“EFFECT OF PLANT DENSITY AND FERTIGATION ON PRODUCTIVITY AND QUALITY OF BANANA cv. MARTAMAN”

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By

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CERTIFICATE

Ms. KATAKAM SATYA SAILAJA has satisfactorily prosecuted the course of research and that the thesis entitled **“EFFECT OF PLANT DENSITY AND FERTIGATION ON PRODUCTIVITY AND QUALITY OF BANANA cv. MARTAMAN”** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part there of has been previously submitted by her for a degree of any University.

Place: Venkataramannagudem **(Dr. M. MUTYALA NAIDU)**

Date: **Major Advisor**

CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF PLANT DENSITY AND FERTIGATION ON PRODUCTIVITY AND QUALITY OF BANANA cv. MARTAMAN”** submitted in partial fulfillment of the requirements for the degree of “**MASTER OF SCIENCE IN HORTICULTURE (Fruit Science)”** of Dr. Y.S.R Horticultural University, Venkataramannagudem is a record of the bonafide research work carried out by **Ms. KATAKAM SATYA SAILAJA** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

(Dr. M. MUTYALA NAIDU)
Chairman of the Advisory Committee

Thesis approved by the Student's Advisory Committee**.**

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DECLARATION

I, Ms. K. SATYA SAILAJA, hereby declare that the thesis entitled **"EFFECT OF PLANT DENSITY AND FERTIGATION ON PRODUCTIVITY AND QUALITY OF BANANA cv. MARTAMAN"** submitted to the Dr. Y.S.R. Horticultural University, Venkataramannagudem, for the degree of Master of Science in Horticulture (Fruit Science) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

Place: Venkataramannagudem   **Name** **:** K. SATYA SAILAJA

Date: **I.D.No** **:** VHM/11-15

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
&	:	And
@	:	At the rate of
°C	:	Degree centigrade
AGR	:	Absolute Growth Rate
ANOVA	:	Analysis of variance
AOAC	:	Association of Official Analytical Chemistry
B:C ratio	:	Benefit Cost ratio
CD	:	Critical difference
cm	:	centimetre
COC	:	Copper Oxy Chloride
cv.	:	cultivar
DAP	:	Days after planting
Dr. Y.S.R.H.U	:	Dr. Y.S. Rajasekhar Reddy Horticultural University
dSm^{-1}	:	deci siemens per metre
et al.	:	and others
F	:	Fertigation
Feddan	:	0.42 hectares
FRBD	:	Factorial Randomized Block Design
FYM	:	Farm yard manure
g	:	gram
ha	:	hectare
ha^{-1}	:	per hectare
HC&RI	:	Horticultural College and Research Institute
HDP	:	High Density Planting
H.P	:	Horse Power
HRS	:	Horticulture Research Station
i.e.	:	that is

K	:	Potash
Kg	:	kilogram
l	:	litre
LAI	:	Leaf Area Index
LDPE	:	Low Density Poly Ethylene
MAP	:	Months After Planting
m	:	metre
mg	:	milligrams
Mha	:	million hectares
ml	:	millilitre
MOP	:	Muriate of Potash
N	:	Nitrogen
NHB	:	National Horticulture Board
No.	:	Number
N.S	:	Non Significant
P	:	Phosphorus
$Plant^{-1}$	:	per plant
ppm	:	parts per million
PVC	:	Poly Vinyl Chloride
RDF	:	Recommended Dose of Fertilizers
RH	:	Relative Humidity
S	:	Spacing
SEm	:	Standard error of mean
sq.m	:	Square metre
SSP	:	Single Super Phosphate
t	:	tonne
t/ha	:	tonnes per hectare
TSS	:	Total Soluble Solids
viz.,	:	namely
wt.	:	Weight

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Date:

CONTENTS

LIST OF TABLES

LIST OF PLATES

APPENDICES

LIST OF ILLUSTRATIONS

Author : **KATAKAM SATYA SAILAJA**

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ABSTRACT

Studies were taken up to find out the influence of varying levels of nitrogen and potassium fertigation on commercial banana cv. Martaman planted at three density levels *viz*., S_1 - planting at 2 × 2 m spacing (2500 plants ha^{-1}), S_2 - planting at 2.5 × 1.25 m spacing (3200 plants ha^{-1}) and S_3 - planting at 2.5 × 1.25 × 1.25 m spacing (4800 plants ha^{-1}). Three fertigation levels *viz*., supply of 100 per cent (F_1), 75 per cent (F_2) and 50 per cent (F_3) of the recommended nitrogen and potassium (200:200 g N and K_2O $plant^{-1}$) were tried with these three density levels. Observations on plant biometrical traits, bunch yield, bunch and finger attributes, soil and leaf nutrient concentration of N, P and K were recorded.

Among different plant densities, the significantly highest plant height was recorded in S_3 (2.5 × 1.25 × 1.25 m) during all stages of plant growth except at 3^{rd} MAP and it was on par with S_2 (2.5 × 1.25 m) at 5^{th} MAP and 7^{th} MAP. The pseudostem girth was highest in the treatment S_3 (2.5 × 1.25 × 1.25 m) at shooting and it was on par with S_2 (2.5 × 1.25 m). The leaf characters like number of green leaves, total leaves and leaf area was highest in the treatment S_1 (2 × 2 m) throughout the growth period especially at 7^{th} MAP and shooting. Leaf Area Index was the highest in the S_2 (2.5 × 1.25 m) during all stages of plant growth.

Among fertigation levels, the F_1 (100% RDF) registered significantly higher pseudostem height and girth as compared to F_2 (75% RDF) and F_3 (50% RDF) at 5^{th} MAP and at 7^{th} MAP. F_1 (100% RDF) also registered the highest number of green leaves, total leaves, leaf area and leaf area index at all stages of growth except at 3^{rd} MAP and above treatment was on par with F_2 (75% RDF).

Among different plant densities, the treatment S_1 (2 × 2 m) recorded the earliest shooting, harvest, highest bunch weight, maximum finger girth, highest number of hands per bunch, number of fingers in 2^{nd} hand and highest total sugars content. Whereas the least bunch weight, finger girth, number of hands per bunch, number of fingers in 2^{nd} hand and total sugars content were observed in the treatment S_3 (2.5 × 1.25 × 1.25 m). However, significantly highest per hectare yield was recorded in S_3 (2.5 × 1.25 × 1.25 m) as compared to S_1 (2 × 2 m) and S_2 (2.5 × 1.25 m).

Among fertigation levels, the treatment F_1 (100% RDF) recorded earliest shooting, harvest, highest per hectare yield, bunch weight, maximum finger girth and maximum number of fingers in 2^{nd} hand and it was on par with F_2 (75% RDF) whereas the least per hectare yield, bunch weight, finger girth and number of fingers in 2^{nd} hand were observed in the treatment F_3 (50% RDF). The TSS, total sugars and shelf life were also highest in F_1 and F_2 fertigation levels.

Among different treatment combinations, S_1F_1 produced the heaviest bunch of 20.40 Kg and it was on par with S_1F_2 (20.33 Kg). S_1F_1 also registered higher number of hands per bunch, more fingers, better finger attributes and it was on par with S_1F_2. The TSS, total sugars and reducing sugars were also highest in S_1F_1. The per hectare yield was enhanced for treatment combination S_3F_1 (64.00 t/ha) and it was on par with S_3F_2 (63.61 t/ha) while minimum per hectare yield was recorded by S_1F_3.

Among different treatment combinations, highest BC ratio was obtained in the treatment combinations S_3F_3 (0.73) and S_2F_3 (0.73) where as lowest BC ratio was observed in S_1F_1 and S_1F_3. The BC ratio among different treatment combinations ranged from 0.56 (S_1F_1 and S_1F_3) to 0.73 (S_3F_3 and S_2F_3).

From the foregoing results of the experiment it can be concluded that, among different plant densities S_3 plant density (2.5 × 1.25 × 1.25 m – 4800 plants/ha) registered the highest productivity (63.27 t/ha) by harnessing more sun light under closer spacing. Similarly, among fertigation levels, F_1 (100% RDF – 200 g N and 200 g K_2O plant^{-1}) applied through drip recorded the highest per hectare yield (51.03 t/ha) followed by F_2 (75% RDF – 150 g N and 150 g K_2O plant^{-1}) (50.82 t/ha). Thus, the 75% RDF (F_2) applied through drip was found equally productive to that of 100% RDF (F_1) indicating 25% fertilizer saving.

Among various treatment combinations, highest productivity was obtained in S_3F_1 (2.5 × 1.25 × 1.25 m spacing – 4800 plants/ha and 100% RDF) (64.0 t/ha) followed by S_3F_2 (2.5 × 1.25 × 1.25 m spacing – 4800 plants/ha and 75% RDF) (63.61 t/ha). However, the highest BC ratio was obtained in S_3F_3 (2.5 × 1.25 × 1.25 m spacing – 4800 plants/ha and 50% RDF) and also in S_2F_3 (2.5 × 1.25 m spacing - 3200 plants/ha and 50% RDF).

Chapter-I

Introduction

CHAPTER I

INTRODUCTION

Banana is an important fruit crop of the tropical and subtropical regions of the world majorly grown in India. In view of its nutritive value and fruit value, banana could be considered as “Poor Man’s Apple” because, it is cheaper than any other fruits in the country.

The earliest scientific classification made by Linnaeus suggested the following species names, *Musa sapientum* (Dessert Banana) and *Musa paradisica* (Plantain group). Now these are known, not as species but closely related to inter-specific triploid hybrids of AAA group. At present, all the varieties existing were reported to contain mixed genomes of *Musa accuminata* and *Musa bulbisiana* (Robinson, 1996).

Banana belongs to family Musaceae, of the order Scitaminae. In general all the edible bananas and plantains are indigenous to warm, moist regions of Tropical Asia, comprising few parts of India, Thailand and Indochina.

In India, banana is appropriately referred as ‘*Kalpatharu*’, a plant of all virtues. Each and every part of the plant is used for specific purposes. Apart from its use as a dessert fruit and for culinary purposes, the banana plant has multifaceted uses: the leaf is commonly used as a hygienic dining plate; the male flower is a favourite vegetable; the inner core of the pseudostem is a popular vegetable with many therapeutic uses; the sap is used as an indelible ink in industry and the underground rhizome is exploited as animal feed in a composite mixture with other feedstuffs (Singh and Uma, 1996). It also has several medicinal values and is useful in curing intestinal disorders by converting harmful bacilli into beneficial ones, fighting ulcers by neutralizing acidic secretions and also against gout and arthritis. Its rich iron content makes it a nutritious food for anemic patients.

In India, banana is grown in almost in all regions except-frost prone areas and temperate regions. Its production has taken over that of Mango, contributing 37% of the total fruit production. Major banana producing states are Tamil Nadu, Maharashtra, Karnataka, Andhra Pradesh, Kerala, Gujarat, Assam and Madhya Pradesh. In India, banana is being grown in an area of 8.30 lakh ha with a production of about 297.8 lakh tonnes. The average productivity in India is 35.9 t/ha. There is an extent of 79300 ha of banana in Andhra Pradesh. In India, Andhra Pradesh occupies about 9.3% of total banana production. (NHB data base, 2011).

Banana cv. Martaman belongs to the AAB (silk) group and is akin to Amruthapani. Martaman cultivar is popularly called as Bengal Amruthapani. The plant is tall and can be identified by the yellowish green stem with brownish blotches, reddish margins of the petiole and leaf sheath. The average bunch weight is about 16 kg. Fruits are medium-sized and similar to that of Poovan in appearance, skin is thin, ivory-yellow in colour, and flesh is firm, sweet in taste with a pleasant aroma.

Population growth and the consequent demand for more food have encouraged the search for innovative methods of production that can obtain higher sustainable yields. High density planting (HDP) is one of the recent and noval concepts of increasing productivity without affecting the quality of fruits. This system of planting (HDP) has been successfully implicated in fruit crops such as mango (Santharam, 1999), citrus (Goswami *et al*., 1993) and banana (Sathiamoorthy and Mustaffa, 2001), since it results in the optimum utilisation of natural resources. In most of the regions, where banana is grown, solar radiation is abundant and thus productivity largely depends upon its efficient utilization. So, the density of planting needs to be designed to intercept the solar radiation effectively. An ideal density of plants is determined by complex interaction of factors like cultivars, soil fertility and management practices.

Tropical and sub tropical zones receive about twice the amount of solar energy compared temperate zones. Being adapted to grow under low light intensities banana plants could withstand large amount of shading and hence, is highly suitable for high density system of planting. This can be achieved either by reducing the spacing or by planting more than one sucker per hill or by both. HDP can significantly increase yield per unit area as the plants are planted closer than that in banana of traditional plantings (Mahalakshmi, 2000).

Banana plant, which mostly feeds at the surface of the soil, it is of paramount importance to maintain a high degree of soil fertility, if the production is to be maintained at an economical level over long periods. The choice of fertilizers, dosage of nutrients, time and method of application, *etc*. vary widely with respect to agro-climatic regions and cultivars. Banana crop gives good response to judicious fertilizer programmes. Any excess or deficit application of fertilizers will not exploit the full potential of its yield. It was estimated that a crop of fifty tones of banana in one hectare removes 320 Kg N, 32 Kg P_20_5 and 925 Kg K_2O every year (Lahav and Turner, 1983) as such banana crop requires more of nitrogen and potash for its growth and production compared to phosphorus.

Water and fertilizers are the most crucial basic sources in crop production. Management of these resources in an efficient way is the need of hour. Fertigation offers the opportunity for precise application of fertilizers to the crop. Fertigation is the application of nutrients to plants through micro irrigation systems. It has vast potential in improving nutrient use efficiency, saving labour and energy in application, reducing the cost of production, reducing the environmental pollution and helps in maintaining the soil health besides to meet the specific nutritional requirements of the crop. Banana responds positively to liberal application of water and nutrients (Holder and Gumbs, 1983).

The information available on density of planting and nutritional requirement for banana through fertigation is meager. This clearly emphasizes the need for research on these aspects, which is expected to provide vital information on practical benefits to the growers. With this background, studies were undertaken to standardize the planting density and nutrition (Fertigation) for banana cv. Martaman under field conditions for maximizing the productivity and quality with the following objectives:

1. To study the effect of HDP and fertigation on growth, yield and quality of banana cv. Martaman.

2. To find out optimum spacing and nutrient level (fertigation) required for improving production of banana cv. Martaman.

3. To study the effect of interaction between plant density and fertigation on growth, yield and quality of banana cv. Martaman.

Chapter-II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Banana is one of the important tropical fruit crops. Tropical and subtropical zones receive about twice the amount of solar energy as compared to temperate zones and their potential for agricultural production is consequently higher. The system of High Density Planting (HDP) has been successfully implicated in banana (Sathiamoorthy and Mustaffa 2001), since high density planting results in the optimum utilization of natural resources. In most of the regions, where banana is grown, solar radiation is abundant and thus productivity largely depends upon its efficient utilization. So, the plant density needs to be designed, to intercept the solar radiation effectively.

Banana plant, mostly feeds at the surface of the soil, subsequently it is of paramount importance to maintain a high degree of soil fertility, if the production is to be maintained at an economical level over long periods. The crop gives good response to judicious fertilizer programmes. Many workers confirmed that banana requires large quantities of potassium, moderate quantities of nitrogen and relatively lower doses of phosphorus, which determine the growth and productivity. It is estimated that a yield of fifty tonnes of banana per hectare removes 320 Kg N, 23 Kg P_2O_5 and 925 Kg K_2O every year (Lahav and Turner, 1983).

Fertigation is now emerging as an improved technology as it permits precise application of required nutritional doses for the specific stage of the crops. Fertigation techniques have been more or less standardized for banana cv. Robusta (Mahalakshmi, 2000; Suganthi, 2002 and Kavino *et al.*, 2004) and cv. Ney Poovan (Murugan, 2003).

In this chapter, the available information on growth, development and quality and the effect of various agro- techniques like plant density (spacing) and fertigation which directly or indirectly affect the yield level and quality in banana and plantations was reviewed under the following headings:

2.1 Influence of plant density on growth, yield and quality

2.1.1 Growth parameters

2.1.2 Physiological parameters

2.1.3 Days taken to shooting and harvest

2.1.4 Yield parameters

2.1.5 Quality parameters

2.2 Influence of nutrients on growth, yield and quality

2.2.1 Nitrogen nutrition

2.2.2 Phosphorus nutrition

2.2.3 Potassium nutrition

2.3 Influence of fertigation on growth, yield and quality

2.3.1 Fertigation in banana

2.3.2 Growth parameters

2.3.3 Physiological parameters and leaf nutrient status

2.3.4 Days taken to shooting and harvest

2.3.5 Yield parameters through fertigation

2.3.6 Quality through fertigation

2.3.7 Need for split application of fertilizers

2.3.8 Fertigation scheduling

2.4 Interaction effect of plant density and fertigation on growth, yield and quality of banana

2.1 Influence of plant density on growth, yield and quality

Being adapted to grow under low light intensities, the banana plant could withstand large amount of shading and hence is highly suitable for High Density Planting (HDP), since high density planting results in the optimum utilization of land and solar energy (Samson, 1980). In most banana growing regions solar radiation is abundant and thus productivity largely depends upon efficient utilization of this resource. For this, the plant density needs to be designed to intercept solar radiation effectively. An ideal planting density is determined by a complex integration of factors *viz*., cultivars, soil fertility, management and economic considerations. High density planting in banana not only provides high production and net returns but also facilitates more efficient utilization of solar energy, nutrients and water. High density can be due to decrease in the spacing or increase in the number of suckers per pit (hill) or both.

2.1.1 Growth parameters

2.1.1.1 Plant height and Girth

Ahmed and Mannan (1970) reported that closely spaced (1.2 m × 1.2 m) Amritsagar banana plants had tallest pseudostem and narrowest top girth under Punjab conditions. On the contrary to the above study, Irrizary *et al*. (1975) found that plant density affected the trunk height but not the plant girth when five plant densities (2128, 2723, 3025, 3630 and 4355 plants per hectare) were maintained in Marl Congo plantains.

Chattopadhyay *et al*. (1980) reported that there appears to be threshold spacing below which, plant height was adversely influenced depending upon the cultivars.

Reddy (1982) reported that girth of Robusta banana was not influenced by varying plant density although tallest plants were produced under closer spacing of 1.2 × 1.2 m.

Mustaffa (1983) opined that the height of Hill banana increased with increasing population and closer spacing (2.4 × 2.4 m) produced the tallest plants in contrast to those produced by lesser population and wider spacing (3.0 × 3.0 m). Similar findings were also reported by Robinson (1984) in cv. Nendran; Sathyanarayana and Rao (1985) in cv. Poovan. In contrary, Kulashekharan (1985) did not find any significant influence of plant density on plant height and girth in banana cv. Robusta.

Rajeevan and Geetha (1989) observed that increase in density from 3086 to 5102 plants per hectare significantly increased the plant height although girth remains unaffected.

Uthaiah and Herle (1995) stated that the height of banana plant increased with increasing population and larger population produced the tallest plants in contrast to those produced by lesser population.

Apshara and Sathiamoorthy (1997) reported that planting of three suckers per hill at closer spacing with 7500 plants per hectare showed an increase in plant height and decrease in girth in banana cv. Nendran.

Lichtemberg *et al*. (1998) recorded the increase in plant height and pseudostem girth with increased plant population in Nanicao banana.

Nalina *et al*. (2000) reported that height and girth of pseudostem at all stages of growth are significantly higher under high density planting system compared with conventional planting in banana cv. Robusta.

Baruah *et al*. (2002) reported that the height of banana cv. Malbhog (AAB) increased with increasing population and closer spacing produced the tallest plants in contrast to those produced by wider spacing. Similar findings were also reported by Deshmukh and Badgujar (2002) in banana cv. Grand Naine.

Nankinga *et al*. (2005) recorded the highest plant height and lowest plant girth with plants spaced at 2 × 2 m compared to 3 × 3m spacing in banana cv. Mpologoma under Uganada conditions.

Badgujar and Gowade (2007) recorded the minimum pseudostem height and maximum pseudostem girth under wider spacing of 1.8 × 1.8 m in banana cv. Basrai (AAA).

Athani *et al*. (2009) reported that vegetative growth parameter like plant girth except plant height were higher in the wider spacing (2.4 × 2.4 m) and lower in the closer spacing (1.0 × 1.2 × 2.0 m) of banana cv. Rajapuri.

Sarrwy *et al*. (2012) recorded the highest pseudostem height and lowest girth with plants spaced at 3 × 1 m (1400 plants/ feddan) compared with 3 × 4 m (1050 plants/ feddan) spacing in the first and second ratoons of Williams banana.

2.1.1.2 Leaf emergence, Leaf area and Sucker production

Irrizary *et al*. (1975) reported that planting density and spacing did not influence the number of functional leaves in Marl Congo plantains. Similar observation was recorded by Kulashekaran (1985) in cv. Robusta. On the other hand, there was a reduction in the number of functional leaves with increase in plant density in cv. Robusta (Reddy, 1982); in cv. Giant Governor (Chattopadyaya *et al*., 1985) and in cv. Poovan (Sathyanarayana and Rao, 1985).

Rajeevan and Geetha (1989) reported that number of leaves, leaf area and sucker production were significantly superior in normal planting as compared to high density planting in banana cv. Robusta. In contrary to this, Manivannan (1994) opined that the high density planting significantly increased the leaf production in banana cv. Poovan.

Nalina *et al*. (2000) reported that compared to conventional planting, all the HDP (1.8 × 1.8 m) treatments resulted in increased vegetative characters such as leaf number, leaf area in banana cv. Robusta.

Nankinga *et al*. (2005) recorded the high suckering rate and less no. of leaves with plants spaced at 2 × 2 m compared to 3 × 3 m spacing in banana cv. Mpologoma under Uganada conditions.

Athani *et al*. (2009) reported that the vegetative growth parameters like no. of green leaves, leaf area and sucker production were higher in the wider spacing (2.4 × 2.4 m) and lower in the closer spacing (1.0 × 1.2 × 2.0 m) of banana cv. Rajapuri.

Sarrwy *et al*. (2012) recorded the less no. of green leaves with plants spaced at 3 × 1 m (1400 plants/feddan) spacing compared with 3 × 4 m (1050 plants/feddan) spacing in the first and second ratoons of Williams banana.

2.1.2 Physiological parameters

Leaf area index calculated by dividing the area of the leaf by the area occupied by the plant, is a useful guide in canopy management (Stover, 1984). Plant density can be designed in such a way that the plants intercept maximum solar radiation effectively. In most banana growing regions solar radiation is abundant and thus the productivity largely depends upon the efficient utilization of this resource (Robinson, 1981).

Reddy (1982) recorded the very high leaf area index (LAI) of 11.87 in 1.2 × 1.2 m spacing at shooting stage compared to 2.1 × 2.1 m spacing was 3.88. The critical LAI necessary for 95% light interception was achieved in closer plantings (1.2 × 1.2 m and 1.5 × 1.5 m) by ninth month in cv. Robusta. Similar observations were also recorded by Robinson and Nel (1988) in cv. Williams (Reddy and Chacko, 1992).

Nankinga *et al*. (2005) reported that Leaf Area Index (LAI) decreased with increased plant spacing.

2.1.3 Days taken to shooting and harvest

Irrizary *et al*. (1978) reported that plants spaced at 1.5 × 1.5 m and 1.8 × 1.8 m flowered one month earlier than plants placed at 1.2 × 1.2 m in main crop. In ratoon crop, flowering was delayed with increase in plant density.

Chattopadyay *et al*. (1980a) stated that larger plant population delayed the fruit maturity and the difference in the time of maturity between 2500 plants per hectare and 1125 plants per hectare was 11 days in main crop and 12 days in ratoon crop.

Chundawat *et al*. (1981a and 1983) reported that high density planting significantly delayed flowering and fruit maturity in Lacatan and Dwarf Cavendish.

Chundawat *et al*. (1981b) reported that in Basrai banana maturity of bunches were significantly delayed with reduction in spacing. Similar results were also stated by Reddy (1982) in Robusta and Chattopadyay *et al*. (1985) in Giant Governor and Cavendish bananas.

Apshara and Sathiamoorthy (1997) reported that treatment of 7500 plants per hectare recorded the highest total crop duration of 379.39 days compared to lowest density of 1666 plants/hectare recording 319.05 days to harvest in banana cv. Nendran.

Lichtemberg *et al*. (1998) stated that an increase in plant density often leads to a longer crop cycle. Such extension in plant duration with increase in plant density was more pronounced under sub tropical conditions, than under tropical conditions. Similar results were also given by Sathiamoorthy and Mustaffa (2001) in cv. Grand Naine.

Badgujar and Gowade (2007) recorded the early flowering (253 days) and early maturity (355 days) under wider spacing of 1.8 × 1.8 m in banana cv. Basrai (AAA) compared to closer spacing of 1.2 × 1.5 m.

Sarrwy *et al*. (2012) recorded the earliest bunch shooting and minimum number of days for harvesting with planting distance of 3 × 4m when compared to 3 × 1 m spacing in the first and second ratoons of Williams banana.

2.1.4 Yield parameters

Yield is a function of bunch mass and number of bunches per unit area. High density planting system normally resulted in reduced bunch weight but maximum fruit yield. The mean bunch weight was generally reduced at closer spacing (2445 plants/ha) but the proportion of export quality crop was not affected (Robinson and Singh, 1974).

Irrizary *et al*. (1975) opined that plant spacing and density apparently exerted a significant effect on number of marketable fruits per bunch and in the number of fruits of the second hand. There was an inverse relationship between plant density and both bunch weight and number of marketable fruits per bunch.

Alagiamanavalan and Balakrishnan (1976) reported that in high density planting system there was a reduction in individual bunch weight but the yield per unit area was more compared to traditional planting system in cv. Robusta.

Patel *et al*. (1978) obtained a yield increase from 32.41 to 79.93 t/ha when spacing was reduced from 2.0 × 2.0 m to 1.2 × 1.2 m. Similar results were also obtained in banana cv. Giant Governor (Chattopadyay *et al*., 1980, 1985), Basrai and Lacatan (Chundawat *et al*., 1982a & b, 1983) and Poovan (Sathyanarayana and Rao, 1985).

Chattopadyay *et al*. (1980a) stated that the individual fruit weight increased significantly with lower plant density compared to higher plant density.

Chundawat *et al*. (1981a & b) reported that closer spacing reduced the bunch weight, number of fingers per bunch and finger weight significantly but higher total fruit yield was obtained in Lacatan and Basrai banana.

According to Obiefuna *et al*. (1982), Robinson (1984) and Daniells *et al*. (1985) planting density increased to obtain higher yields per unit area, due to the greater number of bunches.

Mustaffa (1983) stated that high density planting normally resulted in reduced bunch weight but higher total fruit yield, due to the increased number of plant population.

Several workers have revealed the similar findings after conducting the trials with different varieties of banana Robinson and Nel (1986) in hill banana, Israeli and

Nameri (1998), Mahalakshmi (2000) and Nalina *et al*. (2003) in Robusta. In contrary, Sathyanarayana and Rao (1985) and Shanmugavelu *et al*. (1987) reported that there was not much influence of closer spacing on the bunch weight, number of hands and fingers per bunch.

Rajeevan and Geetha (1989) reported that all the yield parameters like bunch weight, number of hands per bunch, number of fingers per bunch, finger length and girth were reduced significantly under high density planting in banana cv. Robusta.

Reddy and Singh (1993) reported that high density planting in banana resulted in cumulative yields that were higher than with conventional planting densities.

Anil *et al*. (1994) stated that a spacing of 1.75 × 1.75 m accommodating 3265 tissue cultured Nendran banana plants per hectare, gave the highest yield without affecting the marketable grade of the bunch.

Uttaiah and Herle (1995) recorded the maximum yield (t/ha) in Robusta banana planted with two suckers per hill compared to single sucker per hill.

Apshara and Sathiamoorthy (1997) recorded the highest cumulative yield of 58.65 t/ha, even though the individual bunch weight (7.82 kg) was lowered at closer spacing of 7500 plants per hectare in banana cv. Nendran.

Apshara *et al*. (2001) reported that closest spacing of 2 × 2 m recorded the highest yield in all the three planting densities among which the two and three suckers per hill gave an increase of 3.29% and 52.02% respectively, compared to one sucker per hill.

Raskar (2003) reported that bunch weight, hands per bunch and fingers per bunch were significantly higher in normal planting as compared to paired row planting in Basrai banana.

Nankinga *et al*. (2005) concluded that bunch weight, no. of hands/ bunch and fingers/ bunch were high for plants spaced at 3 × 3 m while yield was more under closer spacing (2 × 2 m) in banana cv. Mpologoma under Uganada conditions.

Badgujar and Gowade (2007) recorded maximum number of hands, maximum number of fingers and bunch weight under wider spacing of 1.8 × 1.8 m in banana cv. Basrai (AAA). However, maximum yield (t/ha) was noticed with 1.2 × 1.5 m spacing.

Athani *et al*. (2009) stated that bunch weight and finger characters were superior in the wider spacing (2.4 × 2.4 m) while yield was higher in the closer spacing (1.0 × 1.2 × 2.0 m) of banana cv. Rajapuri.

Sarrwy *et al*. (2012) recorded the highest yield with closer spacing (1400 plants/feddan). While the bunch weight, no. of hands/ bunch, no. of fingers/bunch, finger length and weight were maximum with wider spacing (1050 plants/feddan) in the first and second ratoons of Williams banana.

In most of the cases, reduction in bunch weight manifested in a reduction of number of hands, number of fingers per bunch or size and weight of the fingers.

2.1.5 Quality parameters

The post harvest qualities such as acidity, TSS, total and reducing sugars of fruits were not appreciably affected by plant population in cv. Giant Governor banana (Chattopadyay *et al.*, 1980a) in cv. Basrai and Lacatan (Chundawat *et al*., 1982) and in cv. Poovan (Manivannan, 1994 and Premalatha *et al*., 1996).

Nalina *et al*. (2003) stated that all HDP treatments recorded a reduction in TSS and total sugars, whereas, acidity had no significant differences among all HDP treatments.

Sarrwy *et al*. (2012) recorded the highest titrable acidity and lowest TSS, total sugars with closer spacing (3 × 1 m) when compared to wider spacing (3 × 4 m) in the first and second ratoons of Williams banana.

2.2 Influence of nutrients on growth, yield and quality

2.2.1 Nitrogen Nutrition

The time of application and availability of nutrients in adequate quantities during different growth stages are important for optimum growth and productivity of banana. Nitrogen is chief promoter of growth and requires liberal supply for optimum growth and productivity.

Randhawa *et al*. (1973) reported that with increase in the level of nitrogen application, a quadratic increase in the nitrogen content of leaf tissue was observed in 'Robusta' banana. Further, they concluded that considering the economics, the optimum level was found to be 206.1 g of N per plant per year.

Holder and Gumbs (1983) concluded that nitrogen application increased the potential yield of banana. Increase in plant height, pseudostem girth and fruit yield were recorded by the application of N (Kohli *et al*., 1984). They also observed delayed flowering when no nitrogen was applied.

Hegde and Srinivas (1991) reported increased biomass accumulation and yields but the difference between 200 g and 300 g of nitrogen per plant was not conspicuous. They also recorded increased N and K uptake and total soluble solids with increasing level of N and K fertilization.

Prabhuram (1992) reported that the application of 200 g N per plant in the form of urea increased the bunch weight, number of fingers per hand and hands per bunch in banana cv. Rasthali.

Singh and Kashyap (1992) recorded the highest yield of 69.32 tonnes per hectare on application of 400 g N per plant in banana cv. Robusta.

Singh and Suryanarayana (1999) reported that the number of hands and fingers per bunch were increased by increasing the level of nitrogen.

2.2.2 Phosphorus Nutrition

Phosphorus requirement of banana was less than both nitrogen and potassium (Norris and Ayyar, 1942; Martin-Prevel, 1964; Jauhari *et al*., 1974 and Vadivel, 1976). It increases the growth of young plants. In excess, it has depressing effects on the fruit number, fruit weight and size of fingers (Croucher and Mitchell, 1940; Katyal and Chadha, 1961).

Jagirdar and Ansari (1966) found that in Basarai variety of banana, stem girth increased when P was applied along with K at the rate of 48 and 96 lb per acre respectively.

Ramaswamy (1974) reported that the, number of hands per bunch, bunch weight, fruit size and volume increased up to 60 g P_2O_5 per plant. The ‘P’ requirement under Indian conditions varied from 35 to 225 g $plant^{-1}$.

2.2.3 Potassium nutrition

Potassium stimulates early shooting, shortens the time required for fruit maturity, improves bunch grade, size of fingers and fruit quality as it helps in many of the biochemical processes in fruit crops. Potassium deficiency may lead to marked reduction in growth, the leaves become smaller and enhances the phyllocron interval.

Jambulingam *et al*. (1975) recorded increased psuedostem height, girth, and leaf area, sucker production with higher rates of potassium application. Potassium application also enhanced the flowering and maturity with good graded bunches.

Vadivel (1976) reported that total soluble solids particularly the reducing and non-reducing sugars increased with split application of K_2O.

Hegde and Srinivas (1991) also reported improved growth, yield, total soluble solids and nutrient uptake of Robusta banana with higher levels of K.

Saad and Atawia (1999) stated that increasing potassium fertilizer (from 400 to 800 g/plant/year) caused a significant increase in plant height, girth and also increased the bunch weight, number of hands and fingers per bunch, but also improved fruit quality.

2.3 Influence of fertigation on growth, yield and quality

Application of fertilizer along with irrigation (fertigation) makes it easy to match nutrient application with plant growth. Small, frequent application of fertilizer can be timed to the growth requirement of the plants through fertigation. The fertilizer use efficiency can be high through fertigation as compared with conventional application methods. Besides economizing the water and fertilizer, it also saves labour towards weeding, fertilizer application and irrigation (Robinson, 1996).

Magen (1995) reported that over one million hectare was under drip irrigation, out of which 36 per cent was in USA, 12 per cent in Israel, 10 per cent in Spain, 9 per cent in South Africa, 6 per cent in Egypt and 5 per cent each in France and Australia. In USA, 43, 61 and 35 per cent of the sprinkler, trickle, surface irrigated areas, respectively, being chemigated at least once. In Israel, more than 75 per cent of the irrigated area is fertilized by fertigation.

Magen (1995) summarised the advantages ascribed to fertigation as follows:

1. Improved fertilizer recovery leads to higher yield (25 to 30% increased yield).

2. Minimal losses due to leaching. Nitrogen use efficiency recorded at around 80 to 90 per cent with fertigation compared to only 50 per cent with broadcast application.

3. Controls nutrient concentration in the soil. Feasibility of timing of fertilizer application in relation to crop demand based on physiological stages of growth *i.e.* high phosphorus for early growth to encourage rooting, high nitrogen for vegetative growth and high potash for fruit and flower production.

4. Increased nutrient availability.
5. Savings in quantity of fertilizers to an extent of 20 to 40 per cent.
6. Savings in labour and ease in the application of fertilizers with no damage to root system.

Some of the requirements that should be satisfied by fertilizers used for fertigation according to Magen (1995) include.

- Full solubility (< 0.02 % insolubles in water)
- Quick dissolution in irrigation
- Insolubles of non-clogging mineral and bacterial type
- No chemical interactions between the fertilizer and irrigation water
- Minimum content of conditioning agents.

2.3.1 Fertigation in banana

Banana, being a voracious feeder of nutrients and perennial in nature, has fibrous root system and so fertigation system is highly suitable for banana. In Hawaii, shifting to drip irrigation combined with fertigation in banana has doubled the yield obtained from a well – managed, conventional sprinkler irrigated plantation. Lahav and Kalmar (1988) reported that banana responded well to drip fertigation in Israel.

2.3.2 Growth parameters

Srinivas (1998) found that application of 200 g Nitrogen through fertigation resulted in increased plant height, plant girth in the cv. Ney Poovan. The increased plant height and girth was obtained from plants receiving 800 g muriate of potash per plant per year (Saad and Atawia 1999).

Mahalakshmi (2000) recorded the highest stem growth and maximum number of leaves on application of 200:300 g nitrogen and potassium through fertigation in banana cv. Robusta.

Moitra *et al*. (2000) reported that application of 440:338:778 kg per hectare Urea, Single super phosphate and Muriate of potash through fertigation significantly promoted the growth attributes in Grand Naine banana.

Chandra Kumar *et al*. (2001) recorded the highest plant height and more number of leaves on application of 200 g nitrogen and potassium through fertigation in banana cv. Robusta.

Pandey *et al*. (2001) revealed that application of 125 per cent nitrogen of recommended dose resulted in increased plant height, girth and leaf area.

Srinivas *et al*. (2001) reported that plant height, stem girth and number of functional leaves of banana cv. Robusta increased with ontogeny of the crop and with increase in N and K fertigation up to 200 g/plant.

Dinesh and Pandey (2008) recorded the maximum pseudostem height and circumference on application of 75% RDF (200 g N: 80 g P: 220 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development to mature stage) in banana cv. Rasthali.

Ashok *et al*. (2009) reported that treatment T_1 with 100% of recommended dose of fertilizer (RDF) under drip fertigation of banana gave the highest values of plant height, plant girth and average number of leaves.

Dinesh *et al*. (2012) recorded the maximum pseudostem height, stem circumference, total leaf area and maximum leaf nutrient content on application of 75% RDF (150 g N: 60 g P: 155 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development stage) in banana cv. Monthan.

2.3.3 Physiological parameters and leaf nutrient status

Randhawa *et al*. (1973) reported that there was an increase in the nitrogen content and phosphorus content of the leaf tissue with increased level of nitrogen application and also increased level of potash application significantly increased the potash content of leaf tissue in banana cv. Robusta.

Hazarika and Mohan (1991) reported an increase in nitrogen and potassium content of the leaves with increased levels of nitrogen application.

Hegde and Srinivas (1991) stated that Leaf Area Index increases with increase in nitrogen and potash application up to 100 g N and K in banana.

Apshara and Sathiamoorthy (1997) reported that critical leaf nutrient content was 3.41%, 0.67% and 3.13% of NPK respectively in cv. Nendran under high density planting where as in cv. Robusta it was 2.09%, 0.096% and 4.48% NPK respectively (Nalina *et al*. 2003).

Murugan (2003) recorded the highest Leaf Area Index on application of 100% RDF through drip as compared to 75% and 50% RDF in banana cv. Ney Poovan.

Dinesh *et al*. (2012) recorded the maximum leaf nutrient content on application of 75% RDF (150 g N: 60 g P: 155 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development stage) in banana cv. Monthan.

2.3.4 Days taken to shooting and harvest

Application of 250 g nitrogen and 225 g of potash per plant resulted in short crop duration (350.37 days). Moitra *et al*. (2000) observed that 100 per cent liquid fertilizers of recommended dose resulted in early flowering (194.00 days).

Pandey *et al.* (2001) recorded the early flowering (217.75 days) with 100 per cent moisture regime and Nitrogen fertigation in the banana cv. Nendran.

Kavino *et al*. (2004) reported that 200 per cent pan evaporation along with fertigation of 450:90:675 g NPK per plant shortens the time for shooting (232.30 days) in banana cv. Robusta.

Dinesh and Pandey (2008) recorded the earliest shooting and fruit maturity on application of 75% RDF (200 g N: 80 g P: 220 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development to mature stage) as compared to 100% RDF in banana cv. Rasthali.

2.3.5 Yield parameters through fertigation

Srinivas (1986) recorded the increased fruit yield and number of fingers per bunch at 200 g per plant of nitrogen through fertigation. Application of 800 g potash per plant per year recorded higher bunch weight, number of hands and fingers per bunch.

Lahav and Kalmar (1995) concluded that fertigation of 200 kg of potash per hectare resulted in increased bunch weight and yield (2.27 t/ha).

Sriniva and Raghupathi (1997) opined that banana fruit yield was higher with 100 g nitrogen applied through fertigation.

Mahalakshmi (2000) recorded highest bunch weight, maximum number of fingers per bunch and number of hands per bunch on application of 200:300 g Nitrogen and Potassium through fertigation in banana cv. Robusta.

Moitra *et al*. (2000) reported that application of 440:338:778 kg Urea, Single super phosphate and Muriate of potash per hectare through fertigation resulted in maximum number of hands, fingers and bunch weight in cv. Grand Naine.

Raghupathi *et al*. (2000) concluded that highest yield and increased size of the fingers and bunch weight was obtained with the fertigation of 100 g N and K/plant/crop in banana cv. Robusta.

Chandra Kumar *et al*. (2001) recorded the highest yield, bunch weight and more no. of hands, fingers per bunch with 200 g of N and K fertigation which was on par with 150 g N and K fertigation in banana cv. Robusta.

Srinivas *et al*. (2001) reported that fruit yield, bunch weight, hands/bunch, fingers/bunch of banana cv. Robusta increased with increase in N and K fertigation up to 200 g/plant.

Reddy *et al*. (2002) reported that fruit yield of banana increased with increase in fertigation levels and was the highest with 200 g N and K, which was on a par with 150 g N and K fertigation.

Raskar (2003) recorded the highest fruit yield on application of 100% RDF through drip as compared to 75% and 50% RDF in Basrai banana.

Kavino *et al*. (2004) recorded the maximum bunch weight and yield on application of 100% RDF through fertigation as compared to 75% RDF in banana cv. Robusta.

Dinesh and Pandey (2008) recorded the maximum bunch weight, fruit yield, number of hands and fingers on application of 75% RDF (200 g N: 80 g P: 220 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development to mature stage) in banana cv. Rasthali.

Ashok *et al*. (2009) reported that treatment T1 with 100% of recommended dose of fertilizer (RDF), NPK under drip fertigation of banana gave the highest yield, bunch weight and superiority in finger characters.

Dinesh *et al*. (2012) reported that bunch weight, fruit yield, number of hands and fingers, finger size, finger weight were maximum on application of 75% RDF (150 g N: 60 g P: 155 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development stage) in banana cv. Monthan.

2.3.6 Quality through fertigation

Saad and Atawia (1999) reported that improved quality of fruits was obtained from plants receiving 800 g muriate of potash per plant per year in cv. Grand Naine.

Mahalakshmi (2000) recorded highest TSS, total sugars, reducing sugars and non-reducing sugars on application of 200:300 g Nitrogen and Potassium through fertigation in banana cv. Robusta.

Moitra *et al*. (2000) stated that application of 440:338:778 kg of Urea, Single super phosphate and Muriate of potash per hectare through fertigation resulted in highest TSS, total sugars and reducing sugars in banana cv. Grand Naine.

Suganthi (2002) reported that application of 110:35:330 g of Urea, Single super phosphate and Muriate of potash per plant through fertigation resulted highest TSS, total sugars and reducing sugars in banana cv. Red banana.

Kavino *et al*. (2004) reported that 200 per cent pan evaporation along with fertigation of 450:90:675 g of NPK per plant recorded highest TSS, total sugars, reducing sugars and non-reducing sugars in banana cv. Robusta.

Dinesh and Pandey (2008) recorded the maximum TSS, total sugars and reducing sugar contents on application of 75% RDF (200 g N: 80 g P: 220 g K/plant/crop cycle) + application schedule-II (NPK in the ratio of 3:2:1 at vegetative growth, 1:3:2 at flowering stage and 2:1:3 at fruit development to mature stage) in banana cv. Rasthali.

2.3.7 Need for split application of fertilizers

The time of fertilizer application and availability of nutrients in adequate amounts to meet with the crop needs during different growth stages are essential for optimum growth and productivity. Though banana requires nutrients throughout its growing period, application of N and K before shooting, especially during flower bud initiation (4-6 MAP) ensures uninhibited growth and influences the bunch size, number of fingers and hands per bunch, ultimately the yield (Simmonds, 1982).

N, P and K splitting helped in better availability of nutrients during crop period and thus favouring the yield and quality improvement (Agrawal *et al*., 1997).

The beneficial effect of applying nitrogenous fertilizers in several splits at different growth stages has been emphasized. Application of N at critical growth stages *viz*., early vegetative stages (Keshavamurthy *et al*., 1995), flower bud initiation and differentiation stage (Kulasekaran, 1985; Kesavamurthy *et al*., 1995) and post shooting stage (Lahav and Turner, 1983) has great influence on growth, development, plant health and yield together with maximum utilization of applied nutrients. Split application of nitrogen has been found to enhance yields of banana (Kotur and Mustaffa, 1994 and Ray and Yadav, 1994).

Pradeep *et al*. (1997) reported that application of 200 g N per plant in 4+3 splits as 150 g N per plant at vegetative period (30, 75, 120 and 165 days after planting) and 50 g N per plant at reproductive period (210, 225 and 240 days after planting) favoured better plant growth and bunch weight in banana cv. Nendran.

Tirkey *et al*. (2003) recorded the highest plant height, pseudostem girth and leaf number upon treatment with 300 g N + 5 split applications of NPK. Bunch weight, number of hands, number of fingers per bunch, total soluble solids, total sugar and reducing sugars markedly increased upon treatment with 300 g N + 5 split applications of NPK of tissue culture-raised banana cv. Dwarf Cavendish.

Nalina *et al*. (2009) recorded better growth in the tissue cultured banana cv. Robusta; economic characters like bunch weight, number of hands, number of fingers and finger weight were maximum in the treatment T4 165:52.5:495 g NPK plant^{-1} in four splits.

2.3.8 Fertigation scheduling

Lahav and Kalmar (1995) concluded that fertigation of 200 kg of potash per hectare at weekly application was better than continuous application. Weekly applications at the rate of 62 g Nitrogen per mat per year of multi potassium results better growth and development of Williams banana (Achilea, 1997).

Shahar and Achile (1997) reported that weekly applications of 30% recommended dose of K applied at the time of bunch initiation resulted higher yield in tropical regions.

Mahalakshmi (2000) recorded highest bunch weight, number of fingers per bunch, and number of hands per bunch on application of 200:300 g nitrogen and potassium through fertigation at weekly interval in banana cv. Robusta.

Chandra Kumar *et al*. (2001) recorded the highest plant height and number of leaves on daily application at the rate of 299 g per plant of urea and K_2SO_4 in banana cv. Robusta.

Pandey *et al*. (2001) revealed that application of 125 per cent nitrogen of recommended dose at monthly interval resulted in increased plant height, girth and leaf area.

Suganthi (2002) reported that application of 110:35:330 g of Urea, Single super phosphate and Muriate of potash per plant through fertigation at weekly interval resulted in highest yield and quality fruits in banana cv. Red banana.

Kavino *et al*. (2004) reported that daily application of urea and K_2SO_4 at the rate of 299 g per plant increased the yield in banana cv. Robusta.

2.4 Interaction effect of plant density and fertigation on growth, yield and quality of banana

An ideal planting density is determined by a complex integration of factors viz., cultivar, soil fertility, management and economic considerations. Considerable research work has been done to standardize not only the quantum of different nutrients but also the appropriate time, method of application and optimum plant density to obtain the maximum fertilizer use efficiency under varying agro climatic conditions in different parts of India. A new concept of increasing the plant density by decreasing the plant spacing has proved successful in increasing the productivity of banana. Fertigation is also an emerging technique. It has vast potential in improving nutrient use efficiency, saving labour and energy in application, reducing the cost of production, reducing the environmental pollution and help in maintaining the soil health besides to meet the specific nutritional requirements of the crop at different stages of growth.

Berad *et al*. (1998) reported that the normal planting (1.8 × 1.5 m) with application of 100:40:200 g N, P_2O_5 and K_2O per plant in solid form and only N (urea) through fertigation performed well in respect of all yield attributes and registered the 15% higher yield as compared to paired planting in banana cv. Basrai.

Kulapathi *et al*. (2000) stated that the cv. Robust registered a maximum bunch yield of 106.31 t/ha with 125% of recommended NPK fertilizers when two suckers per hill were retained after shooting of the main crop.

Mahalakshmi (2000) revealed that under both the normal and high density system of planting, fertigation was effective in improving the yield and in maintaining fruit quality.

Nalina *et al*. (2000) opined that reduction in fertilizer rates results in significant reduction in bunch characters such as, finger weight, finger length, finger circumference in all the High Density Planting (HDP) treatments.

Murugan (2003) reported that the treatmental combination, D_1F_1 (2500 plants/ha and 100% recommended NPK, (110: 330 g N and K plant^{-1}) produced the heaviest bunch of 13.3 Kg and registered higher number of hands per bunch, more fingers, better finger attributes, while the maximum productivity 42.59 (t/ha) was obtained with D_3F_1 (4286 plants/ha and 100% recommended NPK). The TSS, ascorbic acid, total sugars, reducing sugars and non reducing sugars were also highest in D_1 and F_1 levels and in their combinations in banana cv. Ney Poovan.

Nalina *et al*. (2003) concluded that planting of three suckers per pit at 1.8 × 3.6 m spacing with 50% recommended fertilizer dose (RDF 200:60:300 g NPK/plant) was the best treatment in terms of registering maximum productivity per hectare in cv. Robusta.

Hannah and Pandian (2004) reported that higher bunch yield of 38.31 t/ha was registered under high density planting. Adoption of fertigation at 125 per cent recommended NK increased the plant height, girth and produced the higher bunch yield. Quality characters like TSS, total sugars, reducing sugars were also superior in this treatment which was followed by 100 percent recommended NK (210:390 g/pit) in banana cv. Rasthali.

Kumar *et al*. (2004) stated that highest yield was recorded with treatment combination D_2F_3 (2 suckers/pit, 1.8 m × 1.8 m, 6172 plants/ha and 100% recommended NPK through fertigation) in banana cv. Robusta while in Red banana (AAA) the highest yield was obtained with D_2F_1 (2 suckers/pit, 1.8 m × 1.8 m, 6172 plants/ha and 50% recommended NPK through fertigation.

Chapter- III

Materials & Methods

CHAPTER-III

MATERIAL AND METHODS

The investigation on **"Effect of plant density and fertigation on productivity and quality of banana cv. Martaman"** was carried out during 2011-12 at Horticulture Research Station, Kovvur (West Godavari District), Andhra Pradesh.

The materials and methods followed in this investigation are described hereunder.

3.1 LOCATION OF THE EXPERIMENTAL FIELD

Geographical location of the experimental site is Horticultural Research Station, Kovvur which is located at 17° 00' N latitude, 81° 43' E longitude and 15.66 m above mean sea level. The topography of the experimental site was fairly uniform.

3.2 CLIMATE

The experimental site receives an annual rainfall of 652.2 mm from South-West monsoon (June to September), North-East monsoon (October to November) and also through summer showers. The climate prevailed during the crop growth period and mean annual meteorological data are presented in Annexure I.

3.3 SOIL CHARACTERISTICS OF THE EXPERIMENTAL SITE

The black alluvial soil at the experimental site is endowed with good drainage and with the p^H of 7.6 and EC 0.42 dSm^{-1}. Before laying out the experiment, soil samples were collected at four randomly selected spots from a depth of 30 cm from the experimental site and composite samples were analysed for chemical analysis. The relevant information is presented below.

Chemical properties of the soil of experimental site:

Properties	Characterization	Method of analysis
Soil p^H	7.6	Glass electrode pH meter model 335 (Jackson, 1973)
Electrical conductivity (dSm^{-1})	0.42	Conductivity Bridge ELICO Model EM 88 (Jackson,1973)
Organic carbon (%)	0.48	Wet digestion procedure (Walkley and Black, 1934)
Available nitrogen (kg ha^{-1})	188.60	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available phosphorus (P_2O_5) (kg ha^{-1})	20.5	Olsen's method (Olsen *et al.*, 1954)
Available potassium (K_2O) (kg ha^{-1})	543.90	Neutral normal ammonium acetate method using Flame Photometer (Muhr, 1965).

3.4 EXPERIMENTAL DETAILS

Crop : Banana

Crop cycle : Plant crop

Plot size : 15.0 × 7.0 m

Design : FRBD

Replications : 3

Treatments : 9

Location : HRS, Kovvur.

3.4.1 Treatments Details

A. Factor -1

Spacing : S at 3 levels

S_1- 2 × 2 m spacing (2500 plants/ha)

S_2 - 2.5 × 1.25 m spacing (3200 plants/ha)

*S_3- 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

* In S_3 between the paired rows, a spacing of 2.5 m was allowed.

B. Factor – 2

Nutrient dose: F at 3 levels

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Recommended dose of fertilizers – 200:200 g/plant N and K_2O.

* For fertigation, straight fertilizers like Urea and MOP (granular form) were used whereas phosphorus was applied as basal @ 50 g/plant in the form of SSP for all the treatments.

Treatment combinations

1. S_1F_1 : 2 × 2 m spacing + 100% RDF
2. S_1F_2 : 2 × 2 m spacing + 75% RDF
3. S_1F_3 : 2 × 2 m spacing + 50% RDF

4. S_2F_1 : 2.5 × 1.25 m spacing + 100% RDF
5. S_2F_2 : 2.5 × 1.25 m spacing + 75% RDF
6. S_2F_3 : 2.5 × 1.25 m spacing + 50% RDF
7. S_3F_1 : 2.5 × 1.25 × 1.25 m spacing + 100% RDF
8. S_3F_2 : 2.5 × 1.25 × 1.25 m spacing+ 75% RDF
9. S_3F_3 : 2.5 × 1.25 × 1.25 m spacing+ 50% RDF

3.5 PREPARATORY CULTIVATION

The experiment field was thoroughly ploughed with tractor drawn mould board plough to depth of 30 cm and harrowed twice to a fine tilt. The field was levelled and divided into plots as per the layout of the experiment.

3.5.1 Design and Layout

Field experiment was laid out in Factorial Randomized Block Design with three replications. There were nine treatments in each block and they were allotted randomly. The layout plan of the experiment was illustrated in **Figure 1**.

3.5.2 Digging of pits

Pits of 45 × 45 × 45 cm size were dug and allowed to expose to sunlight for one week before planting of suckers.

3.5.3 Planting suckers

Healthy, disease free uniform sized sword suckers of 3 months age were selected and treatment was done by dipping paired suckers in solution containing Monocrotophos @ 2.5 ml/litre and Copper Oxy Chloride (COC) @ 5 g/litre. Later, the suckers were planted in the pits. Before planting, 50 g of Phosphorus in the form of SSP was applied to each pit as basal dressing.

3.5.4 Installation of drip irrigation system and fertigation unit

The drip irrigation system was installed in the experimental site consisted of 50 mm PVC valve and filter which were connected in series. The main PVC line was of 50 mm diameter to which a sub-main of 40 mm diameter was fixed. Lateral lines (12 mm LDPE) were drawn from the sub mains parallel to the plant rows. Emitter with a discharge rate of 4 litres per hour was fixed on side of the plant. Each lateral line terminated with the end plug. The required quantity of fertilizers was dissolved in water and kept in water tub. The dissolved fertilizers was sucked through half inch PVC pipe with the support of 0.5 H.P motor and allowed to meet the main line by bypass method.

3.5.5 Fertigation levels and details of split application

3.5.5.1 Fertigation levels

F_1- 100% N and K – 200 g N and 200 g K_2O plant^{-1} (435 g urea and 333 g MOP per plant).

F_2 – 75% N and K – 150 g N and 150 g K_2O plant^{-1} (326.25 g urea and 249.75 g MOP per plant).

F_3 – 50% N and K – 100 g N and 100 g K_2O plant^{-1} (217.5 g urea and 166.5 g MOP per plant).

3.5.5.2 Details of split application

F_1 – The total quantity of 435 g urea and 333 g MOP per plant were applied in 30 equal splits @ 14.5 g urea and 11.1 g MOP (each split) at weekly intervals.

F_2 - The total quantity of 326.25 g urea and 249.75 g MOP per plant were applied in 30 equal splits @ 10.87 g urea and 8.32 g MOP (each split) at weekly intervals.

F_3 - The total quantity of 217.5 g urea and 166.5 g MOP per plant were applied in 30 equal splits @ 7.25 g urea and 5.55 g MOP (each split) at weekly intervals.

3.5.6 Staking/propping

Ten to fifteen days after flowering staking was provided with wooden poles to avoid the falling of plants due to heavy winds and the weight of developing bunch in later stages of growth.

3.6 OBSERVATIONS RECORDED

In the experiment 5 plants in the each plot were selected to record different growth parameters during different phonological stages of the crop and reproductive bunch characters in plant crop.

3.6.1 Growth Parameters

3.6.1.1 Plant height (cm)

Height of the pseudostem was measured at 3rdmonth, 5thmonth, 7thmonth after planting and at shooting stage from the base of the trunk to the axil of the youngest leaf and expressed in cm.

3.6.1.2 Plant girth (cm)

Circumference of the pseudostem was measured at 30 cm above the ground level at 3rdmonth, 5thmonth, 7thmonth after planting and at shooting stage and expressed in cm.

3.6.1.3 Number of leaves plant^{-1}

Progressive leaf number, number of green leaves and dried leaves were recorded by tagging at 3rdmonth, 5thmonth, 7thmonth after planting and at shooting stage

3.6.1.4 Leaf area (sq.m plant^{-1}) and Leaf Area Index (LAI)

The leaf area was calculated by multiplying the product of length and breadth of lamina by the factor 0.83 (Murray, 1960) and expressed in m^2. The length of leaf lamina was measured from the base to apex along with the midrib and width at the broadest portion of the lamina.

Leaf area was measured using the following model developed by Robinson and Nel (1988).

LA = {0.83(L × B)} × number of leaves, where

LA = leaf area per leaf (m^2)

L =leaf length (m)

B = leaf breadth (m)

Leaf area index was determined using the formula suggested by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Land area occupied per plant}}$$

3.6.1.5 Absolute growth rate (cm day^{-1})

Absolute growth rate was estimated for plant height and plant girth by using the following formula.

AGR for plant height

$$\text{Absolute growth rate of plant height (cm day}^{-1}\text{)} : \frac{H_2 - H_1}{t_2 - t_1}$$

Where, H_1 and H_2 are plant heights at times t_1 and t_2 respectively.

AGR of plant girth

$$\text{Absolute growth rate of plant girth (cm day}^{-1}\text{) : } \frac{G_2 - G_1}{t_2 - t_1}$$

Where, G_1 and G_2 are plant girths at times t_1 and t_2 respectively.

3.6.1.6 Days taken to shooting

Days taken for emergence of flower stalk after planting of sucker in the plant crop were counted and recorded.

3.6.1.7 Days taken to bunch harvest

Days taken from flower stalk emergence to fruit maturity (disappearance of angle and fullness of the fruit of the middle hand in the bunch) were counted and recorded.

3.6.2 Yield Parameters

The bunch characters were recorded from all the selected plants in each treatment and then mean values were worked out.

3.6.2.1 Hands bunch^{-1}

In each harvested bunch total number of hands per bunch was counted and expressed in number of hands per bunch.

3.6.2.2 Number of fingers in 2nd hand

Number of fingers present in 2nd hand was recorded by counting the number.

3.6.2.3 Finger length (cm)

Finger length was determined by measuring the outer curve of the individual fruit from the junction point of fruit pulp and fruit stalk to the distal end (flower end) of the fruit in the middle of outer whorl of the second hand from proximal end (top) of bunch (Gottriech *et al*., 1964).

3.6.2.4 Finger girth (cm)

Finger girth was determined by measuring individual fruit circumference with a tape at widest midpoint of the fruit in the middle of outer whorl of the second hand from proximal end (top) of bunch.

3.6.2.5 Bunch weight (Kg)

Individual bunch weight was determined by weighing the bunch using electronic weigh balance immediately after harvest and weight was expressed in kilograms.

3.6.2.6 Yield (t/ha)

Average of bunch weight of selected plants in each treatment multiplied by 80 per cent of population gives the yield.

3.6.3 Quality Parameters

Quality parameters such as TSS, total sugar content, reducing sugar content and titrable acidity were recorded at edible ripe stage.

3.6.3.1 Total soluble solids (TSS)

The total soluble solids were determined by using ERMA hand refractometer and expressed as per cent TSS (^{o}Brix) (Ranganna, 1986).

3.6.3.2 Reducing sugars (%)

Reducing sugars were determined by the method of Lane and Eyon (AOAC, 1965). Ten grams of fruit pulp was taken and ground well and transferred to 250 ml volumetric flask, 100 ml of distilled water added. Two ml of lead acetate solution (45 %) was added to the flask to precipitate colloidal matter and kept for 24 hour. Potassium oxalate (22 %) of 2 ml was added in this solution to precipitate the lead acetate and the volume was made up to 250 ml using distilled water. The contents were then filtered through Whatman No. 1 filter paper after testing a little of filtrate for its freedom from lead by adding a drop of potassium oxalate. Reducing sugars in the lead free solution was taken in burette and titrated against 10 ml of standard Fehling's solution mixture of A and B (1: 1) using methylene blue as an indicator till the end point was indicated by the formation of brick red precipitate. The titration was carried out by keeping the Fehling's solution boiling on the heating mantle. The results were expressed as per cent reducing sugar.

3.6.3.3 Total sugars (%)

Total sugars were determined following the method described by Lane and Eyon (AOAC, 1965). A quantity of 50 ml lead free filtrate was taken in a 100 ml volumetric flask and to it 5 ml of concentrated HCl was added, mixed well and then kept for 24 hours at ambient temperature. Acid was then neutralized with NaOH using a drop of phenolphthalein as an indicator till the pink colour persisted for at least few seconds. The volume was then made up to 100 ml with distilled water. Total sugars were then estimated by taking this solution in a burette and titrating it against standard Fehling's solution mixture of A and B (1:1) using methylene blue as an indicator and taking brick red colour as an end point. The titration was carried out by keeping the Fehling's solution boiling on the heating mantle. The results were expressed as per cent total sugar.

3.6.3.4 Titrable Acidity (%)

Ten grams of fruit pulp was taken and ground well and then transferred to volumetric flask and volume made upto 100 ml with distilled water. The contents were filtered through whatman No.1 filter paper. An aliquot of 10 ml was taken into conical flask to which 2-3 drops of phenolphthalein indicator was added and titrated against 0.1 N NaOH to a pink colour obtained which persists at least for 15 seconds, as end point (Ranganna, 1986).

3.6.3.5 Shelf life (Days)

Shelf life was treated as a period (days) between harvest of the fruit (bunch) and end of edible life of the fruit at room temperature. End of shelf life was treated at a stage where 60-70% of the stored fruits become unfit for consumption.

3.6.4 Nutrient content in the leaf

The third youngest leaf was chosen as the standard leaf (Hewitt, 1955) and leaf samples were collected from mid lamina on either side of the mid rib and used for the estimation of leaf N, P and K content.

3.6.4.1 Nitrogen

Total nitrogen in the leaf samples were estimated by Microjeldahl's method after digesting the samples with concentrated H_2SO_4 and catalytic mixture (Jackson, 1973) and expressed in per cent dry weight basis.

3.6.4.2 Phosphorus

The phosphorus content of the leaf samples was estimated in the triacid digested samples by adopting Venadomolybdate reagent as suggested by (Jackson, 1973) and expressed in per cent dry weight basis.

3.6.4.3 Potassium

The potassium content in leaf samples was estimated by using flame photometer as outlined Jackson (1973) and expressed in per cent dry weight basis.

3.6.5 Soil sampling

Soil samples were collected from the experimental plot and samples were drawn for analysis.

3.6.5.1 Method of soil analysis

The soil samples were analyzed for physical and chemical characters viz., pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium.

3.6.5.2 Available nitrogen

This was estimated by alkaline potassium permanganate method and the values were expressed in kg/ha (Subbaiah and Asija, 1956; Jackson, 1973).

3.6.5.3 Available phosphorus

The available phosphorus in soil was extracted by Bray's extractant No.1 the phosphorus in the aliquot was determined by using molybdate stannous chloride method using spectrophotometer and expressed in kg/ha (Olsen *et al.,* 1954; Jackson, 1973).

3.6.5.4 Available potassium

The available potassium was extracted from the soil with neutral normal ammonium acetate solution and the aliquot was fed to flame photometer for potassium estimation and expressed in kg/ha (Muhr, 1965; Jackson, 1973).

3.6.6 Benefit Cost ratio

The benefit cost ratio for the different treatment combinations were worked out based on the expenditure and return in order to study the economics of banana production.

3.7 STATISTICAL ANALYSIS

3.7.1 Analysis of Variance

The experimental data collected on various parameters were analyzed statistically by adopting Fishers (Fisher and Yates, 1963) method of analysis of variance as outlined by Panse and Sukhatme (1978). The level of significance was expressed at 0.05 probability level. The interpretation of the data was done using critical difference values calculated at 0.05 probabilities.

Chapter-IV

Results & Discussion

CHAPTER IV

RESULTS AND DISCUSSION

Dwindling land resources, increasing cost of inputs, such as fertilizers and labour and limitation in water availability have compelled many growers to switch from conventional system of cultivation to hi-tech system of practices like high density planting (HDP), drip irrigation or drip cum fertigation in many horticultural crops. The positive influence of HDP system in terms of yield enhancement per unit area has been documented in many crops and also in banana (Sathiamoorthy and Mustaffa, 2001). Several attempts have been made to optimize the planting density in Hill banana (Mustaffa, 1983), banana cv. Williams (Robinson, 1985; Sarrwy *et al*., 2012), Robusta (Shanmugavelu *et al*., 1987; Rajeevan and Geetha, 1989; Nalina *et al*., 2003) Poovan (Manivannan, 1994), Nendran (Apshara and Sathiamoorthy, 1997) and Ney Poovan (Murugan, 2003).

Fertigation is now emerging as an improved technology as it permits precise application of required nutritional doses for the specific stage of the crop, improves nutrient use efficiency, saves labour and energy in application, reduces the cost of production and also reduces environment pollution besides maintaining the soil health. Fertigation techniques have been more or less standardized for banana cv. Robusta (Mahalakshmi, 2000; Suganthi, 2002 and Kavino *et al*., 2004).

In the present study, attempts have been made to optimise the planting density and to standardize the fertigation requirement of banana cv. Martaman. Owing to increased demand for fruits of this variety because of its excellent taste and flavour and the premium price it fetches in the market, the present study was taken up. The influence of plant population and the effect of nitrogen and potassium through fertigation on the growth, yield and quality of banana cv. Martaman were discussed under the following headings:-

4.1 Effect of plant density on growth parameters of banana cv. Martaman

4.2 Effect of fertigation on growth parameters of banana cv. Martaman

4.3 Effect of plant density on days taken to shooting and harvest

4.4 Effect of fertigation on days taken to shooting and harvest

4.5 Effect of plant density on yield and yield parameters

4.6 Effect of fertigation on yield and yield parameters

4.7 Effect of plant density on fruit quality

4.8 Effect of fertigation on fruit quality

4.9 Effect of plant density and fertigation on leaf nutrient status

4.10 Effect of plant density and fertigation on soil nutrient status

4.11 Interaction effect of plant density × fertigation levels on growth, yield and quality of banana cv. Martaman

4.12 Economic analysis

4.1 EFFECT OF PLANT DENSITY ON GROWTH PARAMETERS OF BANANA cv. MARTAMAN

Yield in banana is determined by various associated parameters, such as pseudostem height, pseudostem girth, number of photosynthetically active leaves *etc.*, (Robinson and Nel, 1989b). The different plant density levels profoundly influenced the yield attributing characters in this study.

Growth is an irreversible increase in size and shape of the plant and it is affected by the complex interaction between environmental factors and physiological processes which are influenced by external inputs like water and nutrients. In the present study it can be observed that under different plant density levels, the vegetative growth in terms of pseudostem height and girth increased with age of the crop up to shooting. Further, rapid rate of increase in pseudostem height and girth was observed between 5th to 7th MAP. Thereafter, the pseudostem height and girth had slowed down from 7th MAP to shooting.

The results of effect of plant density on growth parameters of banana cv. Martaman are presented in the Tables 1-10.

Among different density levels, planting suckers at a spacing of 2.5 × 1.25 × 1.25 m (S_3) resulted in significant increase in pseudostem height as compared to other treatments at all stages of growth (5th MAP, 7th MAP and shooting) except at 3rd MAP (Table 1 and Figure 2). The above treatment recorded significantly highest plant height of 172.89 cm, 299.67 cm and 372.31cm at 5th MAP, 7th MAP and shooting respectively and it was on par with S_2 (2.5 × 1.25 m) treatment at 5th MAP and 7th MAP stages. The absolute growth rate for plant height was significantly higher in S_3 (2.5 × 1.25 × 1.25 m) and it was on par with S_2 (2.5 × 1.25 m) at 5-7 MAP stage (Table 9). Similarly, in pseudostem girth also the treatment S_3 (2.5 × 1.25 × 1.25 m) registered the significantly highest pseudostem girth (72.26 cm) at shooting stage and it was on par with S_2 (2.5 × 1.25 m) treatment. However, during early stages of growth significant difference among plant densities was observed only at 5th month stage registering maximum pseudostem girth (37.52 cm) in S_2 treatment (2.5 × 1.25 m) and it was on par with S_1 (2 × 2 m) (Table 2 and Figure 4). The absolute growth rate for pseudostem girth was significantly higher in S_3 (2.5 × 1.25 × 1.25 m) at 5-7 MAP stage (Table 10).

The increase in plant height in S_3 (2.5 × 1.25 × 1.25 m) could be attributed to higher interplant competition for light within a plot with the advancement of growth stages. Stover and Simmonds (1987) observed intensification of inter plant competition when two or more followers are allowed to develop till maturity. Similar results were also recorded by Nalina *et al*. (2003), Nankinga *et al*. (2005), Athani *et al*. (2009) and Sarrwy *et al*. (2012). Increase in pseudostem girth especially at shooting stage was also observed in S_3 (72.26 cm) treatments as compared to S_1 and S_2 (Table 2). Loss of plant vigour, as pronounced by decreased pseudostem height and girth under HDP system had been reported by many workers (Ahmed and Mannan, 1970; Chattopadhyay *et al*., 1980; Reddy, 1982 and Mahalakshmi *et al*., 2003). This can be due to the mutual shading of plants and competitive growth rate as attributed by Murray (1960).

Among different plant densities, the significant difference in number of suckers per plant was observed only at 5th MAP stage. S_1 (2 × 2 m) recorded the higher number of suckers (3.80) while S_3 (2.5 × 1.25 × 1.25 m) recorded the less number of suckers (3.40) (Table 3).

Significant difference in number of green leaves was noticed among density levels at 7th MAP and shooting stage (Table 4 and Figure 6). Significantly higher number of green leaves was recorded in S_1 (2 × 2 m) at 7th MAP (16.22) and at shooting (14.19). There was no significant difference with respect to green leaves among plant densities at 3rd MAP and at 5th MAP stages. Similar trend was also observed with respect to dry leaves (Table 5) and total number of leaves per plant (Table 6 and Figure 8). The treatment S_1 (2 × 2 m) registered the significantly higher number of total leaves at 7th MAP (30.32) and at shooting stage (36.23) while S_3 (2.5 × 1.25 × 1.25 m) registered the less number of total leaves per plant.

Plant density levels registered the maximum leaf area in S_1 (2 × 2 m) as compared to S_2 (2.5 × 1.25 m) and S_3 (2.5 × 1.25 × 1.25 m) treatments at 7th MAP (14.47 sq.m plant^{-1}) and at shooting (19.57 sq.m plant^{-1}) while S_3 (2.5 × 1.25 × 1.25 m) registered the minimum leaf area (Table 7 and Figure 10). Leaf Area Index (LAI) was reported to be significantly higher for S_2 (2.5 × 1.25 m) as compared to other treatments at all stages of growth except at 5th MAP stage and it recorded a LAI of 0.59, 4.5 and 5.95 at 3rd MAP, 7th MAP and shooting stage respectively (Table 8 and Figure 12). Lowest LAI was recorded by S_1 (2 × 2 m) at all stages of growth. Similar results were also recorded by Murugan (2003), Nankinga *et al*. (2005), Athani *et al*. (2009) and Sarrwy *et al*. (2012).

Sequential production of leaves during the growth period of banana is crucial for higher photosynthetic assimilation. It has been determined by Turner (1970) that the second to fifth leaves from the top are physiologically most efficient. Robinson and Nel (1989b) have suggested that continuous production of leaves as well as maintaining optimal leaf area are requirements for better productivity and for earlier crop cycle, as this leads to better light interception and high assimilation. The number of leaves present at different stages as well as the estimates of leaf area will provide the information relating to the influence of densities on banana yield.

In the present study, at higher density levels, there was a marginal reduction in number of green leaves produced till seventh month after planting. A higher reduction was noted during the observation at shooting (Table 4 and Figure 6). This was contradictory to the report of Manivannan (1994), Robinson and Nel (1989a) and Nalina *et al*. (2000) who indicated from experiments taken up at sub-tropical conditions that high density planting might force the production of higher number of leaves than normal planting to overcome the competition. According to Reddy (1982) high density planting resulted in increased leaf area as compared to wider spacing in banana. However, only lesser leaf production was noted under HDP system under the tropical conditions of India by Mahalakshmi (2000), Murugan (2003), Nankinga *et al*. (2005), Athani *et al*. (2009) and Sarrwy *et al*. (2012).

It can be recognized that the total leaf area has the greater influence on photosynthetic efficiency through higher light interception, as well as higher light assimilation. In the present study, higher leaf area was noted in the conventional density (S_1 – 2500 plants/ha) as compared to higher density (S_3 – 4800 plants/ha) (Table 7 and Figure 10).

Thus, under high density planting system (HDP) as compared to normal planting system resulted in higher pseudostem height and lower number of leaves due to slower rate of leaf emergence. It has been a natural phenomenon due to competition for sun light as a result of mutual shading resulting in lower number of leaves. Slower rate of leaf emergence might have resulted due to low temperature experienced inside the canopy as reported by Robinson and Nel (1988).

4.2 EFFECT OF FERTIGATION ON GROWTH PARAMETERS OF BANANA cv. MARTAMAN

Banana requires high amount of nutrition for good growth and production. It exhausts large quantities of nutrients from the soil during its growth and these have to be invariably replenished by organic and more efficiently through application of mineral fertilizers which supply nutrients in concentrated and readily available form. To maintain the soil fertility for production of higher yields, it is necessary to replenish the nutrients particularly through fertigation.

The results of effect of fertigation on growth parameters of banana cv. Martaman are presented in the Tables 1-10.

The effect of fertigation levels (F_1-100% RDF, F_2-75% RDF and F_3-50% RDF) on growth, development and yield was studied. Pseudostem height showed the significant difference among different fertigation levels at 5^{th} MAP and 7^{th} MAP stages. Among fertigation levels, the F_1 (100% RDF) registered significantly higher pseudostem height (180.33 cm, 292.61 cm) as compared to F_2 (75% RDF) and F_3 (50% RDF) at 5^{th} MAP and 7^{th} MAP stages. However, the above treatment F_1 (100% RDF) was on par with F_2 (75% RDF) at 7^{th} MAP stage. At shooting stage, there was no significant difference in pseudostem height among different fertigation levels (Table 1 and Figure 3). The absolute growth rate for plant height was significantly higher in F_1 (100% RDF) and it was on par with F_2 (75% RDF) at 3-5 MAP stage (Table 9).

With regard to pseudostem girth significant differences among fertigation levels was observed only in the early stages of crop growth *i.e.* at 3^{rd} MAP. F_1 (100% RDF) registered the significantly higher pseudostem girth (16.46 cm) as compared to F_2 (75% RDF) and F_3 (50% RDF) at 3^{rd} MAP. However, during later stages no significant difference was observed in pseudostem girth with application of different fertigation levels (Table 2 and Figure 5). The absolute growth rate for pseudostem girth was significantly higher in F_1 (100% RDF) at 5-7 MAP stage (Table 10).

Height and girth of pseudostem are important attributes which decide the further reproductive traits. In general, the application of higher level of nutrients (F_1-100% RDF) increased the plant height and girth. Similarly, application of 75% RDF (F_2) also resulted in increased plant height on par with 100% RDF (F_1). The higher levels of nutrient application had a significant influence on plant height and girth especially nitrogen and potash which help in formation of complex nitrogenous substances such as proteins and amino acids which are the building blocks of tissues. This was in confirmation with earlier reports that the increased application of nitrogen and potash increases the plant height and girth Apshara and Sathiamoorthy (1997), Pandey *et al*. (2001), Srinivas *et al*. (2001) and Ashok *et al.* (2009).

Different fertigation levels not showed the significant difference with respect to number of suckers per plant at all stages of growth (Table 3). In case of number of green leaves, no significant difference was observed among treatments at 3^{rd} MAP and 5^{th} MAP. However, in the later stages *i.e*. at 7^{th} MAP and at shooting stage, treatments showed the significant difference. At 7^{th} MAP stage, significantly higher number of green leaves was produced with application of 100% RDF (F_1) through fertigation (16.00) and it was on par with 75% RDF (F_2) (Table 4 and Figure 7). Similarly, higher number of green leaves was also produced by F_1 (13.83) treatment and it was on par with 75% RDF (F_2) at shooting stage (Table 4 and Figure 7).

Fertigation levels showed the significant difference with respect to number of dry leaves at all stages of growth except at 3^{rd} MAP stage (Table 5). In case of total number of leaves, the application of 100% RDF (F_1) recorded significantly higher total number of leaves per plant at all stages of growth (5^{th} MAP, 7^{th} MAP and at shooting) except at 3^{rd} MAP. The F_1 (100% RDF) treatment registered the 22.80, 29.41 and 35.39 number of total leaves at 5^{th} MAP, 7^{th} MAP and shooting stage respectively. The above treatment was on par with F_2 (75% RDF) at 5^{th} MAP (Table 6 and Figure 9).

As far as leaf area was concerned, among fertilizer levels 100% RDF (F_1) maintained its lead over the other treatments at all the stages of growth except at 3rd MAP. F_1 (100% RDF) treatment registered the maximum leaf area of 9.05, 15.03 and 20.29 sq.m plant^{-1} at 5th MAP, 7th MAP and shooting stage respectively. Above treatment was on par with F_2 (75% RDF) at 5th MAP stage while F_3 (50% RDF) recorded the minimum leaf area (Table 7 and Figure 11). Similarly, Leaf Area Index (LAI) was also reported to be significantly higher for F_1 (100% RDF) treatment as compared to other treatments at 5th MAP (2.65), 7th MAP (4.44) and at shooting stage (5.99) while F_3 (50% RDF) recorded the minimum Leaf Area Index (Table 8 and Figure 13).

The total number of leaves produced during the growth is influenced by mineral nutrition. It was evident from the data that higher amount of nutrition application resulted in more number of leaves leading to increased leaf area and leaf area index. The increased production of leaves might help to synthesize more photosynthates and flowering stimulus which can influence early shooting. The effective leaf area available for photosynthetic activity might have positively influenced the growth and development of fruits and thus the total yield (Apshara and Sathiamoorthy, 1997 and Kumar and Nalina, 2001). The different workers on banana have reported that higher levels of nitrogen and potash promote production of more leaves resulting in increased leaf area which have positive correlation with bunch weight (Roy and Yadav, 1994; Raju, 1996; Pandey *et al*., 2001 and Srinivas *et al*., 2001).

The improvement in plant growth with 75% RDF (F_2) through fertigation on par with 100% RDF (F_1) might be due to reduced loss of applied fertilizers by leaching thereby improving the fertilizer use efficiency (Rolston *et al*., 1986). Similar findings were also reported by Hegde and Srinivas (1991); Srinivas (1998) and Srinivas *et al*. (2001). Thus the 75% level of RDF applied through drip was found equally productive to that of 100% level of RDF indicating 25% fertilizer saving.

4.3 EFFECT OF PLANT DENSITY ON DAYS TAKEN TO SHOOTING AND HARVEST

The results of effect of plant density on days taken to shooting and harvest are presented in the Table 11 and depicted in Figure 14.

High density planting took more number of days from planting to shooting (Table 11 and Figure 14). Among different density levels, planting suckers at a spacing of 2.5 × 1.25 × 1.25 m (S_3) took significantly more number of (299.61) days to shooting as compared to S_1 (2 × 2 m) (277.54 days) and S_2 (2.5 × 1.25 m) (282.55 days). Wider spacing S_1 (2 × 2 m) recorded the early shooting and harvest as compared to narrow spacing (S_3 - 2.5 × 1.25 × 1.25 m). Similar trend was also noticed from planting to harvest. The extension of crop duration from planting to shooting and to harvest under narrow spacing (S_3 - 2.5 × 1.25 × 1.25 m) could be attributed to lower leaf production and poor photosynthetic activity. Invariably such extended vegetative or reproductive cycle with increase in plant density were in agree with the results of Mahalakshmi (2000), Murugan (2003), Badgujar and Gowade (2007), Sarrwy *et al.* (2012). Robinson and Nel (1988) suggested that reduced temperature inside the canopy under high density planting could be the reason for enhanced crop duration especially under subtropical conditions.

4.4 EFFECT OF FERTIGATION ON DAYS TAKEN TO SHOOTING AND HARVEST

The results of effect of fertigation on days taken to shooting and harvest are presented in the Table 11 and illustrated in Figure 15.

Among fertigation levels, 100% RDF (F_1) recorded early shooting (277.42 days) leading to early harvest of the crop (373.36 days) while the highest number of days to shooting and highest number of days from planting to harvest were recorded in the treatment F_3 (50% RDF) (Table 11 and Figure 15). The early shooting in the above treatment may be attributed to higher number of leaves and more leaf area recorded during vegetative period leading to better photosynthetic activity. The above results were in conformity with the results of Apshara and Sathiamoorthy (1997), Kumar and Nalina (2001) and Pandey *et al*. (2001). The positive effect of nitrogen and potash in production of more number of leaves with better photosynthetic activity resulted in higher C:N ratio for early shooting and faster bunch development has been indicated by Turner and Barkus (1982).

4.5 EFFECT OF PLANT DENSITY ON YIELD AND YIELD PARAMETERS

Yield in banana is a function of bunch mass and number of bunches per unit area. The aim of any applied research study is to get increased yield. In the present investigation, the effect of different spacing's on number of hands per bunch, number of fingers in 2^{nd} hand, finger length, and finger girth were studied.

The results of effect of plant density on yield and yield parameters are presented in the Tables 12 and 13 and depicted in the Figure 16.

The highest number of hands per bunch was recorded in S_1 (2 × 2 m) treatment (8.86) while it was lowest in S_3 (2.5 × 1.25 × 1.25 m). The treatment S_1 (2 × 2 m) recorded significantly higher values for number of hands per bunch (8.86), fingers in 2^{nd} hand (15.89) and finger girth (11.92) as compared to S_2 (2.5 × 1.25 m) and S_3 (2.5 × 1.25 × 1.25 m) (Table 12 and Figure 16). The lower number of hands, fingers and lesser finger girth were recorded under closer spacing S_3 (2.5 × 1.25 × 1.25 m). However, there was no significant effect of different plant densities on finger length. Similarly, the highest bunch weight per plant (19.89 Kg) was recorded under normal spacing S_1 (2 × 2 m) (Table 13 and Figure 16). This was significantly superior over S_2 (2.5 × 1.25 m) and S_3 (2.5 × 1.25 × 1.25 m) densities. Among different plant densities, the mean bunch weight per plant ranged from 16.48 to 19.89 Kg (Table 13). The increase in bunch weight per plant over S_3 spacing was 20.69 per cent.

With respect to yield per hectare the significantly highest yield was recorded in S_3 (2.5 × 1.25 × 1.25 m) (63.27 t/ha) as compared to S_1 (2 × 2 m) and S_2 (2.5 × 1.25

m). Significantly lowest yield was recorded in normal spacing S_1 (2 × 2 m) (39.69 t/ha). Under closer spacing S_3 (2.5 × 1.25 × 1.25 m) there was a 59.41% increase in yield per hectare over normal spacing S_1 (2 × 2 m) (Table 13 and Figure 16).

The increased number of hands, fingers and finger girth might have resulted in increased bunch weight per plant under normal spacing S_1 (2 × 2 m). However, the per hectare yield was reduced under normal spacing (S_1) due to lesser plant density as compared to closer spacing (S_3). The increase in yield per unit area under HDP can be attributed to increase in plant population per unit area (Ahmed and Mannan, 1970). In general, though total yield per unit area has been high in HDP, the bunch grade as measured by the number of hands and fingers was inferior when compared to lower planting densities. In most of the cases, reduction in bunch weight was manifested by reduction in number of hands, number of fingers or size of the fingers. The finger filling is comparatively poorer in high density treatment as pronounced by lower finger girth. During finger development phase the growing bunches act as a heavy sinks and better assimilate partitioning will result only if the physiological efficiency is maximized. Better development of the finger results with high assimilates flow from the built-up reserves, primarily from the pseudostem and from the leaves. Lower number of functional leaves and lower functional area of leaves can be the responsible factors for reduced photosynthetic efficiency and subsequent bunch weight per plant in plants under high density. Reduction in leaf number by pruning caused poor filling and low bunch weights in cv. Williams (Robinson, 1996).

In the present study, lower bunch weight, reduced number of hands, fingers and lesser finger girth was recorded at high density levels, and such reduction in finger parameters can be attributed to higher inter plant competition for light and less air flow. Under HDP production system, reduced bunch weights and finger traits were also recorded in other cultivars *viz*., Poovan (Manivannan, 1994), Nendran (Apshara and Sathiamoorthy, 1997), Robusta (Mahalakshmi, 2000 and Nalina *et al*., 2003), Ney poovan (Murugan, 2003), Rajapuri (Athani *et al*., 2009) and Williams banana (Sarrwy *et al*., 2012). It was in contrary to Sathayanarayana and Rao (1985) and

Shanmugavelu *et al*. (1987) stating not much influence of closer spacing on the bunch weight, number of hands and fingers per bunch.

4.6 EFFECT OF FERTIGATION ON YIELD AND YIELD PARAMETERS

The results of effect of fertigation on yield and yield parameters are presented in the Tables 12 and 13 and illustrated in the Figure 17.

In Martaman banana, significant increase in number of fingers in second hand and finger girth was observed with application of 100% RDF (F_1) and it was on par with 75% RDF (F_2) (Table 12 and Figure 17). The number of fingers in second hand ranged from 14.02 (F_3) to 14.96 (F_1). Similarly, the highest finger girth was observed in (F_1) (10.99 cm) where as the lowest finger girth was observed in (F_3). There were 6.7 and 9.2 per cent increase in number of fingers and finger girth respectively in 100% RDF (F_1) over 50% RDF (F_3). However, with regard to number of hands per bunch and finger length, no significant difference was observed with application of different levels of fertilizers through drip. Robinson (1981) observed a close relationship between number of hands per bunch, fingers per bunch and mean bunch weight with factors such as climate, management and nutrition particularly during flower initiation and bunch development.

The application of nutrients through drip irrigation resulted in significant variation in bunch weight per plant. The bunch weight among fertigation levels ranged from 17.89 kg (F_1) to 18.64 kg (F_3) (Table 13 and Figure 17). Subsequently higher bunch weight was obtained with application of 100% RDF (F_1) and it was at par with 75% RDF (F_2) while 50% RDF (F_3) recorded the minimum bunch weight. There was 4.2 per cent increase in bunch weight over 50% RDF (F_3). The increase in bunch weight in F_1 and F_2 treatments may be attributed to increase in number of fingers and finger girth. The increased growth parameters such as plant height, number of leaves, leaf area and nutrient uptake also positively correlated for higher yields in F_1 and F_2

treatments. This was in confirmation with the findings of Reddy *et al*. (2002), Murugan (2003) and Ashok *et al*. (2009).

The low yields at lower levels of nitrogen and potash was probably due to the low uptake of nutrients (Martin-Prevel, 1973). Similarly, in the present study lower nutrient levels resulted in production of reduced number of leaves, leaf area, fingers and finger girth.

As far as per hectare bunch yield was concerned, the highest yield (51.03 t/ha) was obtained in 100% RDF (F_1) which was on par with 75% RDF (F_2) (50.82 t/ha). The yield ranged from 51.03 t/ha (F_3) to 49.20 t/ha (F_1) (Table 13 and Figure 17). There was 3.7 per cent increase in per hectare yield over 50% RDF (F_3). The higher yield in F_1 and F_2 treatments may be attributed to constant and continuous supply of nutrients in solution form at optimum level to the wetted area of the root zone. The scheduling of potash in different splits at optimum level in the present study was also helpful in increasing bunch weight. As the number of fingers are decided in a banana plant at the time of fruit bud initiation, application of nitrogen and potash in the most favourable form at the active root zone during the right stage of the crop might have induced the formation of more fruits resulting in heavy bunches.

4.7 EFFECT OF PLANT DENSITY ON FRUIT QUALITY

The results of effect of plant density on fruit quality are presented in the Tables 14 and 15 and depicted in the Figure 18.

The primary objective in production system of any crop is to obtain maximum fruit yield without reduction in the fruit quality. In the present study, fruit quality attributes like TSS, acidity, total sugars, reducing sugars and shelf life were assessed. Among different plant densities, significantly highest total sugars (15.53%) and shelf life (6.78 days) was observed in normal spacing (S_1) where as significant difference were not observed in other quality parameters like TSS and reducing sugars (Table 14 and Figure 18). The titrable acidity increased significantly with increase in the plant density recording highest titrable acidity of 0.42% in closer spacing (S_3) (Table 15 and Figure 18). Increase in total sugars with decrease in acidity under wider spacing (S_1) was also reported by Chundawat *et al.* (1982). Reduction in fruit quality, with increase in plant density in many HDP studies was also observed by Anil *et al*. (1994), Apshara and Sathiamoorthy (1997), Nalina *et al*. (2003) and Sarrwy *et al*. (2012). In contrary to this the TSS percentage remained unaltered due to different planting densities. Population densities did not have any significant effect on the TSS, total sugars and acidity in Giant Governor banana (Chattopadhyay *et al*., 1985).

4.8 EFFECT OF FERTIGATION ON FRUIT QUALITY

The results of effect of fertigation on fruit quality are presented in the Tables 14 and 15 and depicted in the Figure 19.

Marked effect on fruit quality was observed with application of nutrients. A high TSS of (23.61°Brix) and more shelf life (5.78 days) of fruits with lesser acidity were obtained by application of 75% RDF through fertigation (F_2) which was on par with 100% RDF (F_1) through fertigation (Table 14 and Figure 19). However, the total sugars (15.22%) and reducing sugars (7.47%) were found to be significantly highest with 100% RDF (F_1) whereas same treatment recorded the significantly lowest acidity (0.38%). Similarly, the total sugars with application of 100% RDF (F_1) and 75% RDF (F_2) were found to be on par with each other. In the present study, the quality of the fruits with application of 75% RDF (F_2) was found to be superior as compared to 50% RDF (F_3). The storage life of fruits under optimum level of nutrients was significantly higher as compared to lower levels (Table 15 and Figure 19). Similar results were also reported by Mahalakshmi (2000), Moitra *et al*. (2000) and Suganthi (2002) who attributed that it could be due to neutralization of organic acids with increased potassium levels in the tissue and the increase in sugar could be due to respiration demand and adequate supply of nutrients, synthesis of invertase and starch splitting enzymes as observed by Mustaffa (1988).

4.9 EFFECT OF PLANT DENSITY AND FERTIGATION ON LEAF NUTRIENT STATUS

Leaf analysis in banana plant was originated by Hewitt and Osborne (1962) who used lamina of the third youngest leaf of plants. Twyford and Coulter (1965) observed the critical level for nitrogen as 2.9 per cent on most soils, 2.6 per cent on very light soils, for P_2O_5 as 0.29 to 0.48 per cent and for K_2O as 3.8 per cent. Kohli *et al*. (1981) worked out the adequacy levels of nitrogen, phosphorus and potassium in leaf tissues in relation to the optimum yield as 2.85, 0.20 and 4.69 per cent NPK respectively.

The practical aim of leaf tissue analysis is to determine the nutritional status of the plant at various growth stages, remedy deficiencies or excesses or imbalances discovered and thereby improved final yields. Leaf analysis results may be applied with greater precision for establishing inter- relationship between the amount of fertilizer applied to the soil in which the crop is to be grown the concentration of major elements in the leaf tissue of the crop after the fertilizer has been added and fruit yield of the crop. This relationship will help in predicting fertilizer rates for a desired optimum level of nutrient concentration in leaf tissue and subsequent fruit yield. This will be useful in scheduling fertilizer rates and overcoming the problems of luxury consumption and poverty adjustment for different nutrients thereby helping the grower to get maximum return with optimum investment in fertilizer.

The results of effect of plant density and fertigation on leaf nutrient status are presented in the Table 16.

The analysis of leaf samples for nitrogen content ranged from 2.64 to 2.67% (spacing) where as in fertigation levels, it ranged from 2.56 to 2.71% (Table 16). Among fertigation levels, slightly higher N percent in leaves at shooting stage was observed in F_1 and F_2 as compared to F_3. However, among plant densities, no significant difference in N content was observed in leaves. Randhawa *et al*. (1973) also observed increased N content with the application of higher N fertilizers.

However, planting distance could not influence the leaf N content as nitrogen was applied on per plant basis taking care of competition due to more plants in closer spacing. The interaction effect between plant density and fertilizers were not significant (Table 16).

The phosphorus at rate of 50 g per plant was applied as basal at the time of planting. Both fertigation levels (N and K) and plant densities did not show any significant effect on phosphorus content of leaf. The interaction effect between spacing and fertilizers were also non significant (Table 16).

It was observed from the data of analysis that potash content of the leaf tissue was not influenced by varying levels nitrogen and potash application and also by different plant densities. The interaction effect between spacing and fertilizer levels was also non significant. Similar results were also reported by Randhawa *et al*. (1973) (Table 16).

4.10 EFFECT OF PLANT DENSITY AND FERTIGATION ON SOIL NUTRIENT STATUS

The results of soil nutrient status are presented in the Table 17.

4.10.1 Soil available nitrogen

Plant nutrient availability in the soil is very important for exploiting higher production. The applied nutrients at any stage of application should properly reflect in terms of available nutrients in the soil so that the plants could absorb these nutrients efficiently without any hindrance. Leaching, volatilization and fixation of nutrients in the soil are some of the factors that affect the availability of soil nutrients to the plants.

In the present investigation, the nutrient availability status estimated at harvesting stage revealed that application of different levels of fertilizers through fertigation and also by adopting different spacings did not show any impact on available nitrogen in the soil (Table 17).

4.10.2 Soil available phosphorus

The availability of phosphorus in the soil is governed by P^H. In the present study the availability of phosphorus was found to be non significant under different fertigation levels and plant densities. The interaction effect between fertilizers and spacing's was also non significant (Table 17).

4.10.3 Soil available potash

The soil available potash was not affected with application of different levels of fertilizers by adopting different spacings. The interaction effect between fertilizers and spacing was found to be non significant (Table 17).

HDP and fertigation levels showed that under 75% RDF (F_2), higher yields can be reaped comparable with that of 100% RDF (F_1). This observation was in agreement with Apshara and Sathiamoorthy (1997) and Nalina *et al*. (2000).

4.11 INTERACTION EFFECT OF PLANT DENSITY × FERTIGATION LEVELS ON GROWTH, YIELD AND QUALITY

The results of interaction effect of plant density and fertigation on growth parameters are presented in the Tables 1-10 and depicted in Figures 20-25.

With regard to interaction effect between plant density and fertigation, no significant difference was observed in plant height during all the stages of growth except at 5^{th} MAP stage (Table 1 and Figure 20). Similarly, in case of pseudostem girth, (Table 2 and Figure 21) no significant difference was observed during all the stages of growth except at 7^{th} MAP stge. The treatment combination S_3F_1 (2.5 × 1.25 × 1.25 m spacing and 100% RDF) recorded the highest pseudostem height (194.00 cm) at 5^{th} MAP and highest pseudostem girth (62.53 cm) at 7^{th} MAP while lowest pseudostem height and girth was recorded by S_3F_3 (2.5 × 1.25 × 1.25 m spacing and 50% RDF). Interaction effect between plant density and fertigation, showed the significant difference with respect to absolute growth rate for plant height (Table 9) and pseudostem girth (Table 10) at 3-5 MAP and 5-7 MAP stages respectively. In case of number of suckers produced per plant, no significant difference was observed at all stages of growth (Table 3).

With regard to number of green leaves (Table 4 and Figure 22), dry leaves (Table 5) and total leaves (Table 6 and Figure 23) interaction effect between plant density and fertigation showed significant difference at 7th MAP and at shooting stage. Similarly, the leaf area (Table 7 and Figure 24) and Leaf Area Index (LAI) (Table 8 and Figure 25) was also found to be significant at 7th MAP and shooting stage. The treatment combination S_1F_1 (2 × 2 m spacing and 100% RDF) recorded the maximum number of green leaves (17.10 and 15.28), total leaves (32.17 and 38.10) and leaf area (15.88 and 21.36 sq.m plant^{-1}) at 7th MAP and shooting respectively while S_2F_1 (2.5 × 1.25 m spacing and 100% RDF) recorded the maximum leaf area index of 4.84 and 6.69 at 7th MAP and shooting respectively. The treatment combination S_1F_1 (2 × 2 m spacing and 100% RDF) was on par with S_1F_2 (2 × 2 m spacing and 75% RDF) with respect to number of green leaves at 7th MAP and shooting. Similar results were also reported by Murugan (2003) and Kumar *et al*. (2004).

The results of days taken to shooting and harvest are presented in the Table 11 and depicted in Figure 26. The treatment combination S_1F_1 (2 × 2 m spacing and 100% RDF) recorded the earliest shooting (272.38 days) and harvest (369.73 days) as compared to other treatment combinations while maximum days to shooting and harvest were recorded by S_3F_3 (2.5 × 1.25 × 1.25 m spacing and 50% RDF).

The results of interaction effect of plant density and fertigation on yield and yield parameters are presented in the Tables 12 and 13 and depicted in Figures 27 and 28.

With regard to hands per bunch, fingers in 2nd hand, finger girth, bunch weight and yield per hectare the interaction effect between fertilizer levels and plant density was found to be significant. Among different treatment combinations S_1F_1 (2 × 2 m spacing and 100% RDF) recorded the significantly maximum number of hands per bunch (9.12), fingers in 2nd hand (16.47), finger girth (12.50 cm) (Table 12 and Figure 27) and higher bunch weight per plant (20.40 Kg) and it was on par with S_1F_2 (2 × 2 m spacing and 75% RDF) (20.33 Kg). However, the per hectare yield was recorded significantly higher by S_3F_1 (2.5 × 1.25 × 1.25 m spacing and 100% RDF) (64.00 t/ha) and it was on par with S_3F_2 (2.5 × 1.25 × 1.25 m spacing and 75% RDF) (63.61t/ha) attributed by increased plant population and higher fertigation levels. The lowest per hectare yield was recorded by S_1F_3 (Table 13 and Figure 28). Similar results were also reported by Nalina *et al*. (2000), Murugan (2003) and Kumar *et al*. (2004). The interaction effect with respect to finger length was found to be non significant (Table 12 and Figure 27).

The results of interaction effect of plant density and fertigation on quality parameters are presented in the Tables 14 and 15 and depicted in the Figures 29 and 30.

The interaction effect with respect to TSS, reducing sugars and shelf life were found to be non significant. The treatment combinations S_1F_1 and S_1F_2 recorded significantly higher per plant yield (20.40 and 20.33 kg) due to higher number of fingers (16.47 and 16.37), hands (9.12 and 9.00) and also due to higher finger girth (12.50 and 12.40 cm). Similarly, higher total sugars and lower titrable acidity have been recorded in treatment combination S_1F_1 (16.32%) followed by S_1F_2 (16.19%) (Tables 14, 15 and Figures 29, 30).

4.12 ECONOMIC ANALYSIS

While the individual plant yield may be reduced under high density condition, the total production per unit area is to be taken in to account in view of increased plant population. The cost of production per unit area is also to be worked out to find out the economic feasibility of adopting high density treatment. It was estimated that 80 per cent of the population came to harvest in the 12 months duration. With this consideration, the cost of production was worked out and the results were tabulated (Table 18).

Among different treatment combinations, highest BC ratio was obtained in the treatment combinations S_3F_3 (0.73) and S_2F_3 (0.73) where as lowest BC ratio was observed in S_1F_1 and S_1F_3. The BC ratio among different treatment combinations ranged from 0.56 (S_1F_1 and S_1F_3) to 0.73 (S_3F_3 and S_2F_3) (Table 19).

Studies from the productivity analysis revealed that the maximum productivity (64.00 t/ha) was registered in the treatment S_3F_1 *i.e*. application of 100 per cent recommended dose of N and K_2O @ 200:200 g through fertigation to plants spaced at 2.5 × 1.25 × 1.25 m (S_3) and it was on par with S_3F_2 (63.61 t/ha) *i.e*. application of 75 per cent recommended dose of N and K_2O @ 150:150 g through fertigation to plants spaced at 2.5 × 1.25 × 1.25 m (S_3). The lowest per hectare yield was recorded in the treatment combination S_1F_3 (2 × 2 m spacing and 50% RDF).

These combinations S_3F_1 and S_3F_2 recorded a benefit cost ratio of 0.60, 0.67 respectively (Table 19). The normal planting density with full dose of recommended level of fertigation (S_1F_1) registered the benefit cost ratio of 0.56. Though the weight of bunches were more in S_1F_1, the number of bunches produced was far less due to lesser plant density as compared to S_3F_1. The results indicated that by applying optimum fertigation doses, high productivity could be achieved with higher economic returns and reduced unit cost of production. As the most economical treatment combinations required the optimum doses of N and K through fertigation, it will be worth experimenting with still optimum doses of N and K at high plant density levels in cv. Martaman.

From the foregoing results of the experiment it can be concluded that among different plant densities, S_3 spacing (2.5 × 1.25 × 1.25 m- 4800 plants/ha) registered the highest productivity (63.27 t/ha) by harnessing more sun light with better light interception and assimilation under closer spacing. Similarly, among fertilizer levels, F_1 (100% RDF - 200:200 g N and K_2O) applied through fertigation recorded the highest per hectare yield (51.03 t/ha) followed by F_2 (75% RDF - 150:150 g N and K_2O) (50.82 t/ha). Thus, the 75% RDF (F2) applied through drip was found equally productive to that of 100% RDF (F1) indicating 25% saving of fertilizers.

Among various treatment combinations, the highest productivity was obtained in S_3F_1 (2.5 × 1.25 × 1.25 m spacing - 4800 plants/ha and 100% RDF) (64.0 t/ha) followed by S_3F_2 (2.5 × 1.25 × 1.25 m spacing - 4800 plants/ha and 75% RDF) (63.61 t/ha). However, the highest B:C ratio was obtained in S_3F_3 (2.5 × 1.25 × 1.25 m spacing - 4800 plants/ha and 50% RDF) and also in S_2F_3 (2.5 × 1.25 m spacing - 3200 plants/ha and 50% RDF).

Plate: 1 Field view of the experimental plot (3 MAP stage)

Plate: 2 Field view of the experimental plot (7 MAP stage)

Plate: 3 Showing more number of fingers/hand and higher finger girth in S_1F_1 and S_1F_2 as compared to other treatment combinations *viz*., S_3F_1, S_3F_2 and S_3F_3

Plate: 4 Showing higher bunch weight and more number of fingers/hand in S_1F_1 and S_1F_2 as compared to other treatment combinations *viz*., S_3F_1, S_3F_2 and S_3F_3

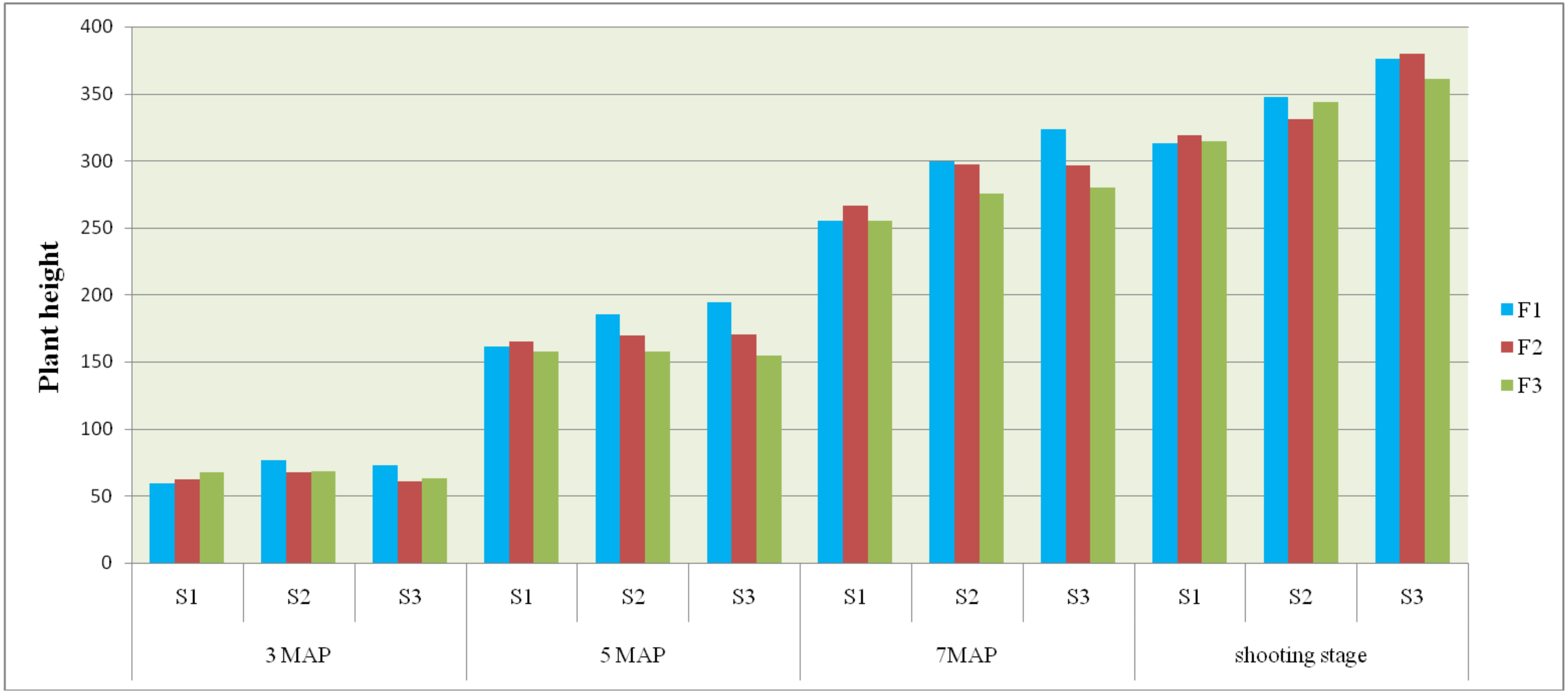

Figure 20: Interaction effect of plant density and fertigation on plant height (cm).

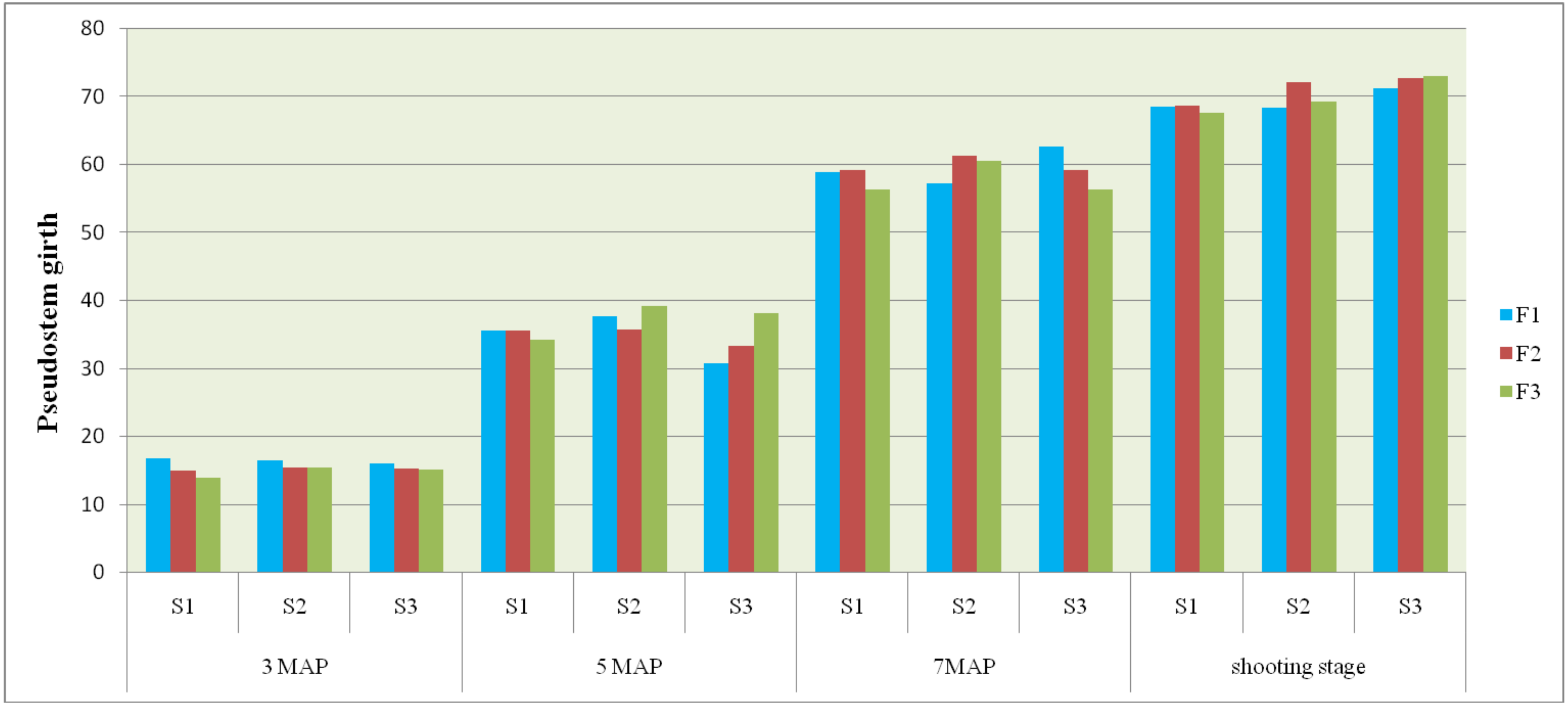

Figure 21: Interaction effect of plant density and fertigation on pseudostem girth (cm).

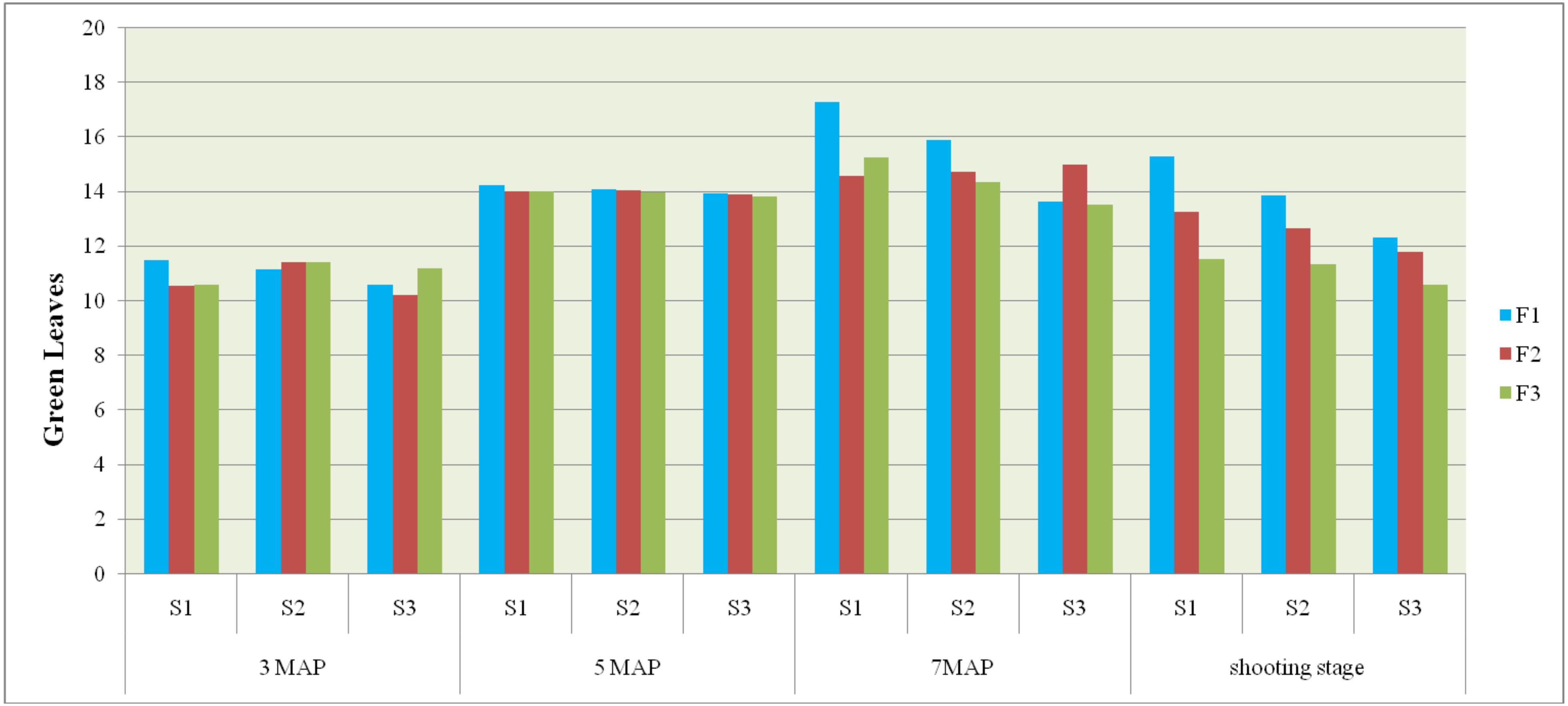

Figure 22: Interaction effect of plant density and fertigation on number of green leaves plant^{-1}.

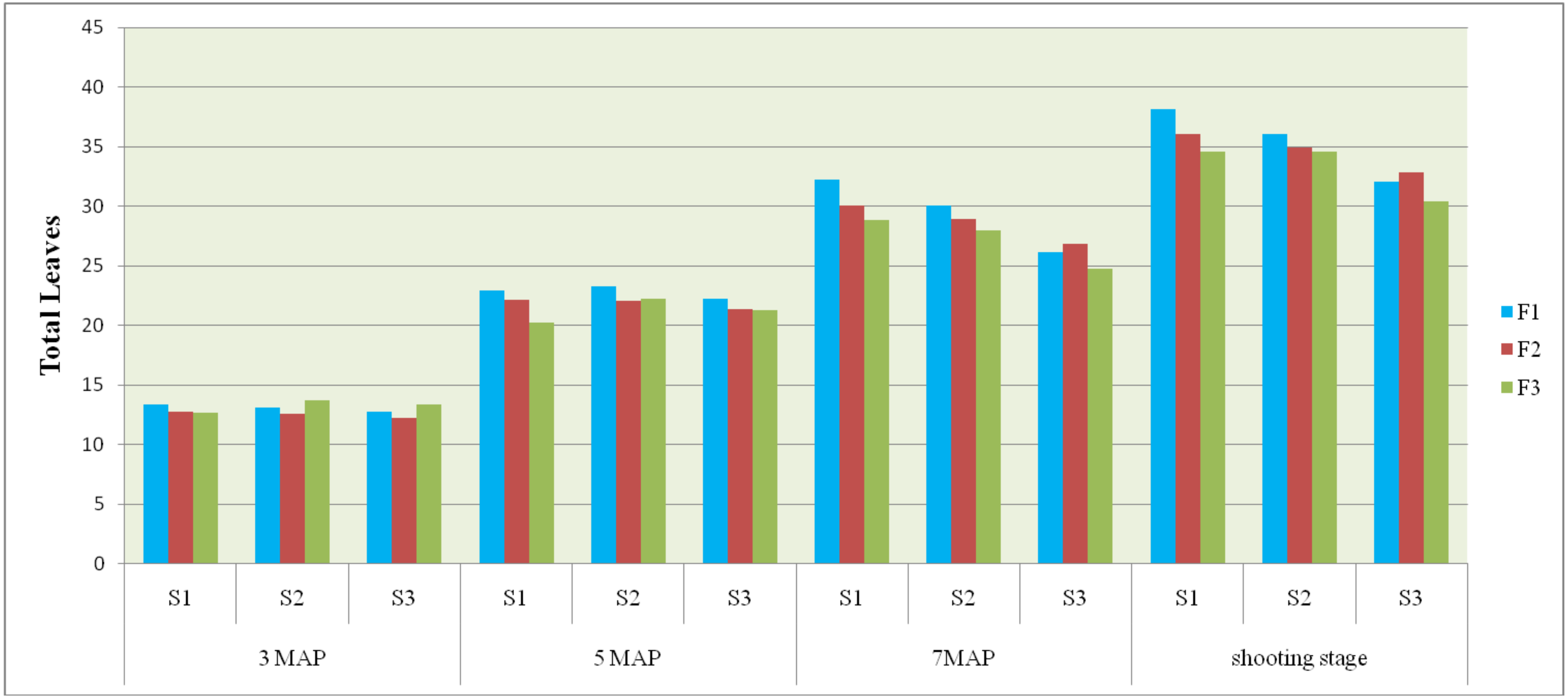

Figure 23: Interaction effect of plant density and fertigation on number of total leaves plant^{-1}.

Figure 24: Interaction effect of plant density and fertigation on leaf area (sq.m plant^{-1}).

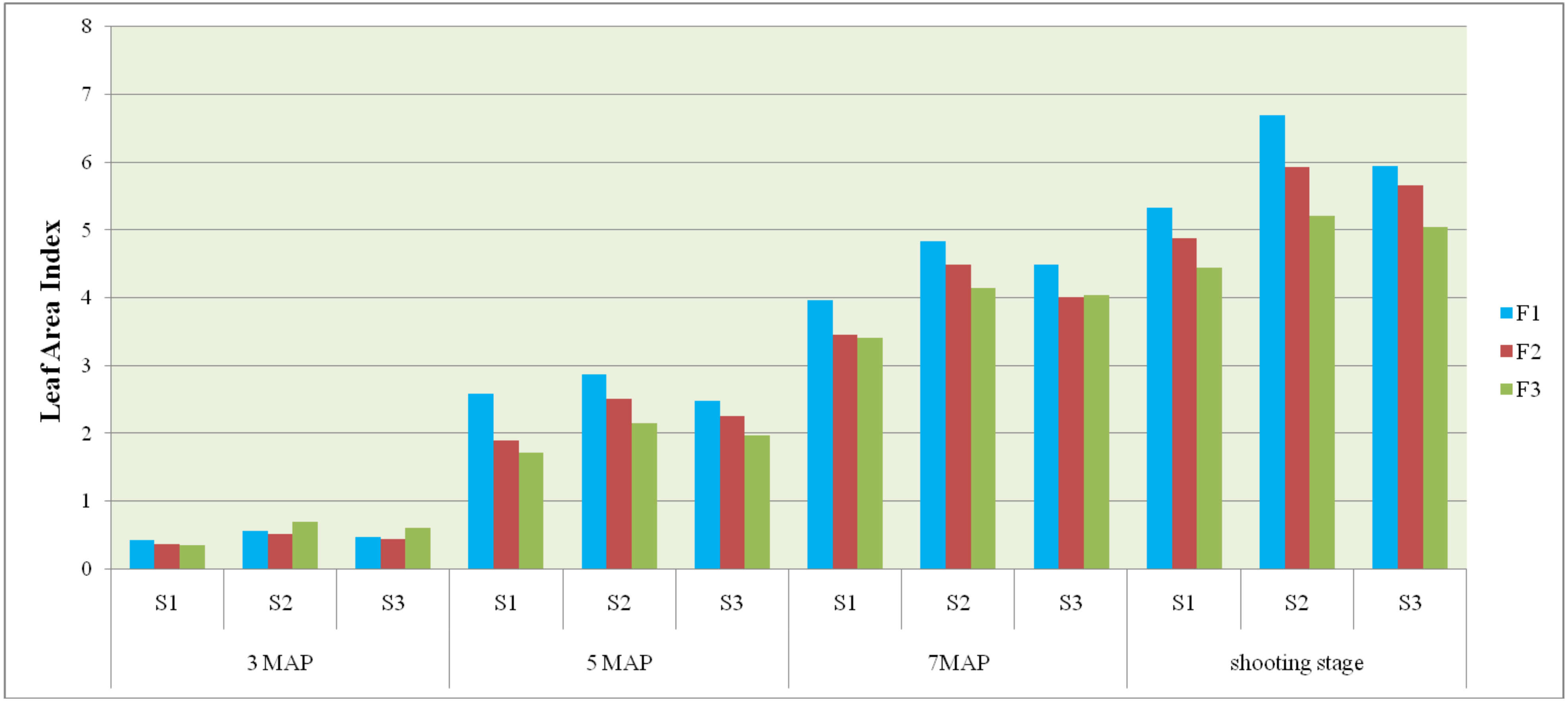

Figure 25: Interaction effect of plant density and fertigation on Leaf Area Index (LAI).

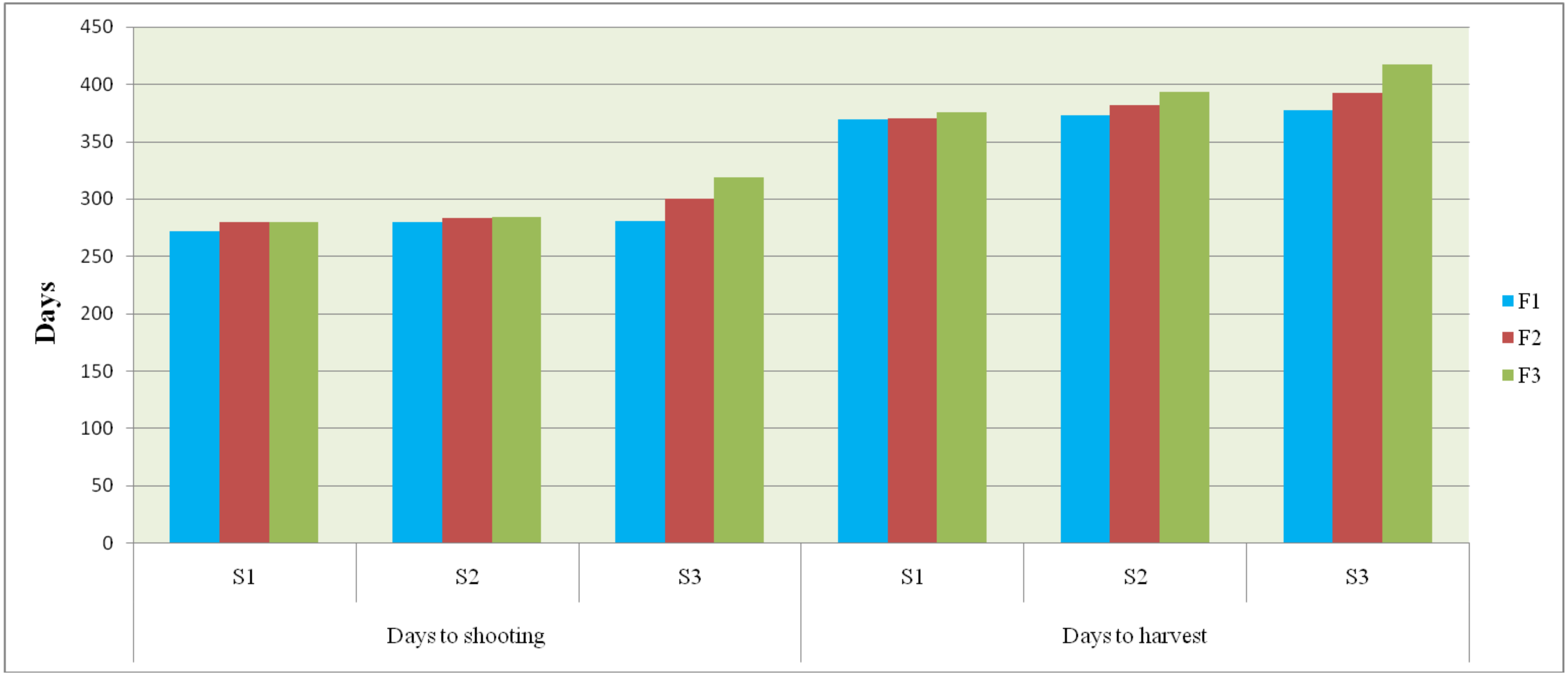

Figure 26: Interaction effect of plant density and fertigation on days taken to shooting and harvest.

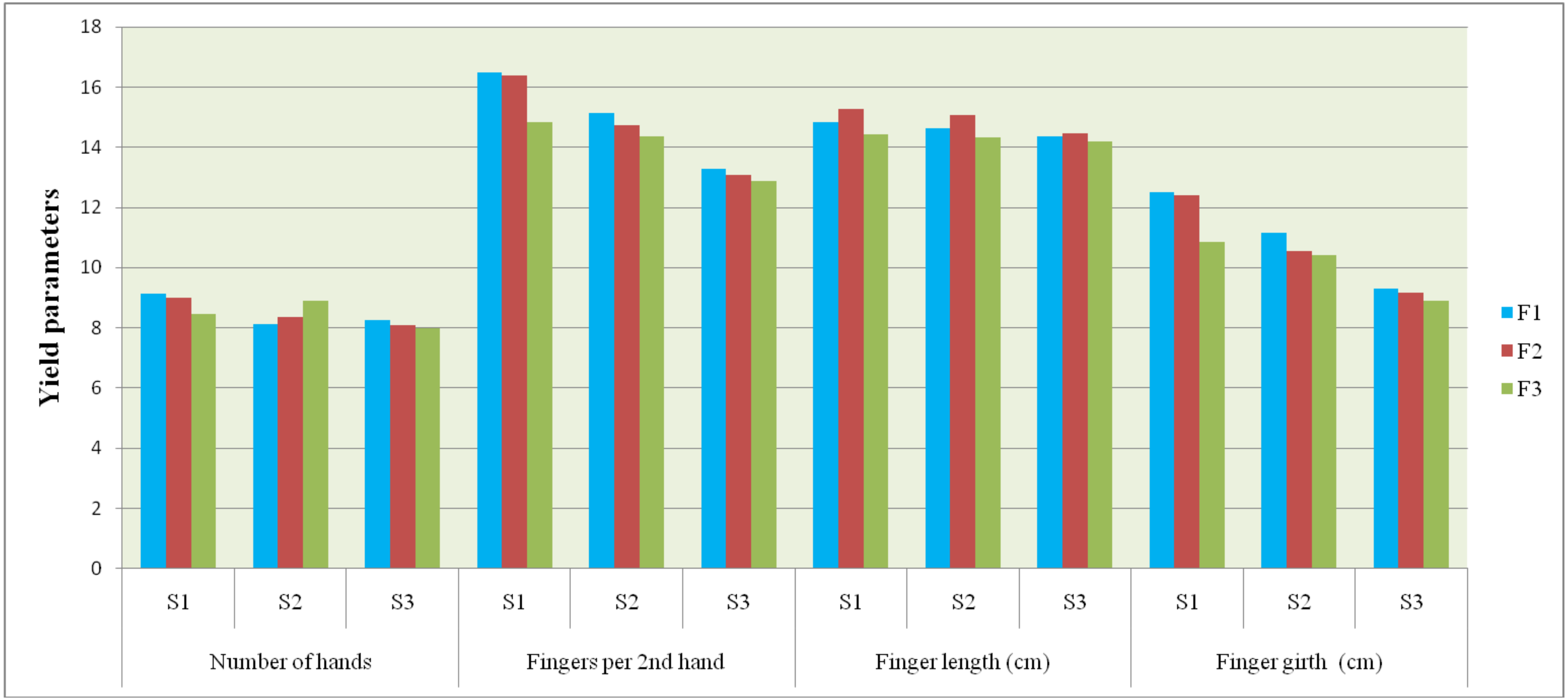

Figure 27: Interaction effect of plant density and fertigation on yield parameters.

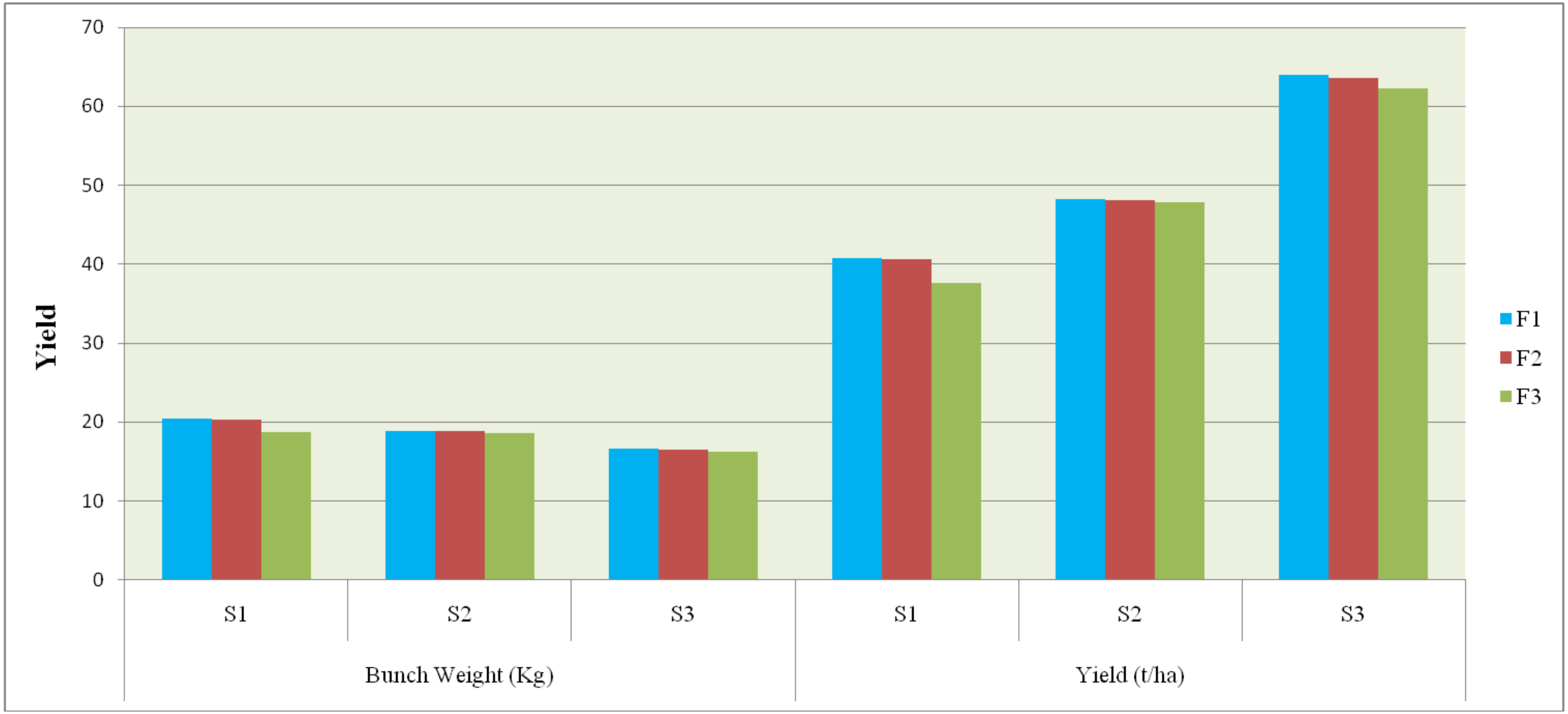

Figure 28: Interaction effect of plant density and fertigation on yield.

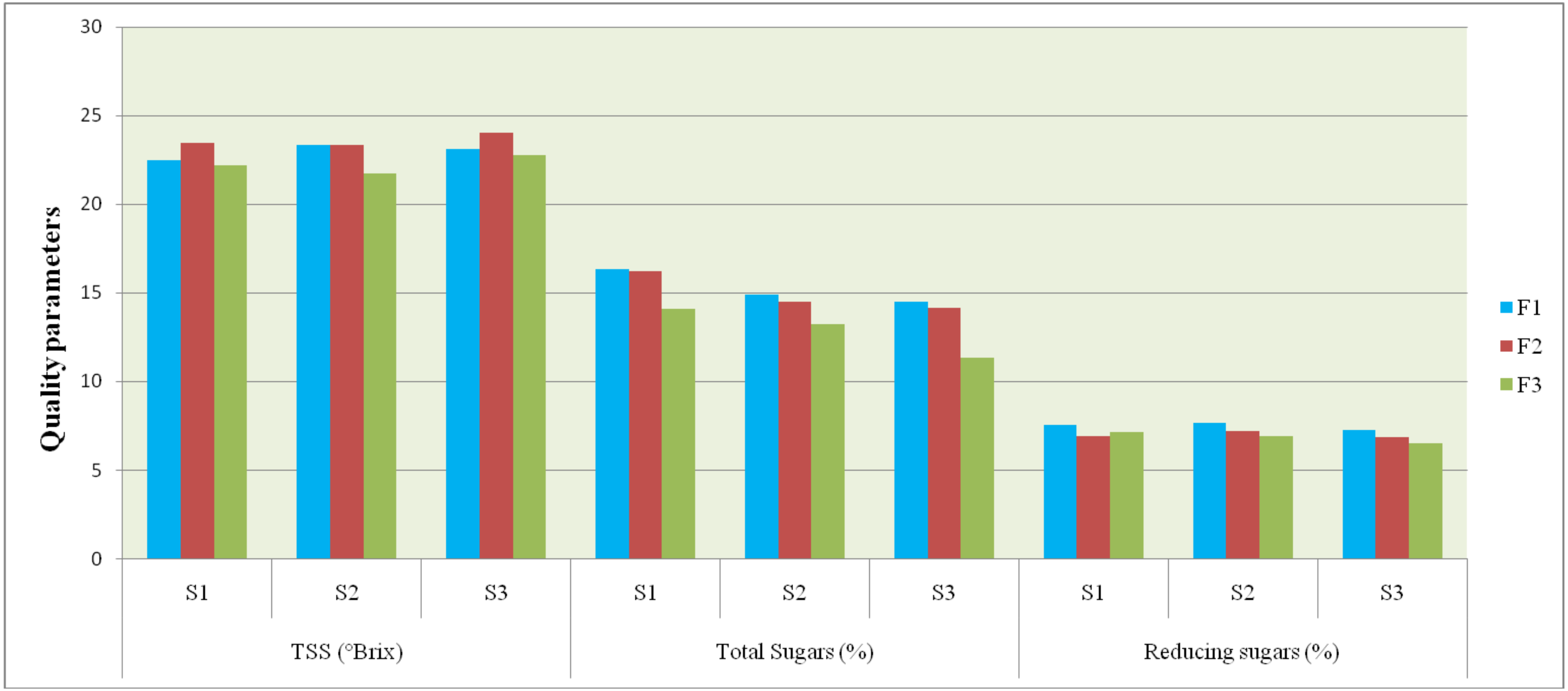

Figure 29: Interaction effect of plant density and fertigation on quality parameters.

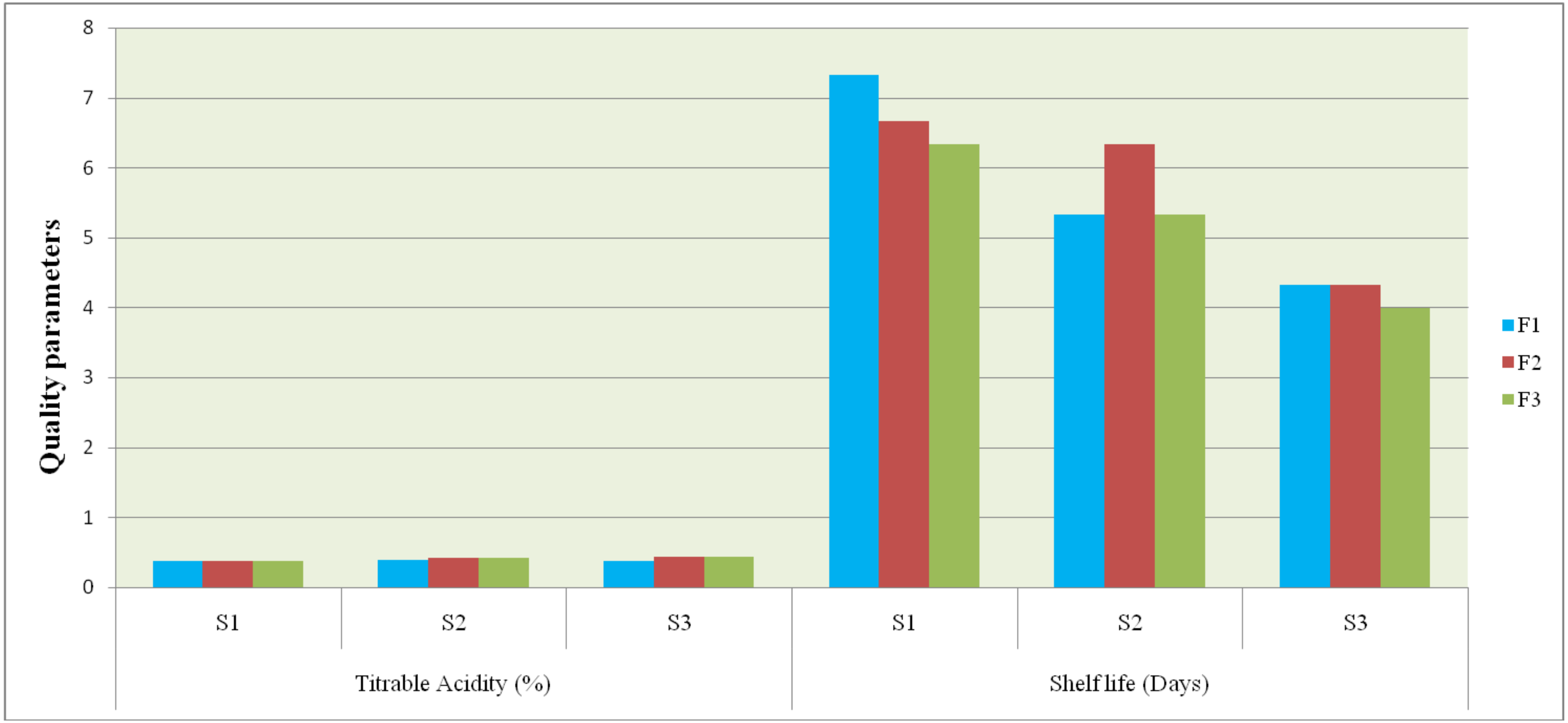

Figure 30: Interaction effect of plant density and fertigation on Quality parameters.

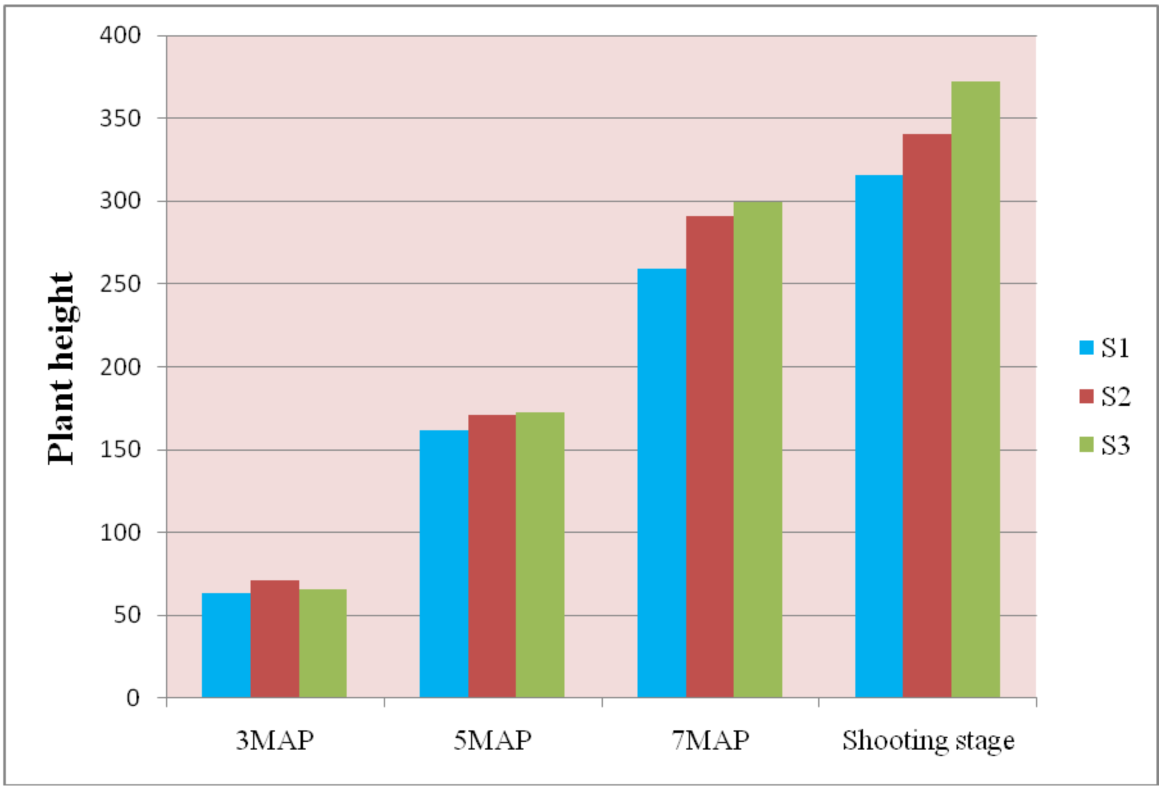

Figure 2: Effect of plant density on plant height (cm).

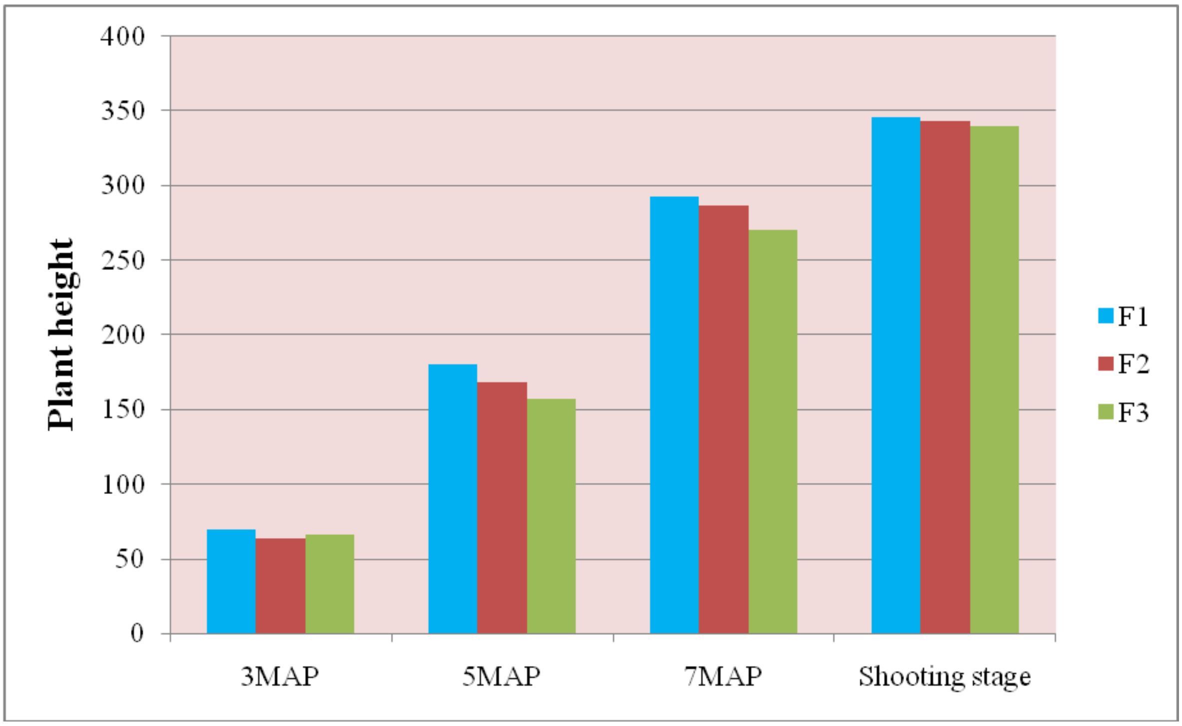

Figure 3: Effect of fertigation on plant height (cm).

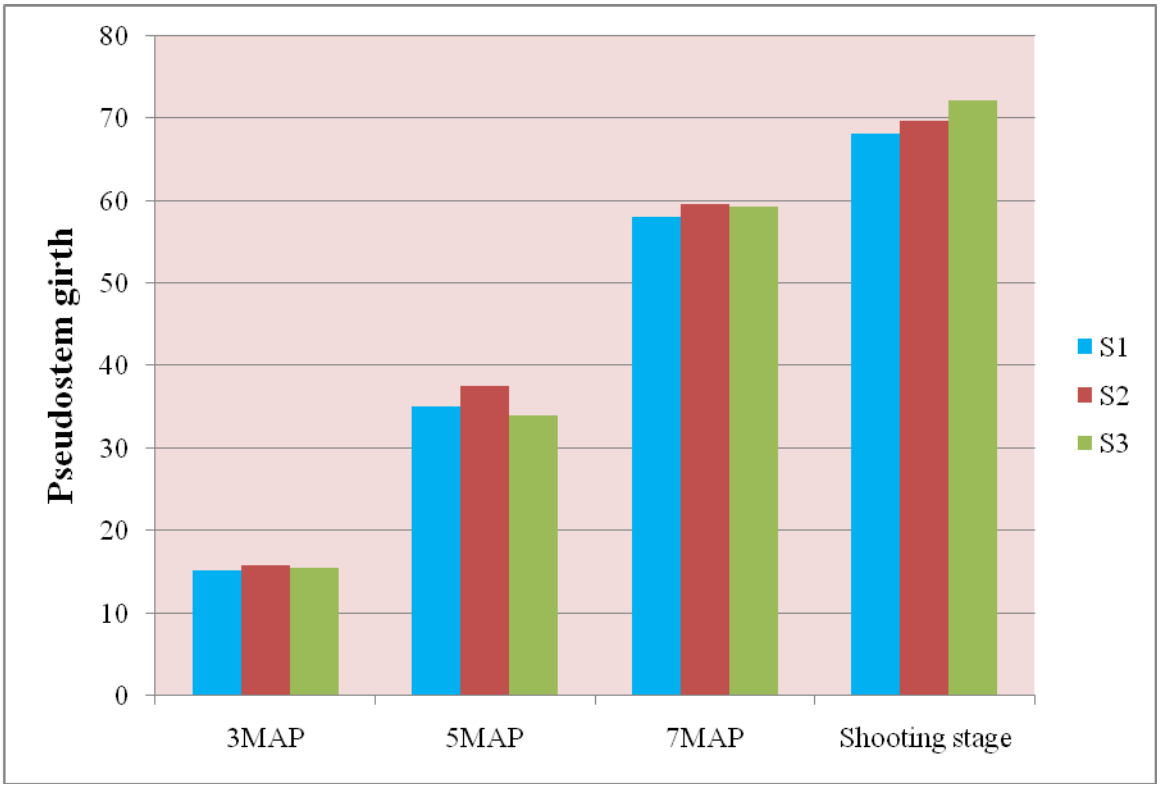

Figure 4: Effect of plant density on pseudostem girth (cm).

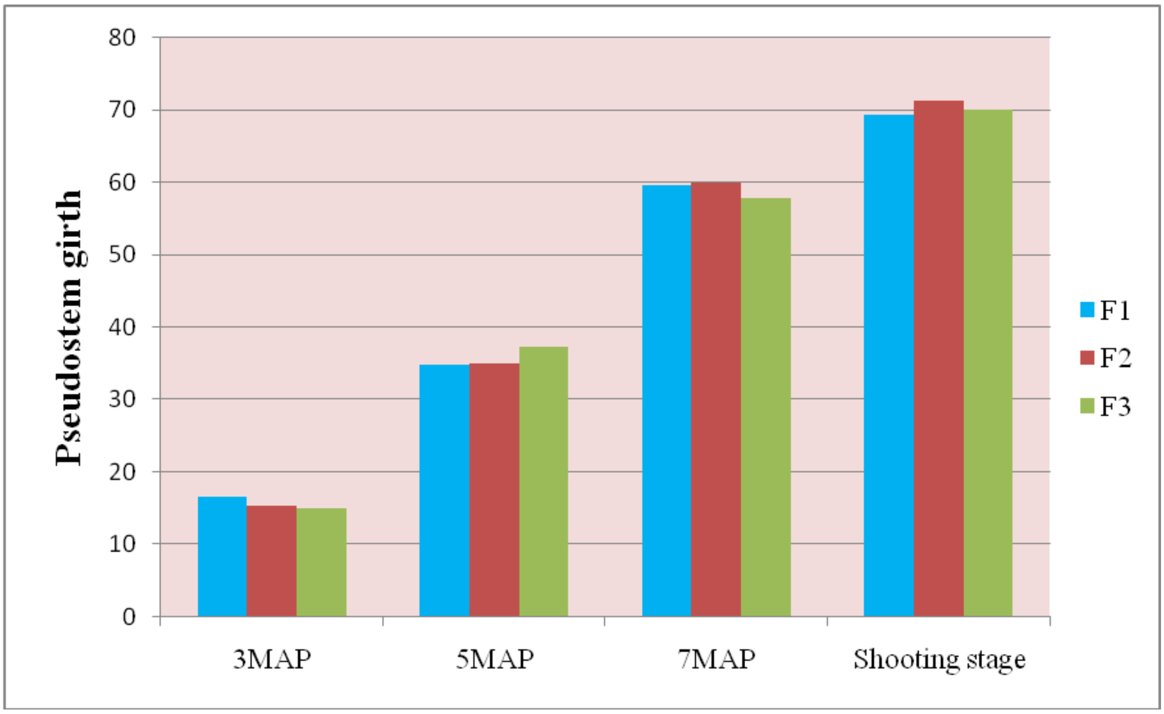

Figure 5: Effect of fertigation on pseudostem girth (cm).

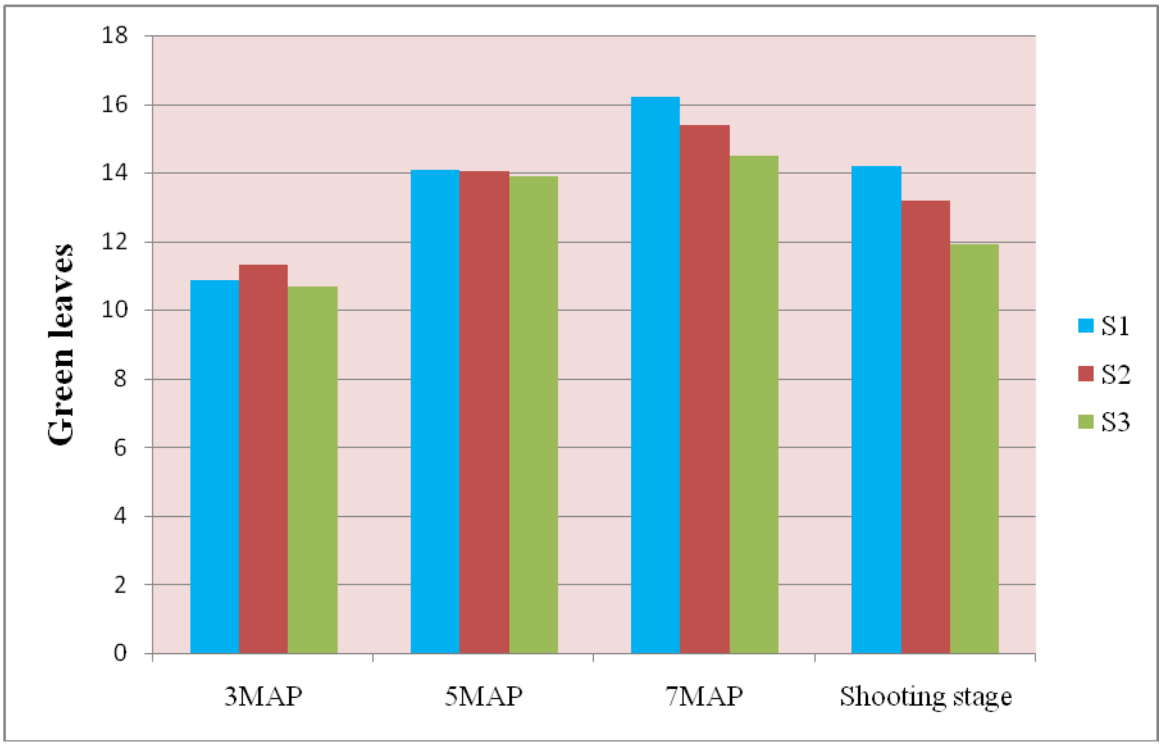

Figure 6: Effect of plant density on number of green leaves plant^{-1}.

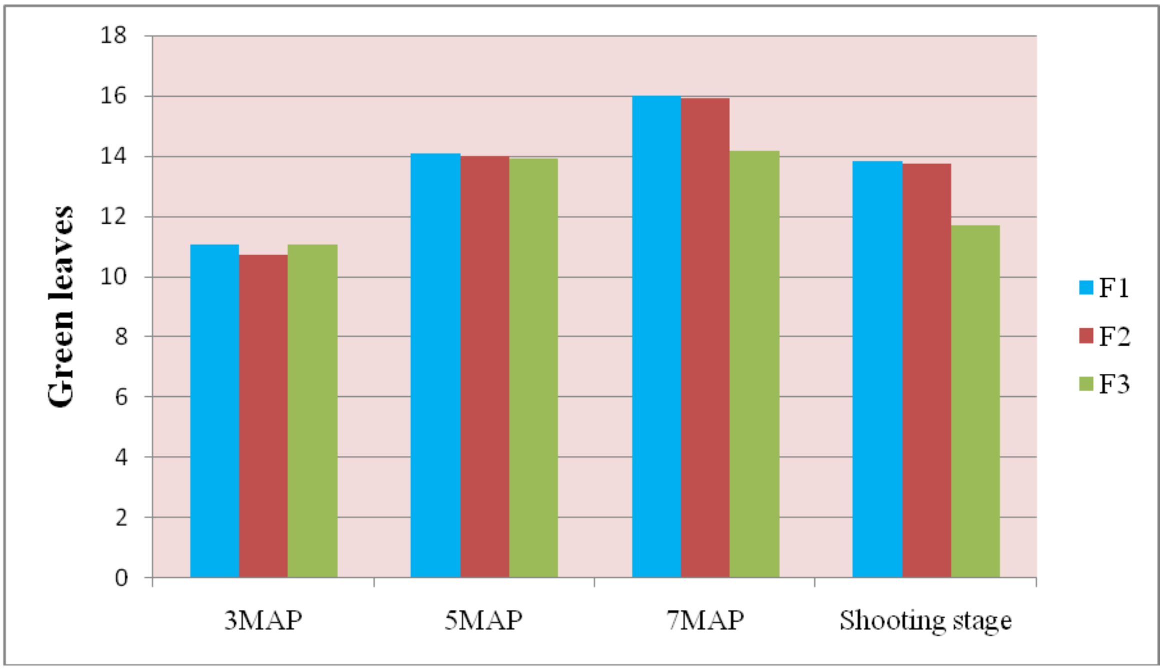

Figure 7: Effect of fertigation on number of green leaves plant^{-1}.

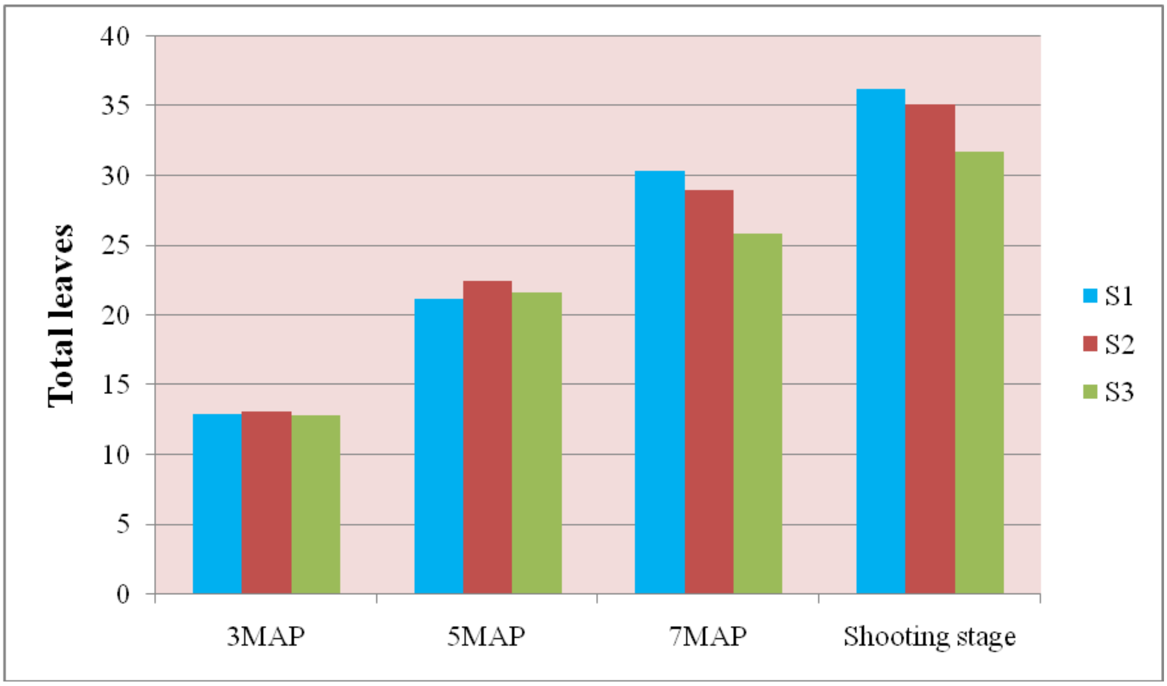

Figure 8: Effect of plant density on number of total leaves plant^{-1}.

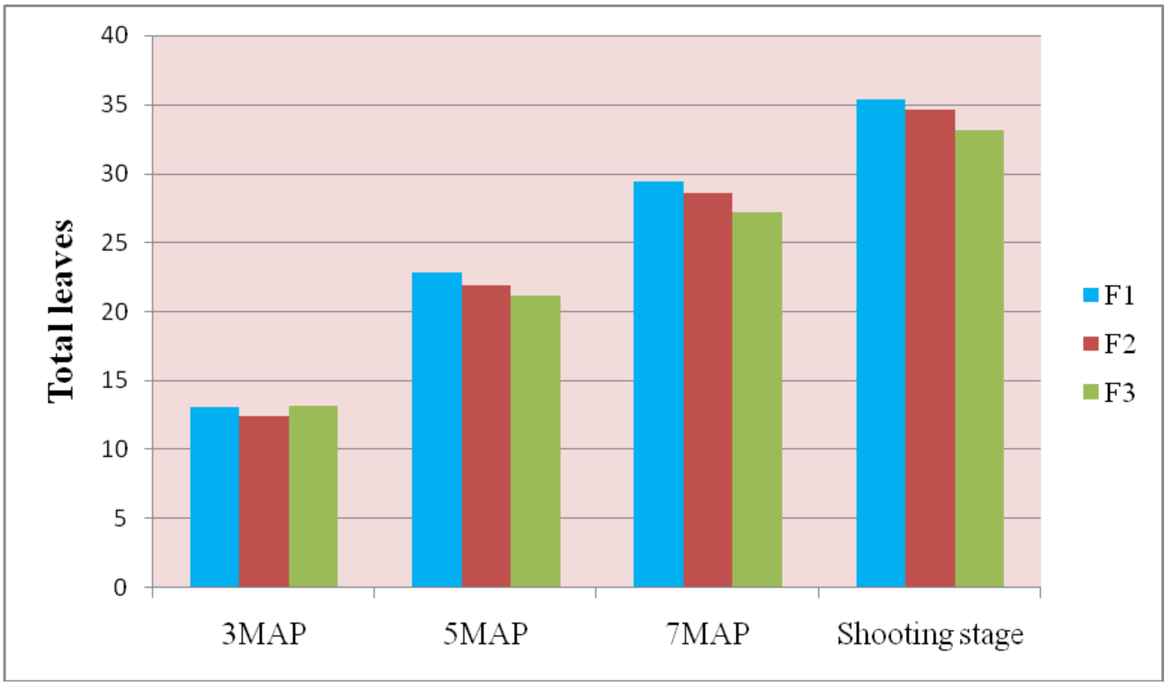

Figure 9: Effect of fertigation on number of total leaves plant^{-1}.

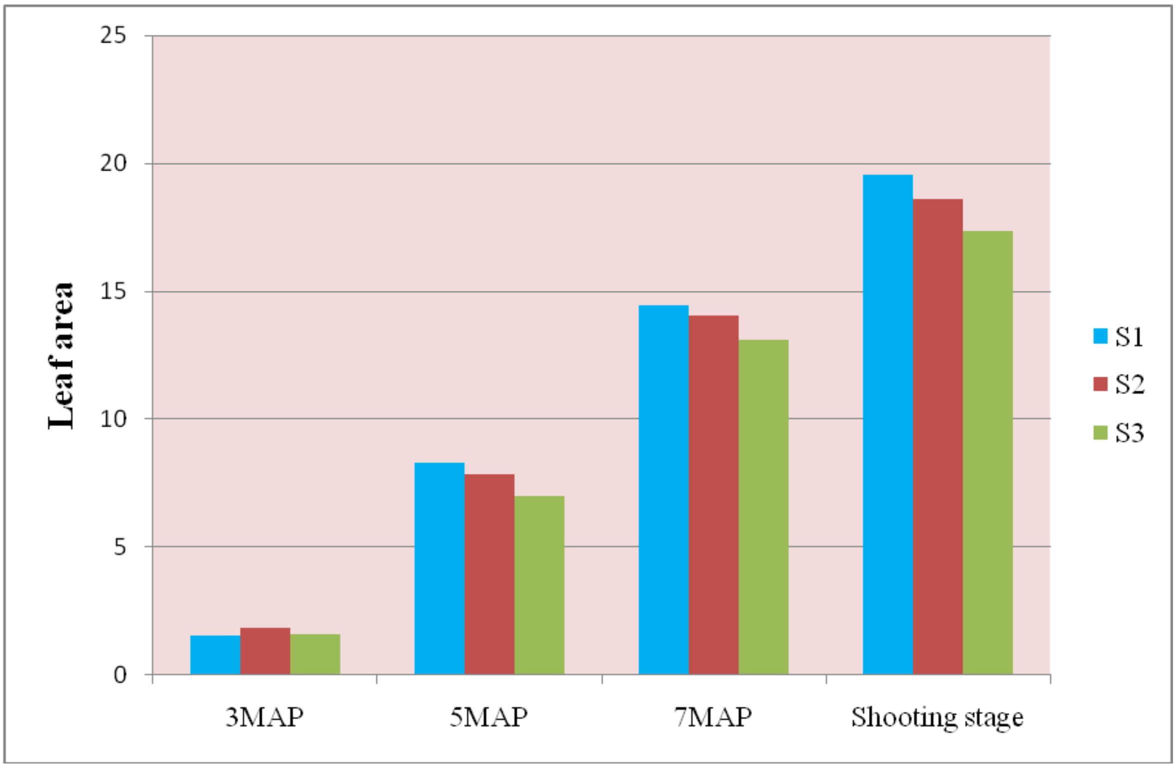

Figure 10: Effect of plant density on leaf area (sq.m plant^{-1}).

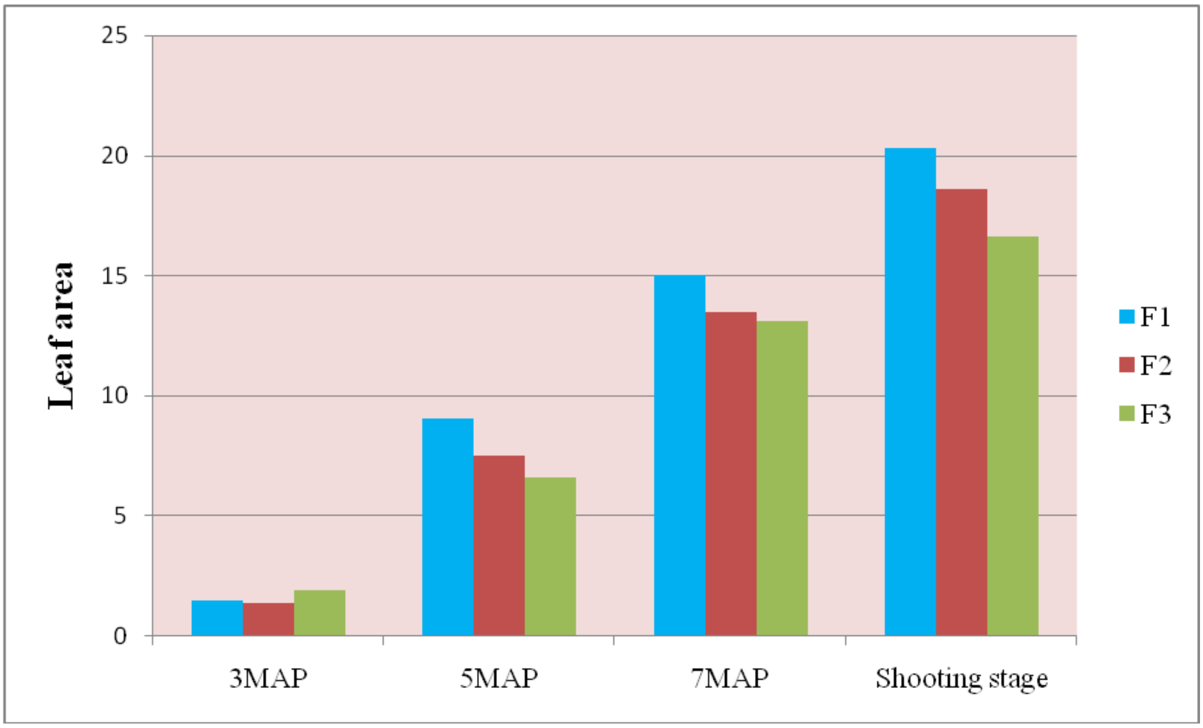

Figure 11: Effect of fertigation on leaf area (sq.m plant^{-1}).

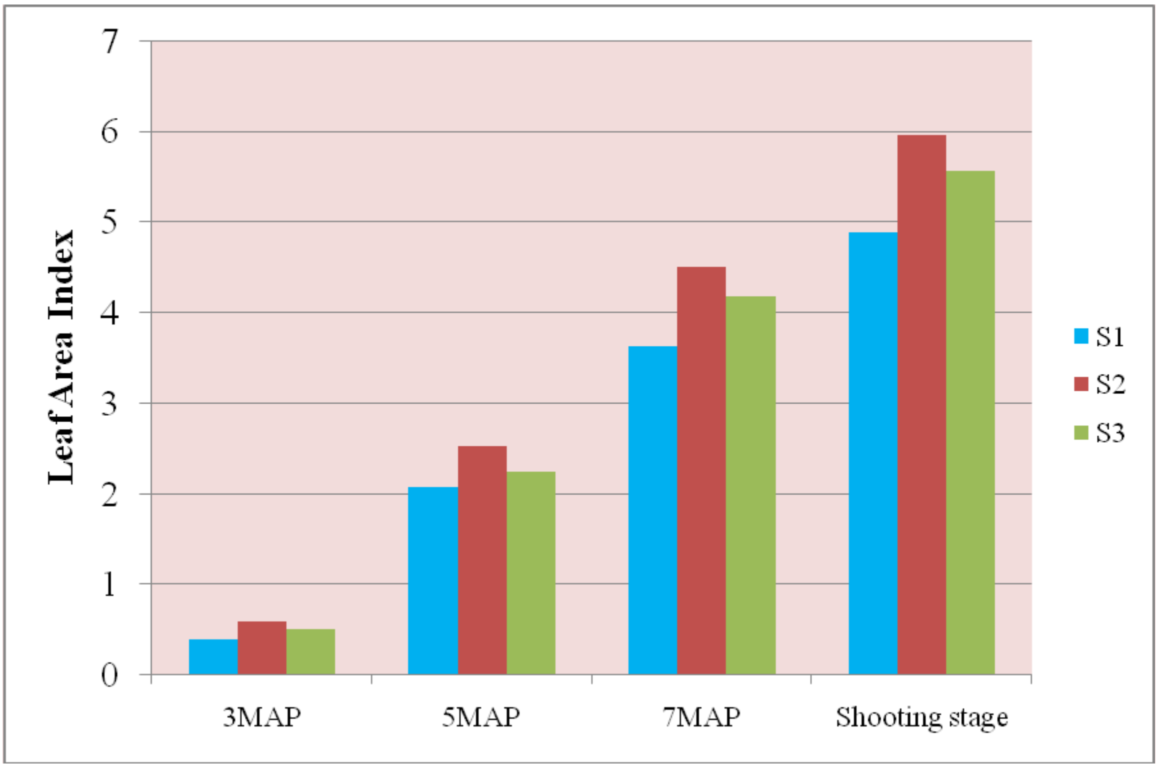

Figure 12: Effect of plant density on Leaf Area Index (LAI).

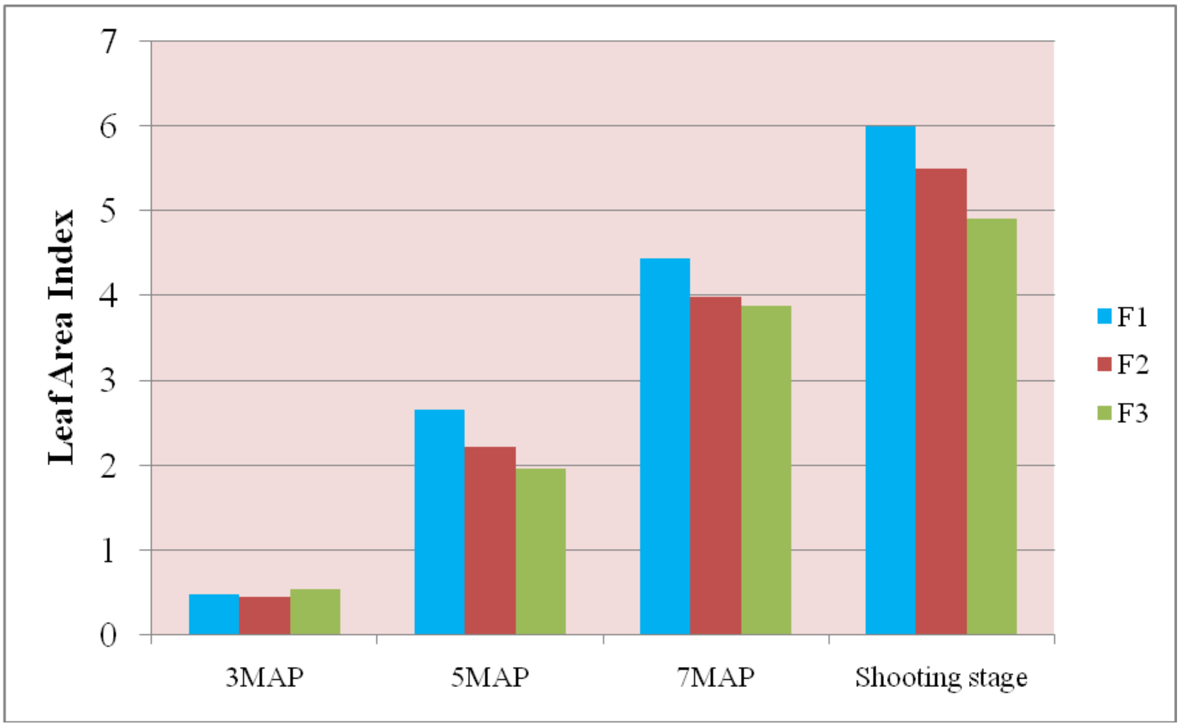

Figure 13: Effect of fertigation on Leaf Area Index (LAI).

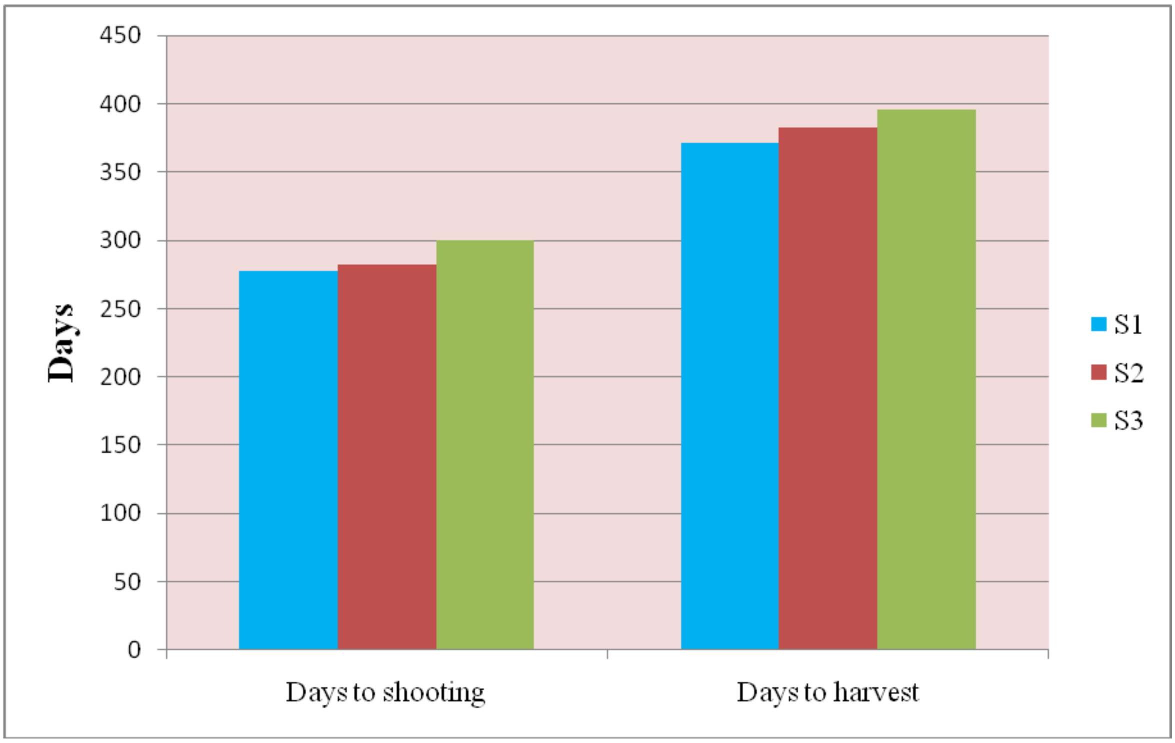

Figure 14: Effect of plant density on days taken to shooting and harvest.

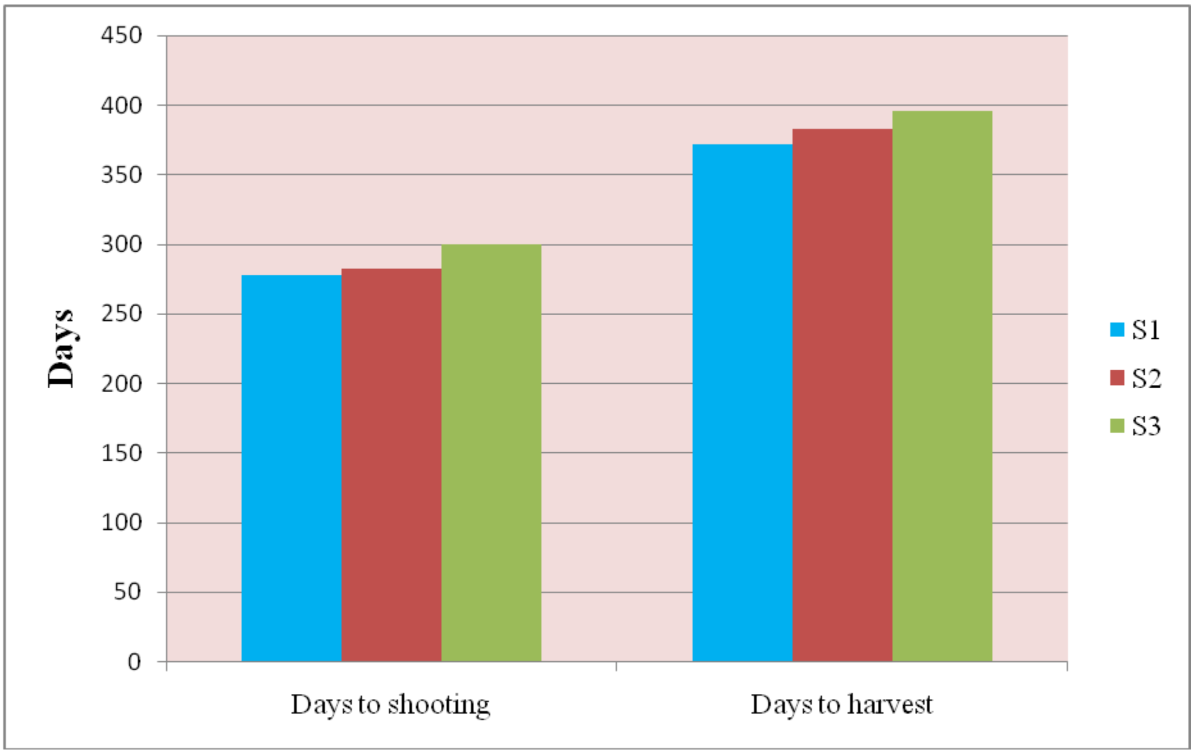

Figure 15: Effect of fertigation on days taken to shooting and harvest.

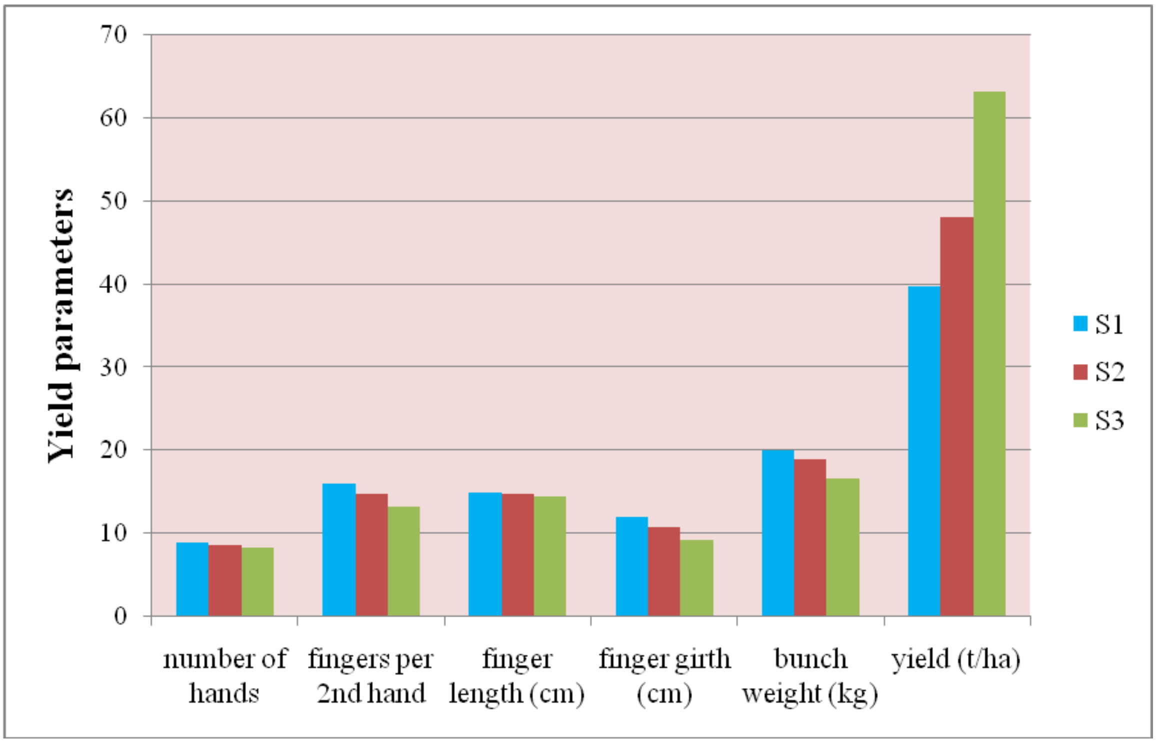

Figure 16: Effect of plant density on yield and yield parameters.

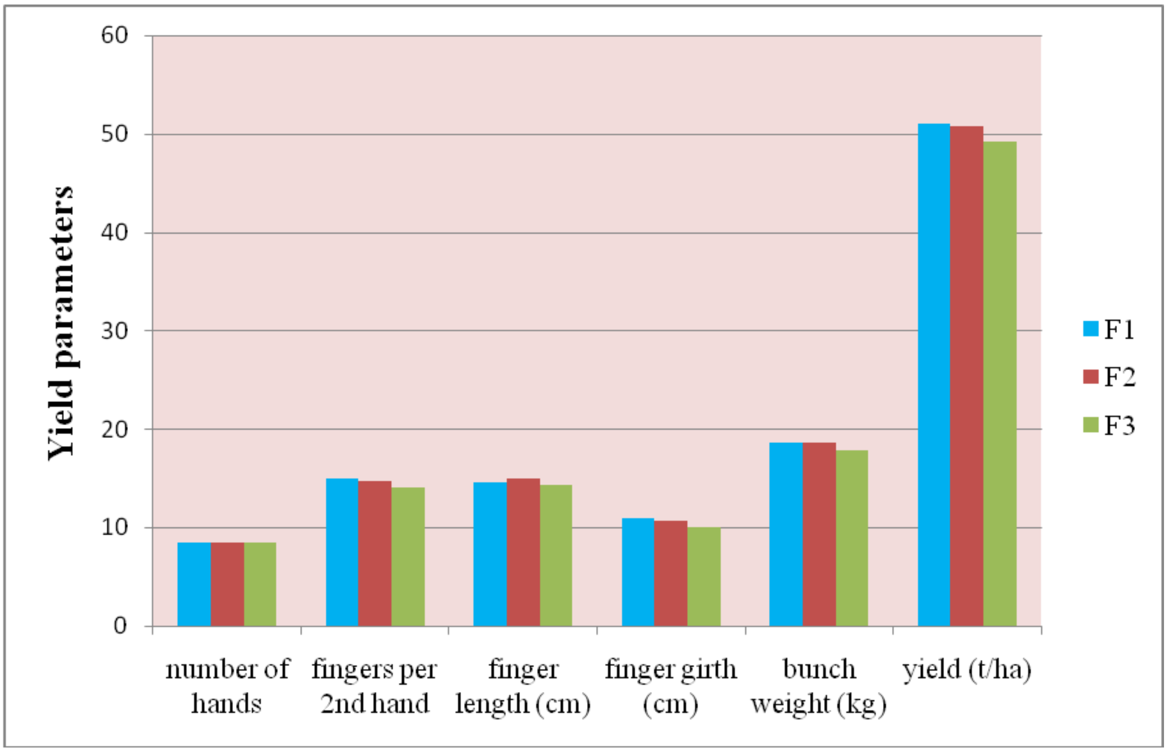

Figure 17: Effect of fertigation on yield and yield parameters.

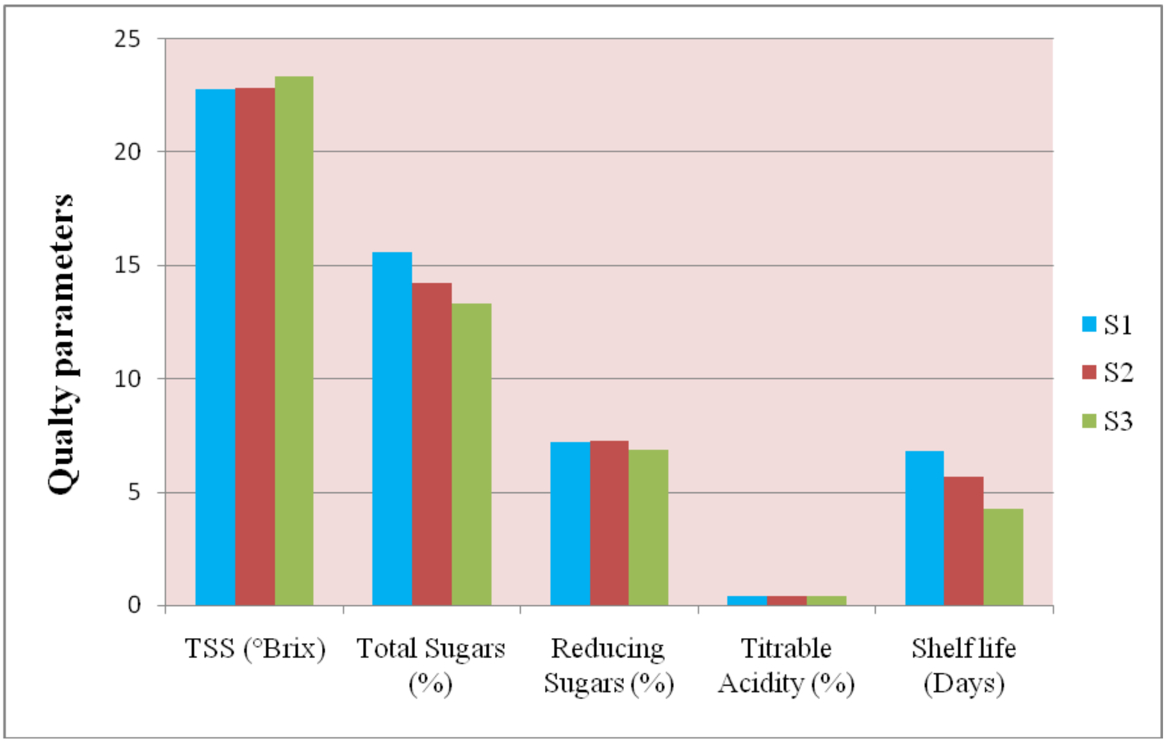

Figure 18: Effect of plant density on Quality parameters.

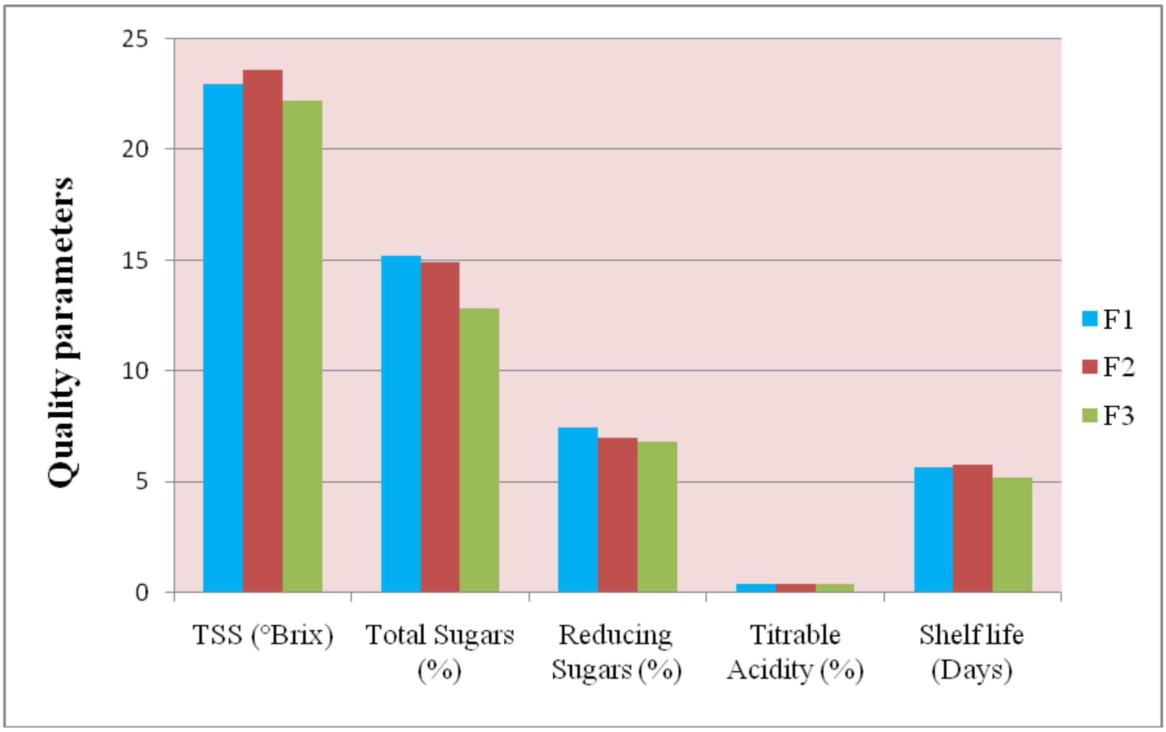

Figure 19: Effect of fertigation on Quality parameters.

Table 1. Effect of plant density and fertigation on plant height (cm) at different stages of growth of banana cv. Martaman

Treatments	**3 MAP**				**5 MAP**				**7 MAP**				**Shooting stage**			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	59.05	76.35	73.00	69.47	161.45	185.53	194.00	180.33	255.42	299.08	323.33	292.61	312.83	347.33	376.35	345.50
F_2	62.50	67.63	61.07	63.73	165.12	169.30	170.20	168.21	266.75	297.00	296.33	286.69	318.83	330.93	379.58	343.12
F_3	67.68	68.60	62.73	66.34	157.67	157.87	154.47	156.66	255.25	275.67	279.67	270.19	314.50	343.67	361.00	339.72
Mean	63.08	70.86	65.60		161.41	170.90	172.89		259.14	290.58	299.67		315.39	340.64	372.31	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	2.1094		N.S		3.1534		9.4552		4.8042		14.4046		7.8596		23.5658	
F	2.1094		N.S		3.1534		9.4552		4.8042		14.4046		7.8596		N.S	
S X F	3.6536		N.S		5.4619		16.377		8.3211		N.S		13.6131		N.S	

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 2. Effect of plant density and fertigation on pseudostem girth (cm) at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	16.85	16.47	16.05	16.46	35.53	37.67	30.80	34.67	58.87	57.13	62.53	59.51	68.42	68.27	71.17	69.28
F_2	14.97	15.42	15.25	15.21	35.60	35.75	33.27	34.87	59.17	61.22	59.07	59.82	68.60	72.07	72.67	71.12
F_3	13.93	15.5	15.13	14.85	34.20	39.13	38.05	37.13	56.30	60.42	56.27	57.66	67.58	69.12	72.95	69.88
Mean	15.25	15.79	15.48		35.11	37.52	34.04		58.11	59.59	59.29		68.20	69.82	72.26	

	3 MAP SE m ±	3 MAP CD (P=0.05)	5 MAP SE m ±	5 MAP CD (P=0.05)	7 MAP SE m ±	7 MAP CD (P=0.05)	Shooting stage SE m ±	Shooting stage CD (P=0.05)
S	0.3104	N.S	0.8874	2.6608	0.7421	N.S	0.9053	2.7144
F	0.3104	0.9307	0.8874	N.S	0.7421	N.S	0.9053	N.S
S X F	0.5376	N.S	1.5371	N.S	1.2854	3.854	1.568	N.S

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 3. Effect of plant density and fertigation on number of suckers plant^{-1} at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	2.17	2.06	2.23	2.16	3.67	4.53	3.20	3.80	6.12	4.80	5.53	5.48	10.58	9.60	8.92	9.70
F_2	1.67	1.72	1.70	1.69	3.77	3.52	3.00	3.43	5.58	6.75	5.00	5.78	9.13	9.52	8.17	8.94
F_3	1.50	1.95	1.50	1.65	3.03	3.95	3.22	3.40	6.17	6.38	4.87	5.80	8.80	9.67	8.23	8.90
Mean	1.78	1.91	1.81		3.49	4.0	3.14		5.96	5.97	5.13		9.51	9.59	8.44	

	3 MAP SE m ±	3 MAP CD (P=0.05)	5 MAP SE m ±	5 MAP CD (P=0.05)	7 MAP SE m ±	7 MAP CD (P=0.05)	Shooting stage SE m ±	Shooting stage CD (P=0.05)
S	0.1579	N.S	0.1987	0.5959	0.3548	N.S	0.4443	N.S
F	0.1579	N.S	0.1987	N.S	0.3548	N.S	0.4443	N.S
S X F	0.2735	N.S	0.3442	N.S	0.6146	N.S	0.7695	N.S

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 4. Effect of plant density and fertigation on number of green leaves plant^{-1} at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	11.47	11.13	10.60	11.07	14.22	14.07	13.93	14.07	17.10	15.90	15.00	16.00	15.28	13.87	12.33	13.83
F_2	10.55	10.42	10.20	10.72	14.00	14.05	13.90	13.98	16.97	15.87	14.93	15.92	15.20	13.77	12.24	13.73
F_3	10.57	11.42	11.20	11.06	14.02	13.97	13.82	13.93	14.58	14.35	13.53	14.16	12.10	11.93	11.13	11.72
Mean	10.86	11.32	10.67		14.08	14.03	13.88		16.22	15.37	14.49		14.19	13.19	11.90	

	3 MAP SE m ±	3 MAP CD (P=0.05)	5 MAP SE m ±	5 MAP CD (P=0.05)	7 MAP SE m ±	7 MAP CD (P=0.05)	Shooting stage SE m ±	Shooting stage CD (P=0.05)
S	0.228	N.S	0.3854	N.S	0.0292	0.0875	0.0344	0.1032
F	0.228	N.S	0.3854	N.S	0.0292	0.0875	0.0344	0.1032
S X F	0.3949	N.S	0.6675	N.S	0.0505	0.152	0.0596	0.1790

S_1 – 2 × 2 m spacing (2500 plants/ a)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 5. Effect of plant density and fertigation on number of dry leaves plant^{-1} at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	1.90	1.93	2.13	1.99	3.76	3.67	3.40	3.61	7.30	8.47	8.47	8.07	10.63	13.53	14.07	12.74
F_2	2.13	2.06	2.00	2.07	3.33	2.97	3.27	3.19	8.45	8.07	8.72	8.41	12.78	13.20	13.38	13.12
F_3	2.10	2.23	2.13	2.16	3.48	4.10	4.32	3.97	9.17	9.87	10.83	9.96	13.40	13.20	16.00	14.20
Mean	2.05	2.08	2.09		3.53	3.58	3.66		8.31	8.80	9.34		12.27	13.31	14.48	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	0.1301		N.S		0.1803		N.S		0.152		0.4558		0.2907		0.8715	
F	0.1301		N.S		0.1803		0.5407		0.152		0.4558		0.2907		0.8715	
S X F	0.2254		N.S		0.3123		N.S		0.2633		0.789		0.5035		1.51	

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 6. Effect of plant density and fertigation on number of total leaves plant^{-1} at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	13.33	13.07	12.73	13.04	22.93	23.27	22.20	22.80	32.17	30.00	26.07	29.41	38.10	36.00	32.07	35.39
F_2	12.68	12.53	12.20	12.47	22.13	21.98	21.33	21.86	30.03	28.92	26.83	28.59	36.03	34.92	32.83	34.59
F_3	12.65	13.65	13.33	13.21	20.18	22.20	21.20	21.19	28.77	27.97	24.72	27.15	34.57	34.57	30.38	33.16
Mean	12.88	13.08	12.76		21.19	22.48	21.58		30.32	28.96	25.87		36.23	35.15	31.76	

	3 MAP		5 MAP		7 MAP		Shooting stage	
	SE m ±	**CD (P=0.05)**	**SE m ±**	**CD (P=0.05)**	**SE m ±**	**CD (P=0.05)**	**SE m ±**	**CD (P=0.05)**
S	0.2147	N.S	0.3948	N.S	0.069	0.2068	0.0777	0.2330
F	0.2147	N.S	0.3948	1.1838	0.069	0.2068	0.0777	0.2330
S X F	0.3718	N.S	0.6838	N.S	0.1194	0.358	0.1346	0.403

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 7. Effect of plant density and fertigation on leaf area (sq.m plant^{-1}) at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	1.75	1.78	1.48	1.48	10.38	8.98	7.78	9.05	15.88	15.13	14.08	15.03	21.36	20.9	18.61	20.29
F_2	1.51	1.65	1.39	1.39	7.60	7.88	7.05	7.51	13.85	14.08	12.52	13.48	19.54	18.54	17.74	18.61
F_3	1.45	2.17	1.91	1.91	6.94	6.75	6.2	6.63	13.68	12.96	12.64	13.09	17.80	16.34	15.77	16.64
Mean	1.57	1.87	1.59		8.31	7.87	7.01		14.47	14.06	13.08		19.57	18.59	17.37	

	3 MAP SE m ±	3 MAP CD (P=0.05)	5 MAP SE m ±	5 MAP CD (P=0.05)	7 MAP SE m ±	7 MAP CD (P=0.05)	Shooting stage SE m ±	Shooting stage CD (P=0.05)
S	0.0925	N.S	0.552	N.S	0.0115	0.0346	0.0063	0.0189
F	0.0925	N.S	0.552	1.6551	0.0115	0.0346	0.0063	0.0189
S X F	0.1601	N.S	0.9561	N.S	0.020	0.060	0.0109	0.033

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 8. Effect of plant density and fertigation on Leaf Area Index (LAI) at different stages of growth of banana cv. Martaman

Treatments	3 MAP				5 MAP				7 MAP				Shooting stage			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	0.44	0.57	0.48	0.49	2.59	2.87	2.49	2.65	3.97	4.84	4.50	4.44	5.34	6.69	5.95	5.99
F_2	0.37	0.53	0.45	0.45	1.90	2.52	2.26	2.22	3.46	4.50	4.01	3.99	4.88	5.93	5.67	5.49
F_3	0.36	0.70	0.61	0.55	1.73	2.16	1.98	1.96	3.42	4.15	4.04	3.87	4.45	5.22	5.05	4.91
Mean	0.39	0.59	0.51		2.07	2.52	2.24		3.62	4.50	4.18		4.89	5.95	5.56	

	3 MAP SE m ±	3 MAP CD (P=0.05)	5 MAP SE m ±	5 MAP CD (P=0.05)	7 MAP SE m ±	7 MAP CD (P=0.05)	Shooting stage SE m ±	Shooting stage CD (P=0.05)
S	0.0279	0.0836	0.1605	N.S	0.0033	0.010	0.0024	0.0072
F	0.0279	N.S	0.1605	0.4812	0.0033	0.010	0.0024	0.0072
S X F	0.0483	N.S	0.278	N.S	0.0058	0.017	0.0042	0.013

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 12. Effect of plant density and fertigation on yield parameters of banana cv. Martaman

Treatments	Number of hands				Fingers per 2nd hand				Finger length (cm)				Finger girth (cm)			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	9.12	8.12	8.27	8.50	16.47	15.13	13.27	14.96	14.82	14.62	14.37	14.60	12.50	11.17	9.30	10.99
F_2	9.00	8.36	8.10	8.49	16.37	14.72	13.07	14.72	15.27	15.07	14.47	14.93	12.40	10.55	9.17	10.71
F_3	8.47	8.90	7.98	8.45	14.83	14.37	12.86	14.02	14.43	14.32	14.20	14.32	10.87	10.40	8.90	10.06
Mean	8.86	8.46	8.12		15.89	14.74	13.07		14.84	14.67	14.34		11.92	10.71	9.12	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	0.095		0.2847		0.1021		0.3062		0.3728		N.S		0.1022		0.3063	
F	0.095		N.S		0.1021		0.3062		0.3728		N.S		0.1022		0.3063	
S X F	0.1645		0.493		0.1769		0.530		0.6457		N.S		0.1769		0.531	

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 14. Effect of plant density and fertigation on quality parameters of banana cv. Martaman

Treatments	TSS (°Brix)				Total Sugars (%)				Reducing sugars (%)			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	22.47	23.33	23.10	22.97	16.32	14.87	14.47	15.22	7.53	7.63	7.24	7.47
F_2	23.47	23.33	24.03	23.61	16.19	14.49	14.13	14.94	6.89	7.20	6.86	6.98
F_3	22.20	21.73	22.73	22.22	14.07	13.24	11.31	12.87	7.11	6.90	6.52	6.85
Mean	22.71	22.80	23.29		15.53	14.19	13.30		7.18	7.25	6.87	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	0.3149		N.S		0.0936		0.2805		0.1093		N.S	
F	0.3149		0.9442		0.0936		0.2805		0.1093		0.330	
S X F	0.5454		N.S		0.1621		0.4860		0.1894		N.S	

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 16. Effect of plant density and fertigation on Leaf nutrient status (NPK) at shooting stage

Treatments	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	2.72	2.71	2.70	2.71	0.32	0.31	0.31	0.31	3.09	3.04	3.04	3.06
F_2	2.72	2.69	2.69	2.70	0.32	0.30	0.29	0.30	3.06	3.04	2.99	3.03
F_3	2.58	2.54	2.55	2.56	0.26	0.23	0.22	0.24	2.96	2.87	2.88	2.90
Mean	2.67	2.65	2.64		0.29	0.28	0.27		3.03	2.99	2.97	

	Nitrogen SE m ±	Nitrogen CD (P=0.05)	Phosphorus SE m ±	Phosphorus CD (P=0.05)	Potassium SE m ±	Potassium CD (P=0.05)
S	0.0372	N.S	0.0837	N.S	0.0569	N.S
F	0.0372	0.1115	0.0837	N.S	0.0569	N.S
S X F	0.0644	N.S	0.1450	N.S	0.0986	N.S

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 17. Effect of plant density and fertigation on Soil nutrient status (NPK)

Treatments	**Nitrogen (t/ha)**				**Phosphorus (t/ha)**				**Potassium (t/ha)**			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	188.53	187.03	186.03	187.2	20.87	20.57	20.27	20.57	546.33	542.60	540.83	543.26
F_2	186.57	185.17	185.23	185.65	20.26	19.93	10.56	19.92	544.77	540.23	539.50	541.50
F_3	185.6	185.13	184.67	185.13	19.37	19.27	19.17	19.27	542.40	539.43	538.87	540.23
Mean	186.9	185.78	185.31		20.17	19.92	19.67		544.50	540.75	539.73	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	6.4761		N.S		0.6556		N.S		5.6217		N.S	
F	6.4761		N.S		0.6556		N.S		5.6217		N.S	
S X F	11.2169		N.S		1.1356		N.S		9.7371		N.S	

S_1 – 2 × 2 m spacing (2500 plants/ha)

S_2 – 2.5 × 1.25 m spacing (3200 plants/ha)

S_3 – 2.5 × 1.25 × 1.25 m spacing (4800 plants/ha)

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 18. Cost of cultivation for Martaman banana per hactare

S.No	Cultural operations	S_1F_1	S_2F_1	S_3F_1	S_1F_2	S_2F_2	S_3F_2	S_1F_3	S_2F_3	S_3F_3
1	Land preparation	5500	5500	5500	5500	5500	5500	5500	5500	5500
2	Farm Yard Manure	9000	9000	9000	9000	9000	9000	9000	9000	9000
3	Mixing of Organic Manures, SSP and planting	3000	3000	3000	3000	3000	3000	3000	3000	3000
4	Cost of Planting material and digging of pits									
	1) Suckers	12500	16000	24000	12500	16000	24000	12500	16000	24000
5	Application of pre emergence weedicide									
	1) Weedicide cost	1000	1000	1000	1000	1000	1000	1000	1000	1000
	2) Labour cost	500	500	500	500	500	500	500	500	500
6	Fertilizer cost	25375	32480	48720	20175	25824	38736	14975	19168	28752
7	Desuckering	3000	3000	3000	3000	3000	3000	3000	3000	3000
8	Weed Management									
	1) Weedicide	1750	1750	1750	1750	1750	1750	1750	1750	1750
	2) Manual weeding 3 times	17000	17000	17000	17000	17000	17000	17000	17000	17000
9	Earthing up	2500	2500	2500	2500	2500	2500	2500	2500	2500
10	Staking including marerial cost	37500	48000	72000	37500	48000	72000	37500	48000	72000
11	Plant protection									
	a) Control of Sigatoka leaf spot ½ sprays	1750	1750	1750	1750	1750	1750	1750	1750	1750
12	Maintenance of Drip system	10000	10000	10000	10000	10000	10000	10000	10000	10000
	Cost of cultivation/ha	**130375**	**151480**	**199720**	**125175**	**144824**	**189736**	**119975**	**138168**	**179752**

Table 19. Benefit cost ratio for treatment combinations

Treatment combinations	Cost of cultivation	Yield (t/ha)	Gross Returns	Benefit	B:C ratio
S_1F_1	130375	40.80	204000	73625	0.56
S_2F_1	151480	48.30	241500	90020	0.59
S_3F_1	199720	64.00	320000	120280	0.60
S_1F_2	125175	40.67	203350	78175	0.62
S_2F_2	144824	48.17	240850	96026	0.66
S_3F_2	189736	63.61	318050	128314	0.67
S_1F_3	119975	37.60	188000	68025	0.56
S_2F_3	138168	47.79	238950	100782	0.73
S_3F_3	179752	62.21	311050	131298	0.73

Table 9. Effect of plant density and fertigation on Absolute Growth Rate (cm day^{-1}) for plant height of banana cv. Martaman

Treatments	**3-5 MAP cm day^{-1}**				**5-7 MAP cm day^{-1}**			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	1.59	1.87	2.04	1.84	1.57	1.89	2.15	1.87
F_2	1.71	1.75	1.71	1.72	1.69	2.13	2.10	1.98
F_3	1.61	1.54	1.55	1.56	1.63	1.96	2.09	1.89
Mean	1.64	1.72	1.76		1.63	2.00	2.11	

	SE m ± (3-5 MAP)	**CD (P=0.05)** (3-5 MAP)	**SE m ±** (5-7 MAP)	**CD (P=0.05)** (5-7 MAP)
S	0.0453	N.S	0.092	0.2757
F	0.0453	0.1357	0.092	N.S
S X F	0.0784	0.235	0.1593	N.S

S_1 – 2 × 2 m spacing
F_1 – 100% Recommended dose of fertilizers (RDF)

S_2 – 2.5 × 1.25 m spacing
F_2 – 75% Recommended dose of fertilizers (RDF)

S_3 – 2.5 × 1.25 × 1.25 m spacing
F_3 – 50% Recommended dose of fertilizers (RDF)

Table 10. Effect of plant density and fertigation on Absolute Growth Rate (cm day^{-1}) for pseudostem girth of banana cv. Martaman

Treatments	**3-5 MAP cm day^{-1}**				**5-7 MAP cm day^{-1}**			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	0.32	0.36	0.26	0.32	0.39	0.33	0.53	0.42
F_2	0.35	0.34	0.30	0.33	0.39	0.42	0.43	0.41
F_3	0.32	0.35	0.38	0.35	0.37	0.35	0.30	0.34
Mean	0.33	0.35	0.32		0.38	0.37	0.42	

	SE m ±	**CD (P=0.05)**	**SE m ±**	**CD (P=0.05)**
S	0.012	N.S	0.010	0.0301
F	0.012	N.S	0.010	0.0301
S X F	0.0207	0.062	0.0174	0.052

S_1 – 2 × 2 m spacing　　F_1 – 100% Recommended dose of fertilizers (RDF)

S_2 – 2.5 × 1.25 m spacing　　F_2 – 75% Recommended dose of fertilizers (RDF)

S_3 – 2.5 × 1.25 × 1.25 m spacing　　F_3 – 50% Recommended dose of fertilizers (RDF)

Table 11. Effect of plant density and fertigation on days taken to shooting and harvest of banana cv. Martaman

Treatments	Days to shooting				Days to harvest			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	272.38	279.48	280.4	277.42	369.73	372.60	377.73	373.36
F_2	280.03	283.43	299.87	287.78	369.87	382.20	392.40	381.49
F_3	280.22	284.73	318.57	294.51	375.47	393.43	417.00	395.30
Mean	277.54	282.55	299.61		371.69	382.74	395.71	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	0.1183		0.3548		0.0487		0.146	
F	0.1183		0.3548		0.0487		0.146	
S X F	0.2049		0.614		0.0843		0.253	

S_1 – 2 × 2 m spacing

S_2 – 2.5 × 1.25 m spacing

S_3 – 2.5 × 1.25 × 1.25 m spacing

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 13. Effect of plant density and fertigation on yield of banana cv. Martaman

Treatments	Bunch Weight (Kg)				Yield (t/ha)			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	20.40	18.87	16.67	18.64	40.80	48.30	64.00	51.03
F_2	20.33	18.82	16.57	18.57	40.67	48.17	63.61	50.82
F_3	18.80	18.67	16.20	17.89	37.60	47.79	62.21	49.20
Mean	19.89	18.78	16.48		39.69	48.09	63.27	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	0.0305		0.0914		0.0945		0.2835	
F	0.0305		0.0914		0.0945		0.2835	
S X F	0.0528		0.158		0.1638		0.491	

S_1 – 2 × 2 m spacing

S_2 – 2.5 × 1.25 m spacing

S_3 – 2.5 × 1.25 × 1.25 m spacing

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Table 15. Effect of plant density and fertigation on quality parameters of banana cv. Martaman

Treatments	Titrable Acidity (%)				Shelf life (Days)			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
F_1	0.37	0.39	0.38	0.38	7.33	5.33	4.33	5.67
F_2	0.37	0.42	0.43	0.41	6.67	6.33	4.33	5.78
F_3	0.38	0.42	0.44	0.41	6.33	5.33	4.00	5.22
Mean	0.37	0.41	0.42		6.78	5.67	4.22	
	SE m ±		**CD (P=0.05)**		**SE m ±**		**CD (P=0.05)**	
S	0.0037		0.0111		0.147		0.4407	
F	0.0037		0.0111		0.147		0.4407	
S X F	0.0064		0.019		0.2546		N.S	

S_1 – 2 × 2 m spacing

S_2 – 2.5 × 1.25 m spacing

S_3 – 2.5 × 1.25 × 1.25 m spacing

F_1 – 100% Recommended dose of fertilizers (RDF)

F_2 – 75% Recommended dose of fertilizers (RDF)

F_3 – 50% Recommended dose of fertilizers (RDF)

Chapter-V

Summary & Conclusion

CHAPTER V

SUMMARY AND CONCLUSIONS

In India, increasing yield by increasing the plant density and also by adopting fertigation has been attempted with varying successes in banana in different cultivars. A field experiment was conducted to study the **"Effect of plant density and fertigation on productivity and quality of banana cv. Martaman"** during 2011-12 at Horticulture Research Station, Kovvur (West Godavari District), Andhra Pradesh.

Among different plant densities, the significantly highest plant height was recorded in S_3 (2.5 × 1.25 × 1.25 m) during all stages of plant growth except at 3^{rd} MAP and it was on par with S_2 (2.5 × 1.25 m) at 5^{th} MAP and 7^{th} MAP. While the lowest plant height was recorded in the S_1 (2 × 2 m). The pseudostem girth was highest in the treatment S_3 (2.5 × 1.25 × 1.25 m) at shooting and it was on par with S_2 (2.5 × 1.25 m) while the lowest plant pseudostem girth was recorded in the treatment S_1 (2 × 2 m) during shooting. The absolute growth rate for plant height was significantly higher in S_3 (2.5 × 1.25 × 1.25 m) and it was on par with S_2 (2.5 × 1.25 m) at 5-7 MAP stage. The leaf characters like number of green leaves, total leaves and leaf area was highest in the treatment S_1 (2 × 2 m) throughout the growth period especially at 7^{th} MAP and shooting whereas the least number of leaves and leaf area were recorded in the treatment S_3 (2.5 × 1.25 × 1.25 m) during all stages of crop growth. However, Leaf Area Index was highest in the S_2 (2.5 × 1.25 m) during all stages of plant growth while S_1 (2 × 2 m) recorded lowest LAI.

Among fertigation levels, the F_1 (100% RDF) registered significantly higher plant height at 5^{th} MAP and at 7^{th} MAP. However, the above treatment F_1 (100% RDF) was on par with F_2 (75% RDF) at 7^{th} MAP. Plant height was lowest in F_3 (50% RDF). F_1 (100% RDF) also registered the highest pseudostem girth at 3^{rd} MAP and it was lowest in F_3 (50% RDF). At 7^{th} MAP and shooting stage, significantly higher number of green leaves was produced with application of 100% RDF (F_1) and it was on par with 75% RDF (F_2). F_1 (100% RDF) also registered the highest number of total leaves, leaf area and leaf area index at all stages of growth except at 3rd MAP and above treatment was on par with F_2 (75% RDF) at 5th MAP stage.

Among different plant densities, earliest shooting from planting and earlier harvest were recorded in the treatment S_1 (2 × 2 m) while the highest number of days to flowering and harvest was recorded in the treatment S_3 (2.5 × 1.25 × 1.25 m). Among fertigation levels, 100% RDF (F_1) recorded early shooting leading to early harvest of the crop while the highest number of days to flowering and harvest were recorded in the treatment F_3 (50% RDF).

Among different plant densities, the treatment S_1 (2 × 2 m) recorded highest bunch weight, maximum finger girth, highest number of hands per bunch and maximum number of fingers in 2nd hand. Whereas the least bunch weight, finger girth, number of hands per bunch and number of fingers in 2nd hand were observed in the treatment S_3 (2.5 × 1.25 × 1.25 m). However, significantly highest per hectare yield was recorded in S_3 (2.5 × 1.25 × 1.25 m) as compared to S_1 (2 × 2 m) and S_2 (2.5 × 1.25 m). Significantly lowest yield/ha was recorded in normal spacing S_1 (2 × 2 m).

Among fertigation levels, the treatment F_1 (100% RDF) recorded highest per hectare yield, bunch weight, maximum finger girth and highest number of fingers in 2nd hand and it was on par with F_2 (75% RDF) whereas the least per hectare yield, bunch weight, finger girth and number of fingers in 2nd hand were observed in the treatment F_3 (50% RDF).

Among different plant densities, the treatment S_1 (2 × 2 m) recorded the better quality parameters like lowest acidity, highest total sugars and shelf life while the highest acidity, lowest total sugars and less shelf life were recorded in the treatment S_3 (2.5 × 1.25 × 1.25 m).

Among fertigation levels, the treatment F_1 (100% RDF) recorded the better quality parameters like lowest acidity, highest total sugars and reducing sugars while highest TSS, shelf life was recorded by F_2 (75% RDF) and it was on par with F_1

(100% RDF). The highest acidity, less TSS, lowest total sugars, reducing sugars and less shelf life were recorded in the treatment F_3 (50% RDF).

Among fertigation levels, slightly higher N% in leaves was recorded in F_1 (100% RDF) and F_2 (75% RDF) at shooting stage as compared to F_3 (50% RDF). However, among plant densities no significant difference was observed in N content of the leaves. Neither plant densities nor fertigation levels did show any effect on P_2O_5 and K_2O content of leaves. Similarly, the soil nutrient status pertaining to N, P and K was not affected under different spacing's and fertilizer levels. The interaction effect between spacings and fertigation levels was also non significant.

Among different treatment combinations, S_3F_1 recorded the highest pseudostem height at 5th MAP and highest pseudostem girth at 7th MAP while lowest pseudostem height and girth were recorded by S_1F_3. The treatment combination S_1F_1 recorded the maximum number of green leaves, total leaves, leaf area and at 7th MAP and shooting while S_2F_1 recorded the maximum leaf area index at 7th MAP and shooting. S_1F_1 also recorded the earliest shooting, harvest, highest bunch weight, maximum number of hands per bunch, fingers in 2nd hand and maximum finger girth compared to other treatments and it was on par with S_1F_2. The per hectare yield was highest for treatment combination S_3F_1 and it was on par with S_3F_2 while lowest per hectare yield was recorded by $S_1F_{3.}$ The treatment combination S_1F_1 also recorded the highest total sugars and less titrable acidity. The lowest total sugars and highest titrable acidity were recorded by the $S_3F_{3.}$

Among different treatment combinations, highest BC ratio was obtained in the S_3F_3 (0.73) and S_2F_3 (0.73) where as lowest BC ratio was observed in S_1F_1 and S_1F_3. The BC ratio among different treatment combinations ranged from 0.56 (S_1F_1 and S_1F_3) to 0.73 (S_3F_3 and S_2F_3).

From the foregoing results of the experiment it can be concluded that among different plant densities S_3 density (2.5 × 1.25 × 1.25 m – 4800 plants/ha) registered the highest productivity (63.27 t/ha) by harnessing more sun light under closer spacing. Similarly, among fertigation levels, F_1 (100% RDF – 200 g N and 200 g K_2O

plant^{-1}) applied through drip recorded the highest per hectare yield (51.03 t/ha) followed by F_2 (75% RDF – 150 g N and 150 g K_2O plant^{-1}) (50.82 t/ha). Thus, the 75% RDF (F_2) applied through drip was found equally productive to that of 100% RDF (F_1) indicating 25% fertilizer saving. Therefore, application of 75% RDF (150 g N and 150 g K_2O plant^{-1}) through fertigation in 30 splits at weekly intervals is recommended for relatively higher yield without compromising on fruit quality.

Among various treatment combinations, highest productivity was obtained in S_3F_1 (2.5 × 1.25 × 1.25 m spacing and 100% RDF) (64.0 t/ha) followed by S_3F_2 (2.5 × 1.25 × 1.25 m spacing and 75% RDF) (63.61 t/ha). However, the highest BC ratio was obtained in S_3F_3 (2.5 × 1.25 × 1.25 m spacing and 50% RDF) and also in S_2F_3 (2.5 × 1.25 m spacing and 50% RDF).

Therefore, keeping the net returns (BC ratio) and higher productivity (62.21 t/ha) in view application of 50% RDF (F_3 -100 g N and 100 g K_2O plant^{-1}) through drip irrigation in 30 splits at weekly intervals is recommended by adopting high density planting (S_3 - 2.5 × 1.25 × 1.25 m spacing) in banana cv. Martaman.

FUTURE LINE OF WORK

- Studies on fertigation using liquid fertilizers may be attempted.
- Emphasis to be placed on the role of micronutrients influencing the yield and quality of banana fruits.
- Experiments on high density planting using tissue cultured plants under different levels of fertigation may be carried out.

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* Original not seen

The pattern of "Literature cited" presented above is in accordance with the "Guidelines" for thesis presentation for Dr. Y.S.R. Horticultural University, Venkataramannagudem.

Appendices

Appendix I: Monthly meteorological data recorded at Horticulture Research Station, Kovvur, West Godavari (Dist.) during 2011-2012.

Month and Year	Temperature (^{o} C)		Relative Humidity (%)		Rainfall (mm)	Rainy days
	Maximum	Minimum	8.0 hrs	14.00 hrs		
Oct,2011	33.48	24.94	85.90	58.38	20.2	2
Nov,2011	32.07	22.87	77.73	42.47	0	0
Dec,2011	30.00	21.90	81.84	46.06	0	0
Jan,2012	29.42	20.64	84.60	53.00	0	0
Feb,2012	26.27	20.58	82.65	41.68	0	0
Mar,2012	33.35	24.25	86.19	56.06	0	0
April,2012	36.20	26.96	78.86	47.43	0	0
May,2012	39.41	28.19	78.83	50.12	14.0	3
June,2012	36.25	26.56	74.60	51.93	40.2	6
July,2012	30.87	25.90	87.45	72.22	163.6	15
Aug,2012	31.96	24.90	80.03	66.29	184.6	12
Sept,2012	31.76	24.96	88.50	66.13	211.8	13
Oct, 2012	32.67	23.64	81.96	59.38	173.4	5
Nov,2012	30.76	22.53	81.90	55.60	265.0	5
Dec,2012	29.96	19.93	79.93	43.87	0	0
Total	-	-	-	-	**1072.8**	**61**
Mean	**32.21**	**23.92**	**82.06**	**54.04**	-	-