STUDIES ON HIGH DENSITY PLANTING IN BANANA CV. ROBUSTA (AAA)

Thesis submitted in part fulfilment of the requirements for the degree of
Master of Science (Horticulture) to the
Tamil Nadu Agricultural University, Coimbatore

By

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1999

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON HIGH DENSITY PLANTING IN BANANA CV. ROBUSTA (AAA)"** submitted in part fulfilment of the requirements for the degree of MASTER OF SCIENCE (HORTICULTURE) to the TAMIL NADU AGRICULTURAL UNIVERSITY, Coimbatore is a record of bonafide research work carried out by **Miss. L. NALINA** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

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A field trial was conducted during 1997-99 in a private farm at Vettaikaranputhur near Pollachi, Coimbatore district to study the effect of planting density and graded levels of nutrients on banana cv. Robusta (AAA). The planting density was increased by planting three or four suckers per pit. 100, 75 and 50 per cent of the recommended doses of fertilizers were given per pit based on the number of suckers planted per pit.

Among the high density planting treatments, three suckers/hill at a spacing of 1.8 x 3.6 m and application of 50% of recommended dose of

NPK fertilizers ie. 300: 90: 450 g/pit produced the highest mean bunch weight of 24.38 kg and total yield of 110 t/ha accounting for an increased yield of 27.70 per cent over conventional planting system (1.8 x 1.8 m) with one sucker per hill.

The same treatment registered good quality of fruits *viz.*, higher TSS, total sugars, reducing sugars and non reducing sugars and less acidity among the high density planting treatments compared, though it was slightly inferior to conventional planting.

Leaf spot incidence was low in lower density than in high density planting. Weed growth decreased under high density planting. Light transmission ratio decreased with increase in plant population.

Highest net profit (Rs. 3,50,406.9) and cost benefit ratio (1:3.85) were obtained from the treatment of 1.8 x 3.6 m with three suckers per hill accommodating 4629 plants/ha and application of 300: 90: 450 g NPK/pit.

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INTRODUCTION

CHAPTER 1

INTRODUCTION

The ever increasing population in our country warrants more production of fruits to bridge the gap between the per capita availability and consumption. This can be achieved by increasing the area under fruit crops and or by increasing the productivity per unit area. High density planting (HDP) is one of the recent and novel concepts of increasing the productivity without affecting the quality of fruits. HDP has been successfully implicated in fruit crops such as apple (Awasthi and Kuldeep, 1993), mango (SantRam, 1993), citrus(Goswami *et al.*, 1993), pineapple (Chadha and Singh, 1993) and banana (Reddy and Singh, 1993).

Several studies have been conducted in banana to elucidate the influence of HDP in different agroclimatic regions using different cultivars (Bhan and Majumdar, 1961; Sharma and Roy, 1972; Randhawa *et al.*, 1973; Patil *et al.*, 1978; Chattopadhyay *et al.*, 1980; Anon, 1989). In all these studies, high density was practiced by narrowing the spacing. Another method by which HDP can be achieved is by planting more than one sucker per hill i.e. 2, 3 or 4 suckers per hill.

Recently, high density planting in banana cv. Nendran was carried out by Elain Apshara (1997) in Tamil Nadu Agricultural University by planting two and three suckers per hill. The nutrient concentrations in all the densities were well within the prescribed adequacy level, despite the application of higher doses of fertilizers. This indicates that the nutrient requirements of banana under HDP with more number of suckers per hill may not be proportionally high.

Hence, there is a need to standardize the optimum spacing cum per hill planting density and nutrient requirement. To evolve suitable techniques for HDP in banana ,this experiment was laid out with the banana cultivar Robusta (AAA) having with the following objectives:

To study the effect of varying planting density, including number of plants/hill and nutrient levels on

a. Growth and development of banana.

b. Yield and quality of fruits.

c. Weed population and incidence of pest and diseases.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

High density planting in banana can be achieved through planting closer than the recommended one or by planting more number of suckers/pit. Choice of the planting density in different parts of the country vary widely from 1000 to 5000 plants/ha,of which 2500 to 4444 plants/ha are predominantly adopted. Factors such as cultivars, soil fertility, management, weed suppression determine the choice of the plant density in banana (Reddy and Singh, 1993).

In the following text, the effect of high density planting on the growth and development, flowering, fruit, yield and quality parameters in banana are reviewed.

The documented evidence on the effect of spacing in banana are listed below:

India

Cultivar	Plant spacing (m) adopted/population /ha tried	Authority
Amrit Sagar	1.2x1.2, 1.8x1.8, 2.4x2.4	Ahmed and Mannan (1970)
Giant Governor	2 x 2, 3 x 3	Chattopadhyay *et al.* (1980)
	10,000, 6666, 4444, 3333, 2500, 2222, 1666	Chattopadhyay *et al.* (1980)
	1x1(10,000), 1.5x2(6666) 1.5x1.5(4444), 2x1.5(3333) 2x2 (2500), 2.5x2(2222) 2.5x2.5(1600)	Bose *et al.* (1992)
Dwarf Cavendish	1.2x1.2, 1.8x1.8	Chundawat *et al.* (1982)
	1.8x1.8 (3086), 1.2x1.8(4629) 1.4x1.4(5120), 1.2x1.4(5952) 1.2x1.2(5208), 1x1.2x2(6250)	Chakrabarty *et al.* (1992)
		Kothavade *et al.* (1992)
	1.8x1.8, 1.5x1.5, 1.2x1.8, 1.2x1.5, 1.2x1.2x2, 1x1.2x2	Patel *et al.* (1992)
	1.8x1.8, 1.2x1.2x2, 1.2x1.5	Anon (1995)
Robusta	2.4x1.8, 2.4x2.4	Randhawa *et al.* (1973)
	2.4x1.8 (Double planting)	Alagiamanavalan and Balakrishnan (1976)
	1.2x1.2(6944), 1.5x1.5(4444), 1.8x1.8(3086), 2.1x2.1(2227)	Chacko and Reddy (1981)
	3.1x3.1, 2.15x2.15, 1.85x1.85, 1.55x1.55	Mohan and Madhava Rao (1984)
	1.8x1.5, 1.8x1.8, 1.8x2.1, 1.8x2.4	Shanmugavalu *et al.* (1987)
	2.4x1.8, 1x1	Rajeevan and Geetha (1989)
	1.2x1.2(6944), 1.5x1.5(4444), 1.8x1.8(3086), 2.1x2.1(2267)	Aravind Reddy and Chacko (1992)

Cultivar	Plant spacing (m) adopted/population /ha tried	Authority
	1.8x1.8, 1.4x1.4	Reddy and Singh (1993)
Kabuli and Dwarf Cavendish	6x6', 8x8'	Bhan and Majumdar (1961)
Lacatan	1.2x1.2, 1.3x1.3, 1.5x1.5, 1.7x1.7, 1.8x1.8	Chundawat *et al.* (1983)
Martaman and Champa	9x9', 12x12'	Bhan and Majumdar (1961)
Nendran	4500 to 7000	Anon (1978)
	3.1x3.1, 2.15x2.15, 1.85x1.85, 1.55x1.55	Mohan and Madhava Rao (1984)
	1.8x1.8, 1.5x1.5, 1.2x1.8, 1.2x1.5, 1.2x1.2x2, 1.2x1.5x2, 2.1x2.1	Anon (1995)
	2x2, 2x2.5, 2x3 (1,2,3)	Elain Apshara (1997)
Poovan	2.1x2.2, 1.5x1.8	Sathyanarayana and Rao (1985)
	1.8x1.8, 1.5x1.5, 1.2x1.8, 1.2x1.5, 2.1x2.1, 1.2x1.2x2, 1.2x1.5x2	Manivannan (1994)
	1.8x1.8, 1.5x1.5, 1.2x1.8, 1.2x1.5, 1.2x1.2x2, 1.2x1.5x2, 2.1x2.1	Anon (1995)
	1.2x1.5	Premalatha *et al.* (1996)

Abroad

Cultivar	Plant spacing (m) adopted/population /ha tried	Authority
Williams	1000, 1250, 1333, 1666, 2222,	Robinson (1983)
	1000, 1250, 1666, 2222	Reynolds and Robinson (1985)
	930 to 3980	Daniells *et al.* (1985)
	3x2, 4x1.5, 6x2x1.5	Robinson (1985)
	1000 – 1250	Robinson (1985a)
	1600 and 1250	Robinson and Nel (1986a)
	1000, 1250, 1666, 2222	Robinson and Nel (1988)
	1000, 1250, 1666, 2222	Robinson and Nel (1988a)
	1666 plants	Robinson and Nel(1989)
	1333, 1666, 1900, 2222, 3333	Robinson and Nel (1989a)
	2381, 3571, 4762 (2,3,4 plants/hole)	Israeli and Nameri (1988)
Grande Naine	1700, 1900, 2100	Stover (1984)
Maricongo	10x5', 10x4', 6x6', 6x5',5x5'	Irizarry *et al.* (1978)
Enxerto banana	930 to 3980	Lichtemberg *et al.* (1986)
Cavendish	1210, 968, 806, 691, 605, 537, 487	Berrill (1963)
Dominico Harton	1500, 2000, 2500	Arango Bernal (1987)

2.1. Effect of high density planting on growth and development of banana

2.1.1. Plant height and girth

The growth in height and girth of the pseudostem are closely related to foliage growth since the pseudostem consists of overlapping leaf sheaths. Height of the pseudostem is invariably increased and the girth is reduced drastically with reduction in spacing in several studies conducted in various cultivars of banana as categorized below.

Cultivar	Authority
Amrit Sagar	Ahmed and Mannan (1970)
Robusta	Chattopadhyay *et al.* (1980, 1985)Reddy (1982) and Anon (1989, 1989a)
Williams	Robinson (1983, 1985) Reynolds and Robinson (1985) Robinson and Nel (1989a)
Dwarf Cavendish	Chakrabarty *et al.* (1992) and Anon (1995)
Giant Governor	Bose *et al.* (1992)
Borjahaji	Baruah and Sharma (1996)
Nendran	Anon (1995) and Elain Apshara (1997)
Poovan	Sathyanarayana and Rao (1985), Anon (1993), Manivannan (1994), Anon (1995) and Premalatha *et al.* (1996)
False horn plantain	Adjei-Nsiah *et al.* (1997)

However, some authors did not find any significant influence on plant height and girth due to high density planting which may probably be due to varietal factor, soil fertility and or population etc.

Cultivar	Authority
Dwarf Cavendish	Bhan and Majumdar (1961) and Reddy (1991)
Robusta	Kulasekharan (1985) Reddy *et al.* (1992)
Basrai	Patel *et al.* (1992)
Poovan	Anon (1991, 1993)

2.1.2. Leaf characters

2.1.2.1. Leaf number

Reduction in number of functional leaves with increase in plant density was observed in many studies as indicated below.

Cultivar	Authority
Robusta	Mondal (1980) and Reddy (1982)
Basrai banana	Kothavade *et al.* (1992)
Giant Governor	Chattopadhyay *et al.* (1985)
Borjahaji	Baruah and Sharma (1996)
Poovan	Sathyanarayana and Rao (1985), Anon (1993) and Anon (1995)

However, Kulasekharan (1985) observed that spacing treatments had no influence on the number of leaves in banana cv. Robusta. On the other hand, Manivannan (1994) reported that high density planting significantly increased the leaf production in banana cv. Poovan.

2.1.2.2. Phyllochron

Phyllochron ie. the rate of leaf emergence normally gets reduced under closer planting owing to lower temperature inside the canopy (Singh, 1990).

2.1.2.3. Leaf area

Leaf area as determined by the leaf length and width is more influenced by increase in leaf width (Stover, 1979). High density planting generally resulted in increased leaf area than wider spacing as observed by Reddy (1982), Anon (1993) and Baruah and Sharma (1996) in Robusta, Poovan and Borjahaji respectively.

2.1.2.4. Leaf area index

The leaf area index which is arrived by dividing the area of the leaf by the area occupied by the plant is a useful guide in canopy management (Stover, 1984). Higher LAI under closer spacing rather than wider spacing has been obtained by many workers in banana as cited below.

Cultivar	Authority
Robusta	Aravind Reddy and Chacko (1992a)
Williams	Robinson (1985a, 1986) and Robinson and Nel (1986, 1988 and 1989a)
Poovan	Manivannan (1994)

2.1.2.5. Sucker production

Sucker production was greatly affected under high density planting in many cultivars like Amrit Sagar (Ahmed and Mannan, 1970), Robusta (Reddy, 1982), Giant Governor (Chattopadhyay *et al.*, 1980), Poovan (Sathyanarayana and Rao, 1985; Manivannan, 1994), Nendran (Elain Apshara, 1997). On the contrary, sucker production was not influenced significantly in Robusta banana with different spacings under Coimbatore condition (Anon, 1991).

2.1.3. Crop duration

The total crop duration which includes the number of days from planting to shooting and shooting to harvest was found to be significantly influenced by the planting densities. Several studies have clearly brought out the fact that the crop duration gets extended under high density planting in different cultivars.

Cultivar	Authority
Cavendish banana	Borel (1952) and Osborne (1953)
Basrai Lacatan	Chundawat *et al.* (1982, 1983)
Williams	Robinson (1983), Robinson and Reynolds (1984) and Daniells *et al.* (1985)
Robusta	Alagiamanavalan and Balakrishnan (1976)
Maricongo	Irizarry *et al.* (1978)
Giant Governor	Chattopadhyay *et al.* (1985)
Enxerto banana	Lichtemberg *et al.* (1986)
Poovan	Sathyanarayana and Rao (1985)

Such extension in crop duration with increase in plant density was more pronounced under subtropical conditions than under tropical conditions (Reddy and Singh, 1993) which may be related to the prevalence of low temperature in subtropical than tropical conditions (Simmonds, 1966).

2.1.4. Fruit yield

High density planting normally resulted in reduced bunch weight hence, higher total fruit yield under high density planting was due to the increased number of plant population. Several workers have recorded this view after conducting trials with various varieties of banana.

Cultivar	Authority
Williams	Robinson and Reynolds (1984), Daniells (1985), Robinson and Nel (1986a, 1987), Israeli and Nameri (1988) and Robinson and Nel (1989)
Cavendish	Berrill (1963), Reddy (1991) and Chakrabarty *et al.* (1992)
Basrai and Harichal	Patil *et al.* (1978), Chundawat *et al.* (1982) and Patel *et al.* (1992)
Robusta	Randhawa *et al.* (1973), Alagiamanavalan and Balakrishnan (1976) and Mondal (1980)
Amrit Sagar	Mondal (1993)
Giant Governor	Chattopadhyay *et al.* (1980)
Nendran	Anon (1978) and Elain Apshara (1997)
Poovan	Sathyanarayana and Rao (1985)
Martaman and Champa	Bhan and Majumdar (1961)
False horn plantain	Adjei-Nsiah *et al.* (1997)

2.1.5. Bunch weight

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

Cultivar	Authority
Robusta	Alagiamanavalan and Balakrishnan (1976) and Sathyanarayana and Rao (1985)
Basrai	Chundawat *et al.* (1982)
Lacatan	Chundawat *et al.* (1982)
Giant Governor	Chattopadhyay *et al.* (1980)
Amrit Sagar	Ahmed and Mannan (1970)
Maricongo	Irizarry and Hernandez (1975)
Dominico Harton	Arango Bernal (1987)
Poovan	Manivannan (1994)
Williams	Israeli and Nameri (1988)

2.1.6. Fruit quality

Fruit quality such as TSS and sugars were not very much affected by closer spacing as reported by Chundawat *et al.* (1982) in Basrai and Lacatan, Chattopadhyay *et al.* (1985) in Giant Governor, Manivannan (1994) and Premalatha *et al.* (1996) in Poovan.

2.1.7. Plant canopy and light interception

Plant density and their arrangement affect plant canopy and thereby light interception under high density planting. Chacko and Reddy (1981) observed reduced light intensity at ground level with increase in size of plant canopy and age but the solar energy conversion efficiency was maximum under closer spacing than under wider spacing. This was reported by many authors as indicated below.

Cultivar	Authority
Williams	Robinson, (1981, 1986,) and Robinson and Nel (1989a)
Robusta	Reddy (1982) and Aravind Reddy and Chacko (1992)
Kabuli and Dwarf Cavendish	Bhan and Majumdar (1961)
Dwarf Cavendish	Neog *et al.* (1992)
Valery and Grande Naine	Stover (1982, 1984)
Martaman and Champa	Bhan and Majumdar (1961)

2.1.8. Weed growth

In high density planting, weed growth was normally suppressed due to the heavy shade effect as reported by Moreau (1965, 1971); Chacko and Reddy (1981) in Robusta, and Lichtemberg *et al.* (1986) in Enxerto banana.

2.1.9. Leaf spot incidence

Higher incidence of sigatoka leaf spot was observed with high density planting in Monsmori banana by Missingham (1963). However, this severity of incidence was often related to agro-ecological factors (Reddy and Singh, 1993).

2.2. Effect of nutrients on growth and development of banana

Banana is a heavy feeder and to ensure high yield of quality bananas, application of adequate nutrients is of paramount importance. Banana generally requires high amounts of mineral nutrients for proper growth and fruit production.

2.2.1. Effect of Nitrogen

Nitrogen is the chief promoter of growth. Tanaka (1937) reported N as the most important nutrient for growth and its absence resulted in poor growth. Excess or deficiency of nitrogen had marked effect on fruit composition which also influenced the quantity of nutrients removed from the soil through the bunches of banana (Martin-Prevel, 1966). The deficiency of nitrogen resulted in stunted growth, reduction in rate of leaf production and suckering (Murray, 1959; Butler, 1960; Carpentier and Martin-Prevel, 1965; Shawky *et al.*, 1993). On the other hand application of nitrogen increased the pseudostem height, leaf area, leaf production and leaf nitrogen content (Battikhah and Khalidy, 1962; Chattopadhyay *et al.*, 1980a).

Increases in bunch weight and also its components such as number of hands, number of fingers and maturity due to N application were reported by many authors as indicated below:

Cultivars	**Authority**
Karpura Chakrakeli	Venkatesam *et al.* (1965)
Giant Governor	Chattopadhyay *et al.* (1980a)
Musa paradisiaca	Hernandez *et al.* (1981)
Hembra	Holder and Gumbs (1983)

Optimum dose of nitrogen varies with cultivar, soil factor and system of cultivation ~~etc.~~ as suggested by various authors as furnished below.

Group and cultivars	Optimum N dose recommended (g/plant) (or) (kg/ha)	Authority
Dwarf Cavendish	170	Arunachalam (1972)
Giant Cavendish	170	Arunachalam (1972)
Robusta	170	Ramaswamy and Muthukrishnan (1974)
	225 (kg/ha)	Turner and Bull (1970)
	170	Arunachalam (1972)
	180, 150-300	Kohli *et al.* (1984, 1986)
	100-200	Champion *et al.* (1958)
	300-400	Singh and Kashyap (1992)
Giant Cavendish	225-425	Oubahou and Dafiri (1987)
	400	Oubahou and Dafiri (1987)
Dwarf Cavendish	200 g lime stone + Amm NO_3	Reynolds and Langenegger (1985)
Cavendish and Williams	240 g CAN	Langenegger (1984)
	56-67	Langenegger and Smith (1990)
	300 (kg/ha)	Srikul and Turner (1995)
Basrai	150-200	Singh *et al.* (1979)
	450 (kg/ha)	Gubbuk *et al.* (1993)
Lacatan	170	Arunachalam (1972)
Rasthali	200	Bhan Majumdar (1956)
	200 urea	Praburam (1992)

It may be inferred that N requirement varies with cultivar and under Cavendish group, the requirement for Robusta varies from 100 - 300 g/plant.

2.2.2. Effect of Phosphorus

Phosphorus requirement of banana was much less than N and K (Norris and Iyer, 1942). Response to the application of P in growth was also poor and did not show any significant effect on maturity, number of hands and fingers per bunch (Bhan and Majundar, 1956). Similar results were obtained by many workers in different cultivars of banana as indicated below:

Cultivar	**Authority**
Gros Michel	Croucher and Mitchell (1940)
Lacatan	Osborne and Hewitt (1963)
Dwarf Cavendish	Martin – Prevel (1964)
Cavendish	Jagirdar and Ansari (1966)
Basrai Dwarf	Jauhari *et al.* (1974)
Robusta	Vadivel (1976)
Nendran	Pillai *et al.* (1977)

According to Ramaswamy (1976), number of hands/bunch, bunch weight and fruit size and volume increased upto 60 g P/plant.

2.2.3. Effect of Potassium

Potassium occupies an important place not only with regard to its content in plant tissue but also for its role in physiological and biochemical functions. Adequate supply of potash fertilizers increases the yield of banana besides improving the fruit quality including tolerance to biotic and abiotic stresses.

Banana requires relatively larger quantity of K through out its normal growth and development, with a maximum requirement at fruit filling stage (Lacoeuilhe, 1973). Hence, fairly a high ratio of K in the fertilizer formulation is essential for better plant growth and development as recommended below.

Authority	**Fertilizer formulation recommended (NPK) mixture**
Fawcett (1921)	1:2:4
Pelegrin (1953)	6:7:28
Twyford (1967)	4:1:14
Twyford and Walmsley (1974c)	9:9:39

Potassium advances flowering and shortens the number of days for maturity in banana (Martin and Prevel, 1981; Lahav and Turner, 1983; Obiefuna, 1984; Israeli and Lahav, 1986; Ray *et al.*, 1993). Besides, potassium is known to increase drought tolerance in banana (Katyal and Chadha, 1961; Mengel and Krikby, 1980).

2.2.3.1. Role of potassium in vegetative character

Application of potassium has significant effect in increasing pseudostem height, girth, number of leaves and leaf area as observed by many workers in different cultivars of banana.

Cultivar	**authority**
Fairy Man	HO (1968, 1969)
Jahaji	Baruah and Mohan (1985)
Dwarf Cavendish	El-khoreiby and Salem (1991) Baruah and Mohan (1991, 1992) and Ray *et al.* (1993).
Robusta	Jambulingam *et al.* (1974) and Mustaffa (1987, 1988)

2.2.3.2. Potassium on yield of banana

Application of Potassium increased the yield of banana in all the varieties as reported by many workers

Cultivar	**Authority**
Lacatan	Osborne and Hewitt (1963)
Basrai	Gandhi (1951) and Ray *et al.*(1993)
Dwarf Cavendish	Yadhav *et al.* (1988) and Baruah and Mohan (1992)
Robusta	Randhawa *et al.* (1973), Vadivel (1976), Pillai *et al.* (1977) and Mustaffa (1987, 1988)
Martaman	Bhan and Majumdar (1956)
Poovan	Gopalan Nayar (1953)
Hill banana	Mustaffa (1987)

Plantain	Obiefuna (1984)
Fairy Man	HO (1969)

2.2.3.3. Potassium on fruit quality

Many workers opined that application of K exerted marked effect on nearly every aspect of fruit quality with an increase in total soluble solids, reducing and non-reducing sugars, total sugars and ascorbic acid. It however, decreased the acidity level in the fruits favourably.

Cultivar	Authority
Gros Michel	Croucher and Mitchell (1940)
Dwarf Cavendish	Chattopadhyay (1981) and Chattopadhyay and Bose (1986)
Jahaji	Baruah and Mohan (1986)
Campierganj local	Ram and Prasad (1989)
Robusta	Sunder Singh (1972) and Jambulingam *et al.* (1974)
	Vadivel (1976), Vadivel and Shanmugavelu (1978) and Mustaffa (1987, 1988)
Local cultivar	Lahav and Turner (1983) and Chu (1961)

2.2.4. Critical level of nutrients in banana

Information on the concentration of nutrients in plant tissue is useful in determining the nutrient status of the plant and also it indicates the level of toxicity or deficiency in the plant. The critical level of nutrient in banana tissue has been reported by many workers in various cultivars.

Cultivars	N%	P%	K%	Authority
Petitonaine	-	-	3.6	Dumas (1960)
Poyo	-	-	4	Dumas (1960)
Gros Michel	-	-	4.3-5.8	Dumas (1960)
Lacatan	2.6	0.45	3.3	Hewitt (1955)
	2.6	0.40	4.4%	Hewitt and Osborne (1962)
Williams and hybrid	2.7-2.9	-	-	Warner and Fox (1977) and Warner *et al.* (1974)
Jahaji	1.932	0.138	2.99 3.38	Baruah and Mohan (1988)
	1.38-2.15	0.25-0.28	2.59-3.07	Hazarika and Mohan (1992)
Plantain	4	0.21	3.3	Carocastos *et al.* (1964)
Fairyman	3.22-3.42	0.21-0.24	3.52-3.94	Ho (1969)
Robusta	2.8-3.0	0.44-0.58	3.8-4.0	Boland (1960)
	3.2	0.19	3.3	Hegin *et al.* (1964)
	2.9	0.29	0.48	Twyford and Coulter (1964)
	2.6-2.9	0.29-0.48	0.38	Twyford (1967)
	3.2	0.44	3.11	Ramaswamy (1971)
	3.29	0.44	3.11	Ramaswamy and Muthukrishnan (1974)
	3.18-3.43	0.46-0.55	3.36-3.76	Arunachalam (1972)
	3.13	0.44	3.89	Sundersingh (1972)
	2.7-3.0	0.215-0.219	4.57-4.67	Randhawa *et al.* (1973)
	0.98-2.36	0.11-0.32	3.6-5.6	Ashok kumar (1977)
	2.32-2.44	0.22-0.25	3.9-4.9	Krishnan and Shanmugavelu (1978)
	2.85	0.20	4.69	Kohli *et al.* (1981)
	2.92-3.56	0.114-0.163	3.96-3.37	Kotur and Mustaffa (1984)
	2.08	0.08	3.49	Fernandez-Falcon *et al.* (1988)
Nendran	2.26-3.39	0.23-0.43	3.18-3.47	Bhavanishankar (1980)
	2.39-3.48	0.19-0.27	2.9-3.35	Bellie (1987)
Hindy	1.99-2.62			Shawky *et al.* (1993)
	2.6	0.45	3.8	Murray (1960)

2.2.5. Combined NPK

Based on the interactive effect of NPK nutrients on growth and development including fruit yield and quality factors, different doses of NPK are recommended for various banana varieties depending upon the cropping system and fertility of soil etc. The following are some of the fertilizer recommendation.

Cultivar	N (kg/ha)	P (kg/ha)	K (kg/ha)	Authority
Robusta	75-150	45-90	85-170	Singh *et al.* (1979)
	405	245	507	Tandon (1987)
	140	35	90	Tandon (1987)
	0-750	50	250	Kohli *et al.* (1986)
	0-250	75	225	Mustaffa (1988)
	180	100	225(g)	Randhawa and Iyer (1978)
	160	-	240 g(N-K)	Champion *et al.* (1958)
	350	160	180 kg	Bhangoo *et al.* (1962)
Dwarf Cavendish	75-150	45-90	85-170	Singh *et al.* (1979)
	230-450 g KAM	110-230 g Super PO_4	170-350 g KCl	Koen *et al.* (1976)
	250	90	480 g	Chattopadhyay and Bose (1986)
	200	40	400 g	Shelke and Nahate (1996)
	400 g Amm. SO4	300 g Super PO_4	250 MOP	Pandit *et al.* (1992)
	200	100	300	Ray *et al.* (1993)
	300	120	300	Pawar *et al.* (1997)
	259	100	600	Martinez *et al.* (1998)
	300	200	250	Tirkey *et al.* (1998)

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The present investigation was carried out in a private farm at Vettaikaranputhur near Pollachi, Coimbatore district during 1997-1999. The soil type of the experimental field was of sandy loam and chemical properties are furnished below.

pH - 7.6

EC - 0.3 $ds.m^{-1}$

Available N - 145 kg/ha

Available P - 22.4 kg/ha

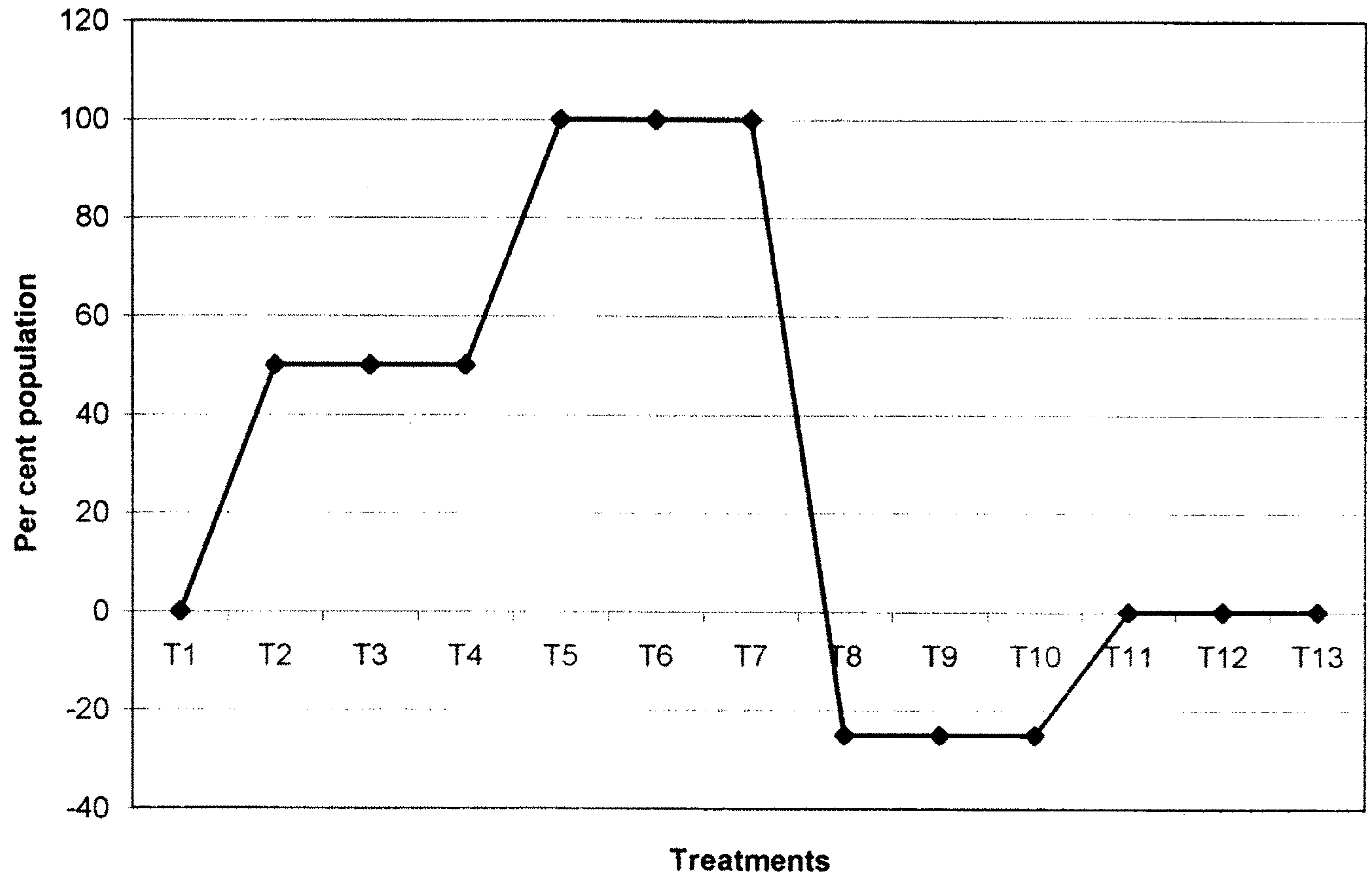
Available K - 465.5 kg/ha

3.1. Experimental details

The experiment was laid out with banana cv. Robusta (AAA) as test crop in a Randomized Block Design with 13 treatments and 4 replications. Guard rows were provided on all sides of the plots. Each treatment occupied a net area of 12 x 12 m. The details of the treatments are furnished below:

Treatment	Code No.	Spacing (m)	Number of suckers/ hill	NPK level (%)	% increase / decrease population over control (Fig. 1)
T_1	$S_1P_1F_{100}$	1.8 x 1.8	1	100	-
T_2	$S_2P_3F_{100}$	1.8 x 3.6	3	100	50
T_3	$S_2P_3F_{75}$	1.8 x 3.6	3	75	50
T_4	$S_2P_3F_{50}$	1.8 x 3.6	3	50	50

FIG 1.RELATIVE PLANT POPULATION IN VARIOUS HDP TREATMENTS



T_5	$S_2P_4F_{100}$	1.8 x 3.6	4	100	100
T_6	$S_2P_4F_{75}$	1.8 x 3.6	4	75	100
T_7	$S_2P_4F_{50}$	1.8 x 3.6	4	50	100
T_8	$S_3P_3F_{100}$	3.6 x 3.6	3	100	-25
T_9	$S_3P_3F_{75}$	3.6 x 3.6	3	75	-25
T_{10}	$S_3P_3F_{50}$	3.6 x 3.6	3	50	-25
T_{11}	$S_3P_4F_{100}$	3.6 x 3.6	4	100	-
T_{12}	$S_3P_4F_{75}$	3.6 x 3.6	4	75	-
T_{13}	$S_3P_4F_{50}$	3.6 x 3.6	4	50	-

The amount of NPK applied to each treatment through urea, single super phosphate and muriate of potash were as follows.

Treatments		NPK fertilizers (g/plant)
T_1	:	200 : 60 : 300 (100% control)
T_2, T_8	:	600 : 180 : 900 g/hill
T_3, T_9	:	450 : 135 : 675
T_4, T_{10}	:	300 : 90 : 450
T_5, T_{11}	:	800 : 240 : 1200 (g/hill)
T_6, T_{12}	:	600 : 180 : 900
T_7, T_{13}	:	400 : 120 : 600

The above fertilizer dose was applied in three splits viz., third, fifth and seventh month after planting.

3.2. Field preparation and planting

Pits were dug out at different spacing as per treatment schedule after thorough ploughing and levelling of the field. Suckers weighing one to two kg were selected. Corms were graded according to their size to form homogenous groups and planted. Suckers were pretreated for nematode control ie. suckers were pared of all roots, lesions and dipped in Emisan 2% solution, prolinaged with 40 g of carbofuran - 3G and planted in pits of 60 cm^3.

Despite the use of graded corms, it was observed that among plants of each productive units, some plants showed marked differences in size and thickness of the pseudostem. To achieve uniformity, levelling by pruning or cutting back was resorted to. This was done either partly or completely eliminating leaf growth or completely cutting back the pseudostem of the most developed plants to a minimum of 10 cm above ground level or to a greater height according to the relative development of the plants to be cut back. This was done when the plants had produced the fifth leaf. Except for the fertilizer level, all the other cultural practices were followed uniformly for all the treatments.

3.3. Observations recorded

Four clumps were selected randomly in each treatment for recording the biometrical and yield characters.

3.3.1. Plant characters

3.3.1.1. Pseudostem height

Height of the pseudostem was measured at different stages from the base of the trunk to the axil of the youngest leaf and expressed in m.

3.3.1.2. Pseudostem girth

The girth of the pseudostem was measured at different stages at 30 cm height from the ground level and expressed in m.

3.3.1.3. Number of leaves

The total number of leaves produced until shooting was counted and recorded. The number of functional leaves at harvest was also recorded.

3.3.1.4. Phyllochron

The date of emergence of each leaf was recorded from which the rate of emergence was calculated (Summerville, 1944).

3.3.1.5. Leaf area

Leaf area was calculated by multiplying the product of length and breadth of lamina by the factor 0.8 (Murray, 1960) and expressed in m^2. The length of the lamina was measured from the base to its apex along the midrib and width at the broadest portion of the lamina.

3.3.1.6. Leaf area index

The leaf area index was calculated using the following formula (Watson, 1952).

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

3.3.1.7. Sucker production

The total number of suckers produced per plant was recorded for each treatment at different stages of growth.

3.3.1.8. Crop duration

Number of days taken from planting to shooting and harvest was recorded.

3.4. Light interception

Light intensity at the base of the plant and at the canopy level was measured using lux meter at 3rd, 5th, 7th months after planting and flowering. Light intensity available in all the four sides *viz.*, north, south, east and west of each plant was recorded at 75 cm from the base of the plant thrice a day at 8 a.m., 12 noon and 3 p.m. and the average value was worked out. Light transmission ratio (LTR) was computed by the method suggested by Yoshida *et al.* (1972).

$$\text{LTR (\%)} = \frac{I_i}{I_o} \times 100$$

I_o = Light intensity above the canopy

I_i = Light intensity at the ground surface

3.5. Bunch characters

The bunch characters were recorded from all the four clumps and the mean values were recorded.

3.5.1. Bunch weight

Weight of the bunch was measured including the peduncle upto first bract leaf node above the first hand and expressed in kilogram.

3.5.2. Bunch length

Length of the bunch was measured from the point of attachment of the first hand on the peduncle to the last hand.

3.5.3. Number of hands and fingers

Total number of hands and fingers were counted.

3.5.4. Average weight of the finger

The middle fingers in the top and bottom rows of the second hand were selected as representative fingers (Gottreich *et al.*, 1964) to record average weight of the finger and for other physical and chemical characters.

3.5.5. Finger length

Length of the finger was measured from the base of the pedicel to the tip of the fruit along the outer curvature and expressed in cm.

3.5.6. Pulp-peel ratio

Fully ripe fruit was weighed and peeled. The peel was weighed and pulp weight was arrived by the difference between the two. The pulp-peel ratio was computed.

3.6. Disease incidence and weed growth

3.6.1. Weed growth

One m^2 area in between the plants were selected and the weeds were collected periodically and their dry weights were recorded.

3.6.2. Estimation of leaf spot

The incidence of yellow sigatoka leaf spot was assessed on 210 and 270 days after planting by scoring each leaf based on the severity of the incidence (Stover, 1971). Results were expressed in percentage.

3.6.3. Stem weevil incidence

The number of pseudostem affected by the stem weevil was recorded on one month after emergence of the bunch and per cent plant infected by the above weevil was worked out.

3.7. Chemical analysis

3.7.1. Soil sample

Soil samples were collected at 3rd, 5th, 7th months after planting and flowering and harvest. The collected samples were air dried in shade, ground with wooden mallet, passed through two mm sieve and used for following analysis.

3.7.1.1. Available Nitrogen

The available nitrogen in soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg/ha.

3.7.1.2. Available Phosphorus

The available phosphorus in soil was estimated by using klett Summerson colorimeter using red filter (Olsen *et al.*, 1954) and expressed in kg/ha.

3.7.1.3. Available Potassium

The available potassium in soil was calculated after extraction with neutral N ammonium acetate, using flame photometer and the values were expressed in kg/ha (Hanway and Heidal, 1952).

3.7.2. Leaf sample

Leaf samples were taken for analysis at shooting. The samples were collected from the third youngest leaf (Hewitt, 1955), dried and analysed for the following nutrients.

3.7.2.1. Estimation of Nitrogen

The nitrogen content was estimated by Microkjeldahl method (Humphries, 1956) and expressed in percentage.

3.7.2.2. Estimation of Phosphorus

The phosphorus content of the leaf was estimated in the triple acid extract by adopting Vanadomolybdate phosphoric yellow colour method (Jackson, 1973).

3.7.2.3. Estimation of Potassium

The potassium content was estimated by the flame photometric method as suggested by Jackson (1973).

3.8. Biochemical analysis

The representative fingers were allowed for natural and uniform ripening. Those fruits were utilised for determining the following parameters.

3.8.1. Total soluble solids

The TSS was determined by using carl-zeiss hand refractometer and the results expressed as percentage after conversion to 21°C.

3.8.2. Titrable acidity

Titrable acidity was estimated by adopting AOAC method (1960).Ten gram of pulp was macerated and volume made upto 100 ml with distilled water and filtered. Ten ml of the filtrate was titrated against N/10 KOH using phenolphthalein indicator and expressed in terms of citric acid per 100 g of fruits.

3.8.3. Ascorbic acid

The ascorbic acid content was estimated using 2, 6, dichlorophenol indophenol dye and expressed as mg of ascorbic acid per 100 g (Freed, 1966).

3.8.4. Estimation of sugars

The total, reducing and non-reducing sugars were estimated as per the method suggested by Somogyi (1952).

3.8.5. Sugar-acid ratio

The ratio was computed by dividing the total sugars by the acidity.

3.9. Statistical analysis

The statistical scrutiny of data and calculation of correlation co-efficients were done by adopting the standard procedures of Sukhatme and Amble (1985) and Gomez and Gomez (1984).

3.10. Economics

The cost of cultivation was worked out taking into account various inputs for cultivation during the entire experimental period.

The following abbreviations were often used in this study.

HDP - High density planting

S_1 - 1.8 x 1.8 m

S_2 - 1.8 x 3.6 m

S_3 - 3.6 x 3.6 m

P_1 - One sucker per hill

P_3 - Three suckers per hill

P_4 - Four suckers per hill

EXPERIMENTAL RESULTS

CHAPTER 4

EXPERIMENTAL RESULTS

Results of the "Studies on high density planting in banana cv. Robusta" are presented under various headings in this chapter.

4.1. Effect of high density planting on growth and development of banana

4.1.1. Pseudostem height

Pseudostem height at 3rd month after planting showed significant differences among the treatments. When compared to control, all the other treatments showed increased pseudostem height. Four suckers per hill registered higher plant height under S_2 and S_3 systems of planting than their corresponding three suckers per hill planting. Irrespective of the spacing or per hill planting density, the plant height showed reduction with a reduction in the nutrient supplied. Among the treatments T_4 (0.630 m) and T_{13} (0.630 m) registered plant height very close to control (0.630 m).

Pseudostem height recorded on 5th, 7th months and shooting stages (Table 1) showed that all the treatments differed significantly from control. The treatments having four suckers per hill invariably registered more plant height than the treatments involving three suckers per hill both under S_2 and S_3 systems of planting. With the decrease in the nutrient level under each set of treatments, there was a corresponding reduction in plant height.

Table 1. Effect of HDP treatments on pseudostem height (m) at different growth stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	0.63	0.96	1.48	2.21
T_2	$S_2P_3F_{100}$	0.68	1.35	1.85	2.41
T_3	$S_2P_3F_{75}$	0.65	1.28	1.81	2.39
T_4	$S_2P_3F_{50}$	0.63	1.23	1.78	2.36
T_5	$S_2P_4F_{100}$	0.75	1.70	2.37	2.82
T_6	$S_2P_4F_{75}$	0.73	1.65	2.28	2.73
T_7	$S_2P_4F_{50}$	0.72	1.51	2.24	2.72
T_8	$S_3P_3F_{100}$	0.66	1.44	1.92	2.50
T_9	$S_3P_3F_{75}$	0.65	1.43	1.91	2.43
T_{10}	$S_3P_3F_{50}$	0.65	1.41	1.89	2.39
T_{11}	$S_3P_4F_{100}$	0.71	1.66	2.16	2.59
T_{12}	$S_3P_4F_{75}$	0.65	1.58	2.08	2.52
T_{13}	$S_3P_4F_{50}$	0.63	1.54	2.01	2.48
	S.Ed	0.014	0.007	0.002	0.006
	CD(P=0.05)	0.029	0.014	0.004	0.012

4.1.2. Pseudostem girth

Pseudostem girth at all stages of observation showed significant differences among the treatments (Table 2). When compared to control, all the HDP treatments registered reduced pseudostem girth. When three and four suckers/hill planting were compared, invariably four suckers/hill showed reduced pseudostem girth under S_2 as well as S_3 system of planting at all stages. Besides, reduction in girth was observed with a corresponding decrease in the nutrient supplied, however, their differences were not significant in certain cases. Among the treatments, T_2 registered maximum girth next to control at all stages.

4.1.3. Number of leaves

When compared to control, all the HDP treatments registered more number of leaves at all stages of observations (Table 3). Between the three and four suckers/hill planting, invariably the treatments with four suckers/hill registered higher number of leaves than the treatments with three suckers/hill under both the S_2 and S_3 systems of planting at all stages. With a decrease in the nutrient supplied, the number of leaves were reduced in all the treatments.

4.1.4. Phyllochron

Phyllochron did not differ significantly among the treatments at any stage of observation (Table 4). Among the HDP treatments three suckers per hill planting at S_2 system registered relatively more number of days for leaf

Table 2. Effect of HDP treatments on pseudostem girth (m) at different growth stages

Treatments	Code	3^{rd} month	5^{th} month	7^{th} month	Shooting
T_1	$S_1P_1F_{100}$	0.32	0.57	0.72	0.85
T_2	$S_2P_3F_{100}$	0.24	0.49	0.65	0.78
T_3	$S_2P_3F_{75}$	0.21	0.43	0.64	0.74
T_4	$S_2P_3F_{50}$	0.18	0.41	0.62	0.72
T_5	$S_2P_4F_{100}$	0.18	0.33	0.49	0.67
T_6	$S_2P_4F_{75}$	0.18	0.31	0.45	0.64
T_7	$S_2P_4F_{50}$	0.18	0.29	0.42	0.62
T_8	$S_3P_3F_{100}$	0.23	0.42	0.58	0.71
T_9	$S_3P_3F_{75}$	0.21	0.40	0.56	0.68
T_{10}	$S_3P_3F_{50}$	0.20	0.38	0.52	0.66
T_{11}	$S_3P_4F_{100}$	0.20	0.38	0.54	0.69
T_{12}	$S_3P_4F_{75}$	0.20	0.36	0.52	0.66
T_{13}	$S_3P_4F_{50}$	0.18	0.33	0.51	0.66
	S.Ed	0.005	0.002	0.002	0.004
	CD(P=0.05)	0.010	0.004	0.005	0.009

Table 3. Effect of HDP treatments on number of leaves at different growth stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	11.31	16.61	18.49	19.48
T_2	$S_2P_3F_{100}$	11.93	16.93	19.17	20.08
T_3	$S_2P_3F_{75}$	11.82	16.84	19.08	19.94
T_4	$S_2P_3F_{50}$	11.67	16.64	19.04	19.78
T_5	$S_2P_4F_{100}$	12.85	17.31	19.31	20.21
T_6	$S_2P_4F_{75}$	12.79	17.13	19.28	20.18
T_7	$S_2P_4F_{50}$	12.73	17.02	19.18	20.12
T_8	$S_3P_3F_{100}$	11.48	16.74	18.63	19.56
T_9	$S_3P_3F_{75}$	11.37	16.58	18.54	19.46
T_{10}	$S_3P_3F_{50}$	11.32	16.63	18.51	19.35
T_{11}	$S_3P_4F_{100}$	11.62	16.82	18.86	19.96
T_{12}	$S_3P_4F_{75}$	11.57	16.78	18.79	19.77
T_{13}	$S_3P_4F_{50}$	11.48	16.69	18.68	19.58
	S.Ed	0.024	0.009	0.081	0.034
	CD(P=0.05)	0.49	0.018	0.163	0.068

Table 4. Effect of HDP treatments on phyllochron at different growth stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	7.10	7.58	8.21	8.41
T_2	$S_2P_3F_{100}$	7.32	7.98	8.42	8.56
T_3	$S_2P_3F_{75}$	7.31	7.89	8.41	8.51
T_4	$S_2P_3F_{50}$	7.28	7.73	8.39	8.49
T_5	$S_2P_4F_{100}$	7.27	7.82	8.37	8.49
T_6	$S_2P_4F_{75}$	7.23	7.79	8.33	8.47
T_7	$S_2P_4F_{50}$	7.19	7.72	8.29	8.43
T_8	$S_3P_3F_{100}$	7.23	7.78	8.31	8.48
T_9	$S_3P_3F_{75}$	7.19	7.75	8.29	8.46
T_{10}	$S_3P_3F_{50}$	7.17	7.68	8.27	8.43
T_{11}	$S_3P_4F_{100}$	7.18	7.69	8.28	8.47
T_{12}	$S_3P_4F_{75}$	7.16	7.65	8.26	8.45
T_{13}	$S_3P_4F_{50}$	7.12	7.63	8.23	8.43
	S.Ed	0.468	0.473	0.409	0.334
	CD(P=0.05)	NS	NS	NS	NS

emergence at all stages than the control. With a decrease in the nutrient supplied, the phyllochron was reduced in all the treatments.

4.1.5. Leaf area

Leaf area measured at 3rd, 5th and 7th months after planting followed a similar trend and all the HDP treatments did differ significantly from control (Table 5). Treatments involving four suckers/hill invariably registered more leaf area than three suckers/hill both under S_2 and S_3 planting systems at all stages. With a reduction in the nutrients supplied, there was no appreciable changes in the leaf area.

4.1.6. Leaf area index

Leaf area index at 3rd month after planting did not show significant differences among the treatments. However, LAI was more than control in all the other treatments at 5th, 7th and shooting stages and also they followed a similar trend at all the three stages (Table 6). Irrespective of the planting density, four suckers per hill registered invariably more LAI than three suckers per hill at all stages. The highest LAI was registered in all the set of treatments with highest level of nutrients at all the three stages. T_5 registered the maximum LAI among all the three stages in all the treatments.

Table 5. Effect of HDP treatments on total leaf area (m^2) at different growth stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	1.68	4.93	12.02	26.28
T_2	$S_2P_3F_{100}$	1.98	5.17	12.23	26.49
T_3	$S_2P_3F_{75}$	1.93	5.12	12.18	26.42
T_4	$S_2P_3F_{50}$	1.91	5.08	12.16	26.38
T_5	$S_2P_4F_{100}$	2.23	5.38	12.51	26.58
T_6	$S_2P_4F_{75}$	2.18	5.29	12.29	26.49
T_7	$S_2P_4F_{50}$	2.08	5.18	12.18	26.47
T_8	$S_3P_3F_{100}$	1.86	5.02	12.08	26.41
T_9	$S_3P_3F_{75}$	1.83	4.97	12.08	26.38
T_{10}	$S_3P_3F_{50}$	1.79	4.95	12.05	26.30
T_{11}	$S_3P_4F_{100}$	1.91	5.08	12.08	26.45
T_{12}	$S_3P_4F_{75}$	1.89	5.06	12.18	26.42
T_{13}	$S_3P_4F_{50}$	1.84	4.98	12.12	26.38
	S.Ed	0.003	0.005	0.098	2.576
	CD(P=0.05)	0.007	0.011	0.098	NS

Table 6. Effect of HDP treatments on leaf area index at different growth stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	1.03	2.57	5.63	11.45
T_2	$S_2P_3F_{100}$	1.16	2.76	5.79	11.65
T_3	$S_2P_3F_{75}$	1.13	2.73	5.73	11.63
T_4	$S_2P_3F_{50}$	1.12	2.70	5.69	11.59
T_5	$S_2P_4F_{100}$	1.18	2.83	5.98	11.73
T_6	$S_2P_4F_{75}$	1.16	2.78	5.89	11.68
T_7	$S_2P_4F_{50}$	1.15	2.75	5.83	11.63
T_8	$S_3P_3F_{100}$	1.09	2.66	5.72	11.55
T_9	$S_3P_3F_{75}$	1.07	2.61	5.69	11.51
T_{10}	$S_3P_3F_{50}$	1.05	2.59	5.67	11.49
T_{11}	$S_3P_4F_{100}$	1.14	2.69	5.75	11.62
T_{12}	$S_3P_4F_{75}$	1.10	2.67	5.73	11.61
T_{13}	$S_3P_4F_{50}$	1.08	2.65	5.71	11.59
	S.Ed	0.181	0.006	0.003	0.004
	CD(P=0.05)	NS	0.012	0.007	0.008

4.1.7. Sucker production

Sucker production at all the four stages of observation showed significant differences among the treatments (Table 7). Control plot registered the maximum sucker production at all stages when compared to HDP treatments. At all stages of observation, three suckers per hill registered more sucker production than under four suckers per hill at S_2 as well as S_3 system of planting (of course with few exceptions under S_2 system). In most of the cases, with the reduction in the nutrient supplied, there was a corresponding reduction in the sucker production. However, this was more marked under S_2 system than under S_3 system.

4.2. Crop duration

4.2.1. Days from planting to shooting

Days taken from planting to shooting differed significantly among the treatments. When compared to control, all the HDP treatments took more days from planting to shooting (Table 8). Planting with four suckers per hill invariably registered more number of days for shooting under S_2 and S_3 system than the corresponding three suckers per hill plants. There was significant difference for shooting due to reduction in fertilizer level. T_1 recorded minimum number of days for shooting followed by T_8.

4.2.2. Shooting to harvest

Days taken from shooting to harvest differed significantly among the treatments (Table 8). Planting with four suckers per hill invariably registered

Table 7. Effect of HDP treatments on sucker production at different growth stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	5.30	7.28	8.58	10.75
T_2	$S_2P_3F_{100}$	4.45	6.27	7.35	8.43
T_3	$S_2P_3F_{75}$	4.05	6.24	7.31	8.36
T_4	$S_2P_3F_{50}$	3.94	6.18	7.23	8.37
T_5	$S_2P_4F_{100}$	3.60	5.60	6.75	7.68
T_6	$S_2P_4F_{75}$	3.46	5.41	6.65	7.32
T_7	$S_2P_4F_{50}$	3.35	5.60	6.47	7.13
T_8	$S_3P_3F_{100}$	5.23	6.76	8.23	9.89
T_9	$S_3P_3F_{75}$	5.22	6.71	8.18	9.23
T_{10}	$S_3P_3F_{50}$	5.17	6.65	8.13	9.18
T_{11}	$S_3P_4F_{100}$	5.11	6.61	7.95	8.94
T_{12}	$S_3P_4F_{75}$	5.03	6.52	7.89	8.23
T_{13}	$S_3P_4F_{50}$	4.75	6.45	7.68	8.14
	S.Ed	0.075	0.387	0.439	0.249
	CD(P=0.05)	0.153	0.785	0.890	0.504

Table 8 .Effect of HDP treatments on crop duration

Treatments	Code	Days taken from planting to shooting	Shooting to harvest	Total crop duration
T_1	$S_1P_1F_{100}$	242.15	85.00	327.15
T_2	$S_2P_3F_{100}$	279.32	85.45	364.77
T_3	$S_2P_3F_{75}$	281.50	88.93	370.43
T_4	$S_2P_3F_{50}$	286.73	92.93	379.66
T_5	$S_2P_4F_{100}$	306.28	97.19	403.47
T_6	$S_2P_4F_{75}$	307.74	101.14	408.88
T_7	$S_2P_4F_{50}$	318.75	106.75	425.50
T_8	$S_3P_3F_{100}$	265.67	89.75	355.42
T_9	$S_3P_3F_{75}$	273.34	90.50	363.84
T_{10}	$S_3P_3F_{50}$	291.85	98.17	390.02
T_{11}	$S_3P_4F_{100}$	314.83	97.50	412.33
T_{12}	$S_3P_4F_{75}$	316.30	102.50	418.80
T_{13}	$S_3P_4F_{50}$	326.99	104.94	431.93
	S.Ed	1.013	4.479	1.109
	CD(P=0.05)	2.054	9.084	2.250

more number of days for maturation than the corresponding three suckers per hill planting under S_2 or S_3 system of planting. There was no significant difference for maturation due to reduction in fertilizer level. T_1 recorded minimum number of days for maturation which was on par with T_2, T_3, T_4, T_8 and T_9.

4.2.3. Total crop duration

Total crop duration differed significantly among the treatments. When compared to control, all the HDP treatments took extended crop duration (Table 8). Planting with four suckers per hill invariably registered more duration than three suckers per hill under both S_2 and S_3 system of planting. With a reduction in the nutrient level supplied, there was a corresponding increase in the crop duration. However the differences in a set of HDP treatments were not different. T_1 recorded minimum crop duration followed by T_2, T_3, T_4, T_8 and T_9.

4.3. Bunch characters

4.3.1. Bunch length

Bunch length differed significantly among the treatments (Table 9). Three suckers per hill and four suckers per hill in S_2 system had registered relatively more bunch length than the control. On the other hand, under wider spacing (S_3), they registered shorter bunch lengths. With a reduction in nutrient level, there was a corresponding reduction in the bunch length.

Table 9. Effect of HDP treatments on bunch characters

Treatments	Code	Bunch length (cm)	Bunch weight (kg)	Number of hands/bunch	Number of fingers/bunch
T_1	$S_1P_1F_{100}$	85.26	28.00	9.73	139.97
T_2	$S_2P_3F_{100}$	88.38	22.45	9.00	126.73
T_3	$S_2P_3F_{75}$	88.23	23.45	9.13	131.60
T_4	$S_2P_3F_{50}$	87.58	24.38	9.19	135.22
T_5	$S_2P_4F_{100}$	86.58	17.47	8.00	108.62
T_6	$S_2P_4F_{75}$	86.21	17.57	8.09	110.27
T_7	$S_2P_4F_{50}$	85.22	18.23	8.33	112.81
T_8	$S_3P_3F_{100}$	84.20	25.38	9.05	134.61
T_9	$S_3P_3F_{75}$	83.20	25.58	9.15	134.27
T_{10}	$S_3P_3F_{50}$	81.50	26.40	9.65	137.45
T_{11}	$S_3P_4F_{100}$	80.45	17.36	7.98	111.11
T_{12}	$S_3P_4F_{75}$	80.20	17.45	8.05	112.11
T_{13}	$S_3P_4F_{50}$	80.05	17.60	8.13	113.69
	S.Ed	0.540	0.496	0.077	4.154
	CD(P=0.05)	1.095	1.006	0.156	8.425

However, the differences were not significant under certain cases. In the S_2 system, T_2 registered the maximum bunch length (88.38 cm).

4.3.2. Bunch weight

Bunch weight differed significantly among the treatments (Table 9). When compared to control, all the HDP treatments registered a reduction in bunch weight. Three suckers per hill planting recorded more bunch weight than four suckers, under both the spacings. Nutrient levels at S_2P_3 or S_3P_3 differed significantly among themselves at F_1 and F_3 levels. Among all the HDP treatments, T_4 recorded the maximum bunch weight next best to control.

4.3.3. Number of hands

Number of hands differed significantly among the treatments. All the HDP treatments registered lesser number of hands than the control (Table 9). Three suckers per hill planting had invariably registered more number of hands per bunch than the corresponding HDP treatments involving four suckers per hill. Wider spacing (S_3) under three suckers had registered more number of hands than under S_2 system. There was no significant reduction in number of hands due to the reduction in fertilizer level. Among the HDP treatments T_4 under S_2 and T_8 under S_3 registered maximum number of hands *viz.*, 9.19 and 9.65 respectively.

4.3.4. Number of fingers

Number of fingers differed significantly among the treatments (Table 9). Among the HDP treatments, four suckers per hill planting under S_2 and S_3 alone did differ significantly from control. Four suckers per hill planting had invariably affected the number of fingers than three suckers per hill planting. There was no significant reduction in number of hands due to reduction in fertilizer level.

4.4. Finger characters

4.4.1. Finger weight

Finger weight differed significantly among the treatments. When compared to control, all the HDP treatments showed reduction in finger weight under both S_2 and S_3 system (Table 10). Three suckers per hill planting registered more finger weight than four suckers per hill planting. In all the cases, with a reduction in the nutrient level, there was an increase in finger weight, even though the differences were not significant. Among the HDP treatments, T_{10} and T_9 under S_3 and T_4 under S_2 recorded maximum finger weight.

4.4.2. Finger length

Finger length differed significantly among the treatments (Table 10). Under both S_2 and S_3 system three suckers per hill registered more length than four suckers per hill planting. Variation in the dose of nutrients applied had no marked effect on finger length. Among the various HDP

Table 10. Effect of HDP treatments on finger characters

Treatments	Code	Finger weight(g)	Finger length(cm)	Finger circumference(cm)	Pulp peel ratio
T_1	$S_1P_1F_{100}$	200.45	26.18	14.83	3.68
T_2	$S_2P_3F_{100}$	177.58	22.13	13.08	3.34
T_3	$S_2P_3F_{75}$	178.55	22.95	13.25	3.37
T_4	$S_2P_3F_{50}$	180.25	23.50	13.45	3.38
T_5	$S_2P_4F_{100}$	159.53	18.78	12.33	2.57
T_6	$S_2P_4F_{75}$	160.79	19.30	12.33	2.70
T_7	$S_2P_4F_{50}$	161.45	20.38	12.50	2.85
T_8	$S_3P_3F_{100}$	188.48	23.60	13.20	3.38
T_9	$S_3P_3F_{75}$	190.45	24.28	13.20	3.42
T_{10}	$S_3P_3F_{50}$	192.05	24.85	13.45	3.68
T_{11}	$S_3P_4F_{100}$	153.53	18.00	12.13	2.35
T_{12}	$S_3P_4F_{75}$	155.60	18.13	12.25	2.48
T_{13}	$S_3P_4F_{50}$	158.50	18.95	12.30	2.53
	S.Ed	3.067	1.027	0.237	0.079
	CD(P=0.05)	6.220	2.084	0.480	0.160

treatments, T_{10} and T_9 under S_3 and T_4 under S_2 registered maximum finger length.

4.4.3. Finger circumference

Finger circumference differed significantly among the treatments. All the HDP treatments affected the circumferences when compared to control (Table 10). Among the HDP treatments, reduction in finger circumference was more pronounced in four suckers/hill planting under S_2 and S_3 system than three suckers per hill planting. With a reduction in the fertilizer level, there was an increase in circumference. However, the differences were trivial to attain statistical differences. T_{10} under S_3 and T_4 under S_2 registered the maximum circumference of finger next to control.

4.4.4. Pulp-peel ratio

Pulp-peel ratio differed significantly among the treatments (Table 10). Three suckers per hill planting under both S_2 and S_3 systems registered higher pulp-peel ratio than the four suckers per hill. There was significant difference for the pulp-peel ratio due to reduction in fertilizer level, under certain set of HDP treatments. T_{10} and T_9 under S_3 and T_4 under S_2 registered the maximum pulp-peel ratio next to control.

4.5. Fruit quality traits

4.5.1. Total soluble solids (TSS)

The TSS showed significant differences among the treatments. When compared to control, all the HDP treatments recorded a reduction in TSS (Table 11a). Three suckers per hill planting under both the spacings registered relatively more TSS than four suckers per hill planting. Irrespective of spacing or per hill planting, it was observed that with a decrease in nutrient level, there was a corresponding reduction in TSS. However, in certain cases, the differences were not statistically perceptible. T_1 recorded maximum TSS followed by T_8

4.5.2. Acidity

Acidity did not show significant differences among the treatments. However, when compared to control, all the HDP treatments recorded more acidity. Increase in nutrient level resulted in decreased acidity (Table 11a).

4.5.3. Ascorbic acid

Ascorbic acid content showed significant differences among the treatments. When compared to control, HDP treatments showed more ascorbic acid content (Table 11a). Four suckers per hill planting, under both spacings registered higher ascorbic acid content than three suckers per hill. With a reduction in the supply of nutrients, there was a corresponding reduction in the ascorbic acid content in all the sets of HDP treatments. However, the differences were apparent.

4.5.4. Sugar acid ratio

Sugar acid ratio showed significant differences among the treatments. When compared to control, all the HDP treatments showed a reduction in sugar acid ratio (Table 11a). This reduction was more pronounced in four

Table 11a. Effect of HDP treatments on fruit quality traits

Treatments	Code	TSS	Acidity (%)	Ascorbic acid (mg/100g)	Sugar acid ratio
T_1	$S_1P_1F_{100}$	23.46	0.27	15.37	78.43
T_2	$S_2P_3F_{100}$	20.73	0.32	16.57	62.35
T_3	$S_2P_3F_{75}$	20.63	0.34	16.64	57.53
T_4	$S_2P_3F_{50}$	20.58	0.35	16.50	54.25
T_5	$S_2P_4F_{100}$	19.37	0.35	17.84	57.14
T_6	$S_2P_4F_{75}$	19.17	0.36	17.73	51.87
T_7	$S_2P_4F_{50}$	19.12	0.38	17.46	50.37
T_8	$S_3P_3F_{100}$	23.23	0.28	16.35	75.46
T_9	$S_3P_3F_{75}$	22.97	0.28	15.36	63.38
T_{10}	$S_3P_3F_{50}$	22.68	0.30	15.43	60.83
T_{11}	$S_3P_4F_{100}$	22.23	0.32	16.60	65.83
T_{12}	$S_3P_4F_{75}$	22.17	0.32	16.33	64.92
T_{13}	$S_3P_4F_{50}$	21.89	0.33	16.21	60.58
	S.Ed	0.006	0.051	0.167	0.081
	CD(P=0.05)	0.012	NS	0.339	0.165

suckers planting, under both S_2 and S_3 spacings than in three suckers per hill planting. Irrespective of spacing and planting per hill, sugar acid ratio decreased with a decrease in the nutrients applied. T_8 recorded maximum sugar acid ratio (75.459) next close to the control (78.43).

4.5.5. Total sugar

Total sugar differed significantly among the treatments. When compared to control, all the HDP treatments except T_8 significantly showed reduced total sugar contents in fruits (Table 11b). Three suckers per hill planting under both S_2 and S_3 registered higher total sugars than four suckers per hill. With a reduction in the nutrient level, there was a corresponding reduction in the total sugars, however under four suckers per hill the differences were not perceptible. T_8, T_9 and T_{10} under S_3 and T_2 under S_2 recorded the maximum total sugar content very close to control.

Similar trend was observed for reducing and non reducing sugars also. T_8, T_9 and T_{10} under S_3 and T_2 under S_2 continued to register maximum reducing sugars and non reducing sugars close to control.

4.6. Effect of HDP on other parameters

4.6.1. Light transmission ratio

Light transmission ratio (LTR) at 3rd month after planting showed significant differences among the treatments (Table 12). When compared to control, all the HDP treatments affected the LTR. Four suckers per hill

Table 11b. Effect of HDP treatments on fruit quality traits

Treatments	Code	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)
T_1	$S_1P_1F_{100}$	21.21	14.50	6.71
T_2	$S_2P_3F_{100}$	20.15	13.48	6.83
T_3	$S_2P_3F_{75}$	19.68	13.44	6.24
T_4	$S_2P_3F_{50}$	19.15	13.08	6.00
T_5	$S_2P_4F_{100}$	18.45	12.81	5.64
T_6	$S_2P_4F_{75}$	18.34	12.78	5.56
T_7	$S_2P_4F_{50}$	18.28	12.72	5.60
T_8	$S_3P_3F_{100}$	21.38	13.50	7.88
T_9	$S_3P_3F_{75}$	20.48	13.74	6.74
T_{10}	$S_3P_3F_{50}$	20.20	13.62	6.58
T_{11}	$S_3P_4F_{100}$	18.44	13.13	5.31
T_{12}	$S_3P_4F_{75}$	18.37	13.28	5.34
T_{13}	$S_3P_4F_{50}$	18.23	13.93	5.00
	S.Ed	0.130	0.207	0.157
	CD(P=0.05)	0.264	0.421	0.318

Table 12. Effect of HDP treatments on light transmission ratio at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting
T_1	$S_1P_1F_{100}$	23.62	35.01	42.64	47.97
T_2	$S_2P_3F_{100}$	20.84	29.20	37.78	42.48
T_3	$S_2P_3F_{75}$	21.40	29.75	38.43	42.70
T_4	$S_2P_3F_{50}$	21.74	29.78	38.66	43.16
T_5	$S_2P_4F_{100}$	19.84	27.51	37.38	40.57
T_6	$S_2P_4F_{75}$	20.39	27.62	37.50	41.29
T_7	$S_2P_4F_{50}$	20.66	27.54	37.49	42.41
T_8	$S_3P_3F_{100}$	23.93	31.77	40.57	46.48
T_9	$S_3P_3F_{75}$	23.58	31.79	41.42	46.85
T_{10}	$S_3P_3F_{50}$	22.71	32.52	41.77	47.46
T_{11}	$S_3P_4F_{100}$	22.79	29.66	39.40	46.07
T_{12}	$S_3P_4F_{75}$	22.58	29.399	39.39	45.63
T_{13}	$S_3P_4F_{50}$	21.71	30.23	39.47	46.36
	S.Ed	0.643	0.404	0.528	0.746
	CD(P=0.05)	1.305	0.819	1.072	1.513

registered relatively reduced LTR than three suckers per hill under both S_2 and S_3 systems of planting. Similar trend was observed at 5^{th}, 7^{th} months and shooting stages. However, at shooting stage, there was significant difference between three and four suckers per hill planting under S_2, but they did not show any marked difference under S_3. Reduction in nutrient levels did not alter the LTR under S_2 system at all stages of observation.

4.6.2. Weed growth

Weed growth differed significantly among the treatments at all stages of observation. When compared to control, all the HDP treatments showed lesser weed growth (Table 13). Planting with four suckers per hill invariably registered lesser weed growth under both S_2 and S_3 systems of planting. With a decrease in fertilizer level, there was a numerical decrease in the weed growth.

4.6.3. Leaf spot

Leaf spot incidence differed significantly among the treatments. Planting with four suckers per hill registered invariably more leaf spot than three suckers per hill under both S_2 and S_3 systems of planting (Table 14). T_1 recorded the minimum per cent of leaf spot which was on par with T_8, T_9, T_{10}, T_4, T_{11}, T_{12} and T_{13}. Similar trend in leaf spot disease incidence was observed during the second stage of observation.

Table 13. Effect of HDP treatments on weed growth (dry wt g/m^2) at different stages

Treatments	Code	3rd month	5th month	7th month	9th month
T_1	$S_1P_1F_{100}$	266.11	111.61	137.69	141.05
T_2	$S_2P_3F_{100}$	208.14	77.82	82.38	90.36
T_3	$S_2P_3F_{75}$	203.18	71.29	80.58	88.26
T_4	$S_2P_3F_{50}$	197.12	67.17	78.61	82.84
T_5	$S_2P_4F_{100}$	183.57	64.75	68.58	72.81
T_6	$S_2P_4F_{75}$	168.17	63.79	67.71	70.88
T_7	$S_2P_4F_{50}$	159.04	56.19	65.87	69.94
T_8	$S_3P_3F_{100}$	261.07	95.72	120.36	125.38
T_9	$S_3P_3F_{75}$	254.73	95.25	116.81	122.33
T_{10}	$S_3P_3F_{50}$	248.09	94.24	115.58	120.14
T_{11}	$S_3P_4F_{100}$	239.46	83.96	110.36	114.53
T_{12}	$S_3P_4F_{75}$	226.12	82.85	107.37	106.89
T_{13}	$S_3P_4F_{50}$	210.31	82.12	98.31	103.71
	S.Ed	4.953	3.949	4.822	3.118
	CD(P=0.05)	10.046	8.010	9.781	6.324

Table 14. Effect of HDP treatments on leaf spot incidence (%) at different dates

Treatments	Code	210DAP	270DAP
T_1	$S_1P_1F_{100}$	1.24	1.33
T_2	$S_2P_3F_{100}$	2.02	2.15
T_3	$S_2P_3F_{75}$	1.98	2.10
T_4	$S_2P_3F_{50}$	1.94	2.05
T_5	$S_2P_4F_{100}$	3.32	2.42
T_6	$S_2P_4F_{75}$	3.22	2.40
T_7	$S_2P_4F_{50}$	3.14	2.39
T_8	$S_3P_3F_{100}$	1.44	1.58
T_9	$S_3P_3F_{75}$	1.20	1.54
T_{10}	$S_3P_3F_{50}$	1.17	1.53
T_{11}	$S_3P_4F_{100}$	1.60	1.85
T_{12}	$S_3P_4F_{75}$	1.55	1.85
T_{13}	$S_3P_4F_{50}$	1.31	1.81
	S.Ed	0.338	0.022
	CD(P=0.05)	0.685	0.044

4.6.4. Stem weevil incidence

The stem weevil incidence was found to be generally higher at HDP per pit. It ranged from 4.4-6.5 per cent under P_3 system of planting in S_2 while it ranged from 5.83-7.50 in P_4 under S_2 as against 3.50 per cent in conventional planting (Table 15).

4.7. Effect of high density planting on soil and leaf nutrients

4.7.1. Soil available nitrogen

Soil available nitrogen at 3rd month after planting, did not differ among the treatments. However, at subsequent stages *viz.*, 5th, 7th months, flowering and harvesting stages, there was marked variation among the treatments (Table 16). At all stages, HDP treatments had registered lower soil available nitrogen than the control. Besides, HDP treatments involving closer spacing (S_2) resulted in more of soil available nitrogen than under wider spacing (S_3). Among the three and four suckers/hill planting invariably the treatments with four hill planting at all stages showed lesser amount of available nitrogen under S_2 and S_3 systems of planting. Irrespective of the spacing or per hill planting, decreased soil available nitrogen was evident with a decrease in nutrient supplied at all stages. T_2 at 5th month and T_8 at 7th months, flowering and harvesting stages registered the maximum soil available nitrogen next to the control.

Table 15. Effect of HDP treatments stem weevil incidence

Treatments	Code	Stem weevil incidence (%)
T_1	$S_1P_1F_{100}$	3.50
T_2	$S_2P_3F_{100}$	6.50
T_3	$S_2P_3F_{75}$	5.50
T_4	$S_2P_3F_{50}$	4.40
T_5	$S_2P_4F_{100}$	7.50
T_6	$S_2P_4F_{75}$	6.60
T_7	$S_2P_4F_{50}$	5.83
T_8	$S_3P_3F_{100}$	4.76
T_9	$S_3P_3F_{75}$	3.10
T_{10}	$S_3P_3F_{50}$	1.58
T_{11}	$S_3P_4F_{100}$	5.35
T_{12}	$S_3P_4F_{75}$	4.46
T_{13}	$S_3P_4F_{50}$	3.80

Table 16. Effect of HDP treatments on soil available nitrogen (kg/ha) at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting	Harvest
T_1	$S_1P_1F_{100}$	137.20	190.00	225.80	202.80	187.28
T_2	$S_2P_3F_{100}$	135.00	180.10	210.30	190.60	176.23
T_3	$S_2P_3F_{75}$	135.50	152.30	180.50	160.20	146.52
T_4	$S_2P_3F_{50}$	135.00	142.20	160.30	141.78	125.54
T_5	$S_2P_4F_{100}$	135.00	177.60	200.50	185.53	171.51
T_6	$S_2P_4F_{75}$	134.00	150.30	170.20	155.43	141.42
T_7	$S_2P_4F_{50}$	133.00	130.20	150.10	135.75	121.57
T_8	$S_3P_3F_{100}$	137.00	176.70	220.48	197.02	184.38
T_9	$S_3P_3F_{75}$	137.50	146.30	195.25	180.43	163.16
T_{10}	$S_3P_3F_{50}$	136.50	126.20	175.30	160.38	143.79
T_{11}	$S_3P_4F_{100}$	131.60	162.40	200.60	195.50	182.39
T_{12}	$S_3P_4F_{75}$	131.60	129.90	170.80	165.18	150.20
T_{13}	$S_3P_4F_{50}$	131.60	112.40	150.90	145.25	120.41
	S.Ed	4.373	6.852	5.073	3.133	1.830
	CD(P=0.05)	NS	13.899	10.290	6.355	3.713

4.7.2. Soil available phosphorus

Available phosphorus at 3rd month after planting differed significantly among the treatments. Most of the HDP treatments were found to be on par except T_2, in which, soil available phosphorus registered the maximum. (Table 17).

Available phosphorus at 5th, 7th months after planting and at shooting and harvesting stages differed significantly among the treatments. It was more in three suckers planting under both the spacings than in four suckers per hill planting at all stages. Irrespective of the spacing or per hill planting, the soil available P was found to be lower with decrease in nutrient supplied. Among the various HDP treatments, T_2 and T_8 recorded higher available phosphorus.

4.7.3. Soil available potassium

Soil available potassium differed significantly at all stages of observations (Table 18). Except at 3rd month stage, invariably at other stages, available potassium was found to be more under three suckers per hill planting than under four suckers per hill planting. Among the HDP treatments T_2 under S_2 and T_8 under S_3 resulted in more soil available K as compared to control at most of the stages.

4.7.4. Leaf nitrogen

Leaf nitrogen at 3rd, 5th, 7th months after planting and also at flowering and harvest stages differed significantly among the treatments

Table 17. Effect of HDP treatments on soil available phosphorus (kg/ha) at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting	Harvest
T_1	$S_1P_1F_{100}$	16.18	18.43	22.38	18.82	15.03
T_2	$S_2P_3F_{100}$	16.85	16.78	21.44	17.64	14.48
T_3	$S_2P_3F_{75}$	16.16	15.25	19.74	16.45	13.24
T_4	$S_2P_3F_{50}$	16.16	14.18	18.22	16.40	12.48
T_5	$S_2P_4F_{100}$	16.26	15.78	20.25	16.50	12.51
T_6	$S_2P_4F_{75}$	16.28	14.28	18.24	15.34	11.35
T_7	$S_2P_4F_{50}$	16.22	13.60	17.29	14.70	11.23
T_8	$S_3P_3F_{100}$	16.24	14.78	22.46	18.07	14.18
T_9	$S_3P_3F_{75}$	16.20	14.25	20.42	17.13	12.75
T_{10}	$S_3P_3F_{50}$	16.24	12.73	19.46	16.03	12.25
T_{11}	$S_3P_4F_{100}$	16.25	14.50	20.52	16.25	12.75
T_{12}	$S_3P_4F_{75}$	16.24	12.80	18.75	15.11	12.50
T_{13}	$S_3P_4F_{50}$	16.17	12.18	17.51	14.15	11.75
	S.Ed	0.163	0.114	0.064	0.079	0.062
	CD(P=0.05)	0.331	0.231	0.130	0.160	0.126

Table 18. Effect of HDP treatments on soil available potassium(kg/ha) at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting	Harvest
T_1	$S_1P_1F_{100}$	471.45	506.05	515.73	495.19	470.58
T_2	$S_2P_3F_{100}$	464.05	495.78	506.42	490.54	465.19
T_3	$S_2P_3F_{75}$	463.08	465.15	475.29	460.54	435.56
T_4	$S_2P_3F_{50}$	461.35	445.23	454.76	440.54	415.13
T_5	$S_2P_4F_{100}$	470.68	490.65	495.55	483.23	465.20
T_6	$S_2P_4F_{75}$	472.20	460.90	464.76	453.78	435.41
T_7	$S_2P_4F_{50}$	470.50	440.25	445.43	426.95	415.55
T_8	$S_3P_3F_{100}$	473.29	503.60	510.15	494.48	470.63
T_9	$S_3P_3F_{75}$	471.43	473.34	480.60	463.92	440.83
T_{10}	$S_3P_3F_{50}$	472.38	454.84	460.62	445.28	420.68
T_{11}	$S_3P_4F_{100}$	470.46	484.02	495.97	474.42	450.34
T_{12}	$S_3P_4F_{75}$	469.30	458.22	465.79	445.10	416.91
T_{13}	$S_3P_4F_{50}$	468.19	444.08	445.57	425.37	401.64
	S.Ed	2.061	3.675	1.352	3.315	2.047
	CD(P=0.05)	4.180	7.454	2.743	6.724	4.153

(Table 19). All the HDP treatments registered lower leaf nitrogen content than the control at all stages of observations. With a reduction in the nutrient level, there was a corresponding reduction in the leaf nitrogen content at all stages excepting few cases. Among the treatments, T_8 registered the maximum leaf nitrogen content next to control at all stages of observations. Irrespective of the treatments, the maximum leaf nitrogen content was observed at 5th month after planting.

4.7.5. Leaf phosphorus

Leaf phosphorus at all stages differed significantly among the treatments. Invariably, the HDP treatments registered lesser leaf phosphorus content than control at all stages (Table 20). Under both S_2 and S_3 system, three suckers per hill planting had registered relatively higher leaf phosphorus content than the four suckers per hill at any stages of observations. With a reduction in the nutrient supplied, there was a corresponding reduction in leaf phosphorus content at all stages of observations. Irrespective of planting density or number of suckers planted per hill, T_8 under S_3 and T_2 under S_2 registered maximum leaf phosphorus content next to control at all stages. In all the treatments, the highest leaf P content was observed at 7th month stage.

4.7.6. Leaf potassium

Leaf K content differed significantly among the treatments at all stages of observations. All the HDP treatments registered lesser leaf K content than control at all stages (Table 21). Three suckers per hill under

Table 19. Effect of HDP treatments on leaf nitrogen (%) at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting	Harvest
T_1	$S_1P_1F_{100}$	2.38	2.61	2.80	2.25	1.97
T_2	$S_2P_3F_{100}$	2.18	2.36	2.63	2.23	1.82
T_3	$S_2P_3F_{75}$	2.16	2.35	2.60	2.20	1.78
T_4	$S_2P_3F_{50}$	2.12	2.29	2.59	2.09	1.76
T_5	$S_2P_4F_{100}$	2.25	2.40	2.66	2.09	1.81
T_6	$S_2P_4F_{75}$	2.21	2.31	2.62	2.07	1.78
T_7	$S_2P_4F_{50}$	1.98	2.26	2.57	2.05	1.78
T_8	$S_3P_3F_{100}$	2.26	2.48	2.66	2.15	1.88
T_9	$S_3P_3F_{75}$	2.21	2.38	2.65	2.12	1.85
T_{10}	$S_3P_3F_{50}$	2.20	2.34	2.63	2.13	1.83
T_{11}	$S_3P_4F_{100}$	2.05	2.24	2.53	2.05	1.74
T_{12}	$S_3P_4F_{75}$	1.98	2.20	2.49	2.04	1.72
T_{13}	$S_3P_4F_{50}$	1.98	2.18	2.44	2.02	1.72
	S.Ed	0.032	0.068	0.034	0.007	0.011
	CD(P=0.05)	0.064	0.139	0.068	0.014	0.022

Table 20. Effect of HDP treatments on leaf phosphorus (%) at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting	Harvest
T_1	$S_1P_1F_{100}$	0.082	0.094	0.237	0.114	0.108
T_2	$S_2P_3F_{100}$	0.072	0.083	0.226	0.102	0.098
T_3	$S_2P_3F_{75}$	0.070	0.082	0.221	0.098	0.094
T_4	$S_2P_3F_{50}$	0.068	0.079	0.220	0.096	0.090
T_5	$S_2P_4F_{100}$	0.066	0.071	0.216	0.094	0.086
T_6	$S_2P_4F_{75}$	0.064	0.069	0.215	0.087	0.084
T_7	$S_2P_4F_{50}$	0.063	0.067	0.218	0.090	0.082
T_8	$S_3P_3F_{100}$	0.078	0.084	0.219	0.108	0.106
T_9	$S_3P_3F_{75}$	0.076	0.082	0.219	0.106	0.104
T_{10}	$S_3P_3F_{50}$	0.074	0.078	0.217	0.102	0.102
T_{11}	$S_3P_4F_{100}$	0.064	0.067	0.208	0.084	0.076
T_{12}	$S_3P_4F_{75}$	0.063	0.066	0.203	0.082	0.074
T_{13}	$S_3P_4F_{50}$	0.062	0.065	0.196	0.078	0.072
	S.Ed	0.0059	0.0057	0.0036	0.0030	0.0030
	CD(P=0.05)	0.0119	0.0116	0.0073	0.0061	0.0062

Table 21. Effect of HDP treatments on leaf potassium (%) at different stages

Treatments	Code	3rd month	5th month	7th month	Shooting	Harvest
T_1	$S_1P_1F_{100}$	4.21	4.43	5.38	5.09	4.77
T_2	$S_2P_3F_{100}$	3.97	4.22	5.12	4.57	4.26
T_3	$S_2P_3F_{75}$	3.97	4.18	5.08	4.52	4.20
T_4	$S_2P_3F_{50}$	3.96	4.14	5.06	4.48	4.18
T_5	$S_2P_4F_{100}$	3.97	3.98	4.76	4.23	4.12
T_6	$S_2P_4F_{75}$	3.93	3.97	4.68	4.19	4.10
T_7	$S_2P_4F_{50}$	3.88	3.93	4.52	4.17	4.03
T_8	$S_3P_3F_{100}$	3.98	4.12	5.04	4.44	4.21
T_9	$S_3P_3F_{75}$	3.99	4.06	5.02	4.39	4.16
T_{10}	$S_3P_3F_{50}$	3.95	3.97	4.98	4.27	4.12
T_{11}	$S_3P_4F_{100}$	3.87	3.97	4.48	4.13	3.98
T_{12}	$S_3P_4F_{75}$	3.83	3.93	4.33	4.09	3.73
T_{13}	$S_3P_4F_{50}$	3.79	3.87	4.28	4.07	3.59
	S.Ed	0.010	0.005	0.005	0.098	0.096
	CD(P=0.05)	0.021	0.010	0.009	0.200	0.194

S_2 and S_3 systems recorded relatively more leaf K content than four suckers per hill at all stages except at 3rd month after planting. With a reduction in the nutrient applied, there was a corresponding reduction in the leaf K content, irrespective of planting density or number of suckers per hill. T_8 under S_3 and T_2 under S_2 continued to register the maximum leaf K content next to control at 5th month and subsequent stages. In all the cases, the highest leaf K content was observed at 7th month after planting.

4.8. Economics of HDP treatments

4.8.1. Harvest percentage

When compared to control, harvest percentage was low in all the HDP treatments. Among them three suckers per hill render more harvest percentage than four suckers per hill (Table 22).

4.8.2. Yield and Cost benefit ratio

Among the various HDP treatments, T_4 registered maximum estimated yield of 110 t/ha as against 86.41 t/ha under conventional planting. All the HDP treatments under S_3 system of planting registered lesser calculated tonnes per hectare than the conventional planting. The cost benefit ratio was found to be maximum with the treatment T_4 (1: 3.85) as against 1: 2.75 under conventional planting. All the P_4 planting under S_2 or S_3 system had minimum cost benefit ratio than conventional planting (Table 22).

Table 22. Economics of cultivation in different treatments

Treatments	Code	Harvest percentage	Yield (t/ha)	Cost of cultivation(Rs)	Total income (Rs)	Net profit (Rs)	Cost benefit ratio
T_1	$S_1P_1F_{100}$	100.00	86.41	92058.36	345632.00	253573.64	1:2.75
T_2	$S_2P_3F_{100}$	96.67	100.44	101913.30	401761.20	299847.90	1: 2.94
T_3	$S_2P_3F_{75}$	96.67	104.92	96450.74	419661.20	323210.44	1:3.35
T_4	$S_2P_3F_{50}$	97.78	110.35	90988.14	441395.04	350406.90	1:3.85
T_5	$S_2P_4F_{100}$	90.00	97.05	156065.42	388169.40	232101.98	1:1.48
T_6	$S_2P_4F_{75}$	90. 00	97.60	145716.58	390391.32	244684.74	1:1.67
T_7	$S_2P_4F_{50}$	88.97	100.10	141498.39	400419.76	258921.37	1:1.82
T_8	$S_3P_3F_{100}$	96.83	56.87	57420.82	227469.76	170048.94	1:2.96
T_9	$S_3P_3F_{75}$	96.83	57.32	53936.58	229962.28	175325.70	1:3.25
T_{10}	$S_3P_3F_{50}$	95.00	58.04	51205.87	232140.48	180934.61	1:3.53
T_{11}	$S_3P_4F_{100}$	90.17	48.31	71777.89	193226.52	121448.63	1:1.69
T_{12}	$S_3P_4F_{75}$	89.28	48.05	68136.14	192201.32	124065.17	1:1.82
T_{13}	$S_3P_4F_{50}$	88.30	47.97	64496.39	191835.04	127328.65	1:1.97

DISCUSSION

CHAPTER 5

DISCUSSION

High density planting is one of the recent and novel concepts of increasing the productivity per unit area in fruit crops including banana. Its productivity under HDP depends upon the extent of the utilization of solar energy which is abundant in tropical areas. An ideal planting density is often determined by complex integration of factors such as cultivar, soil fertility, management level and economic consideration. In the present study, the cultivar Robusta, which belongs to the Cavendish group and is an important principal variety grown in South India was experimented. It has a distinct advantage over other varieties in yield and taste. Under Tamil Nadu condition, this variety is grown mostly under garden land conditions where average potential yield is reported to be 50-60 t/ha (Anon, 1994). Further improvement of yield potential in this cultivar is possible by increasing the plant density by narrowing down the spacing than the recommended one in such a way that it results in optimum land use, higher yields per unit area without affecting the quality of the harvested produce. Earlier studies on high density planting in banana resulted in higher yield vis a vis conventional planting densities (Venero and Marquez, 1979; Chattopadhyadhy *et al.*, 1980, 1985; Reddy, 1982; Reddy and Singh, 1993; Manivannan, 1994).

Another way by which HDP could be achieved is by planting more than one sucker per hill. Such studies on the effect of planting more than one sucker/per hill in combination with variable planting distances are meagre. However, preliminary studies on this conducted earlier in Tamil Nadu showed encouraging results.

Bhakthavatsalu *et al.* (1972) reported that at Cumbum valley of Madurai district two plants/pit were planted at 6 x 6' (1.8 x 1.8 m) spacing to obtain double the number of bunches from the same area, with little or no influence on bunch size and time of maturity of plant crop in cv. Dwarf Cavendish. Alagiamanavalan and Balakrishnan (1976) adopted double planting (2.4 x 1.8 m) in cv. Robusta and obtained 37.70 kg of bunch weight per clump of two plants as against 20.42 kg in single planting, indicating there is a slight reduction in mean bunch weight per plant. Recently, Elain Apshara (1997) compared single, double and three suckers planting per hill at a varying spacing of 2 x 2 m, 2 x 2.5 m, 2 x 3 m and found that yield could be increased substantially per unit area by planting three suckers per hill in cv. Nendran. The above studies showed that HDP by altering the spacing and also by planting more number of suckers/hill is possible in crops like banana. Belalcazar *et al.* (1990a, 1994) lamented that this kind of new options for HDP require to treat the plants as annual rather than perennial system of cultivation. The cv. Robusta is normally grown as an annual crop in Tamil Nadu because of the nematode problem as against the old practice of taking ratoon crop. Hence, the present investigation in the above line is appropriate for cv. Robusta.

In the present investigation, apart from recommended spacing of 1.8x1.8 m with one sucker per hill, two wider spacings namely 1.8 x 3.6 m and 3.6 x 3.6 m, but planting three as well as four suckers per hill were taken up for comparison. This has resulted in increased population of 50-100 per cent over the conventional system. Testing of HDP with more number of suckers per hill at wider spacing than the adopted one is appropriate as banana is often grown as intercrop in coconut plantations in the alley spaces. In such a situation, use of wider spacing may permit easy cultural operations for the main as well as to the intercrops. It is interesting to indicate that no report is available about planting four suckers/hill so far from any research centre. In practice, more than four clumps per mat are normally maintained in Upper Pulney hills in cv. Virupakshi. In any high density plantations, increase in number of plants/ha has direct influence on vegetative traits, crop cycles, yield and yield components including quality of the produce. In the present investigation, the effect of HDP is discussed under the following broad head lines.

5.1.Effect of HDP on vegetative characters

Height and girth of the pseudostem at all stages of growth were affected significantly under HDP than conventional planting. The increase in pseudostem height or reduction in the pseudostem girth under HDP system is a normal phenomenon reported by many workers (Ahmed and Mannan, 1970; Chattopadhyay *et al.*, 1980; Reddy, 1982; Anon, 1989). This is primarily due to the mutual shading of plants resulting in competitive growth rate to intercept the light (Murray, 1960). Among the various HDP treatments, three suckers planted under S_2 system had the minimum effect on increased plant height or reduced girth (Fig. 2a and 2b). This is because of the simple fact that the increased population in this treatment was 50 per cent more compared to conventional planting. On the other hand, 3 or 4 suckers planting under S_3 system though had lesser population than conventional planting, plant height as well as girth were affected negatively indicating the influence of intramat competition for light. Hence, this may not be a suitable system to have HDP.

Various agroclimatic, genetic and cultural factors influence the leaf production in banana (Turner, 1970). In the present study, the leaf number recorded at various stages of observation differed significantly from conventional planting. Three or four sucker planting under both the systems had more number of leaves than conventional planting (Fig. 3a). Robinson and Nel (1989) and Elain Apshara (1997) also obtained similar results. The plants in high density produced more number of leaves to overcome competition and this may be also due to the prolonged vegetative growth phase caused by microclimate with low temperature and more shade.

Fig 2a.Influence of plant density on pseudostem height (m) at shooting

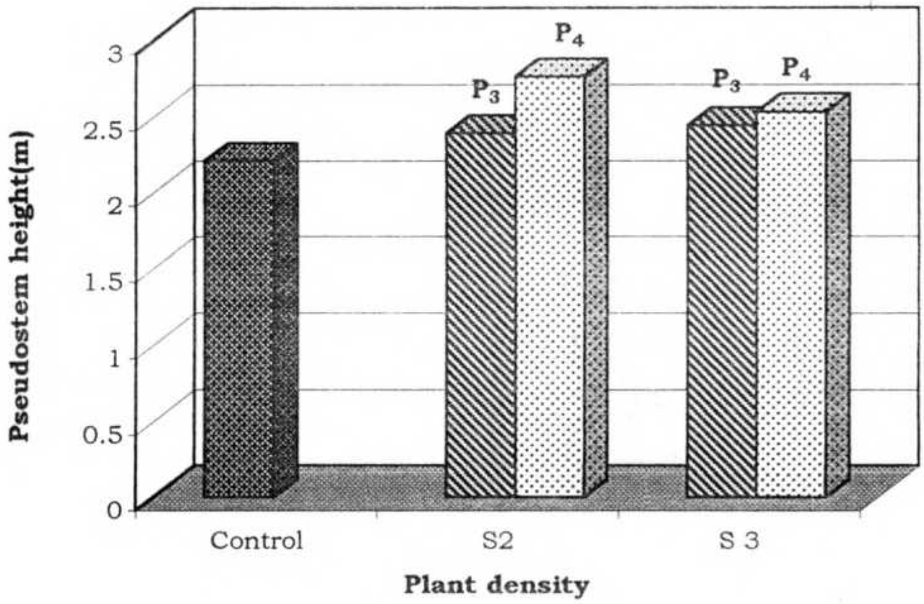


Fig 2b.Influence of plant density on pseudostem girth(m) at shooting

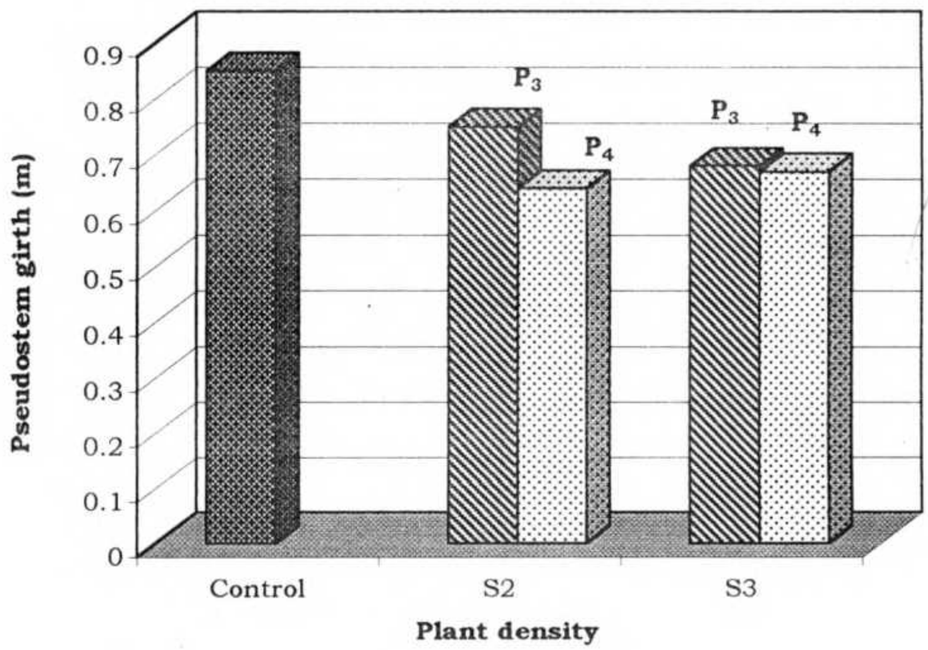


Fig 3a.Influence of plant density on number of leaves at shooting

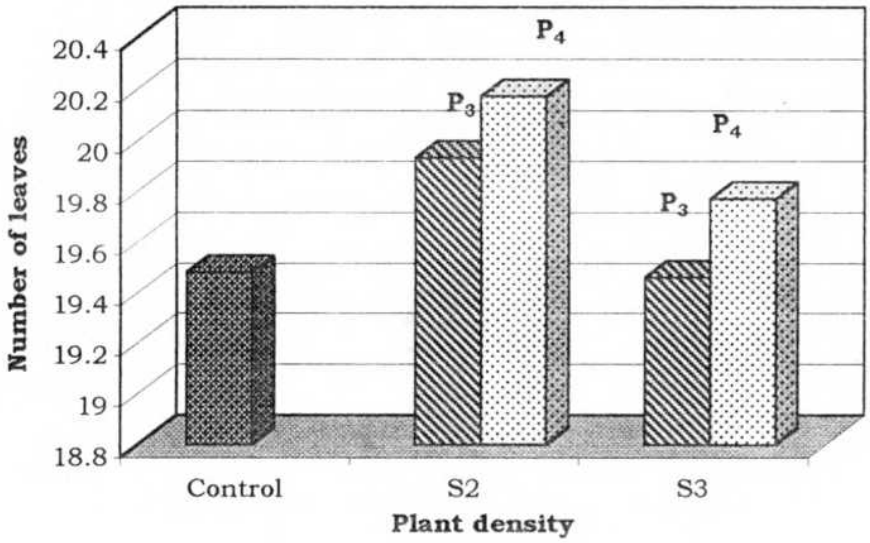
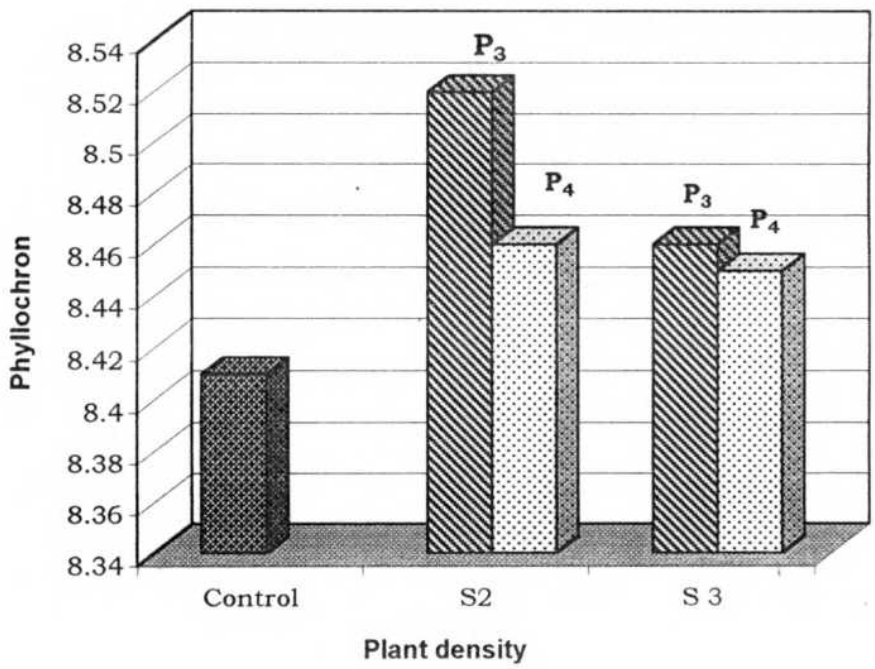


Fig 3b.Influence of plant density on phyllochron at shooting



The phyllochron or the rate of leaf emergence should be at closer intervals in any system of planting so that the vegetative crop cycle is not extended unduly. In the present investigation, the phyllochron between HDP and conventional planting did not differ at any of the stages though numerically HDP treatments showed slightly wider intervals of leaf production (Fig. 3b). Leaf emergence is normally reported to be at slower rate under very closer planting owing to low temperature experienced inside the canopy as temperature had greater influence on leaf production (Robinson and Nel, 1989; Singh, 1990). The reason for not expecting such a drastic reduction in leaf emergence in the present investigation was probably due to spatial arrangement in such a way that the three or four suckers planted had a tendency to grow slightly in inclined angle. Summerville (1944) reported that time interval for emergence of successive leaf is seven days. The phyllochron interval varied from 7 – 8.5 in most of the treatments in the present case depending upon the stages.

The leaf area was found to be higher under HDP treatments when compared to the conventional planting during vegetative phase, however, the differences did not sustain at shooting stages. It is interesting to note that between the three or four suckers per hill planting four suckers planting had invariably more of leaf area than corresponding three suckers per hill (Fig. 4a). This increased leaf area under four suckers planting was due to more number of leaves recorded in these treatments as already discussed. The failure to find difference in leaf area at shooting stage was normally

Fig 4a.Influence of plant density on leaf area(m^2) at shooting

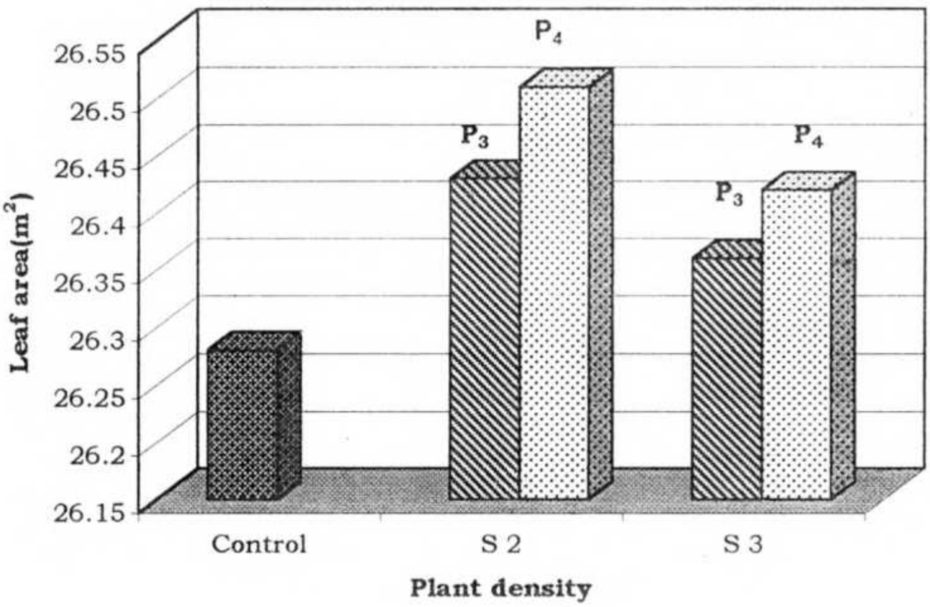
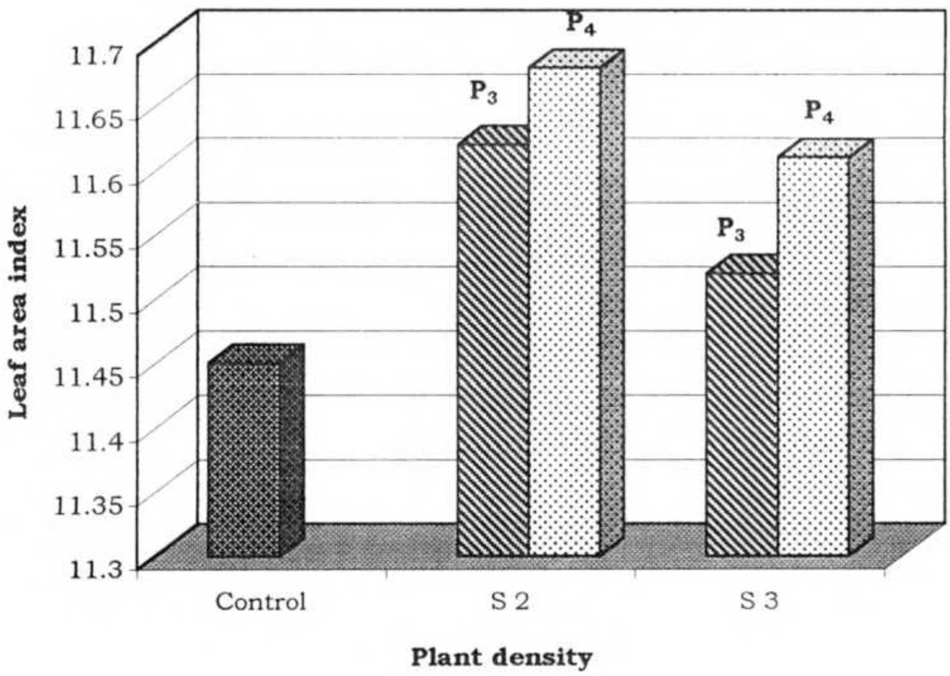


Fig 4b.Influence of plant density on leaf area index (LAI) at shooting



expected as towards shooting stage the leaf production become slower and almost static.

More than the leaf area, leaf are index (LAI) will be an ideal factor to determine the effect of planting density in banana on the vegetative growth. Stover (1984) was of the opinion that LAI is an useful guide in canopy management in banana. In the present study, LAI observed at third month after planting alone did not show significant differences among the treatments. Probably due to lesser number of leaves available at this stage. When compared to control, four suckers planting at S_2 as well as S_3 system had more LAI than the corresponding three suckers planting indicating that HDP always resulted in more LAI in banana (Fig. 4b and 9a). This view has been shared by many workers (Reddy, 1982; Turner, 1982; Stover, 1984; Elain Apshara, 1997) were of the opinion that critical LAI necessary for maximum utilization of photosynthetically effective radiation is in the range of 4 – 4.5. In the present study, the LAI achieved was more than the critical level suggested by Stover (1984) from 7th month onwards.

Sucker production recorded at early vegetative phase as well as at shooting showed that HDP had resulted in lesser number of suckers than normal planting system. This is mainly due to the shade prevailed in high density planting. Competition for moisture and nutrients might be high under HDP and hence resources were utilized more by the plant for its own growth than promoting sucker production. Between the three and four suckers per hill planting, four suckers had lesser sucker production. Stover and Simmonds (1987) observed that intramat competition is intensified when two or three or more followers are allowed to develop and mature fruit, resulting in root rhizome competition for space, water and nutrients. They further stated that plants from doubles are smaller than single follower.

5.2. Effect of HDP on crop duration

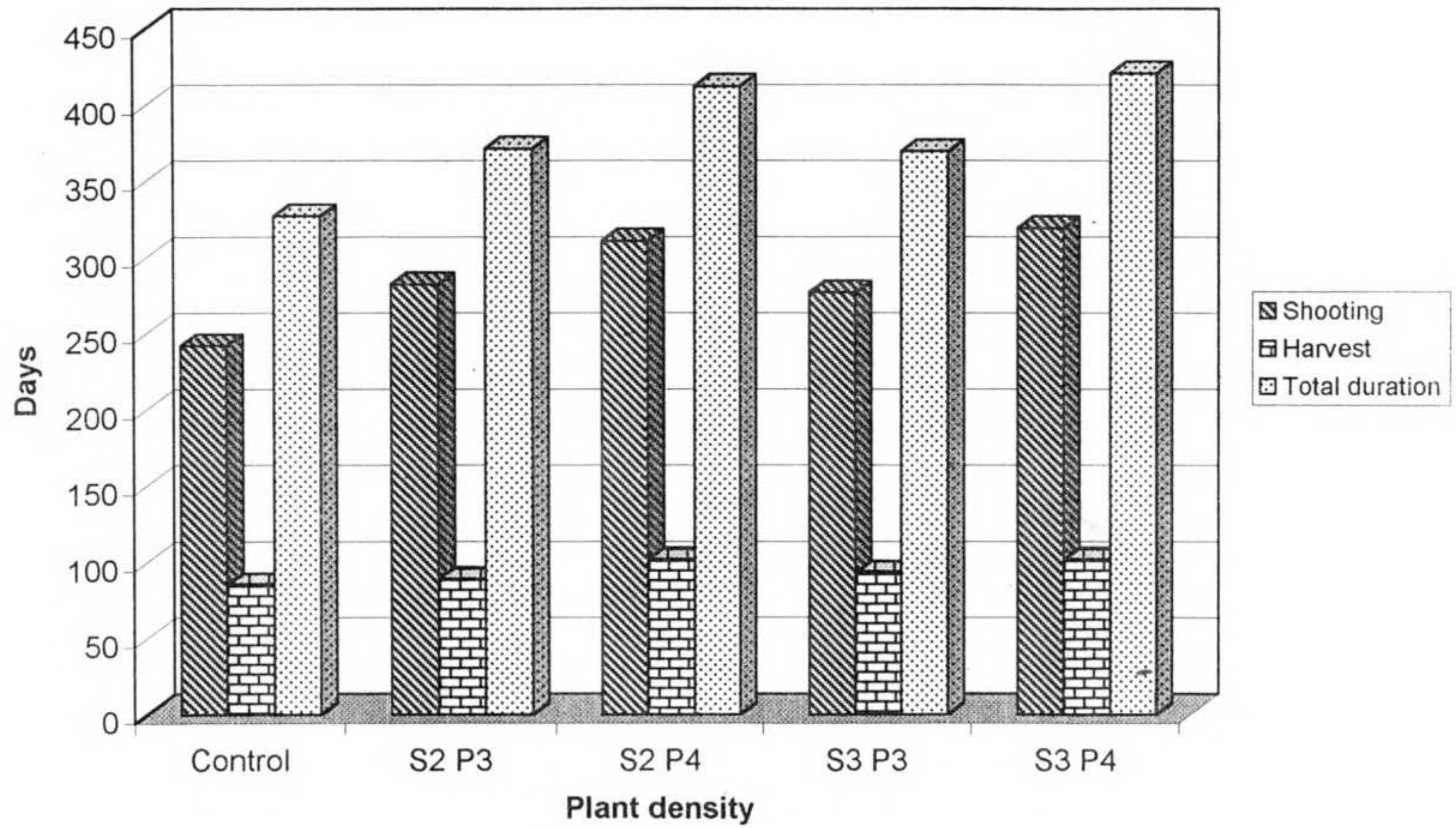
Crop duration or crop cycle interval in the case of ratoon crop is an important factor to be considered in banana. Robusta being a annually replanted variety, the crop duration from planting to harvest should be taken into consideration. This crop duration can be divided into two phases namely days taken from planting to shooting and days taken from shooting to harvest, otherwise known as vegetative cycle and bunch development phases respectively. The effect of HDP in the present investigation showed pronounced extension of crop duration including total crop duration. Almost all the HDP experiments conducted both in India as well as in other countries had also resulted in an extension in the crop duration. Oppenheimer and Gottreich (1960), Mondal (1993), Manivannan (1994) and Krishnakumary *et al.* (1995) reported that when the duration was split into vegetative as well as bunch development stages, it was very clear that HDP treatments had very markedly extended days from shooting to bunch development stage. In the present study, manifestation of such an extension in vegetative cycle was partly due to the slow rate of leaf emergence and partly by an increased total leaf production per plant. These two effects became more pronounced as canopy LAI increased under HDP. Between the three as well as four suckers per hill planting in S_2 or S_3 systems in present investigation, four suckers per hill planting always experienced an extended crop duration inclusive of days taken from planting to shooting and shooting to harvest (Fig. 5). This clearly states that HDP/pit had marked effect on the crop duration due to competition between plants resulting in more number of days for growth, development and maturation as indicated below:

Comparison of mean of certain parameters between P_1, P_3 and P_4 planting pattern

Characters	P_1	P_3	P_4
Plant height (m)	2.21	2.42	2.65
Plant girth (m)	0.85	0.72	0.66
Number of leaves	19.48	19.70	19.97
Leaf area (m^2)	26.28	26.40	26.47
Days to shooting	242.15	279.74	312.15
Shooting to harvest	85.00	100.98	101.67
Total crop duration	327.15	370.69	416.82

It is interesting to note that with an increase in planting density per hill, there was an extension of duration of vegetative cycle and maturation phase. Elain Apshara (1997) while comparing the influence of single, double or three suckers per hill in cv. Nendran reported earlier bunch maturity in high density planting. The reason for such a contradictory result may due to the varietal factor. The extension of total crop duration under HDP was due to the manifestation of extended vegetative traits. Alagiamanavalan and Balakrishnan (1976) attributed extended duration under double planting to the competition between two adjacent plants for light. In the present

FIG 5. INFLUENCE OF PLANT DENSITY ON CROP DURATION (SHOOTING,HARVEST AND TOTAL DURATION)



investigation, when compared to conventional planting, three suckers per hill with S_2 system had an extension of 43.54 days, which should be of little significance if higher production is obtained. Belalcazer *et al.* (1994) opined that the increased length of vegetative cycle under HDP should be compensated by higher yields per unit area, so that farmers can afford to wait for extra 3-5 month. In the present study, the extension is only just 1½ months.

5.3. Effect of HDP on yield and its components

The bunch length should be sufficiently more to permit the development of fingers concomitant with good disposition of fingers in the bunches. In the present investigation both P_3 and P_4 planting system under S_2 had manifested in slightly lengthier bunch than conventional one. This might be due to the availability of lesser space for proper positioning of the bunches in the treatments of three and four suckers per hill planting. Competitive inhibition increased when crowding occurred among one or more suckers (Robinson, 1985a).

The important economic character namely the bunch weight showed that with HDP there was a reduction in its weight. This reduction in bunch weight with increment in plant density has been observed by many workers (Alagiamanavalan and Balakrishnan, 1976; Chundawat *et al.*, 1982; Sathyanarayana and Rao, 1985). This was due to excessive interception of light by the enhanced canopy and consequent reduction in photoshynthesis

(Reddy, 1982; Elain Apshara, 1997). Even under double planting, Bhakthavatsalu *et al.* (1972) claimed that planting two plants per hill at a spacing of 1.8 x 1.8 m had little influence on bunch size in Dwarf Cavendish probably due to selection of a dwarf mutant but Alagiamanavalan and Balakirshnan (1976) obtained reduction in bunch weight under double planting with cv. Robusta. Irizarry *et al.* (1978) also observed reduction in bunch weight under double planting system. When three and four suckers per hill planting were compared under both the systems of planting (Fig. 6a) three suckers per hill had heavier bunches close to conventional planting. In respect of S_3 system though the population was equal or lesser than conventional planting, it had not resulted in equal or heavier bunches as that of conventional planting. This is due to the excessive competition among the four plants in the same pit for light which might have affected the bunch weight. This suggests that HDP by planting four suckers at any plant spacing may not be a possible mean to attain higher yield per unit area. Robinson (1985) opined at a given density, banana plants are physiologically efficient when placed at equal distance from each other and competitive inhibition increases when crowding takes place. The gradual reduction in bunch weight is partly due to climate and partly due to competitive influence. This warrants further studies on the effect of size of pits for planting and varying distance between the corms within a pit. When the distance between plant is decreased below 9 or 10 feet more than the root competition, competition for light is the primary consideration (Berrill, 1963). It was further stressed that reduction in sunlight can't be made good

Fig 6a.Influence of plant density on bunch weight(kg)

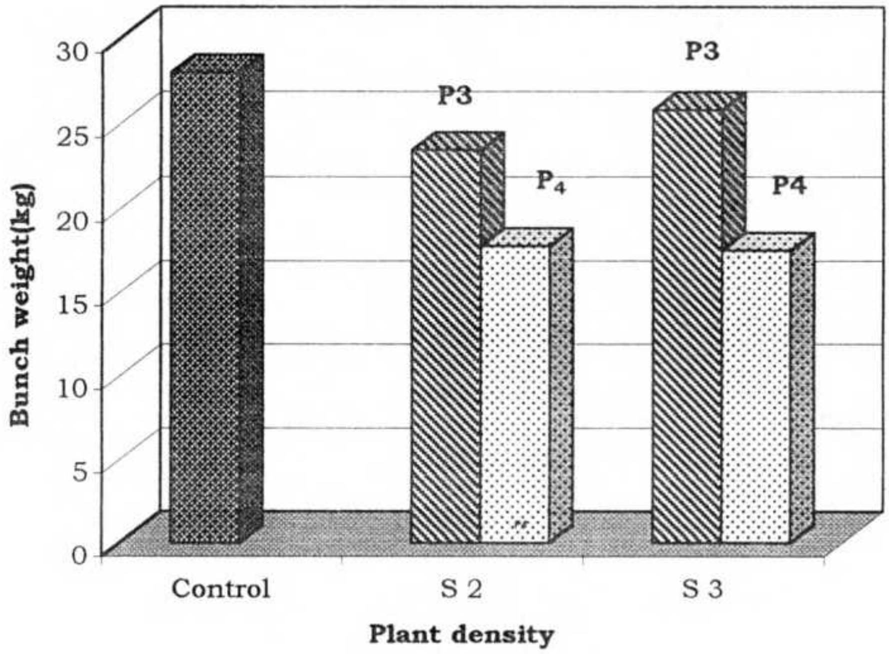
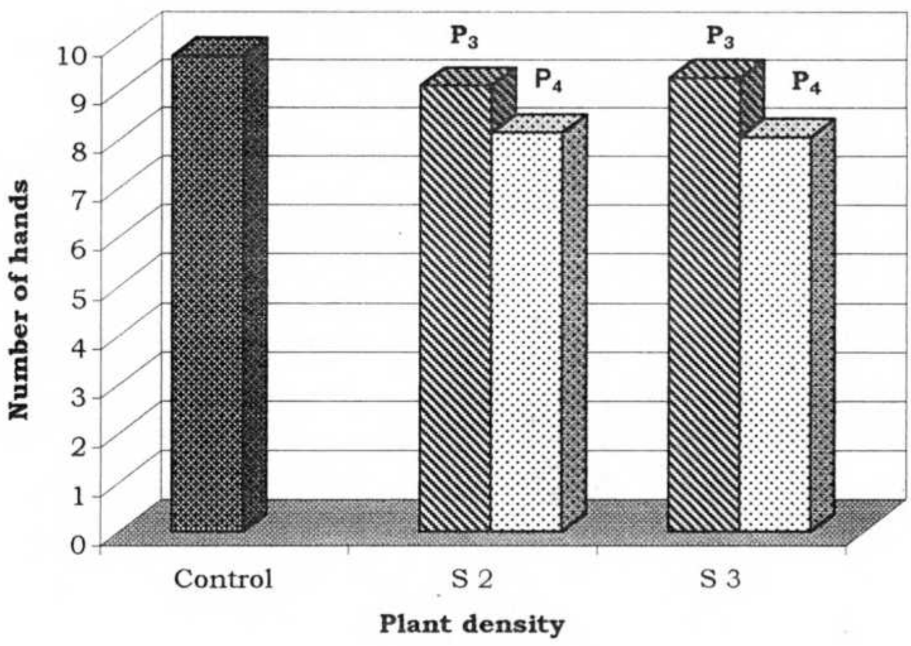


Fig 6b.Influence of plant density on number of hands



by increasing the fertilizer or additional watering. Under HDP, crowded canopy and mutually shading effect might have resulted in excessive interception of light leading to reduction in photosynthesis and consequential reduction in bunch weight (Reddy, 1982; Elain Apshara, 1997).

In Indian market though the bunch is sold by weight basis, physical appearance of the bunch has a bearing on the marketability. An analysis of other bunch characters in the present study showed that number of hands per bunch was not severely affected in any of the HDP treatments more particularly under P_3 planting system in S_2 or S_3 (Fig. 6b). In Robusta banana, number of hands in a bunch normally varies from 9-11. While grading the banana bunches based on the number of hands, Simmonds (1966) assigned 3/4 to 8 hands and full grade (1) to 9 hands and above in a bunch. Such an analysis in the present investigation shows that P_3 system of planting scored maximum grade of 1 as that of conventional planting while P_4 did score only 3/4. Alagiamanavalan and Balakrishnan (1976) also obtained higher grades of bunches under double planting system despite a reduction in mean bunch weight.

Number of fingers per bunch in P_3 system of planting both under S_2 and S_3 systems (Fig. 7a) was relatively more almost close to conventional planting. This indicated that the reduction in bunch weight was more due to the reduction in individual finger weight than number of fingers per bunch

Fig 7a.Influence of plant density on number of fingers

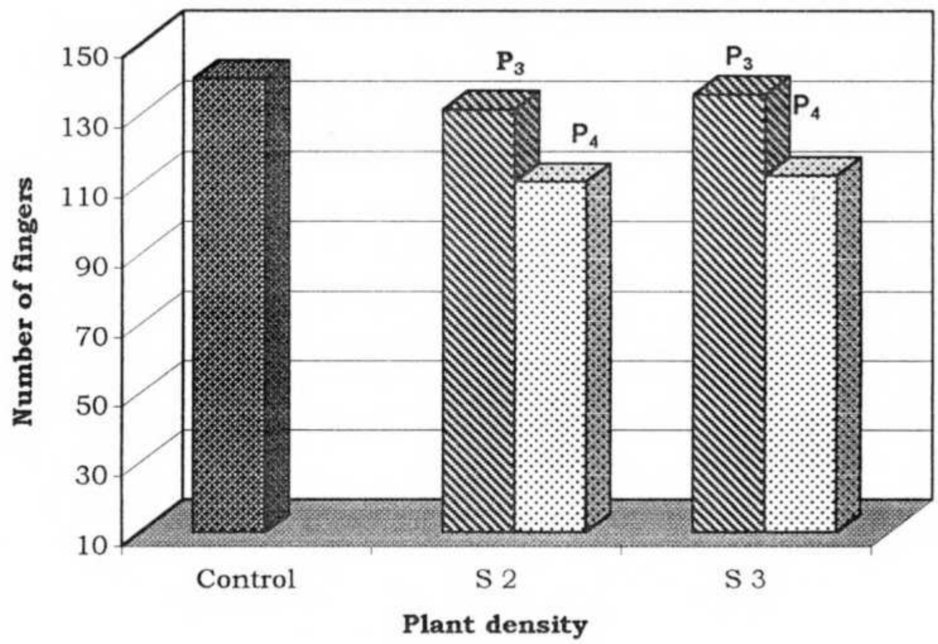
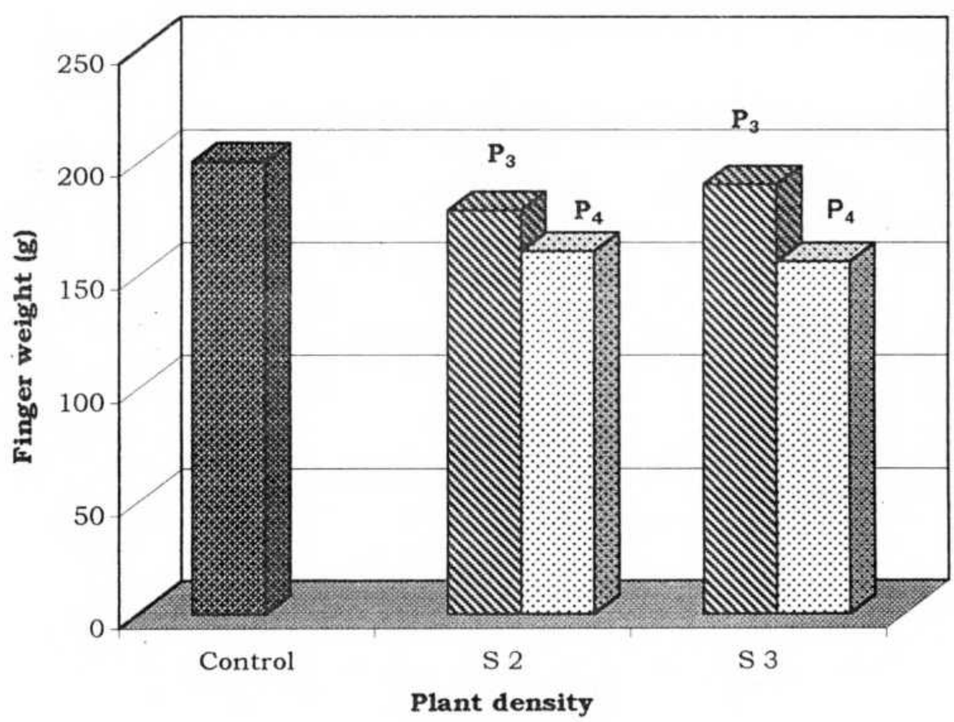


Fig 7b.Influence of plant density on finger weight(g)



under the HDP. The present investigation showed all the HDP had decreased finger weight than conventional planting. However, less reduction in finger weight was manifested in P_3 system of planting (Fig. 7b). Irizarry *et al.* (1978) also obtained reduction in weight of individual fruits under double planting system than the corresponding single planting in the same spacing. Reduction in individual finger weight might be due to competitive effect for light. Robinson (1981) though observed a close relationship between number of hands or fingers per bunch and mean bunch weight, ascribed factors such as climate, management, plant to plant competition particularly during flower initiation and bunch development for the variation in size and number of individual fingers.

The other characters namely finger length, circumference differed significantly among the treatments as compared to conventional planting. Three suckers /hill planting had the least effect on them than the four sucker planting (Fig. 8a and 8b).

In any HDP system, the primary objective is to obtain the maximum fruit yield per unit area without affecting the fruit quality. Fruit quality is mainly attributed to the amount of acidity and total sugar present in the fruit. A fruit with decreased acidity present along with increased sugar content is considered as normal fruit when the quality is taken into consideration. In the present study, though HDP treatments resulted in reduced total sugar, reducing sugar, TSS and increased acidity and ascorbic

Fig 8a.Influence of plant density on finger length(cm)

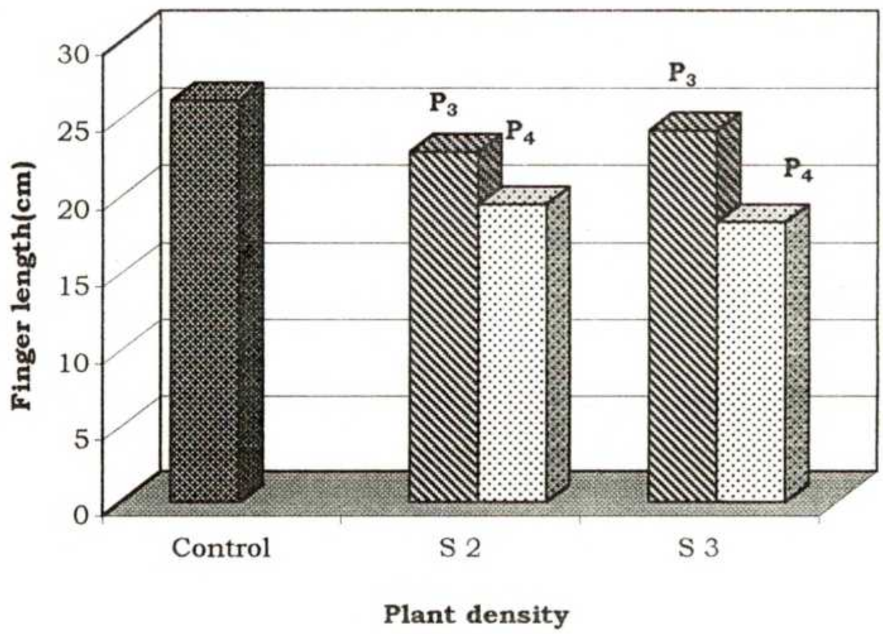
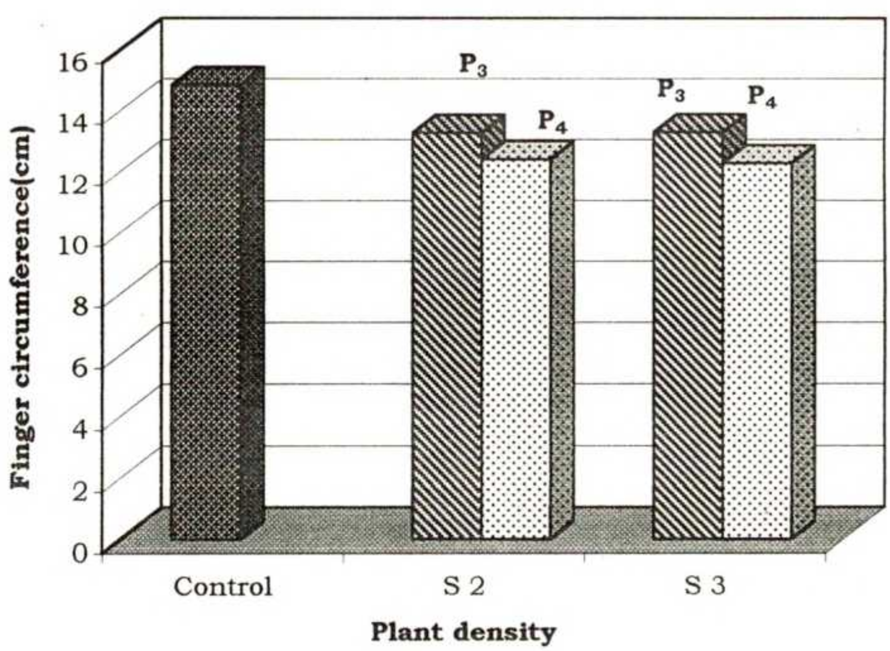


Fig 8b.Influence of plant density on finger circumference(cm)



acid contents, the effect was relatively lesser under three suckers per hill system of planting than under four suckers system of planting. With an increase in planting density, reduction in fruit quality was observed in many HDP studies in banana (Irizarry *et al.*, 1978; Chundawat *et al.*, 1983; Anil *et al.*, 1995; Elain Apshara, 1997).

The utility of a HDP system will be evaluated based on the total yield per hectare rather than based on individual plant yield.

When compared to conventional planting three suckers per hill planting registered higher yield per ha than the corresponding four suckers per hill planting. The increase in bunch yield/ha over conventional planting ranged from 21.79 and 13.70 per cent in three and four suckers per hill in S_2 respectively. While it was lesser than conventional planting in S_3 system (-33.56 per cent to –44.33 per cent). The reduction in S_3 system is due to reduction in population and reduced bunch weight, besides due to reduction in harvest percentage encountered in this present investigation.

Next to conventional planting, three suckers per hill planting under S_2 system ie. (1.8 x 3.6m) had resulted in maximum number of flowers reaching harvest than four suckers plants under S_2 system. When compared to control, harvest percentage was low in HDP treatments, more in four suckers per hill planting which may be due to the pest and disease incidences (Robinson, 1986; Elain Apshara, 1997).

Light transmission ratio (LTR) recorded at different stages, showed that HDP treatments had lesser value as compared to normal planting. Similarly, four suckers planting resulted in lesser value as compared to normal planting and three sucker planting (Fig. 9b). High degree of mutual shading of leaves in closely planted plots might have caused poor penetration of light across the crop canopy.

In the present investigation, when compared to control, all the HDP treatments showed lesser weed growth. The reason for lesser weed growth was due to low availability of sun light under highly shaded conditions. In general, increase in the density of plants limits the light transmission thereby suppressing the weed growth (Premalatha *et al.*, 1995).

More incidence of leaf spot under HDP treatments with four suckers per hill planting than three suckers per hill planting may be due to the favourable microclimate prevailed therein for the development of the fungus. Krishnakumary *et al.* (1992) reported that humid weather favours the rapid spread of sigatoka disease.

Stem weevil incidence was also recorded at early bunch development phases which showed that the incidence was more in four suckers per hill than the three suckers per hill under both S_2 and S_3 systems of planting while the least incidence was recorded in conventional planting. High shade and congenial microclimate under HDP would have favoured the incidence

Fig 9a.Influence of plant population on leaf area index

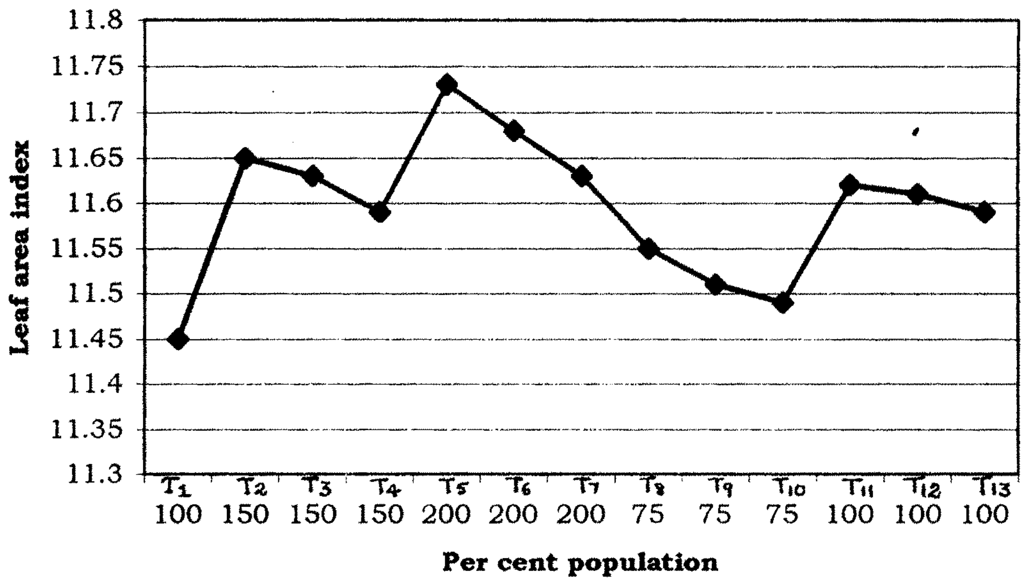
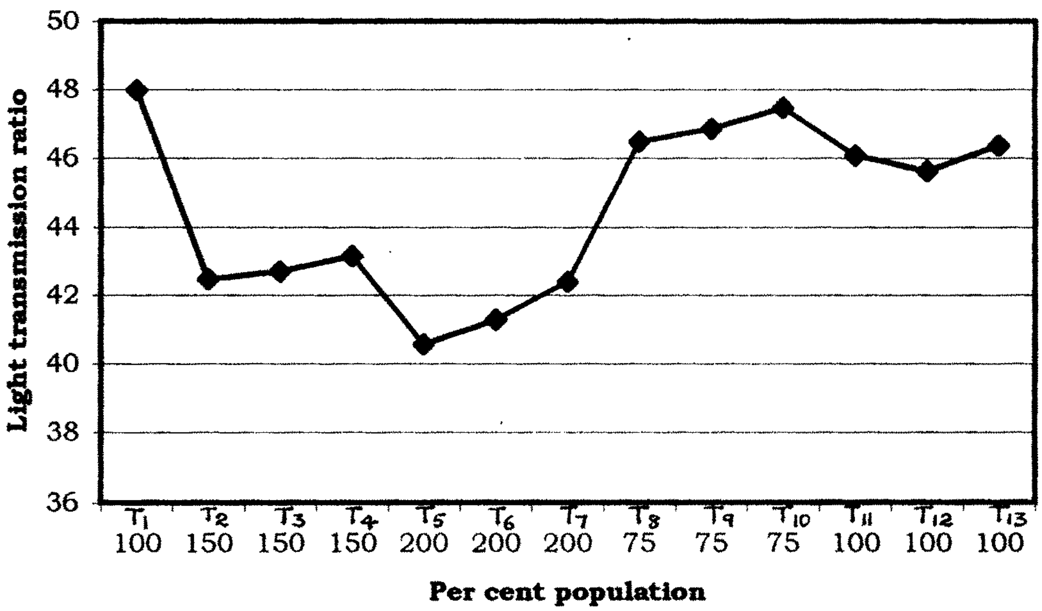


Fig 9b. Influence of plant population on light transmission ratio



of the adult weevil. Pavis and Lemaire (1996) observed that microclimate increased the growth of these grubs.

5.4. Effect of nutrient levels on the growth and development of banana

As reduced bunch weight is normally expected under HDP than the conventional planting, it is persumed that competition for nutrients may be one of the factors which results in reduced bunch weight. Alagiamanavalan and Balakrishnan (1976) gave double the manurial doses for double planting, yet they obtained only reduced bunch weight suggesting that increased manurial dose may not be required for increased number of suckers per hill. On the other hand, Irizarry *et al.* (1978) adopted same fertilizer level for single and double system of planting yet showed appreciable differences in bunch weight and individual finger weight. Elain Apshara (1997) while giving 25and 50 per cent extra doses for two and three suckers per hill planting respectively found the leaf nutrient concentrations to be adequate. Hence, in this present investigation another factor namely giving 100, 75 and 50 per cent of the recommended doses of nutrients was incorporated to find out whether nutrients would be a limiting factor on bunch weight and other economic characters if high density planting by planting few suckers per hill is taken up.

An estimation of soil available N, P, K at different stages showed that higher doses of applied nutrients resulted in higher level of soil available N, P, K. which was confirmed by the positive correlation obtained between graded levels of NPK and soil available NPK (Table 23). Bhangoo *et al.* (1962) obtained similar results.

Leaf nutrient concentration in plant tissue provides information on the nutrient status of the plant and offers diagnosis of toxicity as well as deficiency in the plant. Hewitt (1955) found that 2.6 per cent N, 0.45 per cent P_2O_5 and 3.3 per cent K_2O were the critical concentrations of nutrients in the third leaf of banana. A scanning of literature on the above line shows that critical level of leaf N varies from 2-3 per cent, phosphorus 0.08-0.5 per cent and potassium 3-4.5 per cent for Robusta in most of the cases. A perusal of present result also showed that critical leaf N, P and K at all stages of observations are well within the prescribed level both under conventional planting and HDP treatments suggesting that higher doses of nutrients did not affect the critical nutrient level. This was observed by Kotur and Mustaffa (1984), Manivannan (1994) and Elain Apshara (1997) also observed similar results. Bhangoo *et al.* (1962) were of the opinion that leaf concentration of nutrients did not necessarily represent the adequacy and deficiency levels of NPK in banana leaves. The above view is further confirmed by the correlation analysis conducted between graded levels of nutrients applied and the leaf nutrients which showed that in most of the cases, the correlation coefficient (Table 23) did not show significance indicating higher doses of nutrients did not reflect on the nutrient status of plant tissue. This suggested that a minimum level which maintains an optimum critical level without affecting bunch weight is adequate. In the

Table : 23. Correlation co – efficient (r) of graded levels of nutrients with soil available NPK and leaf NPK

Stages	Correlation co- efficient (r) of graded level of nutrients with					
	Soil available			Leaf content		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
3rd month	0.226	0.389	0.211	0.536	0.379	0.453
5th month	0.899**	0.733**	0.943**	0.565*	0.365	0.469
7th month	0.900**	0.837**	0.945**	0.483	0.366	0.315
Shooting	0.924**	0.695**	0.937**	0.474	0.359	0.388
Harvest	0.940**	0.703**	0.930**	0.453	0.289	0.456

present study, T_4 which received 50 per cent of the recommended doses registered the maximum bunch weight than 75 or 100 per cent nutrient doses.

The correlation coefficient between bunch weight and graded doses of nutrients also showed poor correlation (r value = 0.05 NS) indicating that increased level of nutrients did not necessarily produce increased bunch weight under HDP. The correlation between graded level of nutrients and soil available NPK (Table 23) showed that the correlation coefficient values were positively and highly correlated in most of the stages for P and K and for N only at flowering and harvesting stages, indicating nutrient availability depends upon applied doses. Summerville (1944) found that uptake of N was very high between 5^{th} and 8^{th} leaf stage and again between 15^{th} leaf and flowering stage and stressed the need for providing N in large and adequate quantities in vegetative and flowering phases

Higher the nutrient levels of NPK under HDP, there was increased pseudostem height, girth, leaf number, leaf area, leaf area index etc as compared to conventional planting (Fig. 10a, 10b, 11, 12a and 12b). This suggests that there was adequate nutrients available at higher doses which favoured relatively excessive vegetative growth (Venkatesam *et al.*, 1965; Kohli *et al.*, 1976; Singh *et al.*, 1979).

Fig 10a.Influence of nutrient levels on pseudostem height(m) at shooting

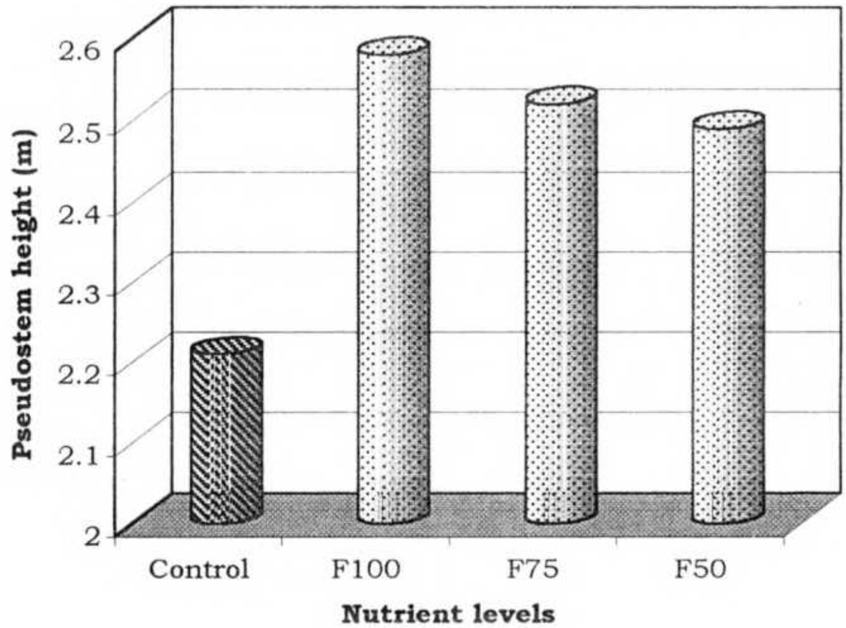


Fig 10b. Influence of nutrient levels on pseudostem girth(m) at shooting

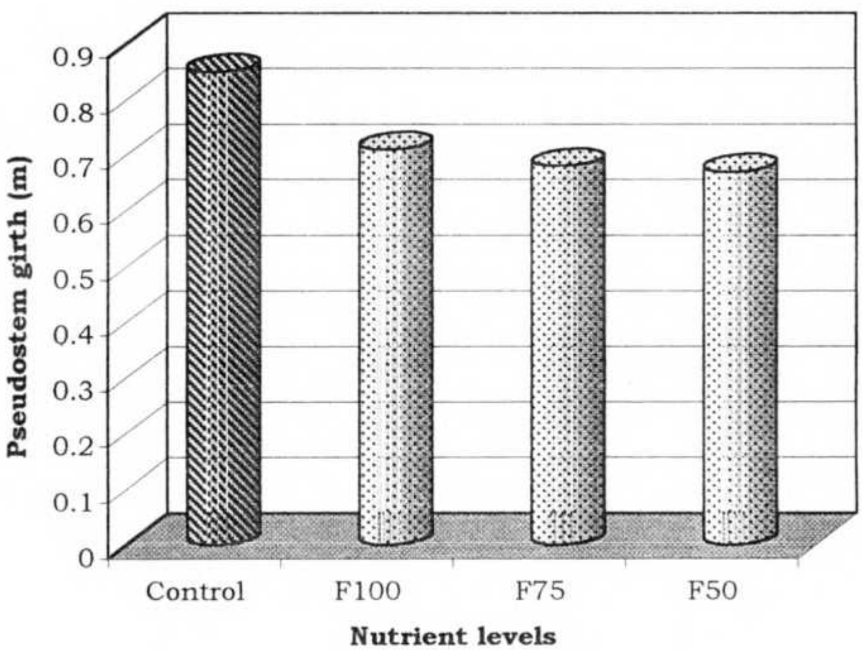


Fig 11. Influence of nutrient levels on number of leaves at shooting

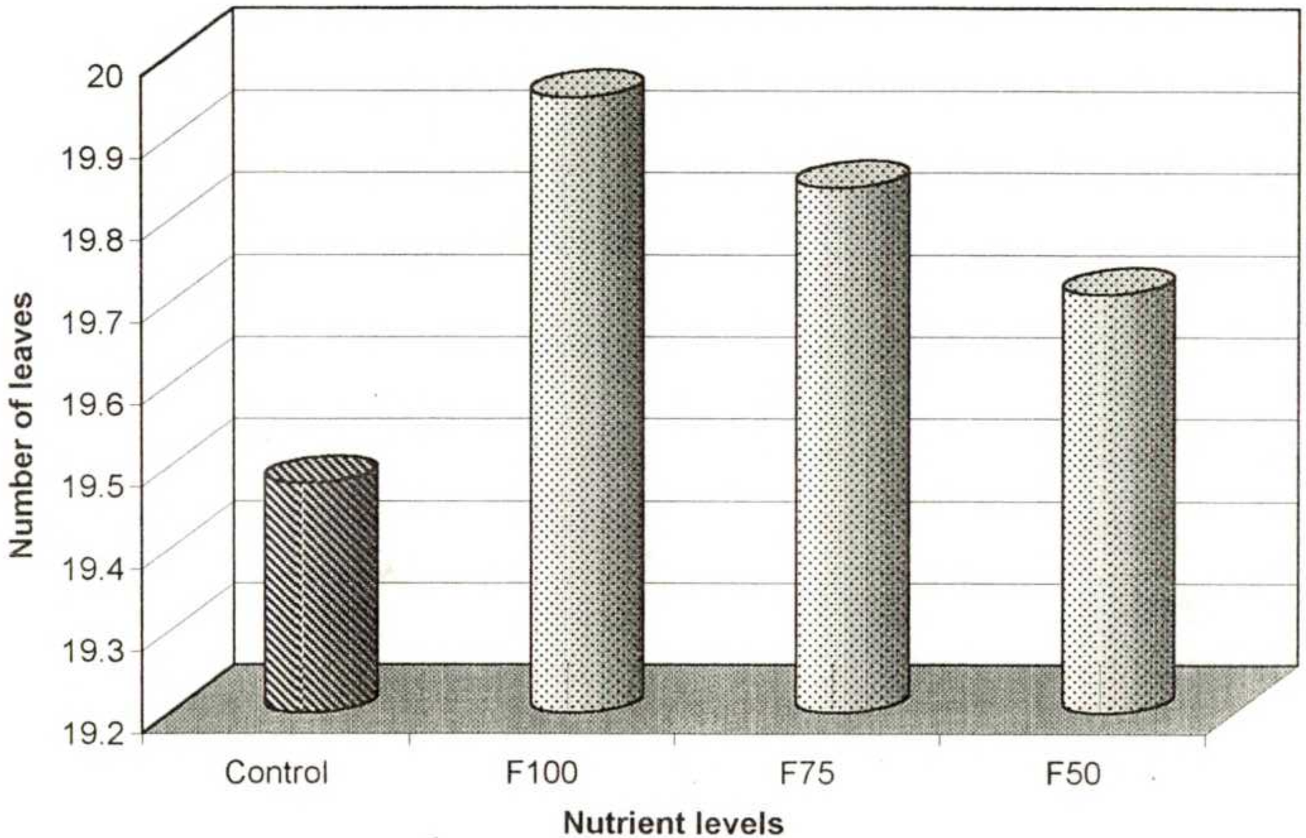


Fig 12a.Influence of nutrient levels on leaf area(m^2) at shooting

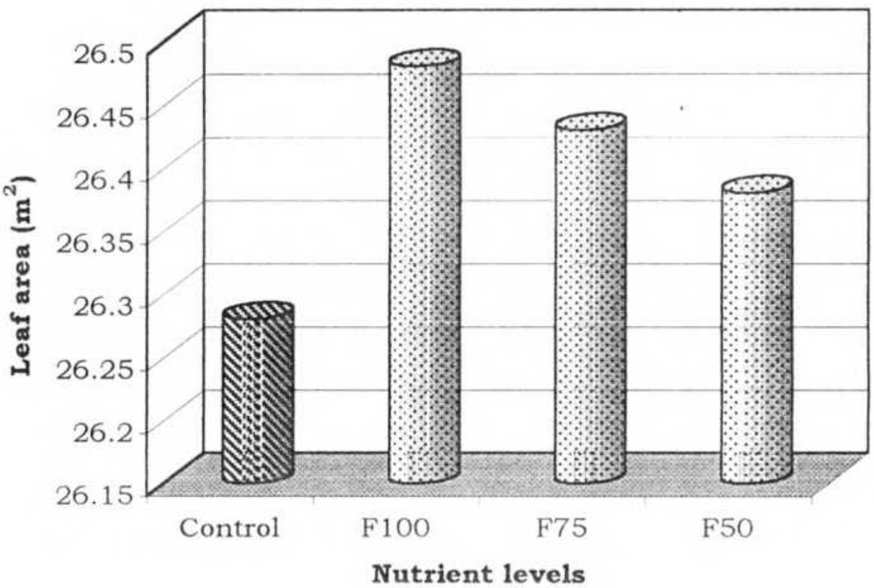
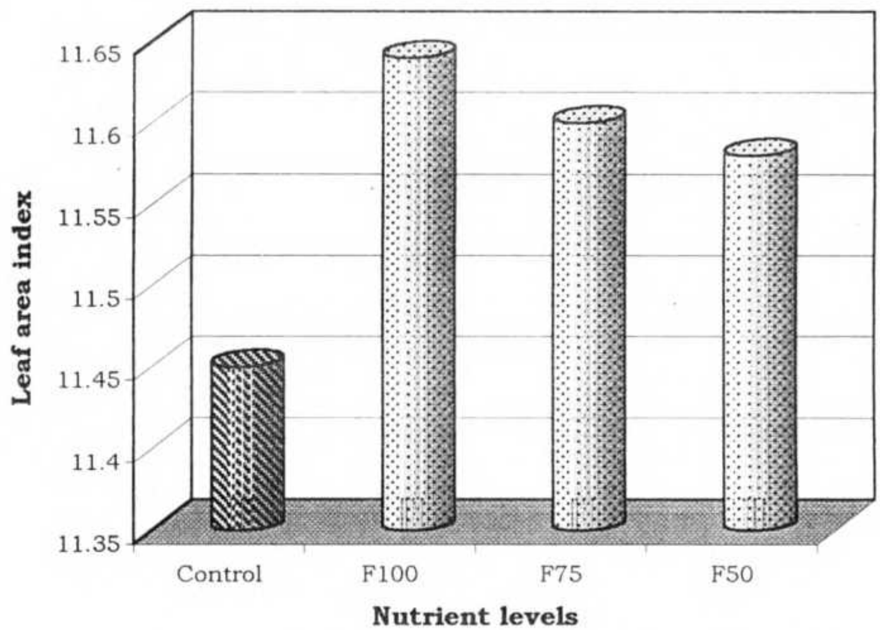


Fig 12b.Influence of nutrient levels on leaf area index at shooting



A critical appraisal of data relating to bunch weight showed that 50 per cent of nutrient level registered higher bunch weight than 75 per cent or 100 per cent graded level (Fig. 14a) indicating that under the three or four suckers/hill planting systems, higher doses of nutrients as recommended for single planting may not be required because of better utilization of nutrients within mat. The HDP treatments conducted earlier with closer spacings (Mohan, 1980; Badshah *et al.*, 1992) and also by planting more suckers per pit (Elain Apshara, 1997) found that number of roots increased with increase in density and also their vertical growth showed increase length with planting density. The nutrients supplied through 50 per cent of recommended dose of NPK might be better utilized by the production of more number of roots under HPD/pit system. Besides, the bunch weight under 50 per cent of recommended NPK at S_2P_3 system (T_4) (Fig. 14a) also registered maximum value for bunch characters namely number of hands/bunch, number of fingers/bunch, finger weight, finger length and finger circumference (Fig. 14b, 15a, 15b, 16a and 16b). This suggests that 50 per cent of recommended NPK was sufficient to have better bunch characters and bunch weight. In respect of crop duration, the 50 per cent of recommended NPK manifested in extended days from planting to shooting, shooting to harvest and thus the total crop duration than either 75 or 100 per cent of recommended nutrients. With the application of increased doses of fertilizers, crop duration was considerably shortened in banana (Fig. 13) (Bhan and Majumdar, 1956; Srivastava, 1961; Jagirdar and Ansari, 1966; Sharma and Roy, 1972; Singh, 1969)

FIG 13. INFLUENCE OF NUTRIENT LEVELS ON CROP DURATION (SHOOTING, HARVEST AND TOTAL DURATION)

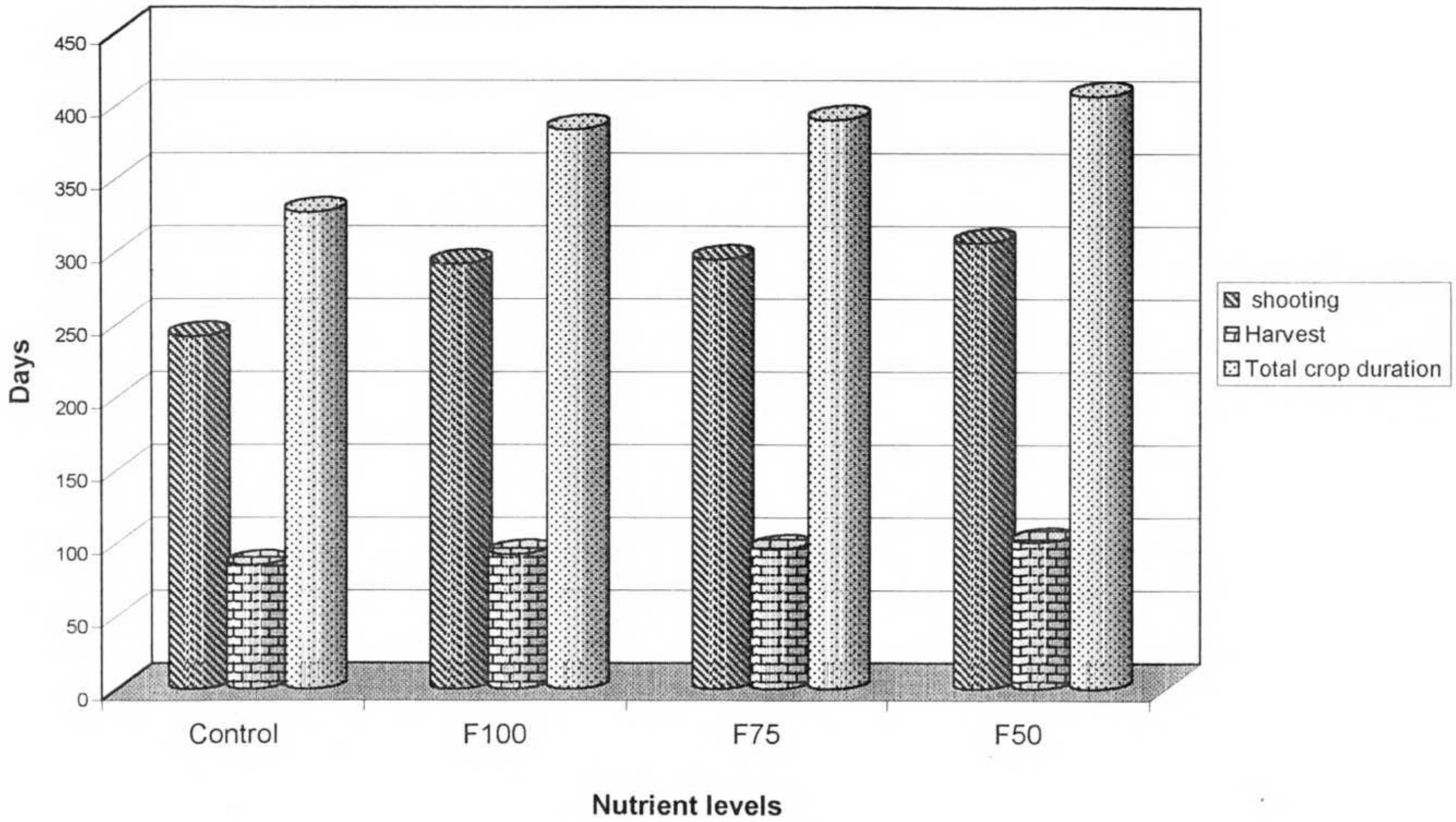


Fig 14a.Influence of nutrient levels on bunch weight(kg)

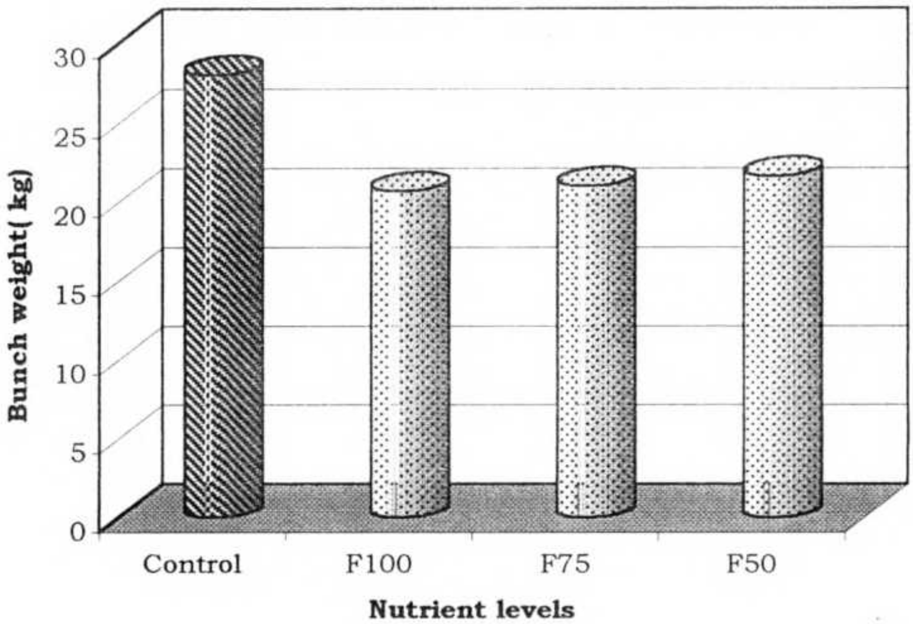


Fig 14b. Influence of nutrient levels on number of hands

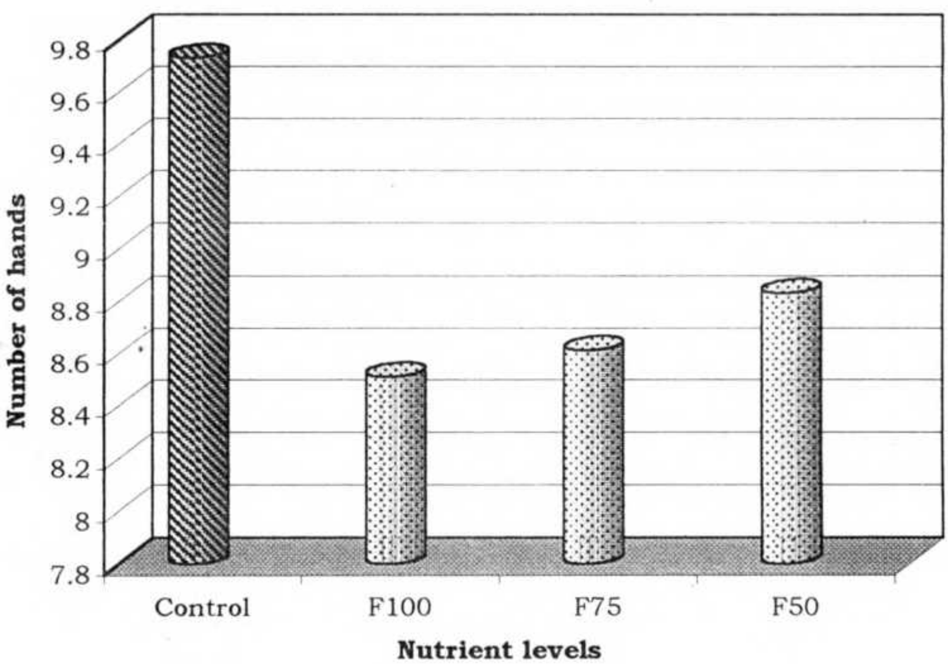


Fig 15a. Influence of nutrient levels on number of fingers

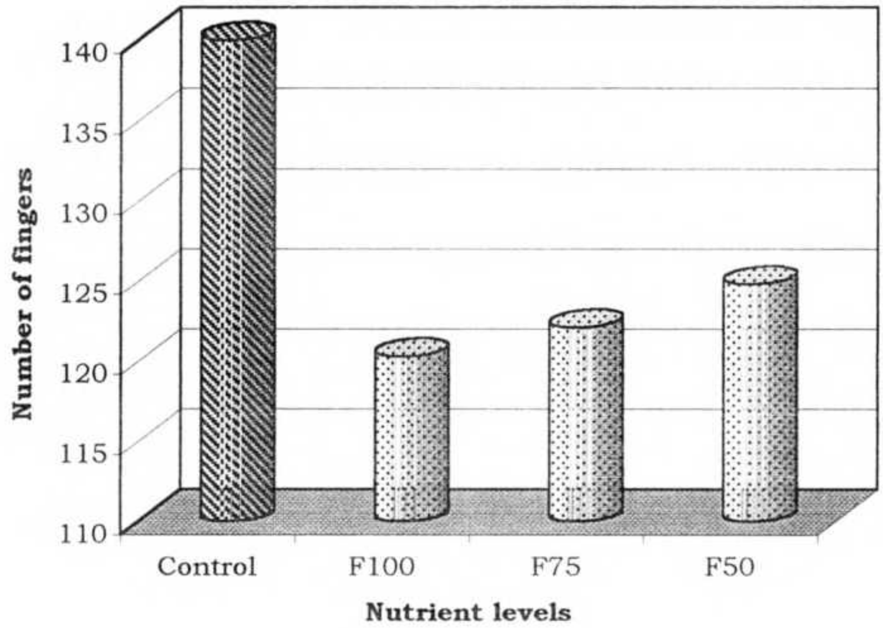


Fig15b. Influence of nutrient levels on finger weight(g)

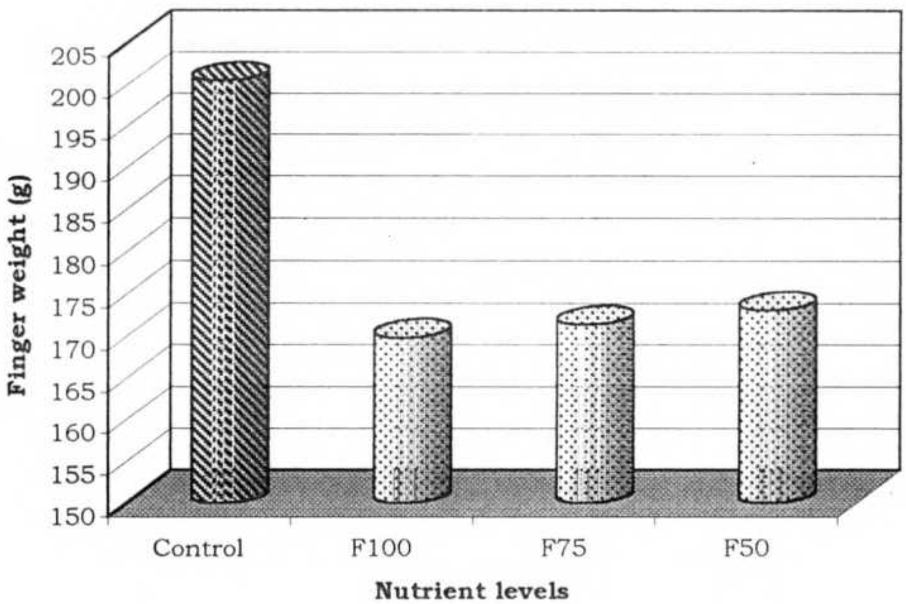


Fig16a.Influence of nutrient levels on finger length(cm)

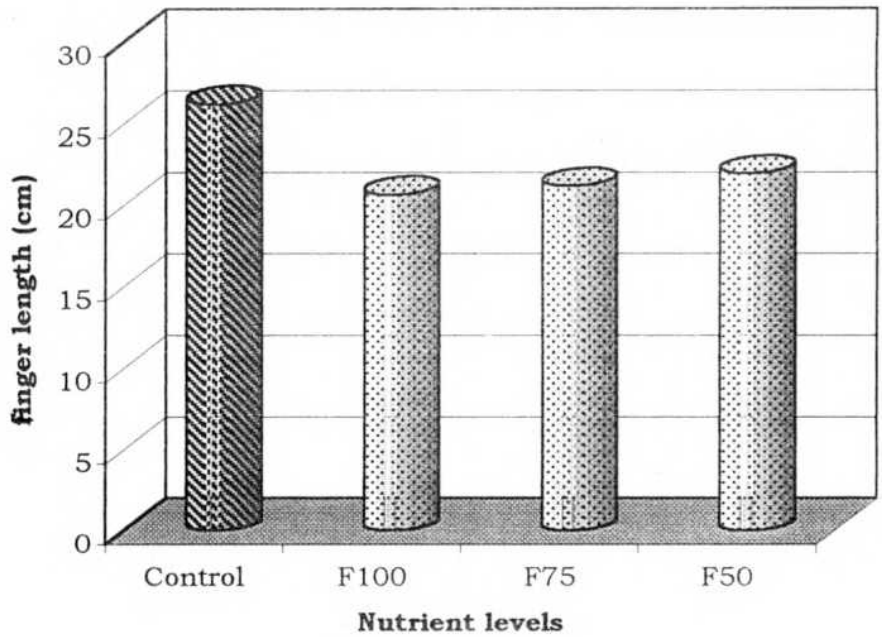
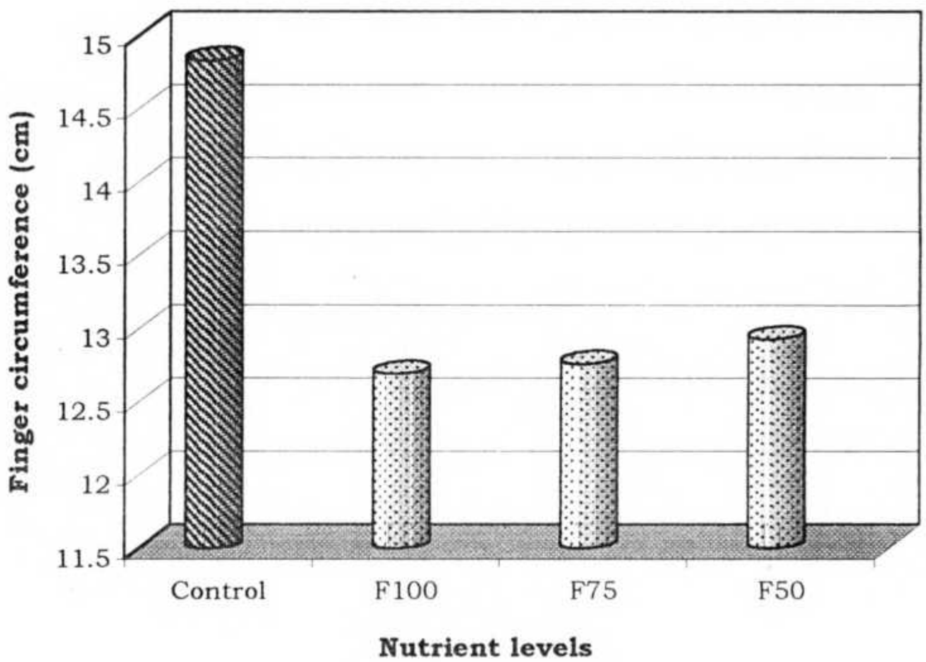


Fig 16b. Influence of nutrient levels on finger circumference(cm)



5.5. Economics of the treatments

Based on the discussion earlier, it has been found that among the HDP planting, three suckers per hill at a spacing of 1.8 x 3.6m has been reckoned as the best planting density based on the bunch weight, total yield/ha and other characters, etc. As the graded level of nutrients did not alter the bunch weight, it may be further concluded that treatment T_4 ie. supplying 50 per cent of the recommended dose of NPK for every sucker planted (in the present case application of 300: 90: 450 g of NPK/ pit/ containing three suckers) is found to be adequate. This particular treatment had the highest cost benefit ratio of 1:3.85 as against 1:2.75 under conventional planting. Wagner (1985) was of the opinion that maximum economic yield should reflect the greatest net return per hectare. Robinson and Nel (1991) while discussing the concepts of HDP stressed that an yield increase of 10 per cent will not counteract the cost of cultivation.

A critical comparison of some of the economic character for the best treatment reckoned and the conventional planting are furnished below ..

It may be seen that high density treatment had almost exhibited good economic character as that of conventional planting.

Character	Conventional planting	Best HDP treatment(T_4)	Per cent increase or decrease over conventional planting
Plant height (m)	2.21	2.36	-6.79
Plant girth (m)	0.85	0.72	-15.29
Leaf number	19.48	19.78	+1.54
Leaf area(m^2)	26.28	26.38	+0.38
Leaf area Index	11.45	11.59	+1.22
Crop duration (days)	327.15	379.66	-16.05
Bunch weight (kg)	28.0	24.38	-12.93
Bunch yield (t/ha)	86.41	110.35	+27.70
Number of hands	9.73	9.19	-5.55
Number of fingers	139.97	135.22	-3.39
Finger weight (g)	200.45	180.25	-10.08
Finger length (cm)	26.18	23.50	-10.24

- indicates negative effect ; + indicates positive effect

Elain Apshara (1997) recommended planting of two suckers/hill at a spacing of 2 x 3 m to earn the highest cost benefit ratio in which increased yield of 36.28 per cent was recorded. In Cavendish group a maximum of 60 per cent under HDP has been reported by Chundawat *et al.* (1982) and in plantain 270 to 345 per cent production increase was observed by Belalcazar *et al.* (1990) and Cardona *et al.* (1991). Based on the experience of present study in Robusta the following future lines of work are suggested.

Modification of planting system involving three suckers per pit by altering the size of pit in such away that there is less competition for light interception; the major factor which has favoured excessive vegetative growth in most cases of HDP.

A critical spatial arrangement study with three suckers per hill in such a way as to have more population per unit area with out affecting the quality as the increased level of 27.70 per cent may not be adequate to convince farmers to adopt this system.

SUMMARY

CHAPTER 6

SUMMARY

With a view to find out the effect of HDP in banana cv. Robusta (AAA), a field experiment was conducted during 1997-99 in a private farm at Vettaikaranputhur, Pollachi taluk of Coimbatore district. The experiment had 13 treatments each replicated four times in a RBD. The treatments included conventional single sucker per pit, three suckers per pit at a spacing of 1.8 X 3.6 m and three and four suckers at a spacing of 3.6 x 3.6 m. There were three levels of NPK added at 100, 75 and 50 per cent of the recommended dose. Observations on vegetative characters, crop duration, bunch yield and its components, soil fertility status and leaf nutrients were analysed besides on the incidence of certain pest and diseases. Based on the results, the following conclusions were drawn.

1. When compared to conventional planting, all the HDP treatments resulted in increased vegetative characters such as pseudostem height, leaf number, leaf area, leaf area index and also reduced the pseudostem girth, phyllochron and sucker production.

2. Among the HDP treatments, the treatments involving four suckers per hill registered relatively more vegetative characters than three suckers per hill planting.

3. When compared to control, all the HDP treatments took more days for planting to shooting, shooting to harvest and thus total crop duration.

4. Between the three and four suckers per hill planting, the treatments having four suckers took comparatively more number of days for shooting, harvest and total crop duration than the three suckers per hill planting.

5. When compared to conventional planting, all the HDP treatments registered a reduction in bunch weight and bunch characters such as number of hands, number of fingers, finger weight, finger length, circumference and pulp-peel ratio.

6. Between the three and four suckers per hill planting, the treatments having three suckers per hill registered more bunch weight and bunch characters than the four suckers per hill.

7. When compared to conventional planting, all the HDP treatments affected slightly the fruit quality traits.

8. Among the HDP treatments, three suckers per hill planting registered more TSS, total sugars, reducing sugars, non reducing sugars and sugar acid ratio and lesser acidity and ascorbic acid than four suckers per hill.

9. With increase in dose of fertilizer levels, increase in vegetative characters such as plant height, girth, leaf number, phyllochron, leaf area and leaf area index were observed.

10. Yield attributing characters such as bunch weight, and its components were not found to be increased with increase in nutrient level 50 per cent of the recommended level ie. 300:90:450 g/pit was to produce the maximum bunch yield in T_4.

11. Fruit quality traits showed increase with increase in fertilizer levels.

12. The crop duration including the days to shooting shooting, to harvest and total crop duration were significantly influenced by nutrient level. With an increase in nutrient level, decreasing trend was observed.

13. When compared to conventional planting, all the HDP treatments under S_2 (1.8x3.6m) spacing alone registered higher yield per hectare. Combining the HDP and fertilizer level T_4 ie. Planting of three suckers at a spacing of 1.8 x 3.6 m with application of 300: 90: 450 g/pit registered the highest cost benefit ratio.

PLATES

1.Conventional planting

2.Three suckers planted at a spacing of 1.8 x 3.6 m

3.Four suckers planted at a spacing of 1.8 x 3.6 m

4.Three suckers planted at a spacing of 3.6 x 3.6 m

5.Four suckers planted at a spacing of 3.6 x 3.6 m

5.T_4 – The best treatment ; three suckers per pit at a spacing of 1.8 x 3.6 m with 300: 90: 450 g NPK/pit.

7. Pseudostem showing inclined growth habit

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