	489.0	572.8	603.7	660.6	770.2	790.7	1010.3	1074.0
F	4.3*	7.5**	6.8**	8.6**	14.3**	11.6	0.95	15.3**	2.3	7.3**
SE	**26.1**	**23.1**	**43.3**	**25.9**	**34.0**	**40.9**	**130.3**	**33.8**	**81.8**	**55.1**
CD (p=0.05)	**80.6**	**71.1**	**133.5**	**79.7**	**104.7**	**126.1**	**NS**	**104.0**	**NS**	**169.8**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 5 b. Effect of nutrition and cropping system on leaf area (cm^2) - Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	298.6	372.2	424.0	463.1	556.2	586.9	607.5	726.8	797.5	812.5
T_2 :13:05:13	405.5	426.4	455.9	656.8	748.4	810.7	835.1	929.4	982.8	1066.1
T_3 :VC+NC	350.1	418.3	486.4	703.3	717.8	773.2	784.8	1021.4	1128.4	1154.6
T_4:VC+NC+BF	298.6	379.7	437.1	541.4	562.9	608.1	660.9	695.9	723.9	912.3
T_5:VC+NC+CF	281.9	325.8	391.8	475.2	624.6	673.0	873.7	864.4	937.4	976.8
F	5.5**	3.6*	0.9	18.5**	5.2*	2.2	13.6*	8.7**	26.5**	7.6**
SE	**25.7**	**21.2**	**37.6**	**25.1**	**35.4**	**67.2**	**30.9**	**46.4**	**30.9**	**48.3**
CD (p=0.05)	**79.3**	**65.3**	**NS**	**77.2**	**118.5**	**NS**	**95.1**	**143.1**	**95.1**	**148.7**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 6 a. Effect of nutrition and cropping system on leaf area index – Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	0.024	0.030	0.031	0.032	0.038	0.045	0.048	0.059	0.063	0.064
T_2 :13:05:13	0.030	0.004	0.046	0.005	0.063	0.072	0.074	0.079	0.086	0.090
T_3 :VC+NC	0.033	0.039	0.054	0.048	0.057	0.007	0.069	0.084	0.085	0.092
T_4:VC+NC+BF	0.023	0.030	0.035	0.041	0.042	0.054	0.065	0.068	0.070	0.075
T_5:VC+NC+CF	0.026	0.029	0.039	0.046	0.048	0.053	0.062	0.063	0.081	0.086
F	4.2*	7.7**	6.6**	9.1**	14.5**	12.0**	1.0	16.1**	2.3	7.4**
SE	**0.002**	**0.002**	**0.004**	**0.002**	**0.003**	**0.003**	**0.001**	**0.003**	**0.007**	**0.004**
CD (p=0.05)	**0.007**	**0.006**	**0.011**	**0.006**	**0.008**	**0.010**	**NS**	**0.008**	**NS**	**0.01**

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 6 b. Effect of nutrition and cropping system on leaf area index –Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	0.024	0.030	0.034	0.053	0.006	0.065	0.070	0.074	0.075	0.078
T_2 :13:05:13	0.033	0.034	0.037	0.037	0.050	0.054	0.067	0.069	0.079	0.085
T_3:VC+NC	0.028	0.034	0.039	0.005	0.060	0.062	0.063	0.082	0.091	0.093
T_4:VC+NC+BF	0.020	0.031	0.035	0.044	0.045	0.049	0.053	0.056	0.058	0.065
T_5:VC+NC+CF	0.023	0.026	0.031	0.038	0.004	0.047	0.049	0.058	0.064	0.073
F	5.1*	3.6*	0.9	17.9**	5.2*	2.2	13.9**	8.3**	26.4**	7.69**
SE	0.002	0.002	0.003	0.002	0.003	0.005	0.002	0.004	0.002	0.004
CD (p=0.05)	0.007	0.005	NS	0.006	0.010	0.016	0.008	0.001	0.008	0.001

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

gave significantly higher value throughout its growth period (Table 7 a).

Under monocropped condition (Table 7 b), the plants grown in treatment T_2 recorded the highest specific leaf area throughout the period of growth which was followed by T_3 plants and was significantly superior to other treatments. The specific leaf area of T_4 plants was significantly lower and was found to be on par with T_1 and T_5 during the period of observation.

4.2.3 Effect Of Nutrition And Cropping System On Leaf Area Duration (cm^2 / 30 days)

The leaf area duration was found to be significant throughout the year under two systems of planting. The data is given in Table 8a and 8b.

Leaf area duration (leaf area produced in 30 days time) of the intercropped plants was significantly higher in T_3 and T_2 plants during the period of observation (Table 8a).The lowest value was recorded in the treatment supplied with 17:17:17 (T_1).

The plants grown under monocropped condition recorded significant difference in leaf area duration throughout the period of observation except in 7MAP (Table 8 b).It was found to be significantly higher for T_3 plants which were followed by T_1 and T_2 plants. The leaf area duration of T_4 plants was significantly the lowest during the period.

4.2.4 Effect Of Nutrition And Cropping System On Leaf Area Density (g/cm^2)

The leaf area density of plants varied significantly among the treatments under the two systems of cropping and was higher in monocropped condition. The data is presented in Table 9a and 9b.

The plants in intercropped area recorded significant difference in their leaf area density except at 14 MAP (Table 9a). The leaf area density was found to be significantly higher in T_4 plants.

Table 7 a. Effect of nutrition and cropping system on specific leaf area ($cm^2 g^{-1}$) – Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	49.03	50.71	48.98	38.08	35.70	40.59	42.06	42.51	39.58	37.35
T_2 :13:05:13	45.41	49.88	36.07	28.20	35.47	41.40	43.01	38.23	41.76	43.33
T_3 :VC+NC	47.91	53.07	51.08	37.85	42.56	41.93	38.34	39.98	40.04	40.19
T_4:VC+NC+BF	29.00	36.57	37.89	34.39	31.27	34.46	40.41	37.89	32.84	34.31
T_5:VC+NC+CF	47.03	46.87	47.89	43.88	35.49	33.59	27.70	32.96	40.46	42.20
F	13.8**	17.6**	12.1**	14.4**	10.9**	4.6*	10.6**	4.3*	2.0	19.1**
SE	2.23	1.54	1.98	1.51	1.24	1.88	1.90	1.69	2.47	0.84
CD (p=0.05)	6.89	4.74	6.11	4.67	3.81	5.78	5.85	5.2	NS	2.59

MAP – Months after planting

NS- Not significant

**Significant at 5%*

*** Significant at 1%*

Table 7 b. Effect of nutrition and cropping system on specific leaf area ($cm^2\ g^{-1}$) – Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	29.54	33.47	33.98	36.87	37.16	37.76	39.44	41.53	42.41	42.53
T_2 :13:05:13	45.32	54.26	54.38	54.85	52.73	57.15	57.20	58.10	58.21	60.57
T_3 :VC+NC	36.82	41.41	41.77	44.05	44.82	45.22	46.96	47.06	50.79	51.71
T_4 :VC+NC+BF	25.56	32.60	34.86	35.24	35.82	36.00	36.22	37.49	38.34	40.30
T_5 :VC+NC+CF	31.29	31.93	33.48	34.81	36.16	36.68	38.18	38.05	38.37	40.44
F	6.0**	20.4**	13.1**	33.4**	3.7*	7.3**	6.5**	16.4**	12.6**	13.7**
SE	3.13	2.10	2.44	1.47	3.81	3.32	3.36	2.10	2.44	2.40
CD (p=0.05)	9.63	6.47	7.55	4.54	11.76	10.23	10.38	6.48	7.53	7.38

MAP – Months after planting

**Significant at 5%*

*** Significant at 1%*

Table 8 a. Effect of nutrition and cropping system on leaf area duration (cm^2 / 30 days) -Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	334.2	381.5	399.3	442.1	518.5	577.3	662.5	758.4	789.8	845.6
T_2 :13:05:13	432.3	527.6	571.4	681.9	846.8	918.6	959.0	1031.2	1099.4	1156.3
T_3 :VC+NC	446.8	577.0	633.3	651.3	770.8	847.2	954.4	1052.6	1104.7	1226.9
T_4:VC+NC+BF	328.5	401.4	470.2	517.4	600.2	743.4	832.2	864.1	903.9	932.6
T_5:VC+NC+CF	344.9	425.5	530.9	588.2	632.2	715. 4	780.5	900.5	1042.2	1094.6
F	8.9**	12.8**	11.9**	16.4**	18.9**	4.3*	3.4*	7.4**	11.2**	18.1**
SE	19.3	23.8	26.2	24.2	30.5	62.8	67.5	45.0	41.0	37.2
CD (p=0.05)	59.4	73.3	80.8	74.5	94.1	193.5	208.0	138.5	126.3	114.5

MAP – Months after planting

**Significant at 5%*

*** Significant at 1%*

Table 8 b. Effect of nutrition and cropping system on leaf area duration (cm^2 / 30 days)- Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	335.4	398.1	540.4	695.6	772.6	842.2	901.5	933.4	957.1	977.2
T_2 :13:05:13	415.9	441.1	459.5	543.9	648.8	754.0	849.7	923.6	1024.4	1066.3
T_3:VC+NC	384.2	452.4	594.9	725.9	760.8	779.0	903.1	1074.9	957.1	1179.6
T_4:VC+NC+BF	316.1	408.4	489.2	552.1	585.5	634.5	678.4	709.9	818.1	840.4
T_5:VC+NC+CF	303.8	358.8	433.5	515.7	571.5	597.2	667.1	762.1	805.0	1024.2
F	7.3**	2.1	10.4**	14.3**	4.3*	7.0**	13.1**	27.4**	18.7**	8.0**
SE	17.5	25.9	20.1	25.5	45.6	38.6	32.7	27.9	32.8	43.9
CD (p=0.05)	54.05	NS	61.8	78.7	140.4	118.9	100.8	86.1	101.2	135.4

MAP – Months after planting

**Significant at 5%*

*** Significant at 1%*

Table 9 a. Effect of nutrition and cropping system on leaf area density (g/cm^2) -Exp I

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	0.021	0.020	0.020	0.026	0.020	0.025	0.024	0.024	0.025	0.027
T_2 :13:05:13	0.022	0.020	0.028	0.036	0.028	0.025	0.023	0.027	0.024	0.023
T_3 :VC+NC	0.021	0.019	0.020	0.027	0.024	0.024	0.027	0.025	0.025	0.025
T_4:VC+NC+BF	0.035	0.028	0.027	0.029	0.032	0.030	0.025	0.027	0.031	0.029
T_5:VC+NC+CF	0.021	0.022	0.021	0.023	0.028	0.030	0.037	0.031	0.025	0.024
F	17.2**	28.2**	11.6**	16.7**	9.1**	4.5*	14.7**	5.9**	2.4	17.0**
SE	0.001	0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
CD (p=0.05)	0.004	0.002	0.004	0.004	0.003	0.004	0.004	0.003	NS	0.002

MAP – Months after planting

NS-Not significant

**Significant at 5%*

*** Significant at 1%*

Table 9 b. Effect of nutrition and cropping system on leaf area density (g/cm^2) - Exp II

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	6MAP	7MAP	8MAP	9MAP	10MAP	11MAP	12MAP	13MAP	14MAP	15MAP
T_1 : 17:17:17	0.024	0.030	0.034	0.053	0.006	0.006	0.070	0.074	0.075	0.078
T_2 :13:05:13	0.033	0.034	0.037	0.037	0.050	0.054	0.067	0.069	0.079	0.085
T_3 :VC+NC	0.028	0.034	0.039	0.006	0.060	0.062	0.063	0.008	0.091	0.093
T_4 :VC+NC+BF	0.020	0.031	0.035	0.044	0.450	0.049	0.053	0.056	0.058	0.073
T_5:VC+NC+CF	0.023	0.026	0.031	0.038	0.004	0.047	0.049	0.058	0.064	0.065
F	5.1*	3.6*	0.9	17.9**	5.2*	2.2	13.9*	8.3**	26.4**	7.7**
SE	0.002	0.002	0.003	0.002	0.003	0.005	0.002	0.004	0.002	0.004
CD (p=0.05)	0.006	0.005	NS	0.006	0.010	NS	0.008	0.001	0.008	0.001

MAP – Months after planting

NS-Not significant

**Significant at 5%*

*** Significant at 1%*

In monocropped condition (Table 9 b) the plants recorded significant difference in leaf area density throughout the year except at 8 and 11 MAP. T_3 plants recorded significantly higher values except at 9 and 13MAP. This was followed by T_2 and T_1 which was on par with T_3 during 6,7,10 and 12 MAP. The lowest value was recorded in T_4 plants.

4.3 DURATION OF THE CROP

4.3.1 Effect Of Nutrition And Cropping System On Number Of Days Taken For First Flowering (days)

There was significant difference among the treatments for the number of days taken for first flowering under both cropping situations and the data is presented in Table.10. In general, the plants in the intercropped condition took less number of days for flowering than in monocropped condition.

There was significant difference among the treatments in intercropped area. T_3 plants recorded the lowest number of days for first flowering (172.8) which was followed by T_4, T_1, T_5 and T_2. In the monocropped condition, there was significant difference between treatments in the number of days taken for first flowering. The plants supplied with VC and NC (T_3) took the lowest number of days (280.3) for first flowering whereas the plants supplied with 13:05:13 (T_2) took the longest time to start flowering (362.5 days).

4.3.2 Effect Of Nutrition And Cropping System On Number Of Days Taken For Fifty Percent Flowering (days)

The days taken for fifty percent flowering showed significant difference among the treatments under monocropped condition and is presented in Table 11. In general, the plants in the intercropped condition took less number of days to attain fifty percent flowering than the monocropped condition.

The treatments in the intercropped area recorded no significant difference between treatments in the flowering behavior and the plants supplied with VC and

NC (T_3) attained fifty percent flowering in 248.5 days which was followed by T_4, T_1, T_2 and T_5 .The days taken for fifty percent flowering were significantly different among the treatments in monocropped condition and was in the order T_3, T_1, T_4, T_5 and T_2.The treatments supplied with VC and NC alone (T_3) took 370.0 days after planting to reach fifty percent flowering whereas the plants supplied with 13:05:13 (T_2) took the longest time to attain fifty percent flowering ie.,437.5 days.

4.4 EFFECT OF NUTRITION AND CROPPING SYSTEM ON LIFE OF FLOWER IN PLANT (DAYS)

The time taken for the inflorescence to undergo different stages of flower monocroppeding under different conditions of *nutritional management* and cropping system was recorded and presented in Table 12.

4.4.1 Effect Of Nutrition And Cropping System On Time (days) Taken From Just Emerged (Stage I) To Just Opened (Stage II)

The days taken for the flowers to shift from Stage I to II is found to have significant difference among the treatment combinations under two systems of cropping (Table 12).

Among the intercropped plants T_5 took the longest time (6.75days) for the shift which was on par with T_4 (5.50 days).The time taken for all other treatments were on par with each other. In monocropped condition, T_3 plants recorded the longest time (6.75days) for the flower to emerge from the pseudostem.

Table 10. Effect of nutrition and cropping system on number of days taken for first flowering – Exp I and II

Treatment	Days taken for first flowering	
	Experiment I	Experiment II
T_1 : 17:17:17	218.3	309.5
T_2 :13:05:13	295.0	362.5
T_3 :VC+NC	172.8	280.3
T_4:VC+NC+BF	190.3	316.3
T_5:VC+NC+CF	235.3	335.8
F	214.3**	28.7**
SE	3.2	5.7
CD (p=0.05)	9.96	17.6

Table 11. Effect of nutrition and cropping system on number of days taken for fifty percent flowering- Exp I and II

Treatment	Days taken for fifty percent flowering	
	Experiment I	Experiment II
T_1 : 17:17:17	315.3	414.0
T_2 :13:05:13	327.2	459.8
T_3 :VC+NC	248.5	370.0
T_4:VC+NC+BF	289.8	427.5
T_5:VC+NC+CF	338.8	437.5
F	0.53	22.1**
SE	49.3	7.1
CD (p=0.05)	NS	21.9

NS- Not significant *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

The shortest time was recorded by T_4 plants (4.25days) which was followed by T_1, T_2 and T_5 plants.

4.4.2 Effect Of Nutrition And Cropping System On Time (days) Taken From Just Opened To Fully Opened (Stage II to III) Condition

The flower opening from stage II to III was also found to be significantly different among the treatments (Table 12) in the two systems of planting. In general, the intercropped plants took longer time to complete the flower opening.

In intercropped condition, T_3 plants took the longest time for flower opening (18.50days) which was followed by T_2, T_1 and T_5. The flower opening was significantly faster in T_4 (9.25days). The plants supplied with 13:05:13 NPK+ VC+NC (T_5) recorded the lowest (4.25days) and T_2 plants the longest (9.50 days) time for complete opening of the flower when grown under monocropped condition. The inflorescence in the T_3 (7.50days) and T_1 (8.50 days) plants also took more than a week time for complete flower opening.

4.4.3 Effect Of Nutrition And Cropping System On Longevity Of Flower (Stage III to IV)

Nutrition was found to have significant influence in the life of fully opened inflorescence in the plant under both the systems of cropping (Table 12.). The longevity of flower on plant was more in the intercropped area.

The plants supplied with VC and NC (T_3) recorded significantly longer inflorescence life (19.75days) on plant. All the other treatments took less time (11.25 to 12.75 days) for the flower senescence. The life of inflorescence on plants grown under monocropped condition was found to be significantly superior in T_3 plants (13 days) followed by T_2 (11.50 days). The shortest life (5.50 days) was recorded in plants supplied with 17:17:17 NPK (T_1). The inflorescence in T_4 (10.75 days) and T_5 plants (11 days) also recorded significantly higher longevity in plants.

4.4.4 Effect Of Nutrition And Cropping System On Time (days) Taken For Opening Of Bracts

The time taken for the adjacent bract opening was recorded and was found to be significantly different among the treatments in intercropped condition and was not significant in monocropped area. The data is presented in Table 12. The inflorescence grown in intercropped plants supplied with VC and NC (T_3) took the longest time for the bract opening (7.50days) followed by T_2 and T_1 (6.50 days). The bract opening interval was the shortest in T_5 (3.50days) followed by T_4 plants (4.50days).The interval between bract openings in the monocropped condition was faster (4.00 to 5.50 days).

4.5 EFFECT OF NUTRITION AND CROPPING SYSTEM ON INFLORESCENCE CHARACTERS

The effect of nutrition and cropping systems on inflorescence characters are presented in Table 13 a.

4.5.1 Effect Of Nutrition And Cropping System On Inflorescence Length

The length of the inflorescence varied significantly with the treatments. The inflorescence produced under intercropped condition recorded superior length than the ones produced in the monocropped condition. The data is given in Table 13 a.

The length of inflorescence in intercropped plants was significantly higher in T_3, T_5 and T_2 plants (104.70, 103.28 and 101.70cm respectively) and lower in T_4 (97.18 cm) and T_1 (70.53 cm) plants. In monocropped condition, only plants supplied with VC +NC (T_3) produced inflorescence having a length more than 1m (105.55cm).The lowest length of inflorescence was recorded in T_1 plants (64.22cm). The inflorescence produced in the other treatments (T_2, T_4 and T_5) were in the medium range (88.83 to 78.73 cm) and were on par with each other.

Table 12 . Effect of nutrition and cropping system on life of flower on plant (days) – Exp I and II

Treatment	Stage I to II		Stage II to III		Stage III to IV		Interval between bract openings	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	3.75	5.25	11.75	8.50	11.25	5.50	6.50	4.00
T_2 :13:05:13	4.50	5.75	13.00	9.50	12.50	11.50	6.50	4.25
T_3 :VC+NC	4.50	6.75	18.50	7.50	19.75	13.00	7.50	4.00
T_4:VC+NC+BF	5.50	4.25	9.25	5.75	14.00	10.75	4.50	5.50
T_5:VC+NC+CF	6.75	5.75	11.50	4.25	12.75	11.00	3.50	4.00
F	**5.92****	**4.95****	**46.76****	**61.1****	**21.58****	**30.0****	**32.4****	**3.00**
SE	**0.48**	**0.41**	**0.51**	**0.27**	**0.72**	**0.52**	**0.29**	**0.38**
CD (p=0.05)	**1.47**	**1.25**	**1.56**	**0.83**	**2.2**	**1.6**	**0.89**	**NS**

NS- Not significant *** Significant at 1%* *Stage I* *Just emerged* *Stage II* *Just opened*

Stage III *Fully opened* *Stage IV* *Senescence*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

4.5.2 Effect Of nutrition And Cropping System On Number Of Flower Bracts

The number of bracts produced in each inflorescence grown under different conditions of cropping systems was found to be significantly different (Table13a).The inflorescence of plants grown under monocropping produced less number of bracts than plants grown under intercropping. Among the treatment combinations, T_3 plants produced inflorescence with the highest number of bracts in monocropped as well as in inter cropped conditions (5.50 and 6.75 respectively) followed by T_5 and T_2 .The lowest number was recorded in T_4 followed by T_1.

4.5.3 Effect Of Nutrition And Cropping System On Length Of Inflorescence Stalk (cm)

The inflorescence stalk length varied significantly among the treatments in both the conditions of planting (Table 13a).The plants grown in monocropped condition produced inflorescence with shorter stalk when compared to intercropped condition. In both the experiments, the treatment T_3 produced inflorescence with the longest stalk (90.63cm and 83.18cm) which was significantly higher than all other treatments. The length of inflorescence stalk was the shortest in T_1 plants in both the experiments (43.05cm and 38.85cm respectively). The length of inflorescence stalk produced in T_2, T_4 and T_5 was on par with each other in both the situations.

4.5.4 Effect Of Nutrition And Cropping System On Girth Of Inflorescence (cm)

There was significant difference between treatments in the girth of inflorescence (Table 13a). In intercropped and monocropped situations, the girth of inflorescence of T_3 plants was significantly higher (10.55cm and 10.28cm respectively).The lowest girth was noticed in T_4 plants (6.70cm and 6.63cm respectively) and T_1 plants(6.88cm and 7.03 cm respectively) .In Exp I the plants in T_2 and T_5 (9.30cm and 9.43cm respectively) treatments also recorded higher inflorescence-girth.

Table 13 a. Effect of nutrition and cropping system on inflorescence characters- Exp I and II

Treatment	Inflorescence length(cm)		Number of bracts		Inflorescence stalk length(cm)		Inflorescence girth (cm)		Bract width(cm)	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	70.53	64.22	3.75	3.00	43.05	38.85	6.88	7.03	3.60	3.98
T_2 :13:05:13	101.70	88.83	4.75	4.50	73.85	58.35	9.30	7.78	4.13	4.30
T_3 :VC+NC	104.70	105.55	6.75	5.50	90.63	83.18	10.55	10.28	4.45	5.08
T_4 :VC+NC+BF	97.18	78.73	4.50	3.50	69.20	53.15	6.70	6.63	4.38	4.25
T_5 :VC+NC+CF	103.28	83.83	5.25	4.50	69.55	54.70	9.43	6.98	3.78	4.75
F	64.10**	15.1**	16.67**	9.50**	61.28**	43.98**	19.98**	28.0**	4.81*	9.2**
SE	1.78	3.87	0.27	0.32	2.20	2.40	0.40	0.28	0.20	0.14
CD (p=0.05)	5.48	11.93	0.84	0.97	6.72	7.47	1.17	0.86	0.52	0.45

**Significant at 5%   ** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

4.5.5 Effect Of Nutrition And Cropping System On Average Width Of Bract (cm)

The width of bract of the inflorescence differed significantly between the treatments in both the systems of planting (Table 13 a).

The width of bracts in T_3 recorded the highest value in both the systems of planting (4.45cm and 5.08cm respectively) and the plants supplied with 17:17:17 (T_1) recorded the lowest values. All other treatment values were on par in monocropped condition. In the intercropped situation, the width of bract was recorded in the order T_4, T_2 and T_5.

4.5.6 Effect Of Nutrition And Cropping System On Size (length and width) Of Just Opened Flower

The length of unopened spike differed significantly under both conditions of cropping system. The data is presented in Table 13 b.

The length and width of unopened spike in intercropped area differed significantly. The unopened spike produced in T_5 recorded the highest length and width (26.55cm x 3.63cm) followed by T_3 (23.30cm x 3.53cm) which was significantly higher than the other treatments. In monocropped plants, the length of unopened spike differed significantly whereas there was no significant difference in width. The unopened spikes of T_3 plants recorded significantly the highest size (length and width- 25.00cm x 3.88cm) followed by T_2 (22.73cm x 2.20 cm) and T_5 (22.30cmx3.38cm) which was on par with T_4 (20.60cm x 3.63 cm). The lowest size was in T_1 plants (16.73cm x3.38cm).

4.5.7 Effect Of Nutrition And Cropping System On Size (length and width) Of Fully Opened Spike

The size of fully opened spike was significantly different among the treatments under the two planting conditions (Table13 b).

Table 13b. Effect of nutrition and cropping system on length and width of spike (cm) – Exp I and II

Treatment	Unopened -spike				Opened-Spike			
	length(cm)		width(cm)		length(cm)		width(cm)	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	22.15	16.73	3.10	3.38	24.93	21.80	18.75	17.35
T_2 :13:05:13	22.73	23.15	2.20	3.15	24.58	23.93	18.85	17.45
T_3 :VC+NC	23.30	25.00	3.53	3.88	34.43	30.60	22.98	17.73
T_4 :VC+NC+BF	19.63	20.60	2.98	3.63	26.83	27.82	18.43	17.55
T_5 :VC+NC+CF	26.55	22.30	3.63	3.38	27.00	29.65	23.83	23.40
F	**6.56****	**11.9****	**4.92***	**1.15**	**28.64****	**28.6****	**6.53****	**12.07****
SE	**0.98**	**0.91**	**0.25**	**0.26**	**0.74**	**0.71**	**1.02**	**0.76**
CD (p=0.05)	**3.00**	**2.79**	**0.79**	**NS**	**2.30**	**2.17**	**3.15**	**2.34**

NS-Not significant **Significant at 5%* *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

The inflorescence produced in the plants as coconut intercrop produced spikes of bigger size. The T_3 plants produced the highest spike size (34.43cm x22.98cm) followed by T_5 plants (27.00cm x 23.83cm). In the monocropped condition the highest size of opened spike was observed in T_5 plants (29.65cm x 23.40 cm) The length of the spike was the highest in T_3 (30.60 cm) and T_5 (29.65cm) plants. The width of the spike was on par in all the treatments except T_5.

4.5.8 Effect Of Nutrition And Cropping System On Number Of Flowering Shoots Per Year

The flowering shoots were more in intercropped plants than in monocropped condition. The plants under coconut canopy produced more number of flowering shoots per year than in the monocropped condition. The flower production varied significantly among the treatments in the both experiments. The plants supplied with VC and NC produced significantly higher number of flowers under monocropped (822.2) as well as in intercropped (1633.5) conditions. In both conditions this was followed in the order T_5, T_2 , T_4 and T_1 .The data is presented in Table.14.

4.5.9 Effect Of Nutrition And Cropping System On Fresh Weight Of Inflorescence (g)

The fresh weight of inflorescence varied significantly in both systems of planting. The inflorescence weight of intercropped plants was higher than the monocropped plants (Table 14).

In the first experiment, T_5 plants produced inflorescence with significantly higher fresh weight (247.2g) followed by T_3 (227.2g) while in the second experiment, T_3 plants produced inflorescence with significantly higher fresh weight (215.9g) followed by T_5 (198.4g). The lowest weight was recorded in T_1 in experiment I and II (131.2g and 99.9g) respectively.

4.6 EFFECT OF NUTRITION AND CROPPING SYSTEM ON VISUAL APPEAL OF FLOWERS

The visual parameter for flower quality was found to be significantly different between treatments under two cropping systems. In general the flowers produced in intercropped conditions scored higher values than those in monocropped situation. The scores are presented in Table.15.

4.6.1 Effect Of Nutrition And Cropping System On General Appearance

The flowers differed significantly in general appearance (Table 15) in the two systems of planting.

In monocropped as well as intercropped condition, T_3 flowers scored significantly higher values (6.24 and 7.38 respectively) followed by T_5 (5.00 and 5.55 respectively). The score values were the lowest for T_1 flowers (2.75 and 4.43) whereas, T_2 (4.00 and 4.75) and T_4 (4.68 and 5.00) were on par with each other.

4. 6.2 Effect Of Nutrition And Cropping System On Bract Arrangement

The score value differed significantly with compactness in bract arrangement (Table 15) under intercropped and monocropped conditions.

The score was the highest in T_3 flowers in experiment I and II (8.30 and 7.18 respectively).In the first experiment, the scoring was in the order T_1, T_5, T_4 ,T_2 while in the second experiment this was followed by T_5 (5.18), T_4 (5.05) and T_2 (4.78). T_1 plants recorded the lowest score (4.18) in bract arrangement.

4. 6.3 Effect Of Nutrition And Cropping System On Glossiness

Glossiness of flowers varied significantly in inflorescence produced in monocropped condition (Table 15). The score was the highest in T_3 flowers (5.5) which was on par with all other treatments except T_1(3.53).

Table 14. Effect of nutrition and cropping system on number of flowering shoots/year/plot (4mx4m) and Fresh weight (FW) of inflorescence (g)

Exp I and II

Treatment	No. of flowering shoots/year		FW of inflorescence(g)	
	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	720.2	364.3	131.2	99.9
T_2 :13:05:13	1035.7	504.8	127.2	119.3
T_3 :VC+NC	1633.5	822.2	227.2	215.9
T_4:VC+NC+BF	998.5	492.3	153.6	101.8
T_5:VC+NC+CF	1260.2	714.0	247.2	198.4
F	**131.0****	**62.1****	**75.4****	**101.7****
SE	**29.8**	**23.4**	**6.46**	**5.5**
CD (p=0.05)	**91.7**	**72.2**	**19.9**	**17.0**

**Significant at 5%   ** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 15. Effect of nutrition and cropping system on visual appeal of flowers – Exp I and II

Treatment	Scoring on general appearance		Scoring on bract arrangement		Scoring on glossiness		Scoring on colour development	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	4.43	2.75	7.13	4.18	5.70	3.53	6.25	3.60
T_2 :13:05:13	4.75	4.00	5.30	4.78	5.98	4.35	6.60	5.65
T_3 :VC+NC	7.38	6.24	8.30	7.18	7.13	5.50	7.75	6.50
T_4 :VC+NC+BF	5.00	4.68	5.45	5.05	5.35	4.95	6.55	5.58
T_5:VC+NC+CF	5.55	5.00	5.85	5.18	6.75	4.48	7.35	5.75
F	9.1**	14.6**	10.4**	23.2**	6.1**	3.4*	6.8**	15.6**
SE	0.39	0.34	0.40	0.23	0.30	0.4	0.24	0.27
CD (p=0.05)	1.2	1.04	1.22	0.72	0.92	1.23	0.74	0.84

Significant at 5%*   * Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Plate 5. Visual appeal test

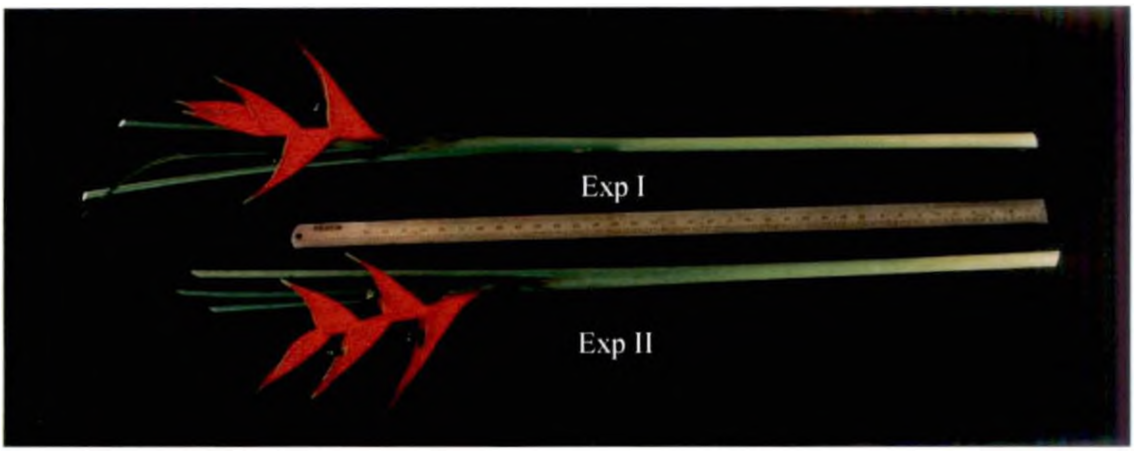


Plate 6. Marketable flowers of the best treatment (T_3) – Exp I and II

4. 6.4 Effect Of Nutrition And Cropping System On Colour Development

The scoring for T_3 (6.5) and T_5 (5.75) flowers were the highest in colour development under monocropped condition(Table 15). This was followed by T_2 (5.65) and T_4 (5.58). The lowest score was for T_1(3.6) flowers.

4.7 PLANT ANALYSIS

4.7.1 Effect Of Nutrition And Cropping System On Leaf Chlorophyll Content (%)

Leaf chlorophyll content varied significantly among the treatments in the two cropping systems and is presented in Table.16. In general, the leaf chlorophyll content of plants grown as coconut intercrop was more than the monocrop. In experiments I and II, the chlorophyll content was significantly higher in T_3 (1.886 and 1.263 respectively) plants. In the intercropped condition, this was followed by T_4,T_5 ,T_1 and T_2 and T_2,T_5 ,T_4 and T_1 in the experiment II.

4.7.2 Effect Of Nutrition And Cropping System On Leaf Wax Content

The leaf wax content varied significantly in both the cropping systems (Table.17).The leaf wax content of plants was more in monocropped condition than in intercropping. The plants in T_3, T_2 and T_5 recorded the highest values in the two experiments. T_1 plants recorded the lowest wax content in leaves.

4. 8 EFFECT OF NUTRITION AND CROPPING SYSTEM ON NUTRIENT CONTENT OF LEAVES

4.8.1 Effect Of Nutrition And Cropping System On N (Nitrogen) Content Of Leaves

The nitrogen content varied significantly in intercropped condition and was not significant in monocropped condition. In intercropped condition all the treatments except T_1 recorded significantly higher values and the data is given in Table 18.a.

4.8.2 Effect Of Nutrition And Cropping System On P (Phosphorus) Content Of Leaves

The phosphorus content of leaves varied significantly among the treatments in both the systems (Table 18.a.). The content of phosphorus in leaves was more in intercropped area than in monocropped condition. In both the situations, T_3 plants recorded significantly higher leaf P content. The plants supplied with 13:05:13 NPK (T_2) and VC+NC+BF (T_4) also recorded higher P content in intercropped area, whereas all the other treatments were on par with T_4.

4.8.3 Effect Of Nutrition And Cropping System On K (Potassium) Content Of Leaves

It showed a significant difference between the nutritional levels in both the experiments with T_5 recording the highest value. The potassium content of leaves was more in intercropped condition than in monocropped condition except in the case of T_5. In the plants under coconut canopy, higher leaf K content was recorded in T_3 and T_2 followed by T_1 and T_4 whereas in monocropped situation all the treatments except T_1 recorded higher values (Table 18.a.).

4.8.4 Effect Of Nutrition And Cropping System On Ca (Calcium) Content Of Leaves

The Ca content of leaves was more in monocropped plants than in the intercropped plants. The value was found to be significant in both the experiments with the highest leaf Ca in T_3 plants followed by T_2 (Table 18b).

4.8.5 Effect Of Nutrition And Cropping System On Mg (Magnesium) Content Of Leaves

The Mg content of leaves was significantly the highest in both the experiments. In intercropped condition, T_3 recorded significantly higher value followed by T_1,T_2 ,T_4 and T_5 . In monocropped condition, T_3 and T_5 recorded significantly higher Ca content followed by T_1 ,T_2 and T_4 .The data is presented in Table 18 b.

4.8.6 Effect Of Nutrition And Cropping System On Fe (Iron) Content Of Leaves

The leaf Fe content differed significantly in both the systems of planting. In general, the content was higher in intercropped plants than in monocropped plants (Table.18.c.).In both the situations, plants supplied with VC and NC (T_3) recorded significantly higher leaf Fe followed by T_5 and T_2. The lowest Fe content was recorded in T_1 plants.

4.8.7 Effect Of Nutrition And Cropping System On Mn (Manganese) Content Of Leaves

The leaf Mn content was more in plants grown in experiment II and T_3 plants recorded significantly higher values in both the systems of planting. The data is given in Table 18 c.In intercropped condition, all the treatments except T_1 recorded significantly higher Mn content. In monocropped condition, all the plants supplied with VC and NC (T_3, T_5 and T_4) recorded significantly higher values followed by T_2 and T_1.

4.8.8 Effect Of Nutrition And Cropping System On Zn (Zinc) Content Of Leaves

The leaf zinc content varied significantly in the monocropped condition and was not significant in the plants grown under coconut canopy. In monocropped situation T_3 plants recorded significantly higher content of zinc in leaves and all other treatments were on par.

4.9 EFFECT OF NUTRITION AND CROPPING SYSTEM ON PLANT UPTAKE OF NUTRIENTS

The plant uptake of N, P and K was significant for the treatments under the two systems of planting. The uptake was more in intercropped situation. The data is given in Table.19.

4.9.1 Effect Of Nutrition And Cropping System On Plant Uptake Of Nitrogen (N)

The plant uptake of nitrogen was the highest in T_2 of the intercropped area and T_4 in monocropped condition. The lowest N uptake was in T_3. In experiment 1, T_2 was followed by T_4, T_1 and T_5, whereas in the second experiment, it was in the order T_2, T_5 and T_1.

4.9.2 Effect Of Nutrition And Cropping System On Plant Uptake Of Phosphorus (P)

The phosphorus uptake was significantly higher in T_4 in intercropped condition and in T_2 in monocropped condition. The lowest uptake was reported in T_1 plants in monocropped as well as intercropped situations.

4.9.3 Effect Of Nutrition And Cropping System On Plant Uptake Of Potassium (K)

The plants supplied with 13:5:13 NPK (T_2) recorded the highest K uptake in both the experiments. The lowest K uptake was found in T_3 and T_1.

4.10 EFFECT OF NUTRITION AND CROPPING SYSTEM ON SOIL NUTRIENT CONTENT

4. 10. 1 Effect Of Nutrition And Cropping System On Soil pH And EC

There is a general improvement in pH in intercropped area after the experiment (Table 20 a). Even though the pH varied significantly, soil of all the treatments all were in the near neutral range.

The EC of intercropped soil supplied with 13:5:13 (T_2 and T_5) gave significantly higher values (0.09 and 0.08 respectively).All other treatments were on par with each other. In monocropped area also T_2 treatment recorded higher EC (0.05).

Table 16. Effect of nutrition and cropping system on chlorophyll content of leaves (%)- Exp I and II

Treatment	chlorophyll a		chlorophyll b		Total chlorophyll	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	0.699	0.344	0.500	0.268	1.199	0.721
T_2 :13:05:13	0.583	0.842	0.411	0.139	1.044	1.025
T_3 :VC+NC	1.243	0.819	0.564	0.469	1.886	1.263
T_4 :VC+NC+BF	1.036	0.408	0.462	0.338	1.498	0.818
T_5 :VC+NC+CF	1.028	0.572	0.363	0.278	1.391	0.875
F	25.9**	61.1**	3.7*	27.1**	35.3**	15.1**
SE	0.05	0.02	0.04	0.02	0.05	0.05
CD (p=0.05)	0.16	0.09	0.12	0.071	0.17	0.17

Table 17. Effect of nutrition and cropping system on wax content (mg/cm^2) of leaves- Exp I and II

Treatment	Wax content(mg/cm^2)	
	Exp I	Exp II
T_1 : 17:17:17	168.6	170.9
T_2 :13:05:13	200.1	209.3
T_3 :VC+NC	200.4	224.0
T_4 :VC+NC+BF	172.3	201.6
T_5 :VC+NC+CF	194.1	210.8
F	12.4**	15.4
SE	4.39	5.1
CD (p=0.05)	13.5	15.6

*Significant at 5% ** Significant at 1%

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 18. Effect of nutrition and cropping system on nutrient content of leaves

Table 18a. Effect of nutrition and cropping system on nitrogen (N), phosphorus (P) and potassium (K) content of leaves (%)

Exp I and II

Treatment	N		P		K	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	1.41	1.70	0.068	0.067	0.139	0.111
T_2 :13:05:13	1.80	1.82	0.071	0.067	0.167	0.157
T_3 :VC+NC	1.62	1.81	0.090	0.085	0.147	0.137
T_4:VC+NC+BF	1.71	1.80	0.077	0.067	0.133	0.131
T_5:VC+NC+CF	1.80	1.81	0.068	0.066	0.175	0.232
F	**4.2***	**1.7**	**1.7****	**2.4****	**3.12****	**2.16****
SE	**0.007**	**0.002**	**0.002**	**0.002**	**0.003**	**0.003**
CD (p=0.05)	**0.20**	**NS**	**0.007**	**0.005**	**0.010**	**0.010**

NS-Not significant **Significant at 5%* *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 18b. Effect of nutrition and cropping system on calcium (Ca) and magnesium (Mg) content of leaves (%)- Exp I and II

Treatment	Ca		Mg	
	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	0.050	0.062	0.044	0.044
T_2 :13:05:13	0.061	0.096	0.040	0.039
T_3 :VC+NC	0.086	0.108	0.065	0.046
T_4 :VC+NC+BF	0.040	0.043	0.037	0.028
T_5 :VC+NC+CF	0.047	0.068	0.032	0.047
F	**6.94****	**9.27****	**13.34****	**2.50****
SE	**0.002**	**0.003**	**0.001**	**0.002**
CD (p=0.05)	**0.007**	**0.008**	**0.003**	**0.005**

NS-Not significant **Significant at 5%* *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 18c. Effect of nutrition and cropping system on iron(Fe),manganese (Mn) and zinc (Zn) content of leaves (ppm) Exp I and II

Treatment	Fe		Mn		Zn	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	170.73	146.60	32.55	47.45	25.98	24.73
T_2 :13:05:13	240.93	228.95	47.33	57.43	25.00	25.53
T_3 :VC+NC	356.27	267.88	50.90	94.73	30.22	33.39
T_4:VC+NC+BF	236.13	235.98	42.90	81.40	30.56	24.98
T_5:VC+NC+CF	248.10	245.93	49.68	73.63	27.74	23.73
F	55.7**	180.2**	4.6*	6.7*	2.5	12.6**
SE	8.95	3.45	3.41	7.26	1.58	1.11
CD (p=0.05)	27.57	10.62	10.50	22.36	NS	3.41

Table 19. Effect of nutrition and cropping system on plant uptake of nitrogen (N), phosphorus (P) and potassium (K) - kg/ha- Exp I and II

Treatment	Uptake of nutrients (kg/ha)					
	N		P		K	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	23.60	13.32	13.32	1.24	2.05	2.26
T_2 :13:05:13	69.23	21.01	20.01	3.84	9.01	3.55
T_3 :VC+NC	14.43	14.02	14.02	1.28	2.06	2.32
T_4:VC+NC+BF	27.33	26.24	26.24	1.51	2.94	3.08
T_5:VC+NC+CF	16.30	19.27	19.327	0.95	3.36	3.06
F	301.6**	51.0**	60.0**	1906.1**	757.2**	89.97**
SE	1.29	0.75	0.74	0.03	0.11	0.058
CD (p=0.05)	3.98	2.29	2.30	0.08	0.33	0.18

NS- Not significant **Significant at 5%* *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden **Experiment II:** Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

4. 10.2 Effect Of Nutrition And Cropping System On Organic Carbon And Available Nitrogen Content Of Soil

The effect of treatments on organic carbon and nitrogen content of intercropped area was not significant whereas, in monocropped area, the effect was significant. In monocropped area, the highest organic carbon and available nitrogen content was recorded in T_3 followed by T_5. The data is given in Table 20b.

4.10.3 Effect Of Nutrition And Cropping System On Phosphorus (P_2O_5) Content Of Soil

The soil P content was significantly different in both the experiments (Table 20b). The treatment supplied with VC and NC (T_3) recorded significantly higher soil P content in experiment I and II (97.07 ppm and 93.44 ppm respectively) followed by T_2 and T_5.The lowest soil P was recorded in T_1 (68.81ppm and 64.38 ppm respectively).

4. 10. 4 Effect Of Nutrition And Cropping System On Potassium (K_2O) Content Of Soil

Soil potassium content varied significantly among the treatments (Table 20b). In both the experiments, T_2 recorded significantly higher values (20.63ppm and 20.00ppm respectively). The lowest value was in T_1 (16.88ppm and 17.50ppm respectively).

4. 10. 5 Effect Of Nutrition And Cropping System On Exchangeable Calcium (Ca) Content Of Soil

The calcium content of soil varied significantly with the treatments and the value was more in monocropped area. The highest Ca content was recorded by T_3 in experiment I and II (386.9ppm and 248.5ppm respectively). The data is represented in Table 20 c.

Table 20. Effect of nutrition and cropping system on soil nutrient content – after the experiment

Table 20a. Effect of nutrition and cropping system on soil pH and EC Exp I and II

Treatment	pH		EC(dSm^{-1})	
	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	6.55	6.41	0.04	0.04
T_2 :13:05:13	6.28	6.41	0.09	0.05
T_3 :VC+NC	6.44	6.85	0.04	0.04
T_4 :VC+NC+BF	6.48	6.71	0.04	0.04
T_5 :VC+NC+CF	6.31	6.26	0.08	0.02
F	12.37**	6.79**	57.9**	12.00**
SE	0.003	0.09	0.003	0.003
CD (p=0.05)	0.01	0.29	0.01	0.01

NS- Not significant   **Significant at 5%*   *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 20b. Effect of nutrition and cropping system on Organic carbon ,available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) content of soil- Exp I and II

Treatment	Organic carbon(%)		Av. N(ppm)		P_2O_5(ppm)		K_2O(ppm)	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	0.206	0.125	178.1	280.3	68.81	64.38	16.88	17.50
T_2 :13:05:13	0.210	0.156	181.2	424.3	93.13	67.50	20.63	20.00
T_3 :VC+NC	0.224	0.194	193.2	735.8	97.07	93.44	18.13	16.88
T_4:VC+NC+BF	0.380	0.158	205.3	400.8	84.69	76.25	18.13	17.50
T_5:VC+NC+CF	0.196	0.177	169.1	629.0	70.69	61.88	18.13	17.50
F	**0.80**	**49.3****	**0.8**	**79.3****	**54.1****	**33.4****	**5.14***	**9.5****
SE	**0.018**	**0.004**	**15.8**	**20.7**	**1.74**	**2.22**	**0.6**	**0.40**
CD (p=0.05)	**NS**	**0.011**	**NS**	**63.8**	**5.37**	**6.83**	**1.86**	**1.22**

NS- Not significant **Significant at 5%* *** Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 20c. Effect of nutrition and cropping system on exchangeable calcium (Ca) and magnesium (Mg) content of soil- Exp I and II

Treatment	Ca(ppm)		Mg(ppm)	
	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	268.8	169.2	47.94	46.63
T_2 :13:05:13	277.6	206.3	55.53	47.50
T_3 :VC+NC	386.9	248.5	71.04	65.16
T_4:VC+NC+BF	295.0	262.6	43.29	55.57
T_5:VC+NC+CF	287.4	236.5	68.72	48.28
F	5.04*	7.75**	27.2**	11.25**
SE	2.13	1.34	2.36	2.34
CD (p=0.05)	65.57	41.26	7.3	7.22

Table 20d. Effect of nutrition and cropping system on iron (Fe), manganese (Mn) and Zinc (Zn) content of soil (ppm) – Exp I and II

Treatment	Fe		Mn		Zn	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	4.91	6.73	1.28	1.00	1.99	1.55
T_2 :13:05:13	7.37	6.97	1.37	1.42	1.98	1.49
T_3 :VC+NC	9.24	9.27	1.15	1.02	2.13	2.12
T_4:VC+NC+BF	8.64	5.84	1.03	0.91	2.64	1.60
T_5:VC+NC+CF	7.62	8.30	1.52	1.53	2.01	0.93
F	43.4**	17.9**	6.59**	61.0**	13.4**	9.2**
SE	0.25	0.32	0.01	0.04	0.008	0.14
CD (p=0.05)	0.78	0.99	0.23	0.11	0.23	0.13

*** Significant at 1%* **Significant at 5%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

4. 10. 6 Effect Of Nutrition And Cropping System On Exchangeable Magnesium (Mg) Content Of Soil

The soil magnesium content showed significant difference between the treatments. In both the systems of planting, T_3 recorded significantly higher values (71.04ppm and 65.16 ppm respectively). The data is given in Table 20 c.

4. 10. 7 Effect Of Nutrition And Cropping System On Iron (Fe) Content Of Soil

The soil iron content recorded significant difference among the treatments in both the experiments (Table 20 d). In both the situations, it was the highest in T_3 (9.24ppm and 9.27 ppm). In intercropped condition T_3 was followed by T_4,T_5 ,T_2 and T_1 and in monocropped condition, it was in the order T_5,T_2 ,T_1 and T_4.

4. 10. 8 Effect Of Nutrition And Cropping System On Manganese (Mn) Content Of Soil

The soil manganese content varied significantly among the treatments and T_4 recorded significantly lower content in both the systems of planting. In both the conditions, T_5 and T_2 recorded significantly higher values followed by T_3 and T_1 (Table 20 d).

4. 10. 9 Effect Of Nutrition And Cropping System On Zinc (Zn) Content Of Soil

There was difference in the zinc content of soil between different treatments in experiment I and II (Table20 d).In intercropped condition, the highest value was recorded in T_4 (2.64ppm) followed by T_3 (2.13ppm). In monocropped condition, the highest value was recorded in T_3 (2.12ppm) followed by T_4 (1.60ppm).

4.11 EFFECT OF NUTRITION AND CROPPING SYSTEM ON WAX CONTENT (mg/cm^2) OF FLOWERS

The wax content of flowers varied significantly in the two systems of planting (Table .21). The flower wax was more in intercropped condition. In both the systems, T_3 plants recorded the highest wax content (248.4 mg/cm^2 and 219.8 mg/cm^2 respectively) and the lowest content was observed in T_1 plants (170.9 mg/cm^2 and 168.6 mg/cm^2 respectively).

4.12 EFFECT OF NUTRITION AND CROPPING SYSTEM ON PIGMENT CONTENT OF FLOWERS

4.12.1 Effect Of Nutrition And Cropping System On Flower Carotenoid Content

The flower caroteniod content was significant among the treatments only in intercropped condition (Table.22). The plants supplied with VC and NC (T_3) recorded the highest carotenoid content (1264.3 ppm) followed by T_4 (1031.2ppm) and T_5 (1008.7 ppm). The lowest carotenoid content was in T_1 (769.1 ppm).

4.12.2 Effect Of Nutrition And Cropping System On Flower Carotenoid-Chlorophyll Ratio

The ratio was significant in the first experiment but was not significant in the second experiment (Table 22.). The ratio was more in intercropped condition.In intercropped condition, the plants supplied with VC and NC (T_3) produced significantly higher ratio followed by T_5. The lowest value was reported in T_2.The data is presented in Table 22.

4.13 Effect Of Nutrition And Cropping System On Vase Life Of Flowers (Days)

The vase life of flowers was more in the inflorescence produced in intercropped condition (Table.23). The vase life was the highest for inflorescences in T_3 plants in experiment I and II (12.9 days and 10.5 days respectively). The lowest vase life was recorded in T_1 plants (6.6 days and 4 days respectively).

Table 21. Effect of nutrition and cropping system on wax (mg/cm^2) of flowers- Exp I and II

Treatment	Wax content(mg/cm^2)	
	Exp I	Exp II
T_1 : 17:17:17	170.9	168.6
T_2 :13:05:13	222.9	202.0
T_3 :VC+NC	248.4	219.8
T_4:VC+NC+BF	192.5	172.2
T_5:VC+NC+CF	215.4	196.7
F	**48.5****	**41.2****
SE	**4.2**	**3.3**
CD (p=0.05)	**13.1**	**10.3**

** *Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 22. Effect of nutrition and cropping system on pigment content of flowers – Exp I and II

Treatment	Flower carotenoid content (ppm)		carotenoid /total chlorophyll		carotenoid /chlorophyll. a		carotenoid / chlorophyll.b	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	769.1	109.5	2.01	0.029	5.26	0.16	2.74	0.039
T_2 :13:05:13	827.1	100.6	1.58	0.023	3.50	0.10	2.30	0.030
T_3 :VC+NC	1264.3	91.7	2.95	0.029	7.59	0.13	6.05	0.038
T_4 :VC+NC+BF	1031.2	85.8	2.13	0.028	4.20	0.12	3.37	0.037
T_5 :VC+NC+CF	1008.7	91.4	2.84	0.024	4.52	0.11	4.19	0.031
F	8.3**	0.28	13.8**	0.52	56.8**	1.1	53.5**	0.43
SE	67.6	12.25	0.15	0.004	0.21	0.02	0.20	0.006
CD (p=0.05)	208.2	NS	0.48	NS	0.64	NS	0.62	NS

NS- Not significant   *Significant at 5%   ** Significant at 1%

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

4.14 EFFECT OF NUTRITION AND CROPPING SYSTEM ON ECONOMICS OF CULTIVATION

4.14.1 Effect Of Nutrition And Cropping System On Number Of Marketable Suckers

The number of marketable suckers varied significantly under both the systems of planting.

The plants in intercropped condition produced more suckers than in monocropped condition. The data is given in Table 24.

In experiment I, the plants supplied with VC and NC (T_3) produced the highest number (309.3) of marketable suckers. This was followed by T_5 (258.0), T_2 (246.5) and T_4 (245.8). The lowest number of marketable suckers was recorded in T_1 (172.0). While in the second experiment, T_3(212.3), T_2 (208.5) and T_5 (186.3) produced significantly higher number of marketable suckers which was followed by T_4 (166) and T_1 (156).

4.14.2 Effect Of Nutrition And Cropping System On Number Of Marketable Flowers

The plants in intercropped area produced more number of marketable flowers than in plants grown under monocropping (Table 24). In experiment I and II, T_3 (1497.5 and 735.8 respectively) and T_1 (607.8 and 280.3respectively) produced the highest and the lowest number of marketable flowers. In the plants under experiment I, T_5 also produced higher number of flowers (1124.8) and was followed by T_2 (903) and T_4 (857.5). In the second experiment it was in the order T_5,T_2 ,T_4 and T_1.

4.14.3 Benefit Cost Ratio

The benefit cost ratio (Table 24) was the highest for T_3 in experiment I and II (3.90 and 2.50 respectively) and the lowest was recorded in T_1 (1.85 and 0.83).

4.15 EFFECT OF NUTRITION AND CROPPING SYSTEM ON LAND EQUIVALENT RATIO (LER)

Table 25 shows the effect of nutrition and cropping system on LER. The land equivalent ratio recorded significant difference between the treatments. Among the treatments, T_5 recorded the highest value (1.49) followed by T_3 (1.43), T_2 and T_4 (1.4) and T_1 (1.39).

4.16 NUTRIENT BALANCE SHEET

The nutrient balance sheet was prepared for the major nutrients N,P and K (Table 26).

The nutrient balance sheet for nitrogen was found to have a minimal balance in all the treatments except T_3 in experiment I. In the second experiment also, the balance was low for all the treatments except T_3 and T_1.

The nutrient balance sheet for phosphorus was low in T_2 and T_4 under the two experiments. The balance was more in monocropped condition. The higher balance was in T_1 and T_5.

In general, the nutrient balance for potassium was more in monocropped condition. In the intercropped area, the balance was highest in T_1 followed by T_3. The treatments T_2 and T_4 recorded the lowest balance. In the monocropped condition, all the treatments recorded a higher balance

Table 23. Effect of nutrition and cropping system on vase life of flowers (days) – Exp I and II

Treatment	Vase life of flowers (days)	
	Exp I	Exp II
T_1 : 17:17:17	6.56	3.95
T_2 :13:05:13	7.60	5.06
T_3 :VC+NC	12.94	10.50
T_4:VC+NC+BF	7.44	7.31
T_5:VC+NC+CF	9.13	7.38
F	**19.7****	**23.6****
SE	**0.57**	**0.52**
CD (p=0.05)	**1.75**	**1.60**

** *Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 24. Effect of nutrition and cropping system on economics of cultivation- Exp I and II

Treatment	Number of marketable suckers		Number of marketable flowers		Benefit cost ratio (in terms of marketable flowers)	
	Exp I	Exp II	Exp I	Exp II	Exp I	Exp II
T_1 : 17:17:17	172.0	156.0	607.8	280.3	1.85	0.83
T_2 :13:05:13	246.5	208.5	903.0	424.3	2.73	1.30
T_3 :VC+NC	309.3	212.3	1497.5	735.8	3.90	2.50
T_4:VC+NC+BF	245.8	166.0	857.5	400.8	2.58	1.20
T_5:VC+NC+CF	258.0	186.3	1124.8	629.0	3.38	1.90
F	**56.9****	**5.7****	**79.3****	**148.6****	**298.6****	**103.1****
SE	**6.7**	**10.4**	**20.7**	**27.4**	**0.005**	**0.07**
CD (p=0.05)	**20.8**	**32.1**	**63.8**	**84.5**	**0.14**	**0.20**

Table 25. Land Equivalent Ratio (LER) - Exp I and II

Treatment	LER
T_1 : 17:17:17	1.39
T_2 :13:05:13	1.40
T_3 :VC+NC	1.43
T_4:VC+NC+BF	1.40
T_5:VC+NC+CF	1.49
F	**18.77****
SE	**0.009**
CD (p=0.05)	**0.003**

** *Significant at 1%*

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 26. Nutrient balance sheet for major nutrients

Table 26a. Nutrient balance sheet for nitrogen (N) - Exp I and II

Experiment: I

Treatment	Soil content(kg/ha)-pre experimental data	Quantity applied (kg/ha)	Plant uptake (kg/ha)	Soil content (kg/ha)-after expteriment	Balance
T_1 : 17:17:17	338.2	247.0	236.0	461.4	-112.2
T_2 :13:05:13	331.5	233.0	692.0	470.4	-597.8
T_3 :VC+NC	434.6	419.0	144.0	501.8	207.8
T_4 :VC+NC+BF	268.8	303.0	273.0	851.2	-552.4
T_5:VC+NC+CF	320.3	326.0	163.0	439.0	44.3

Experiment: II

Treatment	Soil content(kg/ha)-pre-experimental data	Quantity applied (kg/ha)	Plant uptake (kg/ha)	Soil content (kg/ha)-after expteriment	Balance
T_1 : 17:17:17	427.8	247.0	133.0	280.0	261.8
T_2 :13:05:13	378.6	233.0	210.0	349.4	52.1
T_3 :VC+NC	376.3	419.0	140.0	396.5	258.8
T_4 :VC+NC+BF	418.9	303.0	262.0	434.6	25.3
T_5:VC+NC+CF	275.5	326.0	193.0	353.9	54.6

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 26 b. Nutrient balance sheet for phosphorus (P) - Exp I and II

Experiment: I

Treatment	Soil content (kg/ha)-pre-experimental data	Quantity applied (kg/ha)	Plant uptake (kg/ha)	Soil content (kg/ha)-after expteriment	Balance
T_1 : 17:17:17	49.39	635.00	133.00	154.11	397.28
T_2 :13:05:13	56.56	593.00	200.00	208.54	241.02
T_3 :VC+NC	53.38	666.00	140.00	217.50	361.88
T_4:VC+NC+BF	52.08	621.00	262.00	189.73	221.35
T_5:VC+NC+CF	53.76	630.00	193.00	158.368	332.39

Experiment: II

Treatment	Soil content(kg/ha)-pre-experimental data	Quantity applied (kg/ha)	Plant uptake (kg/ha)	Soil content(kg/ha)-after expteriment	Balance
T_1 : 17:17:17	28.56	635.00	12.40	144.3	506.90
T_2 :13:05:13	27.44	593.00	38.40	151.2	430.84
T_3 :VC+NC	28.29	666.00	12.80	209.2	472.28
T_4:VC+NC+BF	27.17	621.00	15.10	170.9	462.16
T_5:VC+NC+CF	28.00	630.00	9.50	138.7	509.84

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Table 26 c. Nutrient balance sheet for potassium (K) - Exp I and II

Experiment: I

Treatment	Soil content (kg/ha)-pre-experimental data	Quantity applied (kg/ha)	Plant uptake (kg/ha)	Soil content(kg/ha) -after expteriment	Balance
T_1 : 17:17:17	49.39	635.00	133.00	154.11	397.28
T_2 :13:05:13	56.56	593.00	200.00	208.54	241.02
T_3 :VC+NC	53.38	666.00	140.00	217.50	361.88
T_4:VC+NC+BF	52.08	621.00	262.00	189.73	221.35
T_5:VC+NC+CF	53.76	630.00	193.00	158.368	332.39

Experiment: II

Treatment	Soil content (kg/ha)-pre-experimental data	Quantity applied (kg/ha)	Plant uptake (kg/ha)	Soil content(kg/ha) -after expteriment	Balance
T_1 : 17:17:17	28.56	635.00	12.40	144.30	506.90
T_2 :13:05:13	27.44	593.00	38.40	151.20	430.84
T_3 :VC+NC	28.29	666.00	12.80	209.20	472.28
T_4:VC+NC+BF	27.17	621.00	15.10	170.90	462.16
T_5:VC+NC+CF	28.00	630.00	9.50	138.70	509.84

Experiment I: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment II: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

a, Experiment I

b, Experiment II

Plate 7.Closer view of the best treatment (T_3)

4.17 OVERALL EFFECT OF HELICONIA INTERCROPPING IN COCONUT

In general, the growth, yield and nutrient content of coconut showed seasonal variations. Hence the results are represented on seasonal basis ie; June and December 2010-2011 during the period of study.

4.17.1 Effect Of Heliconia Intercropping In Coconut Yield And Yield Parameters

From the data given in Table 27.a it was clear that growing *Heliconia* as an intercrop had a positive impact on coconut yield and yield parameters during the two seasons of growth period May and December (2010-2011).

In June, the number of nuts per bunch, average number of buttons per bunch and average number of nuts per palm increased from 13.20 to 13.60, 12.61 to 19.74 and 5.99 to 7.44 respectively. There was a reduction in the number of barren bunches from 2.20 to 1.20. The predicted yield also showed a marginal increase from 56.99 to 57.13 nuts/palm/year.

In December also the number of nuts per bunch, average number of buttons per bunch and average number of nuts per palm increased from 12.00 to 12.20, 5.78 to 12.92 and 4.72 to 4.78 respectively. The number of barren bunches reduced from 4.8 to 4.0 during the period. The predicted yield also recorded an increase from 42.40 to 45.49 nuts/palm/year.

4.17.2 Effect Of Heliconia Intercropping In Coconut Leaf Nutrient Content

The leaf nutrient content of coconut was found to increase gradually during the period of observations (Table 27 b). The leaf N, P and K content increased from 2.11% to 2.80 %, 0.077% to 0.18% and 0.358% to 0.559 % respectively. The leaf Ca and Mg increased from 0.311% to 0.55% and 0.16% to 0.17% respectively. The leaf micronutrients such as Fe,Mn and Zn also increased from 147.9 ppm to 611.2 ppm, 76.70 ppm to 79.80 ppm and 14.88 ppm to 68.20 ppm respectively.

Table 27. Overall effect of intercropping Heliconia on Coconut **

Table 27. a. Effect of intercropping Heliconia on coconut yield and yield parameters

Parameter	May		December	
	2010	2011	2010	2011
Number of leaves	28.80	29.80	27.40	27.60
Number of bunches	13.20	13.60	12.00	12.20
Number of barren bunches	2.20	1.20	4.80	4.00
Average number of buttons/bunch	12.61	19.74	5.78	12.92
Average number of nuts/palm	5.99	7.44	4.72	4.78
Fruit setting percentage	56.99	57.13	42.40	45.49

Table 27 b. Effect of intercropping Heliconia on coconut leaf nutrient content

Nutrient	June 2010	December 2010	June 2011	December 2011
N (%)	2.11	2.18	2.84	2.80
P (%)	0.077	0.078	0.140	0.180
K (%)	0.358	0.367	0.495	0.559
Ca (%)	0.311	0.410	0.470	0.550
Mg (%)	0.160	0.161	0.166	0.170
Fe (ppm)	147.9	168.4	539.3	611.2
Mn (ppm)	76.70	77.70	79.40	79.80
Zn (ppm)	14.88	16.45	66.30	68.20

** Not statistically analysed

Discussion

5. DISCUSSION

A group of new ornamental plants referred to as speciality flowers used mainly as cut flowers are now gaining importance in global floriculture scenario. A number of such speciality flowers are widely grown in a number of countries. Among these Heliconias hold great promise for the development of floriculture in the Indian subcontinent. These flowers are outstanding due to diversity in form, colour, size and durability. There is wide variability in Heliconias ranging from erect flowers to huge pendulous inflorescences in breath taking colour combinations. Heliconias differ in their cultural requirements. Some species perform beautifully in full sunshine while others do well in different shade intensities.

The nutrient requirement in Heliconia also varies from species to species. The growth and flowering of some heliconias such as *H. psittacorum* are known to be light-intensity limited (Broschat *et al.*, 1984a). Yet other species appear better adapted to slight shade conditions and are easily injured under full sunlight in the tropics. *Heliconia stricta* can be grown from full sunlight to 40% shade (Berry and Kress, 1991) with profuse flowering throughout the year (Kress *et al.*, 2002). Fertilization rates strongly affect growth and flowering of Heliconias under high light intensities (full sunlight) (Broschat and Donselman, 1983b).The marketable yield of Heliconia flowers vary with nutrient content of the growing medium and light intensity among the species; ranging from 59.5% to 74.7 % (Powell,1991).

Heliconias grow well in organic rich soils. But little is known about the performance of *H. stricta* cv. Iris Red under different manurial conditions in low fertile sandy soils under open and intercropped condition. Hence two field experiments were conducted at Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State, India from June 2010 to May 2012 for studying the effect of nutrition and cropping system on growth and performance of Heliconia under the same nutrient management in two different cropping situations. The present investigation was carried out with the following objectives.

1. To standardize a cost-effective manurial schedule for *Heliconia stricta* for better flower yield and quality when grown as an intercrop in coconut garden and as a monocrop in open condition.

2. To analyze the effect of substituting chemical fertilizers with vermicompost, neem cake and biofertilizers in flower quality and yield.

3. To evaluate the performance of Heliconia under two cropping systems.

The relevant findings of this study are discussed in this chapter.

5.1 GROWTH CHARACTERS

5.1.1 Plant Height (cm)

Plant height is important as far as Heliconia is concerned as the inflorescence length is positively related to the height of the plant. The plant height was found to be more in intercropped plants (Fig.3) than in monocropped condition(Fig.4). This may be due to the fact that shaded condition in the former one resulted in taller plants. The effect of shading in plant height varies with species. It is reported to have a positive correlation in *H. stricta* (Broschat and Svenson, 1994) whereas a negative correlation in *H. velloziana* and *H. angusta* (Simao and Scatena,2001).

In both the experiments, the height of the plant varied significantly among the treatments only by 8 months after planting (8MAP) and the influence of nutrition increased progressively with passage of time. Later the plants showed significant difference in their plant height and the plants supplied with 13:5:13 NPK as straight fertilizer (T_2) and VC and NC (T_3) recorded the highest value in both the experiments. The plants of treatments supplied with 13:5:13 NPK and organics (T_5) also produced the tallest plants and by 12 MAP T_2 and T_3 recorded

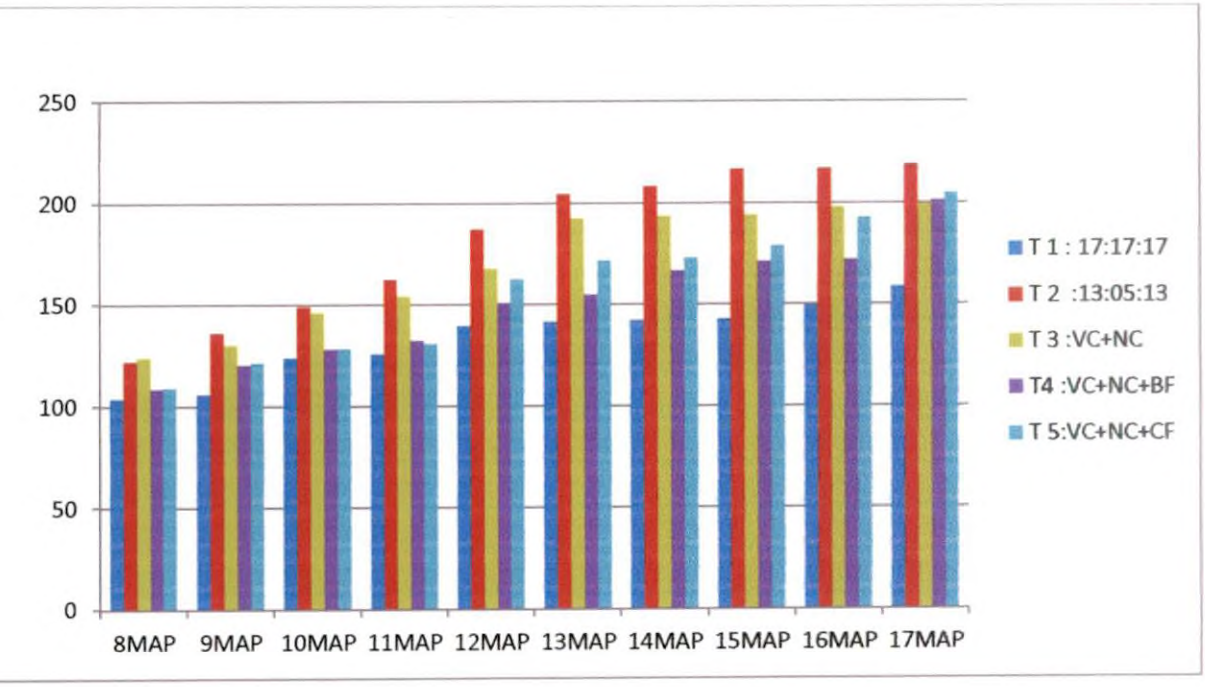


Fig. 3. Effect of nutrition and cropping system on plant height (cm) – Exp I

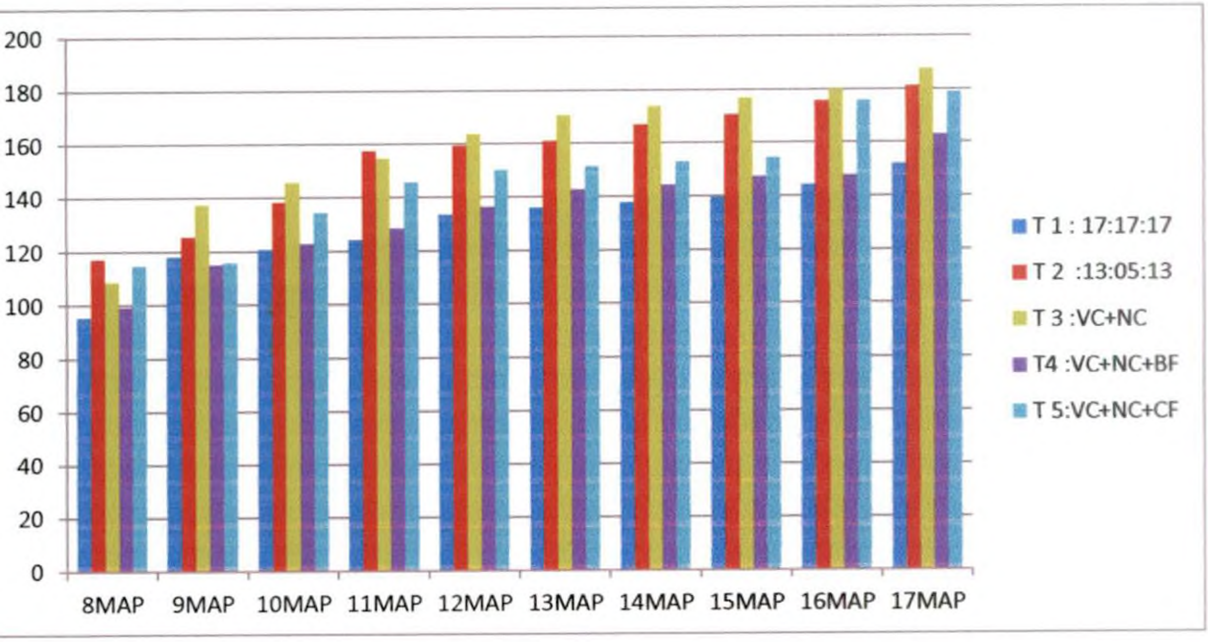


Fig.4. Effect of nutrition and cropping system on plant height (cm) – Exp II

the highest values. This may be due to the low organic matter content of the soil limiting the available energy for soil microorganisms for the mineralization (Fontaine *et al.*, 2003) which might have resulted in delayed availability of the supplied nutrients. The lower plant height in T_4 and T_1 might be due to the inadequate supply of nutrition to the crop.

5.1.2 Number Of Suckers

The study revealed that nutrition and cropping system greatly influenced the total number of suckers produced (Fig. 4 and 5). In *Heliconia stricta* var. Iris Red, results of the present investigation showed a negative correlation of sucker production with photosyntheticaly active radiation (PAR).The suckering was more in intercropped area which received PAR of 937.5 μ mol $s^{-1}m^{-2}$ than in monocropped condition (1253.15 μ mol $s^{-1}m^{-2}$). The impact of PAR on suckering depends on species and is reported to have a positive correlation in Heliconia Golden Torch (Catley and Brooking, 1996). The number of suckers can be considered as an indicator to quantify the expected number of flower yield as the sucker production in Heliconia is positively correlated with the number of inflorescence (Costa *et al.*, 2006b).In both the systems, the highest suckering was recorded in T_2 and T_3 followed by T_5. The sucker production increased with increase in crop growth and was found to be not significantly influenced by the treatment after 14months. In the present investigation it is noted that flowering was initiated in healthy suckers which attained 9cm collar girth in 8months time. This can be attributed to the fact that the duration required for emergence of new suckers reduced with flowering of progressive shoots (Catley and Brooking, 1996). The result of present study is also in conformity with the findings of Loges *et al.* (2006).

5.1.3 Number Of Leaves

The number of leaves per shoot was an indicator to inflorescence emergence and it varied with species (Cabral and Benedetto, 2010; Rocha *et al.*, 2010).The number of leaves per clump was not affected by the systems of cropping(Fig. 7

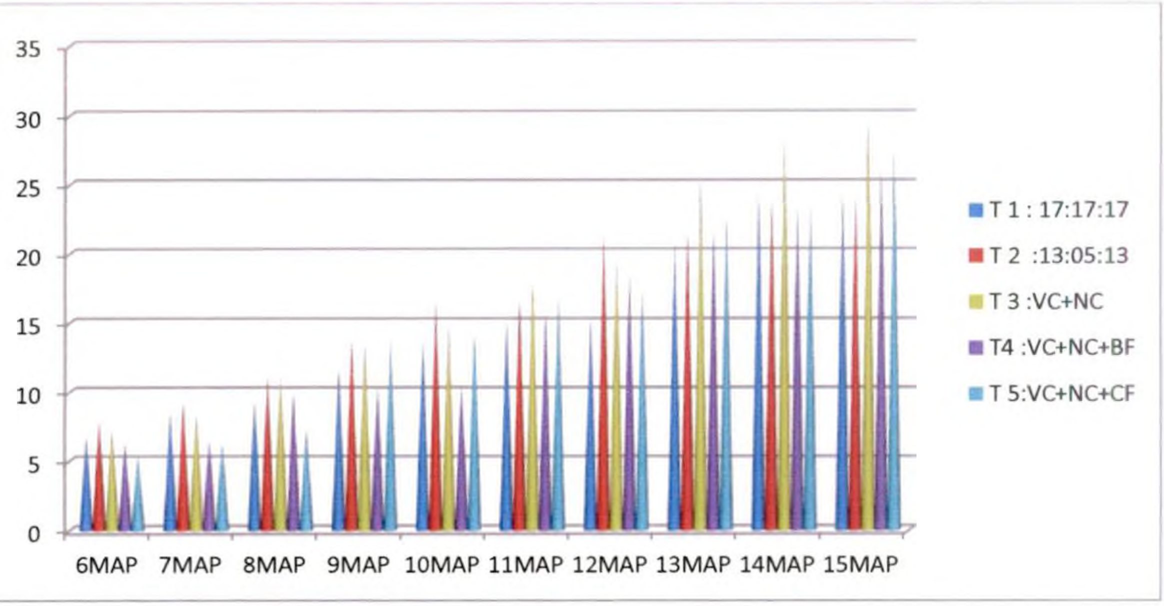


Fig.5. Effect of nutrition and cropping system on number of suckers – Exp I

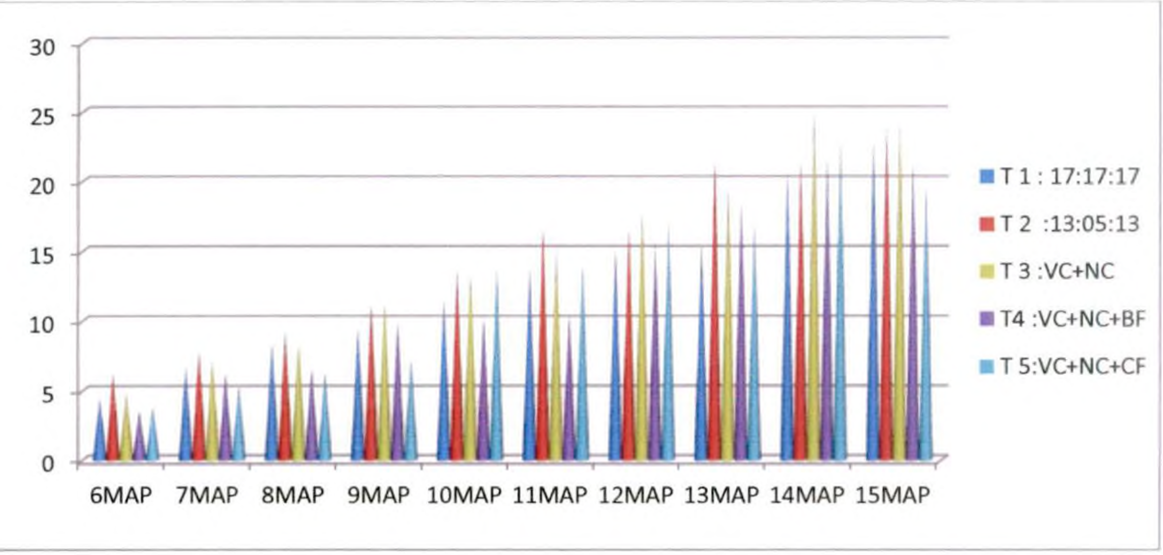


Fig.6. Effect of nutrition and cropping system on number of suckers – Exp II

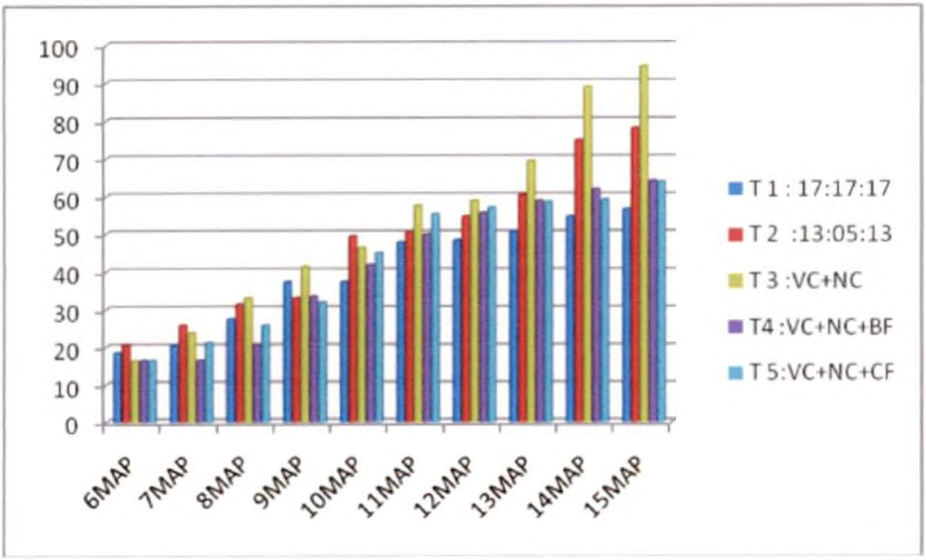


Fig. 7. Effect of nutrition and cropping system on number of leaves – Exp I

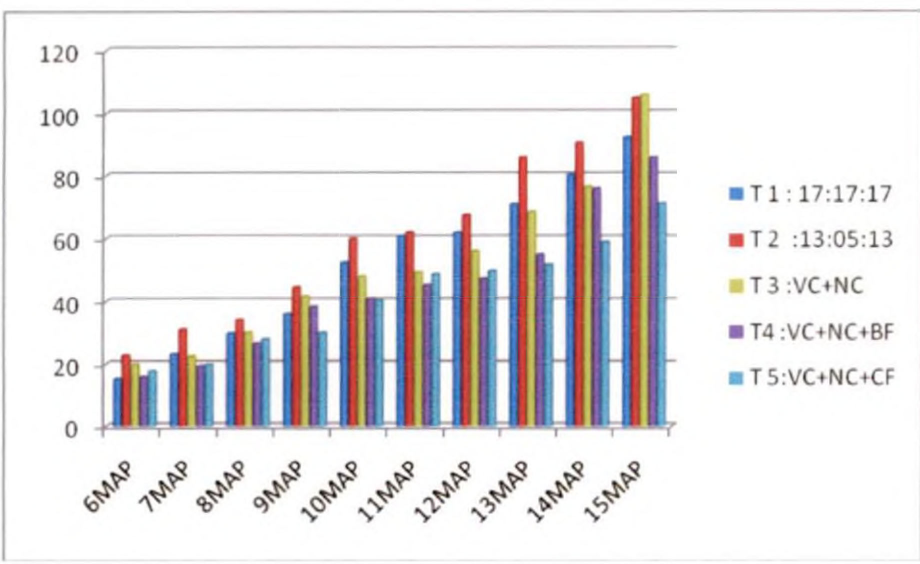


Fig. 8. Effect of nutrition and cropping system on number of leaves – Exp II

and 8). The number of leaves of Heliconia is unaffected by photosynthetic photon flux (Catley and Brooking, 1996) which was found to be true for this species too. In Family Musaceae to which Heliconia formerly belonged, physiological maturity to flowering is attained upon production of a specific number of leaves (Allen *et al*,1988). As in present study Cabral and Benedetto (2010) also observed that *H. stricta* produced four to five leaves irrespective of treatment at the time of flowering. In the present investigation, it was found that *Heliconia stricta* var. Iris Red recorded more number of shoots resulting in more leaves per clump in plants of monocropped area. This is because of the increased vegetative growth and reduced flower production in monocropped plants which resulted in retaining of more shoots per clump for a longer duration. The delay in floral initiation would have resulted in additional development of leaves as observed by Ferreira and Pires (2005).

5.1.4 Collar Girth

Flowering was observed within two months in healthy plants when the shoots attained 9cm collar girth. The collar girth of Heliconia plants is positively related to the inflorescence girth. A similar relationship exists in banana where size of bunch and collar girth is positively related (Turner, 1998). However, significant effect of treatments on collar girth was observed only during certain periods of crop growth. The collar girth of Heliconia plants increased with growth. The plants grown in intercropped conditions which came to flowering in a relatively short time had lower collar girth (Fig.9) compared to the monocropped plants (Fig.10), whereas, the plants in monocropped conditions had a longer vegetative phase in expense of flowering and resulted in higher collar girth during the latter phase. In general, collar girth was recorded to be more than 9 cm when the plants shift to reproductive stage. The results show that the plants in the intercropped area attained the collar girth by 6MAP whereas in monocropped condition the girth was attained only after 8MAP.From this observation, we can say that the collar girth can be taken as an indicative tool for flower initiation.

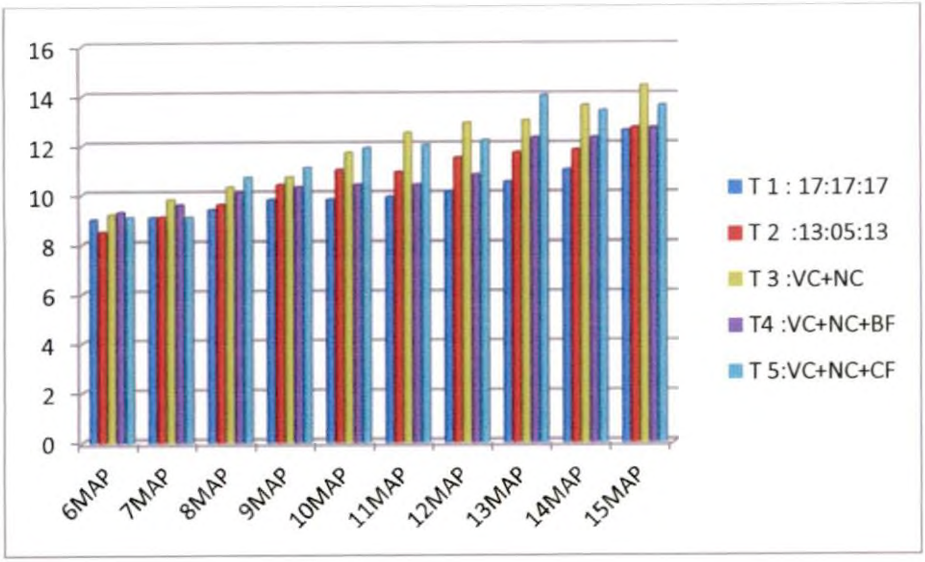


Fig. 9. Effect of nutrition and cropping system on collar girth(cm)- Exp I

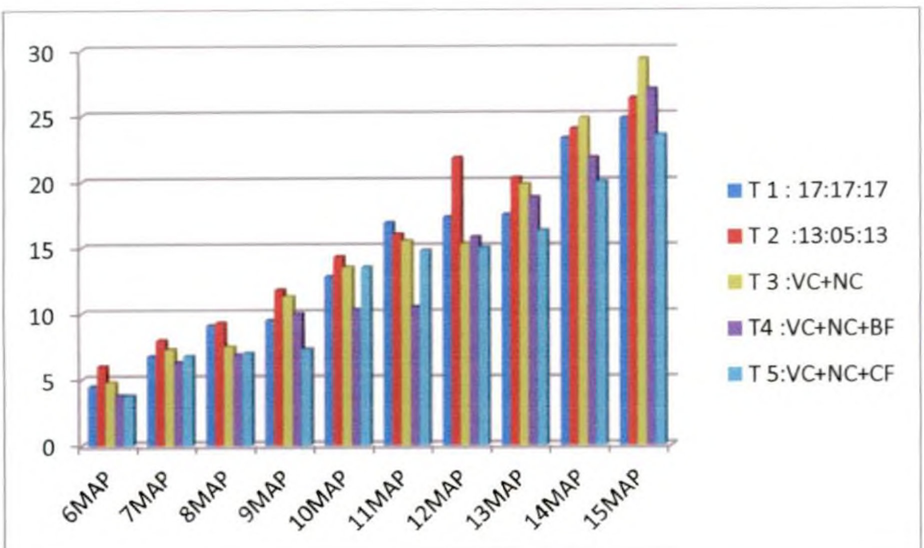


Fig.10. Effect of nutrition and cropping system on collar girth(cm)- Exp II

5.2 PHYSIOLOGICAL CHARACTERS

5. 2.1 Leaf Area

The leaf area of the studied variety increased with increase in growth in both the experiments(Fig.11 and 12). The plants grown under coconut canopy recorded higher leaf area which might be due to the less availability of PAR. The larger leaf area enabled the plants to increase their interception of light. The positive influence of low photosynthetic photon flux (PPF) levels in increasing the leaf area has been reported by Catley and Brooking (1996) but it varies with crop species as higher leaf areas under open conditions has also been reported in some species of Heliconia (Rundel *et al*, 1998) such as *H. acuminata* (Bruna *et al.*, 2002*)*.Higher leaf area has been recorded in T_2 and T_3 which might be due to increased availability of nutrients as higher leaf area represents higher nutrient and water availability in Heliconia (Grubb, 1998; Cunningham *et al.*, 1999).

5.2.2 Leaf Area Index (LAI)

The LAI (leaf area coverage per unit area) was higher in T_3 and T_2 under both the systems of cropping. The higher LAI in T_2 and T_3 revealed the higher radiation use efficiency of these plants. This is in agreement with the findings of Allen *et al.*(1988) according to which higher levels of nutrient application resulted in higher radiation use efficiency in banana.

5.2.3 Specific Leaf Area (SLA)

Specific leaf area (SLA) is inversely proportional to leaf thickness which plays an important role in leaf and plant functioning and resource acquisition and use (Vile *et al.*, 2005).In shaded condition, the leaves will be thinner (Middleton, 2001) which might have resulted in higher SLA in the intercropped plants. The SLA of T_3 plants recorded the highest value in the first experiment while in the second, it was T_2 followed by T_3. This might be due to the better nutrition of these as SLA declines along with the gradients of decreasing moisture and/or nutrient availability (Fonseca *et al.* 2000) The results of present study also showed

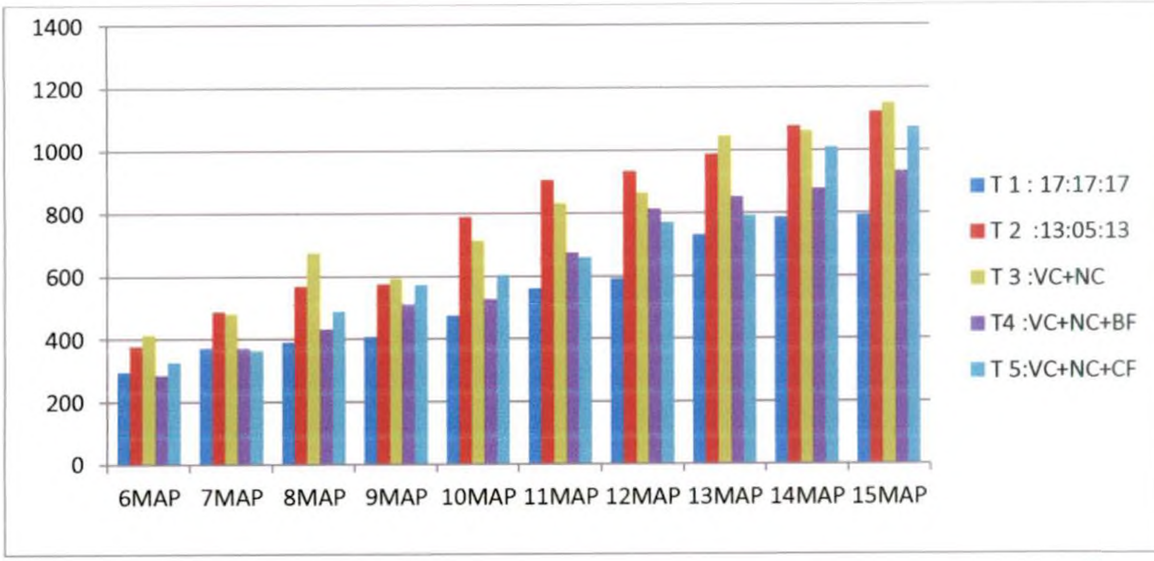


Fig.11. Effect of nutrition and cropping system on leaf area (cm^2)-Exp I

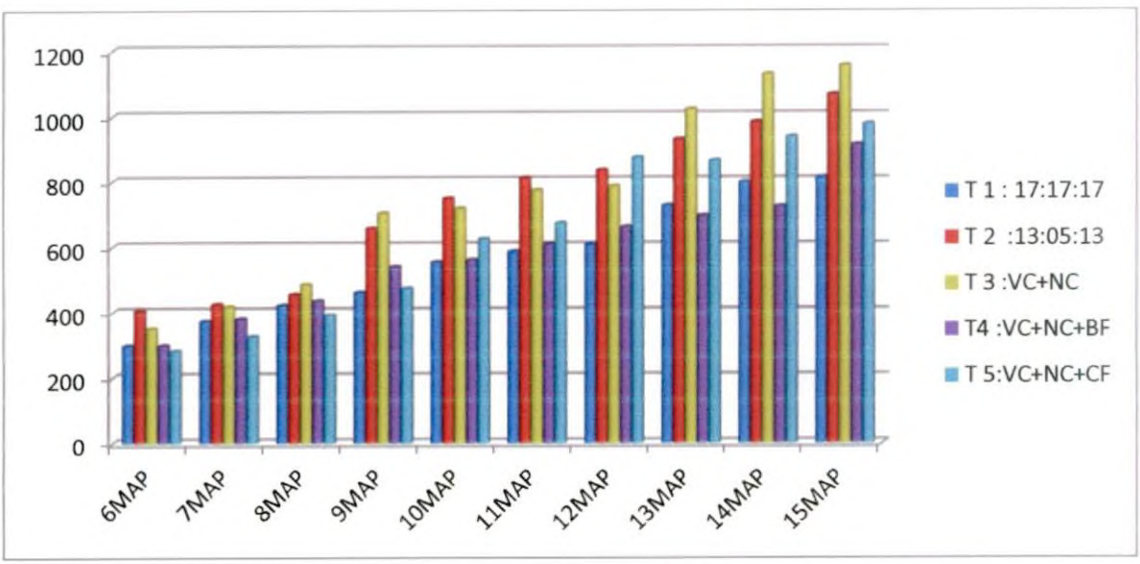


Fig.12. Effect of nutrition and cropping system on leaf area (cm^2) – Exp II

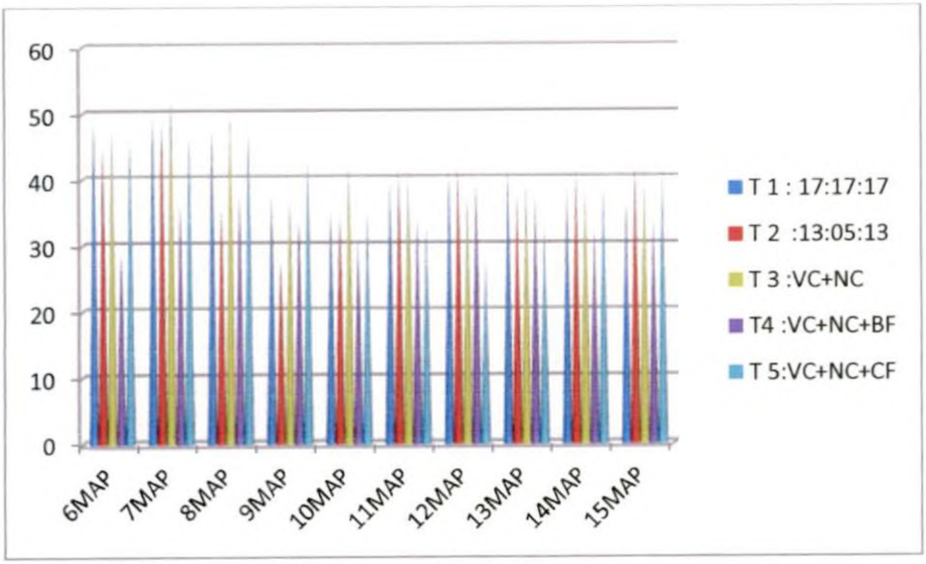


Fig.13.Effect of nutrition and cropping system on specific leaf area (cm^2 g^{-1}) –Exp I

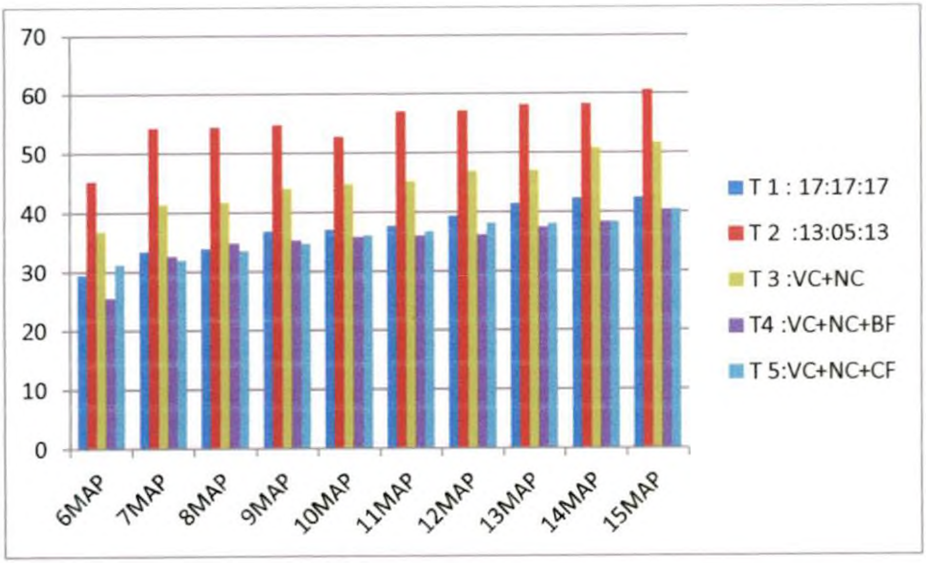


Fig.14.Effect of nutrition and cropping system on specific leaf area (cm^2 g^{-1}) Exp II

that the value decreased by 9MAP in intercropped condition (Fig.13) whereas it was more or less stable in plants grown under full sunlight(Fig.14). In open condition, the stable increase in SLA might be due to the prolonged vegetative phase. In intercropped condition, reduced SLA was noticed when the plants entered reproductive phase ie., 9MAP which might have resulted in reduced leaf life span and assimilation rate as observed by Reich *et al.* (1997).

5.2.4 Leaf Area Duration (cm^2 / 30 days)

The leaf area duration (leaf area produced in unit time) increased with growth and T_3 and T_2 recorded significantly higher values under both the systems of planting. The leaf area duration was more in intercropped condition except for T_1.The increased leaf area duration of T_1 in monocropped condition might be due to its prolonged vegetative phase and delayed flowering/senescence. The data showed that higher values were recorded in treatments with higher flower production and reduced vegetative phase. Decreased leaf area duration observed in monocropped condition of the present investigation is in line with the observations of Bruna *et al.* (2002).They found that Heliconia plants exposed to abiotic stress like high light intensity suffered a setback in growth rates.

5.2.5. Leaf Area Density (g/cm^2)

The leaf area density (dry leaf weight per square centimeter of leaf) was estimated to be higher in monocropped area. This might be due to the lower leaf area and higher leaf thickness of plants grown under open condition. Negative relationships between leaf thickness and photosynthetic (Enriquez *et al.*, 1996) and growth rates (Poorter, 1990) have been observed, and thicker leaves have been associated with increased vegetative phase (Mediavilla *et al.*, 2001). Leaf thickness has therefore often been used as a tool to screen species and/or cultivars for productivity (White and Montes, 2005). In both the systems of planting, higher leaf area density was also recorded in T_2 and T_3 plants. Even though the leaf area density was higher in open condition the crop performance was higher in plants under coconut canopy. This might be because plants in intercropped area had thinner leaves with lesser stomatal density leading to higher water and nutrient use efficiency as reported by Rundel *et al.* (1998).

5.3 DURATION OF THE CROP

5.3.1 Number Of Days Taken To First Flowering

The study revealed that nutrition and cropping system influenced the flower initiation in *H. stricta* var. Iris Red. In the present study, under the same management, the intercropped plants flowered earlier than the monocropped plants(Fig.15). There are many reports regarding time taken to flowering in Heliconia differing from variety to variety and species to species.In this present investigation, the plants supplied with VC and NC (T_3) flowered in 6MAP under intercropped condition while the same treatment took eight months for flowering under open condition. According to Powell and Neilson (1991), Heliconia plants started flowering from 5 to 12 months after planting depending on the variety. Criley and Kawabata (1986) reported that *H. stricta* flowers within one year after emergence of a pseudostem. Later Criley and Lekawatana (1995) observed that flowering of each Heliconia cultivar varied markedly depending on environmental conditions. It was understood from the present study that higher production of biomass adversely affected flower initiation and flower production in *Heliconia stricta*. The results showed that plants in the intercropped area flowered early even under same nutrient management which might be because of the increased leaf support efficiency of the plants under coconut canopy (Rundel *et al*, 1998).The flowering was recorded to be faster in VC and NC(T_3) applied plants. Even though the plants in T_2 and T_3 recorded higher vegetative growth, the flowering in the plants supplied with 13:05:13 (T_2) took the longest time under intercropped (295 days) and open (362.5 days) conditions. This might be because of the higher biomass production of T_2 plants. In Heliconia Iris Red, a negative correlation exist between biomass production and flower initiation whereas in another variety Golden Torch a hybrid of *H.psittacorum* x *H. spathocircinata* flower initiation and biomass production is found to be positively correlated by Catley and Brooking (1996). The delayed flowering in plants grown under open condition in general, and T_2 plants in particular, might be due to the increased number of sucker and resulting biomass production as the probability of shoots to flowering declined markedly with order of shoot emergence which in turn is influenced by appropriate mineral nutrition (Clemens and Morton, 1999).In these treatments, the nutrient reserves was utilized for production of new suckers leading to consequent delay in the emergence of inflorescence. This shows that as in banana(Turner,1998 , it is desirable to limit the number of suckers (which attained 9cm collar girth in 8 months) per plant by pruning to get optimum flower yield. Early flowering was observed in T_1 and T_4 plants which can be explained as stress induced early flowering as the inflorescence produced in these were of inferior quality. Nutrient deficiency induced early flowering was reported in Dendrobium orchid (Yen, 2008).

5. 3.2 Number Of Days Taken To Fifty Percent Flowering (days)

There was no significant difference among the treatments in time taken for fifty percent flowering under intercropped condition (Fig.16). This is because the second and subsequent shoots took less time from emergence to inflorescence initiation (Catley and Brooking, 1996). Bruna *et al.*(2002) reported that the asymmetrical losses of leaf area and shoots during the dry seasons, as well as final differences in growth rates, suggested that the normal abiotic stresses to which these understorey plants were exposed were greatly exhibited in open condition. In the present study, under monocropped condition, a similar trend of flowering behavior was observed. In open condition, there was significant difference in time taken for fifty percent flowering between treatments.T_2 plants with increased vegetative growth took 459.8 days to attain fifty percent flowering, whereas, fifty percent of the T_3 plants flowered in 370.0days.The longer crop duration for the T_2

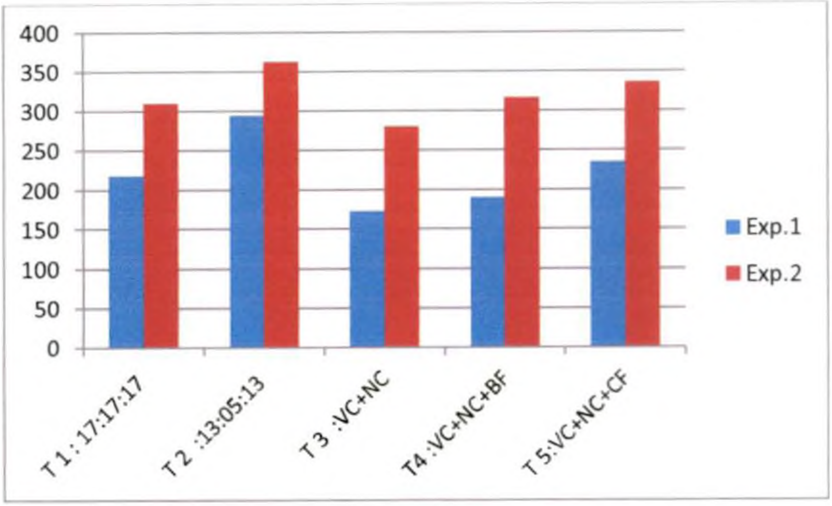


Fig. 15.Effect of nutrition and cropping system on number of days takenfor first flowering-Exp I and ExpII

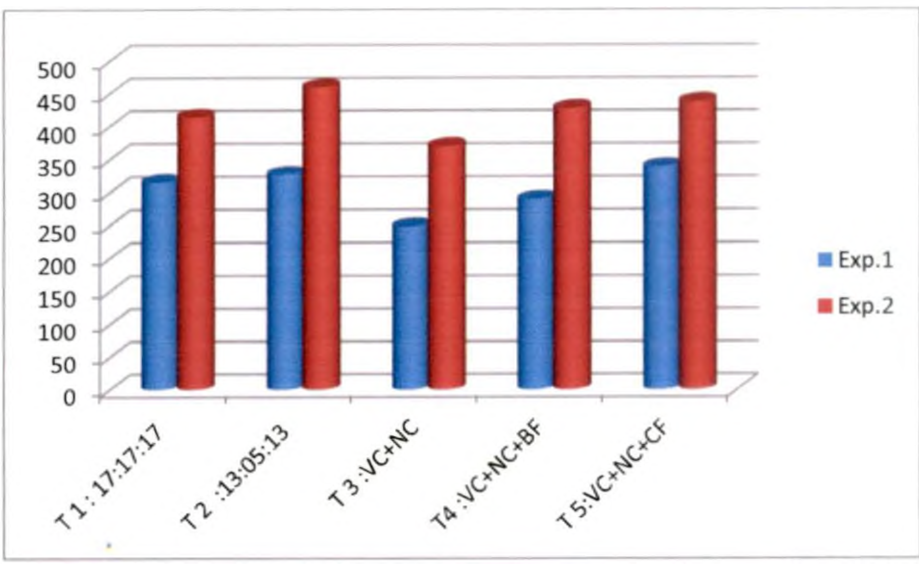


Fig. 16.Effect of nutrition and cropping system on number of days taken for fifty percent flowering Exp I and Exp II

plants might be due to its increased vegetative growth in expense of flowering. According to Clemens and Morton (1999), the proportion of shoots producing flowers declined sharply with order of shoot emergence which was confirmed in the present investigation also.

5.4 LIFE OF FLOWER IN PLANT (DAYS)

The opening of inflorescence was classified into four stages in this study. The time taken for the inflorescence to undergo different stages varied significantly among the treatments in the two experiments. The stages from fully emerged or just opened (Stage II) to complete unfurling of bracts (Stage III) and the life of fully opened flower in plant (Stage III to IV) are the critical stages which determined the life of marketable inflorescences in plant as they can be used for various purposes from Stage II to IV. The duration taken for the inflorescence from Stage II to IV was more in intercropped condition (23.3 days to 38.5 days) resulting in continuous supply of marketable flowers due to higher retention of flower quality in plant. This might be because of the reduced illumination (2278 Wm^{-2} μA) in intercropped area which might have resulted in higher soil moisture retention. The interval between opening of bracts in Heliconia inflorescence increases with more soil moisture retention as reported by Dobkin (1984) and in the present study also, the interval between opening of bracts was more in the plants under coconut canopy. Among the treatments, the inflorescence produced in T_3 plants recorded the longest life of flower in plant. The flower life in T_2 and T_5 plants was also found to be superior. This might be because of the appropriate mineral nutrition (Clemens and Morton, 1999) and sustainable nutrient availability of the plants grown under these treatments. The life of flower in plants under monocropped condition was less (17.05 days to 27.3 days) and T_3 recorded the highest life followed by T_2. Increased soil temperature coupled with increased illumination (4981 Wm^{-2} μA) might have resulted in less soil moisture

a, Stage I

b, Stage II

Plate 8. Different stages of flower opening

a, Stage I

b, Stage II

c, Stages of bract opening

d,Stage III

e, Stage IV

Plate 8.Different stages of flower opening

c, Stages of bract opening

d, Stage III

e, Stage IV

and nutrient retention leading to faster unfurling of the bracts. The information about the time taken for the inflorescence to shift from Stage I to Stage IV helps the farmers on planning the harvesting programme of flowers grown under different nutrition levels under intercropped and monocropped open situations.

5.5 INFLORESCENCE CHARACTERS

5.5.1 Inflorescence Length

The length of the inflorescence stem and number of opened bracts are the main criteria used by farmers for expressing inflorescence quality of Heliconias (Costa *et al*, 2006a).The stem length of *H .stricta* ranged from 50.1cm to 150 cm (Costa *et al.*, 2009b).In the present investigation, the flower stem length was more in intercropped condition. This might be due to the increased plant height in shaded condition as observed by Broschat and Svenson (1994). Production of longer inflorescence in partially shaded condition (30%) was also reported in *Heliconia psittacorum* by Powell (1991). Superior quality flowers having 1m length were produced in T_3 under both the systems of planting. In intercropped condition, T_2 and T_5 plants also produced such flowers. This might be because of the optimal mineral nutrition combined with the shade provided by coconut canopy. According to Broschat et al (1984 a), shade loving Heliconias are reported to be easily affected under full sunlight in the tropics.

5.5.2 Bract Characters

The number of bracts and average bract width was also higher in T_3 . This can be attributed to the optimal nutritional supply to these through slow releasing organic manures such as vermicompost and neemcake. The number of bracts was more in intercropped condition where the average shade intensity was estimated as 26%. According to Sheela (2008), shade influences the bract number and was reported to be more in 25% shade level.

5.5.3 Length Of Inflorescence Stalk

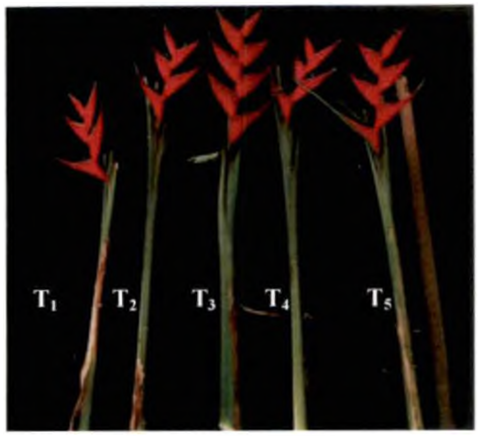
In the present study, the inflorescence stalk length was recorded to be more in intercropped area. It was reported that *H.stricta* produces inflorescence with superior stem length ie; 71.6 cm in partial shade (Costa *et al*., 2007) as seen in this study also. Among the treatments, T_3 recorded the highest stem length in open as well as intercropped conditions in T_3 (83.2 cm and 90.6 cm respectively). Under intercropped condition, T_2 plants also produced superior stem length (73.9 cm) but were significantly different from T_3.

5.5.4 Inflorescence Girth

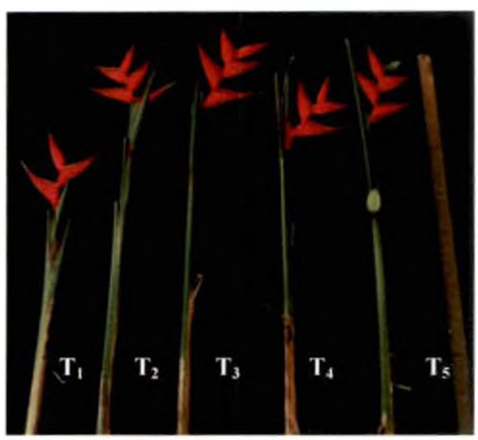
In general, the inflorescence girth of Heliconias tended to be thinner at the lower PPF level (Balla and Starr, 2010).But the present study revealed that inflorescence girth of the Iris Red inflorescence was more under intercropped condition. Moreover, nutrition had higher influence on the girth and the plants supplied with VC and NC (T_3) recorded the highest girth under both the systems of planting. In the intercropped condition, the T_2 and T_5 plants also produced inflorescences with superior girth supporting the better adaptability of the species to shaded condition.

5.5.5 Spike Size

The unopened and fully opened spike sizes are equally important as inflorescences in both the stages are used in flower arrangements and it varied with nutrient content of growing medium and shade level (Powell, 1991).In this study, it was the nutrition which influenced the spike size than the shade level. The spike size of inflorescences in T_5 and T_3 performed better under both the systems of planting. This might be because of the better nutrient availability of the plants in those and its transport to the sink in the two systems of planting. Phosphorus and Potassium influenced positively to increase the length of buds in Heliconia "St. Vincent Red" as reported by Ferreira and Pires (2005).



a, Experiment I



b, Experiment II

Plate 9.Effect of nutrition and cropping system on floral traits of *Heliconia stricta*

Exp I and II

5.5.6 NUMBER OF FLOWERING SHOOTS PER YEAR

Flowering in Heliconia is controlled by photoperiod (Criley and Kawabata, 1986; Criley and Lekawatana, 1995; Sakai *et al.*, 1990) and leaf number (Criley and Kawabata, 1986; Kwon, 1992).The number of flowering shoots was significantly higher under the intercropped condition. This strongly revealed the adaptability of the selected variety as a coconut intercrop. The recovery of number of marketable flowers was lower in T_4 and T_1.It was the percentage of marketable flowers and not the total number of flowering shoots that determined the cost effectiveness of the nutritional trial as the flowering of shoots can also be due to nutrient and/or water stress. This is in conformity with the findings of Achard *et al.* (2006).According to them; plants show a tendency to flowering under nutrient and/or water stress. Even though T_2 recorded the highest biomass production, number of flowering shoots was not proportionately high. Clemens and Morton (1999) reported that Heliconia flower production was probably limited by the plant competition for rooting space. This might have resulted in lesser number of flowering shoots in T_2.

5.5.7 Fresh Weight Of Inflorescence

The fresh weight of fully opened inflorescence was significantly higher in T_3 and T_5 under both the systems of planting. This might be because of the higher spike size of these inflorescences. T_3 and T_5 recorded significantly higher length and width of inflorescence. According to Ferreira and Pires (2005) Heliconias respond satisfactorily to application of fertilizers. The increased vigour of plants in response to fertilizer application resulted in increased size of inflorescences.

5.6 VISUAL APPEAL OF FLOWERS

The visual appeal of flowers was determined based on four major characters viz. general appearance, bract arrangement, glossiness and colour development. The higher total score for the inflorescences produced in the intercropped area revealed the adaptability of the species to partial shade. The score was low for the inflorescence in open condition except for T_3 plants. It was established by Powell (1991) that the marketable yield of Heliconia flowers varied with nutrient content of the growing medium and light intensity. Catley and Brooking (1996) also opined that the quality of Heliconia flowers is influenced by nutrition and environment.

5.7 LEAF CHLOROPHYLL CONTENT

Leaf chlorophyll content was established as a common reference system by which physiological reactions were quantified (Mediavilla *et al.*,2001). In this study leaf chlorophyll content was found to have a positive relation with flowering and was more in intercropped condition. This might be because the exposure of leaves to full sunlight resulted in chlorophyll bleaching. Osmond (1994) reported that in shade loving plants, high light intensity inhibited photosynthesis and led to photosynthetic apparatus (chloroplast) damage. Excessive light intensity resulted in lower quantum utilization and a lower assimilation yield (photo inhibition). According to Goltsev *et al.* (2003), extremely high irradiation destroyed photosynthetic pigments. A decrease in chlorophyll b content was observed in monocropped condition which has been suggested to be an indication of chlorophyll destruction by excess irradiance. A similar tendency of decreased chlorophyll b due to excessive irradiance was reported by Jason *et al.* (2004). Compared with high-light plants, plants grown in low light tend to allocate relatively more resources to these light-harvesting pigments and their associated proteins which might have resulted in the higher concentration of these pigments in shaded condition (Saifuddin *et al.*, 2010). From this it is clear that the Heliconia species selected for study was more adapted to partial shade. The highest chlorophyll content was recorded in T_3 plants under both the systems of planting. This can be explained due to the optimal mineral nutrition. Findings of He *et al.* (2003) were in conformity with this, according to which level of nutrition influenced production of pigments in Heliconia plants. In the present investigation, higher leaf mass density and higher cholorophyll content was observed in T_3 which were in confirmity with the findings of Rundel *et al* (1998). According to them, it was the leaf mass density and not the thickness which determined the chlorophyll content of leaves.

5.8 LEAF WAX

Leaf wax coating was more in plants grown under full sunlight than in the intercropped area which may be described as the self acclimatization of this variety to high light intensity. Plants try to regulate the light capture by changing their leaf-surface properties. As reported by Robinson *et al.* (1993), many plants in high light intensity increased the reflectance of their leaves by producing more wax coating which acted as a photo protective layer from excess irradiance as in the present investigation. The leaves of T_3, T_5 and T_2 plants recorded higher wax content which could be one of the reasons for its enhanced water use efficiency.

5.9 LEAF NUTRIENT CONTENT

Nitrogen (N)

The cropping system did not significantly influence leaf N content. Similar results of constant leaf N regardless of shading treatment was reported in forest understorey crops (Yoshimura, 2010). The plants in T_3 treatment recorded lower leaf nitrogen .Nitrogen can either be used for construction of larger leaf area or storage in leaf tissue. In this context N might have used in crop leaf growth for higher radiation use efficiencies as reported by Sinclair and Horie (1989) rather than leading to higher nitrogen levels.

Phosphorus (P)

The higher P content of leaves was observed in plants under coconut canopy. This might be because of the increased uptake of P by the leaves under shaded condition. The higher leaf P in T_4 may be due to the phosphate solublising bacteria. In this study, the leaf P observed in the range was found to have no effect on flower production. Similar results were observed by Zhang *et al* (2004) in *Scaevola aemula* (fan flower).

Potassium (K)

Potassium was the limiting factor in *Heliconia stricta* which was highly prone to K deficiency according to Criley and Broschat (1992). Leaf potassium level was more in the treatments (T_5, T_2 and T_3) which produced more number of marketable flowers. The increased level of K concentration in increasing flower count with longer and thicker stem with more diameters was reported in *Phalenopsis* by Wang (2007).

Other leaf nutrients

All the other nutrients viz.,Ca, Mg, Fe, Mn and Zn content of leaf was higher in T_3.The higher nutrient content in T_3 explained the influence of these nutrients in enhanced performance under two systems of planting. In the present study, all the nutrients except Ca and Mn increased in intercropped condition. Increased leaf Mg and Zn content in shaded conditions has been reported in *Capsicum annum* by Perez (2012). The higher Ca content in monocropped area might be due to the higher Ca content of the initial soil as revealed by the pre experimental soil analysis. More over at lower light intensity and higher relative humidity the movement of Ca via transpiration was reduced resulting in lower level of Ca in uppermost leaves as reported by Gibson *et al*, (2010). It was also found that the leaf Mn was more in plants grown under full sunlight. This might be due to increased Mn accumulation in both vacuoles and chloroplasts of leaves resulting in increased chloroplast reserve of Mn under full sunlight than in shade which is in agreement with reports of Cain and Markley (1989).

5.10 PLANT UPTAKE NPK

The level of nutrients in plant tissue could be used as a diagnostic tool to assist in developing a fertilizer programme. If the tissue level of a nutrient was below the lower end of the sufficiency range, the nutrient was considered deficient, whereas if the level was above the upper end of the range, the nutrient can be considered as approaching a toxic level. It is important to be near the midpoint for most nutrients, because imbalances in the ratios of nutrients can affect crop growth. Uchida (2000) has reported that environment played a major role in crop development and nutrient uptake. In the present study the plant uptake of N,P and K was higher under partial shade. Similar results of increased N, P, K uptake under shade was reported in ginger by Ancy and Jayachandran (1998). In Heliconia, the nutrient uptake and critical level of nutrients for each nutrient varies with species. The influence of nutrition and cropping system on plant nutrient content of *Heliconia stricta* Var. Iris Red is discussed below:

The whole plant nitrogen content was lower than the leaf nitrogen content and like leaf nitrogen it was not influenced by the cropping system. In the present investigation lower nitrogen content in whole plant composite sample was observed in treatments with higher root-shoot ratio. This might be because of the differential accumulation of nitrogen within the plant and nitrogen content is reported to be lower in rhizomes. This findings are in line with the reports of Castro *et al.* (2011) according to which there is a differential accumulation of nitrates in different parts of Heliconia plant. It was observed in the present study that the nitrogen content in plant was inversely proportional to flower production. The lower levels of nitrogen in plant tissue levels can also be explained as the translocation of the nutrient from the arial parts to the actively growing regions of shoot tip i.e. enhanced translocation of nitrogen to the flowering organs. A similar trend in assimilation and translocation of nutrients was reported in *Curcuma alismatifolia* by Khuankaew *et al.* (2010). This might be the reason for lower N uptake in T_3. These plants had reduced dry matter production as most of the biomass was converted to flower production. The highest uptake was noticed in T_2 plants. This was because of its enhanced vegetative growth and biomass production coupled with reduced flowering.

Phosphorus uptake was more in T_4plants. This might be because of the addition of phosphate solublizing bacteria in the treatment. In the present investigation, P uptake had no influence on flowering as P was mostly concerned with rooting. Treatments with higher P uptake had higher root shoot ratio

(Appendix IV). This was confirmed by the fact that the treatment with higher P uptake had higher root-shoot ratio.

Potassium uptake highly influenced flower production. The higher uptake in T_2 plants was due to the higher biomass production. In Heliconia, K content was more in rhizomes which might be the reason for lower K uptake in T_3 plants which had a lower root shoot ratio. Studies by Castro *et al.* (2011) also revealed a higher K content in roots than leaves. Optimum levels of K nutrition are essential for flowering as reported by Uchida (2000). In the present study also, optimum flowering was observed in all the treatments having optimum levels of nutrient K.

5.11 SOIL NUTRIENT CONTENT

The soil nutrient content of the treatments after the experiments were analysed and compared with the initial soil status. The soil nutrient status was revealed to be higher in the intercropped soil which might be due to higher moisture and nutrient retention due to reduced irradiance. Similar findings were reported by Nobel and Linton (1997).They found that higher incident of solar radiation resulted in higher air and soil temperature resulting in lower soil moisture and nutrient retention. The salient findings of the studies are:

The pH of the soil under both the experiments was adjusted to the range of 6.3 to 6.7 which was ideal for most of the nutrient availability. Hanlon (2012) stated that the nutrient availability to plants depended more on soil pH than on the content of nutrient in soil. In the present study, there was only a slight increase in the EC of the soil after the experiment. But according to studies by Hanlon (2012) EC had no direct detrimental effect on sandy soils.

The organic carbon and available nutrient content of the soils in intercropped area was higher than in monocropped area. This might be due to reduced irradiance and increased soil moisture retention which might have delayed the organic manure decomposition. The higher values in the intercropped area could also be attributed to the higher cropping intensity in coconut garden when compared to the monocropped condition in open area. In a no till agro-ecosystem, organic carbon content of soil was reported to be high as per the findings of Sherrod (2003).

The increased P_2O_5 content of the soil after the experiment was due to the increased uniform supply of P in the form of cowdung and bonemeal (57.5g P/plant) as basal dose. Among the other treatments the highest residual P was recorded in T_3 . This may also be due to increased supply of P in the form of organic manures (1.3 g P each/dose of application). Like plant P, soil P also did not show any influence on flower production.

The potassium content of soil after the experiment was found to be drastically reduced. This implied that the crop required a higher K for its growth and flowering. According to Criley and Broschat (1992), *Heliconia sticta* had a high requirement of K and was highly prone to K deficiency.

The exchangeable calcium and magnesium of the soils were found to be higher in the T_3. But the Ca: Mg ratio was found to be same for the highest and lowest performers (T_3 and T_1) under intercropped (1.59 and 1.56 respectively) and monocropped (3.81 and 3.60 respectively) systems of planting. All other treatments had a lower ratio (1.1 to 1.3) in the intercropped area and higher value (4.3 to 4.9) in the monocropped open situation. According to Sawyer (2003) the highest yielding treatments and the lowest yielding treatments occurred within same ranges of Ca:Mg ratios, thus indicating the Ca:Mg ratio was not the reason for measured yield differences. This was because of the self adjusting mechanism of the plants to adjust the uptake and exclusion of excess Ca or Mg at the root surface.

Among the micronutrients, the Fe and Zn content of soil decreased after the experiment indicating an increased uptake of these elements for the growth and flowering of *Helconia stricta.* Manganese content of the soil before and after the experiment did not show much difference.

5.12 WAX CONTENT OF FLOWERS (mg/cm^2)

The flower glossiness was attributed to the wax content of bracts. The wax content of flowers was more in the intercropped plants which might have resulted in its enhanced glossiness. In the present investigation, the wax content of flowers was positively related to the scoring in glossiness given by the judging panel during the visual appeal test.

5.13 FLOWER PIGMENTS

The flower carotenoid content gives the colour to the flower bracts. The carotenoid content significantly differed with nutrition only under partial shade as intercrop. This is due to the interaction between shade and nutrition which might have resulted in enhanced carotenoid in organic treatments. The carotenoid was found to be higher in the treatment supplied with vermicompost and neemcake. The supply of additional micronutrients and enzymes through the organics might have resulted in this phenomenon. The scoring for colour development was also higher in experiment I. The scoring strongly implied that the visual rating was also higher for the flowers with more carotenoid content.

The bract carotenoid - chlorophyll pigment ratio was also recorded as the bracts had a green border and to assess the impact of full sunlight on the pigment development. The study revealed that the flowers under full sunlight had more chlorophyll and reduced carotenoid content. It was the chlorophyll a which recorded a reduced level in the flower tissues and not chlorophyll b in both the experiments giving a higher chlorophyll a to carotenoid ratio. Similar results were recorded in flower petals of *Phalenopsis* orchids by Tran *et al.* (1995).

5.14 VASE LIFE OF FLOWERS

Post harvest life of Heliconia varied with species from 7 days to 14 days in deionised water without preservatives (Broschat and Donselman, 1983a, 1983b).In the present study flowers in the intercropped area recorded higher vase life(Fig.17). Among the treatments, inflorescences from T_3 recorded highest vase

Plate 10. Vase life studies

life. This could be attributed to the higher flower wax content which has resulted in less moisture loss due to evaporation. The flower wax content was positively correlated to its vase life. The higher the wax content more was vase life. The lower vase life of T_1 flowers might also be due to the increased supply of nitrogen as inorganic form. This is in conformity with the reports in Anthurium by Higaki *et al.*(1995) in which higher nitrogen supply through inorganic fertilizer resulted in lesser vase life.

5.15 ECONOMICS OF CULTIVATION

The economics was calculated based on the number of marketable flowers. The highest number of marketable flowers (Fig.18) and suckers were produced in T_3 revealing that slow releasing fertilizer acted as source of optimal nutritional supply to the plants. The marketable flowers and number of flowering shoots produced in a year varied with the nutrition. Even though T_4 plants produced more flowers, they were of inferior quality. The increased number of flowering shoots is due to the addition of biofertilizers which might have triggered the flowering but due to the suboptimal nutrition supply, the flowers became inferior in quality. All the treatments except T_1 under the coconut canopy produced more number of quality suckers. This can be due to the N:P ratio in the nutrient supply which was 1:1 for T_1 and 2.5:1 for others as Heliconia requires a higher nitrogen for its growth and flowering as found in the present study and also reported by Criley and Broschat (1992). The benefit cost ratio was highest for T_3 under the two experiments. This was due to early flowering and higher number of marketable flowers.

5.16 LAND EQUIVALENT RATIO (IN TERMS OF MARKETABLE FLOWERS)

Land equivalent ratio could be considered as a productivity coefficient. Higher flower production was observed in intercropped condition. Consequently, a higher LER was obtained in the intercropped plants. The present study revealed

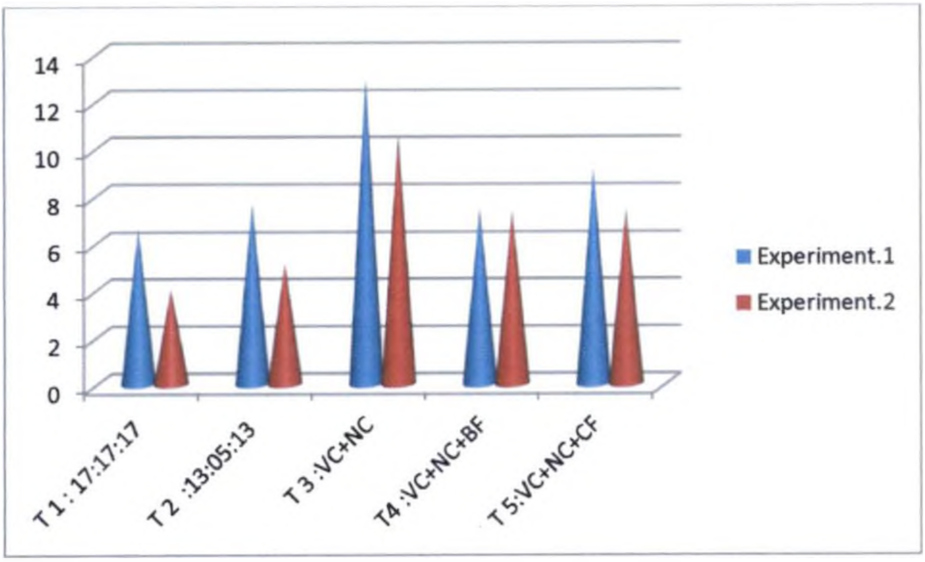


Fig.17. Effect of nutrition and cropping system on vase life of flowers (days) – Exp I and Exp II

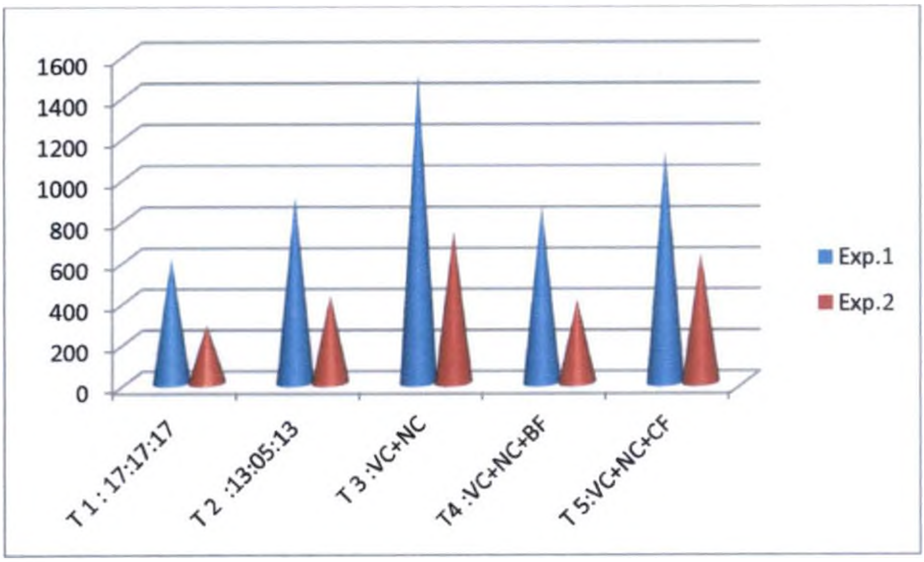


Fig.18. Effect of nutrition and cropping system on number of marketable flowers – Exp I and Exp II

Heliconia as a potential intercrop in coconut garden which had an enhanced productivity under intercropping than in monocropping.

5.17 NUTRIENT BALANCE SHEET

Nitrogen

From the nutrient balance sheet of nitrogen, it could be concluded that nitrogen is one of the most limiting nutrients in *Heliconia stricta* .It gave negative balance in all the treatments except T_3 and T_5. The higher value of T_3 might be because of the increased supply of nitrogen coupled with reduced uptake due to lower vegetative growth resulting in more residual nitrogen in the soil. The highest vegetative growth coupled with lower number of flowers resulted in lower balance in T_2. Increased uptake of nitrogen by T_4 plants resulted in lower balance. The increased uptake of nitrogen by T_4 plants was due to the action of biofertilizers. The increased balance in T_1 under open condition was due to the reduced plant biomass.

Phosphorus

The lower balance of phosphorus nutrient was noticed in intercropped condition due to the higher biomass production of the treatments in that area. The lower P balance in T_2 was due to the lower quantity of supplied P and higher uptake whereas the lower balance in T_4 was due to the higher P uptake. The higher uptake in the latter might be due to the addition of phosphate solublising bacteria. The higher P balance in T_1 might be due to the increased quantity of P supplied in the treatment coupled with lower biomass production.

Potassium

In the intercropped area, the balance was more in T_1. This was due to higher supply of nutrients coupled with lower uptake. The treatment with the highest yield (T_3) also recorded a higher balance. The lowest balance was recorded by T_2 and T_4 plants. This might be because of the higher K uptake. In the second

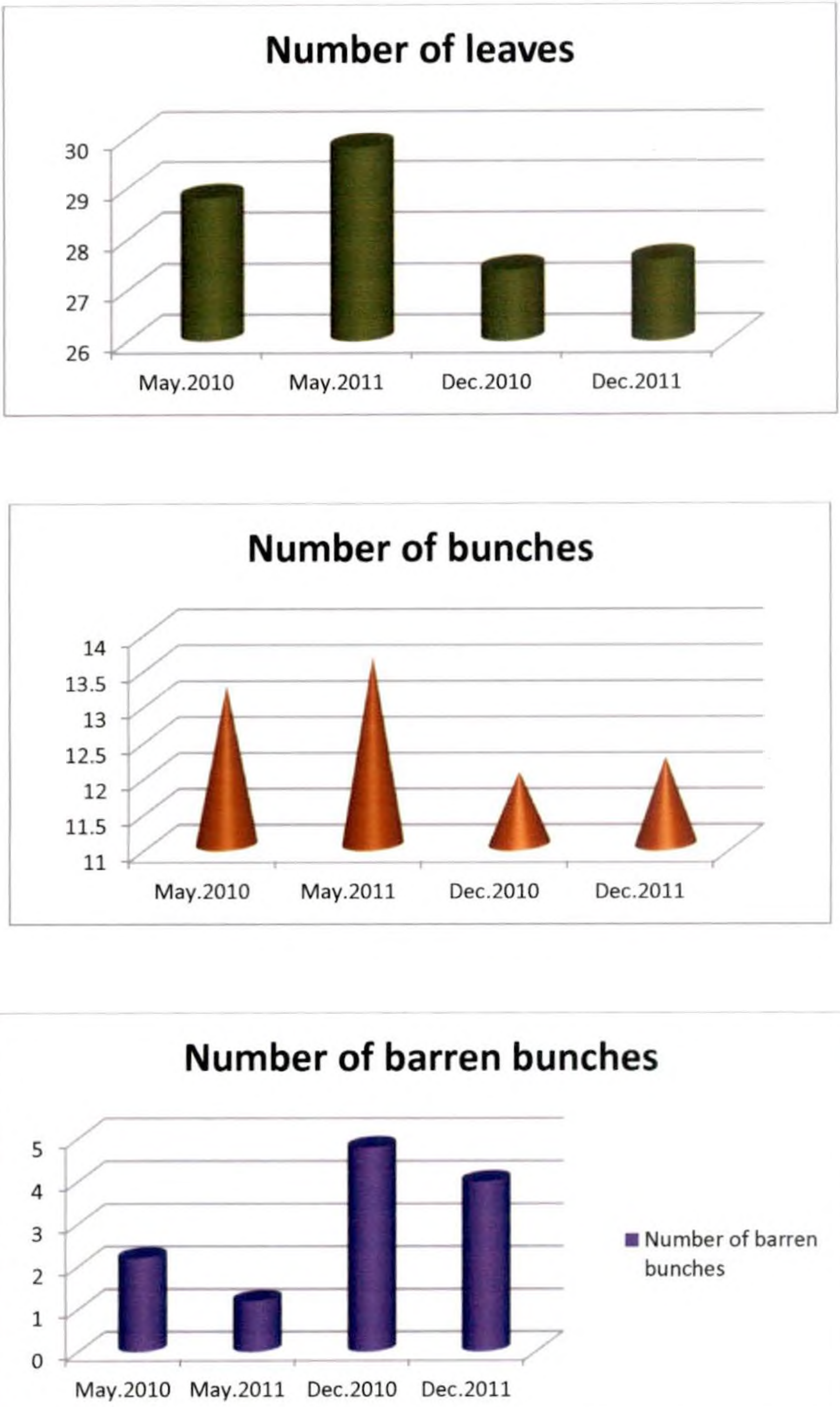


Fig. 19. Effect of intercropping in number of leaves, number of bunches and number of barren bunches

experiment, all the treatments had a higher balance. This might be because of the lower plant biomass production and plant uptake.

5.18 EFFECT OF HELICONIA INTERCROPPING IN COCONUT

The Heliconia had a positive effect on coconut yield and yield parameters(Fig.19). Due to the prolonged fruiting phase of coconut, the notable increase in yield will be exhibited only after three years. There was substantial reduction in the number of barren bunches. The increased retention of nuts in bunches and reduced barren bunches might be due to enhanced desirable properties of soil. The leaf nutrient content showed a steady increase which strongly supported the increased water holding capacity and available water in the coconut basins for a longer time. The increased Fe and Zn content of the coconut leaves might be due to the effect of mulching Heliconia wastes in the coconut basins. The increase in available water was mainly due to increase in field capacity which could be attributed to better soil structural development and stability related to higher organic matter and root activity on intercropping treatments. Mapa (1995) also reported beneficial effects of intercropping in coconut gardens.

FUTURE LINE OF WORK

Further studies may be conducted to assess the effect of different shade levels in growth and flowering of *Heliconia stricta* cv. Iris Red for suggesting it as a potential intercrop in coconut garden of specific age group. The effect of nitrogen and N: P ratio on growth and performance is to be studied. The effect of de-shooting or thinning and its interval should be standardized for enhancing the number of quality inflorescence from unit area.

Summary

6. SUMMARY

Two experiments on *Heliconia stricta* cv. Iris Red as monocrop and intercrop in coconut garden were laid out in RBD for a period of two years during 2010- 2012 with five treatments and four replications in Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State. The experiments aimed at the following objectives.

1. To standardize a cost-effective manurial schedule for *Heliconia stricta* for better flower yield and quality when grown as an intercrop in coconut garden and as a monocrop in open condition.

2. To analyze the effect of substituting chemical fertilizers with vermicompost, neem cake and biofertilizers in flower quality and yield.

3. To evaluate the performance of Heliconia under two cropping systems.

The salient findings of the study as two experiments are summarized below.

- The plants supplied with 5 g @ 13:5:13 NPK (T_2) recorded the maximum height under both the experimental conditions which was followed by Vermicompost (VC) @ 200g/plant +Neemcake (NC) @ 100g/plant (T_3).
- Sucker production was more in plants grown under intercropped condition. The plants in T_2 and T_3 produced significantly higher number of suckers throughout the year in both the systems of planting.
- In intercropped condition, T_3 recorded the highest leaf production. It was on par with T_2 on seven, eight, ten and twelve months after planting (MAP). While in the monocropped condition, T_2 recorded the highest leaf production throughout the period and was on par with T_3 on six and seven MAP.
- The effect of treatment on collar girth was found to be significant only during certain months of observation. It was found to be more than nine cm when the plants shifted to reproductive stage. The results showed that the plants in the intercropped area attained the girth by six MAP, whereas, in monocropped condition, the girth was attained only after eight MAP which strongly suggested collar girth as an indicative tool for flower initiation.

- The leaf area of T_2 and T_3 plants recorded significantly higher values throughout the period of observation under both the systems of cropping condition. The LAI (leaf area coverage per unit area) was higher in T_3 and T_2 under both the systems of cropping. The specific leaf area (SLA) of T_3 plants recorded the highest value in the first experiment, while in the second, it was T_2 followed by T_3.The leaf area duration (leaf area produced in unit time) increased with growth and T_3 and T_2 recorded significantly higher values under both the systems of planting.The leaf area density (dry leaf weight per square centimeter of leaf) of plants varied significantly among the treatments under the two systems of cropping and was higher in monocropped condition. In both the systems of planting, higher leaf area density was also recorded in T_2 and T_3 plants.

- The plants in the intercropped condition took less number of days to flowering than in monocropped condition. In experiment I and II, treatment T_3 took the lowest number of days (172.8 and 280.3 respectively) for first flowering, whereas, T_2 took the longest time to start flowering (295 and 362.5 days respectively).

- There was no significant difference among the treatments for time taken for fifty percent flowering under intercropped condition. In open condition, there was significant difference in time taken for fifty percent flowering between treatments.T_2 plants with increased vegetative growth took 459.8 days to attain fifty percent flowering whereas fifty percent of the T_3 plants flowered in 370.0days.

- The stages from fully emerged or just opened (Stage II) to complete unfurling of bracts (Stage III) and the life of fully opened flower in plant (Stage III to IV) was more in intercropped condition (23.3 to 38.5 days). The time taken (Stage II to IV) for the inflorescence produced under monocropped condition was less (17.05 to 27.3 days) and T_3 recorded the highest longivity followed by T_2.

- The inflorescence produced under intercropped condition recorded superior length than the ones produced in monocropped condition. Superior quality flowers having one meter length were produced in T_3 under both the systems of planting. In intercropped condition T_2 and T_5 (VC @ 100g/plant +NC @ 50g/plant + 2.5 g NPK @ 13:5:13kg/ha) plants also produced such flowers.

- The inflorescence of plants grown under monocropping produced less number of bracts than plants grown under intercropping. Among the treatment combinations, T_3 plants produced inflorescence with the highest number of bracts in monocropped as well as in inter cropped conditions (5.50 and 6.75 respectively) followed by T_5 and T_2 .

- The plants grown in open condition produced inflorescences with shorter stalk when compared to intercropped condition. In both the experiments treatment T_3 produced inflorescence with longest stalk (90.63cm and 83.18cm) which were significantly higher than all other treatments.

- Inflorescence girth was more under intercropped condition. T_3 recorded the highest girth under both the systems of planting (10.55cm and 10.28cm respectively). In the intercropped condition, the T_2 and T_5 plants also produced inflorescences with superior girth.

- In this study it was the nutrition which influenced the spike size than the shade level. The spike size of inflorescence in T_5 and T_3 was better under both the systems of planting.

- The number of flowering shoots was significantly higher under the intercropped condition. The recovery of marketable flowers was low in T_4 (VC @ 100g/plant +NC @ 50g/plant + biofertilizer) and T_1 (5g @ 17:17:17 NPK).

- The fresh weight of fully opened inflorescence was significantly higher in T_3 and T_5 under both the systems of cropping.

- In the visual appeal test the total score for the inflorescences produced in the intercropped area was higher and T_3 scored the highest values under both the experiments.

- The leaf chlorophyll content was found to have a positive relation with flowering and was more in intercropped condition. The highest chlorophyll content was recorded in T_3 plants under both the systems of cropping.

- Leaf wax content was more in plants grown under monocropped than in the intercropped area. In both the experiments, the leaves of T_3 and T_2 plants recorded higher wax content.
- The nitrogen content varied significantly in intercropped condition and was not significant in open condition. In intercropped condition all the treatments except T_1 recorded significantly higher values.
- The content of phosphorus in leaves was more in intercropped area than in monocropped condition. In both the situations, T_3 plants recorded significantly higher leaf P content.
- In the plants under coconut canopy higher leaf K content was recorded in T_3 and T_2 followed by T_1 and T_4, whereas in open situation, all the treatments except T_1 recorded higher values.
- In both the experiments, T_3 recorded the highest Ca, Mg, Fe, Mn and Zn content of leaves.
- The plant uptake of nitrogen was the highest in T_2 of the intercropped area and T_4 in open condition. The lowest N uptake was in T_3 treatment.
- The phosphorus uptake was significantly higher in T_4 plants (26.2kg/ha) in intercropped condition and in T_2 (3.84kg/ha) in open condition.
- The plants supplied with 13:5:13 NPK (T_2) recorded the highest K uptake in both the experiments (9.01 and 3.55kg/ha respectively). The lowest K uptake was found in T_3 and T_1 .
- The effect of treatments on organic carbon content of intercropped area was not significant, whereas, in monocropped area the effect was significant.
- The treatment supplied with VC and NC (T_3) recorded significantly higher soil P_2O_5 content in experiment I and II (97.07ppm and 93.44ppm respectively) followed by T_2 and T_5.
- In both the experiments T_2 recorded significantly higher K values in two systems of cropping (20.63ppm and 20.00ppm respectively).
- The highest Ca content was recorded in T_3 in experiment I (387ppm) and T_3, T_4 and T_5 (248ppm, 262ppm and 236ppm respectively) in open condition.

- In both the systems, T_3 recorded significantly higher Mg and Fe content of soil.
- In both the systems, T_3 plants recorded the highest leaf and bract wax content (248.4 mg/cm^2 and 219.8 mg/cm^2 respectively)
- The flower careteniod content and carotenoid- chlorophyll ratio were significant among the treatments only in intercropped condition. T_3 recorded the highest values for both parameters.
- The vase life was the highest for inflorescences in T_3 in experiment I and II (12.94days and 10.50 days respectively).
- In both the experiments, T_3 produced the highest number of marketable flowers and suckers. Among the treatments T_5 recorded the highest Land Equivalent Ratio (1.49) followed by T_3 (1.43), T_2 and T_4 (1.4), and T_1 (1.39).
- The highest BCR was recorded in T_3 under open (2.5) as well as intercropped (3.9) condition followed by T_5 in Exp. I and II (3.3 and 1.9 respectively)
- The nutrient balance sheet for nitrogen was found to have a minimal balance in all the treatments except T_3 under both the cropping situations.
- The nutrient balance sheet for phosphorus was low in T_2 and T_4 under the two experiments. The balance was more in monocropped condition.
- In general, the nutrient balance for potassium was more in monocropped condition. In the intercropped area, the balance was the highest in T_1 followed by T_3.
- Growing Heliconia as an intercrop had a positive impact on coconut yield and yield parameters during the two seasons of growth period June and December (2010-2011). The leaf nutrient content of coconut was found to increase gradually during the period of observations.

FUTURE LINE OF WORK

Further investigations may be conducted to study the effect of different shade levels in growth and flowering of *Heliconia stricta* cv. Iris Red for suggesting it as a potential intercrop in coconut garden of specific age group. The effect of nitrogen and N: P ratio on growth and performance is to be studied. The effect of de-shooting or thinning and its interval should be standardized for enhancing the number of quality inflorescence from unit area.

References

7. REFERENCES

Allen, R.N., Dettmann, E.B., Johns, G.G., and Turner, D.W. 1988. Estimation of leaf emergence rates of bananas. *Aust. J. Agric. Res.* 39:53–62.

Ancy, J. and Jayachandran, B.K.1998. Nutrient uptake and yield in ginger (*Zingiber officinale* Rosc.) under shade. In: Mathew, N.M. and Jacob, K. (eds.) *Developments in Plantation Crops Research*. Allied Publishers Ltd., New Delhi, pp.236-238.

Arunachalam, V. and Reddy, D.V.S. 2007. Foliar traits of jasmine plants intercropped in coconut. *Agroforest. Syst.* 71:19-23.

Achard, H.,Cheng, L., Grauwe, D., Decat, J., Schoutteten, H., and Motirz, T. 2006. Integration of plant response to environmentally activated phyto-hormonal signals. *Science* 311: 91-94.

Ball, D. 1986. Rhizome propagation of Heliconia cv. Golden Torch and *Heliconia psittacorum* cv. Andromeda. *Bul. Heliconia Soc. Intl.* 1:6–7.

Ballah,S.T. and Starr,C.K. 2010. Composition and activity of ant visitors to inflorescences of *Heliconia hirsuta* (Heliconiaceae). *Sociobiology* 6(3) : 585-599.

Baruah,T.C. and Barthakur,H.P.1998. *A textbook of soil analysis*. Vikas Publishing House Pvt. Ltd. 334p.

Berry,F. and Kress, W. J. 1991. *Heliconia - An Identification Guide*. Smithsonian Institution Press, Washington.103p.

Braconie,S., Cipungahelo, G., Margarate, R.Z., and Klieh, U. 1998. Coconut based farming systems-operational and economic analysis models. *Plant Tech. Dev.* 5(5): 248-259.

Bredmose, N. 1987. Post harvest ability of some new cut flowers. *Acta Hort.* 205: 187-194.

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

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

Broschat, T. K., Donselman. H.M., and Will, A.A., 1984a. 'Andromeda' and 'Golden Torch' Heliconias. *Hort. Science* 19(5): 736-737.

Broschat,T.K., Donselman, H.M., and Will, A.A.1984b. *Golden Torch, an orange heliconia for cut flower use.* Circular 2-308, Agric. Experiment Stat., Univ.Florida, Gainesville. 4p.

Broschat, T.K. and Donselman, H.M. 1987. Tropical cut flower research at the University of Florida's Ft. Lauderdale Research & Education Center. *Bul. Heliconia Soc. Intl.* 2:5–6.

Broschat, T.K. and Donselman, H.M. 1988. Production and post harvest culture of red ginger in South Florida. *Proc.Fla. State Hort. Soc.* 101:326-327.

Broschat, T.K. and Svenson,S.E. 1994. DCPTA enhances growth and flowering of Heliconias. *Hort Science* 29(8): 891–892.

Bruna, E.M., Nardy,O., Strauss,S.Y.,and Harrison,S. 2002.Experimental assessment of *Heliconia acuminata* growth in a fragmented Amazonian landscape. *J. Ecol.* 90: 639–649.

Bruna, E.M. and Kress, W.J. 2002. Habitat fragmentation and the demographic structure of an Amazonian understory herb (*Heliconia acuminata*). *Conservation Biology* 16(5) : 1256-1266.

Cabral, A. and Benedetto, D. 2010. Preliminary studies on the production of cut flower Heliconias in the Colorado. *Hort. Argentina*. 29 (69): 33-40.

Castro C.E.F., May, A., and Gonçalves, C. 2007. Nomenclature review of species of genus Heliconia (Heliconiaceae). *Rev. Bras. Hortic. Ornam.* 13: 38-62.

Castro, A.C.R., Aragao, F.A.S., Loges, V., Costa, A.S., Willadino, L.G., and Castro, M.F.A. 2011. Macronutrient contents in two development phases of *Heliconia psittacorum* × *H. spathocircinata* 'Golden Torch'. *Acta Hort.* 886: 285-288.

Catley, J. and Brooking, I. 1996. Temperature and light influence growth and flower production in Heliconia Golden Torch. *Hort. Science* 31:213-217.

Cain,D.C. and Markley,J.L.1989. More managanese accumulates in maple sun leaves than in shade leaves. *Pl. Physiol.* 90: 1417-1421.

Clemens, J. and Morton, R.H. 1999. Optimizing mineral nutrition for flower production in Heliconia 'golden torch' using response surface methodology. *J. Amer. Soc. Hort. Sci.* 124(6): 713–718.

Costa, A.S., Loges, V., Castro, A.C.R., Nogueira, L.C., Guimaraes, W.N.R. and Batista, F.P.S. 2006 a. Morphological and timing parameters for harvesting Heliconia inflorescences. In: Mercuri, A. and Schiva,T.(eds.), *Proceedings of XXII EUCARPIA Symposium,*11-15 September, 2006, Sanremo, Italy, pp. 21.

Costa, A.S., Loges, V., Castro, A.C.R., Nogueira, L.C., Guimaraes, W.N.R. and Bezerra, G.J.S.M. 2006b. Number of shoots and blooming of Heliconia cultivated under partial shade. In: Mercuri, A. and Schiva,T. (eds.), *Proceedings of XXII EUCARPIA Symposium,*11-15 September, 2006, Sanremo, Italy, pp. 20.

Costa, D., Loges, A.S., de Castro, V., Verona, A.C.R., de O Pessoa, A.L., and Dos Santos, V.F. 2006c. Number of shoots and area per clump of Heliconia. *Hort. Bras.* 24(4): 460-463.

Costa, A.S., Loges, V., Castro, A.C.R., Guimaraes, W.N.R.and Nogueira, L.C.2007. Heliconia genotypes under partial shade: II. Evaluation of flowering stems. In: Dragovic, M.J.O.(ed.), *Proceedings of Sixth International Symposium on New Floricultural Crops*, 11-15 June 2007, Madeira,pp. 150.

Costa, A.S., Loges, V., Castro, A.C.R., Guimaraes, W.N.R., and Nogueira, L.C.2009a. Heliconia genotypes under partial shade: I. Shooting and blooming. *Acta Hort.* 813: 609-614.

Costa, A.S., Loges, V., Castro, A.C.R., Guimaraes, W.N.R., and Nogueira, L.C.2009 b. Heliconia genotypes under partial shade II. Evaluation of flowering stems. *Acta Hort.* 813: 171-176.

CPCRI[Central Plantation Crops Research Institute], 2003.*Annual Report 2002-03.*Central Plantation Crops Research Institute, Kasaragod, India.38p.

Criley, R.A. 1985. *Heliconia - Handbook of flowering.* CRC Press, Inc. Boca Raton, Florida. pp. 125-128.

Criley, R.A. 1989. Development of Heliconia and Alpinia in Hawaii: Cultivar selection and culture. *Acta Hort.* 246:247–258.

Criley, R.A. 1990. Production of Heliconias as cut flowers and their potential as new potted plants. *Hort.Digest* 92:1–7.

Criley, R.A. 1995. Culture profile of *Heliconia psittacorum. Bul. Heliconia Soc. Intl.* 8 :9-11.

Criley, R.A. 1996. Techniques of cultivation in the ornamental Zingiberaceae. *Bul. Heliconia Soc.Intl*. 8:7-11.

Criley,R.A. 1999. Seasonal flowering patterns for Heliconia shown by grower records.In Maloupa,E.(ed.), *Proceedings of the Fourth International Symposium on New Floricultural Crops;* 22-27 May 1999; Chania,Crete, Greece.pp.372

Criley, R.A. and Broschat, T.K. 1992. Heliconia: Botany and horticulture of a new floral crop. *Hort. Rev.* 14:1–55.

Criley, R.A. and Kawabata,O. 1986. Evidence for a short-day flowering response in *Heliconia stricta* 'Dwarf Jamaican'. *Hort Science* 21(3): 506-507.

Criley, R. A. and Lekawatana, S.1991. Managing seasonality in Heliconia. *Res.Ext. Ser.* 124:167-172.

Criley, R A. and Lekawatana,S. 1995. Year around production with high yields may be a possibility for *Heliconia charatacea. Acta Hort.* 397 :85-102.

Criley, R.A. and Paull, R.E. 1993. Review: Post harvest handling of bold tropical cut flowers Anthurium, *Alpinia purpurata*, Heliconia, and Strelitzia. *Acta Hort.* 337:201-21.

Cunningham, S.A., Summerhayes, B.A., and Westoby, M.1999. Evolutionary divergences in leaf structure and chemistry, comparing rainfall and soil nutrient gradients. *Ecol Monogr.* 69: 569–588.

Dai, Y., Shen,Z., Liu,Y., Wang, L., Hannaway, D., and Lu, H. 2009. Effects of shade treatments on the photosynthetic capacity, chlorophyll fluorescence and chlorophyll content of *Tetrastigma hemsleyanum. Environ. Exp. Bot.* 65: 177-182.

Donselman, H. and .Broschat, T.K 1986. Production of *Heliconia psittacorum* for cut flowers in South Florida. *Bul.Heliconia Soc .Int.* 1(4): 4-6.

Dobkin,D.S. 1984.Flowering patterns of long-lived Heliconia inflorescences: Implications for visiting and resident nectarivores. *Oecologia*. 64 (2): 245-254.

Enriquez, S., Duarte, C.M., Sand-Jensen, K.,and Nielsen, S.L. 1996. Broad-scale comparison of photosynthetic rates across phototropic organisms. *Oecologia* 108: 197–206.

Ferreira, D.B. and Pires, L. 2005.Effect of NPK fertilization on the initial productivity of inflorescences *Heliconia* sp. *Electronic Proceedings of the II Seminar of Research and Graduate Studies*[CD-ROM].Available:http:// www.conference.ifas.ufl.edu/gardener10/Proceedings07.pdf. [21 Sep.2011].

Fontaine, S., Mariotti, A., and Abbadie, L.2003.The priming effect of organic matter: question of microbial competition? *Soil Biol. and Biochem.*35: 837-843.

Fonseca, C. R., Overton, J.M., Collins, B., and Westoby, M. 2000. Shifts in trait-combinations along rainfall and phosphorous gradients. *J Ecol.* 88: 964–977.

Geertsen, V. 1989. Effect of photoperiod and temperature on the growth and flower production of *Heliconia psittacorum* 'Tay'. *Acta Hort.* 252: 117-122.

Geertsen,V. 1990. Influence of photoperiod and temperature on the growth and flowering of *Heliconia aurantiaca*. *Hortscience* 25(6): 646-648.

George, V. T., Krishnakumar,V., Maheswarappa, H.P., and Palaniswami,C. 2010. *Coconut based cropping/ farming systems.* Central Plantation crops Research Institute, Kasaragod, India Codeword Process and Printers, Mangalore, 231 p.

Gibson, J.L., Bolles, B., Dunning, S., Friday, T., Mullins, D., Stevenson, C., and Willaims, L. 2010. Nutrient deficiencies in production of annual floral crops. IFAS Extension, University of of Florida. Available :http://edis.ifas.ufl.edu/ep325 [30 Oct.2012].

Goltsev, V., Zaharieva, I., Lambrev, P., Yordanov, I., and Strasser, R. 2003. Simultaneous analysis of prompt and delayed chlorophyll a fluorescence in leaves during the induction period of dark to light adaptation. *J. Theoretical* Biol., 225: 171-183.

Grubb, P.1998. A reassessment of the strategies of plants which cope with shortages of resources. *Plant Ecol. Evol.* 1: 3–31.

Hanlon, E.A.2012. Soil pH and electrical conductivity: A county extension soil laboratory manual[online].Available: http://edis.ifas.ufl.edu/pdffiles/SS/ SS11800. pdf .[29 Sep.2012].

He, J., Chee, C.W., and Goh, C.J. 1996 'Photoinhibition' of Heliconia under natural tropical conditions: the importance of leaf orientation for light interception and leaf temperature. *Plant, Cell and Env.* 19(11): 1238-1248.

He, J., Tan, L.P., and Goh, C.J .2003. Alleviation of photoinhibition in Heliconia grown under tropical natural conditions after release from nutrient stress. *J. Plant Nutr.* 23(2): 181-196.

Higaki, T., Lichty, J.S., and Moniz,D.1995. *Anthurium culture in Hawai.* Researchextensionseries.18p.Available: http://www.ctahr.hawaii.edu/oc/ freepubs/ pdf/RES-152.pdf.[10 Nov.2012].

HSPR Newsletter.2003. Heliconia Society of Puerto Rico, Inc., No. 1[on line]. Available: http://heliconia society.org [17 Sep. 2012].

Jackson,M.L.1973. *Soil Chemical Analysis*.(2nd Ed.).Prentice Hall of India (Pvt.Ltd.), New Delhi,498p.

Janakiram,T. 2009. Speciality Flowers: Prospects for Tropical Humid Condition of Andaman Islands. In: Singh,D.R.(ed.), *Proceedings of the National workshop cum seminar on status and future strategies of Horticulture Development in A & N Islands*;23-25, January, 2009;Port Blair. Central Agricultural Research Institute, Andaman and Nicobar Islands, ICAR, pp.36-44.

Jaroenkit,T. and Paull, E.R. 2003. Post harvest handling of heliconia, redginger and bird of paradise. *Hort. Technol.* 13(2): 259-266.

Jason, J.G., Thomas G.R., and Pharr, D.M., 2004. Photosynthesis, chlorophyll florescence, and carbohydrate content of illicium taxa grown under varied irradiance. J. *Am. Soc. Hort. Sci.* 129: 46-53.

Jerez, E.2007. The Culture of Heliconias. *Trop. Crops*. 28(1): 29-35.

Ken, O.C. 2007. Heliconia Basics.Green Culture Singapore[on line]. Available: <http:// www. greenculturesg. com/ articles/ mar 07_heliconia.htm. [Dec.3.2009].

Khan.H.H.2003. Integrated nutrient management in coconut based cropping/farming system. In: Rajagopal,V(ed.) *Integrated Nutrient Management in Plantation crops and plantation based cropping systems*. Proceedings of a national seminar, Kasaragod,India .Central Plantation crops Research Institute, India, pp. 1-28.

Khuankaew, T., Ruamrungsri, S., Ito, S., Sato, T., Ohtake, N., Sueyoshi, K., and Ohyama, T. 2010. Assimilation and translocation of nitrogen and carbon in *Curcuma alismatifolia* Gagnep. *Plant Biol.*12(30): 414-23.

Kress, W.J. 1990. The diversity and distribution of Heliconia (Heliconiaceae) in Brazil. *Acta Botanica Brasilica* 4: 159-167.

Kress,W.J., Prince,L.M., and Williams,K.J. 2002. The phylogeny and a new classification of the gingers (Zingiberaceae): Evidence from molecular data. *Am. J. of Bot.* 89(11): 1682-1696.

Kwon, E. 1992. Flowering of *Heliconia angusta*. PhD(Hort.).The University of Hawaii, Honolulu, 209p.

Loges, V., Costa A.S., Castro, A.C.R., Nogueira, L.C., Guimaraes, W.N.R., Motta, R.M., and Castro, M.F.A.2006. Inflorescence morphological characters of Heliconia genotypes in Brazil[abstract]. In: *Abstracts, XXII EUCARPIA Symposium (Section Ornamentals) "Breeding For Beauty";* 11-15, September, 2006, Sanremo, Italy,p.25. Abstract No.23

Loges. V., Costa A.S., Guimaraes, W.N.R., Castro. A.C.R., Castro. M.F.A., Nogueira. L.C., and Leite, K.P.2011. Heliconia: Rhizome propagation, shooting and clump area. *Acta Hort.* 886: 277-288.

Lindsay, W. L. and Norvell, W. A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.* 42 (3): 421-428.

Manarangi, A., Sakai, W.S., Gerken, C., Crowell, M., Nielson, G., and Short, R. 1988. Growth and flowering of *Heliconia psittacorum* cv. Parrot in Hawaii. *J. Hawaii Pacific Agr.* 1: 1–3.

Mapa, R.B.1995.Effects of intercropping coconut lands on soil water retention. *Biol. Agri. Hort.* 12(2): 173-183.

Mathew, C.H., Vijaya Kumar,K., Nambiar, P.T.N., and Amaranath, C.H. 1991.Forecasting of annual yield of coconuts based on biometrical characters. *Cocon. Res. Dev.* 7(1): 24–34.

Mead, R. and Willey, W.R. 1980. The concept of land equivalent ratio and advantages in yields from intercropping. *Exp. Agric.* 16: 217-228.

Mediavilla, S., Escudero, A., and Heilmeier, H. 2001. Internal leaf anatomy and photosynthetic resource-use efficiency: interspecific and intraspecific comparisons. *Tree Physiol.* 21: 251–252.

Middleton, I. 2001. Shade tolerant flowering plants: Adaptations and horticultural implications. *Acta Hort.* 552: 95-102.

Moles, A.T., Warton, D.I., Warman, L., Swenson, N.G., Laffan, S.W., Zanne, A. E., Pitman, A., Hemmings, F. A., and Leishman, M. R. 2009. Global patterns in plant height. *J. Ecol.* 97(5): 923-932

Nobel, P. S. and Linton, M. J. 1997. Frequencies, microclimate and root properties for three codominant perennials in the northwestern sonoran desert on north- vs. south-facing slopes. *Ann Bot.* 80:731–739.

Osmond, C.B.1994. What is photoinhibition? Some insights from comparison of shade and sun plants. In: Baker, N.R. and Bowyer, J.R. (eds.),*Photoinhibition of photosynthesis: From molecular mechanisms to the field*. BIOS Scientific Publishers, Lancaster, pp. 1-24.

Panse, V. J. and Sukhatme, P. V.1985. *Statistical Methods for Agricultural Workers* (4th Ed.). Indian Council of Agricultural Research, New Delhi, 347p.

Perez, J.C. 2012. Shade level affects microenvironment, plant growth and plant function in bell pepper (*Capsicum annum*).*ASHS Mobile Abstracts* [on line].Available: http: //ashs.org/abstracts/ m/ abstracts12/ abstract_id_11517.html. [27 Nov.2012].

Poorter, H. 1990. *Interspecific variation in relative growth rate: on ecological causes and physiological consequences.* SPB Academic Publishing, Germany 168p.

Powell, J. 1991.*Ornamental Flower Research*:1989-90, Tech.Bull. No. 170, Berrimah Agriculture Research Centre, Darwin, Australia.15p.

Powell, J. and Nielsen, D.1991. *Technical Annual Report - Horticulture Branch.* Department of Primary Industry and Fisheries, Berrimah Agriculture Research Centre, Darwin, Australia, 182p.

Ramachandrudu, K. and Thangam,M. 2012. Performance of Heliconia under coconut garden and open field conditions. *Indian J.Hort.* 69(3):450-453.

Reddy, D. V. S. and Biddappa, C.C. 2000. Coconut based cropping/farming systems in India. *J. Plantn Crops* 28:1-18.

Reich, P.B., Walters, M.B., and Ellsworth, D.S. 1997. From tropics to tundra: Global convergence in plant functioning. *Proc. Natl Acad. Sci.*94: 13730–13734.

Robinson, S.A., Lovelock, C.E., and Osmond, C.B. 1993. Wax as a mechanism for protection against photoinhibition-A study of *Cotyledon orbiculata. Botanica Acta.* 106: 307-31.

Rocha, F.H.A., Loges, V., Costa, A. S., Aragao, F.A.S., and Santos, V. F. 2010. Genetic study with *Heliconia psittacorum* and interspecific hybrids. *Crop Breed. Appl. Biotech.*10: 282-288.

Rodrigues, P.H.V.2008. Somaclonal variation in micropropagated *Heliconia bihai* cv. Lobster claw plantlets (Heliconiaceae). *Sci. Agric.* 65(6): 681-684.

Rundel, P.W., Sharifi, M.R., Gibson, A.C., and Esler, K.J. 1998. Structural and physiological adaptation to light environments in neotropical Heliconia (Heliconiaceae). *J. Trop. Ecol.* 14: 789-80.

Saini, R.S., Sharma, K.D., Dhankhar, O.P., and Kaushik, R.A. 2001. *Laboratory Manual of Analytical Techniques in Horticulture.* Agrobios, India, 130p.

Saifuddin, M., Hossain, A.M.B.S., and Normaniza, O. 2010. Impacts of shading on flower formation and longevity, leaf chlorophyll and growth of *Bougainvillea glabra. Asian J. Pl. Sci.* 9: 20-27.

Sakai, W. S., Manarangi, A., Short, R., Nielson, G., and Crowell, M.D. 1990. Evidence for long-day flower initiation in *Heliconia angusta* cv. Holiday-Relationship between time of shoot emergence and flowering. *Bull. Heliconia Soc. Int.* 4(4):1-3.

Sawyer, J.E. 2003. Soil calcium: magnesium ratios. *ICM News* 490(5): 40-42.

Sheela, V.L.2008.*Flowers for trade.* In: Peter ,K.V. (ed.), New India Publishing Agency, New Delhi, pp 193-210.

Sherrod, L.A., Peterson, G.A., Westfall, D.G., and Ahuja, L.R.2003. Cropping intensity enhances soil organic carbon and nitrogen in a no-till agroecosysytem. *Soil Sci.Soc.Am.J. Abstr.* 67(5): 1533-1543.

Simao, D.G. and Scatena, V.L. 2001 Morphology and anatomy in *Heliconia angusta* Vell. and *H. velloziana* L. Emygd. (Zingiberales: Heliconiaceae) from the Atlantic forest of southeastern Brazil. *Rev. Bras. Bot.* 24(4): 55-65.

Sinclair, T. R. and Horie, T. 1989. Leaf nitrogen, photosynthesis, and crop radiation use efficiency: A review. *Crop Sci.* 29(1): 90-98.

Skillman, J.B., Garcia, M., and Winter, K. 1999. Whole-plant consequences of crassulacean acid metabolism for a tropical forest understory plant. *Ecology 80: 1584–1593.*

Stiles, F.G.1975. Ecology, flowering phenology, and hummingbird pollination of some Costa Rican Heliconia species. *Ecology* 56: 285-301.

Subramanian, P., Dhanapal, R., Palaniswami, C., Maheswarappa, H.P., Alka, G., and George, V. T. 2009. *Coastal sandy soil management for higher coconut productivity.* Tech. Bull. No.50. Central Plantation Crops Research Institute, Kasaragod, India.20p.

Sudha, M. and Subramanyam.1992.Flower based mixed cropping system in coconut gardens-An economic analysis. *Ind. Cocon. J.* 23(1): 2-4.

Syvertsen, J. P., Lloyd, J., Conchie, M. C., Kriedemann, P.E., and Farquhar, G.D. 1995. On the relationship between leaf anatomy and CO_2 diffusion through the mesophyll of hypostomatous leaves. *Pl. Cell Env. 18*: 149-157.

Tija, B.1988. Postharvest studies of the red plume ginger (*Alpinia purpurata*). *Bul. Heliconia Soc. Intl.* 3 (3): 7-8.

Tija, B. and Sheehan, T.J. 1984. Preserving profits and beauty. *Greenhouse Manager* 2(11): 95-100.

Tran, H., Vu, H., Manunu, A., and Chien, D.1995. Chlorophyll formation in flowers and fruits of *Phalaenopsis* (Orchidaceae) species and hybrids following pollination. *Am. J. Bot.* 82(90): 1089-1094.

Turner, D.W. 1998. Ecophysiology of bananas: The generation and functioning of the leaf canopy. *Acta Hort.* 490: 211-222.

Uchida, R. 2000.Recommended plant tissue nutrient levels from some vegetable, fruit and ornamental foliage and flowering plants in Hawaii. In: Silva,J.A. and Uchida,R.S. (eds.). *Plant nutrient management in Hawaii's soils, approaches for tropical and subtropical agriculture*, College of tropical agriculture and Human Resources, University of Hawaii, Manoa. : Available:http://scholarspace.manoa.hawaii.edu/bitstream/handle/10125/1908/pnm0.pdf?sequence=1[25 Aug.2011]

Vile, D., Garnier, E., Shipley, B., Laurent, G., Navas, M. L., Roumet, C., Lavorel, S., Diaz, S., Hodgson, J. G., Lloret, F., Midgley, G. F., Poorter, H., Rutherford, M. C., Wilson, P.J., and Wright, I. J.2005. Specific leaf area and dry matter content estimate thickness in laminar leaves. *Ann. Bot.* 96: 1129-1136.

Walkley, A. 1947. A critical examination of a rapid method for determining organic carbon in soil: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Sci.*63: 251-263.

Wang, Y.T. 2007. Potassium affects *Phalaenopsis* growth and flowering. *Hort. Sci.* 42(7): 1563-1567.

White, J.W. and Montes, R.C. 2005. Variation in parameters related to leaf thickness in common bean (*Phaseolus vulgaris* L.).*Field Crop Res.*, 91: 7–21.

Wurr, D.C.E., Jane, R.F., and Lynn, A. 2000. The effects of temperature and daylength on flower initiation and development in *Dianthus allwoodii* and *Dianthus alpinus*. *Sci. Hortic.*, 86: 57-70.

Yen, C.B.S. 2008. Effects of nutrient supply and cooling on growth, flower bud differentiation and propagation of Nobile Dendrobium Orchid. MSc (Hort.) thesis, National Taiwan University, Taiwan.96p.

Yoshimura,K. 2010.Irradiance heterogeneity within crown affects photosynthetic capacity and nitrogen distribution of leaves in *Cedrela sinensis* .*Pl. Cell Environ.*33(5):750-758.

Zhang,F. and Li,L. 2003, Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency, *Pl. Soil.* 248: 305–312.

Zhang,D., Moran,R.E., and Stack,l.B.2004.Effect of phosphorous fertilization on growth and flowering of *Scaevola aemula* R.Br.'New Wonder'. *Hort Science* 39(7): 1728-1731.

Appendices

Appendix I

Weather data during the study period(June 2010 to May 2012)

Month/Year	Temperature		Relative humidity		Wind speed (km/hr)	Sunshine (hrs/day)	Evaporation (mm/day)	No. of rainy days
	(max)	(min)	(am)	(pm)				
June.2010	33.5	23.9	93	75	1.3	4.2	2.1	20
Jul.10	30.7	22.3	95	76	1.1	4.4	2.4	25
Aug.10	29.7	23.7	95	76	1.5	4	2.6	12
Sep.10	31.0	23.9	95	71	1.2	5.1	2.7	9
Oct.10	30.9	23.6	95	73	1.2	5.8	2.6	21
Nov.10	30.6	23.5	96	73	0.6	4.3	2.4	16
Dec.10	31.3	22.9	95	65	0.6	6	2.7	3
Jan.2011	32.6	21.2	94	57	1.1	7.2	3.9	1
Feb.11	33.0	21.1	94	54	1.4	8.3	4.1	4
Mar.11	33.7	23	95	53	1.5	9.2	4.5	1
Apr.11	33.6	24.2	95	60	1.4	7.7	3.9	11
May.11	33.2	24.5	95	64	1.6	6.9	2.5	10
June.11	31.8	24.5	95	71	1.7	5.3	2.1	17
Jul.11	30.8	23.5	95	74	1.2	3.8	2.4	22
Aug.11	30.6	23.3	95	72	1.5	3.8	2.6	18
Sep.11	31.0	23.3	95	71	1.2	6.3	2.7	11
Oct.11	32.5	23.4	95	63	1.2	7	2.6	10
Nov.11	32.3	22.4	95	61	1	6.8	2.4	7
Dec.11	32.7	21.7	95	55	0.9	6.9	2.7	4
Jan.2012	33.1	19.8	95	50	1	9.4	3.4	1
Feb.12	34.3	21.6	95	52	1.2	9	3.5	1
Mar.12	34.0	23.4	96	58	1.6	8	3.6	5
Apr.12	34.1	23.9	95	62	1.3	6.7	3.5	11
May.12	34.4	24.9	95	61	1.5	6.6	3.4	3

Appendix II

Nutrient supplied to each treatment through manures and fertilizers

Treatments	Nitrogen (g/plant)	Phosphorus(g/plant)	Pottasium (g/plant)
Basal dose (cowdung +bonemeal)	18.75	57.5	10
T_1 : 17:17:17	0.85	0.85	0.85
T_2 :13:05:13	0.65	0.25	0.65
T_3:VC*+NC**	3.3	1.3	2.4
T_4:VC*+NC**+BF	1.65	0.65	1.2
T_5:VC*+NC**+CF	1.98	0.78	1.53

*VC: Vermicompost – 1.84:0.22:0.28%NPK

**NC: Neemcake- 1.5:1.0:1.4%NPK

Appendix III

Pre-experimental data on soil nutrient status

a) **Experiment 1:** Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Treatment	pH	EC	Org.C	P	K	Ca	Mg	Mn	Fe	Cu	Zn
		(dSm^{-1})	(%)	(ppm)							
T_1	5.89	0.01	0.151	22.05	54.38	212.47	24.5	1.197	13.79	1.465	2.38
T_2	5.8	0.01	0.148	25.25	56.25	216.53	24.5	1.085	13.09	1.471	2.39
T_3	5.54	0.01	0.194	23.83	54.5	218.6	25.4	1.150	13.77	1.383	2.04
T_4	5.59	0.01	0.120	23.25	53.75	216.17	23.8	1.118	13.36	1.337	2.21
T_5	5.71	0.01	0.143	24.00	54.2	217.00	24.8	1.046	13.04	1.302	2.13

b) **Experiment 2:** Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

Treatment	pH	EC	Org.C	P	K	Ca	Mg	Mn	Fe	Cu	Zn
		(dSm^{-1})	(%)	(ppm)							
T_1	6.7	.01	0.191	12.75	67.88	326.8	20.6	1.09	7.22	0.929	1.96
T_2	6.67	.01	0.169	12.25	67.67	336.9	22.8	1.13	7.08	0.898	1.66
T_3	6.33	.01	0.168	12.63	72.5	334.1	22.5	1.24	7.29	0.845	1.89
T_4	6.48	.01	0.187	12.13	68.75	338.5	23.0	1.19	7.39	0.858	1.75
T_5	6.48	.01	0.123	12.5	70.75	324.5	20.8	1.07	6.93	0.9	1.65

Appendix IV

Root-shoot ratio

Treatment	Experiment 1	Experiment 2
T_1 : 17:17:17 NPK	0.77	0.93
T_2 :13:05:13 NPK	1.35	1.57
T_3 :VC+NC	0.79	1.08
T_4 :VC+NC+BF	1.08	1.45
T_5 :VC+NC+CF	0.99	0.86

Experiment 1: Standardisation of nutrient management for *Heliconia stricta* grown as an intercrop in coconut garden

Experiment 2: Standardisation of nutrient management for *Heliconia stricta* grown as a monocrop

NUTRIENT MANAGEMENT PRACTICES FOR HELICONIA UNDER OPEN CONDITION AND AS INTERCROP IN COCONUT GARDEN

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ABSTRACT OF THE THESIS

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ABSTRACT

Heliconias (*Heliconia* spp.) are attractive tropical plants grown for their beautiful, brilliant, long lasting colorful inflorescences. Among the Heliconias, *Heliconia stricta* cv. Iris Red is a commercial variety with high market value due to its unique crimson coloured bracts with a definite shape. They grow well in soils rich in organic matter with full sunlight to 40% shade, but little is known about its nutrient management practices when grown under monocropped or intercropped conditions especially in low fertile soils with less water holding capacity. Hence two experiments on *Heliconia stricta* cv. Iris Red as intercrop in coconut garden (Experiment I) and as monocrop in open condition (Experiment II) were laid out in RBD for a period of two years during 2010- 2012 with five treatments and four replications in Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State. The present investigation was to standardize a manurial schedule for enhancing production and quality of Heliconia flowers when grown under same nutrient management practice in two cropping systems. This also aimed at comparing the quality and vase life of flowers grown under different conditions and thereby standardizing an integrated nutrient recommendation suitable for each system of cropping.

In both the experiments growth parameters such as plant height, number of suckers and number of leaves were significantly higher in treatment supplied with 5 g NPK @ 13:5:13kg/ha (T_2) which was on par with the treatment supplied with Vermicompost (VC) @ 200g/plant +Neemcake (NC) @ 100g/plant (T_3). The values were higher for plants grown under coconut canopy than in open condition.

The physiological characters like leaf area, LAI, specific leaf area, leaf area duration and leaf area density were also higher in T_3 and T_2 under both the systems of cropping. All the parameters except leaf area density were higher in plants under intercropped condition.

In experiment I and II, treatment T_3 took the lowest number of days for first flowering (172.8 and 280.3 respectively) whereas T_2 took the longest time to start flowering (295 and 362.5 days respectively). There was no significant difference among the treatments in time taken for fifty percent flowering under intercropped condition, whereas in open condition, T_2 plants took

the longest (459.8 days) and T_3 plants the shortest (370.0days) duration .to attain fifty percent flowering. The stages from fully emerged or just opened (Stage II) to complete unfurling of bracts (Stage III) and the life of fully opened flower in plant (Stage III to IV) was more in intercropped condition (23.3 to 38.5 days) than in monocropped condition (17.05 days to 27.3 days).In both the experiments, T_3 recorded the highest longivity followed by T_2.

The inflorescence characters such as length, number of bracts, stem length and stem diameter were more under intercropped condition. Superior quality flowers were produced in T_3 under both the systems of planting. In intercropped condition T_2 and T_5 (VC @ 100g/plant +NC @ 50g/plant + 2.5 g NPK @ 13:5:13kg/ha) plants also produced such flowers. The fresh weight of fully opened inflorescence was significantly higher in T_3 and T_5 under both the systems of planting. In the visual appeal test, the total score for the inflorescences produced in the intercropped area was higher and T_3 scored the highest value under both the experiments. T_3 plants recorded the highest wax, caroteniod content, carotenoid- chlorophyll ratio and vase life(12.9 days and 10.5 days respectively) in experiment I and II.

The highest leaf chlorophyll and wax content was recorded in T_3 plants under both the systems of planting. The leaf nutrient content such as N, P, K, Ca, Mg, Fe, Mn and Zn was the highest in T_3 plants under both systems of cropping condition.

The plant uptake of N and P was the highest in T_2 plots of the intercropped area, whereas, T_4 recorded the highest uptake in open condition. T_2 recorded the highest K uptake in both the experiments. The lowest N and K uptake was in T_3 plots.

The treatment supplied with VC and NC (T_3) recorded significantly higher P, Ca, Mg and Fe content of soil in both the systems of planting. In both the experiments, T_2 recorded significantly higher K values (20.6ppm and 20.0ppm respectively).

In both the experiments, T_3 produced the highest number of marketable flowers and suckers. Among the treatments T_5 recorded the highest land equivalent ratio (1.49) followed by T_3 (1.43), T_2 and T_4 (1.4) and T_1 (1.39).

The nutrient balance sheet for N, P and K was higher in T_3 under both the cropping situations. In general, the nutrient balance for P and K was more in monocropped condition.

Growing Heliconia as an intercrop had a positive impact on coconut yield and yield parameters during the two seasons of growth period June and December (2010-2011). The leaf nutrient content of coconut was found to increase gradually during the period of observations.

The present study revealed that *Heliconia stricta* cv. Iris Red is a potential intercrop in coconut gardens. The plants had a superior vegetative growth and inflorescence production in sandy soils with low nutrient and water holding capacity by supplying cowdung @ 1kg/plant + bonemeal @250 g/plant basally and topdressing equal doses of Vermicompost (VC) @ 200g/plant +Neemcake (NC) @ 100g/plant (T_3) at quarterly intervals from three months after planting under both the conditions of cropping system. This was followed by the treatment supplying cowdung @ 1kg/plant + bonemeal @250 g/plant basally and topdressing same doses of VC @ 100g/plant +NC @ 50g/plant + 13:5:13NPK@2.5 g/plant (T_5).