Integrated Nutrient Management for Heliconia

(*Heliconia angusta* cv. Christmas Red)

by

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(2012-12-106)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM – 695 522

KERALA, INDIA

2014

DECLARATION

I, hereby declare that this thesis entitled **"Integrated nutrient management for heliconia"** 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.

Vellayani

Date: 12. 12. 2014

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(2012-12-106)

I am honoured to thank Dr. Arthur Jacob, Professor and Head, Instructional Farm, College of Agriculture for his valuable suggestions and support during the research work.

I wish to express my deep sense of gratitude to Dr.T. Sajitharani, Professer, Department of Agronomy for her affectionate advices, valuable suggestions, whole hearted co-operation and help rendered throughout my study.

I am thankful to Dr. Sverup John, Dean, College of Agriculture, Vellayani for the infrastructural facilities, resources and academic atmosphere extended to me during the course of my study.

I extend my special thanks to all the teaching and non- teaching staffs of Department of soil science and Agricultural Chemistry, Department of Olericulture, Department of Plantation crops and Spices, Department of Processing technology and Department of Plant Breeding and Genetics for their valuable suggestions, moral support, co-operation and timely help.

I place on record my sincere gratitude to Ajith Sir, Grancis chechi, Sasi annan, Girija chechi, Seena chechi for their sincere and whole hearted co-operation and help during the entire period of my research work.

It is a pleasure to acknowledge the affection and inspiration rendered my friends, Dhanya, Anushma, Krishna, Shoney, Anjali, Anupama, Harsha, Reshma, Anju, v.s, Revoo, Priya, Annie, Pintu, Sonia, Karolin, Nimisha,v.p, Arya, Anju,Simi, Vandhana, Chris, Jennie, Sasna, Dipin, Nikhil, Anees, Jacob, Prasanth, Ajay, Anuroop, Henry, Manoj for their love, affection, special care and all time pragmatic help and cooperation which helped for my goal setting and spiritual upliftment during my studies and worries.

I extend my special thanks to Garggi chechi and Lekshmi chechi for their moral support, co-operation and timely help.

I thankfully acknowledge my immense gratitude to Shajma chechi for being with me whenever I was in trouble and encouragement throughout my PG programme.

I express my sincere thanks to Sreejith, Sheena chechi, Meera chechi, Ardra and Adheena for their valuable suggestions and help occasionally.

I am also thankful to my best friends, Sreeja, Nimisha , Suma, Soumya, Anjali, Sruthy and Felix for always listening to me, supporting me, and encouraging me.

Words are not enough to express my whole-hearted and affectionate gratitude to my beloved parents, sister and family members for their unbounding love, unparallel affection and unstinted encouragement throughout my educational career and without whose invaluable moral support, the thesis would not have seen the light of the day.

Finally, I wish my humble thanks to one and all who have directly or indirectly contributed to the conduct of the study.

Aryamba, T.G

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LIST OF ABBREVIATIONS

cm	-Centimeter
cm^2	-Centimeter square
$cm^2 g^{-1}$	-Centimeter square per gram
CD (0.05)	-Critical difference at 5per cent level
cv.	-Cultivar
dSm^{-1}	-Deci siemens per meter
DMSO	-Dimethyl sulfoxide
EC	-Electrical conductivity
et al.	-And others
FYM	-Farm yard manure
FYM m^{-2}	-Farmyard manure per meter square
Fig.	-Figure
g	-Gram
g/plot	-Gram per plot
g m^{-2}	-Gram per meter square
g plant $^{-1}$	-Gram per plant
H.mix	-Heliconia mix
ha^{-1}	-Per hectare
i.e.	-That is
K	-Potassium
kg	-Kilogram
kg/ha	-Kilogram per hectare
LAI	-Leaf area index
MAP	-Months after planting
M1	-PGPR Mix-1
m	-Meter

m^{-2}	-Per meter square
mg	-Milligram
mg g^{-1}	-Milligram per gram
MSL	-Mean sea level
N	-Nitrogen
NC	-Neemcake
NPK	-Nitrogen, Phosphorous and Potassium
NS	-Not significant
nm	-Nanometer
P	-Phosphorous
p^H	-Negative logarithm of hydrogen ion concentration
PSB	-Phosphorous solubilizing bacteria
$Plant^{-1}$	-Per plant
RBD	-Randomized block design
SLA	-Specific leaf area
Rs.ha^{-1}	-Rupees per hectare
sp.	-Species
t	-tonnes
VC	-Vermicompost
viz.	-Namely
$year^{-1}$	-Per year

LIST OF SYMBOLS

@	-At the rate of
^{0}	-Degree
^{0}C	-Degree Celsius
"	-Inch
%	-Per cent

INTRODUCTION

1. INTRODUCTION

The demand for heliconia as cut flower is increasing in many countries around the world. Heliconias are newly identified cut flowers in our country and becoming popular in all metropolitan cities. The interest of agribusiness involving heliconia as cut flower is evident as demonstrated by the continuous increase in the production and commercialization in many countries around the world.

Modern and intensive agriculture calls for a heavy dependency on fertilizers and chemicals, besides neglecting the traditional good practices. In many areas, the overall health and productivity of the soil have declined to such an extent that one cannot sustain profitable farming any more. Even, the high yielding varieties of crops can perform to their potential, only if they are grown in productive soils.

Heliconias are heavy feeders and they respond to high rates of fertilization (Criley, 1999). Nutritional deficiency affects production of heliconia cut flowers and the success of its commercialization. Relative to other floricultural crops, heliconia cultivation generally requires high rates of nutrients. The use of different NPK formulation is very common without considering development phase, whether vegetative or reproductive, species, seasonality or highest flowering period.

Among the nutrients, integrated nutrient management (INM) predominantly influences the plant growth and flower production as well as yield contributing characters. Among the nutrients nitrogen, phosphorus and potassium predominantly influence the plant growth and development as well as the yield characters. Since the quantity of these major and minor nutrients required is higher, their fertilization needs to be done judiciously.

Nutrition is one of the most important aspects in increasing the flower yield of heliconia. The continuous and imbalanced use of conventional fertilizers leads to decreased nutrient uptake efficiency of plants resulting in decreased crop yield. It also causes serious threat to soil health. The use of manures as an organic source occupies an important place as they provide a scope for reduction in use of costly chemical fertilizers. Organic manures also play a crucial role in sustaining the productivity of soil. In this context the present study was undertaken using *Heliconia angusta* cv. Christmas Red. The aim of the work was to standardize an integrated nutrient management schedule for heliconia for optimum flower yield and good quality.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Heliconia (*Heliconia* sp.) is tropical plant of princely dimensions grown for attractive foliage and brilliant flower spikes. It is native to Central and South America. The inflorescence is a cluster of bracts. The flowers are usually colorful, but small. A number of flowers are enclosed by colorful bracts, which are the organs of interest in the flower trade because of their considerable ornamental value. The wide variety of inflorescences, the good array of colors and long vase life make these flowers quite attractive to many consumers. Recently heliconias were included in a new family Heliconiaceae. Heliconia is mostly grown for cut flowers and landscaping purpose.The plants of Heliconia genus (Zingiberales: Heliconiaceae) are herbaceous, perennial, and rhizomatous. The erect pseudostems are formed by overlapping basal leaves. Its vegetative growth is vigorous, yielding many shoots and forming large clumps (Criley and Broschat, 1991). Colorful bracts protect the small flowers of the inflorescences. The most attractive characteristics of the inflorescence are vivid colors and unusual shapes with an exotic tropical appearance. The rhizomes are used for plant propagation, but also have the function of nutrient and water storage, which brings more resistance to adverse conditions for plants that have this kind of storage organs (Rundel *et al.,* 1998).

Heliconia sp. are reported to be grown commercially with fertilizer mixtures of N, P, and K in the ratios that include 1:1:1, 1:2:2, 3:1:2, and 3:1:5 (Ball, 1986; Criley, 1990). Van and Wichers (1973) recommended a ratio of 1 N: 2 K. Broschat and Donselman (1987) investigated N to K ratios in *H. psittacorum* and reported that K was not a limiting factor at K application rates in the range 0.0 to 0.65 kg m^{-2} $year^{-1}$. The effects that individual rates and ratios of N, P, and K have on specific aspects of growth and flowering in *Heliconia* have not been studied comprehensively. In addition, little published research is available on fertilizer requirements of potted *Heliconia* sp. (Criley and Broschat, 1992; Van and Wichers, 1973).

Nutritional deficiency affects heliconia cut flower production and the success of its commercialization. Relative to other floricultural crops, heliconia cultivation generally requires high rates of macro-elements, particularly N. There is a great variation in heliconia management in farm production, mainly concerning fertilization. The fertilization adopted frequently does not consider development phase, whether vegetative or reproductive, species, seasonality or highest flowering period. Aspects of nutritional requirements have not been studied comprehensively and little published researches are available.

2.1 EFFECT OF NUTRIENT TREATMENTS ON GROWTH CHARACTERS/ MORPHOLOGICAL CHARACTERS

2.1.1 Plant Height

Broschat and Donselman (1984a) reported that the application of 400 and 650g $N/m^2/yr$ gave higher plant height (178.5 cm), while the application of 125 g $N/m^2/yr$ gave least (168.1 cm) plant height in Heliconia cv. Andromeda.

Broschat *et al.* (1984b) recorded that, high application of K (3.6 kg m^{-2} $year^{-1}$) gave plant height in the range of 1.0 to 1.8 m in Heliconia cv. Golden Torch and cv. Andromeda.

Girish (2006) concluded that plant height in Heliconia cv. Golden Torch was significantly higher (93.88 cm) in plants grown under (40 x 40 cm with 2 kg FYM + 25 g N/m^2), followed by (93.60 cm) in (40 x 40 cm with + 2 kg FYM 25:20:20 g NPK/m^2) and least (89.04 cm) in plants nourished with 2 kg FYM/m^2 + 20 g K and 30 x 30 cm spacing.

Sushma *et al.* (2012a) observed that plant height (156.95 cm) was superior in treatment with the application of N, P and K (25:15:20 g + 2 kg FYM/ m^2) with wider spacing (40 cm x 40 cm) followed by treatment with 40 cm x 40 cm spacing and 25:20:20 g NPK + 2 kg FYM/ m^2 in heliconia (*Heliconia* sp.).

The treatment supplied with 25:10:20 g NPK+2 kg FYM/ m^2 recorded highest value for plant height (156.95 cm) in Heliconia cv. Golden Torch (Sushma *et al*,. 2012 b).

Nihad (2013) observed that plants supplied with NPK @ 13:5:13kg/ha recorded the highest value which was followed by Vermicompost @ 200g/plant +Neemcake @ 100g/plant.

2.1.2 Number of Leaves per Plant (Clump)

Broschat *et al.* (1984) reported that, high dose of N (3.6 kg m^2 $year^{-1}$) produced an average of 5 leaves per shoot in Heliconia cv. Andromeda and 4 to 5 leaves per shoot in Heliconia cv. Golden Torch.

Shoura and Hosni (1996) conducted pot experiment on Bird of Paradise. Plants were fertilized with N (g/plot) at 0.49 (low), 0.99 (intermediate) and 1.48 (high).Within fertilizer treatments, the intermediate level of N produced plants with highest no. of leaves per plant and longest leaves.

Clemens and Morton (1999) noticed significant influence of N and P in Heliconia cv. Golden Torch. A maximum of 6.7 to 7.0 leaves were produced at high rate of N (0.9 kg m^{-2}) and P (0.6 kg m^{-2}), respectively.

2.1.3 Number of Leaves per Shoot

Number of leaves subtending the inflorescence on the first shoot to emerge was affected by mineral nutrition, the number declining particularly in response to N rates above and below the predicted maximum (Clemons and Morton, 1999). Maximum number of subtending leaves was about seven, although Broschat *et al.* (1984b) reported that four to five leaves were typical. Catley and Brooking (1996) found that the number of leaves subtending the inflorescence in *Heliconia* 'Golden Torch' was lower with decreasing temperature.

Atehortua (1998) revealed that heliconia plants start flowering after emitting 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. Criley and Sakai (1998) reported that the heliconia flowering occurs with three expanded leaves. Castro (1995) reported that four to five leaves are needed for inflorescence emission. Criley (2000) stated that weather and environmental factors, such as light and humidity, have influence on timing of leaves and inflorescence emission.

Nihad (2013) observed that plants supplied with Vermicompost @ 200g/plant +Neemcake @ 100g/plant recorded the highest leaf production in intercropped condition. The plants supplied with 13:5:13 NPK recorded the highest leaf production throughout the period and was on par with vermicompost @ 200g/plant + Neemcake @ 100g/plant in monocropped condition.

2.1.4 Number of Shoots

Clemens and Morton (1999) found significant and positive linear effect of N and P on sucker production in heliconia cv. Golden Torch. Maximum numbers of suckers per plant were observed at N and P rate of 1.16 kg m^{-2}, 0.67 kg m^{-2}, respectively. When Heliconia cv. Golden Torch was fertilized with NPK (1.16:0.67:0.25 kg m^{-2}) maximum number of suckers per plant was observed (6.7 to 7).

Girish (2006) observed that the number of sucker produced per plant in Heliconia cv. Golden Torch varied significantly among different treatment combinations. The maximum no. of suckers (5.33) was noticed in treatment with (40x40 cm with 25 g N +10 g P +2 kg FYM/m^2) and (40x40 cm with 25 g N +20 g P+2 kg FYM/m^2) while it was minimum (3.33) in treatment (30x30 cm with 20 g K + 2 kg FYM/m^2).

Sushma *et al.* (2012a) reported number of suckers per plant (19.10) was recorded in treatment supplied with the application of N, P and K (25:15:20 g + 2 kg FYM/ m^2) with wider spacing (40 cm x 40 cm) followed by treatment with 40 cm x 40 cm spacing and 25:20:20 g NPK + 2 kg FYM/ m^2 in Heliconia (*Heliconia* sp.).

Sushma *et al.* (2012b) observed that treatment with 25:10:20 g NPK + 2 kg FYM/ m^2 recorded highest number of shoots in Heliconia cv. Golden Torch (19.10).

2.1.5 Leaf Area

Clemens and Morton (1999) revealed that application of N, P and K @ 1.2, 0.5 and 0.63 kg m^{-2}, respectively gave maximal response for leaf area in Heliconia cv. Golden Torch.

Girish (2006) observed that, leaf area varied significantly in different treatment combination of spacing and fertilizers. The leaf area was significantly maximum (195.63 cm^2) in treatment (40 x 40 cm with 25 g N+2 kg FYM/m^2), while it was minimum in the treatment (30 x 30 cm with 15 g N/m^2+2 kg FYM / m^2) at 11^{th} month after planting in Heliconia cv. Golden Torch.

Plants grown under full sunlight recorded significant difference in leaf area. The plants supplied with (13:05:13 NPK @ 5g/plant) and (Vermicompost @ 200 g/plant+Neem cake @100g/plant) recorded significantly the highest leaf area (Nihad, 2013).

2.1.6 Leaf Area Index (LAI)

The leaf area index of plants grown under monocropped condition was significantly different between the treatments except at eight months after planting. The plants under (Vermicompost @ 200 g/plant + Neem cake @100g / plant) treatment recorded the highest LAI (Nihad, 2013).

2.1.7 Leaf Area Ratio

The specific leaf area of the intercropped plants varied significantly throughout the period except at 14 months after planting. The plants supplied with Vermicompost +Neemcake gave significantly higher value throughout its growth period. Under monocropped condition, the plants grown in treatment (13:05:13 NPK @ 5g/plant) recorded the highest specific leaf area throughout the period of growth which was followed by plants grown under (Vermicompost @ 200g/plant+Neemcake @100g/plant) plants and was significantly superior to other treatments (Nihad, 2013).

2.2 EFFECT OF NUTRIENT TREATMENTS ON FLOWERING CHARACTERS

2.2.1 Type of Inflorescence

Once a plant is mature, each shoot produced from rhizome has the potential to generate a single inflorescence; each inflorescence may last from several days to several months (Berry and Kress, 1991).The most conspicuous feature of a fertile plant is the colorful inflorescence. Inflorescences are almost always terminal on erect, leafy shoots, but in few species they may arise on a basal leafless shoot. When terminal, the inflorescence may have an erect or pendent orientation with respect to the leafy shoot from which it emerges. The inflorescence is made up of modified leaf like structures called cincinnal bracts. Inflorescence and flower parts may be glabrous, puberulous, tomentose, velutinous, villous or woolly (Kress, 1984).

2.2.2 Length of Inflorescence

The heliconia inflorescence is a colorful, multi-bracted structure which may be upright or pendent. Two to 20 white, yellow, or orange florets are borne in the axil of each bract. The stalk lengths range from 0.5 to 3m, and inflorescence sizes from 10 to 50 cm. At least 30 of more than 250 species are grown for cut flowers to provide a considerable variety of forms, colors, seasonal availability, and post harvest life (Criley and Broschat, 1991).

Lekawatana (1995) stated that length of infloresceсe was different in different treatments. There was no single inflorescence when Heliconia stricta cv. Dwarf Jamaica was grown under continuous long day. Inflorescence length of 14.4 cm was observed with plants grown under continuous short day.

Nihad (2013) reported that the length of inflorescence in intercropped plants was significantly higher in treatments supplied with (Vermicompost @200 g / plant + Neemcake @100g/plant), (13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant+ Neem cake @50g/plant) and (13:05:13 NPK @ 5g/plant) plants (104.70, 103.28 and 101.70 cm respectively) and lower in the treatment supplied with Vermicompost @ 100 g/plant +Neemcake @50g/plant +Biofertilizers (*Azospirillum* and Phosphate Solublising Bacteria each @1.0 g/plant) 97.18 cm and (17:17:17 NPK complex fertilizer @5.0g/plant) 70.53 cm . In monocropped condition, only plants supplied with VC +NC produced inflorescence having a length more than 1.0 m (105.55cm).The lowest value for length of inflorescence was recorded in plants supplied with 17:17:17 NPK complex fertilizer @5.0g/plant.

2.2.3 Length of Spike

Goel (2004) reported variation in spike length of *Heliconia rostrata* (20-45 cm). Sheela *et al.* (2005) reported the length of spike was maximum in variety Guyana (19.89cm).

Nikhil (2012) reported that *Heliconia wagneriana* recorded highest value for spike length and *Heliconia psittacorum* cv. Strawberries recorded lowest value for spike length.

Nihad (2013) reported that in monocropped plants, the length of unopened spike differed significantly. The unopened spikes of plants grown under (Vermicompost @ 200 g/plant+Neemcake @100g/plant) recorded significantly the highest size (length and width- 25.00cm x 3.88cm) followed by the plants supplied with 13:05:13 NPK @ 5.0 g/plant (22.73cm x 2.20 cm) and 13:05:13 NPK @ 2.5g+Vermicompost @100 g/plant+Neem cake @50g/plant (22.30cmx3.38cm).The lowest size was in (17:17:17 NPK complex fertilizer @5.0g/plant) plants (16.73cm x3.38cm). In monocropped condition the highest size of opened spike was observed in plants grown under (29.65cm x 23.40 cm).

2.2.4 Length of petiole

Nikhil (2012) observed that the petiole length was highest in *Heliconia psittacorum* cv. Petra (34.89) which was on par with *Heliconia psittacorum* x *Heliconia marginata* cv. DeRooij (33.75cm). Smitha (2005) also recorded highest length of petiole in *Heliconia latispatha* and cultivar Petra.

2.2.5 Number of Flower Bracts

Bracts are the main floral part contributing to the attractiveness of spike. Each flower of the cincinnus is subtended by an individual floral bract. The cincinnal bracts are distichous or are spirally arranged due to twisting of the rachis. The cincinnal bracts are usually bright red and/or yellow but are sometimes green. Their colour and texture generally differ on the inside and outside surfaces. The margins may be straight, revolute, or involute near the rachis (Kress, 1984).

Sanjeev (2005) recorded that the highest number of bracts per inflorescence was registered by genotype Peedro Ortiz (7.42) and the lowest number of flower bracts were observed in genotype Deep Orange (2.83).

Nikhil (2012) observed that the number of flower bracts was highest in *Heliconia lingulata* cv. Fan 13.75 and the lowest number of flower bracts was recorded in *Heliconia psittacorum* x *Heliconia spathocircinata* cv. Tropics (3.00).

Nihad (2013) concluded that inflorescence of plants grown under monocropping produced less number of bracts than plants grown under intercropping. Among the treatment combinations plants suppied with (Vermicompost @ 200 g/plant + Neem cake @100g/plant) produced inflorescence with the highest number of bracts in monocropped as well as in inter cropped conditions (5.50 and 6.75 respectively) followed by (13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant + Neem cake @ 50g/plant) . The lowest number was recorded in (Vermicompost @ 100 g/plant + Neem cake @50g/plant + Biofertilizers (*Azospirillum* and Phosphate Solublising Bacteria each @1.0 g/plant)) followed by (17:17:17 NPK complex fertilizer @5g/plant).

2.2.6 Visual Appeal of Flowers

Nikhil (2012) assessed visual appeal of flowers based on blending of colour, orientation of bracts, shape of bracts and flower colour. Based on these characters *Heliconia angus*ta cv. Christmas Red obtained a good score (20).

The visual appeal of flowers was assessed by Nihad (2013) based on four characters viz. bract arrangement, general appearance of flower, colour development and glossiness of flower. In monocropped as well as intercropped condition, plants grown with (Vermicompost @ 200 g/plant + Neem cake @100g/plant) flowers scored significantly higher values (6.24 and 7.38 respectively) for general appearance followed by (13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant + Neem cake @50g/plant). The score values were the lowest for treatment supplied with (17:17:17 NPK complex fertilizer @5.0 g/ plant) flowers (2.75 and 4.43).

2.2.7 Flowering Season

Dobkin (1984) observed that the interval between opening of bracts in Heliconia inflorescence increased with more soil moisture retention. In *H. psittacorum*, it was reported that the main factors influencing flowering were irradiance and temperature (Broschat *et al.*, 1984b), but photoperiod also appeared to have a slight influence (Geertsen, 1989). Heliconia species of commercial interest with strong seasonal flowering periods were noted by Criley (1999). They were *H.angusta, H.bihai, H.caribaea, H.caribaea X H.bihai, H.collinsiana, H.lingulata, H.rostrata, H.stricta, H.wagneriana* whereas the *H.psittacorum* cultivars and hybrids were observed as species with longer periods of bloom. In another study by Costa *et al.* (2006b), the number of days between the shoot emission and the inflorescence emission (DBSI) was observed in 10 genotypes of Heliconia. The shortest was 105 and 45 days and the longest was 126 and 93 days respectively. The average harvesting interval (interval between emission of inflorescence bud and the harvesting day) varied from 14 and 4 days (Hybrid Golden Torch) to 27 and 9 days (*H. bihai* cv. Nappi Yellow) (Costa *et al.*, 2009a).

2.2.8 Flowering Duration (Days)

H.psittacorum cultivars and hybrids were observed as species with longer periods of bloom Criley (1999).

Criley and Sakai (1998) reported that lowering occurs in *Heliconia wagneriana* with three expanded leaves. Pederson and Kress (1999) found flowering duration in *Heliconia paka* is around 74 days whereas in *Heliconia laufa* is 78 days. Maximum duration of flowering in field was observed for Guyana (22.11days), followed by deRooj Red (20.89 days) and Golden Torch (19.45 days) (Sheela *et al.*, 2005).

Nikhil (2012) observed that the highest flowering duration was recorded by *Heliconia characteraceae* cv. Sexy Pink (28.50 days) and the lowest flowering duration i.e 10.25 days recorded by *Heliconia psittacorum* x *Heliconia spathocircinata* cv. Tropics, which was on par with *Heliconia angusta* cv. Christmas Red (11.50 days).

2.2.9 Number of Flowering Shoots per Year

Broschat *et al.* (1984a) observed an enhancement of flower yield in *H. psittacorum* 'Andromeda' when nutrient status increased from 0.125 kg m^{-2} for each of N, P, and K to 1.05, 0.4, and 0.75 kg m^{-3} for N, P, and K, respectively.

Nikhil (2012) reported that highest number of flowering shoots was recorded in cultivar *Heliconia psittacorum* cv. Lady Di (28.82) and lowest number of flowering shoots was recorded in Heliconia latispatha cv. Orange gyro. Cultivar *Heliconia angusta* cv. Christmas Red registered seventeen flowering shoots per year.

Sushma *et al.* (2012a) stated that maximum number of flowers per plant (3.07) in treatment nourished with 25:10:20 NPK g/ m^2 and wider spacing (40 x 40 cm^2). The lowest number of flowers per plant (1.57) was recorded in plants with 20g K+ 2kg FYM/ m^2 and 30cm x 30cm spacing Heliconia (*Heliconia* sp.).

Sushma *et al.* (2012b) observed that treatment supplied with 25:10:20 g NPK + 2 kg FYM/ m^2, recorded maximum flowers yield per plant (3.07) and flower yield per meter square (64.73 flowers) in Heliconia cv. Golden Torch.

2.2.10 Size of Bract

The size of the bract is important because it usually represents the biggest highlight in flower arrangements and therefore customer appreciation. The treatment with organic and mineral fertilizers (18.8 cm), mineral fertilizers (18.0 cm) and mineral fertilizers with filter cake (18.1 cm) showed the highest values of size of bract (Abel *et al.*, 2010). Farias (2004) obtained under similar conditions for the length of bract, superior to that obtained in the present study (19.7 cm) average.

Sanjeev (2005) observed that the size of bract was highest for the genotype Pedro Ortiz (173.85 cm^2) and the lowest value was recorded by St. Vincent Red (14.6 cm^2).

Nikhil (2012) reported that the highest size of bract was recorded in cultivar *Heliconia stricta* cv. Iris Red (132.00 cm^2) and *Heliconia angusta* cv. Christmas Red recorded 37.50 cm^2.

2.2.11 Number of Flowers per Bract

The Heliconiaceae is a particularly important group in which to study floral development because its floral structure coupled with its potential placement as the sister group of the ginger families suggests that it represents an important evolutionary transition of floral form in the order (Kress *et. al.*, 2001 ; Rudall and Bateman, 2004).

Sanjeev (2005) reported that the genotype Petra orange (4.17) recorded lowest number of flowers per bract and highest was observed in Pedro Ortiz (19.25).

Nikhil (2012) concluded that *Heliconia wagneriana* cv. Yellow recorded highest number of flowers per bract with mean value 14.00, which was on par with *Heliconia stricta* cv. Iris Red (12.75). *Heliconia psittacorum* cv. Strawberries and *Heliconia mathiasiae* recorded lowest number of flowers per bract and *Heliconia angusta* cv. Christmas Red recorded 6.80 flowers per bract.

2.2.12 Length of Inflorescence Stalk

Nihad (2013) reported that plants grown in monocropped condition produced inflorescence with shorter stalk when compared to intercropped condition. In monocropped and intercropped condition the treatment supplied with Vermicompost @ 200g/ plant +Neemcake @ 100g per plant produced inflorescence with the longest stalk (90.63cm and 83.18cm) which was significantly higher than all other treatments. The length of inflorescence stalk was the shortest in plants nourished with 17:17:17 NPK complex fertilizer @ 5.0 g/plant) plants in monocropped and intercropped conditions (43.05cm and 38.85cm respectively).

Castro *et al.* (2007) obtained for the flower stem length, average value of 84.60 cm and found that the application of increasing doses of N, P and K in field conditions favored the productivity of Heliconia cv. Golden Torch.

Farias (2004) observed that the combination of organic and mineral fertilization provided increases in flower stem length compared with organic fertilizers and mineral fertilizer in Heliconia cv. Golden Torch.

2.2.13 Fresh Weight of Inflorescence

Clemons and Morton (1999) observed that application rates for N, P, and K (1.2, 0.5, and 0.63 kg m^{-2}respectively) gave maximal response for inflorescence weight. These rates, in the approximate ratio of 2:1:1 are similar to the nutrient regime reported by Broschat *et al.* (1984).

Nihad (2013) observed that treatment supplied with 13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant + Neem cake @50g/plant produced inflorescence with higher fresh weight (247.2g) followed by (Vermicompost @ 200 g/plant + Neem cake @100g/plant, (227.2g) in monocropped condition. In intercropped condition the highest fresh weight of inflorescence was recorded by treatment supplied with Vermicompost @ 200 g/plant + Neem cake @100g/plant, (227.2g).

2.3 EFFECT OF NUTRIENT TREATMENTS ON DURATION OF CROP

2.3.1 Days Taken to First and Fifty Per Cent Flowering

Sushma *et al.* (2012a) stated that the early bud initiation (213.00 days), early flowering (222.57 days) and maximum flowers per plant (3.07) were obtained in treatment nourished with 25:10:20 NPK g/ m^2 and wider spacing (40 x 40 cm^2). Whereas, late bud initiation (224.80 days), flowering (234.30 days) and less number of flower per plant (1.57) was recorded in plants treated with 20 g K + 2 kg FYM/ m^2 and 30 cm x 30 cm spacing Heliconia (*Heliconia* sp.).

In the monocropped condition, there was significant difference between treatments in the number of days taken for first flowering. The plants supplied with VC and NC (T_3) took the lowest number of days (280.3) for first flowering whereas the plants supplied with 13:05:13 (T_2) took the longest time to start flowering (362.5 days). The treatments in the intercropped area recorded no significant difference between treatments in the flowering behavior and the plants supplied with Vermicompost and Neemcake attained fifty percent flowering in 248.5 days. The treatments supplied with Vermicompost and Neemcake alone took 370.0 days after planting to reach fifty percent flowering whereas the plants supplied with 13:05:13 NPK took the longest time to attain fifty percent flowering i.e. 437.5 days. (Nihad, 2013).

2.3.2 Life of Flower in the Plant

Nihad (2013) revealed that in monocropped condition plants treated with Vermicompost @ 200 g/plant +Neem cake @100g/plant recorded the longest time (6.75days) for the flower to emerge from the pseudostem. The plants supplied with 13:05:13 NPK+ Vermicompost +Neemcake, 13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant + Neem cake @50g/plant recorded the lowest (4.25days) and the treatment supplied with (13:05:13 NPK @ 5.0 g/plant) plants the longest (9.50 days) time for complete opening of the flower when grown under monocropped condition. The plants supplied with vermicompost and neemcake recorded significantly longer inflorescence life (19.75days) on plant. The shortest life (5.50 days) was recorded in plants supplied with 17:17:17 NPK (T_1).

2.4 EFFECT OF NUTRIENT TREATMENTS ON PLANT ANALYSIS

2.4.1 Leaf Chlorophyll Content

The increases in heliconia leaf chlorophyll content was associated with increased leaf mass density rather than to changes in leaf thickness according to Rundel *et al.* (1998). However, it was later found that a reduction in chlorophyll content occurred when the nutrient supply to plants was limited and photo inhibition of plants grown under full sun disappeared when applying nutrients particularly nitrogen (He and Goel , 2003).

Sushma *et al.* (2012a) recorded that the highest chlorophyll content such as chlorophyll a, chlorophyll b and total chlorophyll (0.83 mg/ g, 0.42 mg/ g and 1.25 mg/ g respectively) was registered by plants grown under (40 cm x 40 cm spacing and 25:20:20 g NPK+ 2 kg FYM/ m^2) in Heliconia (*Heliconia* sp.).

Nihad (2013) observed that the leaf chlorophyll content of *Heliconia stricta* cv. Iris red grown as coconut intercrop was more than the monocrop. The chlorophyll content was significantly higher in plants supplied with

Vermicompost @ 200 g/plant +Neem cake@100g/plant (1.886 and 1.263 respectively).

2.4.2 Leaf NPK Analysis

Sushma *et al.* (2012a) reported that maximum nitrogen (1.83 %), phosphorus (0.42 %), potassium (3.24 %) in the plants was recorded in plants grown under (40 cm x 40 cm spacing and 25:20:20 g NPK+ 2 kg FYM/ m^2). Whereas lower nitrogen (1.31 %), phosphorus (0.09 %),potassium (2.4 %) content in leaves was recorded by treatment supplied with (30 cm x 30 cm spacing and 20 g K+ 2 kg FYM/ m^2) in Heliconia (*Heliconia* sp.).

Sushma *et al.* (2012b) reported nitrogen (1.72 %), phosphorus (0.37 %) and potassium (3.09 %) in leaves were recorded maximum in treatment (25:10:20 g NPK + 2 kg FYM/ m^2), followed by plants supplied with 25:10:20 g NPK+ vermicompost 2 t/ ha in Heliconia cv. Golden Torch.

2.5 EFFECT OF NUTRIENT TREATMENTS ON SOIL ANALYSIS

2.5.1 Soil Organic Carbon

Nihad (2013) observed that the effect of nutrient treatments on organic carbon in intercropped area was not significant whereas, in monocropped area, the effect was significant. In monocropped area, the highest organic carbon content was recorded in plants nourished with Vermicompost @ 200 g/plant+Neemcake @100g/plant followed by plants supplied with 13:05:13 NPK @ 2.5g + Vermicompost @100 g/plant +Neem cake @50g/plant) in *Heliconia stricta* cv. Iris red.

2.5.2 Soil pH

Nihad (2013) revealed that there was a general improvement in pH in intercropped area after the field experiment in *Heliconia stricta* cv. Iris red. Even though the pH varied significantly, soil of all the treatments were in the near neutral range.

2.5.3 Soil EC

Nihad (2013) reported that the EC of intercropped soil supplied with (13:5:13 NPK) and (13:05:13 NPK @ 2.5g +Vermicompost @100 g/plant+Neem cake @50g/plant) gave significantly higher values (0.09 and 0.08 respectively). In monocropped area also plants supplied with 13:5:13 NPK recorded higher EC (0.05).

2.5.4 Soil Available NPK

Sushma *et al.* (2012b) reported that Phosphorus (37.42 kg/ ha), potassium (285.24 kg/ ha) in soil was observed in plants which grown with treatment (40 cm x 40 cm spacing and 25:20:20 g NPK+ 2 kg FYM/ m^2). Whereas significantly higher content (133.73 kg/ ha) of nitrogen in soil was observed in plants supplied with (40 cm x 40 cm spacing with 25:15:20 g NPK+2 kg FYM/ m^2). Lower content of nitrogen (98.81 kg/ ha), phosphorus (37.42 kg/ ha), potassium (285.24 kg/ ha) in soil was in treatment with (30 cm x 30 cm spacing and 20 g K+2 kg FYM/ m^2). The treatment (25:10:20 g NPK+2kg FYM/ m^2), recorded higher content of nitrogen (133.73 kg/ ha), phosphorus (35.84 kg/ ha) and potassium (284.78 kg/ ha) in soil.

2.6 EFFECT OF NUTRIENT TREATMENTS ON VASE LIFE STUDY OF INFLORESCENCE

Broschat and Donselman (1983a,b) reported that postharvest life of Heliconia flowers varied with variety and ranged from 7-14 days in deionized water, with or without floral preservatives. Flowers were damaged when stored at temperatures below 10° C. No varietal difference was reported. Broschat and Donselman (1983a) observed that generally, Heliconia inflorescences did not continue to open once cut. Hence Heliconia flowers must be cut at the desired stage of opening since further opening of the bracts does not occur after cutting, even if sucrose solutions were used (Criley and Lekawatana, 1995). It was also observed that *H.psittaçorum* inflorescences could be cut at the tight flower stage or when one to three bracts wereopen (Criley, 1995; Donselman and Broschat, 1986). However, Tija and Sheehan (1984) reported that those inflorescences harvested at a younger stage (no open bract) lasted 42% longer than those harvested at a mature stage (three to four bracts open).The common practice for Hawaiian growers was to harvest Heliconia by cutting the inflorescence stalks near the soil line in the early morning (Criley and Paull, 1993; Criley, 1996).

Postharvest quality of tropical cut flowers depended on both preharvest and postharvest factors. Preharvest factors included environmental factors such as rainfall and temperature, cultivar, fertilizer levels, stage of flower development at harvest and time of day when harvested; whereas postharvest factors included all the steps in the handling system until the flowers reached the consumer (Jaroenkit and Paull, 2003).

To get the maximum vase life of heliconias it should be harvested early in the morning before flowers take up field heat and should place flowers in water as soon as possible and cool them down before packing them. Before packing heliconias wash them with a little detergent and rinse with fresh water. Florists, immediately on receipt of their heliconias, should immerse the entire bloom and stem under water for 20 minutes. After immersion, re-cut the end of the stem 1" with a sharp knife and immediately place the stem in water. Mist the heliconias with water once or twice a day and change the water every few days at which time another 1" should be cut off the stem. Heliconia should be stored standing upright. Floral preservatives and sugar solutions are ineffective for heliconias, since their water uptake is minimal (Kepler and Mau, 1999).

2.7 EFFECT OF NUTRIENT TREATMENTS ON PEST AND DISEASE INCIDENCE

Heliconias are normally free of most serious pest and diseases if they are grown in the conditions that suit them. Insect pest such as aphids, mites, mealy bugs and other scale insects will be found on heliconias. These can cause some damage to the inflorescences and thus reduce marketability. The uses of chemical insecticides are usually not justified for heliconia. Birds and bats can also cause damage to the bracts when collecting nectar.

Fungal diseases, *Phytophthora* root rot and *Phythium* stem rot are the main disease problems for heliconia. These diseases can occur when there is an extended wet period, particularly if drainage is poor. Fungal disease problems can be increased when heliconias are too crowded restricting air circulation. The spraying of chemical fungicides usually cannot be recommended.

In addition to nematodes, heliconias can be infested with ants, aphids, scales and mealy bugs. If the insect population builds up to high levels it may necessitate spraying insecticide, particularly if export markets are being targeted. Making the correct insecticide spraying decision requires the monitoring of fields to identify the pest and the level of infestation (Hara *et al.*, 1993).

The monitoring for pest should be a regular part of field management programme. It is recommended that inspections be made on at least a monthly basis. To find insect pests pull down on the tight, lower bracts and leaves. Scales can be found anywhere on the flower stem and foliage (Burness and Gregor, 2003).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "Integrated nutrient management for Heliconia" was carried out at the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2013-2014. The study was undertaken to standardize an integrated nutrient management schedule for heliconia for optimum flower yield and quality. The details regarding experimental material used and methodology adopted while conducting investigation are presented here.

3.1 LOCATION

The field experiment was conducted at the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during 2013 – 2014(Fig. 1 and Plate 1a and b). The area is situated at 8^0 30' North latitude and 76^0 54' East longitude at an altitude of 29 m above MSL.

3.2 SOIL

The soil of the experimental site is red loam and belongs to vellayani series which comes under the Order Ultisol.

3.3 SEASON

The field experiment was conducted from June 2013 to May 2014.

3.4 MATERIALS

3.4.1 Planting Material

Uniform sized good quality *Heliconia angusta* cv. Christmas Red suckers were collected for the experiment.

3.4.2 Manures and Biofertilizers

All treatments were supplied with

bone meal/plant basally and biofertilizers i.e., azospirillum & PSB (phosphorous solubilizing bacteria) each at 1.0g/plant at the time of planting. Two organic manures (vermicompost and neem cake) and one biofertilizer (PGPR Mix - I) and heliconia mix (13:5:13 NPK) were used for the study. Top dressing was given at trimonthly interval.

3.5 METHODS

3.5.1 Design and Layout of the Experiment

Variety: *Heliconia angusta* cv. Christmas Red

Design: RBD

No. of treatments: 9

No. of replications: 4

Plot size: 3 x 3 m

Spacing: 75 x 75 cm

No. of plants /plot: 16

3.5.2 Land Preparation and Planting

The experimental area was cleaned of weeds, ploughed and laid out in randomized block design. Initial soil samples were taken for analysis. The individual plots were dug thoroughly and pits were taken at 75 x 75 cm spacing with a plant density of 16 plants/ plot. Between plots, a spacing of 50 cm was maintained. The pits were filled with 1.0 kg farm yard manure and biofertilizers i.e., azospirillum & PSB (phosphorous solubilizing bacteria) each at 1.0 g/plant.

3.5.3 Treatment Details

All treatments were supplied with 1.0 kg Farm yard manure/Plant+ 250g bonemeal/plant basally and Biofertilizers i.e., Azospirillum & PSB (Phosphorous solubilizing bacteria) each at 1g/plant at the time of planting. Top dressing was given at trimonthly interval. (The treatments were fixed based on the results of the previous study). Heliconiamix is NPK 13:5:13 and M1 is PGPR Mix-I, which is a consortium of NPK biofertilizer organism. PGPR Mix-I was applied at the rate of 2.0 g/ plant.

T_1: Heliconiamix2.5g + Vermicompost100g + Neem cake50g

T_2: Heliconiamix2.5g + Vermicompost150g + Neem cake75g

T_3: Heliconiamix2.5g + Vermicompost200g + Neem cake100g

T_4: Vermicompost 200g + Neem cake150g

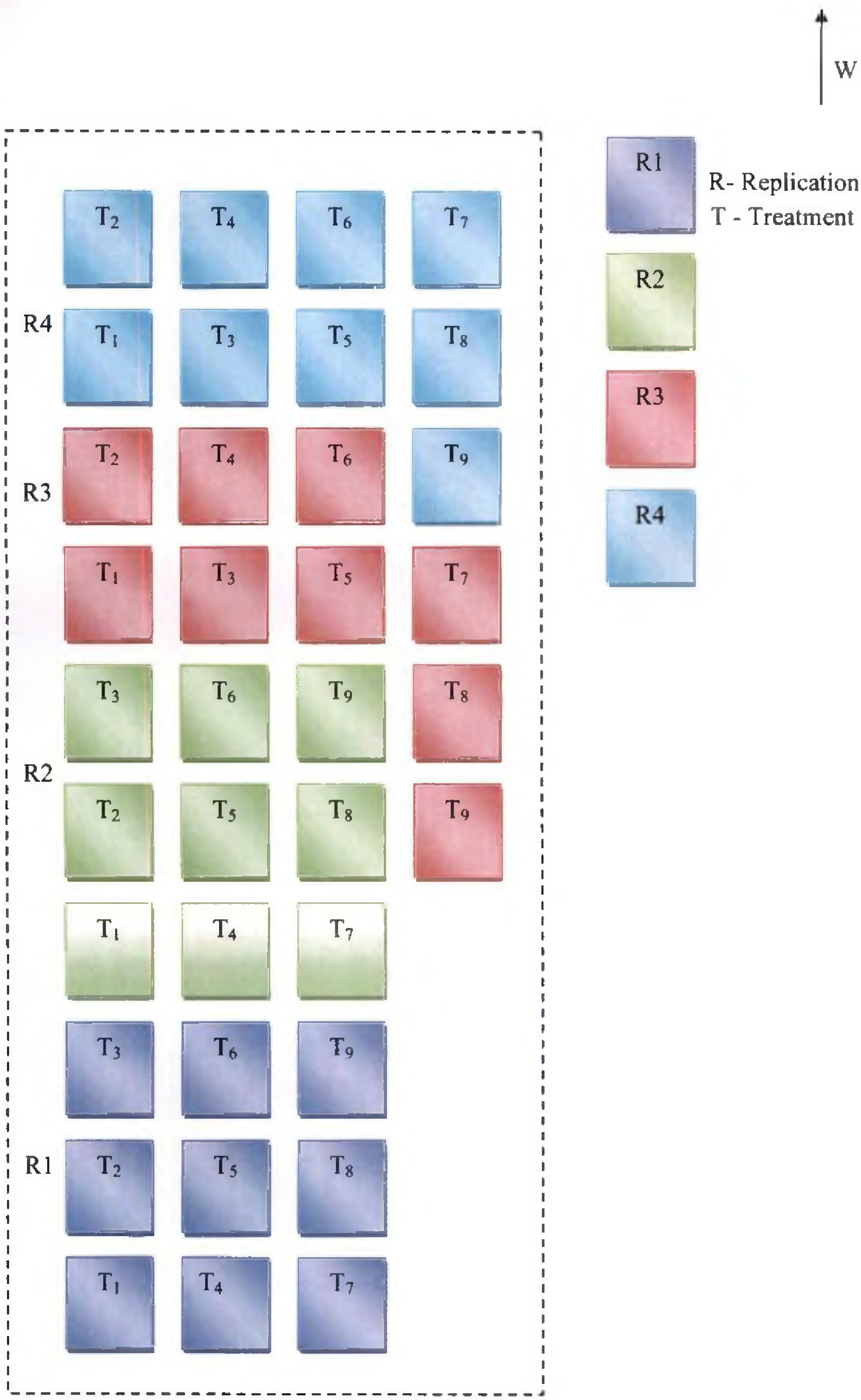

Fig.1 Field lay-out of experiment

T_5: Vermicompost 300g + Neem cake150g

T_6: Vermicompost 400g + Neem cake150g

T_7: M1 + Vermicompost100g + Neem cake50g

T_8: M1 + Vermicompost150g + Neem cake75g

T_9: M1 + Vermicompost200g + Neem cake100g

3.5.4 After Cultivation

The crop was given regular irrigation and hand weeding throughout the observation period depending upon the intensity of weed growth. Old shoots and flowers were removed periodically (Plate 2, Plate 6 and Plate 7).

3.5.5 Plant Protection

The plants were observed frequently for any pest /disease occurrence throughout the crop period.

3.6 OBSERVATIONS

Four each treatment combination, four replications were maintained. In each treatment four plants were tagged per replication as observational plants (Plate 2). Observations were taken at bimonthly interval from one month after transplanting. The inflorescence characters were taken at bimonthly interval from five months after planting. Leaf nutrient content (one year after planting) and various soil parameters like soil p^H, EC, organic carbon and soil NPK were also analysed before and after the field experiment.

3.6.1 Morphological Characters/ Growth Characters

The observations on growth characters were taken from four plants in each plot at bimonthly intervals from one month after planting for a period of one year and the mean values were recorded.

3.6.1.1 Plant Height (cm)

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

a. General view of the experimental field

b. General view of the experimental field

Plate 1. General view of the experimental field at four months after planting

3.6.1.2 Plant Spread (cm)

The plant spread was recorded by measuring the North- South and East-West spread of plant at bimonthly interval of tagged plants and average was worked out in cm.

3.6.1.3 Number of Leaves per Plant (Clump)

Number of leaves produced by plant was recorded from the tagged plants by counting the number of leaves first at one month after planting and thereafter at bi-monthly interval. Then average was worked out.

3.6.1.4 Number of Leaves per Shoot

Numbers of leaves per shoot were counted first at one month after emerging of shoot and later at bi-monthly interval and mean value calculated.

3.6.1.5 Number of Shoots (Suckers)

Numbers of shoots arising from the rhizome were recorded at bi-monthly interval.

3.6.1.6 Flower Canopy Height (cm)

The flower canopy height was measured from the ground to base of the flower receptacle.

3.6.1.7 Leaf Area (cm^2)

Leaf area of the plants was calculated by the following formula and the mean value was recorded.

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

(Bruna *et al.*, 2002)

3.6.1.8 Leaf Area Index (LAI)

The leaf area index is computed by using the equation and the mean value was recorded.

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

3.6.1.9 Leaf Area Ratio ($cm^2\ g^{-1}$)

Leaf area ratio is computed using the equation and the mean value was recorded.

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

3.6.2 Flowering Characters

3.6.2.1 Type of Inflorescence

Type of inflorescence was observed and recorded as to whether erect, pendent or intermediate.

3.6.2.2 Length of Inflorescence (cm)

Inflorescence length was measured from base of the inflorescence stalk to the tip of the axis of fully opened inflorescence.

3.6.2.3 Length of Spike (cm)

The spike length was measured from the point of emergence from the top most leaf to the tip of the axis of fully opened inflorescence. Then average spike length was worked out in cm.

3.6.2.4 Length of Petiole (cm)

Length of petiole was measured from the point of emergence from the shoot to the base of first flower bract and mean calculated and expressed in cm.

3.6.2.5 Number of Flower Bracts

The number of bracts in fully opened inflorescence was counted and the mean value was recorded (Plate 3a, 4b and 4c).

3.6.2.6 Visual Appeal of Flowers

The visual appeal of flowers was assessed by a panel of ten judges. Different morphological and visual characters of flowers were observed and evaluated based on four characters *viz.* general appearance, glossiness of flower, colour development and bract arrangement (Table 1 and Table 2). Flowers were categorised into three groups *viz.* Average (1- 5), Good (6-8), Very good (9-10) on a 10 point basis.

3.6.2.7 Days Taken for Flowering (days)

Days taken for average flower production was observed and mean calculated.

3.6.2.8 Flowering Duration (days)

The total number of days taken by the spike from complete opening of flower to the stage when the first bract started showing symptoms of senescence is recorded and average number of day's calculated.

SCORE CARD

Table 1. Visual appeal of *Heliconia angusta* cv. Christmas Red

Sl.No.	General appearance				Bract arrangement				Glossiness of flower				Colour development				Total score			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				

Table 2. Visual appeal of flowers (score card showing score distribution)

General appearance	Bract arrangement	Glossiness of flower	Colour development	Total score
Average (1 to5)	Average (1 to5)	Average (1 to5)	Average (1 to5)	Average (1 to5)
Good (6 to 8)	Good (6 to 8)	Good (6 to 8)	Good (6 to 8)	Good (6 to 8)
Very good (9-10)	Very good (9-10)	Very good (9-10)	Very good (9-10)	Very good (9-10)

3.6.2.9 Number of Flowering Shoots per Year

Monthly counts were made for estimating number of flowering shoots during June 2013 to May 2014. Total number of flowering shoots produced by each clump was observed for one year and the mean value was calculated.

3.6.2.10 Size of Bract (cm)

The length of bract measured from base of bract to the tip of the flower bract was recorded and mean value expressed in cm (Plate 5d and 5e).

3.6.2.11 Number of Flowers per Bract

Second bract from below was selected as standard for counting the number of flowers per bract. The average was worked out and recorded for all the varieties.

3.6.2.12 Length of Inflorescence Stalk (cm)

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

3.6.2.13 Fresh Weight of Inflorescence (g)

From each replication four fully opened inflorescences were collected at bimonthly interval and the fresh weight was recorded and the mean value was calculated.

3.6.3 Duration of Crop

3.6.3.1 Days Taken to First and Fifty Per Cent Flowering

Days taken to first flowering is the number of days taken from planting to commencement of flowering and the days taken to fifty percent flowering is the number of days taken by fifty percent of plants in a plot to flower.

3.6.3.2 Life of Flower in the Plant (Days)

It is the number of days taken from just emergence of inflorescence from terminal end of psuedostem to the days taken for fully opened inflorescence to senescence (Distinct loss of colour, with bracts turning from dark red to blackish).

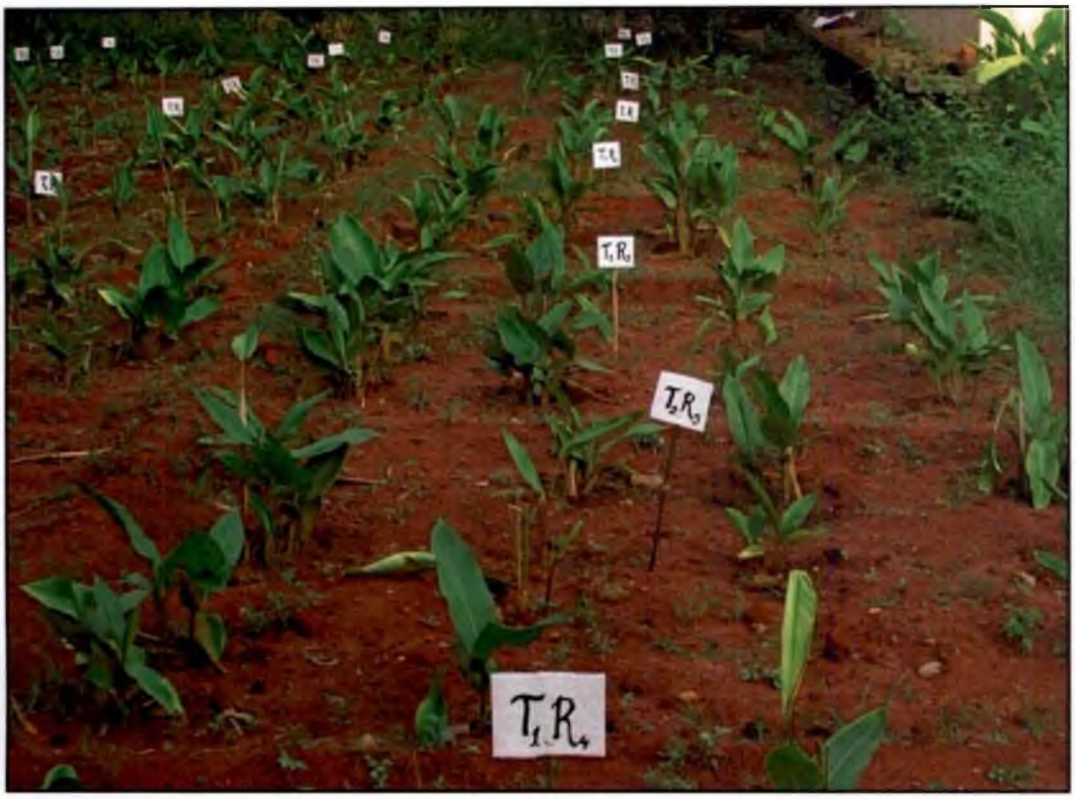

Plate 2. General view of the experimental field at six months after planting

a. Stage I

Plate 3. Different stages of flower opening

b. Stage II

c. Stage III

Plate 4. Different stages of flower opening

d. Stage IV

e. Stage V

Plate 5. Different stages of flower opening

3.6.4 Plant Analysis

3.6.4.1 Leaf Chlorophyll Content (mg g^{-1})

The leaf chlorophyll content was estimated by DMSO (Dimethyl sulfoxide) method and estimated chlorophyll a, chlorophyll b and total chlorophyll.

3.6.4.2 Leaf NPK Analysis (After the Experiment)

Leaf samples were taken from the top most fully opened leaves (Uchida, 2000) of flowered shoots during May 2014 and dried and powdered. The leaf samples were analyzed for nitrogen, phosphorous and potassium.

The methods adopted were,

a) ***Total N***

Modified Microkjeldhal method (Jackson, 1973)

b) ***Total P***

Plant digest was taken in diacid (Nitric and Perchloric acid in 4:1) (Baruah and Barthakur, 1998) and estimated by Vanadomolybdophosphoric yellow colour method and read in spectrophotometer at wavelength 470 nm (Jackson, 1973).

c) ***Total K***

Plant digest was taken in diacid (Nitric and Perchloric acid in 9:4) (Baruah and Barthakur, 1998) and estimated by Flame photometric method in Systronics Flame Photometer (Jackson, 1973).

3.6.5 Soil Analysis (Before and After the Experiment)

a) ***Organic Carbon***

Wet Digestion method (Walkley and Black, 1935)

b) ***Soil p^H***

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

c) ***Soil EC (dSm^{-1})***

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

3.6.5.1 Soil Available NPK

a) ***Available N***

Alkaline permanganate method (Subbiah and Asija., 1956)

b) ***Available P_2O_5***

Extraction by Bray solution and estimation by colorimetry method (Jackson, 1973)

c) ***Available K_2O***

Flame photometry (Jackson, 1973)

3.6.6 Vase Life Study of Inflorescence

Fully opened flowers were immersed in distilled water and the seasonal variation on vase life was recorded during observation period. The end point of flower is noticed with distinct loss of colour with bracts going from dark red to blackish. The data was recorded and average vase life of flowers was statistically analysed.

3.6.7 Pest and Disease Incidence

The plants were observed frequently for any pest / disease occurrence.

3.6.8 Economics of Cultivation

In order to assess the effects of each treatment with the combination of fertilizer, the cost of cultivation was worked out. This included the cost of fertilizer (urea, rajphos, muriate of potash), the cost of organic manures (farm yard manure, bone meal, neemcake, vermicompost) and biofertilizers (phosphorous solubilizing bacteria, azospirillum and PGPR Mix-1), taken at the current existing rates. The labour cost, including fertilizer application, irrigation, weeding and plant protection etc., during the cropping period were worked out. The Marketable flowers and suckers obtained under individual treatment during the observation period were taken into consideration for working out the economics. Based on the total cost of cultivation and gross income obtained, the net income and benefit: cost were worked out and was computed per hectare.

RESULTS

4. RESULTS

The investigation on "Integrated nutrient management for Heliconia" was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during the period of 2013 – 2014. The study was undertaken to standardize an integrated nutrient management schedule for heliconia for optimum flower yield and quality. The results obtained are presented in this chapter.

4.1 EFFECT OF NUTRIENT TREATMENTS ON MORPHOLOGICAL CHARACTERS

4.1.1 Plant Height

The height of the plants was found to be different significantly between treatments from three months after planting and thereafter at five, seven and nine months after planting (Table 3 and Fig. 2). The plants supplied with T_3 recorded the highest value (85.90cm) and was on par with T_4 and T_8. The lowest value recorded in the treatment T_6 was on par with T_1 and T_7 at nine months after planting.

4.1.2 Plant Spread

The spread of plants was recorded at bimonthly intervals from one month after planting and the effect of treatments was found to have significant difference only in one, five and seven months after planting. The highest value was recorded in T_3(50.31cm, 58.70cm, 80.99cm, 64.20cm, 66.95cm respectively) throughout the observation period and was on par with T_8 (Table 4 and Fig. 3).The lowest value was recorded in the treatment T_1 which was on par with T_6, T_9 and T_7.

4.1.3 Number of Leaves per Plant

The number of leaves per plants was observed at bimonthly intervals from one month after planting. Significant difference was observed between treatments in the number of leaves per plant at five months after planting (Table 5 and Fig. 4). The highest value (19.86) was recorded in T_3 which was on par with T_8 and T_4 (16.78 and 18.22). At five months after planting T_9 recorded the lowest number of leaves per plant.

Table 3. Effect of nutrient treatments on plant height (cm)

Treatments	Plant height (cm)				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	46.81	48.24	53.98	58.90	62.23
T_2(H.mix2.5g+VC150g + NC 75g)	43.36	46.53	59.64	63.83	68.08
T_3(H.mix2.5g+VC200g+NC100g)	52.24	59.32	80.94	83.33	85.90
T_4(VC200g +NC150g)	44.15	49.15	56.37	70.55	75.40
T_5(VC300g +NC150g)	45.42	50.42	57.00	59.12	65.87
T_6(VC400g +NC150g)	44.50	47.19	52.35	55.25	58.85
T_7(M1+VC100g+NC50g)	40.79	43.78	49.18	58.43	61.13
T_8(M1+VC150g+NC75g)	50.24	55.46	61.35	64.61	70.73
T_9 (M1+VC200g+NC100g)	38.90	47.68	54.30	56.78	63.13
CD(0.05)	NS	4.80	4.34	6.79	4.87

MAP – Months after planting

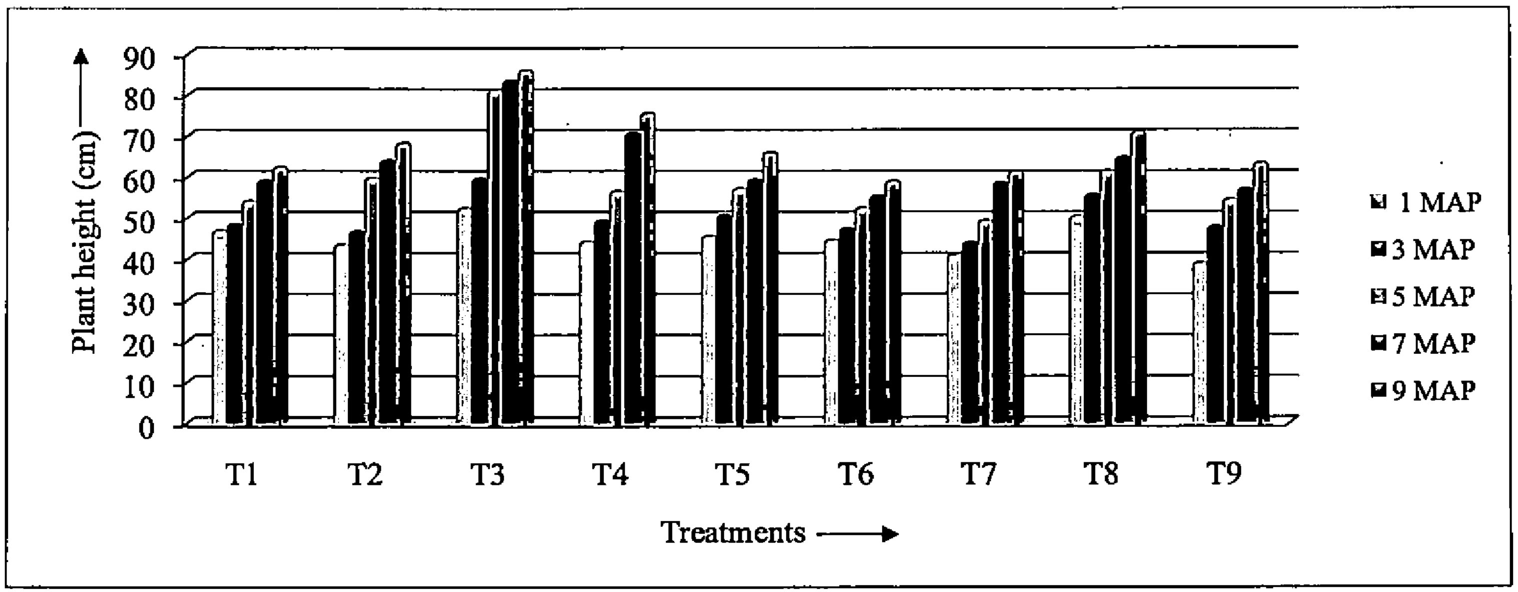

Fig.2 Effect of nutrient treatments on plant height

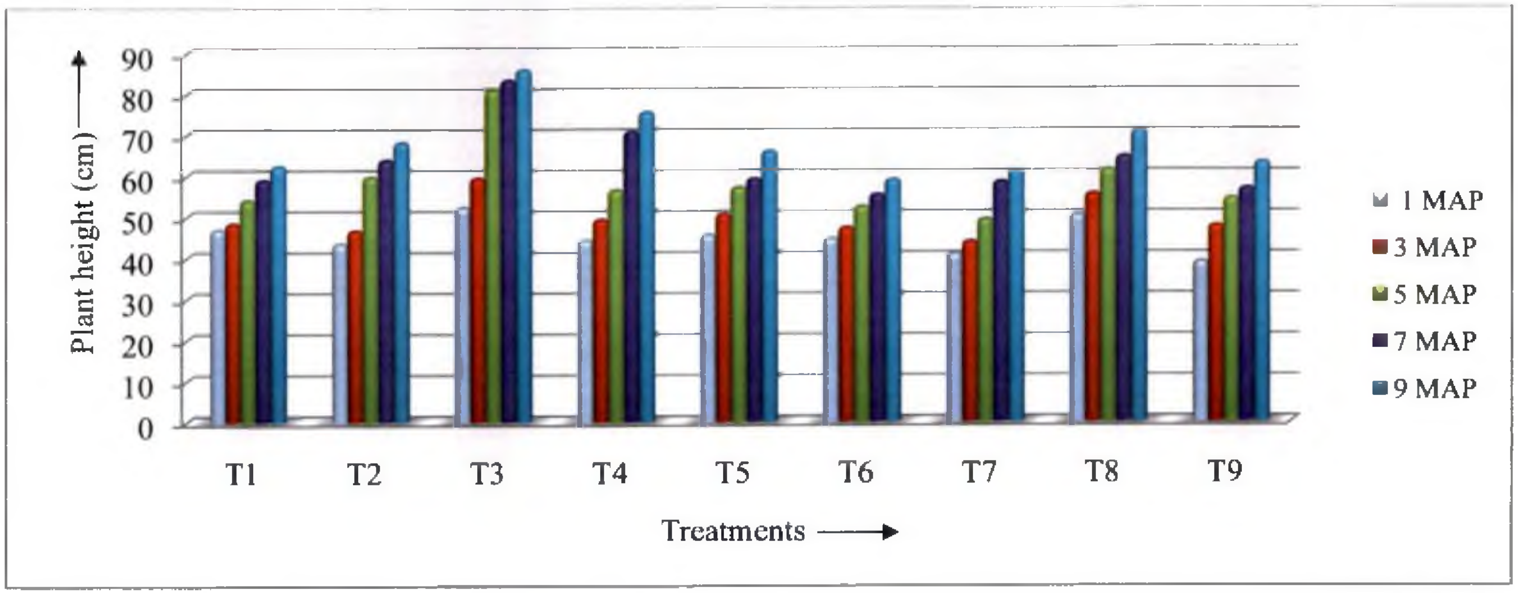

Fig.2 Effect of nutrient treatments on plant height

Table 4. Effect of nutrient treatments on plant spread (cm)

Treatments	Plant spread (cm)				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	40.63	49.06	57.08	50.90	54.16
T_2 (H.mix2.5g+VC150g + NC 75g)	43.11	47.15	62.92	58.44	63.06
T_3(H.mix2.5g+VC200g+NC100g)	50.31	58.70	80.99	64.20	66.95
T_4(VC200g +NC150g)	35.13	48.48	58.70	55.87	59.43
T_5(VC300g +NC150g)	34.12	49.88	55.56	60.58	62.52
T_6 (VC400g +NC150g)	36.52	45.55	56.10	52.50	55.29
T_7(M1+VC100g+NC50g)	42.10	47.77	57.87	59.20	58.48
T_8(M1+VC150g+NC75g)	38.67	55.61	63.17	65.16	64.88
T_9(M1+VC200g+NC100g)	40.71	47.50	54.82	55.20	55.77
CD(0.05)	3.91	NS	4.31	4.91	NS

MAP – Months after planting

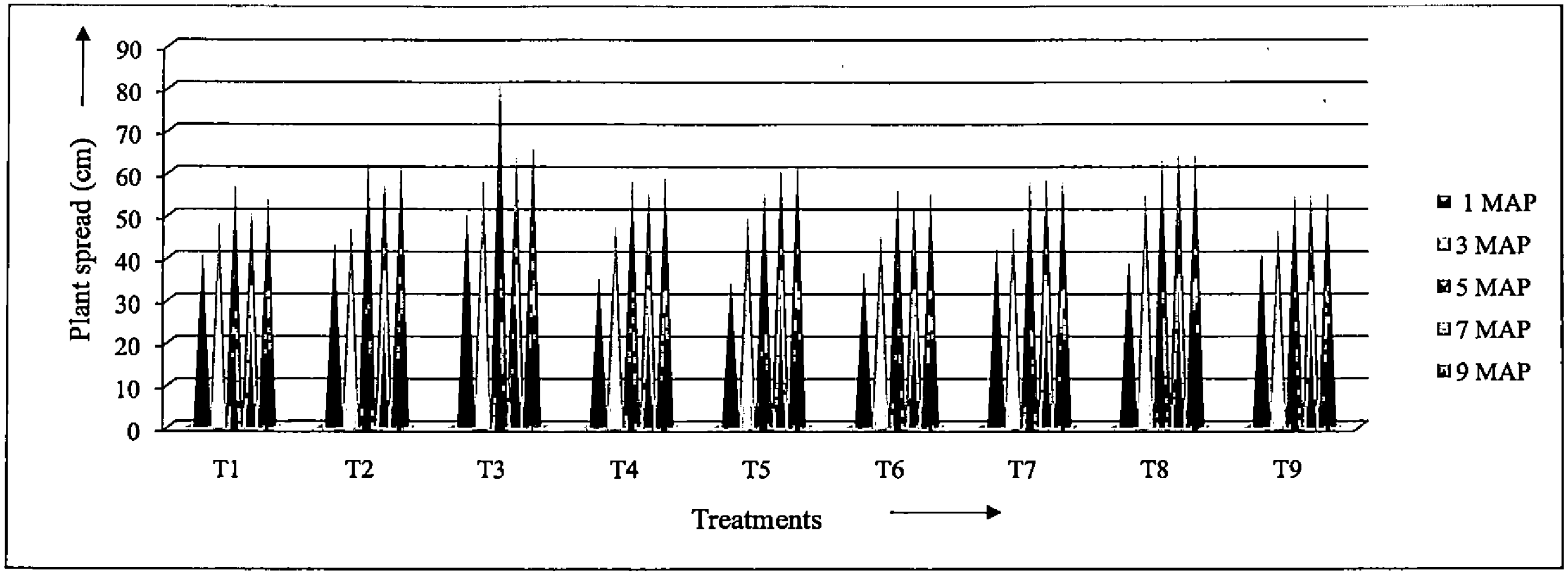

Fig.3 Effect of nutrient treatments on plant spread

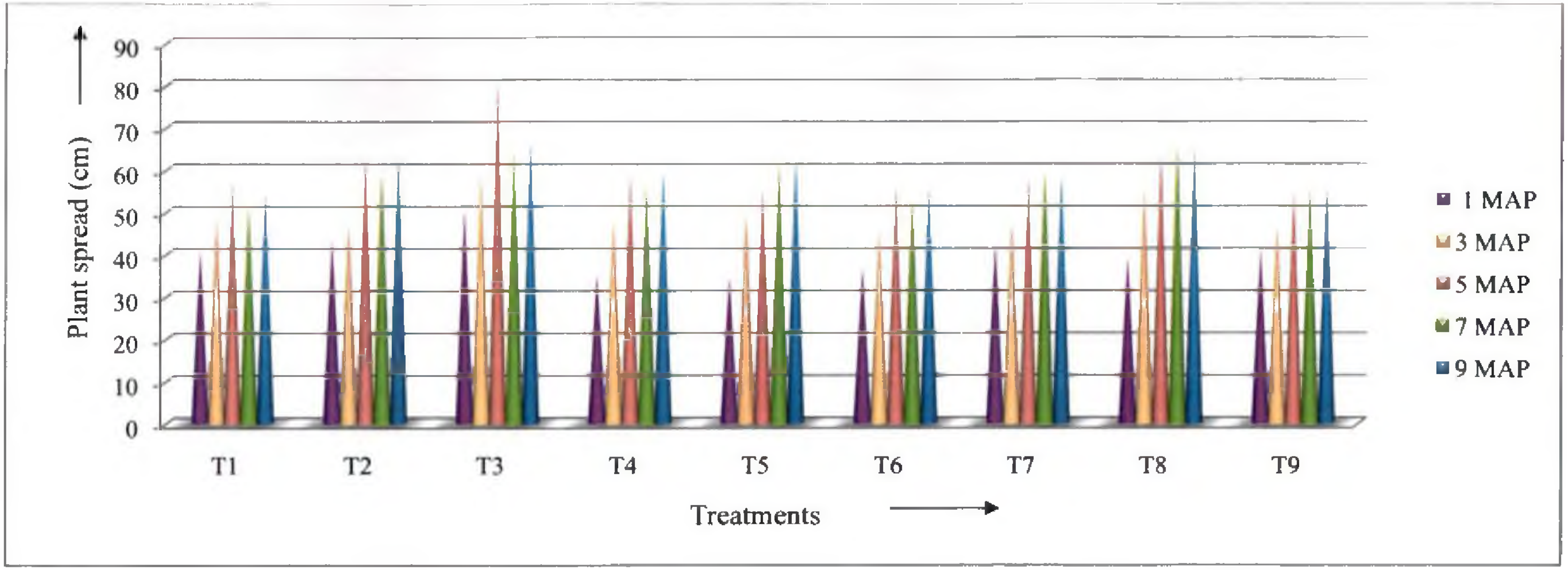

Fig.3 Effect of nutrient treatments on plant spread

Table 5. Effect of nutrient treatments on number of leaves per plant

Treatments	Number of leaves per plant				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	5.56	9.21	13.81	21.39	18.93
T_2(H.mix2.5g+VC150g + NC 75g)	3.68	8.56	16.46	19.45	18.75
T_3(H.mix2.5g+VC200g+NC100g)	6.50	12.60	19.86	22.56	19.68
T_4(VC200g +NC150g)	4.75	9.07	18.22	16.46	16.52
T_5(VC300g +NC150g)	5.30	7.30	14.56	22.18	23.12
T_6(VC400g +NC150g)	4.33	8.92	11.77	20.23	22.17
T_7(M1+VC100g+NC50g)	4.95	8.69	12.88	24.16	23.06
T_8(M1+VC150g+NC75g)	3.82	9.80	16.78	24.98	24.80
T_9(M1+VC200g+NC100g)	3.32	8.36	10.45	22.27	22.61
CD(0.05)	NS	NS	3.10	NS	NS

MAP – Months after planting

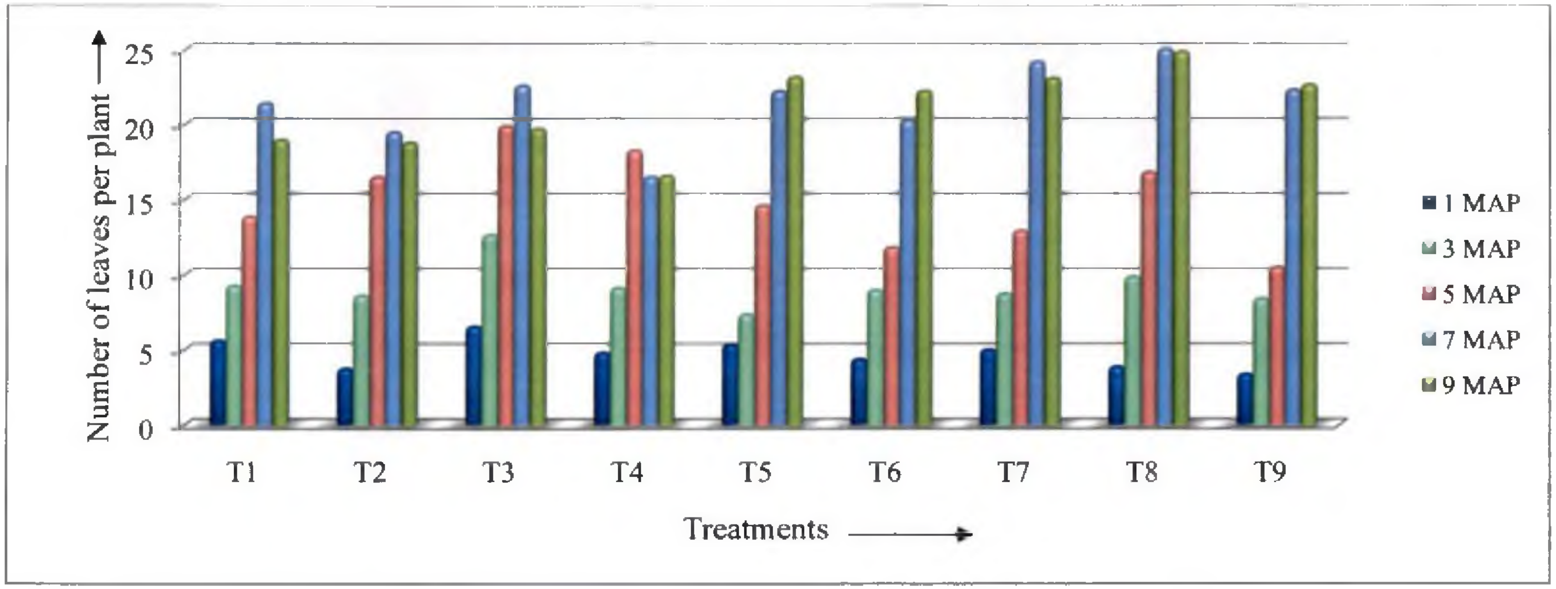

Fig.4 Effect of nutrient treatments on number of leaves per plant

4.1.4 Number of Leaves per Shoot

There was no significant difference among the treatments in the number of leaves per shoot. The number of leaves ranged from 3.63 in T_3 to 4.32 in T_8 at nine months after planting (Table 6).

4.1.5 Number of Shoots/Suckers

The number of shoots was found to be significantly different among the treatments throughout the observation period (Table 7 and Fig. 5). At one month after planting T_8 registered the highest number of shoots (3.12) and was on par with T_3 (3.07)and T_5 (3.00). At three months after planting T_3 showed the highest number of shoots (4.43). The treatment T_3 also recorded highest number of shoots at five, seven and nine months after planting followed by T_2 and T_1 at five months after planting (Table 7 and Plate 8). At seven months after planting T_1 and T_8 recorded number of shoots on par with each other. The lowest value was recorded by T_6 and was found to be on par with T_5 and T_4. The last observation at nine months after planting showed that there was significant difference among the treatments on number of shoots and the highest number of shoots was produced by T_3 (9.37)and the lowest number of shoots was produced by T_5 (5.50).

4.1.6 Flower Canopy Height

The flower canopy height showed significant difference among the treatments throughout the year (Table 8 and Fig. 6). The flower canopy height of the plants was higher in T_3 (99.10 cm) followed by T_5 (84.92 cm) at nine months after planting. The lowest value (70.53 cm) was observed in T_2.

4.1.7 Leaf Area

The leaf area of the plants grown under different treatments was found to be significantly different throughout the period of growth (Table 9). The leaf area of T_3 (220.47 cm and 222.23 cm respectively) and T_8 (200.51 cm^2 and 205.60 cm^2 respectively) plants recorded significantly higher values at seven and nine months after planting. The lowest leaf area (132.12 cm^2 and 137.07 cm^2) was recorded in plants grown under T_2.

Table 6. Effect of nutrient treatments on number of leaves per shoot /sucker

Treatments	Number of leaves per shoot /sucker				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	3.06	3.86	4.52	3.38	3.85
T_2(H.mix2.5g+VC150g + NC 75g)	3.18	4.06	4.46	4.18	3.76
T_3(H.mix2.5g+VC200g+NC100g)	4.50	4.06	4.43	4.31	3.63
T_4(VC200g +NC150g)	3.06	4.32	4.43	4.12	3.81
T_5(VC300g +NC150g)	3.12	3.77	4.73	4.45	4.18
T_6(VC400g +NC150g)	3.56	4.45	4.40	3.91	3.85
T_7(M1+VC100g+NC50g)	3.45	5.07	4.73	4.29	3.76
T_8(M1+VC150g+NC75g)	3.07	4.01	4.40	4.64	4.32
T_9(M1+VC200g+NC100g)	2.97	4.00	4.25	4.44	4.08
CD(0.05)	NS	NS	NS	NS	NS

MAP – Months after planting

Table 7. Effect of nutrient treatments on number of shoots

Treatments	Number of shoots				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	2.31	2.88	4.21	7.00	7.82
T_2(H.mix2.5g+VC150g + NC 75g)	1.75	2.93	4.33	6.32	6.50
T_3(H.mix2.5g+VC200g+NC100g)	3.07	4.43	5.50	7.85	9.37
T_4(VC200g +NC150g)	1.57	3.72	4.43	5.87	5.25
T_5(VC300g +NC150g)	3.00	1.97	4.30	5.70	5.50
T_6(VC400g +NC150g)	1.56	2.88	3.38	5.70	6.90
T_7(M1+VC100g+NC50g)	1.40	3.12	3.43	6.70	7.82
T_8(M1+VC150g+NC75g)	3.12	3.68	4.57	7.52	8.37
T_9(M1+VC200g+NC100g)	1.38	2.15	3.56	6.50	8.00
CD(0.05)	0.58	0.57	0.94	1.45	1.89

MAP – Months after planting

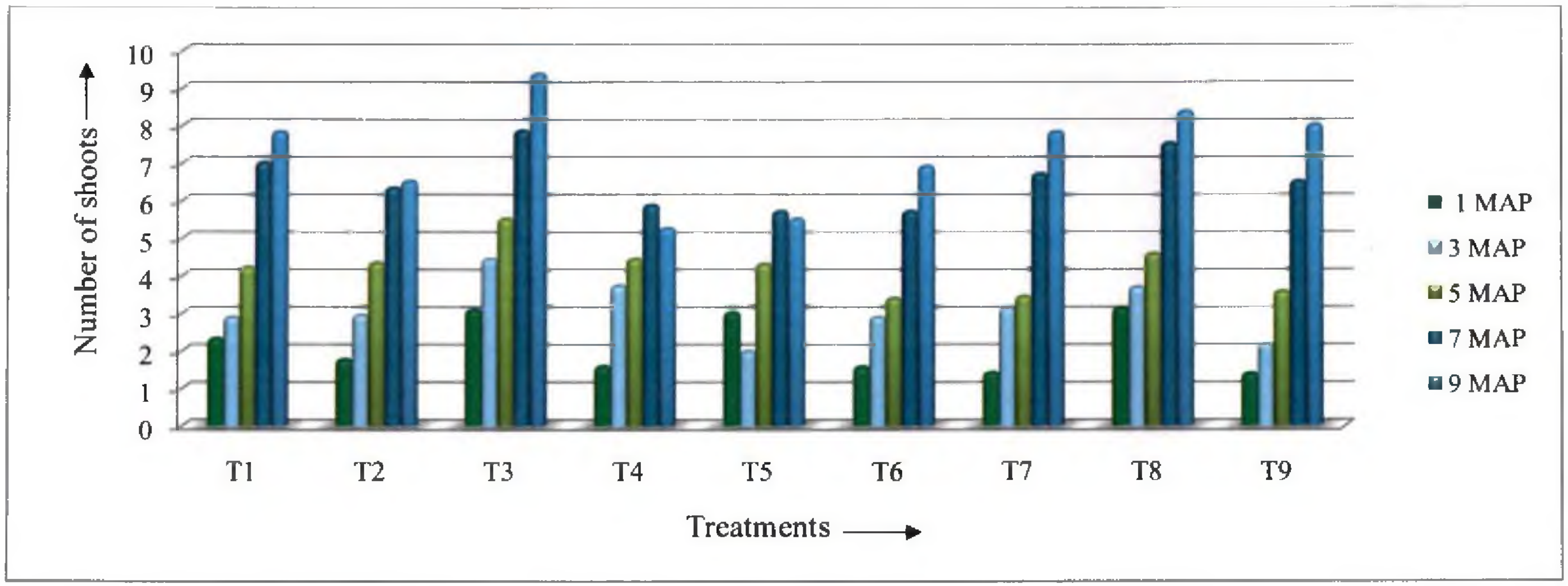

Fig.5 Effect of nutrient treatments on number of shoots

Plate 6. General view of the experimental field at eight months after planting

Plate 7. General view of the experimental field at nine months after planting

Plate 8. Closer view of the best treatment (T_3)

Plate 9a. Marketable flowers

Plate 9b. Marketable flowers

Plate 9. Marketable flowers in the best treatment (T_3)

Table 8. Effect of nutrient treatments on flower canopy height (cm)

Treatments	Flower canopy height (cm)		
	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	63.34	67.05	75.90
T_2(H.mix2.5g+VC150g + NC 75g)	60.51	63.55	70.53
T_3(H.mix2.5g+VC200g+NC100g)	81.53	84.24	99.01
T_4(VC200g +NC150g)	66.52	69.37	74.63
T_5(VC300g +NC150g)	70.06	71.92	84.92
T_6(VC400g +NC150g)	61.71	69.73	72.22
T_7(M1+VC100g+NC50g)	70.18	74.82	82.74
T_8(M1+VC150g+NC75g)	67.71	68.52	70.76
T_9(M1+VC200g+NC100g)	66.96	71.40	72.60
CD(0.05)	3.37	3.14	3.14

MAP – Months after planting

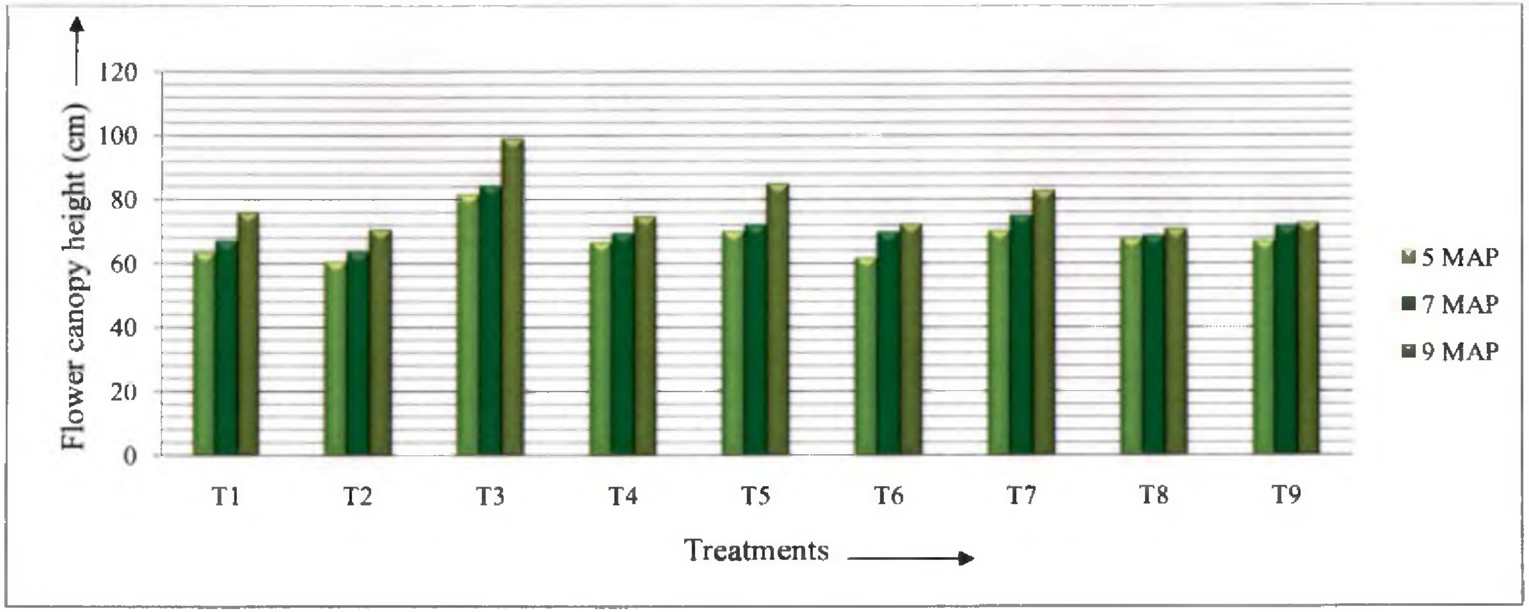

Fig.6 Effect of nutrient treatments on flower canopy height

Table 9. Effect of nutrient treatments on leaf area (cm^2)

Treatments	Leaf area (cm^2)				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	98.80	110.72	120.80	135.55	141.50
T_2(H.mix2.5g+VC150g + NC 75g)	99.23	106.06	116.51	132.12	137.07
T_3(H.mix2.5g+VC200g+NC100g)	133.88	136.61	191.14	220.47	222.23
T_4(VC200g +NC150g)	101.93	127.55	136.68	143.70	147.48
T_5(VC300g +NC150g)	131.01	134.82	141.41	150.55	152.50
T_6(VC400g +NC150g)	128.42	131.13	135.34	146.89	152.69
T_7(M1+VC100g+NC50g)	130.13	134.19	167.63	181.55	182.89
T_8(M1+VC150g+NC75g)	128.46	138.17	157.92	205.60	214.90
T_9(M1+VC200g+NC100g)	134.77	149.56	166.98	200.51	205.52
CD(0.05)	3.79	3.97	3.23	5.02	3.10

MAP – Months after planting

4.1.8 Leaf Area Index (LAI)

The leaf area index of the plants was found to differ significantly between the treatments throughout the year (Table 10). The treatment T_3 (0.0391 and 0.0395) was found to be significantly different from all other treatments at seven and nine months after planting followed by T_8 (0.0365 and 0.0382 respectively). At nine months after planting the lowest value was recorded by T_2 (0.0243) which was on par with T_1 (0.0251).

4.1.9 Leaf Area Ratio

The leaf area ratio was significantly influenced by different treatments at one, five and nine months after planting (Table 11). Treatment T_3 recorded the highest value of leaf area ratio (59.65, 84.64 and 78.32 respectively) and was significantly different from all other treatments during this period. The treatment T_2 recorded the lowest value and was found to be on par with T_4 at nine months after transplanting (49.75 and 52.67).

4.2 EFFECT OF NUTRIENT TREATMENTS ON FLOWERING CHARACTERS

4.2.1 Type of Inflorescence

The type of inflorescence in all treatments was found to be erect in nature.

4.2.2 Length of Inflorescence

The length of inflorescence in different treatments was recorded at bimonthly intervals and was found to be significantly different among the treatments throughout the observation period (Table 12 and Fig. 7). At five months after planting highest value for length of inflorescence (18.41 cm) was registered by T_6 and was found to be on par with T_3, T_8 and T_7 (Table 12). The lowest value was obtained by T_1 and T_2. At seven months after planting highest length of inflorescence was attained by T_3 (17.56 cm) and was found to be significantly different from all other treatments. The treatment T_9 registered the lowest value (14.87 cm) of length of inflorescence and was on par with T_2, T_1 and T_6. At nine months after planting the highest value was registered by T_3 (18.11

Table 10. Effect of nutrient treatments on leaf area index

Treatments	Leaf area index				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	0.0175	0.0196	0.0214	0.0240	0.0251
T_2(H.mix2.5g+VC150g + NC 75g)	0.0176	0.0183	0.0207	0.0234	0.0243
T_3 (H.mix2.5g+VC200g+NC100g)	0.0238	0.0242	0.0339	0.0391	0.0395
T_4(VC200g +NC150g)	0.0181	0.0223	0.0242	0.0255	0.0262
T_5(VC300g +NC150g)	0.0232	0.0232	0.0251	0.0267	0.0271
T_6(VC400g +NC150g)	0.0228	0.0231	0.0240	0.0261	0.0271
T_7 (M1+VC100g+NC50g)	0.0231	0.0232	0.0298	0.0322	0.0325
T_8(M1+VC150g+NC75g)	0.0228	0.0245	0.0280	0.0365	0.0382
T_9(M1+VC200g+NC100g)	0.0239	0.0265	0.0296	0.0356	0.0365
CD(0.05)	0.0007	0.0007	0.0006	0.0009	0.0006

MAP – Months after planting

Table 11. Effect of nutrient treatments on leaf area ratio($cm^2\ g^{-1}$)

Treatments	Leaf area ratio ($cm^2\ g^{-1}$)				
	1 MAP	3 MAP	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	88.85	64.87	61.68	67.39	57.85
T_2(H.mix2.5g+VC150g + NC 75g)	63.61	57.02	61.57	65.39	49.75
T_3 (H.mix2.5g+VC200g+NC100g)	59.65	61.34	84.64	79.55	78.32
T_4(VC200g +NC150g)	47.27	66.59	69.03	64.81	52.67
T_5(VC300g +NC150g)	59.87	61.15	61.48	66.21	65.34
T_6 (VC400g +NC150g)	62.23	60.51	72.14	63.34	61.01
T_7(M1+VC100g+NC50g)	67.64	68.54	84.20	67.54	67.14
T_8(M1+VC150g+NC75g)	63.94	65.47	70.30	70.49	68.72
T_9(M1+VC200g+NC100g)	67.92	72.30	77.22	71.52	65.86
CD(0.05)	10.48	NS	8.26	NS	7.28

MAP – Months after planting

cm) followed by T_8 (16.32 cm). The lowest length of inflorescence was by T_9 (14.87 cm).

4.2.3 Length of Spike

There was significant difference among the treatments in the length of spike. Different treatments influenced the spike length at five, seven and nine months after planting. The length of spike was significantly higher in T_3 which was superior at five, seven and nine months after planting (29.62 cm, 32.26cm, 31.96 cm respectively) (Table13 and Fig. 8). The lowest value (24.30, 25.46 and 26.18 cm respectively) was recorded by the treatment T_9.

4.2.4 Length of Petiole

The data on effect of nutrients on length of petiole is presented in Table 14 and Fig. 9. The influence of treatments on length of petiole was recorded from five months after planting and it was found there was significant difference among the treatments on the length of petiole throughout the year. The highest value was recorded by T_3 throughout the observation period (17.97, 20.53 and 20.80 cm at five, seven and nine months after planting respectively). The lowest petiole length was observed in T_6 (16.31 cm) at nine months after planting.

4.2.5 Number of Flower Bracts

Data are presented in Table 15 and Fig.10 revealed that number of flower bracts varied significantly among the treatments. At five months after planting the highest number of flower bracts were registered by T_3 (5.25) and these were on par with T_8 (4.97 and 4.85). The highest number of flower bracts was observed in T_8 (5.32) at seven months after planting and was found to be on par with T_3 (5.22). At nine months after planting the highest number of flower bracts was recorded in T_3 (5.20) and were on par with T_8 (5.07) and T_2 (4.87).

4.2.6 Visual Appeal of Flowers

The visual appeal of flowers was observed based on four characters such as general appearance, bract arrangement, glossiness of flower and colour development (Table16).

All the characters showed significant difference among the treatments. The colour development of flower was significantly influenced by treatments and the

Table 12. Effect of nutrient treatments on length of inflorescence (cm)

Treatments	Length of inflorescence (cm)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	14.27	15.07	14.94
T_2 (H.mix2.5g+VC150g + NC 75g)	14.27	15.06	15.21
T_3 (H.mix2.5g+VC200g+NC100g)	16.98	17.56	18.11
T_4 (VC200g +NC150g)	15.85	16.35	16.07
T_5 (VC300g +NC150g)	15.37	16.25	15.37
T_6 (VC400g +NC150g)	18.41	15.23	15.13
T_7 (M1+VC100g+NC50g)	16.31	16.05	15.22
T_8 (M1+VC150g+NC75g)	16.40	16.32	16.32
T_9 (M1+VC200g+NC100g)	15.36	14.87	14.87
CD(0.05)	2.27	0.84	0.85

MAP – Months after planting

Table 13. Effect of nutrient treatments on length of spike (cm)

Treatments	Length of spike (cm)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	24.47	27.08	28.25
T_2 (H.mix2.5g+VC150g + NC 75g)	26.43	27.67	28.56
T_3 (H.mix2.5g+VC200g+NC100g)	29.62	32.26	31.96
T_4 (VC200g +NC150g)	27.65	28.13	28.82
T_5 (VC300g +NC150g)	28.31	29.21	29.23
T_6 (VC400g +NC150g)	27.39	27.63	27.78
T_7 (M1+VC100g+NC50g)	26.99	27.78	28.18
T_8 (M1+VC150g+NC75g)	26.19	26.88	27.35
T_9 (M1+VC200g+NC100g)	24.30	25.46	26.18
CD(0.05)	1.83	1.49	1.32

MAP – Months after planting

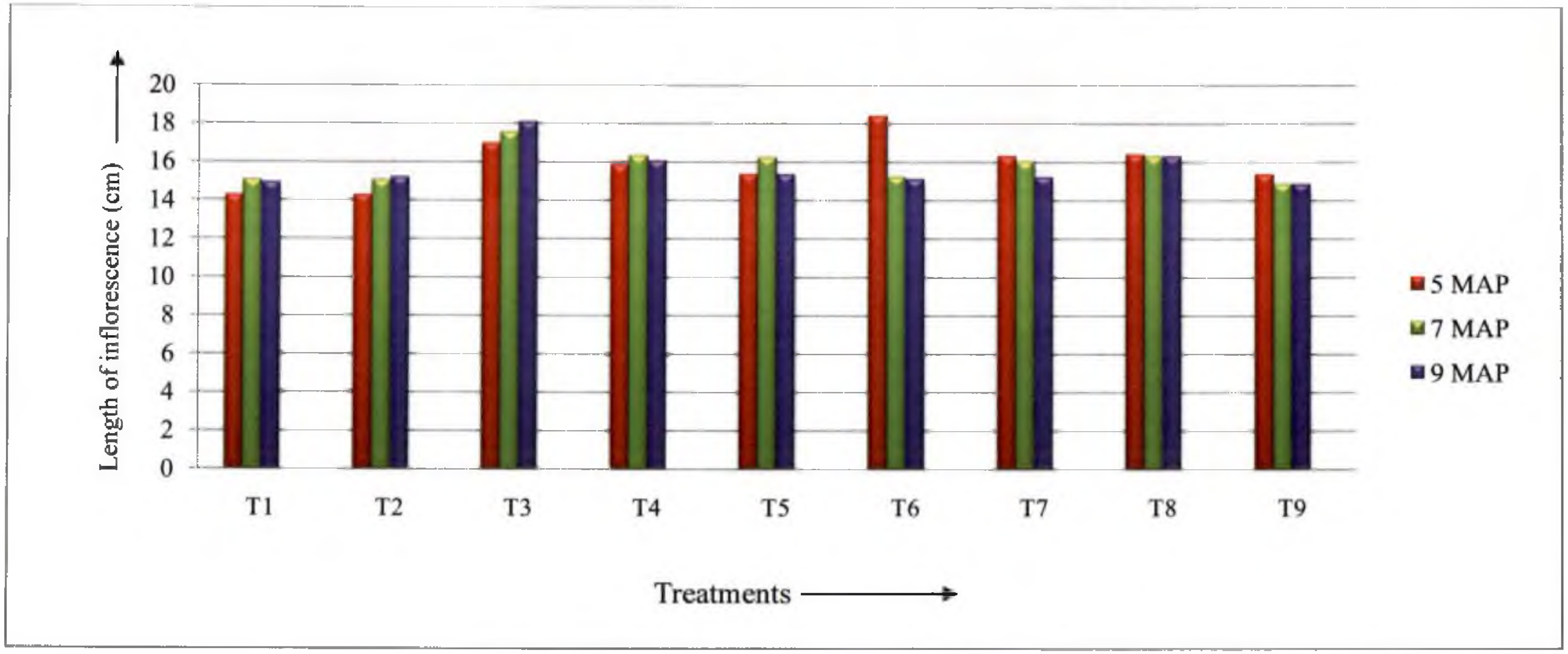

Fig.7 Effect of nutrient treatments on length of inflorescence

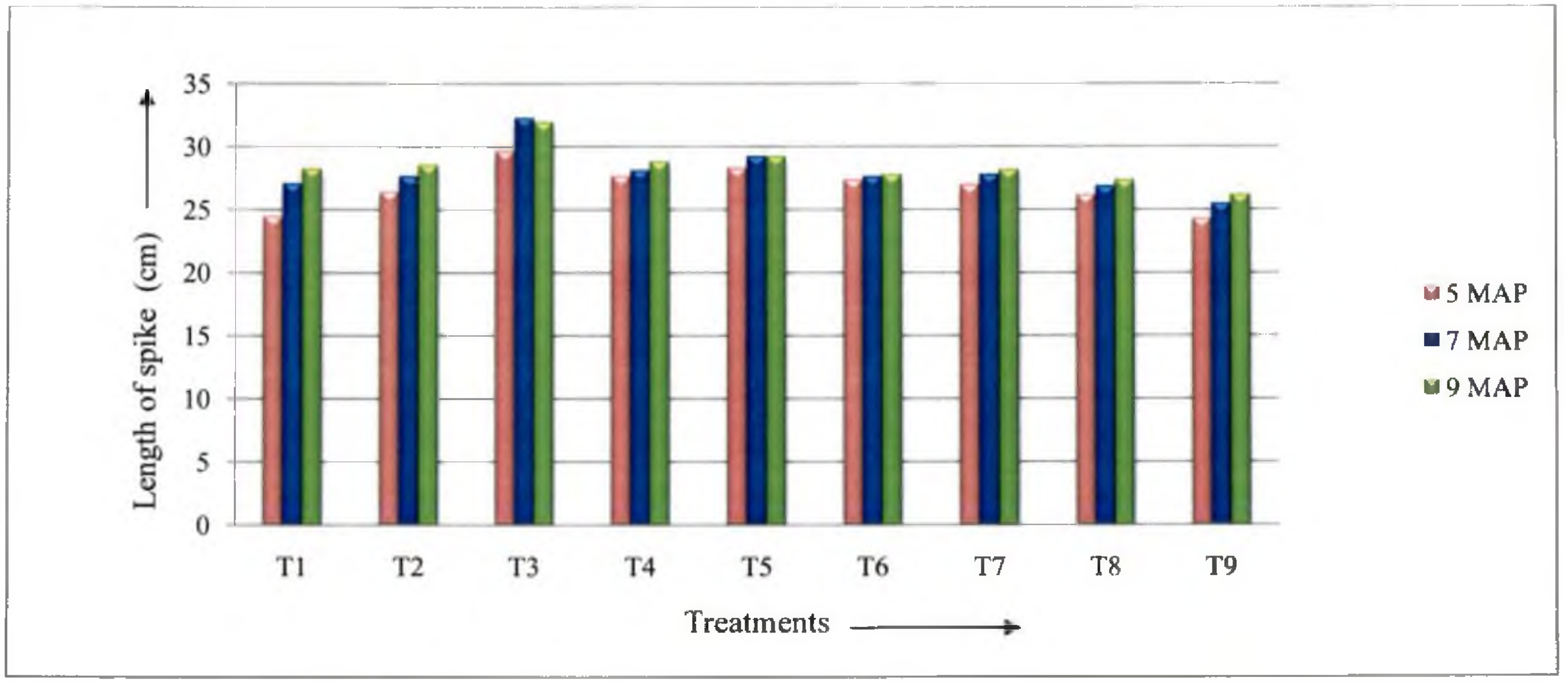

Fig.8 Effect of nutrient treatments on length of spike

Table 14. Effect of nutrient treatments on length of petiole (cm)

Treatments	Length of petiole (cm)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	16.65	16.32	17.42
T_2 (H.mix2.5g+VC150g + NC 75g)	15.57	15.93	16.70
T_3 (H.mix2.5g+VC200g+NC100g)	17.97	20.53	20.80
T_4 (VC200g +NC150g)	15.36	16.22	16.88
T_5 (VC300g +NC150g)	14.35	16.25	16.95
T_6 (VC400g +NC150g)	13.90	15.71	16.31
T_7 (M1+VC100g+NC50g)	16.05	16.27	16.87
T_8 (M1+VC150g+NC75g)	16.63	18.27	18.77
T_9 (M1+VC200g+NC100g)	15.38	16.56	16.76
CD(0.05)	1.27	1.10	0.97

MAP – Months after planting

Table 15. Effect of nutrient treatments on number of flower bracts per inflorescence

Treatments	Number of flower bracts per inflorescence		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	4.52	4.57	4.56
T_2 (H.mix2.5g+VC150g + NC 75g)	4.40	4.50	4.87
T_3 (H.mix2.5g+VC200g+NC100g)	5.25	5.22	5.20
T_4 (VC200g +NC150g)	4.26	4.63	4.51
T_5 (VC300g +NC150g)	4.45	4.68	4.31
T_6 (VC400g +NC150g)	4.25	4.32	4.58
T_7 (M1+VC100g+NC50g)	4.40	4.32	4.33
T_8 (M1+VC150g+NC75g)	4.85	5.32	5.07
T_9 (M1+VC200g+NC100g)	4.31	4.43	4.33
CD(0.05)	0.52	0.58	0.51

MAP – Months after planting

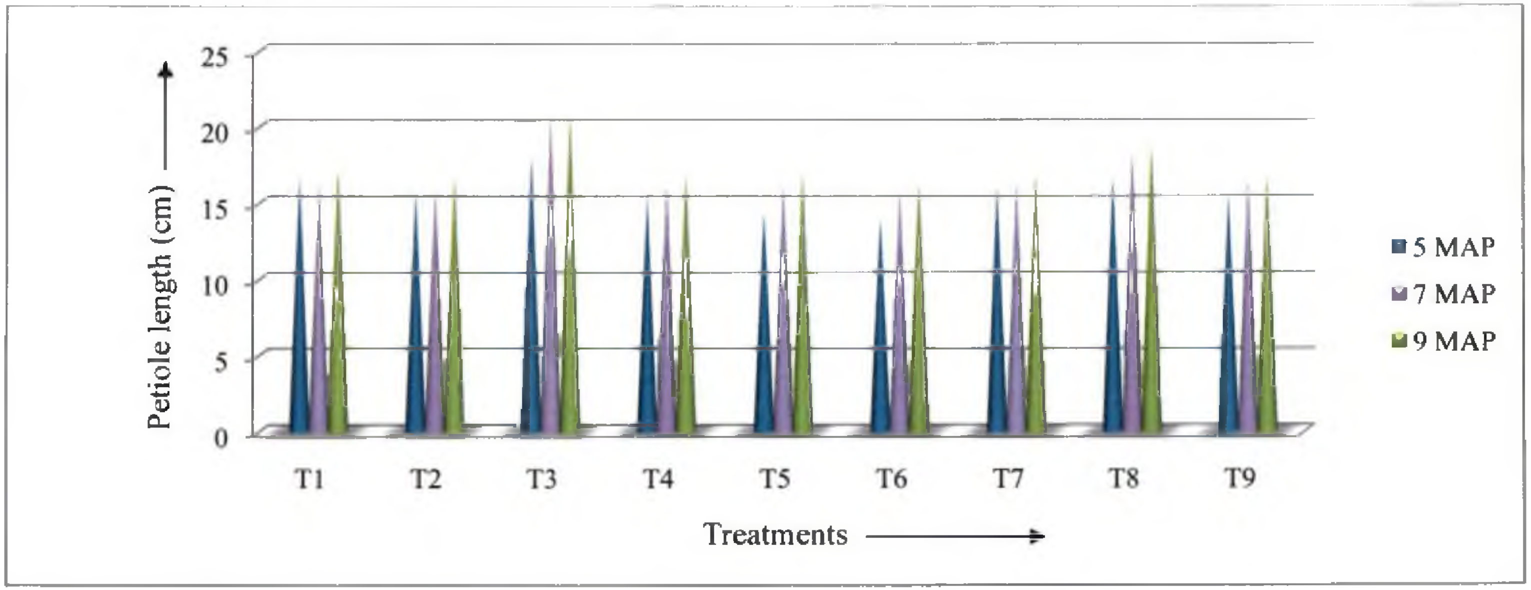

Fig.9 Effect of nutrient treatments on length of petiole

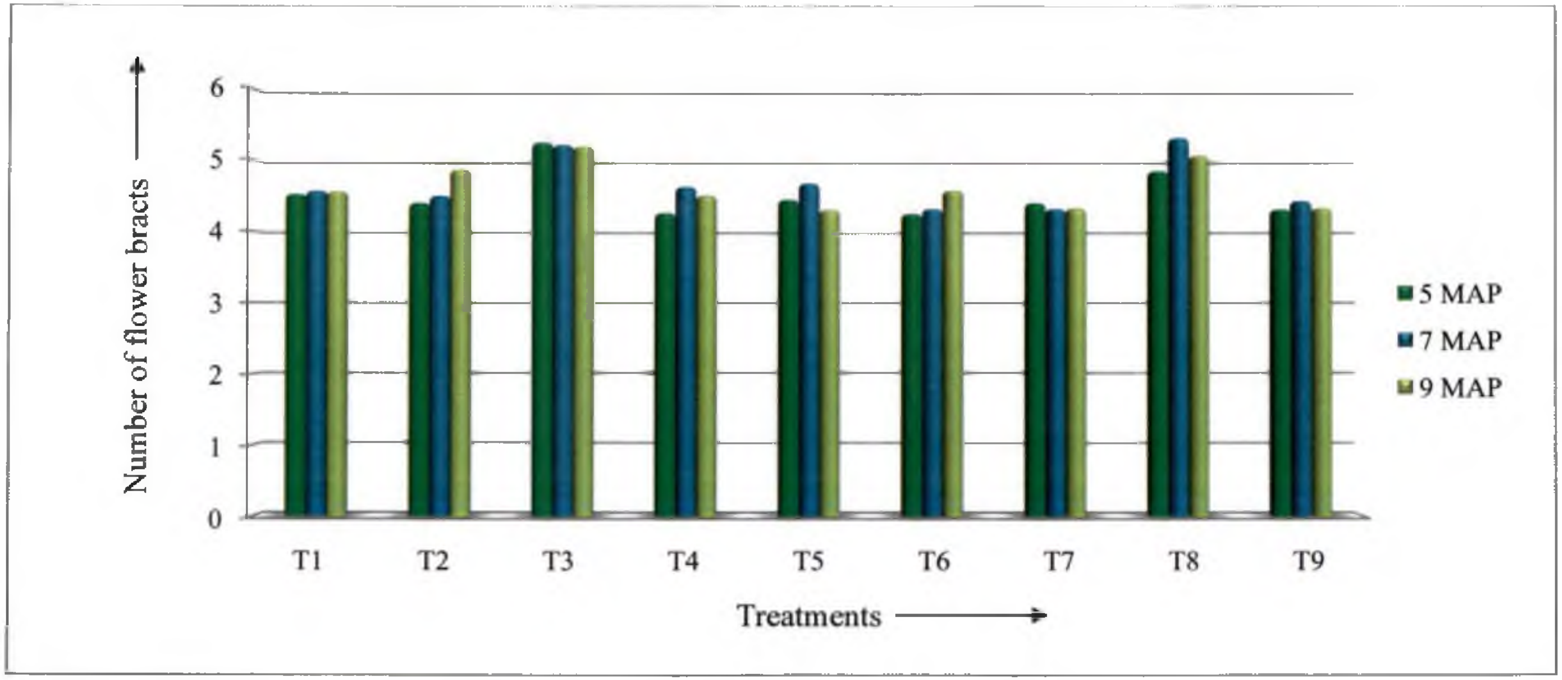

Fig.10 Effect of nutrient treatments on number of flower bracts

Table 16. Effect of nutrient treatments on visual appeal of flowers

Treatments	General appearance	Bract arrangement	Glossiness of flower	Colour development
T_1(H.mix2.5g+VC100g + NC 50g)	4.81	4.29	4.03	3.87
T_2(H.mix2.5g+VC150g + NC 75g)	5.00	4.87	4.26	4.35
T_3(H.mix2.5g+VC200g+NC100g)	5.76	5.81	5.42	5.70
T_4(VC200g +NC150g)	4.80	4.56	5.40	4.22
T_5(VC300g +NC150g)	4.67	4.44	4.19	4.39
T_6(VC400g +NC150g)	4.52	4.47	4.35	4.37
T_7(M1+VC100g+NC50g)	4.69	4.40	4.29	4.37
T_8(M1+VC150g+NC75g)	5.85	5.18	5.43	4.42
T_9 (M1+VC200g+NC100g)	4.29	4.45	4.26	4.31

<u>Score distribution</u>

Average - 1 to 5

Good - 6 to 8

Very good – 9 to 10

highest value was recorded by T_3 (5.70). The lowest value was recorded by T_1 which was on par with T_4.

The general appearance of flower showed significant difference among the treatments. The highest value (5.85) recorded in T_8 was on par with T_3 (5.76). The lowest value recorded by T_9 was found to be on par with T_6 andT_5 (Table16).

The bract arrangement of the flowers in all treatments was observed and the scores presented in table 16. The highest score was recorded by T_3 (5.81) and the lowest value was recorded by T_1 (4.29) and was on par with all other treatments except T_2, T_8 and T_3.

The glossiness of flower showed significant difference among the treatments. T_8 recorded the highest value which was found to be on par with T_3 and T_4. Treatments T_1, T_2, T_5, T_6, T_9 and T_4 recorded low scores on par with each other.

4.2.7 Days Taken for Flowering (Days)

There was significant difference among the treatments on days taken for flowering. The lowest number of days taken for flowering was recorded by T_6 (116.8) and was on par with T_4, T_1 and T_5 (118.5, 119.3 and 118.6 respectively) (Table 23). The treatment T_2 (128.0) registered the highest number of days taken for flowering.

4.2.8 Flowering Duration (Days)

The flowering duration of treatments was significantly influenced by all treatments (Table17). The treatments showed significant influence on the flowering duration at five, seven, and nine months after planting. At five, seven and nine months after planting the highest flowering duration was observed in T_3 (11.27, 11.95, 12.12 respectively) which was on par with T_8 (11.10, 11.42, 11.37). T_7 recorded the lowest number of days (9.87, 10.35 and 10.22).

4.2.9 Number of Flowering Shoots per Year

There was significant difference among the treatments on number of flowering shoots per year (Table 18 and Fig. 11). The maximum number of flowering shoots per year was recorded by T_2 (7.62) and was found to be on par

Table 17. Effect of nutrient treatments on duration of flowering (Days)

Treatments	Duration of flowering (Days)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	10.05	10.55	10.05
T_2 (H.mix2.5g+VC150g + NC 75g)	10.62	10.90	10.47
T_3 (H.mix2.5g+VC200g+NC100g)	11.27	11.95	12.12
T_4 (VC200g +NC150g)	10.90	10.50	10.42
T_5 (VC300g +NC150g)	10.27	10.52	10.52
T_6 (VC400g +NC150g)	9.97	10.55	10.90
T_7 (M1+VC100g+NC50g)	9.87	10.35	10.22
T_8 (M1+VC150g+NC75g)	11.10	11.42	11.37
T_9 (M1+VC200g+NC100g)	10.40	10.80	10.85
CD(0.05)	0.96	0.93	0.79

MAP – Months after planting

Table 18. Effect of nutrient treatments on number of flowering shoots per year

Treatments	Number of flowering shoots per year
T_1 (H.mix2.5g+VC100g + NC 50g)	5.68
T_2 (H.mix2.5g+VC150g + NC 75g)	7.62
T_3 (H.mix2.5g+VC200g+NC100g)	7.40
T_4 (VC200g +NC150g)	6.90
T_5 (VC300g +NC150g)	6.52
T_6 (VC400g +NC150g)	6.82
T_7 (M1+VC100g+NC50g)	6.23
T_8 (M1+VC150g+NC75g)	6.70
T_9 (M1+VC200g+NC100g)	6.06
CD(0.05)	0.95

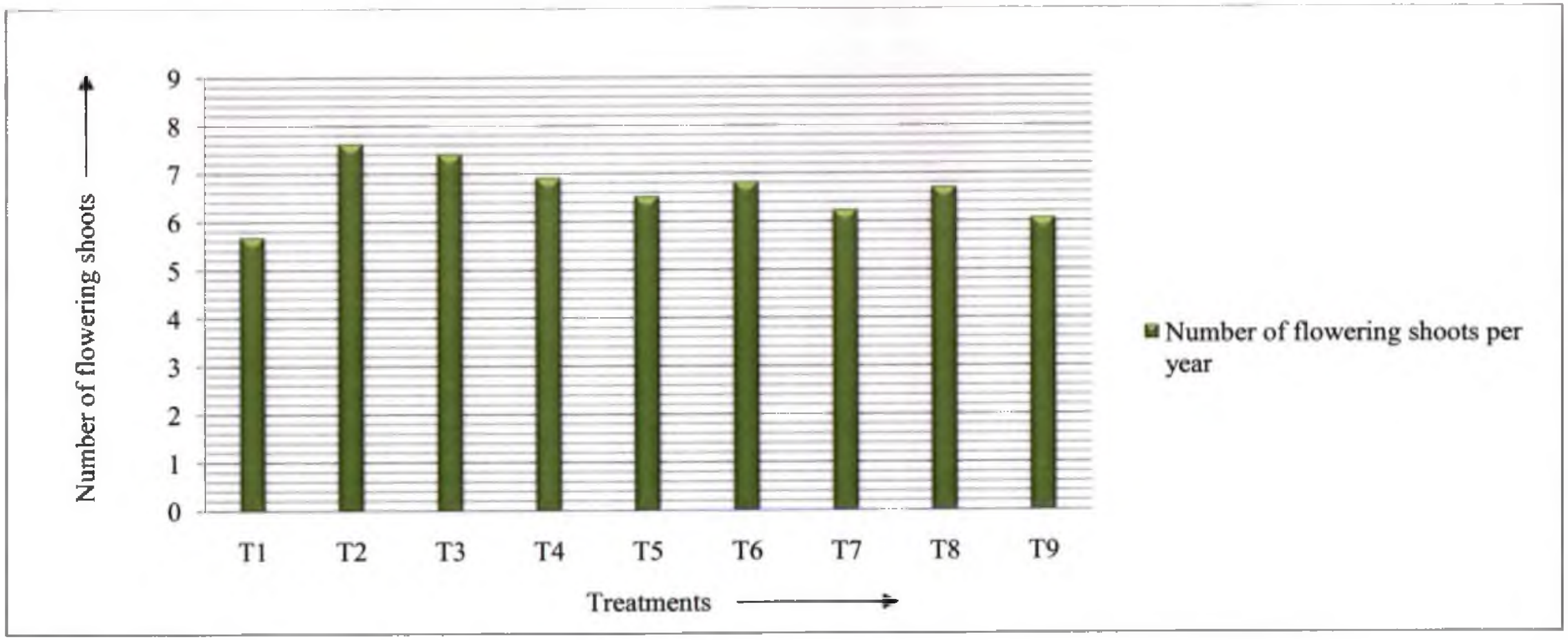

Fig.11 Effect of nutrient treatments on number of flowering shoots per year

with T_3 (7.40). The lowest number of flowering shoots per year was recorded by T_1 (5.68).

4.2.10 Size of Bract

The size of bract of inflorescence was recorded at bimonthly intervals from five months after planting (Table 19). There was significant influence of treatments on the size of bract. At five, seven and nine months after planting T_3 registered the highest value (18.15cm, 18.53cm and 19.82 cm respectively). At nine months after planting the lowest size of bract was recorded by T_2 (14.88 cm) and was on par with T_7, T_6 and T_9 (Table 20).

4.2.11 Flowers per Bract

The results revealed that number of flowers per bract was significantly influenced by the treatments (Table 20). At five months after planting T_3 (16.98) recorded the highest number of flowers per bract which was found to be significantly higher than all other treatments. The lowest number of flowers per bract was recorded by T_9 (14.25). This was found to be on par with T_4 (14.27). The highest number of flowers per bract was by T_3 (17.58) at seven months after planting which was on par with T_8 (16.55). The lowest number of flowers per bract was by T_2 (14.50) and was found to be on par with T_4, T_1 and T_7 (Table 20). At nine months after planting T_3 recorded highest number of flowers per bract (19.10) which was significantly higher from all other treatments. Lowest number of flowers per bract was recorded by T_5 (14.37).

4.2.12 Length of Inflorescence Stalk

The length of inflorescence stalk was significantly different throughout the observation period. At five, seven and nine months after planting T_3 recorded highest length of inflorescence stalk (75.82cm, 78.93 cm and 93.58 cm respectively). The treatments T_2 and T_6 recorded the lowest value for length of inflorescence stalk on par with each other at five, seven and nine months after planting (Table21 and Fig. 12).

4.2.13 Fresh Weight of Inflorescence

The Fresh weight of inflorescence was significantly influenced by treatments at all stages of growth (Table 22 and Fig. 13). Throughout the

Table 19. Effect of nutrient treatments on size of bract (cm)

Treatments	Size of bract (cm)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	14.75	15.11	15.86
T_2 (H.mix2.5g+VC150g + NC 75g)	13.38	15.36	14.88
T_3 (H.mix2.5g+VC200g+NC100g)	18.15	18.53	19.82
T_4 (VC200g +NC150g)	14.82	16.32	16.81
T_5 (VC300g +NC150g)	14.52	15.03	15.91
T_6 (VC400g +NC150g)	15.01	15.83	15.08
T_7 (M1+VC100g+NC50g)	13.86	14.90	14.98
T_8 (M1+VC150g+NC75g)	15.77	16.16	18.45
T_9 (M1+VC200g+NC100g)	14.08	15.00	15.27
CD(0.05)	1.44	1.18	1.11

MAP – Months after planting

Table 20. Effect of nutrient treatments on number of flowers per bract

Treatments	Number of flowers per bract		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	14.50	14.62	15.38
T_2 (H.mix2.5g+VC150g + NC 75g)	14.93	14.50	15.56
T_3 (H.mix2.5g+VC200g+NC100g)	16.98	17.58	19.10
T_4 (VC200g +NC150g)	14.27	14.62	15.28
T_5 (VC300g +NC150g)	14.90	14.93	14.37
T_6 (VC400g +NC150g)	15.40	16.12	15.71
T_7 (M1+VC100g+NC50g)	15.15	14.68	15.86
T_8 (M1+VC150g+NC75g)	15.57	16.55	17.15
T_9 (M1+VC200g+NC100g)	14.25	15.02	15.82
CD(0.05)	1.07	1.42	1.25

MAP – Months after planting

Table 21. Effect of nutrient treatments on length of inflorescence stalk (cm)

Treatments	Length of inflorescence stalk (cm)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	58.15	62.09	71.12
T_2 (H.mix2.5g+VC150g + NC 75g)	55.66	58.10	64.67
T_3 (H.mix2.5g+VC200g+NC100g)	75.82	78.93	93.58
T_4 (VC200g +NC150g)	61.93	64.14	70.06
T_5 (VC300g +NC150g)	64.75	66.68	79.74
T_6 (VC400g +NC150g)	56.79	62.88	66.95
T_7 (M1+VC100g+NC50g)	65.70	69.59	75.56
T_8 (M1+VC150g+NC75g)	63.24	63.25	66.16
T_9 (M1+VC200g+NC100g)	62.68	65.54	68.12
CD(0.05)	3.86	3.26	4.31

MAP – Months after planting

Table 22. Effect of nutrient treatments on fresh weight of inflorescence (g)

Treatments	Fresh weight of inflorescence (g)		
	5 MAP	7 MAP	9 MAP
T_1 (H.mix2.5g+VC100g + NC 50g)	56.46	56.25	58.05
T_2 (H.mix2.5g+VC150g + NC 75g)	65.79	66.58	68.56
T_3 (H.mix2.5g+VC200g+NC100g)	90.90	102.01	101.93
T_4 (VC200g +NC150g)	63.97	67.37	72.14
T_5 (VC300g +NC150g)	53.66	60.03	62.03
T_6 (VC400g +NC150g)	60.21	65.59	70.90
T_7 (M1+VC100g+NC50g)	59.92	63.16	65.25
T_8 (M1+VC150g+NC75g)	62.75	65.55	69.33
T_9 (M1+VC200g+NC100g)	50.94	61.82	69.80
CD(0.05)	3.68	2.72	2.17

MAP – Months after planting

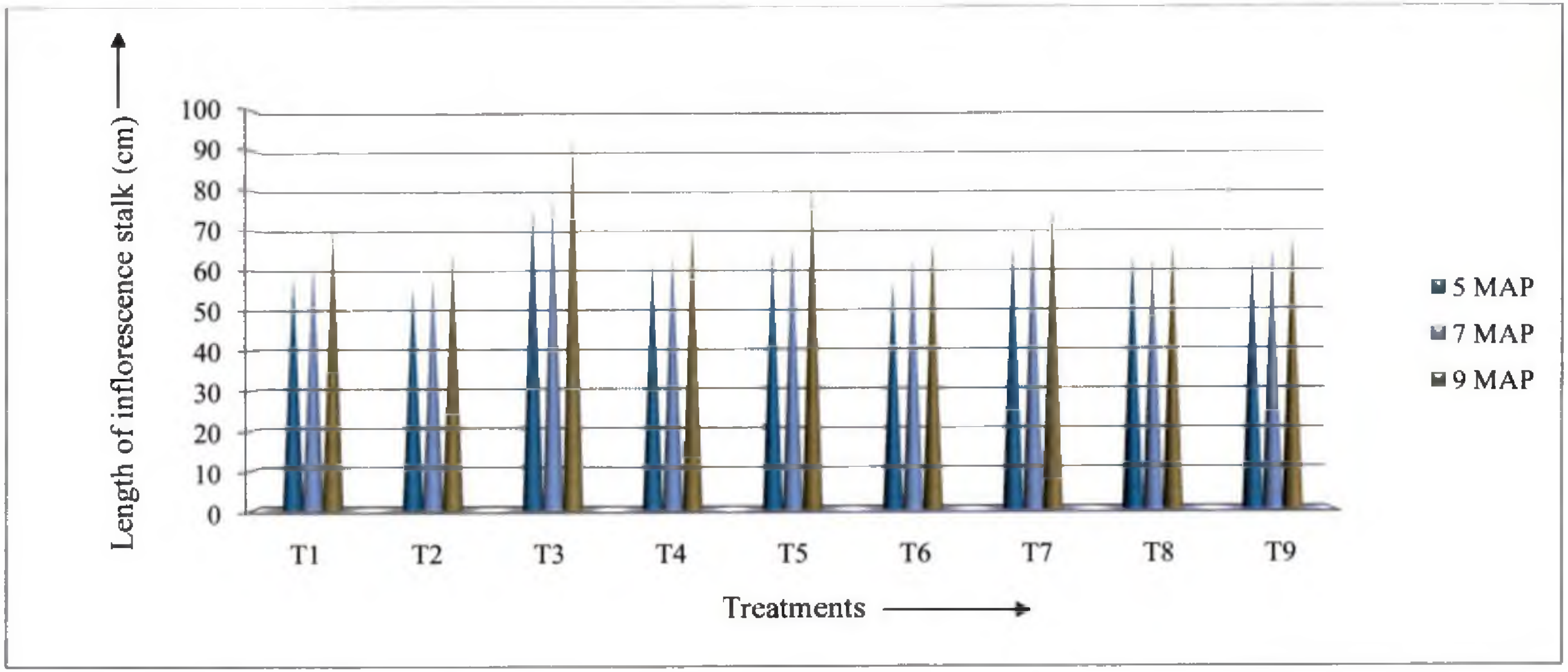

Fig.12 Effect of nutrient treatments on length of inflorescence stalk

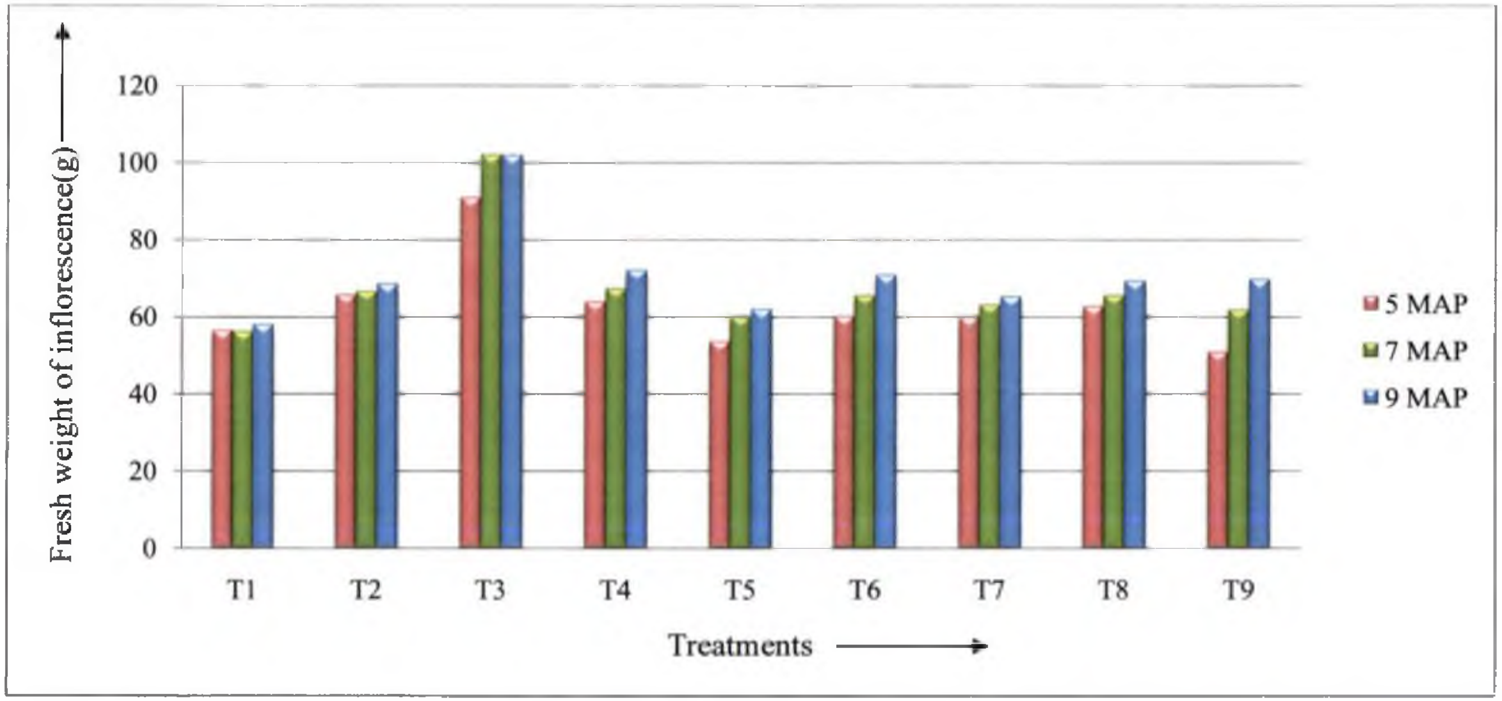

Fig.13 Effect of nutrient treatments on fresh weight of inflorescence

observation period T_3 recorded highest fresh weight of inflorescence (90.90 g, 102.01g and 101.93 g). At five months after planting T_9 (50.94 g) recorded the lowest value and was found to be on par with T_4 (63.97 g). At seven and nine months after planting T_1 (56.25 g and 58.05 g) recorded the lowest value of fresh weight of inflorescence and was found to be on par with T_5.

4.3. EFFECT OF NUTRIENT TREATMENTS ON DURATION OF CROP

4.3.1 Days Taken to First and Fifty Per Cent Flowering

Days taken to first and fifty percent flowering were significantly influenced by the treatments. The lowest number of days taken for first flowering was recorded by T_2 (113.31) and highest number of days taken for first flowering was registered by T_8 (118.20) followed by T_3 (117.67) (Table 23). The lowest number of days was taken for attaining 50 percent flowering was recorded by T_2 (147.20) and T_4 (147.31). The treatment T_8 recorded highest number of days (157.46) to attain 50 percent flowering.

4.3.2 Life of Flower in the Plant

There was significant difference among the treatments on the life of flower in the plant. The highest value for life of flower in the plant was recorded by T_8 (22.75 days) and was significantly different from other treatments. The lowest value was recorded by T_1 (19.00) and was found to be on par with T_7, T_2 and T_5 (Table 24).

4.4 PLANT ANALYSIS

4.4.1 Effect of Nutrient Treatments on Leaf Chlorophyll Content

Table 25 shows the chlorophyll content of leaves recorded by different treatments. It was found that there was no significant difference among the different treatments on the chlorophyll content of the leaves.

4.4.2 Effect of Nutrient Treatments on Plant Nutrients (NPK)

The content of N, P and K of leaves was analyzed and the data presented in table 26.

Table 23. Effect of nutrient treatments on days taken for flowering

Treatments	Days taken for first flowering	Days taken for fifty percent Flowering	Days taken for average flower production
T_1(H.mix2.5g+VC100g + NC 50g)	115.82	151.27	118.62
T_2(H.mix2.5g+VC150g + NC 75g)	113.31	147.20	128.05
T_3(H.mix2.5g+VC200g+NC100g)	117.67	147.72	121.53
T_4(VC200g +NC150g)	113.80	147.31	118.50
T_5(VC300g +NC150g)	114.40	153.71	119.31
T_6(VC400g +NC150g)	114.30	153.41	116.81
T_7 (M1+VC100g+NC50g)	113.72	155.50	126.17
T_8(M1+VC150g+NC75g)	118.20	157.46	124.90
T_9 (M1+VC200g+NC100g)	114.57	151.46	124.40
CD(0.05)	3.04	2.90	4.28

MAP – Months after planting

Table 24. Effect of nutrient treatments on life of flower in the plant (days)

Treatments	Life of flower in the plant
T_1 (H.mix2.5g+VC100g + NC 50g)	19.00
T_2 (H.mix2.5g+VC150g + NC 75g)	19.75
T_3 (H.mix2.5g+VC200g+NC100g)	20.87
T_4 (VC200g +NC150g)	20.60
T_5 (VC300g +NC150g)	19.57
T_6 (VC400g +NC150g)	20.20
T_7 (M1+VC100g+NC50g)	19.50
T_8 (M1+VC150g+NC75g)	22.75
T_9 (M1+VC200g+NC100g)	20.50
CD(0.05)	1.11

Table 25. Effect of nutrient treatments on leaf chlorophyll content

Treatments	Leaf chlorophyll content		
	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Total Chlorophyll (mg g^{-1})
T_1 (H.mix2.5g+VC100g + NC 50g)	0.15	0.21	0.43
T_2 (H.mix2.5g+VC150g + NC 75g)	0.15	0.22	0.44
T_3 (H.mix2.5g+VC200g+NC100g)	0.14	0.22	0.45
T_4 (VC200g +NC150g)	0.10	0.16	0.32
T_5 (VC300g +NC150g)	0.15	0.28	0.57
T_6 (VC400g +NC150g)	0.16	0.27	0.54
T_7 (M1+VC100g+NC50g)	0.14	0.31	0.62
T_8 (M1+VC150g+NC75g)	0.14	0.24	0.49
T_9 (M1+VC200g+NC100g)	0.16	0.24	0.48
CD(0.05)	NS	NS	NS

4.4.2.1 Effect of Nutrient Treatments on Content of Nitrogen (N) in Leaves

There was no significant difference among the treatments on the content of nitrogen in the leaves. The leaf content of nitrogen was the highest in T_3 (3.80 %) and the lowest value of nitrogen content was recorded by T_4 (2.75 %).

4.4.2.2 Effect of Nutrient Treatments on Content of Phosphorous (P) in Leaves

The data on nutrient content of leaves revealed that there was significant influence among the treatments on the phosphorous content of leaves. The highest content of P was recorded by T_6 (0.37 %) and was found to be on par with T_8, T_1, T_7 and T_5. The treatments T_4, T_9, T_2 and T_3 were on par and recorded low values for the phosphorous content of leaves (Table26).

4.4.2.3 Effect of Nutrient Treatments on Content of Potassium (K) in Leaves

The highest content of potassium was recorded by T_1 (2.40) and was on par with T_2 (2.36). The lowest content was recorded by the treatment T_5 and was on par with T_6 and T_8 (Table26).

4.5 SOIL ANALYSIS (before and after the experiment)

4.5.1 Effect of Nutrient Treatments on Soil Nutrient Content

4.5.1.1 Effect of Nutrient Treatments on Soil Organic Carbon content

The data showed that there was no significant difference among the treatments on organic carbon content (Table 27).

4.5.1.2 Effect of Nutrient Treatments on Soil p^H

Soil analysis before and after the experiment shows there was no significant difference among the treatments on soil P^H (Table 28).

4.5.1.3 Effect of Nutrient Treatments on Soil EC

The data on soil EC showed that there was no significant difference in soil EC before and after the experiment (Table 29).

4.5.1.4 Effect of Nutrient Treatments on Soil Available NPK

4.5.1.4.1 Effect of Nutrient Treatments on Soil Available N

There was no significant difference among the treatments on the soil available nitrogen before and after the experiment.

Table 26. Effect of nutrient treatments on leaf nutrient content (NPK)

Treatments	N	P	K
	(%)		
T_1 (H.mix2.5g+VC100g + NC 50g)	3.34	0.36	2.40
T_2 (H.mix2.5g+VC150g + NC 75g)	3.70	0.32	2.36
T_3 (H.mix2.5g+VC200g+NC100g)	3.80	0.32	1.87
T_4 (VC200g +NC150g)	2.75	0.29	1.96
T_5 (VC300g +NC150g)	3.56	0.34	1.58
T_6 (VC400g +NC150g)	3.60	0.37	1.80
T_7 (M1+VC100g+NC50g)	3.69	0.35	1.97
T_8 (M1+VC150g+NC75g)	3.53	0.36	1.81
T_9 (M1+VC200g+NC100g)	3.19	0.29	1.96
CD(0.05)	NS	0.04	0.22

Table 27. Effect of nutrient treatments on soil organic carbon content

Treatments	Before the experiment	After the experiment
	(%)	
T_1 (H.mix2.5g+VC100g + NC 50g)	1.11	1.82
T_2 (H.mix2.5g+VC150g + NC 75g)	1.23	1.41
T_3 (H.mix2.5g+VC200g+NC100g)	1.20	1.33
T_4 (VC200g +NC150g)	1.19	1.15
T_5 (VC300g +NC150g)	1.23	1.37
T_6 (VC400g +NC150g)	1.01	1.51
T_7 (M1+VC100g+NC50g)	1.26	1.73
T_8 (M1+VC150g+NC75g)	1.21	1.30
T_9 (M1+VC200g+NC100g)	1.09	1.11
CD(0.05)	NS	NS

Table 28. Effect of nutrient treatments on soil P^H

Treatments	Before the experiment	After the experiment
T_1 (H.mix2.5g+VC100g + NC 50g)	4.94	5.39
T_2 (H.mix2.5g+VC150g + NC 75g)	4.30	5.56
T_3 (H.mix2.5g+VC200g+NC100g)	4.64	5.40
T_4 (VC200g +NC150g)	4.31	5.72
T_5 (VC300g +NC150g)	4.65	5.11
T_6 (VC400g +NC150g)	4.52	5.19
T_7 (M1+VC100g+NC50g)	5.10	5.36
T_8 (M1+VC150g+NC75g)	4.49	5.40
T_9 (M1+VC200g+NC100g)	4.38	5.36
CD(0.05)	NS	NS

Table 29. Effect of nutrient treatments on soil EC

Treatments	Before the experiment	After the experiment
	(dSm^{-1})	
T_1 (H.mix2.5g+VC100g + NC 50g)	0.14	0.15
T_2 (H.mix2.5g+VC150g + NC 75g)	0.14	0.12
T_3 (H.mix2.5g+VC200g+NC100g)	0.14	0.13
T_4 (VC200g +NC150g)	0.12	0.12
T_5 (VC300g +NC150g)	0.14	0.12
T_6 (VC400g +NC150g)	0.15	0.13
T_7 (M1+VC100g+NC50g)	0.14	0.15
T_8 (M1+VC150g+NC75g)	0.15	0.16
T_9 (M1+VC200g+NC100g)	0.15	0.10
CD(0.05)	NS	NS

4.5.1.4.2 Effect of Nutrient Treatments on Soil Available P

The data on soil available phosphorous showed that there was no significant difference among the treatments before the experiment. There was significant difference among the treatments on the available phosphorous after the experiment. The highest value of available phosphorous was recorded by T_3 (94.41) which were on par with T_6, T_9 and T_2 (Table 30). The lowest value of available phosphorous was recorded by T_1 and was on par with T_8 and T_4.

4.5.1.4.2 Effect of Nutrient Treatments on Soil Available K

There was significant difference on the amount of available potassium after the experiment. The highest amount of available potassium after the experiment was recorded by T_9 (435.19) and was on par with T_1 and T_6. The lowest amount of available potassium was recorded byT_4 (154.33) (Table 30).

4.6 VASE LIFE STUDIES OF INFLORESCENCE

4.6.1 Effect of Nutrient Treatments on Vase Life of Inflorescence

There was significant difference on the vase life of inflorescence among the different treatments (Table 31). The highest value on vase life was recorded by T_3 at nine months after planting (13.46) followed by T_1 (12.40). The lowest value was recorded by T_4 (11.13).

4.7 PEST AND DISEASE INCIDENCE

There was no major pest and disease incidence. At the final stage of observation low incidence of grasshopper was noticed. Once planted heliconia crop remains in the field for a period of three years yielding economic returns. This being the first year of planting may be the reason for the low incidence of pest and diseases in field. However low incidence of pest and diseases was recorded throughout the year and found to not infect the crop beyond economic threshold level to take control measures.

Table 30. Effect of nutrient treatments on soil available NPK (before and after the experiment)

Treatments	Before the experiment (kg/ha)			After the experiment (kg/ha)		
	N	P	K	N	P	K
T_1(H.mix2.5g+VC100g + NC 50g)	266.11	27.15	137.42	323.01	77.31	425.09
T_2(H.mix2.5g+VC150g + NC 75g)	286.01	37.54	134.55	305.41	90.26	328.84
T_3(H.mix2.5g+VC200g+NC100g)	308.25	32.11	148.68	290.12	94.41	387.41
T_4(VC200g +NC150g)	273.21	32.20	143.35	297.27	80.79	154.33
T_5(VC300g +NC150g)	340.23	27.75	129.50	281.08	84.32	383.02
T_6(VC400g +NC150g)	250.14	26.66	139.11	281.72	92.61	424.06
T_7(M1+VC100g+NC50g)	311.11	26.97	148.26	277.97	87.27	285.66
T_8 (M1+VC150g+NC75g)	292.21	27.19	147.28	314.79	74.32	333.01
T_9(M1+VC200g+NC100g)	242.27	27.14	147.05	254.32	90.94	435.19
CD(0.05)	NS	NS	NS	NS	6.57	34.79

MAP – Months after planting

Table 31. Effect of nutrient treatments on vase life of inflorescence (days)

Treatments	Vase life of inflorescence (days)		
	5 MAP	7 MAP	9 MAP
T_1(H.mix2.5g+VC100g + NC 50g)	9.72	10.21	12.40
T_2(H.mix2.5g+VC150g + NC 75g)	9.16	11.22	11.81
T_3(H.mix2.5g+VC200g+NC100g)	10.67	11.83	13.46
T_4(VC200g +NC150g)	10.37	10.66	11.13
T_5(VC300g +NC150g)	8.87	10.71	11.66
T_6(VC400g +NC150g)	8.92	11.13	11.60
T_7(M1+VC100g+NC50g)	8.92	11.21	11.15
T_8(M1+VC150g+NC75g)	10.83	11.60	11.92
T_9(M1+VC200g+NC100g)	10.10	11.05	11.35
CD(0.05)	0.78	0.84	0.81

MAP – Months after planting

Table 32. Economics of cultivation

Treatments	Gross Income (Rs.ha^{-1})	Net Income (Rs.ha^{-1})	Benefit : Cost
T_1(H.mix2.5g+VC100g + NC 50g)	1613262.71	494677.79	1.31
T_2(H.mix2.5g+VC150g + NC 75g)	1515489.22	316817.28	1.23
T_3 (H.mix2.5g+VC200g+NC100g)	1959914.23	681282.27	1.51
T_4(VC200g +NC150g)	1484379.50	118927.50	1.00
T_5(VC300g +NC150g)	1462158.21	114471.29	0.91
T_6(VC400g +NC150g)	1577708.73	70056.77	1.00
T_7(M1+VC100g+NC50g)	1639928.21	498476.29	1.43
T_8(M1+VC150g+NC75g)	1755478.73	533966.77	1.41
T_9(M1+VC200g+NC100g)	1582153.00	280681.00	1.11
CD(0.05)	286938.31	272545.13	0.24

4.8 ECONOMICS OF CULTIVATION

Gross income per hectare for treatment T_3 (Heliconiamix2.5g + Vermicompost 200g + Neemcake100g) was Rs.1959914.23/ha and was highest among the different treatments and net income for this treatment was Rs.681282.27/ha. BC ratio was highest (1.51) for same treatment and this was followed by T_8 (1.43) PGPR Mix-1+ Vermicompost 150g+Neemcake 75g. Gross income for this treatment was Rs. 1755478.73/ha and net income was Rs.533966.7/ha. Marketable flowers and suckers were found to attribute to the BC ratio which was significantly different between treatments (Table 32, Plate 9a and 9b).

DISCUSSION

5. DISCUSSION

The continuous increase in the production and commercialization of heliconia as cut flower and ornamental plant in many countries around the world shows the importance of heliconia cultivation to agribusiness. The *Heliconiaceae* contains a great diversity of species, cultivars and hybrids with potential to be used as cut flower. The demand for heliconia inflorescences is increasing in many countries around the world. Due to its unusual inflorescence *Heliconia is* categorized as 'Specialty Flower'. With the world's fastest growing retail market and large consumer base, floriculture industry is growing. *Heliconia angusta* cv Christmas Red is a small plant with erect inflorescences and bracts with red color. This species is sold, generally, with two to three open bracts.

Total organic farming may be a desirable proposition for sustainable agriculture as well as improving the quality of agricultural produce. But it is difficult to meet the nutrient requirements of crops, exclusively through organic farming in commercial agriculture as the stress is mainly on yield.

Under these circumstances, integrated nutrient management practices involving judicious combination of organic manures, bio-fertilizers and chemical fertilizers can be made feasible and viable for sustainable agriculture on a commercial and profitable scale. Organic manures and biofertilizers are ecofriendly, easily available and cost-effective. Therefore, emphasis is now focused on the use of organic manures such as farm yard manure, vermicompost and biofertilizers like *Azospirillum* and phosphorous solubilizing bacteria (PSB).

The nutrient requirement of heliconia varies from species to species. It grows well in organic rich soils. But little is known about integrated nutrient management of the crop. A Ph.D programme was undertaken in the Department of Pomology and Floriculture, COA, Vellayani, entitled 'Nutrient management practices for heliconia under open condition and as intercrop in coconut garden' in cultivar Iris Red. In this study the best results were obtained in the treatment combination heliconia mixture (13:5:13NPK) at the rate of 2.5g/plant+ vermicompost100g/plant+ neemcake50g/plant. However the nutrient requirement of heliconia varies from species to species. Based on the results obtained in the above study an integrated nutrient management trial in the *Heliconia angusta* cv. Christmas Red was undertaken to standardize an integrated nutrient schedule for optimum flower yield and quality. The field experiment was carried out at Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India from June 2013 to May 2014.

5.1 GROWTH CHARACTERS

5.1.1 Plant Height

The plants supplied with Heliconiamix2.5g + Vermicompost200g+ Neemcake100g (T_3) recorded the highest value (85.90 cm) and was on par with Vermicompost 200g + Neem cake150g (T_4) and M1+ Vermicompost 150g + Neem cake 75g (T_8). It was observed that generally increase in organic matter content of treatments led to increase in plant height. At the same time the application of PGPR Mix-I whose favourable effect on solubilization of nutrients favoured increase in height of plants in treatments like T_8 with lower doses of organic manures. The lowest plant height was recorded in the treatment T_6, T_1 and T_7 which showed that the levels of nutrients in these treatments were inadequate. Plant height is one of the most important growth characters. Plant height is a central part of plant ecological strategy. It is strongly correlated with life span and time to maturity (Moles *et al.*, 2009). In previous trials in heliconia (Broshat and Donselman, 1984; Girish, 2006 and Sushma *et al.*, 2012a) mineral fertilizers were supplied alone or supplemented with limited quantities of organic manure. Compared to this in the present study it was observed that when organic manures were supplied in enhanced quantities along with the mineral fertilizers the requirement of mineral fertilizers could be substantially reduced. Nihad (2013) also reported that plants supplied with mineral fertilizers (NPK @ 13:5:13 kg/ha) and organic manures (Vermicompost @ 200g/plant +Neemcake @ 100g/plant) recorded maximum plant height.

5.1.2 Plant Spread

The present study revealed that the nutrients greatly influenced plant spread. The effect of treatments was found to be significant one, five and seven months after planting. However, there was no significant influence among treatments on plant spread at nine months after planting. This may be due to the enhanced uptake of nutrients over time which resulted in better plant growth and increase in yield attributes (Singh *et al.*, 2010). The output of any plant is influenced by vigour of the plant where the plant spread along with the plant height play an important role (Nikhil, 2012).

5.1.3 Number of Leaves per Shoot

The number of leaves per shoot was an indicator to inflorescence emergence and it varied with species (Cabral and Benedetto, 2010; Rocha *et al.*, 2010). In family Musaceae to which heliconia formerly belonged, physiological maturity to flowering is attained upon production of a specific number of leaves (Allen *et al.*, 1988). The same trend was observed in this crop also. There was no significant influence among treatments on number of leaves per shoot. In general, the number of leaves per shoot ranged from three to four at the time of flowering.

5.1.4 Number of Shoots /Suckers

The study revealed that nutrient content greatly influenced the total number of suckers produced. The maximum sucker production was noticed in Heliconiamix 2.5g+Vermicompost 200g+Neemcake 100g (T_3). This might be due to increased availability of nutrients from manures and the active role of biofertilizers in enhancing nutrient availability. The biofertilizers may also trigger the activity of substances like IAA, gibberellins and cytokinin. This is in conformity with the previous reports in heliconia (Girish, 2006) where sucker production was enhanced at higher levels of nutrients.The number of suckers can be considered as an indicator to quantify the expected number of flower yield as the sucker production in Heliconia is positively correlated with the number of inflorescence (Costa *et al.*, 2006b). According to Clemens and Morton (1999) there is positive linear effect of N and P on sucker production in Heliconia cv.

Golden Torch and maximum numbers of shoots to emerge per plant was predicted at N and P rates of 1.16 and 0.67 kg m^{-2}.

5.1.5 Flower Canopy Height

In heliconia increase in flower canopy height is an indication of increase in length of flower stalk, which is a critical attribute in determining the cut flower quality of flower. The results of present study showed that the highest flower canopy height was registered in Heliconiamix 2.5g +Vermicompost 200g +Neemcake 100g (T_3), which was combination of organic and inorganic fertilizers. This might be due to availability of optimum amount of nutrients through inorganic fertilizer in combination with organic fertilizers.

5.1.6 Leaf Area

In this study higher leaf area has been recorded in Heliconiamix 2.5g +Vermicompost 200g +Neemcake 100g (T_3) and M1+ Vermicompost 150g + Neem cake 75g (T_8) which might be due to increased availability of nutrients. It also leads to better flower production. Higher leaf area represents higher nutrient and water availability in heliconia as reported previously (Grubb, 1998; Cunningham *et al.*, 1999).

5.1.7 Leaf Area Index (LAI)

Leaf area index was highest in treatment T_3 (Heliconiamix2.5g+ Vermicompost 200g +Neemcake 100g) where heliconiamix was supplied in combination with organic manures and in T_8 where PGPR Mix- I is substituted in place of mineral fertilizers and low quantities of organic manures. Reports by Gomma and Mohammed (2000) also showed that increase in nutrient contents of leaves which manifested the highest leaf area index resulted in more carbohydrate production through photosynthesis and might act as sink. Allen *et al.* (1988) reported that higher levels of nutrient application resulted in higher radiation use efficiency in banana.

5.1.8 Leaf Area Ratio (LAR)

The results of leaf area ratio obtained in this study confirm the previous reports in this regard. Highest value of leaf area ratio was obtained in the treatment T_3 (Heliconiamix2.5g+ Vermicompost 200g +Neemcake 100g) at higher nutrient levels. Fonseca *et al.* (2000) opinioned that increase in leaf area may be due to better nutrition of these as SLA/ LAR declines along with the gradients of decreasing moisture and/or nutrient availability.

5.2 FLOWERING CHARACTERS

5.2.1 Length of Inflorescence

Fertilization rates strongly affect growth and flowering of heliconia under high light intensities (full sun). The plants supplied with Heliconiamix 2.5g+ Vermicompost 200g+Neemcake 100g (T_3) and M1+Vermicompost 150g+Neem cake 75g (T_8) recoded highest inflorescence length. The length of the inflorescence stem and number of opened bracts are the main criteria used by farmers for expressing inflorescence quality of heliconias (Costa *et al*, 2006a). The superior quality flowers produced in these nutrient treatments might be due to the application of NPK fertilizers along with organic manures and soil inoculation of biofertilizers with organic manures which might have influenced the availability of nutrients in soil. Nihad (2013) also reported superior quality flowers were produced in treatment supplied with combination of mineral fertilizers and organic manures. The organic manures and biofertilizers might have contributed to nutrient uptake and yield characters. In the present study length of inflorescence ranged from 15 to 20 cm.

5.2.2 Length of Spike

In this study the nutrient treatments influenced the spike length and T_3 registered the maximum spike length. This might be because of the better nutrient availability of the plants in this treatment and its transport to the sink as reported by Nihad (2013) also. In heliconia the unopened and fully opened spike sizes are equally important as inflorescences in both the stages are used in flower arrangements and it varied with nutrient content of growing medium (Powell, 1991). Phosphorus and Potassium influenced positively the length of buds in Heliconia "St. Vincent Red" as reported by Ferreira and Pires (2005). The uptake of nutrients by plants promotes more vegetative growth by increasing the amount of assimilates that are needed for improvement of spike length.

5.2.3 Length of Petiole

The length of petiole was influenced by the level of nutrients. An increase in the uptake of nutrients led to increase in length of petiole in the study also. The increase in petiole length enables them to store higher amount of water contributing to more vase life and packing the inflorescence without supplementing materials for water conservation for near markets. Higher petiole length also enables easy handling of the inflorescence, making it suitable for flower arrangements and bouquet making (Nikhil, 2012).

5.2.4 Visual Appeal of Flowers

In general balanced nutrition always leads to production of quality flowers with optimum characteristics. The visual appeal of flowers was observed based on four characters such as general appearance, bract arrangement, glossiness of flower and colour development. The high total score for the inflorescences was recorded by T_3 (Heliconiamix2.5g + Vermicompost200g + Neem cake100g) and T_8 (M1 + Vermicompost150g + Neem cake75g). This might be due to the availability of optimum amount of nutrients from inorganic fertilizer in combination with biofertilizers and organic manures. Nihad (2013) concluded that treatment combination of organic and inorganic manures produced good quality flowers. Higher nutrient content might have accelerated photosynthesis thus promoting the good quality of flowers. Optimum fertilizer application leads to increased carbohydrate assimilation which helped in producing quality flowers. Powell (1991) reported that the marketable yield of Heliconia flowers varied with nutrient content of the growing medium and light intensity. Catley and Brooking (1996) also opined that the quality of Heliconia flowers is influenced by nutrition and environment.

5.2.5 Days Taken for Flowering (days)

The present investigation revealed that early flowering was observed in T_6 (Vermicompost 400g + Neem cake150g), T_4 (Vermicompost 200g + Neem cake150g) and T_5 (Vermicompost 300g + Neem cake150g). Late flowering was recorded in T_2. The delay in flowering might be due to the synthesis of more protein and protoplasm from carbohydrates and less amount of carbohydrate stored in vegetative parts which resulted delayed flowering.

5.2.6 Flowering Duration (Days)

Flowering duration is an important character when heliconias are used in landscaping. It also contributes to vase life of inflorescence. Flowering duration had significant positive correlation both at genotypic and phenotypic level with number of flower bracts (Nikhil, 2012). Flowering duration is more influenced by soil moisture retention and photoperiod than differences in nutrient levels as observed by Dobkin (1984), Broschat *et al.* (1984b) and Geertsen (1989). However in the present study the level of nutrients influenced the flowering duration which showed optimum nutrient levels are essential for enhanced flowering duration. It was observed that application of organic manures in variably lead to an increase in flowering duration.

5.2.7 Number of Flowering Shoots per Year

Beneficial effect of substituting chemical fertilizers with organic manure and biofertilizers is evident from the increased flower yield and quality inflorescence at higher levels of organic manures. Number of flowering shoots is a critical factor contributing to the yield potential of the cut flowers. The maximum number of flowering shoots per year was recorded by T_2 and T_3. Flowering in Heliconia is controlled by photoperiod (Criley and Kawabata, 1986; Criley and Lekawatana, 1995; Sakai *et al.*, 1990) and leaf number (Criley and Kawabata, 1986; Kwon, 1992). In this study it was observed that percentage of marketable flowers and not the total number of flowering shoots determined the cost effectiveness of the nutritional trial. The number of flowering of shoots can also be dependent on nutrient and/or water stress. This is in conformity with the findings of Achard *et al.* (2006). According to them, plants showed a tendency for flowering under nutrient and or water stress. Organic manures when applied with biofertilizers and chemical fertilizers increases the effectiveness of chemical fertilizers (Robert and Stephen, 1953). This in turn leads to a higher C/N ratio and increased plant metabolism. The increased vegetative growth and balanced C/N ratio leads to increased synthesis of carbohydrates which ultimately promoted flowering.

5.2.8 Size of Bract

The size of the bract is important because usually it represents the biggest highlight in flower arrangements and therefore customer appreciation. Higher bract size contributes to greater attractiveness in heliconia and occupies large display area in decoration which ultimately limits the number of inflorescences needed for display. The present investigation revealed that the nutrient treatments influenced bract size and was recorded highest in T_3. This can be attributed to the optimal nutritional supply in this treatment through slow releasing organic manures such as vermicompost and neemcake which is in line with the reports of Nihad (2013).

5.2.9 Number of Flowers per Bract

In this study number of flowers per bract was highest in treatment T_3 (Heliconiamix2.5g + Vermicompost200g +Neemcake100g) supplying nutrients in the organic and inorganic form over a period of time. This result is in conformity with the findings of Ahmed *et al.* (2004). Bracts are the main floral part contributing to the attractiveness of spike (Kress, 1984). Number of flowers per bract is not a critical factor in determining the value of cultivar as commercial flower or landscape plant (Nikhil, 2012). At the same time within a cultivar more number of flowers per bract enhances the cut flower value.

5.2.10 Length of Inflorescence Stalk

According to Castro *et al.* (2007) in the cultivar Golden Torch the average flower stem length obtained was 84.60 cm. In an earlier study by Farias (2004) in the same cultivar it was observed that combination of organic and mineral fertilizers increased the length of inflorescence stalk compared with chemical fertilizers alone. The flower stem length recorded in this study ranged from 75 to 95 cm and it was in agreement with the previous studies. It was found that combination of organic and mineral fertilizers favourably influenced flower stem length.

5.2.11 Fresh Weight of Inflorescence

The increased vigour of plants in response to fertilizer application resulted in increased size of inflorescences. According to Ferreira and Pires (2005) heliconias respond satisfactorily to application of fertilizers. Clemons and Morton (1999) also concluded that fertilizers gave maximal response for inflorescence weight. The fresh weight of inflorescence was significantly influenced by nutrient treatments at all stages of growth. Throughout the observation period T_3 recorded highest fresh weight of inflorescence. Nihad (2013) also observed that higher spike size of inflorescence leads to increase in fresh weight of inflorescence.

5.2.12 Life of Flower in the Plant

Clemens and Morton (1999) reported that appropriate mineral nutrition combined with sustainable nutrient availability leads to an increase in the number of days of flower in the plant. In contrast reduction in soil moisture retention coupled with increased soil temperature and increased illumination results in lowering of the life of flower in plant according to Dobkin (1984). These findings are applicable in the present study regarding life of flower in the plant where the highest value for this factor was recorded in T_8 (22.75 days). This treatment includes the application of PGPR Mix-I which is a consortium of NPK solubilizing biofertilizer organisms.

5.4 PLANT ANALYSIS

5.4.1 Leaf Chlorophyll Content

Earlier reports indicated that in heliconia leaf chlorophyll content was associated with increased leaf mass density rather than with changes in leaf thickness according to Rundel *et al.* (1998). Increase in chlorophyll content also attributed to increase in nitrogen content (Lalitha *et al.*, 2004). Hayman (1983) attributed physiological causes like enhanced stomatal conductance, photosynthesis and transpiration as the reason for chlorophyll content. Leaf chlorophyll content was established as a common reference system by which physiological reactions were quantified (Mediavilla *et al.*, 2001).However, in this study there was no significant difference in chlorophyll content between treatments.

5.4.2 Leaf NPK Analysis

The level of nutrients in plant tissue could be used as a diagnostic tool to assist in developing a fertilizer programme. If the tissue level of a nutrient was below the lower end of the sufficiency range, the nutrient was considered deficient, whereas if the level was above the upper end of the range, the nutrient can be considered as approaching a toxic level. It is important to be near the midpoint for most nutrients, because imbalances in the ratios of nutrients can affect crop growth (Nihad, 2013). Uchida (2000) has reported that environment played a major role in crop development and nutrient uptake. In Heliconia, the nutrient uptake and critical level of nutrients for each nutrient varies with species. The influence of nutrient treatments on plant nutrient content of *Heliconia angusta* cv. Christmas Red is discussed below.

The translocation of nutrients from the leaf and shoots to actively growing shoot tip leads to enhanced translocation of nitrogen to flowering organs as reported by Nihad (2013). Consequently there is a reduction in the level of nitrogen in these parts. This explains the absence of significant difference among treatments on nitrogen content of leaves.

Phosphorous is a constituent of chlorophyll and is involved in many physiological processes including cell division, development of meristematic tissue, photosynthesis, metabolism of carbohydrates, fats and proteins etc. In the present study the treatment T_6 which consisted of organic manure alone had the highest uptake of phosphorous. This treatment incidentally produced the best quality flowers as evidenced by the score card. Similar findings were reported by Girish (2006) in heliconia.

Potassium is an important element in plant nutrition as far as flowering is concerned. Optimum levels of K nutrition are essential for flowering as reported by Uchida (2000). Studies by Castro *et al.* (2011) revealed higher content of K in roots than leaves. In the present study it was observed that the uptake was highest in T_1 which was a combination of mineral fertilizers and organic manures.

5.5 SOIL NUTRIENT CONTENT

Organic sources, on application to the soil, improve the physical properties of soil such as aggregation, aeration, permeability and water holding capacity which promote growth and development of plants. It has been reported that among the organic sources of nutrients vermicompost proved to be the best source of organic manure which helped in improving physico-chemical properties (p^H, EC, organic carbon) of soil because of its higher analytical values.

The soil nutrient content was analysed along with soil p^H and EC before and after the experiment. In general, the acidity of the soil reduced due to treatment application. The increase in p^H might be due to increase in bases of active degradation of organic matter content. Hanlon (2012) stated that the nutrient availability to plants depended more on soil p^H than on the content of nutrient in soil.

The results of soil electrical conductivity showed there was no significant difference on soil EC. Organic carbon content also showed no significant difference. The increased P_2O_5 content of the soil after the experiment was due to the increased uniform supply of P in the form of cowdung and bonemeal as basal dose along with organic and inorganic manures. The highest P_2O_5 content was registered by T_3. This may also be due to increased solubilization of P in the presence of organic manures. The soil available potassium was highest in T_9. This might be due to the application of organic manures with PGPR Mix-I, which is a consortium of NPK solubilizing biofertilizer organisms.

5.6 VASE LIFE STUDY OF INFLORESCENCE

Postharvest quality of tropical cut flowers depended on both preharvest and postharvest factors. Preharvest factors included environmental factors such as rainfall and temperature, cultivar, fertilizer levels, stage of flower development at harvest and time of day when harvested; whereas post harvest factors included all the steps in the handling system until the flowers reached the consumer (Jaroenkit and Paull, 2003).

The post harvest life of heliconia varied with species from 7 days to 14 days in deionised water without preservatives (Broschat and Donselman, 1983a, 1983b). In the present study inflorescences from T_3 recorded highest vaselife. This might be due to the influence of vermicompost and neemcake in conjunction with chemical fertilizers and biofertilizers. The plant growth promoting substances produced by these manures might have enhanced the vaselife of flowers. Increase in wax content of flowers under favourable situation increases longevity of flowers as reported by Nihad (2013) and Higaki *et al.* (1995).

The results on vase life of heliconia revealed that application of integrated nutrient management has significant effect on shelf life of flowers. Addition of organic manures altered the nutrient availability and water release pattern of the soil. As a result, slow and steady release of nutrient and moisture to the plant assisted in maintenance of turgor in the leaf and flower which favourably extended the vaselife (Chakraborthy *et al.*, 2010). Hauser and Aswala (1999) supported the hypothesis and according to them addition of vermicompost favourably removed micropores in the soil which had direct impact on the turgidity maintenance of plants.

5.7 ECONOMICS OF CULTIVATION

Marketable flowers and suckers were found to attribute to higher B:C ratio which was significantly different between treatments. Benefit: cost analysis showed that the T_3 (Heliconiamix2.5g + Vermicompost 200g + Neemcake100g) recorded high B:C ratio (1.51).

CONCLUSION

In the present study T_3 (Heliconiamix 2.5g + Vermicompost 200g+ Neem cake 100g) showed best results for morphological characters and flowering characters. T_3 was found to be significantly superior for morphological characters i.e., plant height (85.90cm), plant spread (80.99cm), number of leaves per plant (19.86), number of shoots (9.37), flower canopy height (99.10cm), leaf area (222.23 cm^2), leaf area ratio (78.32 cm^2 g^{-1}), leaf area index and flowering characters i.e., length of inflorescence (18.11cm), length of spike (31.96 cm), length of petiole (20.80 cm), number of flower bracts(5.20), size of bract (19.82 cm), number flowers per bract (19.10), length of inflorescence stalk (93.58 cm) and vase life of inflorescence (13.46 days). However treatment T_8 (PGPR Mix-1+ Vermicompost 150g +Neemcake 75g) also obtained on par results for these characters.

In commercial cultivation availability of organic manures a limiting factor in bulk quantities. Under these circumstances the best treatment T_3 which is a combination of organic and inorganic manures can be promoted for commercial flower production. T_8 being an organic combination can reduce the cost of cultivation and improve the soil health by enhancing the nutrient availability in soil with the help of beneficial micro organisms. This treatment can be promoted for production of better quality flowers organically.

FUTURE LINE OF WORK

Cultivars of heliconia differ greatly in the size of plants as well as size of inflorescence. *Heliconia angusta* cv. Christmas Red used in this study is comparatively small sized cultivar. For the large sized cultivars like Bihai and Carribea higher nutrient levels may be required for better flower production. Further nutrient trials in such varieties can be taken up based on the information gathered from present study.

SUMMARY

6. SUMMARY

The present investigation on "Integrated nutrient management for heliconia" was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram during 2013-2014. The experiment was laid out in randomized block design consisting of nine treatments and four replications. The treatments consisted of different combinations of heliconia mix, vermicompost, neem cake and PGPR mix-I with the basal application of FYM, bone meal and biofertilizers. The present study was undertaken to standardize an integrated nutrient management (INM) schedule for optimum flower yield and quality.

The salient findings of the above studies are summarized in this chapter.

- The plants supplied with Heliconiamix 2.5g+Vermicompost 200g+Neem cake 100g (T_3) was found to be significantly superior in morphological characters such as plant height, plant spread, number of leaves per plant, number of shoots, flower canopy height, leaf area, leaf area ratio and leaf area index which were followed by Vermicompost 200g+Neemcake 150g (T_4) and PGPR Mix-1+ Vermicompost 150g+Neemcake 75g (T_8).
- There was no significant difference among the treatments for the number of leaves per shoot. The highest value was recorded in plants supplied with PGPR Mix-1 +Vermicompost 150g +Neemcake 75g (T_8).
- The inflorescence characters i.e., inflorescence length, petiole length, spike length, size of bract and number of flower bracts were found to differ significantly with treatments. The highest petiole length, inflorescence length, spike length, size of bract and number of flower bracts were registered by Heliconiamix 2.5g+Vermicompost 200g + Neemcake 100g (T_3). At nine months after planting, treatment supplied with PGPR Mix-1+ Vermicompost 150g +Neemcake 75g (T_8) also recorded highest number of flower bracts.
- Treatment T_3 (Heliconiamix 2.5g + Vermicompost 200g + Neem cake100g) recorded highest value for colour development and bract

arrangement and T_8 (M1 + Vermicompost 150g + Neem cake 75g) recorded highest value for glossiness and general appearance of flower.

- There was significant difference in flowering duration between treatments. At five, seven and nine months after planting the highest flowering duration was observed in T_3 (11.27, 11.95,12.12 respectively).
- The maximum number of flowering shoots per year was recorded by T_2 (7.62) and was found to be on par with T_3 (7.40). The lowest number of flowering shoots per year was recorded by T_1 (5.68).
- The length of inflorescence stalk was significantly different throughout the observation period. The treatment T_3 recorded highest length of inflorescence stalk (78.02cm, 75.82cm, 78.93 cm, 93.58 cm respectively) and number of flowers per bract (19.10) throughout the observation period.
- The fresh weight of inflorescence was found to differ significantly between treatments. Throughout the observation period, T_3 recorded highest fresh weight of inflorescence.
- There was significant difference among the treatments on days taken for average flower production. The lowest number of days taken for average flower production was recorded by T_6 and was followed by T_4, T_1 and T_5. The days taken to first and fifty percent flowering were significantly influenced by the treatments and the lowest number of days for first flowering was taken by T_2. The lowest number of days taken for attaining fifty percent flowering was recorded by T_4 (147.22) and T_3.
- Life of flower in the plant was found to differ significantly between treatments. The highest number of days of flower in the plant was recorded by T_8 (22.75 days).
- The data on nutrient content of leaves revealed that there was significant influence of treatments on the phosphorous content. The highest content of potassium was recorded by T_1 (2.40) and was on par with T_2 (2.36).
- Soil analysis before and after the experiment showed that there was no significant difference among the treatments on soil P^H, EC, organic carbon

and soil available nitrogen. There was significant difference among the treatments on the available phosphorous and available potassium after the experiment. The highest value of available phosphorous and potassium were recorded by T_3 (94.41) and T_9 (435.19) respectively.

- The vase life of inflorescence was found to differ significantly among treatments. The highest vase life was recorded by T_3 at nine months after planting (13.46) followed by T_1.
- There was no major pest and disease incidence except at the final stage when low incidence of grasshopper was noticed which was also below the economic threshold level.
- The benefit cost ratio was the highest for (T_3) Heliconiamix 2.5g + Vermicompost 200g+Neemcake 100g (1.51) and the lowest was by T_5 Vermicompost 300g+Neemcake150g (0.91).

FUTURE LINE OF WORK

Cultivars of heliconia differ greatly in the size of plants as well as size of inflorescence. *Heliconia angusta* cv. Christmas Red used in this study is comparatively small sized cultivar. For the large sized cultivars like Bihai and Carribea, higher nutrient levels may be required for better flower production. Further, nutrient trials in such varieties can be taken up based on the information gathered from present study.

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APPENDIX

APPENDIX – I

Visual appeal of flowers (Score card)

Sl.No.	General appearance				Bract arrangement				Glossiness of flower				Colour development			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
T_1	5.2	4.3	5.6	4.1	5.1	4.2	3.7	4.1	4.6	4.3	3.7	3.5	3.4	3.6	4.1	4.3
T_2	5.8	5.1	3.8	5.3	4.5	5.4	4.6	4.9	4.6	5.1	4.2	3.1	4.8	4.2	4.1	4.3
T_3	6.2	5.8	5.2	5.8	5.8	4.6	6.4	6.4	5.3	5.4	5.7	5.2	5.8	5.6	5.4	6.0
T_4	4.8	5.2	4.1	4.5	4.3	4.2	5.2	4.5	5.6	5.5	5.0	5.4	4.5	4.3	4.2	3.8
T_5	4.6	4.1	5.0	4.3	4.8	4.3	4.6	4.0	4.3	4.2	4.1	4.1	4.6	4.6	4.4	3.9
T_6	4.2	5.3	4.3	4.9	4.6	4.5	4.1	4.6	4.8	4.2	4.1	4.3	4.1	4.8	4.2	4.2
T_7	4.2	5.3	4.3	4.9	4.8	4.0	4.2	4.6	4.6	4.0	4.3	4.2	4.3	4.7	4.2	4.2
T_8	5.6	4.8	6.4	6.6	5.3	5.2	5.4	4.8	5.2	5.6	5.2	5.7	4.5	4.2	4.6	4.3
T_9	4.2	3.8	4.6	4.5	4.6	4.3	4.7	4.2	4.2	4.3	4.4	4.1	4.6	4.2	4.3	4.1

<u>Score distribution</u>

Average - 1 to 5

Good - 6 to 8

Very good – 9 to 10

APPENDIX - II

Weather data for the cropping period

(June 2013 to May 2014)

Standard week	Temperature (°C)		Sunshine hours	Rainfall (mm)	Relative Humidity (%)
	Maximum	Minimum			
23	29.2	22.8	8.7	15.0	93.6
24	29.1	23.2	7.0	20.2	95.1
25	28.3	22.5	7.6	23.6	95.4
26	29.9	23.3	9.3	8.6	90.0
27	29.3	23.4	9.0	6.7	93.9
28	28.5	23.0	8.4	10.1	93.7
29	28.3	23.5	8.1	10.1	94.0
30	29.4	21.9	9.0	11.6	92.3
31	29.0	21.6	8.4	23.2	93.1
32	28.8	23.9	9.4	3.9	96.7
33	28.6	23.7	9.5	1.6	93.3
34	29.8	24.0	9.9	1.5	92.7
35	30.2	24.4	9.3	2.4	86.6
36	28.8	23.7	7.9	20.1	97.0
37	28.7	23.4	8.2	6.2	98.6
38	28.8	24.3	8.6	7.3	96.3
39	30.2	24.0	10.2	2.3	93.7
40	30.5	22.6	9.7	6.7	94.0
41	30.6	23.3	9.5	5.7	91.4
42	30.7	23.7	8.5	16.5	92.1
43	30.7	23.0	9.1	18.1	95.0
44	30.7	23.6	7.8	10.3	93.9

Standard week	Temperature (°C)		Sunshine hours	Rainfall (mm)	Relative Humidity (%)
	Maximum	Minimum			
45	30.9	23.7	8.8	1.6	97.0
46	30.3	23.4	7.8	46.3	97.7
47	30.6	23.7	8.0	14.5	97.3
48	30.8	23.0	8.5	16.6	97.3
49	30.9	22.8	7.8	1.4	98.6
50	30.3	22.6	8.4	26.0	96.7
51	31.2	21.7	9.2	47.0	97.7
52	31.0	20.2	9.2	0.0	96.6
1	30.9	21.5	8.9	0.0	94.9
2	29.0	22.3	7.6	14.0	94.4
3	31.0	21.8	9.3	0.0	94.1
4	31.3	20.7	9.4	0.5	90.4
5	31.4	21.9	9.3	0.0	92.3
6	30.7	20.2	9.4	0.0	95.1
7	31.4	22.8	9.4	3.0	92.0
8	31.5	23.8	9.1	9.0	90.6
9	31.9	23.1	9.4	12.5	92.3
10	31.9	23.4	9.8	0.0	90.4
11	32.4	21.4	10.1	0.0	93.0
12	33.0	24.1	9.9	3.3	93.7
13	33.0	22.2	10.0	0.0	89.1
14	32.4	24.5	10.0	0.0	89.9
15	32	24.2	8.4	0.5	91.0
16	32	25	9.4	3.0	90.7
17	32.8	24.4	9.9	0.5	94.0
18	32.2	23.8	8.9	3.0	93.1
19	30.7	24.3	6.6	0.0	92.0
20	32.5	25.1	7.3	0.0	88.3
21	32.4	25.5	10.0	0.5	86.3

ABSTRACT

Integrated Nutrient Management for Heliconia

(*Heliconia angusta* cv. Christmas Red)

ARYAMBA T.G.

(2012-12-106)

ABSTRACT

of the thesis submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF AGRICULTURE

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2014

ABSTRACT

The present investigation on "Integrated nutrient management for heliconia" was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2013-2014. Objective of the study was to standardize an integrated nutrient management schedule for heliconia for optimum flower yield and quality. The variety used for the present study was *Heliconia angusta* cv. Christmas Red. The treatments consisted of different combinations of heliconia mix, vermicompost, neem cake and PGPR mix-I with the basal application of FYM, bone meal and biofertilizers. The experiment was laid out in randomized block design consisting of nine treatments and four replications.

The treatment T_3 (Heliconia mix 2.5g +Vermicompost 200g + Neem cake100g) was found to be significantly superior in morphological characters (plant height, plant spread, number of leaves per plant, number of shoots, flower canopy height, leaf area, leaf area ratio and leaf area index), flower characters (length of inflorescence, length of spike, length of petiole, number of flower bracts, size of bract, flowers per bract, length of inflorescence stalk , vase life of inflorescence), leaf nitrogen content and soil available P (after the experiment).

The lowest number of days taken for flowering was recorded in T_6 (Vermicompost 400g + Neem cake 150g). The highest number of flowering shoots per year and the minimum number of days taken to first and fifty percent flowering was registered by T_2 (Heliconia mix 2.5g + Vermicompost 150g+Neem cake 75g). The life of flower was observed to be highest for the treatment T_8 (PGPR Mix-I + Vermicompost 150g + Neem cake 75g). The visual appeal of flowers were assessed based on four characters, among which T_3 (Heliconia mix 2.5g + Vermicompost 200g + Neem cake100g) recorded highest value for colour development and bract arrangement and T_8 (PGPR Mix-I + Vermicompost 150g + Neem cake 75g) recorded highest value for glossiness and general appearance of flower.

The leaf P content was highest in T_6 (Vermicompost 400g + Neem cake 150g) whereas T_1 (Heliconia mix 2.5g + Vermicompost 100g + Neem cake50g) recorded the highest content of potassium and soil available organic carbon. The highest amount of soil available potassium before the experiment was recorded by T_2 and after the experiment T_9 registered the highest value. Highest benefit cost ratio was recorded in T_3 (Heliconia mix 2.5g + Vermicompost 200g+Neem cake100g).

The study revealed T_3 (Heliconia mix 2.5g + Vermicompost 200g + Neem cake100g) as the best treatment in terms of growth characters, flowering characters and vase life studies followed by T_8 (PGPR Mix-I + Vermicompost 150g + Neem cake 75g).

Cultivars of heliconia differ greatly in size of plants as well as size of inflorescences. *Heliconia angusta* cv. Christmas Red used in this study was comparatively small sized cultivar. Further nutrient trials with large sized cultivars like Bihai and Carribea can be taken up considering the results obtained in the present study as a guideline.

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