REGULATION OF GROWTH AND FLOWERING IN *HELICONIA spp.*

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"REGULATION OF GROWTH AND FLOWERING IN *HELICONIA spp.*"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Padannakkad
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CERTIFICATE

Certified that this thesis entitled **"REGULATION OF GROWTH AND FLOWERING IN *HELICONIA spp.*"** is a record of research work done independently by Ms. Kokila. K. R under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	-	Per cent
^{0}C	-	Degree Celsius
CD	-	Critical difference
cm	-	Centimetre
DAP	-	Days after planting
et al	-	And others
Fig.	-	Figure
FYM	-	Farmyard manure
g	-	Gram
HI	-	Harvest Index
kg	-	Kilogram
LAI	-	Leaf Area Index
l	-	Litre
m	-	Metre
m^2	-	Square metre
m^3	-	Cubic metre
ml	-	Millilitre
NS	-	Not significant
RARS	-	Regional Agricultural Research Station
SE	-	Standard error
Rs.	-	Rupees
SPAD	-	Soil Plant Analysis Development
SCMR	-	SPAD Chlorophyll Meter Reading
CCC	-	Chlormequat Chloride
8 HQC	-	8 Hydroxyquinoline Citrate

INTRODUCTION

1. INTRODUCTION

Floriculture is gaining the status of an important agri-business enterprise in Kerala as the climatic conditions favor the production of certain tropical flowers and ornamental plants of excellent quality. Floriculture could be made into a successful component even in smaller land holdings which would deliver rapid returns on the invested capital. In this context, Heliconia appears to be an ideal crop for commercial cultivation in Kerala.

Heliconias stand out as cut flowers, due to their exotic beauty with diversity of colors and shapes of inflorescence, easiness in cultivation, ease of handling, transport, pronged postharvest life, tolerance to biotic and abiotic stresses and reasonable prices (Albuquerque *et al.*, 2014). Commercial cultivation of Heliconia is getting popular in the states of Andhra Pradesh, Karnataka, Kerala and some parts of Tamil Nadu. India has an annual production of about 1 lakh flower stems which accounts for less than 1% of the total production of cut flowers in the country (Sheela, 2008). About 50% of the production comes from coconut farm located in the west Godavari district in Andhra Pradesh (Abraham, 2013).

In Kerala, Heliconias are becoming increasingly popular among flower growers mainly due to easiness in cultivation, availability of nearby markets and its suitability as an intercrop in coconut gardens. Heliconia is a good choice for intercropping in coconut gardens in the plains and coastal areas of Kerala, were filtered light is available in plenty. There is vast scope for expansion of the crop on a commercial scale, to meet national as well as international demand. However, lack of suitable variety compatible for the prevailing agro-climatic conditions as well as appropriate management techniques constitute the major constraints in heliconia cultivation in Kerala. Unavailability of dwarf varieties with good flower production also restricts the farmers of Kerala from commercial cultivation of heliconia.

There are over 450 species, varieties, hybrids and cultivars of heliconias either endemic or cultivated throughout the world (Kress, 1990) of which *Heliconia stricta, Heliconia psittacorum and Heliconia rostrata* are the commercially important species as cut flower crops. Among these, *Heliconia psittacorum cv.* 'Golden Torch' is very promising because of its attractive flowers, long straight clean peduncles, prolific and year round flower production, tolerance to pest and diseases and minimum post harvest losses (Thangam *et al.*, 2014). *Heliconia psittacorum cv.* 'Golden Torch' is more compact in growth habit which grows to a maximum height of 5-6 feet with10-15 tillers per plant.

Genetic control of plant height is primarily achieved by selecting shorter cultivars. However, this could also be achieved to a certain extent by manipulating the environmental conditions involving modification of light intensity, far-red light, photoperiod and/or temperature. The growth and flowering of *H. psittacorum* is photosensitive. The light intensity affects the flower production in Heliconia by increasing number of flowers and stalk length (Souza *et al.*, 2016).

Colored shade nets are a relatively new tool in Horticulture primarily because of their ability to manipulate the spectra of radiation reaching the crops. Colored shading is becoming popular due to its effect on quality of flowers in many crops. Apart from providing physical protection against the radiation and insect pests, use of photo selective shade nets also induce vegetative vigor, dwarfing, branching, leaf variegation, flower production and quality. In addition, shade nets may also modify environmental variables such as temperatures, wind speed or relative humidity inside the canopy (Arthurs *et al.*, 2013). Colored shade netting exhibits special optical properties that allow the control of light and influences the microclimate in which the plants are exposed to (Oren-Shamir *et al.*, 2001).

Growth regulators play an important role in morphological and physiological changes in plants and are widely employed in flower crops for

achieving better flower yield, high quality, increased vase life and other post harvest qualities (Sajjad *et al.*, 2014). Among these, plant growth retardant (PGR) are widely employed to produce compact plants through regulating vegetative growth and promoting more flower production in flower crops. Beneficial effect of growth retardants such as paclobutrazol, cycocel and ethephon are reported in many flower crops. *Heliconia psittacorum cv.* "Golden Torch" possesses vigorous vegetative growth, therefore application of retardant may induce dwarfing in the crop and indirectly facilitate flower production.

Research evidences are scanty on the beneficial effects of colored shading and application of growth retardants on *Heliconia psittacorum* (cv. 'Golden Torch'). Therefore, further research on the influence of colored shade nets and growth regulator on yield and quality of inflorescences and post harvest life in heliconia are required for better management in the production environment. The outcome of the research will provide valuable information that will allow a better light management regime in the production environment and the use of growth retardants for maximizing yield and quality of flowers in heliconia which will ultimately contribute to income of the growers.

In this context, the present study was undertaken with the following objectives:

1. Evaluation of the effect of different shaded environments with colored shade nets on flowering, yield and quality of inflorescences of *Heliconia psittacorum* (cv. 'Golden Torch').
2. To assess the growth and productivity of *Heliconia psittacorum* (*cv.* 'Golden Torch') as influenced by external application of bio-regulators.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Heliconia is an important perennial flower crop commercially cultivated in many tropical countries. Beautiful flowers, attractive foliage, longer keeping quality and wide spectrum of colors make it an interesting component in florist trade.

The investigation entitled "Regulation of growth and flowering in Heliconia (*spp*)" was undertaken during the period from April 2014 to July 2016 at the College of Agriculture, Padannakkad, Kasaragod (Dt.). The objective of the study was to assess the growth and productivity of heliconia as influenced by photo-selective shade nets and external application of bio-regulators.

The literature available on various aspects relevant to the study is reviewed here.

2.1 RESPONSE OF HELICONIA TO VARYING LIGHT CONDITIONS

Fluctuation in light intensity and light quality has a profound influence on the biochemical, physiological and developmental processes in plants. The effect of light can be directly involved in the production of biological energy in plants, thus affecting the crop production. According to Dai *et al.* (2009) light affects metabolism directly through photosynthesis and indirectly through growth and development. The plants grown under the low light level exhibit a disturbed growth and development due to insufficient energy whereas excess light intensity may cause photo damage due to overload of the plant's system (Humby and Durnford, 2006). According to Ivanov *et al.* (2008), excess energy is produced when plants are grown in environments with excessive light radiation, which damages the photosynthetic apparatus resulting from photo inhibition. Under certain environmental conditions, the light energy absorbed by plants can be higher or lower than its capacity. In these conditions the crop development and yield can be affected, thus to overcome this conditions, shade regulation can be carried out by altering the light intensity as reported by Craven *et al.* (2010).

Crops like heliconia, anthurium and jasmine were reported to perform well under partial shade of coconut garden (Arunachalam and Reddy, 2002). About 50% of solar radiation is being intercepted by the coconut canopy thus improving the scope for using underutilized space and solar radiation in coconut plantation as reported by Nair, 1979. Thus there is a good scope for intercropping heliconia in coconut gardens under natural shade. In an experiment conducted by ICAR Central Coastal Agricultural Research Institute, Goa, various intercrops were evaluated in order to enhance the profitability of coconut in which heliconia performed well under coconut plantation for three years. A plant population of 600-700 numbers can be accommodated in one hectare of coconut plantation as inter crop (Thangam *et al.*, 2014).

The light requirements of heliconia vary among species. The environmental changes associated with the light intensity can even affect the growth and development adversely in species of heliconia (Bruna and Kress, 2002). In general a wide range of light intensity can be utilized for heliconia production as reported by Broschat and Svenson (1994).

It is reported that different light intensity through shading treatments could affect the plant development including flowering, physiology and morphology of leaf, and coloration in several ornamental plants (Brand, 1997). Normally shade nettings are used to mitigate temporary heat-induced cessation in reproductive growth (Wagstaffe and Battey, 2008). Shading with net is a method used to increase quantity and quality of ornamental plant production (Payuyong *et al.*, 2011).

Costa *et al.* (2009) studied heliconia genotypes under partial shade and concluded that *H. psittacorum* L. performs better under partial shade condition. In *Calathea crotalifera* significant increase in growth and development was reported when grown under open condition as compared to different shade levels such as 40%, 60% and 80% (Rozali *et al.*, 2016).

In order to obtain inflorescence with better quality, excess light should be avoided in *H. psittacorum cv.* 'Golden Torch' (Meena *et al.*, 2005). In an experiment on the influence of spacing and shading on growth performance and yield of *Heliconia sp cv.* 'Golden Torch' carried out in Annamalai University, (Tamilnadu, India), shading conditions significantly influenced the growth and yield parameters. The growth and yield parameters recorded maximum values under spacing of 45 cm × 30 cm and 75 percent shade individually. The interaction between spacing and shade also significantly influenced the yield parameters (Sudhakar and Kumar, 2012). The vegetative growth and yield were more under shade net compared to open condition.

The quality of cut flower in *Curcuma alismatifolia* was better at a shade level of 70% with a good appeal, and the cut flower production also was better at this shade level. However, in potted plant culture, the optimum shade level for the production of *Curcuma alismatifolia* was at 30% (Thohirah *et al.*, 2010).

2.1.1 Response of horticultural crops to photo selective shade nets

Spectral filter films and nets with differential light scattering properties have been used as a nonchemical means of growth control in horticultural crops (Fletcher *et al.*, 2005; Shahak, 2002). Colored shade nets have been developed during the past decade to filter selected regions of the spectrum of sunlight, along with inducing light scattering. They are designed specifically to modify the incident radiation (spectrum, scattering and thermal components). Depending on the pigmentation of the plastic threads and the knitting design, these nets provide varying mixtures of natural, unmodified light, together with spectrally modified scattered light. Spectrum of the incident radiation in the visible region is modified by colored netting and it also enriches the relative content of scattered light. Stamps (2009) reported that using colored nets, it is possible manipulate light in the ultraviolet spectra (UV), especially the visible region or far-red, which can increase the amount of diffuse light under nets. Similarly, Arthurs *et al.* (2013) observed that spectral measurements revealed differences in the penetration of

radiation based on different colored nets. According to Bandara *et al.* (2014) colored shade nets can increase the light scattering by 50% or more and influence plant growth and development. His study also revealed that the plant performance under varying light spectra is species dependent. In an experiment conducted by Ombodi *et al.* (2015) also, it was revealed that shading with colored nets considerably affect the intensity and spectra of incident radiation.

Special optical properties are exhibited by colored shade netting that allow the control of light and influences the microclimate in which the plants are exposed to (Oren-Shamir *et al.*, 2001 and Priel, 2001). Under colored shade nets the relative humidity and soil moisture will be higher. Eco-friendly net covers modified the microclimate resulting in significantly higher relative humidity, compared with the open treatment (Gogo *et al.*, 2012). Shade nets reduce both light intensity and effective heat during the daytime while changing the spectrum. Under high radiation conditions, colored shade nets are also useful in physical protection such as preventing attack of pests and birds apart from manipulating the light spectrum in cut flowers. They are also helpful in optimizing desirable physiological responses, in addition to providing physical protection to the crop (Shahak *et al.*, 2002).

Blue light, either alone or in combination with other types of visible radiation have a critical role in the photomorphogenic response of plants as reported by Rajapakse *et al.* (1992) and Brown *et al.* (1995). The transmittance of light by the blue netting is in the range of 400-540 nm regions and that of the red netting is in the 590-760 nm regions as revealed by Oren-Shamir *et al.* (2001). As reported by Shahak et al. (2014) blue net has a wide peak of transmittance in the blue-green region (400-540 nm), while red net transmitting from 590 nm and up. The heat use efficiency had higher value under green shade nets followed by red, white, and black in *H. psittacorum* (*cv.* 'Golden Torch') as reported by Meena *et al.* (2005).

2.1.2. Morphological parameters

2.1.2.1. Tiller production

The number of tillers is an important feature since the greater the number of tillers greater will also be the number of leaves which capture solar energy producing organic matter through photosynthesis and improving crop production (Assisi *et al.*, 2009).

Ibiapaba *et al.* (2000) observed that the first shoots of heliconia cultivars 'Sassy' and 'Andromeda' appeared about 20-30 days after planting while Carvalho *et al.* (2012) found that the emergence of the first tiller occurred 55 days after planting.

Maciel *et al.* (1994) in their study on growth and development of heliconia under 3 different levels of shades such as 0, 40 and 60% has observed more number of shoots/clump under open conditions rather than shade in heliconia. According to Costa *et al.* (2006), heliconia cultivars like 'Golden Torch' produced higher number of tillers as compared to that of large cultivars. He also observed that *H. psittacorum* x *H.spathocircinata cv.* 'Golden Torch' and *H. bihai* grown in full sun and half-shade produced similar number of tillers, which indicated that tiller production was not influenced by different levels of shade.

Beckmann-Cavalcante *et al.* (2011) evaluated the effect of different substrates and environmental conditions such as full sun and 50% shading on the production of heliconia (*Heliconia psittacorum* L.) and found no significant effect of shaded environments on the number of days for the emergence of the first tiller. A similar finding was reported by Souza *et al.* (2016) in which tiller emergence was shade independent but the length of the stems responded to shading treatments for the cultivar 'Golden Torch'.

In an experiment Conducted by Nascimento *et al.* (2015) it was reported that the Torch ginger plants grown in full sun produced the highest number of tillers than in plants grown under the shade.

2.1.2.2. Leaf production under controlled light regimes

The quality and quantity of diffused light is the most important factor influencing foliage plant performances under interior conditions as reported by Jeong *et al.* (2009). A plant grown under the shaded condition produces sufficient leaves so that the photosynthetic area can be utilized for harnessing the light energy which can contribute to the amount of photosynthates in the biomass production, which leads to the production of leaves. Criley (2000) stated that weather and environmental factors, such as light and humidity, have influence on timing of emergence of leaves in heliconia. According to Perez *et al.* (2013) the number of leaves per flower shoots, was not affected by shading level in *Heliconia psittacorum cv.* 'Golden Torch'.

In *Heliconia spathocircinata X Heliconia psittacorum cv.* 'Golden Torch', 4-5 leaves were produced per shoot (Broschat and Donselman, 1984), while the number of leaves in the flowering stem at inflorescence emission (NLI) varied from 5.25 in *H. rostrata* to 6.17 in *H. collinsiana* as reported by Costa *et al.* (2009). The numbers of leaves were observed to be higher in autumn season (Sheela, 2005).

In pittosporum plants, red shade netting produced the maximum number of new leaves which are smaller in area and thicker than the leaves produced under the other shade cloth treatments (Kawabata *et al.*, 2007). In turmeric plants, Padmapriya *et al,* (2009) had observed that the number leaves increased when grown under shaded condition.

In an experiment conducted by Nascimento *et al.* (2015) it was reported that the Torch ginger plants grown in full sun produced the maximum number of leaves than in plants grown under the shade.

2.1.2.3. Height of the plant

Heliconias in their natural habitat perform well under partial shade compared to full sunlight. Shade loving Heliconia plants exposed to open light conditions showed delayed growth as reported by Bruna *et al.*, (2002). Jeong *et al.* (2009) reported that some species of heliconia like *H. psittacorum* which were sun-loving grow well in full sun, while some other tall cultivars required partial shade of about 50%. Once the plants get shade, they tend to grow taller and look a bit fuller than the ones out in full sun.

Broschat *et al.* (1984) reported that the plant height of *H. psittacorum cv.* 'Golden Torch' ranges from 1.0 to 1.8m while Lalrinawani and Talukdar (2000), in India, observed that plant height varied from 91.77 cm to 116.90 cm in one-year old *H. psittacorum* plants. According to Alan (2004), the plants of *Heliconia spathocircinata X Heliconia psittacorum cv.* 'Golden Torch' was sturdier and was larger than any other *H. psittacorum* which exhibited a height ranging from 0.8 to 2.75m.

In order to bring control in the plant height, the practice of modifying environment by manipulating light and temperature is adopted. Sudhakar and Kumar (2012) reported that the maximum plant height was observed in plants grown under 75% shade while in open condition, plant height was the least.

In an experiment conducted by Nascimento *et al.* (2015) it was reported that the Torch ginger plants grown in full sun produced the maximum height in plants grown under the shade. In an experiment conducted by Ramachandrudu and Thangam (2006) in gladiolus, plant heights were more in coconut garden when compared to open conditions.

The plant height and flowering in crops can be manipulated using the photo selective shade cloths which can have a strong response to blue irradiance (Cumming *et al.,* 2008). As an example, blue net significantly decreased plant height in *Pittosporum variegatum* (Oren-Shamir *et al.,* 2001) and Lisianthus

(Torres-Hernandez *et al.,* 2012). Similarly, plants grown under blue net had a shorter stem-length in two sunflower cultivars and in trachelium as reported by Ovadia *et al.* (2008). According to a finding by Payuyong *et al.* (2011) pseudostem height in *Globba williamsiana* was the least under green shade net which was followed by blue, red and black shade nets in the ascending order.

2.1.3 Physiological parameters

The light intensity had profound influence on the physiological processes of plants, in full sun than under shaded condition (Lima *et al.,* 2016). According to Vendrame *et al.* (2004), light intensity can affect plant form, leaf size, and color in herbaceous plants. As reported by Saud *et al.,* (2005) shade loving plants when exposed to excess light can easily be susceptible to a reduction in photosynthetic activity because their net photosynthesis rate is maximized under shade condition.

When different heliconia were grown under full sunlight, they exhibited reduced photosynthetic capacities as compared with those grown under intermediate and deep shade (He *et al.,* 1996).

In an experiment conducted by Henrique *et al.* (2011) in coffee, it was revealed that red and blue net affected the accumulation of soluble sugars and starch in plant tissues and the photosynthetic rate of plants was greater under red net and sunlight compared to blue net.

2.1.3.1. Leaf area

The quality of light is the major factor affecting the specific leaf area and it also depends upon the species. According to Vile *et al.*, (2005), when the plants were grown under low light intensity conditions, an increase in Specific Leaf Area (SLA) were observed. Specific Leaf Area is inversely proportional to leaf thickness, which plays an important role in light and nutrient use efficiency of plants.

Specific Leaf Area (SLA) was higher in *Heliconia psittacorum* "Golden Torch" intercropped in coconut garden than in open condition as reported by

Nihad and Krishnakumar (2015). Leaf area and leaf area index of *H. stricta* was higher in plants grown under coconut canopy; this might be due to its prolonged vegetative phase in shaded condition (Nihad and Krishnakumar, 2015). The leaf area was observed to be very low in *Heliconia bihai cv.* Lobster Claw grown under full sunlight. This might be due to the lower photosynthetic rate and lower translocation of assimilates (Lima *et al.,* 2016).

In an experiment conducted by Ramachandrudu and Thangam (2006) in gladiolus, leaf length was more when cultivated under natural shade in coconut garden compared to open conditions.

Reduction in the thickness of the leaf blade was seen under shading conditions in papaya plants as revealed by Buisson and Lee (1993).

As reported by Oren-Shamir *et al.* (2001), *Pittosporum variegatum* plants grown under grey colored nets produced dense plants with short side shoots and smaller leaves. Similarly, pittasporum plants grown under red shade net produced thicker leaves with lesser leaf area than the leaves in plants under the other shade cloth treatments (Kawabata *et al.*, 2007).

In an experiment conducted by Meena *et al.* (2005) in spinach, different coloured shade nets resulted in increased leaf area.

2.1.3.2. Leaf chlorophyll content influenced by light conditions

According to Middleton (2001), under shaded condition, ornamental plants in general produced thinner leaves with higher chlorophyll content. In his study, leaf chlorophyll content had a positive correlation with flowering which he attributed to the photochemical energy provided by the light being utilized for the activity of photosynthesis and flowering.

In open condition, chlorophyll content gets depleted due to bleaching under full sunlight. The photosynthetic pigments can be destroyed at higher rate of irradiation (Goltsev *et al.,* 2003). Jason *et al.* (2004) similarly reported a decrease in chlorophyll b content of Lilly leaves in open condition which

indicated disintegration of chlorophyll by excess light. In gladiolus also, Pandya *et al.* (2003) observed that chlorophyll content in leaves increased with the reduction in light intensity.

He *et al.* (1996) reported that when heliconia plants were grown in full sunlight, a reduction in chlorophyll content per leaf area was observed compared to those grown under intermediate or partial shade, which consequently reduced photosynthetic capacity of leaves. According to Rundel *et al,* (1998), the increases in heliconia leaf chlorophyll content indicated an increase in the density of leaf.

Saud *et al.* (2005) in gladiolus found that different levels of shading increased chlorophyll content in both the seasons. In an experiment conducted by Meena *et al.* (2005) in spinach, different coloured shade nets increased the chlorophyll content. In Pittosporum plants, lower levels of red light and the blue shade cloth contributed to the reduced levels of chlorophyll (Kawabata *et al.*, 2007). Zhu *et al.* (2012) based on his experiment using colored shade nets reported that shading with 60% and 30% intensity resulted in the highest SPAD values in gladiolus.

2.1.3.3 Dry weight and total plant biomass

Total dry biomass of heliconia plants cultivated in open condition was significantly higher than that of those maintained under red or blue shading as reported by Costa *et al.* (2010). However, dry weight of inflorescence was not significant.

In an experiment conducted by Meena *et al.* (2005), use of colored shade nets increased the biomass, yield as well as radiation use efficiency and water use efficiency in spinach. Higher yield was observed under green coloured shade nets followed by red, white and black. As reported by Ovadia *et al,* (2008) fresh weight of *Trachelium* cut flowers was lower when grown under the blue net.

2.1.4 Yield parameters

2.1.4.1. Days to flowering

The production of Heliconia flowers in the tropics is year round. This indicates that photoperiod has no effect on growth and flower production in heliconia. According to Broschat and Donselman (1984), flower production was related to rate of vegetative growth as well as plant density. According to Atehortua (1998), heliconia plants started flowering after producing a number of leaves depending on species or variety. Criley and Kawabata (1986) observed inflorescence emission in *H. stricta* 'Dwarf Jamaica' when plants presented 6 or 7 leaves. However, in *Heliconia spathocircinata X Heliconia psittacorum cv.* Golden Torch, a terminal inflorescence was produced after the emergence of 4-5 leaves. According to Criley and Sakai (1998) in heliconia, flowering occurred with three expanded leaves. Castro (1995) and Costa *et al.* (2009) also reported that four to five leaves were needed for inflorescence emission.

According to Criley (2000), weather and environmental factors, such as light and humidity, have influence on inflorescence emergence. The peak flowering was observed during the month of July to September. Studies conducted by Beckmann-Cavalcante *et al.* (2016) in *H. psittacorum* (*cv.* 'Golden Torch') showed that flowering usually occurred between 120 and 170 days after planting.

As reported by Saud *et al.* (2005) in gladiolus, different levels of shading induced earliness to flowering in summer. Shading shortened the durations of first floret to show color than under control conditions.

In tropical areas, *Heliconia psittacorum cv.* Lady Di when grown in full sun and upto 40% shade, peak flowering was observed during the month of April to November (Juan, 1997).

In a study by Sudhakar and Kumar (2012), the days taken to first flowering was earliest under 75% shade followed by 50% in plants of *Heliconia psittacorum cv* 'Golden Torch'. Perez *et al.* (2013) reported that the days to

flowering decreased with increasing shade level in *H. psittacorum* L.f. X *H. spathocircinata* Aristeguieta 'Golden Torch Adrian'. In an experiment conducted by Souza *et al.* (2016) in heliconia (Golden Torch), plants grown under full sunlight, inflorescence emerged after 159 days of emergence of tillers. However, the plants grown under 35% shade produced flowering in 103 days after emergence of tillers which indicated that the decrease in light intensity at the level of 35% was enough to obtain early flowering.

In *H. psittacorum* (cv. 'Golden Torch'), it was observed that plants grown under full sun and those grown in shaded environments produced inflorescences with similar duration from flowering to harvest but showed low quality due to the burns on the tips of the bracts due to exposure to sun (Albuquerque *et al.*, 2014).

Ramachandrudu and Thangam (2012) in their study observed that, in *H. psittacorum var.* Golden Torch, emergence of spike and opening of spike was found to be earlier under open conditions than those intercropped in coconut garden.

As reported by Oren-Shamir *et al.* (2001), photoselective shade nets with different colors have differentially affected the flowering time as well as flower quality in cut flowers. They also modify the harvest season to early and late flowering and improve the yield, quality of flowers (Shahak *et al.*, 2014; Ovadia *et al.*, 2008) observed that the red net caused a significantly shorter time to flowering in *Ornithogalum.*

2.1.4.2 Inflorescence parameters

Heliconias are well adapted to the major agro-climatic zones of the humid tropics, which range from full sunlight to natural shade. Normally they thrive in a humid environment with temperature profile around 15°C to 40°C which it can tolerate. Under optimum conditions the production of inflorescence in heliconia was found to be higher as reported by Geertsen (1990).

2.1.4.3 Bract characters

An experiment was conducted in *Heliconia psittacorum cv.* 'Golden Torch' by Ramachandrudu and Thangam (2012) to study their performance under partial shade of coconut garden and open field conditions. The results revealed that spike length, spike width, spike and rhizome yield were more in open condition than under shade. Number of bracts/spike was similar under shade as well as open conditions. However, Perez *et al.* (2013) reported that the number of bracts per inflorescence, and the bracts color decreased with increasing shading level in *H. psittacorum L.f. X H. spathocircinata Aristeguieta* 'Golden Torch Adrian'.

2.1.4.4 Inflorescence characters

According to Costa *et al.* (2006), the main harvest index used by the farmers for Heliconia flowers were the inflorescence stem length and the number of bracts that were opened. Inflorescence with average stem length greater than 70 cm was ideal for marketing in heliconia (Albuquerque *et al.* 2014).

Ramachandrudu and Thangam (2012) reported that spike length and width in *Heliconia psittacorum cv.* 'Golden Torch' recorded was not significantly different in plants grown under both open and shaded conditions. Perez *et al.* (2013) reported that the inflorescence length decreased with increasing shade level in *H. psittacorum L.f. X H. spathocircinata* Aristeguieta 'Golden Torch Adrian'

Yield parameters such as stalk length (32.12 cm), rachis length (15.21 cm) and flowers yield per ha in Heliconia (1,80,204 numbers) were maximum in 75 per cent shade and 45cm × 30cm spacing (Sudhakar and Kumar, 2012).

According to Nihad and Krishnakumar (2015), light use efficiency and flower quality (general appearance, bract arrangement, glossiness and colour development) were positively influenced in heliconia plants grown under the coconut canopy compared to open conditions. The flower quality was higher for

inflorescences produced in plants grown under coconut canopy revealing enhanced light use efficiency and flower quality of *H. stricta* in coconut based cropping system.

In an experiment conducted by Ramachandrudu and Thangam (2006) in gladiolus spike length was more in coconut garden when compared to open conditions.

As reported by Ovadia *et al.*, (2008) lisianthus and sunflower cultivars grown under red and yellow colored shade-nets recorded a significant increase in stem-length of flowers. In an experiment conducted in gladiolus by Henrique *et al.* (2011) flowers from plants grown under blue net were thinner and elongated compared to the stems harvested from plants grown under red shade net.

2.1.4.5 Number of inflorescence

Inflorescence production in Heliconia was greatly influenced by the light intensity. According to Broschat *et al.* (1984), *Heliconia spathocircinata* X *Heliconia psittacorum cv.* 'Golden Torch' recorded a reduction in flower production by about 50% when grown under 63 per cent shade. Production of inflorescence in plants grown under shade was reported to be only one fourth of the flower production in plants grown in full sun. However, the bract color of inflorescence appears to be more intense under shaded condition. Contrasting results were reported by Sudhakar and Kumar, (2012) in *Heliconia psittacorum* cv.' Golden Torch' in which production of flowers per plant was less under open conditions.

Heliconia grows well in full sun to 40 per cent shade as reported by Alan (2004). Shade netting increases light scattering but does not affect the light spectrum, it has been shown to increase branching, plant compactness, and the number of flowers per plant in ornamental potted plants, according to Nissim-Levi *et al.* (2008). Perez *et al.* (2013) reported that the number of inflorescence per

plant decreased with increasing shading level in *H. psittacorum L.f.* X *H. spathocircinata Aristeguieta* 'Golden Torch Adrian'.

According to Shahak *et al.* (2014), flowering of 'Hermosa' peaches was increased by five photoselective shade nets (white - 12% shading; blue, pearl, red and yellow - 30% shading) treatments after two years, compared to open field control.

An experiment was conducted in *Heliconia psittacorum cv.* 'Golden Torch' by Ramachandrudu and Thangam (2012) to study their performance under partial shade of coconut garden and open field conditions. The results revealed that spike and rhizome yield were more in open condition than under shade. Number of bracts/spike was similar under shade as well as open conditions.

In an experiment by Souza *et al.* (2016) the yield and quality of inflorescences of *H. psittacorum cv.* 'Golden Torch' plants grown under black shade nets with 50% shading was recommended for better quality ((length and diameter of stems) inflorescence. In *Strelitzia reginae* the yield was higher in full sun, with 37 flower stalks and fresh weight of 100.2 g (Fava *et al.*, 2015).

2.1.5 Post harvest parameters

2.1.5.1 Vase life

According to Broschat and Donselman (1984), heliconia flowers could be cut when 2 or 3 bracts were open. Once the inflorescence was harvested, the opening of flowers did not happen even after use of bud opening solution. In order to prevent the cold injury, heliconia flowers must be stored at temperature above 10°C. It was observed that when silver nitrate or 8-HQC were used to prolong vase life, there was no uptake of water and the uptake of floral preservative was reduced indicating that preservatives does not have any effect on postharvest life of heliconia cut flowers.

In heliconia, the post harvest life was influenced by post harvest problems like low water absorption and uptake, rapid bract and florets darkening and senescence as reported by Paulo *et al.* (2005). Based on the scale of appearance, the inflorescences treated with 300 mg L^{-1} of 8-HQC had superior vase life compared with the other treatments, within eight days of evaluation (Castro *et al.*, 2015).

In *Bougainvillea glabra*, different shaded condition did not influence the vase life of flowers as reported by Saifuddin *et al.* (2010).

2.2. RESPONSE OF BIO-REGULATORS IN GROWTH AND FLOWERING IN HELICONIA

Growth regulators play an important role in morphological and physiological changes in plants and are widely employed in flower crops for achieving better flower yield, high quality, increased vase life and other post harvest qualities (Sajjad *et al.*, 2014). Their effect varied with plant, species, variety, concentration used and method of application and frequency of applications (Munikrishnappa and Chandrasekhar, 2014).

Chemical growth retardants like cycocel and ethrel were useful in manipulating shape, size and form of floricultural crops as reported by Davis and Anderson, (1990). Plant growth retardants inhibit cell division in the sub apical meristem of the shoot, inhibits cell elongation, enhance foliage colour and decrease time to flower as reported by Dole and Wilkins (1999). According to Fishel (2015), the growth regulator paclobutrazol functions as the inhibitor of plant growth, promotes uniform flowering and reduces internodal length, Chlorocholine Chloride (CCC) acts as the shoot inhibitor and ethephon acts as a floral stimulant.

Ethephon is not an anti-gibberellin; ethephon releases ethylene, which reduces elongation in some crops. Ethephon taken up by the plant is broken down inside the plant to produce ethylene gas. Ethylene gas is a natural plant hormone

that influences fruit ripening, senescence, branching and growth. The growth retardants are exploited for controlling growth and enhancing production and quality in many flower crops as reported by Grossman (1992).

2.2.1. Morphological parameters

2.2.1.1. Tiller production

Corm treatments of gladiolus with ethrel at the rate of 1000ppm reported to cause early sprouting by acting as dormancy breaker by Halevy *et al.* (1970). An inhibition in the early growth in gladiolus was also observed by ethrel dip as reported by Tonecki (1979).

Pal and Choudhury (1998) reported that Ethrel at 100 ppm significantly reduced the number of days for sprouting over control in gladiolus. Similarly in Freesia, the use of ethephon had an effect on the increase of number of shoots (Zurawik and Placek, 2013).

2.2.1.2. Number of leaves

Varying responses on leaf production as a result of application of growth retardants has been reported in many ornamental crops. In heliconia plants *cv.* Red Torch, the number of leaves increased when sprayed with CCC at 2 different levels of 100ppm and 200 ppm (Jadhav *et al.,* 2015).

Similar results were reported in gypsophilla, where the number of leaves per plant increased when cycocel at 2400 ppm was applied to the plants (Kumar *et al.* 2011). The probable reason for this response might be due to an increase in number of branches per plant even though there was a reduction in shoot growth. Different treatments of cycocel and their interaction had no significant effect on the leaf number in *Calendula officinalis* (Kazemi *et al.*, 2014) in contrast to this statements, freesia plants treated with $20mgl^{-1}$ of cycocel recorded increased number of leaves (Ibrahim, 2014).

However, contrasting results were reported in gladiolus, where application of 16mg of paclobutrazol reduced the number of leaves as reported by Milandri *et al.* (2008). Similar reports are available in Begonia plants where the number of leaves tend to decrease when treated with paclobutrazol (Suradinata *et al.*, 2013). In Freesia, the use of ethephon decreased the number of leaves (Zurawik and Placek, 2013).

2.2.1.3 Height of the plant

CCC and paclobutrazol were used for control of plant height and for stimulation of lateral branching (Bailey and Whipker, 1998).

In heliconia, duration between planting and flowering is longer and this problem can be overcome by using various growth retardants as they shorten the plant height and induce early flowering. Jadhav and Chawla (2015) observed that in heliconia, there was a drastic reduction in the height of the plants treated with paclobutrazol at different concentration.

In an experiment conducted by Hwang *et al.* (1986), gladiolus plants were treated with paclobutrazol as soil drench and foliar spray at different stages and the results revealed that the plants treated by paclobutrazol as soil drench recorded the shortest plant height. Further studies by Barzilay *et al.* (1992) also proved that application of paclobutrazol significantly reduced plant height in gladiolus. Similarly, in lilium, Francescangeli *et al.*, (2007) observed that the plant height and duration of flowering was drastically reduced when treated with paclobutrazol resulting in chemical dwarfing. Such responses were also available in container grown ornamentals in which spraying or applying the chemicals directly into the potting media produced shorter plants compared to untreated plants (Grossi, 2009). Similarly, Wanderley *et al.* (2014) reported that soil drenching of paclobutrazol to the Orchids at a minimum concentration showed reduction in plant height.

Chlormequat chloride (CCC) is used for height control in many ornamental plants including heliconias, poinsettias, azaleas, geraniums and hibiscus (Barret, 2001). In an experiment conducted by Papageorgiou *et al.* (2002), lavender plants treated with paclobutrazol exhibited a drastic reduction in plant height and reduced shoot elongation rate and resulted in early flowering. However, when treated with CCC, even though a reduction in plant height was observed, there was no effect on flowering.

According to Warner and Erwin (2003), hibiscus plants sprayed with CCC and paclobutrazol at different concentration reduced stem elongation and height of the plant. The plants sprayed with CCC showed symptoms of chlorosis, apparently due to breakdown of chloroplast. Karaguzel *et al.* (2004) reported that the retarding effect of paclobutrazol could be seen one week after application as soil drench. According to Sunitha (2006), the plant growth retardants like CCC and Paclobutrazol, reduced the plant height and increased production in African marigold.

In dahlia, the plants treated with CCC at 5000 ppm resulted in the suppression of height as reported by Bhattacharjee (1984). According to Devendra *et al.* (1999), tuberose plants sprayed with ethrel significantly reduced the plant height and that the plants treated with cycocel recorded the shortest plant height.

Ethephon reduced height by 23, 42, 46, 40, or 46% when applied three times at $1000mgl^{-1}$ on Achillea, Echinacea, Leucanthemum, Monarda, or Physostegia, respectively, compared to that of control plants (Hayashi *et al.*, 2001). Similarly in freesia, the height was considerably reduced when applied with ethephon (Mynett *et al.*, 2001). Drenching of Florel (ethephon) had a moderate to strong effect on suppressing plant height of angelonia, celosia,geranium (seed), petunia, tomato, verbena and vinca (Runkle, 2013).

2.2.2. Physiological parameters

2.2.2.1. Leaf area

In an experiment conducted in heliconia plants by Jadhav and Chawla (2015), application of CCC @ 100ppm as soil drenching resulted in an increased leaf area. In contrast to this, reduction in leaf area was reported in *Erysimum marshallii* when applied with a higher concentration of cycocel (1500 mg l^{-1}) (Bhat *et al.*, 2011)

However, when paclobutrazol was applied in *Lantana camara* it was reported that increasing concentrations generally causes a vast reduction in leaf area (Matsoukis *et al.*, 2001). Leaf size in gladiolus reduced when treated with 16mgl^{-1} of paclobutrazol as soil drench as reported by Milandri *et al.* (2008). A reduction in leaf area consequent to the application of paclobutrazol in increased concentrations has been exemplified in Begonia, as it was observed that plants without paclobutrazol application had larger average leaf area. When the plants were without paclobutrazol application, gibberellins hormone synthesis in plants was not inhibited so that cell division and enlargement took place in plants as reported by Suradinata *et al.* (2013).

An increase in leaf area was reported in mustard as a result of application of ethephon (Khan *et al.*, 2008).

2.2.2.2. SPAD chlorophyll meter reading

The chlorophyll content of the leaves have high influence on its photosynthetic activities. The plant growth retardants have varying effects on the accumulation of pigments in leaves of the crops. In an experiment conducted in heliconia plants by Jadhav and Chawla (2015), application of CCC @ 100ppm as soil drenching resulted in an increase in chlorophyll content, anthocyanins content and total soluble sugars. Application of cycocel enhanced the chlorophyll content of leaves which helped to increase the functional life of the

source for a longer period leading to improve partitioning efficiency and productivity in sunflower (Kashid *et al.*, 2010)

As reported by Pinto *et al.* (2005), paclobutrazol treatment in Zinnia plants resulted in darker green leaves which could be attributed to the increased chlorophyll biosynthesis and reduction in the leaf area. In Begonia also, increased concentration of paclobutrazol resulted in decreased leaf area and an increase in carotenoid pigments instead of chlorophyll (Suradinata *et al.,* 2013). Similarly it was reported by Tekalign *et al.* (2005) that the use of paclobutrazol can enhance the formation of carotenoids in the leaf and increased leaf color in crops.

In *Avena sativa*, there was a reduction in leaf chlorophyll content when the plants were treated with ethephon at a concentration of 0.445ppm (Choe and Whang, 2012). Similarly in Freesia, the use of ethephon had an effect on the decrease of chlorophyll content of leaves (Zurawik and Placek, 2013).

2.2.2.3 Dry weight and total plant biomass

A reduction in plant biomass was recorded in Dendrobium applied with paclobutrazol (Te-Chato *et al.,* 2009). The effect of paclobutrazol in influencing plant biomass was operated at the levels of leaf cell elongation, shoot elongation, dry matter production and other plant characteristics as an inhibitor of gibberellin biosynthesis (Wanderley *et al.,* 2014). The general effect of application of paclobutrazol was a reduction in plant biomass.

Higher clump weight was observed in the tuberose plants treated with 4000 ppm of cycocel (Reddy *et al.*, 1997). Similarly Garib Sahi (2009) reported that in *Zinnia elegans,* spraying plants with 2000 mgl^{-1} cycocel and 1 mgl^{-1} $CaCl_2$ increased dry weight of leaves and roots. The fresh and dry weight of root, leaves and stem was relatively lower in plants sprayed with cycocel (Bhat *et al.,* 2011). In marigold, plant fresh weight increased as the concentration of cycocel and daminozide increased, while this does not have any significant effect on plant dry matter (Kazemi *et al.*, 2014)

Application of Florel (ethephon) through drenching noticeably decreased shoot and root biomass in many crops. In calibrachoa, a single 50-ppm Florel drench reduced shoot mass by 40 percent and root mass by 31 percent (Runkle, 2013). Similarly Ethephon, as a source of ethylene, decreased the corm weight in freesia (Zurawik and Placek, 2013). A similar trend was observed in *Curcuma alismatifolia* were application of ethephon led to the reduction in rhizome weight per plant, as reported by Khuankaew *et al.* (2009).

2.2.3. Yield parameters

2.2.3.1. Days to flowering

The beneficial effects of plant growth retardants in reducing the time to flowering have been reported in many crops (Dole and Wilkins, 1999).

According to Bailey and Whipker (1998), CCC and paclobutrazol were used for promoting flower initiation. They inhibited the synthesis of gibberellins within the plant. Ethephon was often employed to manage the timing of flowering and to manage plant growth such as increased branching and consequent increase in flowering.

In Heliconia cultivar 'Red Torch' days to first flowering was minimum in the plants treated with CCC at 100ppm as reported by Jadhav and Chawla (2015).

Reports on reducing the duration to first flowering as a result of application of growth retardants are available in many flower crops. Flowering was earlier in *Polyanthus tuberosa*, when tubers were treated before planting with ethrel (50-3000 ppm) and cycocel (50-5000 ppm) as reported by Ramaswamy *et al.* (1979). Naidu *et al.* (2014) reported that in marigold, the application of CCC at 1250 ppm resulted in reducing the number of days to first flowering and a concentration of 750ppm resulted in maximum flower yield. In an experiment conducted by Wazir (2015) in potted Fuchsia, the days to flower bud formation and days to first flowering were effectively reduced by application of CCC. CCC

@1500 ppm again advanced flowering by 16 days where as ethrel sprays significantly delayed flowering.

Kristensen and Adriansen, (1988) reported that flowering was delayed in gladiolus plants treated with paclobutrazol. However, Paclobutrazol can significantly accelerate flowering at certain doses in several woody, perennial and annual plants (Karaguzel and Ortacesme, 2002).

In a study conducted by Runkle (2013), application of Florel (ethephon) delayed flowering in crops like angelonia, celosia, geranium (seed), petunia, tomato, verbena and vinca, and the delay was positively correlated with the drench concentration used. However, in crops like chrysanthemum, dianthus, impatiens and snapdragon, drenching of Florel had an inhibitive effect on plant height with little or no flowering delay. In angelonia, a single 25-ppm drench inhibited plant height by 16 percent while a 50-ppm drench produced 35 percent shorter plants than control. Similarly in celosia, a 25-ppm Florel drench reduced plant height by 36 percent and a 50-ppm drench reduced height by 53 percent.

Spraying ethephon three times at $1000mgl^{-1}$ delayed the flowering of Echinacea, Monarda, and Physostegia by 6, 7 and 9 days, respectively (Hayashi *et al.,* 2001). Foliar applications of ethephon at 1200 to 4800 mgl^{-1} inhibited flowering of purple velvet plants *Gynura aurantiaca* (Blume) and also stunted plants (Pallez and Dole, 2001).

2.2.3.2 Number of flowers

In an experiment conducted by Barzilay *et al.* (1992) in gladiolus, it was observed that drenching of paclobutrazol resulted in less flower production. Similar result was also reported by Milandri *et al.* (2008) in gladiolus, were there was a reduction in number of flowers with the increasing rate of paclobutrazol In Begonia, independent application of Paclobutrazol could increase the number of buds which might be due to induction of flower buds by formation of cytokinin

and allocation of photosynthates to the meristems as reported by Suradinata *et al.* (2013).

When the tubers of tuberose were treated with cycocel at 1000ppm the number of flowers appears to increase (Ramaswamy *et al.*, 1979). Jana and Biswas (1982) also obtained similar results in tuberose plants sprayed with Cycocel at 2000ppm where production of flowers per plant was highest. As reported by Choudhary (1987), the number of flowers produced was higher in tuberose plants treated with 50 ppm of cycocel.

Drenching of Florel (ethephon) increased the production of flower buds in Achillea (36%), Coreopsis (52%), and Phlox (25%), but was decreased in Echinacea (33%), Leucanthemum (21%), Monarda (62%), and Physostegia (24%) (Hayashi *et al.*, 2001)

Inflorescences per pot were increased at an ethephon concentration of 500 mgl^{-1} applied twice in Achillea 'Weser River Sandstone,' Coreopsis 'Moonbeam,' Leucanthemum 'Thomas Killen,' and Monarda 'Blue Stocking' (Hayashi *et al.,* 2001).

The number of flowers and the number of flowering spikes were increased when the tuberose plants were treated with cycocel at 500-5000ppm Similarly, cycocel at 2000 ppm increased flower yield and reduced vegetative growth without affecting initiation of flower bud and commencement of flowering in marigold (Kumar *et al.*, 2011). Such reports were also available in gypsophila where there was an increase in the number of flowers per plant when treated with cycocel (Bhattacharjee and Das, 1979).

2.2.3.3 Bract characters

In an experiment conducted by Joshi and Reddy (2006), heliconia plants treated with CCC have resulted in an increased number of florets per bracts and bracts per spike. Similar result was obtained in poinsettia plants treated with CCC (Lodeta *et al.*, 2010).

In an experiment conducted by Hassan and Agina (1980), in tuberose higher number of florets and stalks were produced when the plants were sprayed with 1000-2000ppm of cycocel. According to Jadhav *et al.* (2015), application of MH and CCC produced significantly higher number of spikes per clump while paclobutrazol did not produce flowering.

Bract area reduced with the application of paclobutrazol at higher concentration and does not had any significant effect at lower concentration as reported by Niu *et al.* (2002) in poinsettias and El-Quesni *et al.* (2007) in bougainvilleae.

2.2.3.4 Inflorescence parameters

Barzilay *et al.* (1992) observed that gladiolus plants drenched with paclobutrazol recorded reduced spike length, number of florets and flower and a reduced percentage of flowering. Thompson *et al.* (2005) reported that drenching of paclobutrazol at different concentrations had a dwarfing effect on inflorescence in gladiolus plants. An experiment conducted by Banon *et al.* (2002) in carnations , response to paclobutrazol found that drench treatments were effective in reducing inflorescence height. The flower spikes of gladiolus plants treated with 2, 4 and 8 mg a.i. of paclobutrazol per pot appears to be shorter as reported by Milandri *et al.* (2008).

According to Bhattacharjee (1984), the tuberose plants treated with cycocel reduced its spike length and increased the number of spikes per plant. Similar report was available in tuberose as observed by Reddy *et al.* (1997).

Application of ethrel 100ppm increased inflorescence length and flower size in gladioli (Roychoudhari, 1989). In contrast to this, the use of ethephon solution in concentrations of 125, 250 and 500 mg dm^{-3} reduced the length of inflorescence in freesia (Zurawik and Placek, 2013). Such results was also reported in dahlia were there was a reduction in the length of the inflorescence when applied with ethephon (Miller *et al.*, 2012)

In Phalaenopsis Orchids, the plants applied with paclobutrazol recorded reduction in stem length of inflorescence as reported by Wang (1994). C*onsolida orientalis* plants treated with paclobutrazol resulted in reduction of stalk length as reported by Karaguzel *et al.* (2004). Similarly in *G. jamesonii*, the stalk length tend to reduce due to the effect of paclobutrazol (Lee and Lee, 1990). The flower stalk length of freesia is observed to reduce its length when sprayed with $20mgl^{-1}$ of paclobutrazol (Ibrahim, 2014).

As reported by Roychoudhari (1989), an increased length in flower stalk, was observed in gladioli applied with 100ppm of ethrel.

CCC led to decrease in the stalk length of flower in Iris plant (Taha, 2012). In contrast to this in Fuchsia, Wazir (2015) reported that plants treated with CCC @500 ppm recorded maximum length of flower stalk, number of flowers and flower diameter. However, maximum reduction in flower stalk length was recorded with the application of ethrel-350 ppm. Such retardation in height due to application of ethrel may be due to killing the terminal buds or severe disruption in apical meristematic region while CCC acts by blocking GA biosynthesis in the sub apical meristematic region.

2.2.4 Post harvest parameters

2.2.4.1. Vase life

Munikrishnappa and Chandrashekar (2014) reported that CCC and Paclobutrazol increased flower yield and enhanced the vase life of cut flowers. In China aster, foliar application of CCC at 1500 ppm recorded the highest flower yield and also flower quality parameters and soil drenching of paclobutrazol at 25 ppm results in early flowering.

According to Grossman (1992), the type of inhibition depends upon the species and the concentration of the growth retardant applied. In bird of paradise, the plants sprayed with ethephon at a concentration of $1000mll^{-1}$ resulted in reduced vase life as reported by Finger *et al.,* 1999.

Pre harvest spray of 3000 ppm of cycocel and 40ppm of paclobutrazol does not have any significant difference in the vase life of garland chrysanthemum (Dorajeerao and Mokashi, 2011). Similarly in freesia flowers, the plants treated with paclobutrazol at $20mgl^{-1}$ recorded highest vase life (Ibrahim, 2014).

The growth retardants does not have any significant effect on the vase life as reported by Dorajeerao and Mokashi (2011) in chrysanthemum and Patil *et al.* (2013) in China aster. In contrast to this, in *Solidago Canadensis,* application of CCC improved vase life (Osman, 2014).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation entitled "Regulation of growth and flowering in *Heliconia spp*" was carried out with the objective of assessing the response of *Heliconia psittacorum* with respect to colored shade nets and bioregulators at College of Agriculture, Padannakkad and RARS, Pilicode, Kasaragod during the period from April 2014 to July 2016.

3.1 CLIMATIC CONDITIONS

The monthly mean values of light, temperature, relative humidity and rainfall were recorded.

3.2 SOILS

The soil of the experimental site was lateritic soil.

3.3 THE EXPERIMENTAL MATERIAL:

The variety 'Golden Torch' belonging to the species *Heliconia psittacorum* was used in the experiment. The suckers of *Heliconia psittacorum cv.* 'Golden Torch' were procured from a reputed grower in Wayanad district during the month of April, 2015 and brought to Regional Agricultural Research Station, Pilicode.

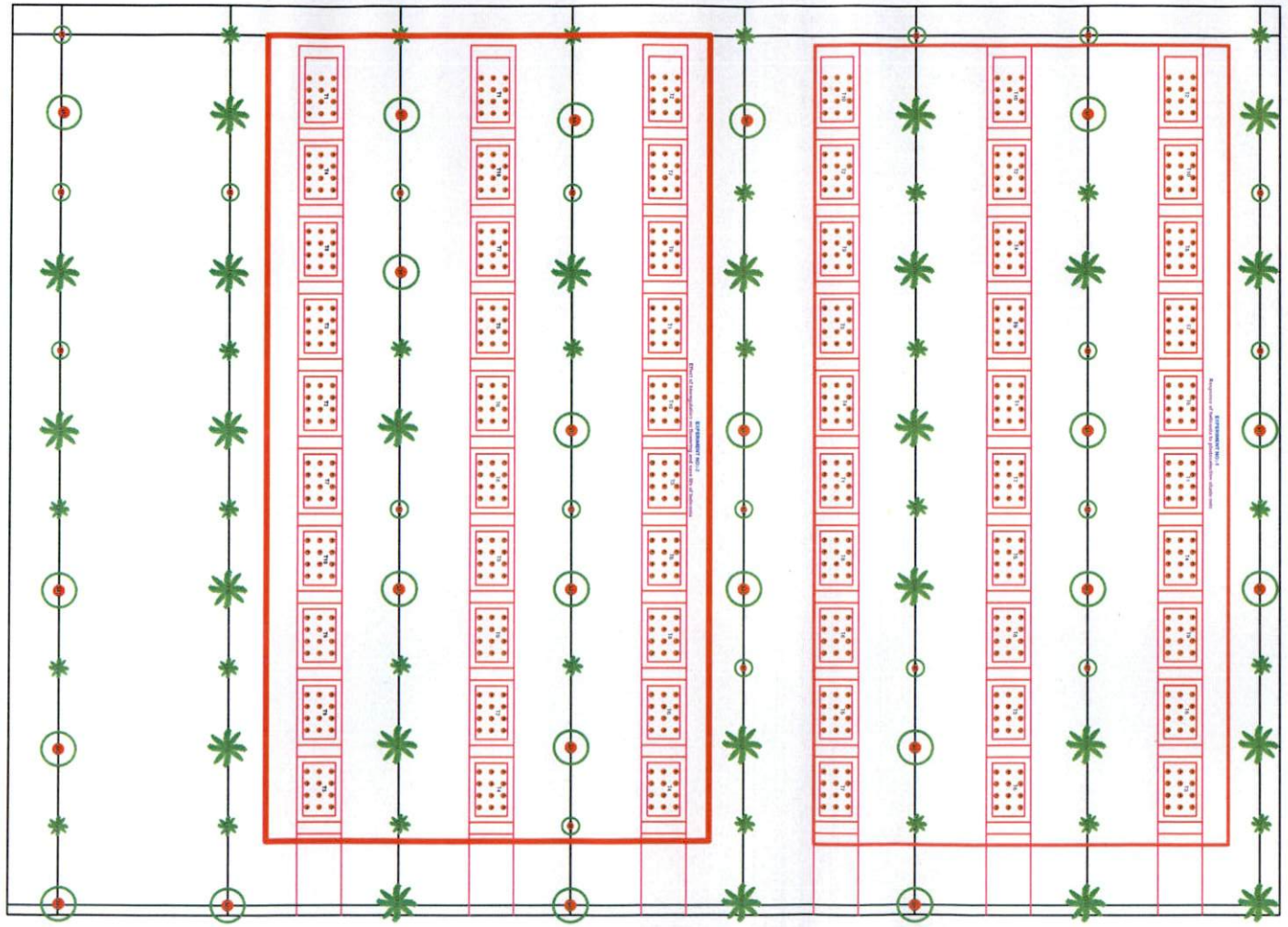
3.4 DESCRIPTION OF VARIETY:

Heliconia psittacorum x spathocircinata cv. Golden Torch is a vigorous, hardy, rhizomatous and perennial herb that grows 4-6 feet tall. It has large musoid leaves that contrast beautifully with the deep yellow flowers. The large yellow bracts and sepals create dramatic displays all year long and are excellent as cut flowers. It can be grown in partial to full sun.

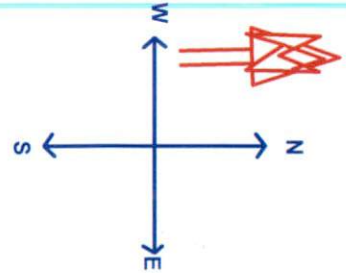
VEGETABLE FIELD

TISSUE CULTURE LAB

POLYHOUSE



FARM ROAD



Sl No	Block	Block Name	Quantity
		Coconut Palm Old	25
		Coconut Missing Old	23
		Coconut Palm Young	28
		Coconut Missing Young	15
		Heliconia	720

CLIENT:	DRAWING TITLE :	PROJECT		PROPOSED BY
RARS PILICODE	LAY OUT OF THE EXPERIMENT IN BLOCK N6 RARS PILICODE	Regulation of growth and flowering in Heliconia		KOKILA, R. 2014-12-123 TEL: ---------- PADANNAKKAD, KASARAGOD Dt.

3.5 LAYOUT OF EXPERIMENT:

The experiment was laid out in N6 block of Regional Agricultural Research Station, Pilicode in Randomized Block Design with 10 treatments and 3 replications. The layout of the experiment is enclosed as plate 1.

Two different experiments were conducted with ten treatments each. The first experiment was to study the response of heliconia to photo selective shade nets and the second experiment was to study the effect of bio-regulators on flowering and vase life of heliconia. The experiment was laid out in RBD with three replications each.

3.5.1 Treatments:

Experiment 1: The response of heliconia to photo selective shade nets

T_1- Red shade net 25 %

T_2- Red shade net 50 %

T_3-Blue shade net 25 %

T_4- Blue shade net 50 %

T_5- Grey shade net 25 %

T_6- Grey shade net 50 %

T_7- Green shade net 25 %

T_8- Green shade net 50 %

T_9-Under coconut plantation (without shade net)

T_{10}-Open condition

Experiment 2: Effect of bio-regulators on flowering and vase life of heliconia

T_1: Paclobutrazol 10 ppm

T_2: Paclobutrazol 20 ppm

T_3: Paclobutrazol 30 ppm

T_4: Cycocel 250 ppm

T_5: Cycocel 500 ppm

T_6: Cycocel 750 ppm

T_7: Ethephon 10 ppm

T_8: Ethephon 20 ppm

T_9: Ethephon 30 ppm

T_{10}: Water spray (Control)

3.5.2 Planting

The collected suckers were initially planted in the nursery at RARS, Pilicode and were maintained in the nursery till sprouting and were transplanted in the main field during first week of May, 2015. Beds of size 3.0 m x 2.4 m were prepared with ridges all around leaving a gap of 0.5 m from the ridges for each treatment. Planting pits of size 20 cm x 20 cm x 20 cm were made with a spacing of 60 cm between the pits.

3.5.3 Crop management:

Organic manure in the form of Farm Yard Manure was applied approximately @ 2 kg per planting pit. The healthy suckers were planted into the pits at a depth of 15 cm. Irrigation was provided twice in a week. Weeding was carried out once in a month. In order to control weed growth, the beds were mulched with dried coconut leaves in between the plants. The mulches were eventually collected and removed when dried.

3.5.4 Imposing of treatments

Experiment 1:

The treatments under Experiment I were imposed 30 days after planting of suckers. Depending on the treatment lay out, shade nets of red, blue, grey and

green with 2 different percentages such as 25 % and 50 % were used for covering the plots. A frame work was initially constructed for spreading the shade nets of size 4.0 m x 3.0 M on which they were tied above the specific plots depending upon the treatments. The shade nets were periodically cleaned of dust and dirt by using irrigation water. The control treatment (T_{10}) and the treatment under coconut plantation (T_9) were left uncovered for comparison.

Experiment 2:

The plant bioregulators used are Paclobutrazol, Cycocel and Ethephon at 3 different concentrations. Treatments were applied from 60 days after planting at 30 days interval till 150 days after planting. Paclobutrazol (95% NLT) of Titan biotech ltd. was used for application. Stock solutions were prepared after dissolving powdered form of paclobutrazol in diluted HCl and the growth retardant was diluted further at the rate of 180 mg/18 *l*, 360 mg/18 *l* and 540 mg/18 *l* attaining a concentration of 10, 20 and 30 ppm respectively. Each plant was applied with 500 ml of pachlobutrazol solution through drenching into the soil. Ethephon (39% EC) of Loba Chemie was prepared at a concentration of 10, 20 and 30ppm by diluting 0.461 ml/18 *l*, 0.92 ml/18 *l* and 1.38 ml/ 18 *l* respectively. This was applied as foliar spray and approximately 500 ml were required for each plant. Cycocel (50 % EC) of Loba Chemie were applied at 3 different concentrations of 250, 500 and 750 ppm by diluting 9 ml/18 l, 18 ml/18 l and 27 ml/18 l respectively. This was also provided as foliar spray (500 ml /plant).

3.6 COLLECTION OF EXPERIMENTAL DATA

3.6.1 Sampling procedure

Six plants were randomly selected from each plot per each replication of all treatments and tagged with labels at 30 days after planting. Observations were recorded at 30 days intervals.

3.7 OBSERVATIONS

3.7.1 Growth parameters

3.7.1.1 Days to tillering

Six plants were selected and tagged from each treatment for observing the total number of days required for the first tillering by counting the days from planting to first tillering and the mean of these readings were expressed as number of days to tillering.

3.7.1.2 Number of tillers (bimonthly intervals)

Number of tillers were counted at 60 days intervals and expressed as the number of tillers per plant.

3.7.1.3 Total number of leaves (at flowering)

The number of leaves present on the plant at the time of flowering was recorded from 6 plants randomly selected from each treatments and the mean of leaf number were expressed as total number of leaves per plant at the time of flowering.

3.7.1.4 Height of the plant at 30 days intervals (cm)

The height of 6 randomly selected and tagged plants per treatment were measured from base of the plant to the tip of the leaf, at 30 days interval. The average height was worked out and expressed in centimeters.

3.7.2 Physiological parameters

3.7.2.1 Leaf area at flowering (cm^2)

The leaf area from all leaves of selected and tagged plants was measured at flowering and total leaf area was calculated by using portable leaf area meter, Model LI-3000A and expressed as square centimeter per plant.

3.7.2.2 Spad chlorophyll meter reading (SCMR)

Chlorophyll content was measured by using SPAD-502 chlorophyll meter, Konica Minolta, Japan at monthly intervals from 30 days after planting and expressed as SCMR. The reading was taken from 12 leaves per plant and the mean of these readings were recorded.

3.7.2.3 Total plant biomass (g)

The biomass was obtained 10 months after planting. Flowered plants from each replication were dried separately in oven till constant weight is obtained. After complete drying, dry weight was measured and expressed as grams per plant (g).

3.7.3 Yield parameters

3.7.3.1 Days to flowering (d)

The number of days taken for commencement of flowering was recorded by counting the days from planting to first flower opening and expressed as number of days to flowering. The observation was taken from 6 plants per treatment and the mean of these values were recorded.

3.7.3.2 Number of florets per inflorescence

Number of florets per inflorescence was recorded from randomly selected 10 flowers from each treatment and the mean of these were expressed as number of florets per inflorescence.

3.7.3.3 Width of bract (cm)

The measure of width of bract was taken from the widest part of the bract and was expressed in centimeters. The observations were recorded from 10 inflorescences and the mean of these readings were recorded.

3.7.3.4 Length of bract (cm)

The measure of length of the bract was taken from the tip to bottom of each bract of an inflorescence and the average was expressed in terms of centimeters. The observations were recorded from 10 inflorescences and the mean of these readings were arrived at.

3.7.3.5 Inter space between bracts (cm)

The measure of inter space between bracts was observed and recorded. The measure was recorded and expressed in terms of centimeters. The observations were made from 10 inflorescences and the mean of these readings were recorded.

3.7.3.6 Length of inflorescence (cm)

The measure of length of inflorescence was taken from the tip to bottom of the stalk and was recorded and expressed in centimeters. The observations were made from 10 inflorescences and the mean of these readings were recorded.

3.7.3.7 Duration of inflorescence from emergence to harvest (d)

The inflorescence was harvested when 2-3 basal bracts were opened. 10 plants each were randomly selected from treatments and the number of days taken from flower emergence to the inflorescence opening and harvesting of 10 flowers were recorded and the mean of these readings were expressed as number of days.

3.7.3.8 Length of stalk (cm)

The length of the stalk was measured from the bottom of the inflorescence to the base of the stalk and were recorded and expressed in centimeters (cm). The observations were recorded from 10 inflorescences and the mean of these readings were recorded.

3.7.3.9 Weight of inflorescence (g)

The number of flowers and fresh weight of flowers were recorded immediately after harvest. The individual weight of inflorescence from 10 randomly selected inflorescences from each treatment was measured and the mean of these readings were expressed as gram per inflorescence (g).

3.7.3.10 Number of inflorescence

The inflorescence were harvested and counted from each plant and the mean of these readings were recorded as number of inflorescence per plant.

3.7.4 Post harvest parameters

3.7.4.1 Vase life (d)

The vase life of inflorescence was observed from the days of harvest till the inflorescence remained fresh. Soon after harvest, the flowers were dipped in cold water for 2hrs. This was transferred to a vase solution containing 5 per cent sucrose + 200 ppm 8 HQC and observed for vase life. Three inflorescences per treatment were observed and the mean of these readings were recorded as number of days.

3.8 STATISTICAL ANALYSIS

Data collected were analyzed using the SAS programme and WASP agri stat ICAR Goa.com.

RESULTS

4. RESULTS

The study entitled "Regulation of growth and flowering in Heliconia (*spp*)" was conducted to find out the response of heliconia to photoselective shade nets and to the application of bioregulators. The data recorded were subjected to statistical analysis and the results are presented in this chapter.

4.1 EFFECT OF PHOTOSELECTIVE SHADE NETS ON GROWTH AND YIELD PARAMETERS OF HELICONIA

4.1.1 Morphological parameters

4.1.1.1 Days to tillering (days)

The results of the effect of photoselective shade nets on the number of days taken from planting to tillering are furnished in Table 1

Table 1. Effect of photo selective shade nets on days to tillering

Treatments	Number of days to tillering (days)
T1 (25 % red shade net)	31.580
T2 (50 % red shade net)	31.137
T3 (25 % blue shade net)	30.110
T4 (50 % blue shade net)	33.053
T5 (25 % grey shade net)	30.610
T6 (50 % gray shade net)	31.137
T7 (25 % green shade net)	33.553
T8 (50 % green shade net)	30.637
T9 (under coconut shade)	32.107
T10 (open condition)	31.747
SEm(±)	**4.488**
C.D(0.05)	**NS**

Plate 2 Layout of experiment 1

Coloured shade nets in general do not significantly alter the number of days taken from planting to tillering. However tillering was the earliest in plants grown under 25 % blue shade nets (T_3). Under this treatment, tillering occurred within 30.11 days after planting. The period required for tillering was longer in plants grown under 25 % green shade nets (T_7).

4.1.1.2 Number of tillers per plant

The observations on tiller production were recorded at 60 days intervals upto 300 days after planting and the data are presented in Table 2.

Table 2. Effect of photo selective shade nets on number of tillers per plant (60 days intervals)

Treatments	60 DAP	120 DAP	180 DAP	240 DAP	300 DAP
T1	0.78	1.33	2.94	5.27	6.00
T2	0.89	0.94	2.12	4.12	4.38
T3	0.94	2.50	4.09	7.37	7.86
T4	0.65	1.05	2.49	4.36	5.41
T5	0.72	0.95	4.05	7.17	7.80
T6	0.83	1.16	4.66	7.54	8.88
T7	0.83	0.99	2.61	4.86	5.90
T8	0.89	2.83	3.26	6.22	7.70
T9	0.77	1.44	3.75	7.11	7.98
T10	0.83	0.55	2.44	4.87	6.08
SEm(±)	**0.09**	**0.18**	**0.21**	**0.11**	**0.57**
C.D(0.05)	**NS**	**0.74**	**0.79**	**0.72**	**1.29**

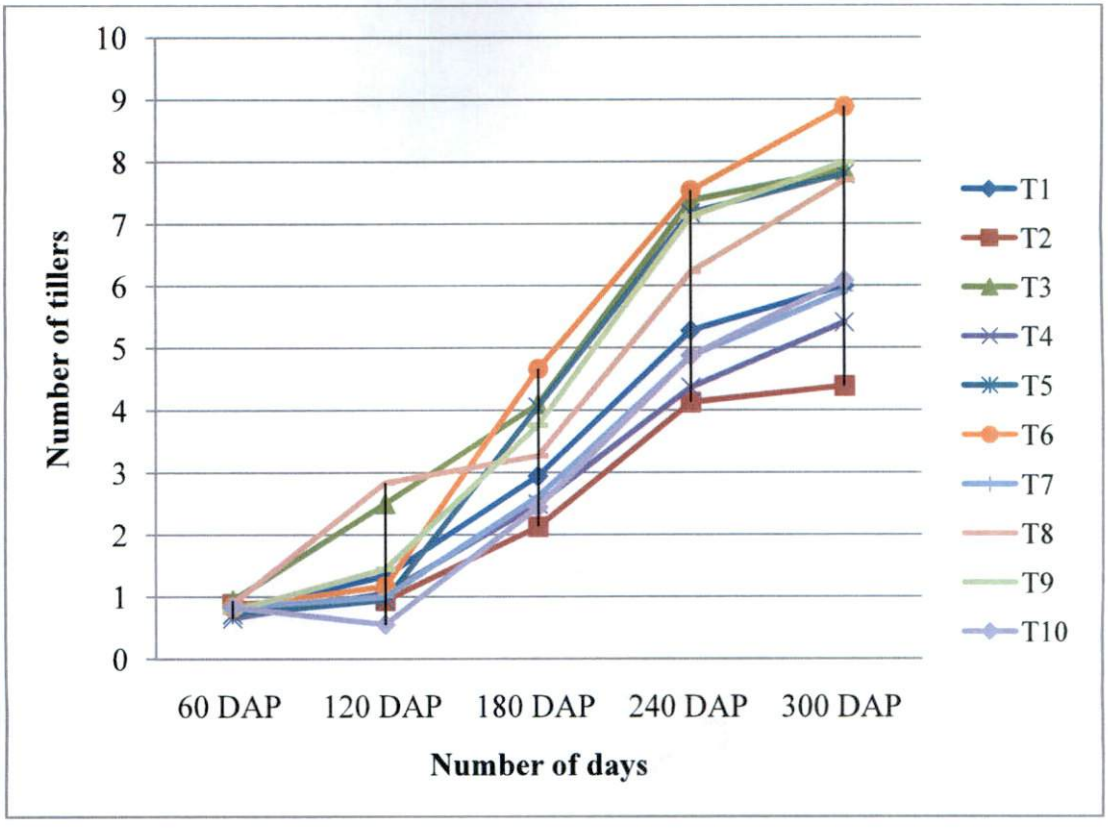


Fig. 1 Effect of photo selective shade nets on number of tillers per plant (60 days intervals)

Maximum tiller production was observed between 180 and 240 days after planting in plants under all the treatments. The number of tillers per plant recorded 180 days after planting varied from 2.12 (T_2) to 4.66 (T_6). The variation in tiller production ranged from 4.12 (T_2) to 7.54 (T_6) at 240 days after planting. The variation in tiller production was from 4.38 (T_2) to 8.88 (T_6) when the plants attained the age of 300 days.

Photoselective shade nets did not significantly influence the production of tillers upto 60 days after planting. Thereafter, the number of tillers per plants showed significant difference between treatments. The plants grown under 50 % green shade nets (T_8) recorded maximum number of tillers 120 days after planting. From 180 days after planting onwards the plants grown under 50 % grey shade net (T_6) produced maximum number of tillers upto 300 days after planting. This was followed by plants grown under coconut shade (T_9) during 300 days after planting. The plants grown under 50 % red shade net (T_2) recorded the lowest number of tillers from 120 days after planting onwards upto 300 days after planting.

4.1.1.3 Total number of leaves

Total numbers of leaves per plant were recorded at the time of flowering. The mean data of the statistical analysis are presented in Table 3.

The total number of leaves at flowering stage varied from 20.33 to 27.55. Among the treatments the plants grown under 50 % green shade nets (T_8) produced highest number of leaves followed by the plants grown under 50 % grey shade nets. However the photoselective colored shade nets did not show significant influence on the number of leaves produced by the plants at flowering.

Table 3. Effect of photo selective shade nets on total number of leaves (at flowering)

Treatments	Number of leaves (at flowering)
T1 (25 % red shade net)	22.00
T2 (50 % red shade net)	24.66
T3 (25 % blue shade net)	23.94
T4 (50 % blue shade net)	20.43
T5 (25 % grey shade net)	22.77
T6 (50 % gray shade net)	26.50
T7 (25 % green shade net)	21.16
T8 (50 % green shade net)	27.55
T9 (under coconut shade)	25.89
T10 (open condition)	23.05
SEm(±)	**16.04**
C.D(0.05)	**NS**

4.1.1.4 Plant height

The plant height was measured at 30 days intervals from 30 days after planting to 180 days after planting. The data are presented in Table 4.

The plants grown under coconut shade (T_9) exhibited maximum plant height during the entire growth period upto 180 days after planting. Under this treatment, the plant height was 44.4 cm at 30 days after planting and gradually increased upto 74.63 cm. From 90 days after planting up to 180 days after planting, plants grown under open condition (T_{10}) recorded minimum plant height. The plant height differed significantly among the treatments from 60 days after planting to 180 days after planting.

Minimum plant height under green shade net 25 %

Maximum plant height under coconut plantation

Plate 3. Effect of photoselective shade nets on plant height

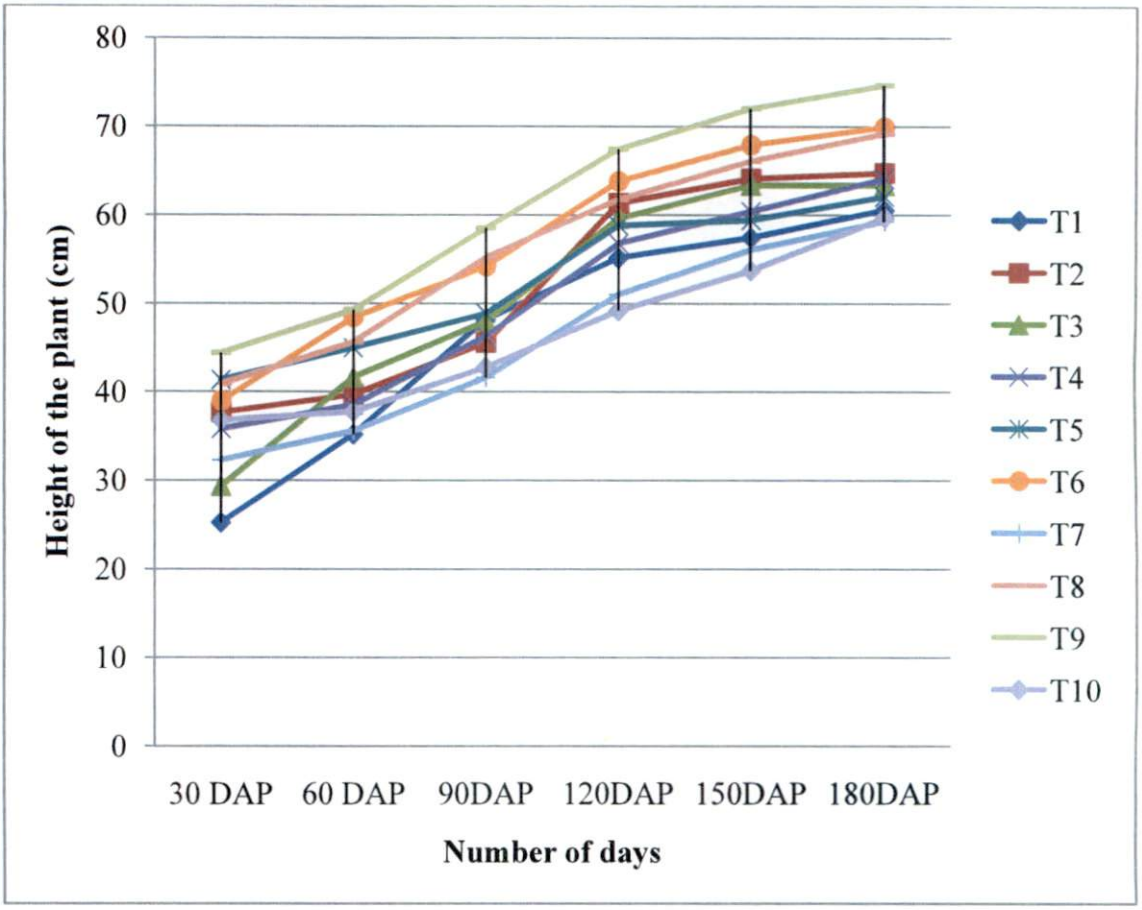


Fig. 2 Effect of photo selective shade nets on height of the plant (30 days intervals)

Table 4. Effect of photo selective shade nets on height of the plant (30 days intervals)

Treatments	30DAP (cm)	60DAP (cm)	90DAP (cm)	120DAP (cm)	150DAP (cm)	180DAP (cm)
T1	25.20	35.20	48.20	55.16	57.44	60.55
T2	37.70	39.70	45.56	61.36	64.16	64.79
T3	29.33	41.63	48.00	59.59	63.37	63.37
T4	35.83	38.53	46.33	56.77	60.41	64.08
T5	41.33	45.00	48.90	58.82	59.41	62.08
T6	39.00	48.43	54.20	63.83	67.9	69.96
T7	32.26	35.60	41.60	51.04	56.05	59.26
T8	40.86	45.66	55.20	61.78	66.13	69.20
T9	44.40	49.30	58.50	67.45	72.02	74.63
T10	36.80	37.76	42.76	49.20	53.74	59.68
SEm(±)	**85.63**	**24.92**	**19.80**	**16.47**	**15.28**	**12.95**
C.D(0.05)	**NS**	**8.56**	**7.63**	**6.96**	**6.70**	**6.17**

4.1.2 Physiological parameters

4.1.2.1 Leaf area at flowering

The mean leaf area at the time of flowering was measured. The treatments differed significantly with respect to the mean leaf area at flowering. Maximum leaf area was recorded in plants grown under 25 % red shade net (T_1) and minimum in plants grown under 25 % red shade net (T_5) as presented in Table 5.

4.1.2.2. SCMR (at flowering)

The observation recorded for SCMR is presented in Table 5.

Significant difference was observed in the SCMR chlorophyll meter reading recorded at the time of flowering. Maximum reading (49.02) was recorded by plants grown under 25 % grey shade net (T_5). It was followed by the plants grown under 50 % green shade net (T_8). Minimum SCMR (36.73) was recorded by plants grown under 25 % red shade net (T_1).

Table 5. Effect of photo selective shade nets on leaf area and SCMR (at flowering)

Treatments	Leaf area at flowering (cm^2)	SPAD reading
T1	178.71	36.73
T2	166.57	45.91
T3	142.75	41.51
T4	146.97	45.70
T5	131.22	49.02
T6	144.19	44.61
T7	149.37	39.50
T8	165.05	48.26
T9	145.95	45.45
T10	152.29	37.24
SEm(±)	**169.39**	**8.14**
C.D(0.05)	**22.32**	**4.89**

4.1.2.3 Fresh weight of shoot, fresh weight of inflorescence, fresh weight of total plant biomass, dry weight of shoot, dry weight of inflorescence and dry weight of total plant biomass (300 days after planting)

The observation recorded on fresh weight of shoot, fresh weight of inflorescence, fresh weight of total plant biomass, dry weight of shoot and total plant biomass is presented in Table 6.

The treatment differed significantly with regard to the total fresh weight of plants at 300 days after planting. The maximum fresh weight of shoot and total plant biomass was recorded in plants under 50 % red shade nets (T_2). The minimum was observed in plants under open condition (T_{10}). The maximum fresh weight of inflorescence was recorded in plants under 25 % grey shade nets (T_5). The minimum fresh weight of inflorescence was recorded in plants under 25 % red shade nets (T_2).

The treatments differed significantly with respect to the total dry weight of shoot at 300 days after planting. The minimum dry weight of shoot (330 g) was recorded by the plants grown under 25 % grey shade nets (T_5). The maximum dry weight (594g) of shoot was observed in plants under 50 % red shade net (T_2). The maximum dry weight of inflorescence was recorded in plants under 25 % grey shade net (T_5). The minimum dry weight of inflorescence was recorded in plants under 50 % red shade nets (T_2).

Significant differences were observed with regard to total biomass of plants recorded 300 days after planting. Plants grown under coconut shade (T_9) recorded the lowest plant biomass (411.08g) followed by T_4 (412.54g). The plants grown under 50 % red shade nets (T_2) recorded the maximum biomass (642.89g). The maximum dry weight of inflorescence to dry weight of total plant biomass was recorded in plants grown under 25 % grey shade net and the minimum was observed in plants under 50 % red shade nets.

Table 6. Effect of photo selective shade nets on fresh weight of shoot, fresh weight of inflorescence, fresh weight of total plant biomass, dry weight of shoot, dry weight of inflorescence and dry weight of total plant biomass.

Treatments	Fresh weight of shoot (g)	Fresh weight of inflorescence per plant(g)	Fresh weight of total plant biomass (g)	Dry weight of shoot (g)	Dry weight of inflorescences per plant (g)	Total biomass (g)	Ratio (I:S)
T1	958.00	103.57	967.33	454.00	53.90	509.35	10:90
T2	1196.96	64.62	1241.00	594.00	49.83	642.89	8:92
T3	974.99	108.53	1041.66	408.00	63.43	473.10	14:86
T4	975.52	73.82	1040.33	348.00	59.53	412.54	16:84
T5	898.80	147.61	1126.66	330.00	85.10	418.70	21:79
T6	875.60	70.22	985.66	462.00	64.36	522.11	12:88
T7	992.83	94.00	995.66	417.00	52.28	467.98	11:89
T8	918.84	136.8	1077.66	376.00	63.50	436.12	14:86
T9	1051.05	85.5	1126.66	361.00	52.70	411.08	13:87
T10	772.60	67.2	958.00	488.00	53.33	538.93	12:88
SEm(±)	31491.9	156.45	8257.12	40.03	50.53	5433.63	
C.D(0.05)	NS	NS	NS	10.85	NS	126.45	

4.1.3 Yield parameters

4.1.3.1 Days to flowering and duration from inflorescence emergence to harvest

The number of days taken for first flowering and the duration from inflorescence emergence to harvest were recorded and data are presented in Table 7.

The data revealed that there were no significant differences between the treatments with regard to the days to flowering and duration of inflorescence emergence to harvest.

Stage 1: Emergence

Stage 2: 5 days after emergence

Stage 3: 10-15 days after emergence

Stage 4: 15-20 days after emergence

Plate 4. Different stages of inflorescence emergence to harvest

Table 7. Effect of photo selective shade nets on days to flowering and duration from inflorescence emergence to harvest

Treatments	Days to flowering	Duration from inflorescence emergence to harvest
T1	151.33	20.37
T2	151.33	19.77
T3	153.67	18.50
T4	150.33	18.00
T5	150.67	20.53
T6	153.33	17.77
T7	153.33	19.37
T8	155.67	20.60
T9	145.00	21.10
T10	143.00	20.43
SEm(±)	**50.44**	**18.12**
C.D(0.05)	**NS**	**NS**

4.1.3.2 Number of inflorescence and number of florets per inflorescence

The number of inflorescence and number of florets per inflorescence were recorded and data are presented in Table 8.

The analysis of data on the number of inflorescence revealed that the treatments differed significantly for the parameter. The maximum number of inflorescence was recorded in T_5 (6.05) followed by T_3 (5.69). The minimum number of inflorescence was recorded in T_2 (3.91) followed by T_4 (4.05).

Maximum number of inflorescence in plants grown under grey shade net 25 %

Minimum number of inflorescence in plants grown under red shade net 50 %

Plate 5. Effect of photoselective shade nets on number of inflorescence per plant

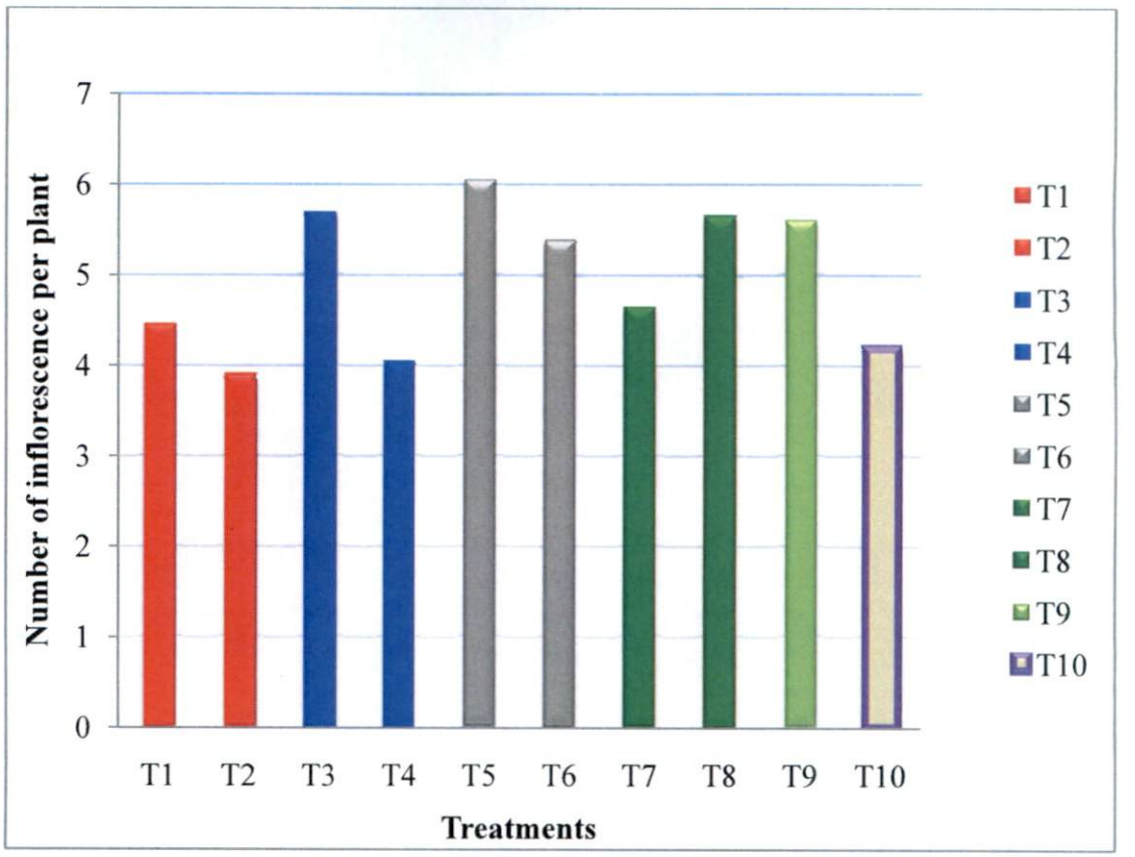


Fig. 3 Effect of photo selective shade nets on number of inflorescence per plant

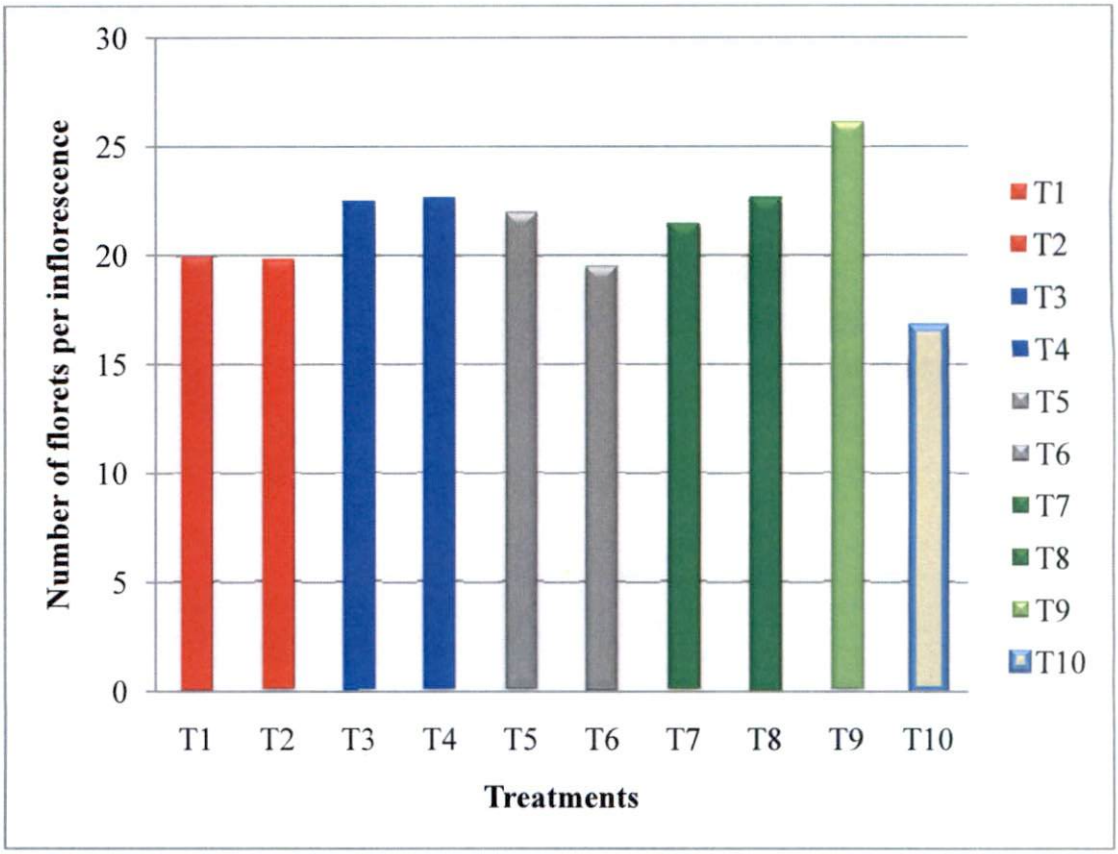


Fig. 4 Effect of photo selective shade nets on number of florets per inflorescence

The treatments differed significantly with regard to the number of florets per inflorescence. The maximum number of florets per inflorescence was recorded in T_9 (26.17) followed by T_8 (22.67). The minimum number of florets per inflorescence was recorded in T_{10} (16.67).

Table 8. Effect of photo selective shade nets on number of inflorescence and number of florets per inflorescence

Treatments	Number of inflorescence per plants	Number of florets per inflorescence
T1	4.47	20.00
T2	3.91	19.83
T3	5.69	22.50
T4	4.05	22.67
T5	6.05	22.00
T6	5.39	19.50
T7	4.66	21.50
T8	5.66	22.67
T9	5.61	26.17
T10	4.19	16.67
SEm(±)	**0.13**	**6.46**
C.D(0.05)	**0.62**	**4.36**

4.1.3.3 Bract characters

The number of bracts per inflorescence, the length and width of bract and interspace between bracts at the time of harvest were recorded and the data analyzed are presented in the Table 9.

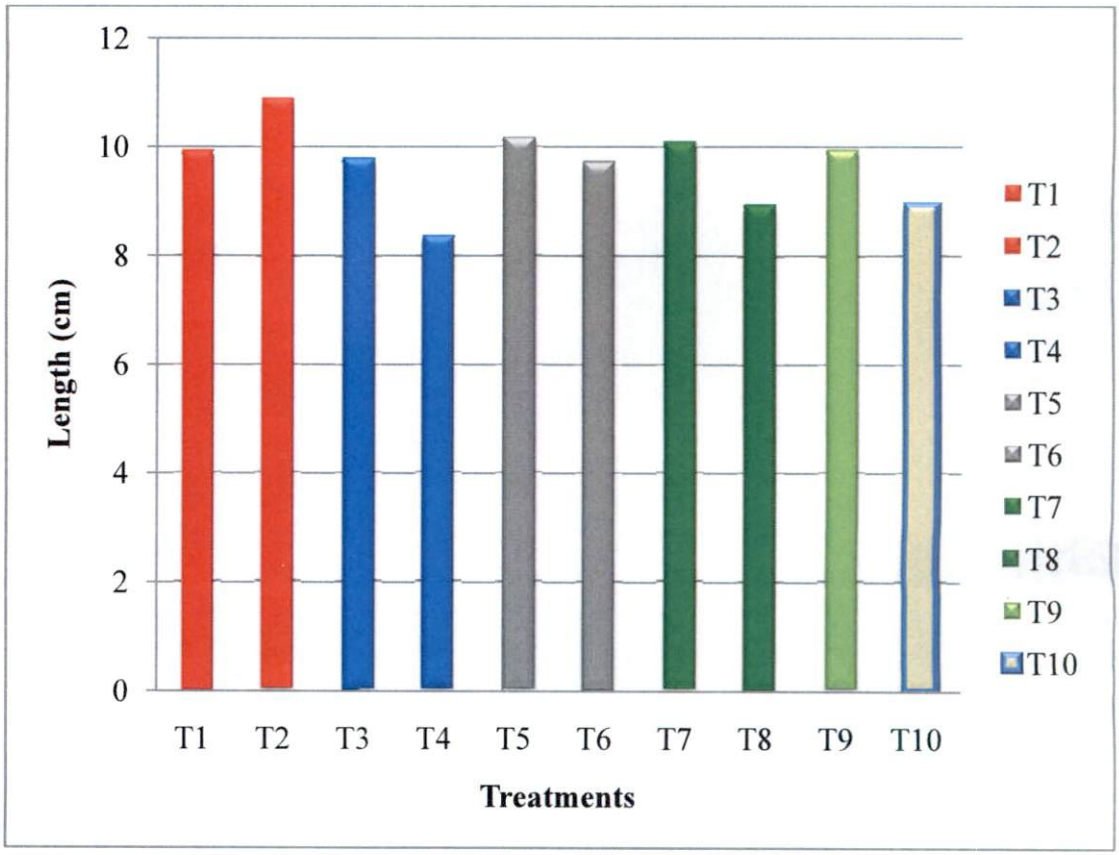


Fig. 5 Effect of photo selective shade nets on length of bract

The analysis of data on the number of bracts, width of bract, inter space between bracts revealed that the treatments did not differ significantly.

The treatments differed significantly for bract length. The maximum bract length was recorded by T_2 (10.92 cm) followed by T_5 (10.17) minimum bract length were observed in plants under T_4 (8.38 cm).

Table 9. Effect of photo selective shade nets on number of bract per inflorescence, width of bract, length of bract and interspace between bracts

Treatments	No of bracts per inflorescence	Width of bract (cm)	Length of bract (cm)	Interspace between bracts (cm)
T1	4.33	1.75	9.93	3.00
T2	5.00	1.97	10.92	3.00
T3	4.50	1.55	9.81	3.08
T4	4.50	1.60	8.38	3.00
T5	4.67	1.58	10.17	3.00
T6	4.33	1.35	9.73	3.08
T7	4.67	1.77	10.09	3.00
T8	5.00	1.67	8.94	3.00
T9	4.67	1.53	9.95	3.00
T10	4.50	1.68	8.92	3.00
SEm(±)	**0.17**	**0.07**	**0.30**	**0.004**
C.D(0.05)	**NS**	**NS**	**0.95**	**NS**

4.1.3.4 Inflorescence characters

The length of inflorescence, length of inflorescence stalk, fresh and dry weight of inflorescence was recorded and the data are presented in Table 10.

Length of inflorescence differed significantly among the treatments. The maximum length of inflorescence (18.16 cm) was recorded in the plants grown under T_2 followed by T_8 (17.67 cm). The minimum length of inflorescence was recorded in T_6 (15.50 cm).

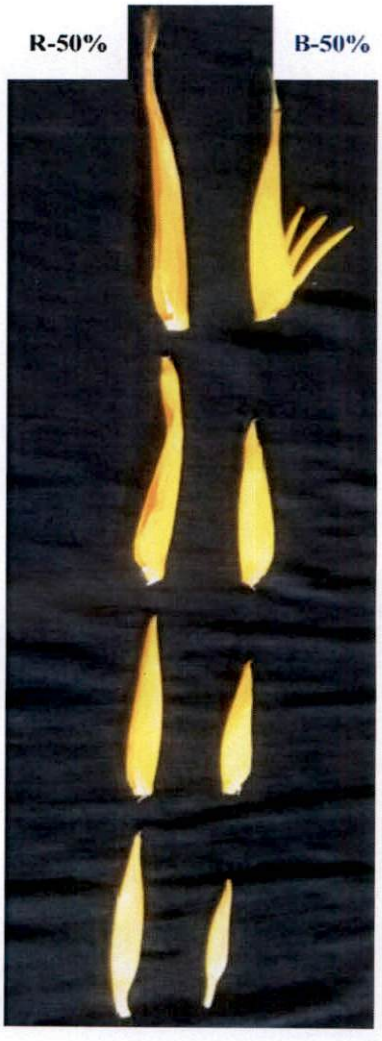


Plate 6. Effect of photoselective shade nets on length of bract

Maximum bract length- Red shade net 50 % (10.92 cm)

Minimum bract length- Blue shade net 50 % (8.38 cm)

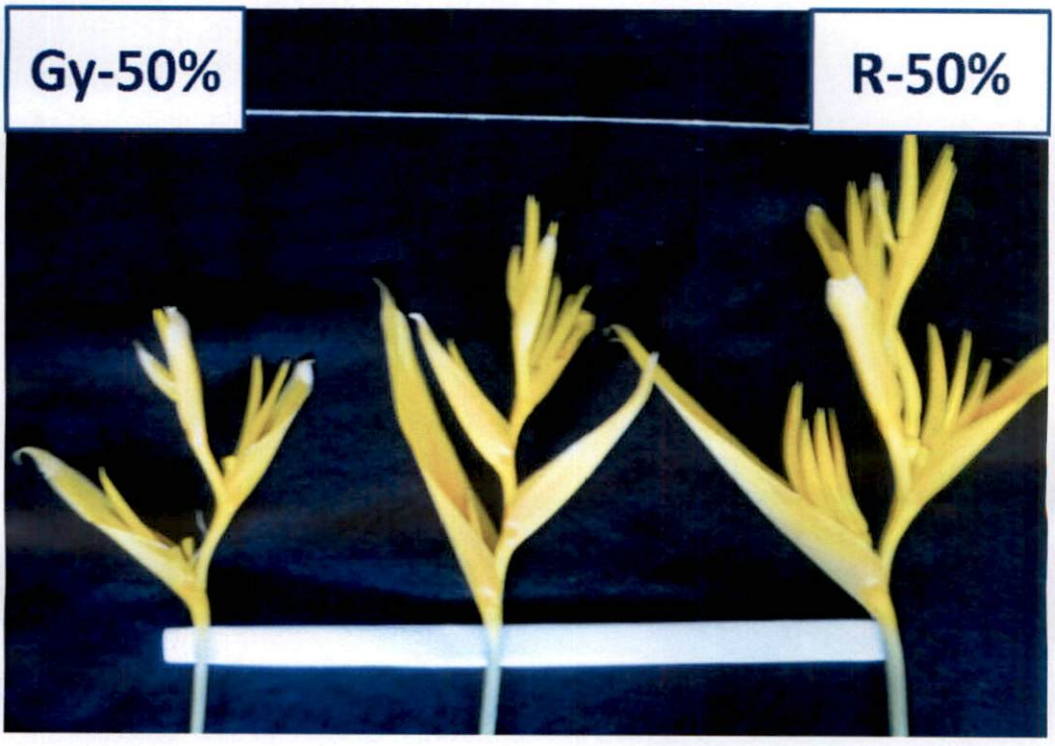


Plate 7. Effect of photoselective shade nets on inflorescence length

Maximum inflorescence length- Red shade net 50 % (18.17 cm)

Minimum inflorescence length- Grey shade net 50 % (15.50 cm)

The analysis of data on the dry weight of inflorescence revealed that the treatments did not differ significantly for this parameter.

Table 10. Effect of photo selective shade nets on length of inflorescence, length of stalk, dry weight of inflorescence

Treatments	Length of inflorescence (cm)	Length of stalk (cm)	Dry Weight of inflorescence (g)
T1	16.00	50.33	11.66
T2	18.17	55.17	12.51
T3	16.00	50.50	13.11
T4	17.00	50.83	16.68
T5	16.50	47.83	13.09
T6	15.50	50.33	12.60
T7	16.67	43.67	12.36
T8	17.67	51.00	12.93
T9	16.67	50.67	10.78
T10	16.50	41.92	12.91
SEm(±)	**0.56**	**87.93**	**22.48**
C.D(0.05)	**1.29**	**NS**	**NS**

4.1.4 Post harvest parameters

4.1.4.1 Vase life

Analysis of data on vase life of flowers revealed that different photo selective shade nets and their shading intensity did not show any significant difference in the vase life of inflorescence. However the maximum vase life was observed under the treatment T_4 and the minimum was observed under treatment T_3 when treated with 200 ppm 8 HQC+ 5 % sucrose, as presented in Table 11.

Table 11. Effect of bioregulators on vase life

Treatments	Vase life in days (200ppm 8HQC+ 5 % sucrose)	Vase life (control)
T1 (25 % red shade net)	6.000	4.67
T2(50 % red shade net)	5.000	3.33
T3(25 % blue shade net)	6.333	4.00
T4(50 % blue shade net)	7.333	4.00
T5(25 % grey shade net)	7.000	3.33
T6(50 % gray shade net)	6.667	4.33
T7(25 % green shade net)	6.000	4.67
T8(50 % green shade net)	5.667	3.67
T9(under coconut shade)	5.667	3.67
T10(open condition)	7.000	4.67
SEm(±)	1.848	0.404
C.D(0.05)	NS	NS

3.1.5 Multiple correlation

The correlation coefficient for different growth and yield parameters is presented in Table 12a, 12b and 12c.

Among the different parameters, plant height at various stages are significantly positively correlated with number of tillers at 300 DAP (0.8**) and number of leaves (0.7**). SCMR were also positively correlated with plant height at various stages. Highly significant positive correlation was observed between total number of flowers and number of tillers (0.8**) along with plant height (0.9**). Width of the bracts exhibited significantly negative correlation with number of tillers (-0.8**) and plant heights (-0.6*).

The interspaces between bracts exhibited significant positive correlation with number of tillers (0.69*). Length of inflorescence exhibited a significantly negative correlation with number of tillers (-0.64*). The length of stalk is significantly positively correlated with plant height (0.75*)

Table 12a. Multiple correlation between growth and yield parameters of heliconia (A to O vs A to O)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	1														
B	-0.5	1													
C	-0.5	0.51	1												
D	-0.5	0.09	0.36	1											
E	-0.6	0.17	0.44	0.974	1										
F	-0.5	0.13	0.45	0.945	0.96	1									
G	-0.6	0.54	0.52	0.478	0.54	0.58	1								
H	-0.1	-0.2	-0.06	0.232	0.29	0.35	0.551	1							
I	-0.4	0.05	0.33	0.75*	0.7**	0.8**	0.7**	0.77	1						
J	-0.4	0.01	0.5	0.64*	0.6**	0.71*	0.7**	0.55	0.87	1					
K	-0.4	0.1	0.42	0.569	0.59	0.52	0.7*	0.55	0.85	0.87	1				
L	-0.3	0.18	0.45	0.53	0.55	0.53	0.7**	0.56	0.84	0.88	0.972	1			
M	-0.2	0.05	0.37	0.477	0.51	0.54	0.7**	0.67	0.87	0.92	0.91	0.961	1		
N	0.02	0.25	0.15	-0.54	-0.53	-0.5	0.079	-0.43	-0.44	-0.1	-0.13	-0.11	-0.11	1	
O	-0.3	-0.2	0.26	0.316	0.32	0.3	0.442	0.74*	0.70*	0.53	0.68*	0.607	0.58	-0.37	1

**- Correlation is significant at the 0.01 level *- Correlation is significant at the 0.05 level

Characters code

A=Days to tillering, B= Number of tillers 60 DAP, C= Number of tillers 120 DAP, D= Number of tillers 180 DAP, E= Number of tillers 240 DAP, F= Number of tillers 300 DAP, G= Number of leaves, H= Plant height at 30 DAP, I= Plant height at 60 DAP, J= Plant height at 90 DAP, K= Plant height at 120 DAP, L= Plant height at 150 DAP, M= Plant height at 180 DAP, N= Leaf area, O= SCMR, P= Shoot dry weight, Q= Total plant biomass, R= Days to flowering, S= Duration from inflorescence emergence to harvest, T= Number of inflorescence, U= Number of florets per inflorescence, V= Number of bracts, W= Width of bract, X= Length of bract, Y= Interspace between bract, Z= Length of inflorescence, AA= length of stalk, AB= Dry weight of inflorescence, AC= Vase life.

Table 12b. Multiple correlation between growth and yield parameters of heliconia (A to O vs P to AC)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
P	-0.1	0.51	-0.31	-0.42	-0.46	-0.51	0.122	-0.24	-0.33	-0.4	-0.15	-0.13	-0.2	0.53	-0.4
Q	-0.2	0.5	-0.32	-0.38	-0.42	-0.49	0.11	-0.23	-0.32	-0.4	-0.15	-0.15	-0.24	0.48	-0.3
R	-0.3	0.34	0.57	0.241	0.16	0.16	0.165	-0.28	0.02	0.07	0.174	0.149	-0.01	0.14	0.28
S	-0.1	0.01	0.02	-0.19	-0.01	-0.04	0.199	0.29	0.07	0.2	0.012	-0.03	0.07	0.28	0.01
T	-0.5	0.15	0.55	0.8**	0.9**	0.8**	0.508	0.36	0.74*	0.65*	0.525	0.482	0.44	-0.51	0.46
U	0.08	-0.2	0.47	0.315	0.39	0.34	0.173	0.33	0.48	0.59	0.618	0.623	0.59	-0.28	0.52
V	-0.1	0.32	0.28	-0.34	-0.23	-0.25	0.38	0.48	0.16	0.09	0.254	0.253	0.22	0.18	0.56
W	0.18	0.2	-0.19	-0.8**	-0.8**	-0.8**	-0.29	-0.28	-0.6*	-0.6	-0.39	-0.41	-0.47	0.62	-0.2
X	-0.2	0.34	-0.17	0.099	0.11	-0.09	0.122	-0.05	0.04	-0	0.252	0.164	-0.01	0.07	0.03
Y	-0.5	0.45	0.33	0.69*	0.62	0.58	0.319	-0.19	0.34	0.21	0.301	0.332	0.2	-0.33	-0
Z	0.07	0.11	0.08	-0.64*	-0.56	-0.57	0.13	0.35	-0.09	-0.1	0.094	0.094	0.09	0.34	0.44
AA	-0.4	0.11	0.38	0.119	0.08	-0.03	0.394	0.1	0.33	0.48	0.746*	0.669*	0.53	0.3	0.53
AB	0.21	-0.4	-0.07	-0.24	-0.34	-0.28	-0.46	-0.06	-0.24	-0.3	-0.25	-0.27	-0.25	-0.24	0.24
AC	0.14	-0.6	-0.32	0.208	0.12	0.2	-0.46	-0.03	-0.06	-0.2	-0.38	-0.41	-0.31	-0.58	-0.1

**- Correlation is significant at the 0.01 level *- Correlation is significant at the 0.05 level

Characters code

A=Days to tillering, B= Number of tillers 60 DAP, C= Number of tillers 120 DAP, D= Number of tillers 180 DAP, E= Number of tillers 240 DAP, F= Number of tillers 300 DAP, G= Number of leaves, H= Plant height at 30 DAP, I= Plant height at 60 DAP, J= Plant height at 90 DAP, K= Plant height at 120 DAP, L= Plant height at 150 DAP, M= Plant height at 180 DAP, N= Leaf area, O= SCMR, P= Shoot dry weight, Q= Total plant biomass, R= Days to flowering, S= Duration from inflorescence emergence to harvest, T= Number of inflorescence, U= Number of florets per inflorescence, V= Number of bracts, W= Width of bract, X= Length of bract, Y= Interspace between bract, Z= Length of inflorescence, AA= length of stalk, AB= Dry weight of inflorescence, AC= Vase life.

Table 12c. Multiple correlation between growth and yield parameters of heliconia (P to AC vs P to AC)

	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
P	1													
Q	0.991	1												
R	-0.06	-0	1											
S	-0.06	-0.1	-0.42	1										
T	-0.61	-0.6	0.268	0.169	1									
U	-0.67	-0.7	0.131	0.146	0.52	1								
V	0.133	0.13	0.198	0.428	0.041	0.25	1							
W	0.551	0.54	0.001	0.37	-0.62	-0.2	0.554	1						
X	0.452	0.48	0.138	0.207	0.101	0.02	0.24	0.364	1					
Y	0.074	0.1	0.365	-0.67	0.379	-0.0	-0.45	-0.62	0.06	1				
Z	0.235	0.22	0.057	0.329	-0.33	0.13	0.90	0.704	0.08	-0.609	1			
AA	0.171	0.19	0.387	-0.15	0.041	0.37	0.31	0.09	0.29	0.163	0.356	1		
AB	-0.26	-0.2	0.152	-0.59	-0.31	-0.0	-0.09	-0.09	-0.63	-0.003	0.157	0.03	1	
AC	-0.47	-0.4	-0.23	-0.39	0.041	-0.2	-0.63	-0.55	-0.62	0.168	-0.52	-0.4	0.62	1

**- Correlation is significant at the 0.01 level *- Correlation is significant at the 0.05 level

Characters code

P= Shoot dry weight, Q= Total plant biomass, R= Days to flowering, S= Duration from inflorescence emergence to harvest, T= Number of inflorescence, U= Number of florets per inflorescence, V= Number of bracts, W= Width of bract, X= Length of bract, Y= Interspace between bract, Z= Length of inflorescence, AA= length of stalk, AB= Dry weight of inflorescence, AC= Vase life.

Plate 8. Layout of experiment II

4.2 EFFECT OF BIO-REGULATORS ON GROWTH AND YIELD OF HELICONIA

4.2.1 Morphological parameters

4.2.1.1 Days to tillering

The results on the effect of bioregulators on the number of days taken from planting to tillering are presented in Table 13.

The data regarding the days to tillering revealed that the treatments did not show any significant difference in the days to tillering.

Table 13. Effect of bio-regulators on days to tillering

Treatments	No of days to tillering
T1 (Paclobutrazol 10 ppm)	33.59
T2 (Paclobutrazol 20 ppm)	30.75
T3 (Paclobutrazol 30 ppm)	31.90
T4 (Cycocel 250 ppm)	31.17
T5 (Cycocel 500 ppm)	31.30
T6 (Cycocel 750 ppm)	31.22
T7 (Ethephon 10 ppm)	32.45
T8 (Ethephon 20 ppm)	30.14
T9 (Ethephon 30 ppm)	32.39
T10 (Control)	31.40
SEm(±)	**3.87**
C.D(0.05)	**NS**

4.2.1.2 Number of tillers per plant

The observations on tiller production were recorded at bimonthly intervals upto 300 days after planting and the data are presented in Table 14.

Maximum tiller production was observed between 240 and 300 days after planting under all the treatments. The number of tillers per plant recorded 180 days after planting varied from 2.23 (T_5) to 3.33 (T_9). The variation in tiller production ranged from 3.05 (T_2) to 4.05 (T_7) at 240 days after planting. The variation in tiller production was from 5.09 (T_2) to 8.72 (T_8) when the plants attained the age of 300 days.

The bio-regulators did not significantly influence the production of tillers upto 120 days after planting. Thereafter, the number of tillers per plants showed significant difference between treatments. The plants treated with 30 ppm of ethephon (T_9) recorded maximum number of tillers and plants treated with cycocel 500 ppm showed lowest number of tillers 180 days after planting. At 240 days after planting, the plants treated with 10 ppm of ethephon (T_7) showed highest number of tillers followed by 30 ppm of ethephon (T_9) and the lowest number of tillers was recorded by plants treated with 20 ppm of paclobutrazol (T_2). The plants treated with 20 ppm of ethephon (T_8) showed highest number of tillers followed by 10 ppm of ethephon (T_7) during 300 days after planting.

Table 14. Effect of bioregulators on number of tillers (60 days intervals)

Treatments	60DAP	120DAP	180DAP	240DAP	300DAP
T1	0.72	2.05	2.60	3.61	6.20
T2	0.72	2.04	2.53	3.05	5.09
T3	0.50	2.50	2.80	3.50	6.48
T4	0.70	2.33	2.60	3.67	5.66
T5	0.67	2.10	2.23	3.44	5.22
T6	0.42	2.33	2.37	3.67	5.33
T7	0.78	2.11	2.60	4.05	8.14
T8	0.60	1.89	2.37	3.67	8.72
T9	0.32	2.22	3.33	3.86	6.81
T10	0.54	2.09	2.35	3.44	5.25
SEm(±)	**0.11**	**1.33**	**0.12**	**0.07**	**0.85**
C.D(0.05)	**NS**	**NS**	**0.59**	**0.46**	**1.58**

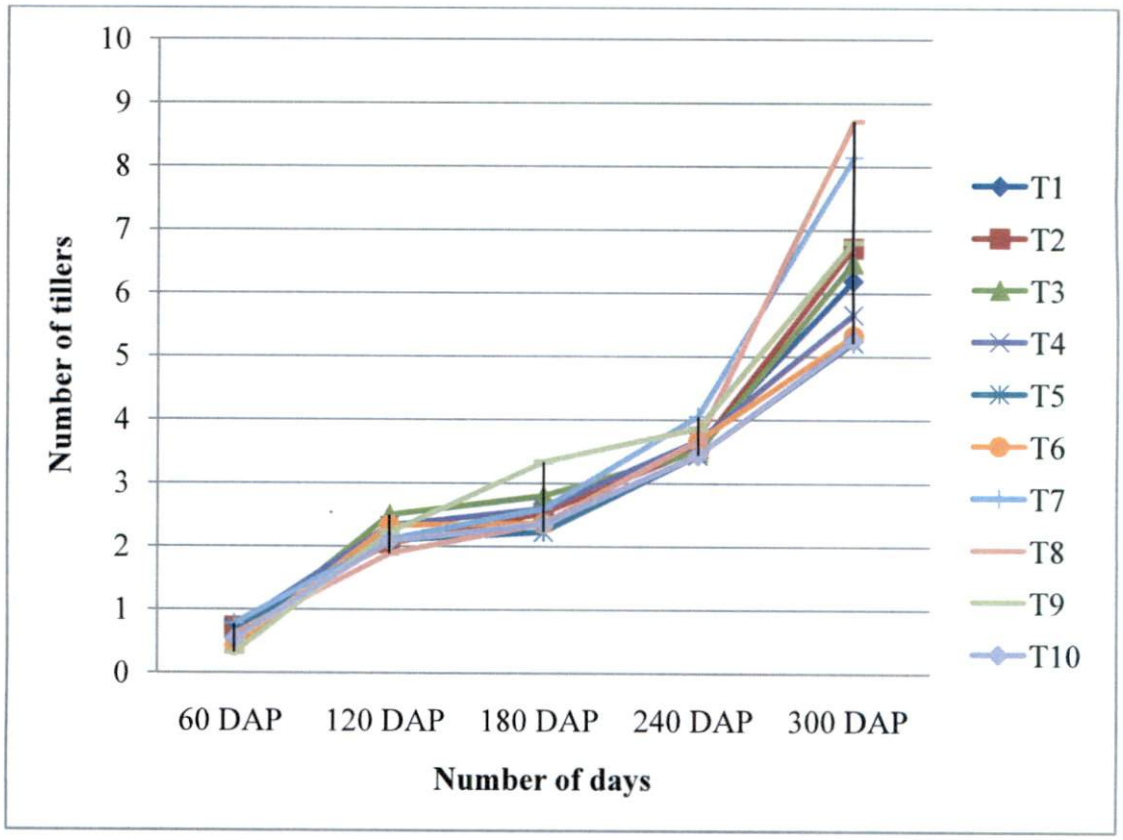


Fig. 6 Effect of bioregulators on number of tillers (60 days intervals)

Maximum number of tillers in plants treated with ethephon 20 ppm

Minimum number of tillers in plants treated with cycocel 500 ppm

Plate 9. Effect of bioregulators on number of tillers per plant

4.2.1.3 Total number of leaves

Total numbers of leaves per plant were recorded at the time of flowering. The mean data of the statistical analysis are presented in Table 15.

Significant differences were observed in the total number of leaves recorded at the time of flowering. Maximum number of leaves (38.83) was recorded by plants treated with 20 ppm of paclobutrazol (T_2). It was followed by the plants treated with 10 ppm of ethephon (T_7). Minimum number of leaves (22.86) was recorded by plants treated with 30 ppm of ethephon (T_9)

Table 15. Effect of bio-regulators on total number of leaves

Treatments	Total number of leaves
T1 (Paclobutrazol 10 ppm)	31.94
T2 (Paclobutrazol 20 ppm)	38.83
T3 (Paclobutrazol 30 ppm)	30.44
T4 (Cycocel 250 ppm)	27.05
T5 (Cycocel 500 ppm)	27.05
T6 (Cycocel 750 ppm)	25.61
T7 (Ethephon 10 ppm)	33.50
T8 (Ethephon 20 ppm)	24.22
T9 (Ethephon 30 ppm)	22.86
T10 (Control)	27.22
SEm(±)	**24.28**
C.D(0.05)	**8.45**

4.2.1.4 Plant height

The plant height was measured at monthly intervals from 30 days after planting to 180 days after planting. The data are presented in Table 16.

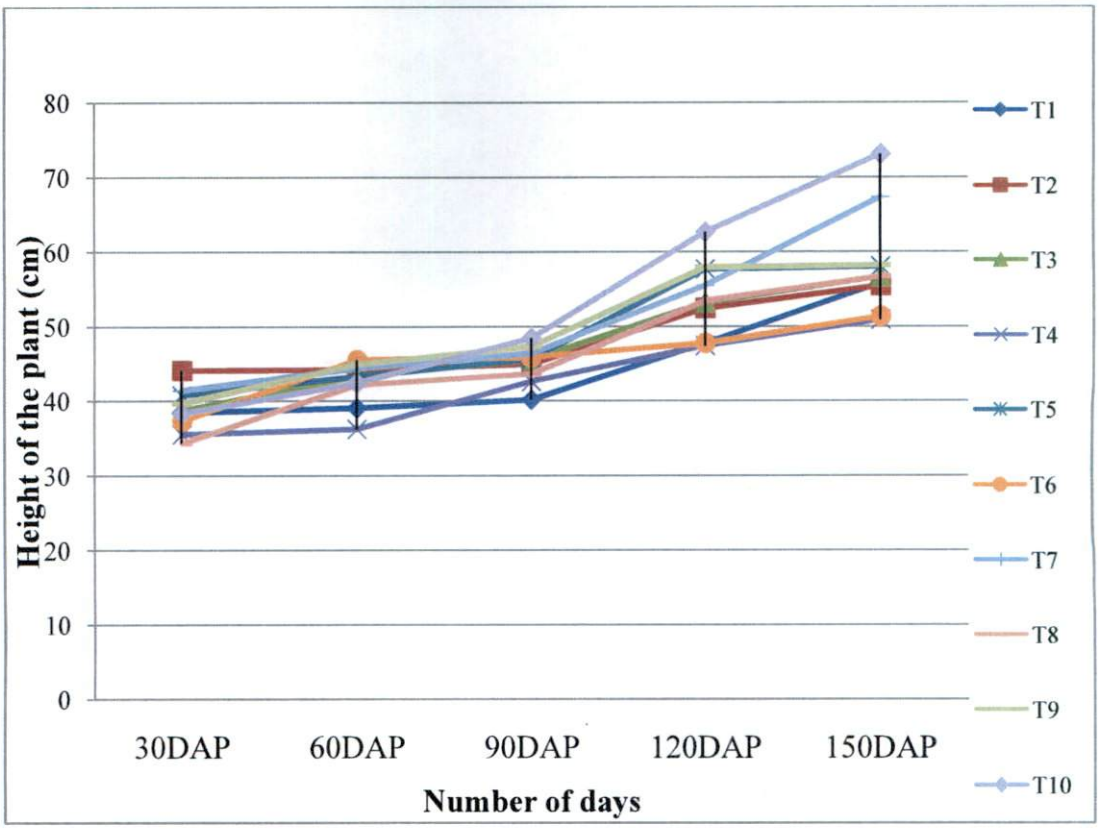


Fig. 7 Effect of bioregulators on height of the plant (30 days intervals)

There was no significant difference in plant height at 30 days after planting. Reduction in plant height was observed under all bioregulators treatments from 60 days after planting onwards.

The plant height differed significantly among the treatments from 60 days after planting up to 150 days after planting. At 90 days after planting, the plants treated with 10 ppm of paclobutrazol (T_1) showed minimum plant height (40.140 cm) and the plants under control showed maximum plant height (48.437 cm). Among the various treatments, the plants treated with cycocel 250 ppm (T_4) exhibited minimum plant height at 60 (36.193 cm), 120 (47.387) and 150 (50. 887 cm) days after planting.

Table 16. Effect of bioregulators on height of the plant (30 days intervals)

Treatments	30DAP	60DAP	90DAP	120DAP	150DAP
T1	38.413	39.027	40.140	47.720	55.777
T2	44.123	44.183	44.923	52.413	55.440
T3	38.620	43.330	45.527	53.163	56.663
T4	35.500	36.193	42.597	47.387	50.887
T5	40.720	43.250	45.623	57.663	58.007
T6	37.303	45.530	45.863	47.717	51.330
T7	41.387	44.387	46.380	55.470	67.330
T8	34.330	42.163	43.600	53.417	56.663
T9	39.637	44.917	47.300	57.915	58.160
T10	38.287	42.417	48.437	62.660	73.107
SEm(±)	**23.899**	**6.484**	**6.687**	**15.880**	**15.019**
C.D(0.05)	**NS**	**4.368**	**4.437**	**6.836**	**6.648**

4.2.2 Physiological parameters

4.2.2.1 Leaf area at the time of flowering

The results on the effect of bioregulators on leaf area and SCMR (at the time of flowering) are presented in the Table 17.

The mean leaf area at the time of flowering was measured. The treatments differed significantly with respect to the mean leaf area at flowering. Maximum leaf area (187.683 cm^2) was recorded in plants treated with ethephon 30 ppm (T_9) followed by (181.977 cm^2) plants treated with ethephon 20ppm (T_8).

4.2.2.2 SPAD chlorophyll meter reading

Significant difference was observed in the SPAD chlorophyll meter reading recorded at the time of flowering. Maximum reading (45.820) was recorded by plants treated with paclobutrazol 20ppm (T_2). It was followed by the plants treated with paclobutrazol 30 ppm (T_3). Minimum SPAD chlorophyll meter reading (36.867) was recorded by plants treated with 500 ppm of cycocel (T_5).

Table 17. Effect of bioregulators on leaf area and SCMR (at flowering)

Treatments	Leaf area at flowering (cm2)	SPAD chlorophyll reading
T1	161.873	36.877
T2	161.900	45.820
T3	157.243	44.097
T4	150.410	39.967
T5	152.200	36.443
T6	148.787	41.010
T7	156.893	37.147
T8	181.977	41.237
T9	187.683	42.520
T10	140.387	42.993
SEm(±)	**194.156**	**12.035**
C.D(0.05)	**23.903**	**5.951**

4.2.2.3 Fresh weight of shoot, fresh weight of inflorescence and fresh weight of total plant biomass, dry weight of shoot, dry weight of inflorescence and dry weight of total plant biomass

The treatment differed significantly with regard to the total dry weight of shoot at 300 days after planting. The minimum dry weight of shoot (265 g) was recorded by the plants treated with paclobutrazol 20 ppm (T_2). The maximum dry weight (534g) of shoot was observed in plants under control (T_{10}) as presented in Table 18.

The analysis of data on the total plant biomass revealed that the different level of growth retardants does not have any significant effect on the total plant biomass as presented in Table 18.

Table 18. Effect of bio-regulators Fresh weight of shoot, fresh weight of inflorescence and fresh weight of total plant biomass, dry weight of shoot, dry eight of inflorescence and dry weight of total plant biomass (at 300 DAP)

Treatments	Fresh weight of shoot (g)	Fresh weight of inflorescence per plant (g)	Fresh weight of total plant biomass (g)	Dry weight of Shoot (g)	Dry weight of inflorescence (g)	Dry weight of total plant biomass (g)	Ratio (I:S)
T1	995.00	110.67	1112.00	406.00	47.60	454.63	11:89
T2	962.00	127.00	1057.00	265.00	54.33	319.78	17:83
T3	1149.00	115.00	1246.00	392.00	42.67	428.33	9:91
T4	1217.00	163.00	1432.00	529.00	64.33	593.71	11:89
T5	1192.00	122.33	1229.00	453.00	54.33	513.06	11:88
T6	968.00	106.33	1124.00	354.00	39.00	387.75	9:91
T7	1125.67	187.67	1154.67	448.00	72.66	518.48	14:86
T8	1401.00	93.33	1187.00	441.00	40.00	480.17	9:91
T9	1214.00	131.33	1177.33	456.66	50.00	501.11	9:91
T10	1156.67	127.00	1188.000	534.00	46.00	578.42	8:92
SEm(±)	156748	86.18	12975.285	50.30	4.34	911.41	
C.D(0.05)	NS	NS	NS	12.16	3.57	NS	

4.2.3 Yield parameters

4.2.3.1 Days to flowering and duration from inflorescence emergences to harvest

The number of days taken for first flowering and the duration from inflorescence emergence to harvest were recorded and data are presented in Table 19.

Table 19. Effect of bioregulators on days to flowering and duration from inflorescence emergences to harvest

Treatments	Days to flowering	Duration from Inflorescence emergence to harvest
T1	133.333	20.367
T2	130.667	19.767
T3	131.667	18.500
T4	154.000	18.000
T5	151.333	20.533
T6	164.667	17.767
T7	137.667	19.367
T8	139.000	20.600
T9	142.000	21.100
T10	151.333	20.433
SEm(±)	**32.844**	**18.120**
C.D(0.05)	**9.831**	**NS**

The data on number of days to first flowering revealed that there was significant difference between the treatments. The number of days required from planting to first flowering was the lowest (130.667) in the plants treated with 20 ppm of paclobutrazol (T_2) followed by T_3 (131.667). The period required for flowering was longest for the plants treated with 750 ppm of cycocel T_6 (164.667).

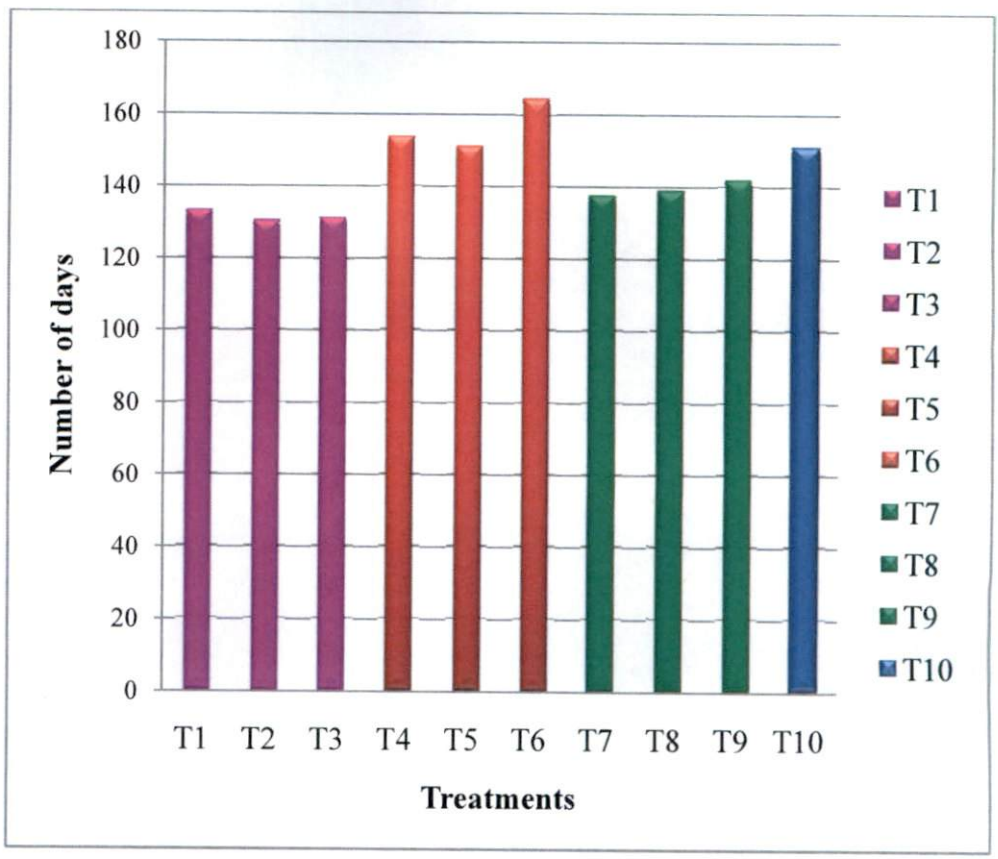


Fig. 8 Effect of bioregulators on days to flowering

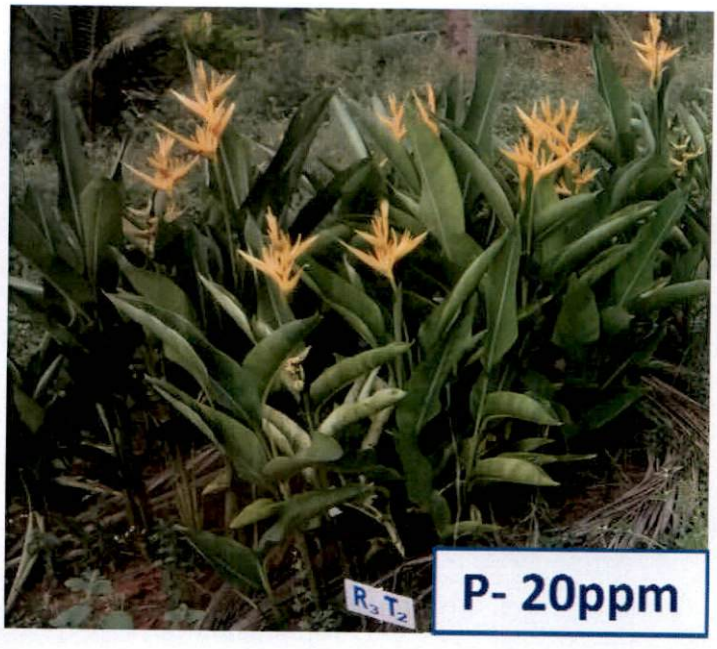
The analysis of data on the days required from inflorescence emergence to harvest revealed that application of growth retardants does not have any significant effect on the parameter studied.

4.2.3.2 Number of inflorescence per plant and number of florets per inflorescence

The number of inflorescence per plant and number of florets per inflorescence were recorded and data are presented in Table 20.

Table 20. Effect of bioregulators on number of inflorescence and number of florets per inflorescence

Treatments	Number of inflorescence per plant (300 days after planting)	Number of florets per inflorescence
T1	5.273	15.833
T2	6.357	16.167
T3	4.553	10.600
T4	4.690	11.333
T5	4.357	12.333
T6	3.970	12.833
T7	5.857	18.667
T8	3.803	19.667
T9	4.053	14.833
T10	4.193	13.500
SEm(±)	**0.115**	**2.521**
C.D(0.05)	**0.582**	**2.724**



Maximum number of inflorescence in plants treated with paclobutrazol @ 20 ppm

Minimum number of inflorescence in plants treated with ethephon @ 20 ppm

Plate 10. Effect of bioregulators on number of inflorescence per plant

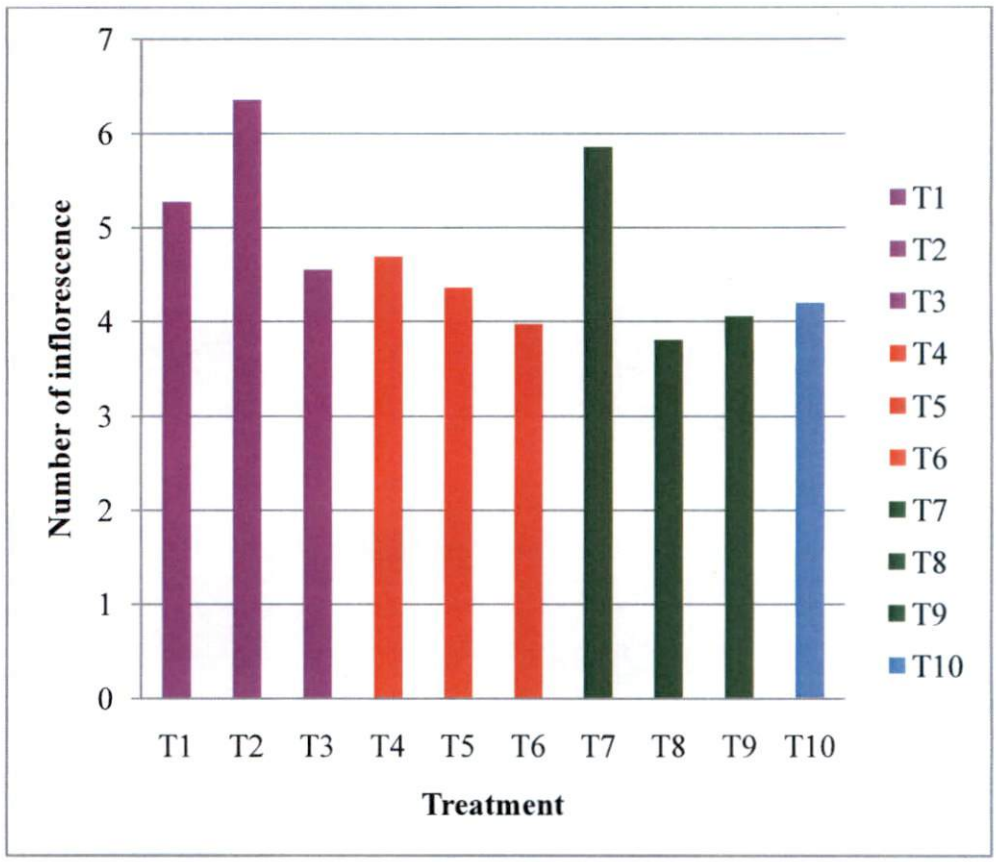


Fig. 9 Effect of bioregulators on number of inflorescence per plant

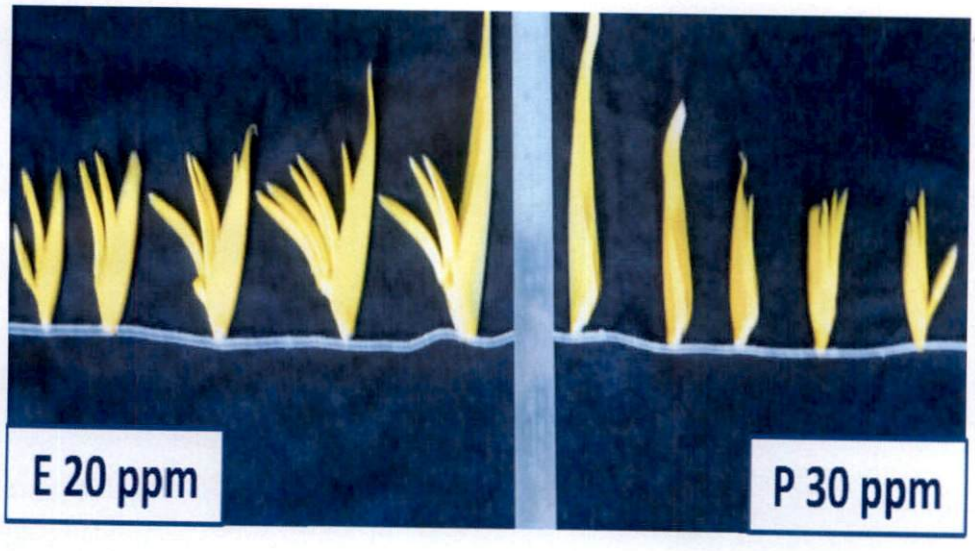


Plate 11. Effect of bioregulators on number of florets per inflorescence

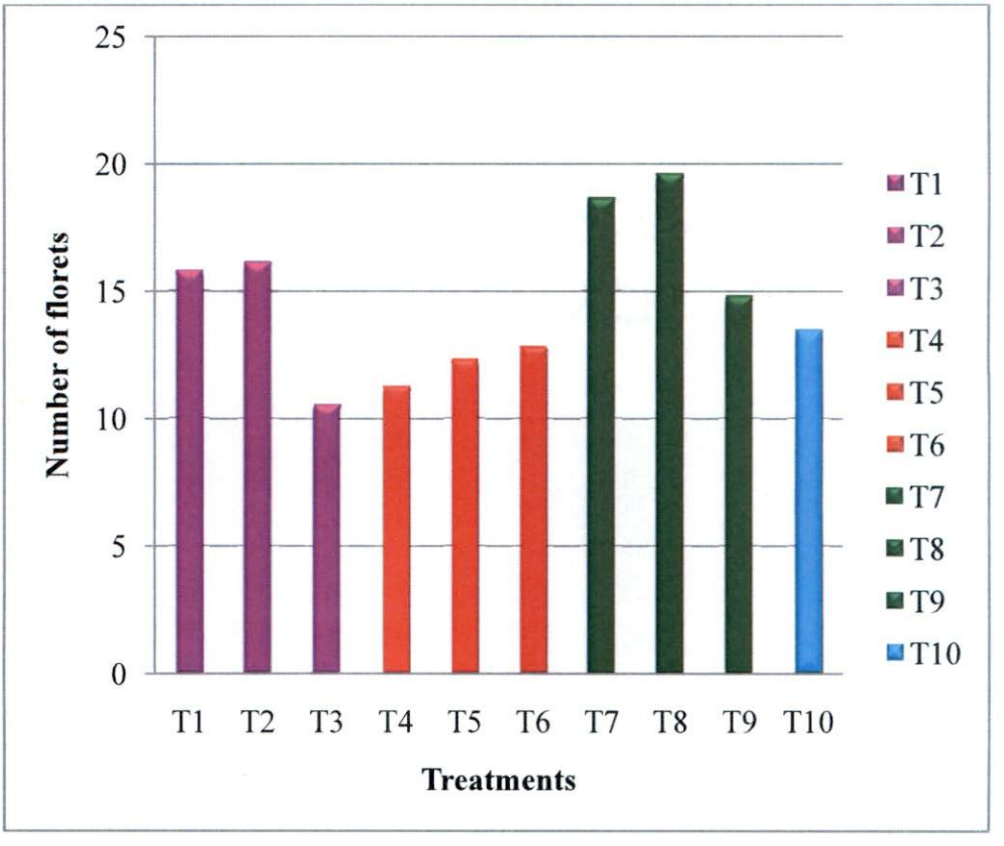


Fig. 10 Effect of bioregulators on number of florets per inflorescence

The analysis of data on the number of inflorescence revealed that the treatments differed significantly for the parameter. The highest number of inflorescence (6.357) was recorded in plants treated with paclobutrazol 20 ppm (T2). The lowest number of inflorescence (3.803) was recorded in plants treated with ethephon 20ppm (T_8).

The treatments differed significantly with respect to the number of florets per inflorescence. The maximum number of florets per inflorescence (19.667) was observed in plants treated with ethephon 20ppm (T_8) followed by (18.667) plants treated with ethephon 10ppm (T_7). The least number of florets per inflorescence (10.600) was recorded in plants treated with paclobutrazol 30ppm (T_3).

4.2.3.3 Bract characters

The number of bracts per inflorescence, the length and width of bract and interspace between bracts at the time of harvest were recorded and the data analyzed are presented in the Table 21.

Table 21. Effect of bioregulators on number of bracts per inflorescence, width of bract, length of bract and interspace between bracts

Treatments	No of bracts per inflorescence	Width of bract (cm)	Length of bract (cm)	Interspaces between bracts (cm)
T1	4.167	1.800	8.287	3.250
T2	3.433	2.000	8.800	3.250
T3	3.833	1.233	8.553	3.167
T4	3.500	1.233	8.753	3.083
T5	3.500	1.400	9.807	3.083
T6	3.333	1.517	8.990	3.083
T7	3.667	1.667	7.687	3.167
T8	4.000	1.200	7.507	3.000
T9	3.500	1.333	7.950	3.167
T10	3.500	1.200	7.967	2.917
SEm(±)	**0.203**	**0.041**	**0.165**	**0.023**
C.D(0.05)	**NS**	**0.346**	**0.696**	**NS**

The analysis of data on the number of bracts revealed that the treatments did not differ significantly for this parameter.

Bract width differed significantly with respect to the treatments. The widest bracts was recorded in T_2 (2.00) followed byT_1 (1.800). Width of bract was the lowest in both T_{10} (1.200 cm) and T_8 (1.200). Bract length also differed significantly for the treatments. The maximum bract length was recorded by T_5 (9.807 cm). The minimum bract length was observed in plants treated with T_8 (7.507 cm).

The analysis of data on the interspace between the bracts revealed that the treatments did not differ significantly for this parameter.

4.2.3.4 Inflorescence characters

Table 22. Effect of bioregulators on length of inflorescence, length of stalk, dry weight of inflorescence

Treatments	Length of inflorescence cm)	Length of stalk (cm)	Dry Weight of inflorescence (g)
T1	12.583	32.750	9.040
T2	12.833	37.000	9.337
T3	12.917	38.500	9.967
T4	13.833	39.000	11.350
T5	14.000	38.833	11.693
T6	13.667	38.000	11.693
T7	13.250	44.250	14.957
T8	13.500	45.000	13.920
T9	15.500	46.833	15.667
T10	16.500	47.100	16.383
SEm(±)	**1.379**	**20.099**	**7.278**
C.D(0.05)	**2.015**	**7.691**	**4.628**

Plate 12. Effect of bioregulators on length of stalk

Maximum stalk length- control (47.100 cm)

Minimum stalk length- paclobutrazol 10 ppm (32.750 cm)

The length of inflorescence, length of inflorescence stalk, fresh and dry weight of inflorescence was recorded and the data are presented in Table 22.

Length of inflorescence differed significantly among the treatments the longest inflorescence was recorded in the T_{10} (16.500 cm) followed by T_9 (15.500 cm). The lowest length of inflorescence was recorded in T_1 (12.583 cm) followed by T_2 (12.833 cm).

The length of stalk significantly differed for the treatments. The longest stalk was recorded in the T_{10} (47.100 cm) followed by T_9 (46.833 cm). The least stalk length was recorded in T_1 (32. 750 cm) followed by T_2 (37.000 cm).

The analysis of data on the dry weight of inflorescence revealed that the treatments differed significantly for this parameter. The highest overall mean weight was recorded for T_{10} (16.383 g) followed by T_9 (15.677g).The least overall mean was recorded in T_1 (9.040g) followed by T_2 (9.337g).

4.2.4 Post harvest parameters

4.2.4.1 Vase life of inflorescence

Analysis of the data on the effect of bioregulators on vase life of flowers revealed that the treatments did not show any significant difference for vase life of inflorescence. However the maximum vase life was observed under the treatment T_1 and T_7. The minimum was observed under treatment T_5 and T_{10} as presented in Table 23.

Table 23. Effect of bioregulators on vase life

Treatments	Vase life (200ppm 8HQC+ 5 % sucrose) (days)	Vase life control
T1 (Paclobutrazol 10 ppm)	7.333	3.67
T2 (Paclobutrazol 20 ppm)	6.333	3.33
T3 (Paclobutrazol 30 ppm)	6.333	3.67
T4 (Cycocel 250 ppm)	7.000	4.00
T5 (Cycocel 500 ppm)	6.000	4.00
T6 (Cycocel 750 ppm)	6.333	4.33
T7 (Ethephon 10 ppm)	7.333	4.67
T8 (Ethephon 20 ppm)	6.667	4.00
T9 (Ethephon 30 ppm)	6.667	3.67
T10 (Control)	6.000	3.67
SEm(±)	1.381	0.416
C.D(0.05)	NS	NS

In the experiment for assessing the growth and yield of heliconia under colored shade nets and using different bioregulators, we can arrive at the conclusion that the plants grown under grey shade net 50 % and the plants treated with paclobutrazol 20 ppm produces maximum number of inflorescence. The short statured plants were obtained when the plants were grown under green colored shade nets 25 % as well as in open condition and the plants treated with CCC 250 ppm.

4.2.5 Multiple correlation

The number of leaves (0.67*) and total plant biomass (0.65*) are significantly positively correlated with number of tillers. Similarly, plant height also has significant positive correlation between and number of leaves (0.71*) and shoot dry weight (0.67*). A significant negative correlation was observed between duration of flower emergence and number of tillers (-0.7*). Number of inflorescence is significantly correlated with number of tillers (0.71*), number of leaves (0.95**) and plant height (0.722*).However, number of florets per inflorescence exhibited significant negative correlation with numbers of tillers (-0.8**). Numbers of bracts exhibited significant negative correlation with plant height (-0.6*4). Width of bract showed significant positive correlation with number of flowers (0.83**), number of leaves (0.79**) and plant height (0.70*) and negatively correlated with shoot dry weight (-0.6*). Length of bract is negatively correlated with number of tillers (-0.76*) and number of florets per inflorescence (-0.7*). Interspace between bracts is negatively correlated with shoot dry weight (-0.8*) and showed positive correlation with number of inflorescence (0.69*) and width of bract (0.75*). Length of inflorescence is positively correlated with plant height (0.73*) and shoot dry weight (0.79**) and negative correlation with interspace between bracts (-0.67*). Length of stalk showed a significantly positive correlation with length of inflorescence (0.74*) and plant height (0.73*). Dry weight of inflorescence showed a positive significant correlation with total plant biomass (0.783**).

Table 24a. Multiple correlation between growth and yield parameters of heliconia (A to O vs A to O)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	1														
B	0.04	1													
C	0.19	-0.4	1												
D	0.47	-0.5	0.37	1											
E	0.41	-0.2	0.1	0.36	1										
F	0.04	0.06	-0.3	0.22	0.65*	1									
G	0.16	0.67*	-0.1	-0.13	-0.45	-0.18	1								
H	0.22	0.25	-0.1	0.13	-0.35	-0.31	0.71*	1							
I	-0.1	-0.5	0	0.12	0.015	0.082	0.028	0.492	1						
J	-0.2	-0.5	0.15	0.13	0.058	-0.09	-0.2	0.312	0.70*	1					
K	-0.1	-0.2	-0.3	0.06	-0.02	0.051	-0.18	0.292	0.426	0.78*	1				
L	0.16	0.08	-0.3	-0.09	0.144	0.157	0.079	0.246	0.247	0.597	0.82*	1			
M	0.02	-0.3	-0.3	0.6	0.272	0.621	-0.25	-0.08	0.185	-0.13	0.02	-0.23	1		
N	-0.4	-0.4	0.22	0.28	-0.52	-0.19	0.136	0.129	0.293	0.372	0.15	-0.03	0.138	1	
O	0.01	-0.1	-0.1	-0.12	0.207	-0.04	-0.45	-0.37	-0.31	0.35	0.57	0.67*	-0.34	-0.12	1

**- Correlation is significant at the 0.01 level *- Correlation is significant at the 0.05 level

Characters code

A=Days to tillering, B= Number of tillers 60 DAP, C= Number of tillers 120 DAP, D= Number of tillers 180 DAP, E= Number of tillers 240 DAP, F= Number of tillers 300 DAP, G= Number of leaves, H= Plant height at 30 DAP, I= Plant height at 60 DAP, J= Plant height at 90 DAP, K= Plant height at 120 DAP, L= Plant height at 150 DAP, M= Leaf area, N= SCMR, O= Shoot dry weight, P= Total plant biomass, Q= Days to flowering, R= Duration from inflorescence emergence to harvest, S= Number of inflorescence, T= Number of florets per inflorescence, U= Number of bracts, V= Width of bract, W= Length of bract, X= Interspace between bract, Y= Length of inflorescence, Z= length of stalk, AA= Dry weight of inflorescence, AB= Vase life.

Table 24b.Multiple correlation between growth and yield parameters of heliconia (A to O vs P to Ac)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
P	0.17	0.17	0.1	0.2	0.65*	0.383	-0.43	-0.4	-0.5	-0.27	-0.12	-0.15	0.18	-0.63	0.25
Q	-0.3	-0.3	0.23	-0.36	0.166	-0.4	-0.59	-0.39	-0.02	0.262	-0.05	-0.11	-0.46	-0.21	0.37
R	0.14	-0	-0.7*	0.16	-0.04	0.236	-0.13	0.209	0.153	0.121	0.63	0.439	0.521	-0.09	0.22
S	0.26	0.71*	-0.2	0.01	-0.25	-0.09	0.95**	0.722*	-0.03	-0.23	-0.19	0.072	-0.14	0.004	-0.4
T	-0	0.32	-0.8**	-0.05	0.275	0.707*	0.187	0.081	0.194	-0.12	0.09	0.258	0.53	-0.14	-0.2
U	0.38	0.28	-0.3	0.03	0.173	0.568	0.076	-0.33	-0.37	-0.6*4	-0.22	-0.01	0.353	-0.29	-0.1
V	0.3	0.48	-0.3	-0.05	-0.28	-0.19	0.79**	0.70*	0.177	-0.3	-0.33	-0.13	-0.01	-0.07	-0.6*
W	-0.1	0.07	0.34	-0.34	-0.49	-0.76*	0.1	0.269	-0.02	-0.08	-0.22	-0.46	-0.46	-0.14	-0.3
X	0.53	0.25	0.15	0.45	-0.07	-0.03	0.622	0.571	0.059	-0.41	-0.45	-0.4	0.281	-0.03	-0.8*
Y	-0.1	-0.5	-0	0.15	0.111	-0.19	-0.57	-0.13	0.135	0.684*	0.73*	0.564	-0.08	0.19	0.79**
Z	-0.3	-0.4	-0.2	0.23	0.41	0.438	-0.48	-0.15	0.325	0.712*	0.74*	0.628	0.275	0.202	0.59
AA	-0.3	0.25	-0.1	-0.26	0.443	0.24	-0.39	-0.3	-0.25	0.057	0.08	0.005	-0.1	-0.52	0.31
AB	0.56	0.42	-0.1	0.31	0.614	0.537	0.19	-0.14	-0.43	-0.59	-0.49	-0.13	0.281	-0.47	-0.2

**- Correlation is significant at the 0.01 level *- Correlation is significant at the 0.05 level

Characters code

A=Days to tillering, B= Number of tillers 60 DAP, C= Number of tillers 120 DAP, D= Number of tillers 180 DAP, E= Number of tillers 240 DAP, F= Number of tillers 300 DAP, G= Number of leaves, H= Plant height at 30 DAP, I= Plant height at 60 DAP, J= Plant height at 90 DAP, K= Plant height at 120 DAP, L= Plant height at 150 DAP, M= Leaf area, N= SCMR, O= Shoot dry weight, P= Total plant biomass, Q= Days to flowering, R= Duration from inflorescence emergence to harvest, S= Number of inflorescence, T= Number of florets per inflorescence, U= Number of bracts, V= Width of bract, W= Length of bract, X= Interspace between bract, Y= Length of inflorescence, Z= length of stalk, AA= Dry weight of inflorescence, AB= Vase life.

Table 24b.Multiple correlation between growth and yield parameters of heliconia (P to AC vs P to Ac)

	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
P	1												
Q	0.169	1											
R	-0.027	-0.37	1										
S	-0.214	-0.57	-0.07	1									
T	-0.041	-0.42	0.482	0.28	1								
U	0.156	-0.61	0.291	0.04	0.4	1							
V	-0.417	-0.39	0.03	0.83**	0.36	0.02	1						
W	-0.046	0.381	-0.31	0.03	-0.7*	-0.4	0.15	1					
X	-0.077	-0.6	-0.06	0.69*	0.09	0.2	0.75*	0.15	1				
Y	0.008	0.457	0.368	-0.5	-0.2	-0.4	-0.55	-0.189	-0.67*	1			
Z	0.151	0.135	0.386	-0.4	0.3	-0.2	-0.55	-0.592	-0.61	0.74*	1		
AA	0.783**	0.464	-0.12	-0.2	0.01	-0.2	-0.43	0.118	-0.42	0.14	0.32	1	
AB	0.5	-0.33	-0.08	0.39	0.45	0.52	0.3	-0.47	0.46	-0.4	-0.2	0.12	1

**- Correlation is significant at the 0.01 level *- Correlation is significant at the 0.05 level

Characters code

A=Days to tillering, B= Number of tillers 60 DAP, C= Number of tillers 120 DAP, D= Number of tillers 180 DAP, E= Number of tillers 240 DAP, F= Number of tillers 300 DAP, G= Number of leaves, H= Plant height at 30 DAP, I= Plant height at 60 DAP, J= Plant height at 90 DAP, K= Plant height at 120 DAP, L= Plant height at 150 DAP, M= Leaf area, N= SCMR, O= Shoot dry weight, P= Total plant biomass, Q= Days to flowering, R= Duration from inflorescence emergence to harvest, S= Number of inflorescence, T= Number of florets per inflorescence, U= Number of bracts, V= Width of bract, W= Length of bract, X= Interspace between bract, Y= Length of inflorescence, Z= length of stalk, AA= Dry weight of inflorescence, AB= Vase life.

DISCUSSION

5. DISCUSSION

In Kerala, heliconia has excellent opportunity to expand its potential to generate employment and income in rural areas. However, the commercial cultivation of heliconia is limited due to the lack of scientific information on agro techniques of this crop in the homesteads and coconut gardens. Therefore the present study was conducted at Department of Pomology and Floriculture, College of Agriculture, Padannakkad, Kasaragod during the period from April 2015 to July 2016. The results of the study are briefly discussed below.

5.1 EFFECT OF PHOTO SELECTIVE SHADE NETS ON GROWTH AND FLOWERING OF HELICONIA

In the present study, there were significant differences in the morphological, physiological and yield parameters of heliconia grown under different photoselective shade nets.

5.1.1Morphological parameters

5.1.1.1 Days to tillering

There was no significant difference in the days to tillering by the use of photo selective shade nets. Similar results were obtained by Beckmann-Cavalcante *et al.* (2011) and Souza *et al.*, (2016) in *Heliconia psittacorum cv. 'Golden* Torch'. This indicates that tiller emergence in *H psittacorum* is shade independent.

In the present study, the number of days for tiller emergence varied from 31 to 34 days. Ibiapaba *et al.* (2000) reported that in *Heliconia psittacorum* cultivars 'Sassy' and 'Andromeda', the first shoots appeared 20-30 days after planting. However, Carvalho *et al.* (2012) found that the emergence of the first tiller occurred 55 days after planting in *Heliconia psittacorum cv.*'Golden Torch'. The earliness in tiller emergence in the present study compared to the above report indicates the suitability of *Heliconia psittacorum cv.*'Golden Torch' for our climatic conditions which is more favourable for its growth and

development. So it could be assumed that the duration to tillering is primarily dependent on variety or species and climatic conditions.

5.1.1.2 Number of tillers per plant

Photoselective shade nets did not significantly influence the production of tillers upto 60 days after planting. Thereafter, the number of tillers per plants showed significant difference between treatments. After 120 days of planting, plants grown under 50 % green shade nets recorded maximum number of tillers. However, from 180 days to 300 days after planting, the plants grown under 50 % grey shade net produced maximum number of tillers. Tiller production was also better in plants grown under coconut shade at 300 days after planting. The lowest number of tillers was recorded in plants grown under 50 % red shade net from 120 days to 300 days after planting.

From the above results, it could be observed in general that filtered sunlight is beneficial for tiller production in *Heliconia psittacorum* since the plants grown under 50 percent shade in green, grey and those under coconut shade has recorded better tiller production. The present results are not in line with the report by Catley and Brooking (1996) in which tiller production in *Heliconia psittacorum* was promoted under higher light intensity and those by Souza *et al.* (2016) in which tiller production in *Heliconia psittacorum* is shade independent.

However, different colors of shade nets have varying response with respect to tiller production. Green and grey colored shade nets promoted tillering while tiller production was not encouraged under red shade nets.

5.1.1.3 Total number of leaves

The photoselective shade nets as well as the different percentages of shade did not have any significant influence on the number of leaves at the time of flowering. The results obtained in the present study were also corroborated by Perez *et al.* (2013) who reported that the number of leaves at the time of

flowering was not affected by shading level in *Heliconia psittacorum cv.* 'Golden Torch'.

5.1.1.4 Plant height

Generally growers prefer heliconia plants with short stature. In the present study it was observed that photoselective shade nets could significantly influence the height of heliconia plants.

In *Heliconia psittacorum cv.*'Golden Torch', minimum plant height was recorded in the plants grown under 25 % grey shade net and open condition. Plants grown under coconut shade recorded maximum height upto 180 days. However, shoot growth pattern was similar for all the treatments. Shade of 50 % has resulted in more plant height in all the treatments.

The above results indicate that higher shade conditions favor plant height increase in *Heliconia psittacorum* cv. 'Golden Torch', irrespective of color of shade nets. Nascimento *et al.* (2015) also has reported that the maximum plant height in torch ginger, which is a related species, under shaded condition. In gladiolus also, Ramachandrudu and Thangam (2006) reported plant height was more when grown under the natural shade of coconut garden. However, according to Bandara *et al.* (2014) plant height in heliconia is species dependant when grown under colored shade nets.

5.1.2 Physiological parameters

5.1.2.1 Leaf area at flowering

The leaf area at the time of flowering was significantly influenced by photoselective shade nets. Maximum leaf area at the time of flowering was observed in plants grown under 25% followed by 50% red colored shade nets. This indicates that red colored shade nets are useful in enhancing leaf area with lower percentage of shade. However, Kawabata *et al.* (2007) reported that in pittosporum plants grown under red shade net produced thicker leaves with lesser leaf area than plants under other colored shade which is contradictory. This

points out that the effect of shade net color may be species dependent with respect to leaf area.

Positive influence on Specific Leaf Area (SLA) under shaded condition was also reported in *Heliconia psittacorum* by Nihad and Krishnakumar (2015) when grown as an intercrop in coconut garden compared to plants grown in open condition. Similarly, when grown under full sunlight conditions, the leaf area was low in *Heliconia bihai cv.* 'Lobster Claw' (Lima *et al.*, 2016).

Positive response to shade in increasing leaf area is also available in other flower crops such as gladiolus where more leaf area was reported in all cultivars grown under coconut garden as compared to open field conditions (Ramachandrudu and Thangam, 2006).

5.1.2.2 SPAD chlorophyll reading

The colored shade nets had significant influence on the chlorophyll content in heliconia leaves. The maximum chlorophyll content was recorded in plants grown under 25% grey shade nets. This is line with the findings by He *et al.* (1996) in which heliconia plants when grown in full sunlight showed a reduction in chlorophyll content per leaf area compared to those grown under intermediate or partial shade, which consequently reduced photosynthetic capacity of leaves. This may be due to the fact that in open condition, chlorophyll content gets depleted and the photosynthetic pigments can be destroyed at higher rate of irradiation (Goltsev *et al.*, 2003).

5.1.2.3 Dry weight and total plant biomass

The photo selective shade net showed significant influence on the dry weight of shoot and total plant biomass. The minimum dry weight of shoot (330 g) was recorded in plants grown under 25 % grey shade nets while maximum dry weight was observed under 50 % red shade net. The lowest plant biomass was recorded in plants grown under partial coconut shade while maximum was observed in plants grown under 50% red shade net. Hence it could be assumed

that red shade nets are effective in enhancing dry weight and total biomass in *Heliconia psittacorum cv.* 'Golden torch'. Reports on increase in shoot fresh weight under red shade cloth is also available in sweet basil, Thai basil, Genovese basil and parsley plants. Shoot fresh weight also increased in cilantro plants grown under red shade cloth (Appling, 2012).

5.1.3 Yield parameters

5.1.3.1 Days to flowering and duration from inflorescence emergence to harvest

The photoselective shade net did not have any significant influence on the number of days to first flowering and duration from inflorescence emergence to harvest. However the number of days to flowering was minimum in plants grown under open condition. The present finding was corroborated by Ramachandrudu and Thangam (2012) in *H. psittacorum cv.* 'Golden Torch' in which the emergence of spike and opening of spike was found to be early under open conditions. Earliness in flowering under open conditions also has been reported by Souza *et al.* (2016) in which *Heliconia psittacorum cv.* 'Golden Torch', plants grown under full sunlight produced inflorescence 103 days after the emergence of tillers while the plants grown under 35% shade produced inflorescence 153 days after emergence of tillers.

5.1.3.2 Number of inflorescence and number of florets per inflorescence

The number of inflorescence is an important feature of cut flower production. Normally *Heliconia psittacorum cv.* 'Golden Torch' has a year round flower production. In the present study, the average inflorescence production for the treatments ranged from 4 to 6 up to 300 days. The maximum number of inflorescence was recorded in plants grown under 25% grey shade net. The beneficial effect of shade in flowering of heliconia was also reported in a study by Sudhakar and Kumar, (2012) in which the number of flowers was less in plants grown under open conditions in *Heliconia psittacorum cv.*'Golden Torch'. Similar result was also reported by Perez *et al.* (2013). In *H.*

psittacorum X H. spathocircinata. However, Souza *et al.* (2016) reported that maximum number of inflorescence was produced by the use of 50 % black shade net in *H. psittacorum cv. 'Golden* Torch'.

The number of florets in heliconia adds to its beauty, thus production of maximum number of florets per inflorescence is an important feature. In this study the highest number of florets was observed in plants grown under partial coconut shade.

5.1.3.3 Bract characters

Though photoselective shade net did not have any significant effect on number of bract per inflorescence, width of bract and interspace between bracts, length of bract was significantly affected. The longest bract was observed in inflorescence of the plants grown under 50% red shade net.

5.1.3.4 Inflorescence characters

The longest inflorescence was observed in the plants grown under 50% red shade net, 50% green shade net and 50% blue shade net. This indicates that 50% shade is ideal for longer flowers in *Heliconia psittacorum.* This was in line with the findings of Henrique *et al.* (2011) in gladiolus.

The photoselective shade net did not have any effect on length of stalk and weight of inflorescence.

5.1.4 Post harvest parameters

5.1.4.1Vase life of inflorescence

Photoselective shade nets did not show any influence on the vase life of Heliconia inflorescence. Similar findings were reported by Stamps (2009) in heliconia and by Saifuddin *et al.*, (2010) in *Bougainvillea glabra.*

5.1.5 Multiple correlation

A significant correlation was observed between plant height and number of tillers along with number of leaves and length of stalk when grown under different level of shade and shade net colors. Such correlations were also reported by Kumar *et al.* (2011) in heliconia.

The number of flowers was highly significantly correlated with number of tillers and plant height. The bract size was positively correlated with number of tillers and plant height. This was in line with the findings of Sheela *et al.* (2006) in heliconia.

5.2 EFFECT OF BIO-REGULATORS ON GROWTH AND YIELD OF HELICONIA

The study showed that, *Heliconia psittacorum cv.* 'Golden Torch' had significant variations in growth and yield parameters in response to different levels of bioregulators.

5.2.1 Morphological parameters

5.2.1.1 Days to tillering

The bioregulators at different concentration used in the present study did not have any significant influence on earliness to tillering planting to first tillering. Similar result was reported by Mansuroglu *et al.* (2009) in *Consolida orientalis.*

5.2.1.2 Number of tillers

Bioregulators had a significant influence on the tiller production. The plants treated with 20 ppm of ethephon showed highest number of tillers followed by 10 ppm of ethephon at 300 days after planting. The positive influence of ethephon in tillering was also reported by Zurawik and Placek, (2013) in Freesia.

5.2.1.3 Total number of leaves

Leaf production was improved in the plants treated with paclobutrazol 20 ppm. The action of this bioregulator seems to vary in different plant species which is demonstrated by the fact that application of paclobutrazol reduced the number of leaves in gladiolus (Milandri *et al.,* 2008) and in begonia (Suradinata *et al.,* 2013) which is contrary to the present finding.

5.2.1.4 Plant height

One of the objectives of using growth retardants in heliconia was to reduce plant height, since the plants exhibited a vigorous vegetative growth. From the 60 days of planting, there was a significant difference in the height of plants.

The plants were of shorter stature when applied with cycocel 250ppm and paclobutrazol 10ppm. This result is in close conformity with that of Jadhav and Chawla (2015) in Heliconia, where there was a drastic reduction in the height of heliconia plants treated with paclobutrazol at different concentration. The possible reason for the retardation in plant height as a result of application of paclobutrazol may be due to inhibition in the production of gibberellins which is responsible for cell enlargement and elongation (Latimer, 2009). When gibberellin production was inhibited, cell division still occurred, but the enlargement and elongation of new cells was inhibited (Chaney, 2004). CCC also was antagonistic to gibberellins which could be used to reduce unwanted shoot elongation (Singh, 2004).

5.2.2 Physiological parameters

5.2.2.1 Leaf area at the time of flowering

Leaf area recorded was maximum in the plants treated with ethephon 30ppm and ethephon 20ppm. Positive influence on leaf area expansion was also reported by Khan *et al.* (2008) in mustard. In contrast to this study, there was a

reduction in leaf area treated with cycocel and paclobutrazol in *Tabernaemontana coronaria* (Youssef and El-Aal, 2013).

5.2.2.2 SPAD chlorophyll meter reading

The chlorophyll content was maximum in the plants treated with different concentration of paclobutrazol and Cycocel. This finding was supported by Jadhav and Chawla (2015) in heliconia where soil drenching of cycocel and paclobutrazol resulted in increasing the chlorophyll content, anthocyanins and total soluble sugars. They opined that the plant growth retardants might have different effects on the pigmentation of the crops.

Similarly, the result obtained by Tezuka *et al.* (1989) in hollyhock was in conformity with the present finding where maximum chlorophyll content was observed in plants treated with cycocel and paclobutrazol.

5.2.2.3 Dry weight of shoot and total plant biomass

The Bioregulators at different concentration significantly influenced the dry weight of shoot and total plant biomass. The minimum dry weight of shoot and total plant biomass was in the plants treated with 20 ppm paclobutrazol. Earlier reports are not available on the effect of Bioregulators on dry weight of shoot and total plant biomass in heliconia. However, in the orchid genus dendrobium, Te-Chato *et al.* (2009) obtained similar results. The effect of paclobutrazol in influencing dry matter production and other plant characteristics was due to the inhibitory actions on gibberellins in orchids as reported by Wanderley *et al.* (2014).

5.2.3 Yield parameters

5.2.3.1 Days to first flowering and duration from inflorescence emergence to harvest

The days to first flowering is an important parameter to be considered and the minimum number of days to first flowering was recorded by plants treated

with paclobutrazol. This was in accordance the findings of Ramaswamy *et al.*, (1979) in tuberose. Bailey and Whipker (1998) reported that paclobutrazol stimulated lateral branching and promoted flower initiation for earlier flowering in poinsettias.

In the present study, it was observed that bioregulators did not have any significant influence on the duration from inflorescence emergence to harvest.

5.2.3.2 Number of inflorescence per plant and number of florets per inflorescence

Bioregulators had a significant effect on number of inflorescence per plants. Maximum number of inflorescence was observed in plants treated with paclobutrazol 20 ppm followed by the plants treated with ethephon 20 ppm. Reports available on the effect of bioregulators on inflorescence production in heliconia are scanty. However the studies conducted in other flower crops support the present finding (Hayashi *et al.,* 2001; Mansuroglu *et al.,* 2009; Suradinata *et al.,* 2013). Increased flower production as a result of Paclobutrazol application may be due to an increase in cytokinin synthesis which increased the number of flower buds formed utilizing the photosynthates (Suradinata *et al.,* 2013).

Bioregulators at different concentration had a significant influence on number of florets per inflorescence. Maximum number of florets per inflorescence was recorded in plants treated with ethephon 20 ppm followed by the plants treated with ethephon 10 ppm. Joshi and Reddy (2006) reported that application of ethephon and CCC increased the number of florets per inflorescence in Heliconia. They concluded that buildup of food reserves due to the reduction in plant height consequent to the application of CCC resulted in increase in the number of leaves leading to higher production and accumulation of photosynthates. Mobilizations of such photosynthates from the leaves to flowers might have culminated in increased flowering.

5.2.3.3 Bract characters

Bioregulators used in the present study did not have any significant influence on number of bracts per inflorescence and interspace between bracts.

Bioregulators at different concentration significantly influence on the width and length of bract. The widest bract was recorded by the treatments paclobutrazol 20 ppm and ethephon 10 ppm. The longest bract was recorded by the plants treated with cycocel 500 ppm. Similar result was obtained in poinsettia plants treated with CCC (Lodeta *et al.*, 2010). However a reduction in bract area was observed by the application of paclobutrazol in poinsettias (Niu *et al.*, 2002) in poinsettias and in bougainvillea (El-Quesni *et al.*, 2007).

5.2.3.4 Inflorescence characters

Bioregulators at different concentration significantly influenced the length of inflorescence. The shortest inflorescence was observed in plants treated with paclobutrazol 10 ppm followed by plants treated with paclobutrazol 20 ppm. The shortest stalk length was observed in the plants treated with paclobutrazol. Similar findings were reported in gerbera (Lee and Lee, 1990); in orchid (Wang, 1994) and in *Consolida orientalis* (Karaguzel *et al.*, 2009).

The dry weight of inflorescence recorded was minimum in plants treated with paclobutrazol 10 ppm.

5.2.4 Post harvest parameters

5.2.4.1Vase life of inflorescence

The growth retardants did not have any significant effect on the vase life of *Heliconia psittscorum cv.* 'Golden Torch'. Similar observation was reported in China aster (Patil *et al.*, 2013) and in chrysanthemum (Dorajeerao and Mokashi, 2011).

In bird of paradise the plants treated with ethephon reduced the vase life (Finger *et al.*, 1999). Osman (2014) reported that application of CCC improved vase life in *Solidago canadensis*.

5.2.5 Multiple correlation

The number of tillers and plant height were significantly positively correlated with number of leaves. Similarly number of tillers was highly positively correlated with number of inflorescence. Similar reports were given by Sheela *et al.* (2006).

The length of the stalk was highly positively correlated with plant height. Similar observation was reported by John *et al.* (2002) in gladiolus.

5.2.6 Conclusion

By interpreting the results obtained from the above experiments it can be concluded that the production of maximum number of inflorescence, which is an important economic character of a cut flower, can be achieved by growing the plants under 25 % grey shade net and by treating the plants with paclobutrazol 20 ppm.

In the present study, the best treatment with respect to the production of inflorescence was observed to be under grey shade net (25 %), which is 6.05 stems per plant. Simultaneously the plants grown under coconut have recorded inflorescence number of 5.61 stems per plant. So there is only an advantage 8% increase in yield of inflorescence with respect to the shade cover. In this respect, it will be worthwhile to compare the economics of cultivating *Heliconia psittacorum cv.* 'Golden Torch', with 50 % shade nets and under coconut plantation to know the comparative advantage. This could be the future line of work.

With respect to the bioregulators, the growth retardants paclobutrazol and cycocel had the effect of retarding the growth. Even though the number of inflorescence was observed to be maximum under plants treated with

paclobutrazol, the short statured plants were obtained when treated with cycocel 250 ppm. The best treatment with respect to the production of inflorescence was observed to be in plants treated with paclobutrazol 20 ppm, which is 6.35 stems per plant, while plants under control treatment yielded 4.19 stems per plant. Hence there is an enhancement of 34 % yield over control under paclobutrazol treatment. In this respect, the comparative benefit of using paclobutrazol with the cost of the bioregulator and that of the control must be considered for its recommendation. This also could form the future line of work.

SUMMARY

6. SUMMARY

An investigation entitled "Regulation of growth and flowering in heliconia (*spp.*)" was carried out at College of Agriculture, Padannakkad during 2014-2016 with the objective of assessing the growth and productivity of heliconia as influenced by photo-selective shade nets and external application of bio-regulators consisting two sets of experiments.

The results are summarized below.

- There was no significant difference in the days to tillering by the use of photo selective shade nets. At the same time the number of tillers per plants showed significant difference between treatments. The plants under 50% grey shade net produces maximum number of tillers.
- Photo selective shade nets did not significantly influence the number of leaves at the time of flowering. However, the treatments were significant for the height of heliconia plants. The minimum plant height was observed in the plants grown under 25 % green shade net and open condition.
- Leaf area, chlorophyll content, dry weight of shoots and total plant biomass were significantly influenced by the photo selective shade nets at the time of flowering.
- The photo selective shade nets had no significant influence on the number of days to first flowering, duration from inflorescence emergence to harvest, number of bracts per inflorescence, width of bract and inter space between bracts. Among the plants grown under different photo selective shade nets, the length of bract differed significantly. Whereas, the treatments did not influence stalk length, dry weight of inflorescence and vase life.
- A significant correlation was observed between plant height and number of tillers along with number of leaves and length of stalk when grown under different level of shade and shade net colors

- Bioregulators did not significantly influence the number of days taken from planting to first tillering. Whereas, the number of tillers per plant were significantly influenced by the treatments.
- The number of leaves and the plant height were significantly influenced by the treatments. Minimum plant height was observed in the plants treated with cycocel 250 ppm.
- The bioregulators at different concentration significantly influenced the leaf area, chlorophyll content, dry weight of shoot and total plant biomass.
- The number of days required for the first flowering was significantly influenced by the treatments. However, the duration of inflorescence emergence to harvest was not significantly influenced by the bioregulator application.
- Significant influence of bioregulator on number of inflorescence and number of florets per inflorescence were observed. The maximum number of inflorescence was recorded in plants treated with paclobutrazol 20 ppm.
- There were no significant influence on the number of bracts per inflorescence and interspace between bracts, but the width and length of bract differed significantly with respect to the treatments.
- The inflorescence length, stalk length and dry weight of inflorescence were significantly influenced by bioregulator application but have no effect on extending vase life of inflorescence.
- The number of tillers and plant height were significantly positively correlated with number of leaves. The length of the stalk was highly positively correlated with plant height. The number of inflorescence was significantly positively correlated with the number of tillers.

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REGULATION OF GROWTH AND FLOWERING IN *HELICONIA spp.*

by

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Abstract of the Thesis

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ABSTRACT

The experiment entitled "Regulation of growth and flowering in *Heliconia spp.*" was carried out with the objective to assess the growth and productivity of heliconia as influenced by photo selective shade nets and external application of bio-regulators, at College of Agriculture, Padannakkad during 2014-2016.

Response of heliconia to photo selective shade nets was evaluated with following treatments. They were T_1- (red shade net 25 %), T_2- (red shade net 50 %), T_3-(blue shade net 25 %) , T_4-(blue shade net 50 %), T_5- (grey shade net 25 %), T_6- (grey shade net 50 %), T_7- (green shade net 25 %), T_8- (green shade net 50 %), T_9-(under coconut plantation), T_{10}-(open condition). The photo selective shade nets significantly influenced numbers of tillers per plant, plant height, leaf area, leaf chlorophyll, dry weight of shoots, total plant biomass, number of inflorescence per plant, number of floret per inflorescence, bract length and inflorescence length. However no significant influence was observed on days to tillering, number of leaves, days to flowering, duration from inflorescence emergence to harvest, number of bracts, width of bracts, interspace between bracts, stalk length, dry weight of inflorescence and vase life of inflorescence.

Response of heliconia to bioregulators was evaluated with treatments viz, T_1: (paclobutrazol 10 ppm), T_2: (paclobutrazol 20 ppm), T_3: (paclobutrazol 30 ppm), T_4: (cycocel 250 ppm), T_5: (cycocel 500 ppm), T_6: (cycocel 750 ppm), T_7: (ethephon 10 ppm), T_8: (ethephon 20 ppm), T_9: (ethephon 30 ppm), T_{10}: (control). Bioregulators significantly influenced number of tillers, number of leaves, plant height, leaf area, chlorophyll content, dry weight of shoot, days to flowering, number of inflorescence per plant, number of florets per inflorescence, length and width of bract, inflorescence length, stalk length and dry weight of inflorescence. There were no significant differences on days to tillering, total plant biomass, duration of inflorescence emergence to harvest, number of bracts, interspace between bracts and vase life of inflorescence.

Among the photo selective shade nets, grey shade net (25 %) and among the bioregulators, paclobutrazol 20 ppm led to the production of maximum number of inflorescence per plant.

സംക്ഷിപ്തം

ഹെലിക്കോണിയ എന്ന അലങ്കാര പുഷ്പച്ചെടി കേരളത്തിൽ വളരെയധികം പ്രാധാന്യം നേടിവരുന്നു. ഹെലിക്കോണിയുടെ പരിപാലനവുമായി ബന്ധപ്പെട്ട് രണ്ട് തരം പരീക്ഷണങ്ങൾ നടത്തുകയുണ്ടായി. വിവിധ നിറങ്ങളിലുള്ള തണൽപായകൾ, വളർച്ചാനിയന്ത്രണ ഹോർമോണുകളുടെ ഉപയോഗം എന്നിവ അവലംബിച്ചുകൊണ്ട് ഹെലിക്കോണിയുടെ വളർച്ചയും ഉത്പാദനവും ലക്ഷ്യമിട്ടുകൊണ്ട് ഒരു പരീക്ഷണം 2014 - 16 കാലയളവിൽ പ്രാദേശിക കാർഷിക ഗവേഷണ കേന്ദ്രം, പിലിക്കോടിൽ വെച്ച് നടത്തുകയുണ്ടായി.

വിവിധ നിറങ്ങളിലും, ഇനങ്ങളിലും ഉൾപ്പെട്ട തണൽപായകൾ ഈ പരീക്ഷണത്തിനായി ഉപയോഗിക്കു കയുണ്ടായി. അവ യഥാക്രമം 25%, 50%, ചുവന്ന നിറത്തിലുള്ള തണൽപായ, 25%, 50% നീല നിറത്തിലുള്ള തണൽപായ, 25%, 50% ചാര നിറത്തിലുള്ള തണൽപായ, 25%, 50%, പച്ചനിറത്തിലുള്ള തണൽപായ, തെങ്ങിന്റെ തണലിൽ, എന്നിവയായിരുന്നു.

മേൽപറഞ്ഞ തണൽപായയുടെ ഉപയോഗം ചെടികളുടെ ഉയരം, കന്നുകളുടെ എണ്ണം, ഇലകളിലെ ഹരിതകം, പൂക്കളുടെ എണ്ണം, പൂക്കളിലെ ബ്രാക്ട്കളുടെ എണ്ണം, പൂക്കളുടെ നീളം എന്നിവ വർധിപ്പിക്കുന്നതായി കണ്ടെത്തി.

വ്യത്യസ്ഥങ്ങളായ വളർച്ച നിയന്ത്രണ ഹോർമോണുകൾ പല വീര്യങ്ങളിൽ ഈ പരീക്ഷണത്തിൽ ഉപയോഗിക്കു കയുണ്ടായി. അവ യഥാക്രമം 10 പിപിഎം, 20 പിപിഎം, 30 പിപിഎം, വീര്യമുള്ള പാക്ലോബ്യൂട്രാസോൾ, 250 പിപിഎം, 500 പിപിഎം, 750 പിപിഎം, വീര്യമുള്ള സൈക്കോസിൽ, 10 പിപിഎം, 20 പിപിഎം, 30 പിപിഎം വിര്യമുള്ള എതിഫോൺ എന്നിവയായിരുന്നു.

മേൽപറഞ്ഞ വളർച്ചനിയന്ത്രണ ഹോർമോണുകൾ ചെടികളുടെ കന്നുകളുടെ എണ്ണം, ഇലകളുടെ എണ്ണം, ചെടിയുടെ ഉയരം, ഇലകളുടെ വലുപ്പം, ഇലകളിലെ ഹരിതകം, പൂക്കളുടെ എണ്ണം, ബ്രാക്ട്കളുടെ എണ്ണം, പൂക്കളുടെ നീളം എന്നിവ വർധിപ്പിക്കുന്നതായി കണ്ടെത്തി

ചാരനിറത്തിലുള്ള തണൽപായകൾ (25%), 20 പിപിഎം, വീര്യമുള്ള പാക്ലോബ്യൂട്രാസോൾ, എന്നിവയുടെ ഉപയോഗം ഹെലിക്കോണിയുടെ ഉത്പാദനവർധനയ്ക്ക് ഉതകുന്നതാകുന്നു എന്ന് പരീക്ഷണം തെളിയിച്ചു.

APPENDIX

1.Weather data during the crop period

Standard week	Temperature (°C)		Relative humidity (%)		BSS hours	Rainfall (mm)	Evaporation (mm)
	Max	Min	7.22 am	2.20 pm			
April-2015	33.07	23.44	86.00	66.00	6.71	15.00	3.99
May-2015	32.50	24.50	88.14	70.29	3.90	8.10	2.93
June-2015	30.27	23.83	93.17	81.33	2.15	130.80	3.14
July-2015	30.71	23.04	94.57	82.86	2.46	58.80	3.16
August-2015	30.89	22.96	89.00	77.00	2.76	108.60	4.00
September-2015	31.39	23.17	95.29	79.29	2.03	213.80	3.50
October-2015	31.34	23.62	92.84	76.30	2.21	265.70	3.15
November-2015	31.38	23.04	91.37	72.13	3.14	106.80	2.95
December-2015	32.26	21.73	94.10	68.30	5.07	1.60	3.22
January-2015	32.25	19.56	93.42	56.58	4.71	0.00	3.67
February-2015	32.25	21.93	92.24	58.92	3.00	0.00	4.53
March-2015	33.61	24.57	88.50	61.67	2.82	0.00	5.34

2. Lux meter Reading

Treatments	Lux Reading
T_1 (25 % red shade net)	539 lux
T_2 (50 % red shade net)	477 lux
T_3 (25 % blue shade net)	560 lux
T_4 (50 % blue shade net)	524 lux
T_5 (25 % grey shade net)	898 lux
T_6 (50 % grey shade net)	858 lux
T_7 (25 % green shade net)	635 lux
T_8 (50 % green shade net)	558 lux
T_9 (under coconut shade)	233 lux
T_{10} (open condition)	941 lux