STANDARDISATION OF SPACING FOR TISSUE CULTURE BANANA cv. NENDRAN (AAB Group)

By

B. K. ANIL B. Sc. (Ag) T. Tech.

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN HORTICULTURE

FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HORTICULTURE

COLLEGE OF AGRICULTURE

VELLAYANI — THIRUVANANTHAPURAM

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DEDICATED TO MY BELOVED PARENTS

DECLARATION

I hereby declare that this thesis entitled "**Standardisation of spacing for tissue culture banana** cv. Nendran (AAB group)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

31-1-94

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31-1-1994.

CERTIFICATE

Certified that this thesis entitled "**Standardisation of spacing for tissue culture banana cv. Nendran (AAB group)**" is a record of research work done independently by **Shri. B.K. ANIL** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

College of
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INTRODUCTION

INTRODUCTION

Among the tropical fruits of the world, banana occupies a place of pride and ranks third in importance. Banana is commercially grown from the equator to a latitude of 30^{0} or more. The crop is grown extensively in India, African countries, Philippines and other tropical countries for home consumption as well as for export. In India, the crop is grown in an area of 3,25,700 hectares with an annual production of 60,56,400 tonnes. This corresponds to 9.75 per cent of total area and 21.45 per cent of total production of fruit crops in India. The crop occupies an area of 65,637 hectares with a production of 4,91,935 tonnes in Kerala and the state has the seventh position in banana production within the country. Of the various varieties of banana cultivated in Kerala, Nendran belonging to French plantain group is well known for its multifarious uses as dessert and cooking variety. It also forms the raw material for several processed food such as flour, chips etc.

Banana being adapted to grow under low light intensities (Samson, 1980), it can withstand large amount of shading and hence is highly suitable for close planting, provided such planting would not result in rapid spread of leaf diseases like Sigatoka. Of late, with the standardisation of tissue culture techniques, the dearth of quality planting material is no more a problem. These tissue culture materials are smaller in size compared to the suckers of same age; consequently in the initial vegetative growth period, they occupy only a portion of the land area available to them under the present recommended spacing of 2.0 x 2.0 m for the conventional planting materials. However, they catchup with the sucker-raised plants in the subsequent growth phase, where the number of hands and fingers are decided by flower initiation and the later development of bunches is only interms of length, girth and weight of fingers and other parts of the bunch.

(The planting distance used for banana varies a great deal throughout India, depending on the variety grown and the duration for which a plantation is retained. Proper spacing is utmost important, for it not only affects the out-turn and its quality, but also influences the economic life of the plantation, besides warranting modifications in the management practices) It appears that though the growth and yield response of banana plants to an increase in population density has been well researched and documended in both tropical and subtropical regions (Robinson and Nel, 1988), little experimental work has been done on spacing of tissue culture banana. Hence it is worth while to attempt the peculiarities in growth habit of these non-conventional planting materials to exploit their potential for production as well as productivity.

It is quite obvious that when the spacing is reduced, a number of leaves will be shaded at least partially, and the overall efficiency of individual plant is reduced to some extent. However, it reduces the growth of weeds and soil moisture loss through evaporation, leading to a reduction in the cost of plantation management. It is also possible that close planting in Nendran, as observed in other cultivars may decrease the number and growth rate of suckers and enhance the crop cycle which may provide more time and energy for productivity parts to develop properly. Confined to an optimum level, higher plant density may increase the tonnage without sacrificing the marketability of bunches, inspite of slight reduction in individual bunch weight.

The spatial arrangement of plants in a plantation is very important and usually involves a choice between physiological efficiency and practical suitability. The jurisdiction of such planting thus lies at a level where competition between plants is minimum, the total yield is maximum and quality is optimum.

The global level research work have found the optimum population of cultivars belonging to AAB group to which Nendran belongs, to a level of 2500 plants ha^{-1}.

(Simmods, 1966). However, close spacing have been tried in different cultivars, like Palayankodan, Robusta etc., and a balance with increased yield, minimum loss of quality and marketability could be struck under different agro-climatic conditions in various parts of the country.

The present study was thus undertaken to determine the optimum spacing for maximum yield by careful evaluation and analysis of the effect of plant spacing and density upon various quantitative and qualitative characters of the tissue culture planting materials of Nendran banana, so as to chalkout a better space management strategy for higher yield per unit area with minimal loss of market acceptability.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Banana is one of the major tropical fruits of the world. The crop is extensively grown in India, African countries, South America, Bangladesh, Srilanka, Egypt, Hawaii, Philippines and other tropical countries for home consumption as well as for export. According to the official sources (1989-'90) banana was cultivated in the country in an area of 3,25,700 ha producing 60,56,400 tonnes (Anon., 1990). This corresponds to 9.79 per cent of total area and 21.45 per cent of total production of fruit crops in India. It can be seen that the crop occupies a place second only to mango in Indian fruit cultivation scenario. In Kerala, banana and other plantains are cultivated in 65,637 ha with a production of 4,91,935 tonnes (Anon., 1993). Among the major cultivars, 'Nendran' occupies a place of pride in Kerala and its cultivation is spreading to the bordering districts of Tamilnadu. This dual purpose variety is cultivated in a commercial scale under irrigated condition on the entire length and breadth of the State.

The present spacing recommendation for the variety is 2 x 2m as per the Package of practices of Kerala Agricultural University (Anon., 1989 a), accommodating a density of 2500 plants ha^{-1}. However, in several farmers fields, it is observed that this spacing is not strictly adhered to. In general observations, comparatively closer spacing was not found to markedly affect the bunch size. With the development of tissue culture techniques, Nendran bananas are easy to be propagated rapidly. The notable feature of tissue culture plants is that they are smaller in size compared to the suckers of the same age and hence occupy only lesser land area during their early growth stages. Therefore, it is felt that it is worth while to explore the possibilities of decreasing spacing to a certain level where more number of marketable bunches can be produced per unit area without significantly affecting individual bunch and finger size or the quality of fruits.

The results of research on high density planting conducted in similar lines in banana as well as other crops are depicted below:

2.1 Effect of spacing on vegetative characters

2.1.1 Effect of spacing on height of plants

Bhan and Majumdar (1961) reported that in 'Martaman' and 'Champa' (tall varieties planted at 2.7 x 2.7m and 3.6 x 3.6m and 'Kabuli' varieties (Dwarf Cavendish planted at 1.8 x 1.8m and 2.4 x 2.4m) of banana, the spacings had no significant effect on height of plants.

Moreau (1965) observed that banana plants from closer spacing (2 x 2.4 m) were taller than the plants from wider spacing (3.2 x 3.2 m). Ahmed and Mannan (1970) from their studies on different levels of spacing (1.2 x 1.2m, 1.8 x 1.8m, and 2.4 x 2.4m) and sizes of pits (0.30x0.30x0.30m, 0.45x0.45x0.45m, 0.60x0.60x0.60m) found that closely spaced plants had the tallest pseudostem in 'Amritsagar' banana . In Maricongo plantains (Musa acuminata x Musa balbisiana, AAB) in a comparison of five plant densities (871, 1089, 1210, 1452 and 1742 plants acre^{-1}) Irizarry et al. (1975) observed that plant density affected the height at flowering. Chattopadhyay et al. (1980) also noticed an increased height of banana plants ('Giant Governor') with increase in plant population both in plant and ratoon crops. From an experiment with Robusta banana with different spacings, Reddy (1982) found that plant height was not influenced by plant population densities upto two months after planting. However, significant differences in plant height were noticed from the fourth month onwards when plant height increased with increase in population density. Plant height was maximum (270 cm) at 1.2 x 1.2m and minimum (235 cm) at 2.1 x 2.1m spacing at shooting.

Mustaffa (1983) found that in Hill banana, the plant height increased with increase in population; the closer spacing (2.4 x 2.4m) producing taller plants than the wider spaced (3 x 3m) ones. Chattopadhyay et al. (1984) also observed that plant height increased with an increase in planting density of 'Giant Governor' banana, in West Bengal. They recorded the highest plant height (134.7 cm) in plant crop and the ratoon crop (153.3 cm) when the density was 10,000 plants ha^{-1}.

From the trials conducted at Banana Research Station, Kannara, Kerala (Anon., 1985 a) on banana cv. 'Palayankodan' it was clear that plants spaced wider recorded lesser heights in the second ratoon. The smallest spacing under square method (1.5 x 1.5m) recorded more height (435 cm). But in 'Poovan', the results revealed that the plant height at flowering did not show any significant difference among different spacings tried. In 'Nendran', the height of the plants at shooting was higher with closely spaced plants. Plants at 1.2 x 1.5m spacing grew to 4.04 m as against 3.75 m at 2 x 2m spacing. An increased or higher pseudostem height in plants under high density planting at flowering in bananas was noticed by Sathyanarayana and Rao (1985) and Daniells et al. (1987). The results of the studies on the performance of 'Robusta' under different spacings (Mustaffa, 1988 a) showed that the increment in the height of pseudostem followed an increasing trend with increasing population. The closest spacing (1.8 x 1.8m) produced the tallest plants compared to other spacings (2.4m x 2.4m and 2.4 x 1.8m). Plants in close spacing were 23 per cent taller than the widest spacing (2.4 x 2.4m) under rainfed condition.

Robinson and Nel (1988 and 1989) from their studies with 'Williams' banana observed that at all densities of 1000, 1250, 1666 and 2222 plants ha^{-1}, pseudostem height at flowering increased with plantation age upto second ratoon. They also noticed that the highest density produced significantly taller plants in the first ratoon. There was a substantial increase in pseudostem height from 2.6 to 3.6m between plant crop and first ratoon at spacing 4 x 1.5m and 3 x 2m. Thereafter, only a smaller progressive increase was observed in pseudostem size upto R_4 cycle. It was also reported that (Anon., 1989 b) height of pseudostem invariably increased with reduction in spacing in banana.

Rajeevan and Geetha (1989) carried out a study at Banana Research Station, Kannara, in 'Robusta' at two planting densities (2.4 x 1.8m and 1 x 1m). The results revealed that at five months, plants at wider spacing as well as closer spacing showed no significant difference in their height. However, at the time of flowering, the plants at closer spacing were significantly taller.

2.1.2 Effect of spacing on girth of plants

Bhan and Majumdar (1961) observed no significant effect on the girth of plant in 'Martaman', 'Champa' and 'Kabuli' bananas at different spacings or different population densities tried. But Ahmed and Mannan (1970) noticed that closely spaced 'Amritsagar' bananas had narrowest top girth than those with wider spacing. Irizarry et al. (1975) from their studies in Maricongo plantains (AAB) at five plant densities (871, 1089, 1210, 1452 and 1742 plants $acre^{-1}$) found that plant density did not affect the plant girth. But Chattopadhyay et al. (1980) reported that increase in plant population decreased the girth of pseudostem of both plant and ratoon crops in 'Giant Governor' banana.

Reddy (1982) noticed that different plant population densities in 'Robusta' banana did not significantly affect the plant girth. However, it was higher (76.58cm) in plants with closer spacing (1.2 x 1.2m) than with wider spacing (2.1 x 2.1m) where girth was 72.34 cm.

Mustaffa (1983) from an experiment with Hill banana revealed that the plant girth increased significantly with wider spacing (3 x 3m) compared to closer spacing (2.4 x 2.4m). Chattopadhyay et al. (1984) reported that the girth of plants decreased with increase in plant density. In the plant crop, the girth was the highest (49.7 cm) when there were 1600 plants ha^{-1} and the lowest (43.2 cm) when the population was 10,000 plants ha^{-1}. A trial on population density on 'Palayankodan' (Anon., 1985 a) revealed that the smallest spacing under square method (1.5 x 1.5m) recorded more girth. But in 'Poovan', the results revealed that the vegetative characters at flowering did not show any significant differences among different spacings.

At different densities of planting, (1000, 1250, 1666 and 2222 plants ha^{-1}), banana cv. 'Williams' showed a small but significant reduction in pseudostem circumference in third and fourth ratoon crops at the highest density (Robinson and Nel, 1988 and 1989). They also noticed substantial increase in pseudostem circumference from 0.79 to 1.05m between plant crop and first ratoon at spacings 4 x 1.5m and 3 x 2m. Thereafter, slight progressive increase in pseudostem size occurred upto R_4 cycle.

Rajeevan and Geetha (1989) found that 'Robusta' plants of five months age at 2.4 x 1.8m were superior with respect to girth compared to those at 1 x 1m spacing. But at the time of flowering, the plants did not show any significant differences in pseudostem girth (both lower and upper) at different spacings tried.

2.1.3 Effect of spacing on leaf characters

2.1.3.1 Effect of spacing on the number of leaves

Irizarry *et al*. (1975) reported that planting distance or planting densities did not influence the number of functional leaves in Maricongo plantains.

Reddy (1982), from his studies on 'Robusta' banana reported that the number of functional leaves per plant was not affected by the density of plant population upto seventh month, but it was influenced by spacing by the end of ninth month. Highest number of functional leaves (18.95) was recorded in lowest plant population density (2.1 x 2.1m) followed by 17.12 leaves in next lowest population density (1.8 x 1.8m) and lowest (13.46) in high density (1.2 x 1.2m). He also noticed that at flowering time too, the number of functional leaves per plant decreased with increase in density of planting.

From an experiment with Hill banana, Mustaffa (1983) reported that the number of leaves increased significantly with wider spacing and higher population density reduced them. Robinson and Nel (1988) reported that number of functional leaves at flowering increased with plantation age upto second ratoon in banana cv. 'Williams' at all densities of 1000, 1250, 1666 and 2222 plants ha^{-1}.

Rajeevan and Geetha (1989) noted increased number of leaves (15.7) with wider spaced (2.4 x 1.8m) plants than those with closer spacing (11.3 leaves at 1 x 1m spacing) in 'Robusta'.

Robinson and Nel (1989) inferred from their studies in 'Williams' banana that it produced lower number of (42.8) leaves in wider spacing (4 x 1.5m) as against 46.1 leaves in closer spacing (3 x 2m), eventhough both treatments accommodated the same plant population of 1667 plants ha^{-1}.

2.1.3.2 Effect of spacing on leaf growth, leaf area, leaf area index and leaf area duration

Reddy (1982) observed that 'Robusta' banana plants at closer spacing produced more leaf area compared to wider spacing (3.01, 2.66, 2.16 and 2.17 m^2 in 1.2 x 1.2m, 1.5 x 1.5m, 1.8 x 1.8m and 2.1 x 2.1m respectively) from planting to fifth month. From tenth month to flowering, increase in leaf area was found to be significantly influenced by the treatments. It was more (11.30 m^2) in closely planted treatments (1.2 x 1.2m) compared to widely planted (2.1 x 2.1m) treatments (7.36 m^2). He also pointed out that leaf size increased progressively with increase in population density and leaf area index (LAI) increased with increase in plant population density at fifth month (1.92, 1.12, 0.65, 0.48 in 1.2 x 1.2m, 1.5 x 1.5m, 1.8 x 1.8m and 2.1 x 2.1m respectively). At ninth month maximum LAI of 8.64 was observed in higher density of planting (1.2 x 1.2m) and minimum (2.72) in 2.1 x 2.1m spacing. He also noted that all treatments recorded maximum leaf area index at shooting stage. There was a progressive and significant increase in LAI with increase in plant population density.

Stover (1984) recorded a leaf area index of 5.1 and 6.1 for 'Valery' bananas at 1700 and 1900 plants ha^{-1}. In the latter case only 2 - 3 per cent of available radiation was transmitted to the ground. He concluded that LAI increased with increase in plant population density. Reynolds and Robinson (1985) noticed that leaf area and LAI at flowering increased with increase in plant population density (1666 to 2222 plants ha^{-1}). Later Robinson and Nel (1988) noted that leaf area at flowering increased with plantation age up to second ratoon in 'Williams' banana at all densities of 1000, 1250, 1666 and 2222 plants ha^{-1}.

Reddy (1982) noticed that leaf area duration (LAD) increased progressively with increase in plant population density. He recorded maximum LAD of 3381.38 in 1.2 x 1.2m spacing followed by 2048.01, 1221.72 and 842.14 in 1.5 x 1.5m, 1.8 x 1.8m and 2.1 x 2.1m respectively.

2.1.3.3 Effect of spacing on leaf emergence rate and interval of leaf production

According to Oppenheimer and Gottriech (1960,) in 'Dwarf Cavendish' banana in the coastal plains of Israel, wider spacing made the leaves unfurl more frequently during autumn followed by winter and spring.

Reddy (1982) from his experiment on 'Robusta' banana concluded that mean monthly rate of leaf production increased with increase in planting distance. He also explained that rate of leaf emergence at later stages of plant growth decreased with increasing plant population density. Allen et al. (1988) reported that leaf emergence rate (LER) decreased with increasing stature and LER decreased with increasing plant density. Robinson and Nel (1988 and 1989) explained that annual leaf emergence was significantly reduced upto five leaves with an increase in plant density from 1000 to 2222 plants ha^{-1}, which was also accompanied by a 3 - $4^{0}C$ reduction in pseudostem temperature. They also inferred from their studies with 'Williams' banana, that there was a decrease in leaf emergence rate from 25.4 to 23.1 leaves $year^{-1}$ and an increase in total leaves produced before flower emergence from 42.8 to 46.1 in 4 x 1.5m and 3 x 2m spacings.

Leaf emergence was found to be reduced under very close planting owing to lower temperature inside the canopy because temperature had significant influence on rate of leaf emergence (Singh, 1990) which in turn would affect flowering, since flower initiation would induce only when a minimum effective leaf area was achieved (Simmonds, 1966).

2.1.4 Effect of spacing on time taken for flowering

Wider spacing resulted in earlier flowering, as compared to closer spacing. This was attributed to the unfurling of leaves more frequently in wider spacing (Oppenheimer and Gottriech, 1960, Berrill, 1963 and Ahmed and Mannan, 1970).

Irizarry et al. (1978) noticed that in plant crop, plants spaced at 1.5 x 1.5m and 1.8 x 1.8m (with one plant per hole) flowered one month earlier than plants spaced at 1.2 x 1.2m (with one plant per hole). Double plants (with two plants per hole) when compared to their corresponding plant densities in single plantings flowered one to two months later. In ratoon crop (where there was no double planting) flowering was delayed with increase in plant density.

Chattopadhyay *et al*. (1980) observed that larger plant population delayed shooting in both plant and ratoon crops. In plant crop the inflorescence appeared in 418 days after planting in closer spacing (2500 plants ha^{-1}) compared to 407 days in wider spacing (1125 plants ha^{-1}). In ratoon, the values were 540 days for closer spacing and 516 days for wider spacing.

Maharana and Das (1981) explained that shooting and harvesting were the highest under closer spacing (1.8 x 1.8m), but time taken for flowering was lesser under wider spacing (2.5 x 2.5m).

Reddy (1982) reported that with increase in plant population or with decrease in plant spacing, the number of days taken for shooting increased. He found that number of days taken for shooting were maximum (382.35) in 1.2 x 1.2m spacing and minimum (336.10) in 2.1 x 2.1m spacing. According to Chattopadhyay *et al*. (1984) higher plant population delayed shooting in both plant and ratoon crops in 'Giant Governor'. When the planting density was 2222 plants ha^{-1} or less, the number of days required for flowering was minimum in plant crop (376 days) as well as the ratoon crops (480 days). From a trial conducted at Banana Research Station, Kannara (Anon., 1985 b) it was highlighted that the closely spaced 'Nendran' banana took more time to come to flowering.

Rajeevan and Geetha (1989) found that in 'Robusta' banana, flowering duration was delayed significantly by reduced spacing. Plants at 1 x 1m spacing took more time (292.2 days) for flowering as compared to 2.4 x 1.8m (236.8 days).

2.1.5 Effect of spacing on bunch maturity and harvest

Baghadadi et al. (1959) reported that time of maturity was not affected by spacing.

Kebby and Green-halgh (1959) observed that in 'Cavendish' bananas, bunch developed more slowly as planting distance decreased. Missinghan (1963) reported that variations in intra row spacings (0.90, 1.20, 1.50 and 1.80m) did not influence the time of harvesting when inter row spacing (3.9m) was kept constant.

Chattopadhyay et al. (1980) noticed that closer spacing delayed the fruit maturity and the difference in the time of maturity between 2500 plants ha^{-1} and 1125 plants ha^{-1} was 11 days in plant crop and 12 days in ratoon crop.

In an experiment with 'Lacatan' banana, Chundawat et al. (1981 a) observed that closer spacing significantly delayed the bunch maturity. It took about 407 days for bunches to mature in 1.8 x 1.8m spacing while in 1.2 x 1.2m spacing it took about 587 days from planting, causing a considerable delay of 180 days. They (Chundawat et al., 1981 b) also noticed that in 'Basrai' banana maturity of bunches was significantly delayed and with every step of reduction in spacing (1.8 x 1.8m, 1.7 x 1.7m, 1.5 x 1.5m, 1.3 x 1.3m and 1.2 x 1.2m), there was a delay of about one month resulting into a difference approximately of six months in maturity between 1.8 x 1.8m and 1.2 x 1.2m spacing.

Reddy (1982) from his studies in 'Robusta' banana concluded that the number of days taken for bunch maturity (shooting to harvest) increased significantly with increase in plant population density. Bunches in 2.1 x 2.1m spacing matured much earlier (130.43 days) than bunches in 1.2 x 1.2m (151.65 days). He also pointed out that crop maturity was significantly affected by plant population density. Mustaffa

(1983) explained that closer spacing in Robusta hastened maturity while high nitrogen rate reversed the trend.

2.1.6 Effect of spacing on crop duration

Alagiamanavalan and Balakrishnan (1976) reported from their experiment with 'Robusta' banana under different system of planting (single and double planting) that the duration of the crop in double planting system was higher (417 days) and lesser (395 days) in single planting system.

In the sub-tropics of Zimbabwe (Anon., 1980), it was clearly seen that for 'Williams' bananas, total cycle time from sucker selection to harvest in the first ratoon (R_1) was 100 days longer at 2222 plants ha^{-1} than 890 plants ha^{-1}.

It was highlighted (Anon., 1985 b) that time taken for planting to harvest were higher with closely spaced 'Nendran' banana. Robinson and Nel (1984 and 1986) noted that total crop cycle time was drastically reduced as the density decreased or as the plant spacing increased. The harvest interval between two successive crop cycle was reduced at lower density. But Daniells et al. (1987) found that duration of crop cycle in 'Williams' under two planting system was unaffected by density of planting. However, in ratoons, the length of the crop cycle increased with increasing density.

2.1.7 Effect of spacing on number of suckers produced

Berrill (1963) reported that sucker production was influenced by planting distance and it was found to be more in widely spaced plants.

Jagirdhar et al. (1963) and Moreau (1965) found that in 'Basrai' banana, the sucker production was more in plants spaced wider than plants at lesser distance.

Caro-costas (1968) also reported that sucker production was more with wider spaced plants. However, with increase in population, sucker growth was delayed until harvesting was well underway, which resulted in a more uniform growth of ratoon crop. Similar conclusions were drawn by Ahmed and Mannan (1970), Irizarry et al. (1975) and Chattopadhyay et al. (1980) from their experiments on the effect of plant population on sucker production in banana.

Reddy (1982) found that number of suckers per plant increased with increase in spacing in 'Robusta' banana. Maximum number (6.73) of suckers per plant was recorded in 2.1 x 2.1m spacing and minimum (3.46) in 1.2 x 1.2m spacing. However, the number of suckers per unit area increased with decrease in planting distance because of increased population. Rajeevan and Geetha (1989) noticed that banana plants with normal spacing (2.4 x 1.8m) produced significantly more number of suckers (4.12) than plants at closer spacing (1 x 1m) which produced 1.84 suckers per plant.

2.1.8 Biomass and drymatter production

According to Berrill (1956), throughout the life of the banana plant, starch, sugars and porteins are manufactured in leaves and pseudostem and some of these are used directly in the growth process of the plant and its developing suckers, and the balance is stored in the corm. After shooting, the reserve food material becomes available to meet the requirement of bunch and flowers.

Martin-prevel (1967) suggested that during the lifetime of banana plant, corm accumulated starch in storage tissues, but the major mineral nutrients were not stored to any extend.

Sheela and Aravindakshan (1990) noticed a progressive increase in total drymatter content of banana cv. 'Palayankodan' with age of plant and it was most rapid between the late vegetative phase and shooting time. This was because the plant showed a very high rate of growth during the period.

2.1.8.1 Effect of spacing on biomass and drymatter production

Reddy (1982) in an experiment with 'Robusta' banana showed that biomass production per plant increased with increase in planting distance. He recorded the maximum biomass production per plant at the spacing 2.1 x 2.1m (24.740 kg dry weight) and minimum at the spacing 1.2 x 1.2m (22.083 kg dry weight). However, the biomass production per unit area increased with decrease in planting distance because of increased plant population.

Turner (1984) reported that at high density planting, the degree of shading was very high and this at high density reduced the photosynthetic capacity and drymatter production.

2.2 Effect of spacing on yield character of banana

The ultimate profit of banana cultivation depends on the weight of bunches at harvest. The bunch weight is a complex character influenced by the component morphological characters of plant and bunch. Under suitable agroclimatic conditions where soil moisture, nutrients and disease are not limiting factors, spacing or plant population density is probably the most important factor that determines the productivity in banana.

2.2.1 Effect of spacing on bunch weight and yield of banana

Baghadadi *et al*. (1959) found that bunch weight was considerably lower in the first and somewhat lower in the second year from 1 m than from 2 or 3m spacings. When planted 3m apart, the presence of two or three fruiting plants per hole did not gave lower bunch weight than with one plant per hole. However, Kebby and Green-halgh (1959) and Berrill (1963) found an increased bunch weight with increase in the plant spacing studied.

With closer spacing the mean bunch weight of 'Martaman' ('Rasthali') and 'Kabuli' varieties did not show any statistically significant reduction (Bhan and Majumdar 1961). Vincente - chandler and Figarella (1962) found that yield of plantains (*Musa paradisiaca*) increased from 5025 to 8786 kg ha^{-1} when plant population was increased from 500 to 800 plants $acre^{-1}$ planted in rows of 3m spacing.

Berrill (1963), Ahmed and Mannan (1970), Azouz *et al*. (1971), Randhawa *et al*. (1973), Patil *et al*. (1978), Chattopadhyay *et al*. (1980) and Daniells *et al*. (1987) reported that per hectare yield of banana was more in closer spacing compared to wider spacing.

Missinghan (1963) using five different row spacings (0.90 x 3.9 m, 1.2 x 3.9 m, 1.5 x 3.9 m, 1.8 x 3.9 m and 2.1 x 3.9 m) observed that spacing had little effect on the bunch size and fruit quality in plant crop. In ratoon crop, closer spacing resulted in lighter bunches due to poor filling of the fruits rather than to a reduction in the number of fruits per bunch.

Moreau (1965) in Ecuador, working with 'Gros Michel' bananas, found that dense planting (1600 plants ha^{-1}) produced bunches with mean weight of 24.70 kg and normal planting (1000 plants ha^{-1}) produced bunches with mean weight of 25.30 kg in first cycle. But Caro-costas (1968) found that bunch and fruit size were not significantly affected by the population levels. (725, 1090 and 1450 plants $acre^{-1}$) although bunches tended to be smaller with high population (1450 plants $acre^{-1}$) level. He also reported that plantain yields increased from 21950 to 31000 fruits per acre, when population was increased from 725 to 1090 plants $acre^{-1}$ by keeping inter row space (3 m)constant. Planting 1450 plants $acre^{-1}$ in rows 3 m apart did not further increase yields but planting same number of (1450) plants $acre^{-1}$, approximately on square (1.5 x 1.8 m) increased yields to 39080 fruits per acre.

Robinson and Singh (1974), Chundawat et al. (1981 a and b and 1983), Reddy (1982), Mustaffa (1983), and Chattopadhyay et al. (1984) reported that mean bunch weight of banana generally reduced by reduction in plant spacing.

Irizarry et al. (1975) found that planting density and spacing apparently excerted a significant effect on weight of bunches and marketable fruits per bunch. But in Maricongo plantains (Irizarry et al., 1978) it was found that single plantings (one plant per hole) with spacings of 1.2 x 1.2 m (6726 plants ha^{-1}) and 1.5 x 1.5 m (4303 plants ha^{-1}) showed significant differences in bunch and fruit characterestics when compared with corresponding plant population levels.

Results of a trial carried out at Kerala Agricultural University (Anon., 1978) revealed that yield increased from 46.95 t ha^{-1} to 72.12 t ha^{-1} when plant population was increased from 4500 to 7000 plants ha^{-1}. In these treatments, the weight of bunches were 10.5 and 10.3 kg respectively.

Venero and Marquez (1979) reported that cumulative yields over two year were higher in banana cv. 'Robusta' planted at 1667 to 2315 plants ha^{-1} than when planted at conventional densities of 625 and 1250 plants ha^{-1}. Yields of 120, 118, 114 t ha^{-1} were obtained with 1786, 1667 and

2315 plants ha^{-1} respectively compared with 75 and 102 t ha^{-1} with 625 and 1250 plants ha^{-1}. They explained that as the plant density increased, the mean bunch weight decreased from 26 to 16 kg.

The mean bunch weight per plant usually increased with increase in plant spacing or increased with decrease in plant population density (Robinson and Singh, 1974, Chundawat et al., 1981 a and b and 1983, Reddy, 1982, Mustaffa, 1983, Chattopadhyay et al., 1984, Daniells et al., 1985 and Rajeevan and Geetha, 1989). Reynolds and Robinson (1985) and Robinson and Nel (1989) found that the total yield per year after three cycles was 11 per cent higher at 2222 plants ha^{-1} than 1666 plants ha^{-1} in banana. Robinson and Nel (1986) explained the effect of density on yield. They reported that significant increase in bunch mass per plant was associated mainly with decrease in density. The cumulative yield per annum for plant crop and first ratoon cycle was significantly increased by 19.2 per cent at the higher density of 1666 plants ha^{-1}. Skikh et al. (1986) planted 'Williams' Hybrid' at 2.7 x 1.8m, 2.7 x 2.7m and 2.7 x 3.6m and inferred that yield per unit area was the highest at the closest spacing (2.7 x 1.8m) and growth was the best at 2.7 x 2.7m.

Morales and Rodriguez (1988) when compared traditional planting system for Horn plantains (Musa AAB) at

Ahmed and Mannan (1970), Irizarry et al. (1975), Chattopadhyay et al. (1980 and 1984), Chundawat et al. (1981 a and b and 1983), Mustaffa (1983), Daniells et al. (1987) and Rajeevan and Geetha (1989) explained that the number of fruits or fingers per bunch decreased with increased plant population density or with decreased spacing. But Reddy (1982) reported that various plant spacing had no significant effect on number of fingers per hand or per bunch in the spacings tried.

2.2.4 Effect of spacing on length, girth, weight and size of fingers

Caro-costas (1968) reported that various population densities of banana did not affect the size of fruits. Individual fruit weight, length and girth increased significantly with increase in plant spacing or with decrease in population density in banana (Chattopadhyay et al., 1980 and 1984, Chundawat et al., 1981 a and b and 1983, Reddy, 1982, Mustaffa, 1983, Daniells et al., 1987, Robinson and Nel, 1986 and 1989 and Rajeevan and Geetha, 1989)

2.2.5 Effect of spacing on shape of fingers and fruit filling

Missinghan (1963) by using five different row spacings observed that spacing had little effect on fruit filling in plant crop, while in ratoon crop closer spacing resulted in poor filling of the fruits.

Caro-costas (1968) found that fruit size and shape were not significantly affected by the population levels.

2.2.6 Effect of spacing on peel weight, pulp weight and pulp/peel ratio

Chattopadhyay et al. (1980) and Reddy (1982) found that pulp/peel ratio decreased with higher plant population.

2.3 Effect of spacing on quality of fruits

Missinghan (1963) using five different spacings (0.90 x 3.9 m., 1.2 x 3.9 m, 1.5 x 3.9 m, 1.8 x 3.9 m and 2.1 x 3.9 m) observed that spacing had little effect on fruit quality in plant crop.

Robinson and Singh (1974) also observed that spacing had little effect on marketable quality of banana. Irizarry et al. (1975) reported that plant spacing and density apparently excerted a significant effect on marketable fruits per bunch. There was an inverse relationship between plant density and number of marketable fruits per bunch. A trial conducted at Banana Research Station, Kannara (Anon., 1978) on banana, revealed that when plant population increased from 4000 to 7000 plants ha^{-1}, marketable quality was found affected and at higher population the marketable quality was very poor.

Irizarry et al. (1978) observed that in Maricongo plantains planting densities in both single and double system of planting gave bunches and fruits of inferior quality in terms of sugars, sugar/acid ratio and TSS. Chattopadhyay et al. (1980) explained that acidity, TSS, total sugars, reducing sugars and protein content of fruits were not appreciably affected by plant population density. Chundawat et al. (1981 a) also explained that in Lacatan banana, different plant spacing had little detrimental effect on TSS and other quality attributes. Reddy (1982) and Chattopadhyay et al. (1984) reported that plant population density had no effect on fruit quality in terms of TSS, sugar/acid ratio as well as consumer preference.

Chundawat et al. (1983) reported that TSS decreased with increasing plant density. Mustaffa (1983) stated that closer spacing in 'Robusta' improved fruit quality while high nitrogen rates reversed the trend.

Morales and Rodriguez (1988) inferred from the study with Horn plantains at three planting densities (1111, 1720 and 1704 plants ha^{-1}) that the system gave fruits which met export standards but fruit quality decreased with increase in plant density.

Influence of plant spacing on total sugars and acidity was not significant in pineapple, when the population density from 49,000 to 111,111 plants ha^{-1} were evaluated (Dass *et al*., 1978). Similar observations were recorded by Chadha *et al*. (1973) for TSS but they observed increased acidity under high density planting. Increased acidity without influencing TSS was reported by Biswas *et al*. (1987) and Mustaffa (1988 b)in pineapple. Increased ascorbic acid content with increasing density also has been reported. (Mustaffa, 1988 b).

2.4 Effect of spacing on the benefit/cost ratio

Moreau (1965) reported that dense planting reduced weed growth in banana field, which also reduced the cost of cultivation. Caro-costas (1968) also observed that weeding cost was reduced with increasing plant population (1790 to 3850 plants ha^{-1}) per unit area.

Sharma and Roy (1972) in a fertilizer-cum-spacing trial on 'Dwarf Cavendish' banana cv. 'Jahajee', found that more profits can be earned from double fertilizer rate at closer spacing.

Chadha *et al*. (1975) in order to explore the possibility of obtaining higher yields with increasing planting densities in pineapple found that, in general, the economics was in favour of going in for higher densities. With increasing densities, it was observed that not only the total yield of fruits, but also the net returns increased. The net return in the highest population was found to be three times the net returns of the lowest population.

Alagiamanavalan and Balakrishnan (1976) adopted a spacing of 2.4 x 1.8m for single and double system of planting in 'Robusta' banana. In double planting system, two suckers were planted in adjacent pits between rows spaced 30 cm apart. They pointed out that the net profit per ha was greater (Rs. 37,740.00) than single planting (Rs. 20,920.00). However, production cost was higher in double planting system.

Reddy (1982) inferred from his experiment with 'Robusta' banana that the cost of cultivation, gross income and net profit increased with increase in plant population density. He concluded that net profit per unit area increased with increase in plant population density and cost/ benefit ratio increased with decrease in plant population density.

Rajeevan and Geetha (1989) worked out cost/ benefit ratio in 'Robusta' banana under two planting densities (2.4 x 1.8m - normal spacing and 1 x 1m - high density) and it was 1.86 for high density planting and 0.73

for normal spacing. Net profit was Rs. 69,716.00 in high density, while it was Rs. 47,732.00 for normal spacing.

Thomas et al. (1989) also worked out the cost of cultivation for 'Nendran' and 'Robusta' on the assumption that they could be grown at planting densities of 2500 and 2310 plants ha^{-1} respectively. The factors considered were cost of planting materials, manures, fertilizers, proping materials, labour, income from bunches and suckers and losses due to pests and diseases. They found that 'Robusta' was more profitable than 'Nendran', with benefit/cost ratios 1.34 and 1.28 respectively.

2.5 Effect of spacing on incidence of pests and diseases

Bunting and Dade (1926) observed that Cordana leaf spot diseases caused by *Cordana musae* Zimm. in banana was more in shaded leaves than those in full sun.

Heavy losses were met within New South Wales in 1956 on account of banana leaf spot caused by *Cercospora musae* (Anon., 1957). The incidence of the disease increased greately in wet summer. Young banana leaves were particularly susceptible during the period of high temperature and humidity prevailing in the north coast between December and March. Moreover plants in dense planting were found to be affected highe, where the humidity within the canopy was the highest. Vincente-chandler <u>et al</u>. (1966) reported that leaf spot diseases in banana was less under 50 per cent shade than in full sunlight.

With varying planting distances, the leaf emergence rate (LER) also changed, which was also used to estimate critical time of events related to fruit abnormality (Robinson, 1982) called November-dump and to banana bunchy top disease (Allen, 1978) and for timing control measures for leaf diseases (Allen, 1981).

Chundawat <u>et al</u>. (1981 a) reported poor growth and incidence of leaf spot in closer spaced banana plants.

A study conducted at Banana Research Station, Kannara, revealed that incidence of Sigatoka leaf spot disease was thee highest (33.69 per cent) in closer spacing of 1.2x 1.5 m and least in wider spacing of 2 x 2m (Anon., 1985 a).

Field experience suggests that incidence of Sigatoka leaf spot caused by <u>Mycosphaerella musicola</u> increased under high density planting especially in high rainfall and coastal regions. At Kovvur in Andra Pradesh, higher incidence of leaf spot disease was noticed under 1.4 x 1.4 m spacing than with 1.8 x 1.8 m planting. However, in dry regions of Maharashtra (Jalgaon), no incidence of leaf spot disease was noticed (Reddy and Singh, 1993).

Sherif and Thomas (1988) reported that the banana pseudostem boring weevil (_Odoiporus longicollis_) damage was severely manifested in the post- flowering phase of the crop. Bunched plants and those nearing bunching were the worst affected. Incidence of weevil were seldom observed in young plants below five months. 'Palayankodan', 'Kunnan', 'Poovan' and 'Nendran' were the most susceptible to the pest.

2.6 Effect of spacing on nutrient uptake

Manurial experiments as early as 1921 had revealed that nitrogen and potassium were required in large amounts by banana plant (Fawcett, 1921). Baillon _et al_. (1933) reported that a single banana plant of Cavendish variety in Canary Islands removed approximately 165g of N, 35g of P_2O_5 and 772g of K_2O from the soil. Norris and Ayyar (1942) reported that banana plant required large quantities of potassium, moderate quantities of nitrogen and relatively little phosphorus for optimum production.

Jacob and Uexkull (1960) found that the nutrient removal by a 30 tonne crop was to the tune of 50 to 75 kg N, 15 to 20 kg P_2O_5 and 175 to 220 kg K_2O respectively. Martin - prevel (1964) estimated the nutrient uptake in Dwarf Cavendish banana as 50 kg N, 12.5 kg P_2O_5 and 150 kg K_2O ha^{-1}, for a production of 25 M tonnes $ha^{-1}year^{-1}$. Shanmugham and Velayudham (1972) estimated the uptake of nutrients by banana plants as 300 kg N, 80 kg P_2O_5 and 800 kg K_2O ha^{-1}. Studies on nutrient uptake by Jauhari et al. (1974) revealed that in the first few months of planting there was rapid uptake of N, P_2O_5 and K_2O. The content of potassium in leaves and roots decreased with age but that in rhizome and pseudostem increased, pseudostem was the richest in potassium. Veeranna et al. (1976) reported that nitrogen and potassium were absorbed more in pre-flowering stage in 'Robusta'. There was, however, a continuous and steady uptake of nitrogen and potassium and the quantities were almost equal before and after flowering in 'Poovan'.

Sheela and Aravindakshan (1990) stated that in banana cv. 'Palayankodan', the uptake of nitrogen increased progressively with the growth of plant till shooting time irrespective of the amount of potassium applied, but between shooting and harvest, there was a decline. At harvest a decrease in total uptake was noticed. They also reported that the total uptake of phosphorus continued to increase throughout the duration of crop. The total uptake of potassium also continued to increase throughout the duration of crop. Among the nutrients, the uptake of potassium was the highest compared to the other two elements.

Kulasekaran (1993) reported that banana require high amount of mineral nutrients for proper growth and production. From one hectare, by a 50 t banana crop, 320 kg N, 23 kg P_2O_5 and 925 kg K_2O were removed every year. To maintain soil fertility and to permit continuous production, these nutrients must be replanished every year through organic manures and mineral fertilizers. Besides, Ca, Mg and other macro and micro nutrients were also essential for satisfactory production.

Randhawa et al. (1973) reported that in 'Robusta' banana 180 g N, 32 g P_2O_5 and 225 g K_2O $plant^{-1}$ $year^{-1}$ gave a maximum fruit yield of 42 to 53 t ha^{-1} when planted at a spacing of 2.4 x 1.8m than further closer spacing.

Patil et al. (1978) in an experiment with 'Basrai' banana found that when they were fertilized with 180g N, 180g P_2O_5 and 180g K_2O, yielded 32.410 and 79.93 t ha^{-1} at spacings 2 x 2m and 1.2 x 1.2m respectively.

Reddy (1982) reported that in 'Robusta' banana, the leaf nutrient status of the plant at shooting did not change with increase in plant population density. However, the total nutrient content of the plants at harvest increased with decrease in plant population density. He also reported that there was no significant difference in soil nutrient status at the end of the experiment in all treatments.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation on "Standardisation of spacing for tissue culture banana cv. Nendran (AAB group)" was conducted at the Department of Horticulture, College of Agriculture, Vellayani, Thiruvananthapuram during 1992-'93 situated at 8°5' North latitude, 77°1' East longitude and at an altitude of 29 m above the mean sea level. Soil of the experimental site is red loam belonging to Vellayani series, texturally classified as sandy clay loam.

The plantlets produced through tissue culture with three months age were planted in August, 1992. The plants were maintained as per the package of practices recommendations of Kerala Agricultural University for irrigated Nendran banana (Anon., 1989 a). Fertilizers were applied in six split doses as per the Kerala Agricultural University recommendations.

The experimental design adopted was Randomized Block Design (RBD) with five spacings as treatments, including the present recommended spacing of 2 x 2m; each with five replications. Each replication consisted of four experimental plants from which observations were recorded. The details of the various treatments imposed are furnished below:

Treatment No.	Spacing	Number of experimental plants per treatment	Number of plants ha^{-1}
T_1	2.25 x 2.25 m	20	1975
T_2	2.0 x 2.0 m	20	2500
T_3	1.75 x 1.75 m	20	3265
T_4	1.50 x 1.50 m	20	4444
T_5	1.25 x 1.25m	20	6400

The following observations were recorded to evaluate the performance of the treatment plants under varying spacings:

3.1 Vegetative characters

3.1.1 Height of the plants

Height of plants (cm) was recorded from the soil level to the base of the unopened leaf. Observations were continued at monthly intervals till flowering.

3.1.2 Girth of the plants

Girth of plants (cm) at monthly intervals was recorded at 10 cm above the ground level till flowering.

3.1.3 Number of leaves per plant

Number of leaves per plant at monthly intervals was recorded till flowering.

3.1.4 Leaf area index (LAI)

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

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

Leaf area in banana cv. Nendran was measured using the following model suggested by Robinson and Nel (1988):

LA = 0.83 L x B, where

LA = leaf area per leaf; L = leaf length

B = leaf breadth

3.1.5 Interval of leaf production

Interval of leaf production in different treatments were recorded observing the time interval between opening of two successive leaves.

3.1.6 Leaf area duration (LAD)

Leaf area duration was determined using the formula,

$$LAD = \frac{(L_0 + L_1)}{2} \times (t_1 - t_0) + \frac{(L_1 + L_2)}{2} \times (t_2 - t_1)$$

$$+ \ldots\ldots\ldots + \frac{(Ln_1 + Ln_2)}{2} \times (tn_2 - tn_1), \quad \text{where}$$

LAD = Leaf area duration, L_0 and L_1, L_1 and L_2, Ln_1 and Ln_2 are the LAI of the plants at time t_0 and t_1, t_1 and t_2, tn_1 and tn_2 respectively (Power et al., 1967).

3.1.7 Time taken for flowering

Time taken for flowering was recorded from the date of planting to visual bunch emergence and expressed in days.

3.1.8 Time taken for harvest

Time taken for harvest was recorded from the date of visual bunch emergence to date of harvest and was expressed in days.

3.1.9 Duration of crop

The total duration of the crop was recorded from the date of planting to harvest and was expressed in days.

3.1.10 Number of suckers per plant

Total number of suckers per plant in each treatment was recorded at the time of harvest.

3.1.11 Biomass production per plant

One plant from each treatment was uprooted immediately after harvest and separated into corm, suckers, leaves and leafsheaths and their weights were recorded. Bunch was separated into fingers and peduncle and their weights were recorded. This weights were then added to the total weight. Five hundred grams of each part was dried in hot air oven to calculate the drymatter content. Dryweight of senescent leaves and pruned suckers collected at different periods were added to the total weight of the plant at harvest. Biomass per hectare was calculated by multiplying biomass of individual plants with number of plants in one hectare under each treatment.

3.2 Yield characterestics

The observations were recorded immediately after harvest. The following observations were recorded.

3.2.1 Bunch weight

3.2.2 Number of hands per bunch

3.2.3 Number of fingers per bunch and hand

3.2.4 Length, girth and weight of the fingers

The middle finger in the top row of the second hand (Gottriech *et al*., 1964)were sampled to record length, girth and weight of fruits.

3.2.5 Shape of fingers

Visual observations on angularity of fingers and smoothness were recorded in the sample fruits.

3.2.6 Peel weight and pulp weight of fruits

The peel weight and pulp weight of the fully ripened sampled fruits were recorded and expressed in grams.

3.2.7 Pulp/peel ratio

Observations under 3.2.6 were used for calculating pulp/peel ratio.

3.3 Quality of fruits

Fully ripe fruits collected from bunches of different treatments were used for quality analysis. The middle fruit in the top row of the second hand was selected as the representative sample (Gottriech *et al*., 1964). Samples were taken from three portions (top, middle and bottom) from each sample fruit and these samples were then pooled and macerated in a waring blender. Three samples drawn from this were used for analysis of the different constituents in the fruits.

3.3.1 Drymatter content

Drymatter content was determined as per the procedure proposed by Piper (1950) using 500g of fresh fruit sample.

Drymatter percentage was calculated using the formula,

$$DM\ \% = \frac{\text{Total dry weight of sample (g)}}{\text{Total fresh weight of sample (g)}} \times 100$$

3.3.2 Titrable acidity

Titrable acidity was calculated by following the procedure proposed by Ranganna (1977).

A sample of 25 g madeup to 250 ml with distilled water was used for estimation. Results were expressed as per cent anhydrous citric acid.

3.3.3 Total soluble solids (TSS)

TSS was measured directly by using Erma refractometer (Pocket type) and was expressed as percentage on fresh weight basis.

3.3.4 Total sugars

The total sugars were determined as per the method described by Ranganna (1977). The results were expressed as percentage on fresh weight basis.

3.3.5 Reducing sugars

The reducing sugars of the samples were determined as per the method described by Ranganna (1977) on fresh weight basis.

Sample consisted of 25 g of fresh fruit material madeup to 250 ml with distilled water.

3.3.6 Non-reducing sugars

Non-reducing sugar content of the fruit samples were computed as follows using the values obtained for total and reducing sugars.

Non-reducing sugar = Total sugars - Reducing sugars (Ranganna, 1977)

3.3.7 Sugar/acid ratio

Sugar/ acid ratio was arrived at by dividing the value for total sugars with the value for titrable acidity of the corresponding sample.

3.3.8 Ascorbic acid

Ascorbic acid content was estimated as per the method suggested by Ranganna (1977). A sample of 25 g of fresh fruit madeup to 250 ml with 3 per cent meta-phosphoric acid was used for estimation.

The results were expressed as mg per 100g of fruit.

3.3.9 Time taken for ripening

The fruit samples were stored at room temperature in open card board boxes in a single row. The number of days taken from harvest to ripening, as indicated by change in fruit colour from green to light yellow was recorded (Stover and Simmonds, 1987).

3.3.10 Storage life at room temperature

The number of days taken from harvest to the development of black colour on the peel was recorded to determine the storage life of fruits at room temperatu (Stover and Simmonds, 1987)

3.4 Other observations

3.4.1 Benefit/cost ratio

Benefit/cost ratio of various treatments were worked out, considering all aspects of cost of cultivation and the income derived from the plant. It was calculated as per the norms and rates fixed by the Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram.

3.4.2 Incidence of pests and diseases

The various diseases and pests observed in the plant were recorded as and when they appeared. Disease scoring was carriedout as per the method suggested by Suharban (1977).

3.4.3 Soil nutrient status

Soil samples were collected from the plot before planting and after harvest and were analysed for available nitrogen, phosphorus and potassium following the method of Jackson (1960).

3.4.4 Uptake of major plant nutrients

To assess the nutrient uptake, plant samples were collected at the time of harvest. Sampling was done following the method of Twyford and Walmsley (1973).

The plant parts used for analysis were corm, pseudostem, leaf, leaf sheath and bunch. The samples were analysed for nitrogen, phosphorus and potassium content. Results were expressed as gram $plant^{-1}$ on dry weight basis.

3.4.5 Statistical analysis

The data collected on different characters were analysed by applying the technique of analysis of variance for randomised block design following Panse and Sukhatme (1967).

RESULTS

EXPERIMENTAL RESULTS

The present investigation was carried out to study the effect of different levels of plant spacings on growth, yield and quality of 'Nendran' banana produced through tissue culture, so as to determine the optimum spacing for maximum yield and quality attributes. The experiment was conducted at the Department of Horticulture, College of Agriculture, Vellayani, Thiruvananthapuram during 1992-'93. The results of the study are presented below:

4.1 Vegetative characters

4.1.1 Effect of spacing on the height of tissue culture Nendran banana

The results of the study on the effect of different spacings on the height of tissue culture Nendran plants are presented in Table 1 and Fig 1.

The data indicated that there was no significant difference among the treatments on the height of plants till fourth month after planting. From the fifth month onwards, the treatments showed significant differences in the plant height.

During the fifth month, the treatment T_5 (1.25 x 1.25m) showed the highest mean values for plant height (172.90 cm) followed by T_4 (1.5 x 1.5m) which recorded a mean plant height of 171.30 cm; both the treatments being statistically on par. However, T_4 did not differ significantly from T_3 (1.75 x 1.75 m) which recorded a mean plant height of 155.80 cm. The treatments T_3 and T_2 (2.0 x 2.0m) were statistically on par; the latter recording a mean plant height of 144.40 cm. The lowest values for plant height was recorded in a wider spacing tried (2.25 x 2.25m) which recorded a mean height of 137.10 cm; the value being statistically on par with that of T_2.

During the sixth month, the plants were the tallest in T_5 (226.50 cm) followed by T_4 (220.40 cm) and T_3 (202.10 cm); all the three treatments being statistically on par. The lowest values for plant height was recorded in T_1 (178.00 cm) followed by T_2 (185.60 cm). These two treatments were statistically on par with T_3.

The plant height was the highest in T_5 (279.90 cm) followed by T_4 (262.10 cm) in the seventh month after planting and these treatments were statistically on par. The treatment T_3 (245.20 cm) did not differ significantly from T_4. The lowest values for plant height were recorded in T_1 (221.20 cm) followed by T_2 (227.40 cm) and T_3 (245.20 cm); the three treatments being statistically on par.

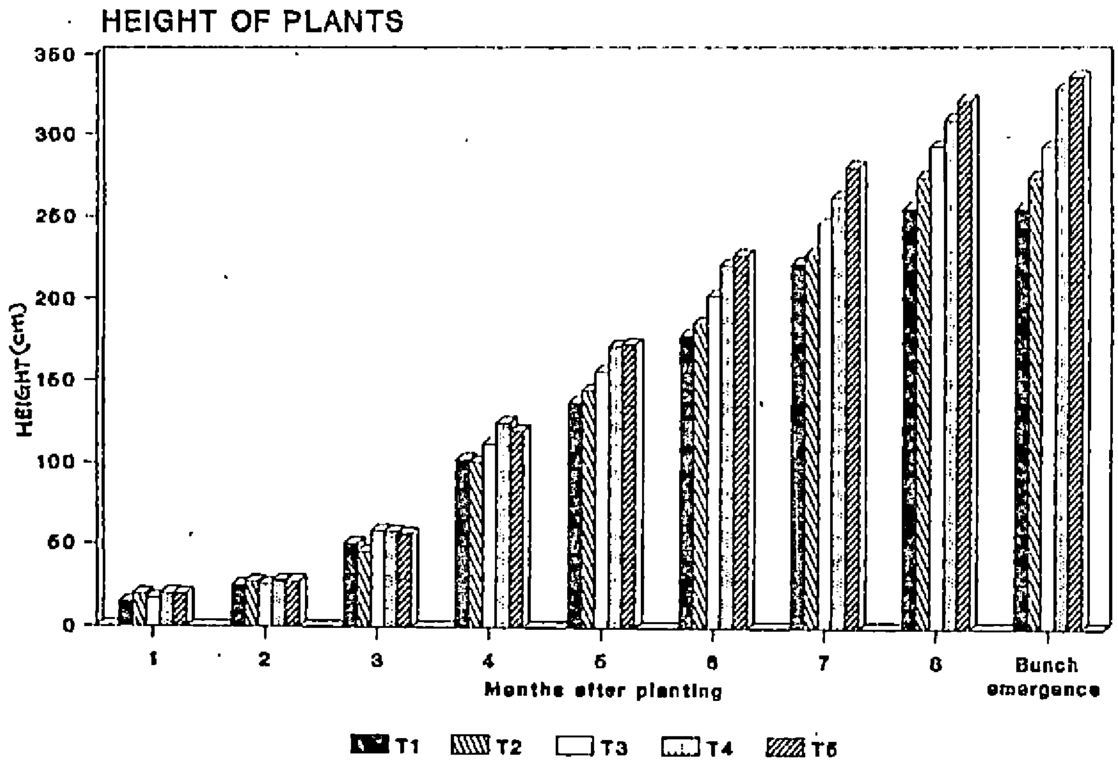
Table 1. Effect of spacing on the height of tissue culture Nendran banana

Treatments	Height of plants (cm) - Months after planting									
	1	2	3	4	5	6	7	8	9	At bunch emergence
T_1	14.70	24.50	50.50	102.10	137.10	178.00	221.20	255.00	255.00	255.00
T_2	19.20	27.16	45.50	100.80	144.40	185.60	227.40	273.90	273.90	273.90
T_3	17.10	25.72	58.10	111.80	155.80	202.10	245.20	292.30	292.30	292.30
T_4	19.60	27.60	57.40	124.40	171.30	220.40	262.10	308.70	327.90	327.90
T_5	19.37	27.36	56.40	119.50	172.90	226.50	279.90	320.90	335.70	335.70
F-test	NS	NS	NS	NS	*	**	**	**	**	**
CD(0.05)	-	-	-	-	24.369	28.542	27.683	24.020	22.223	22.223

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level



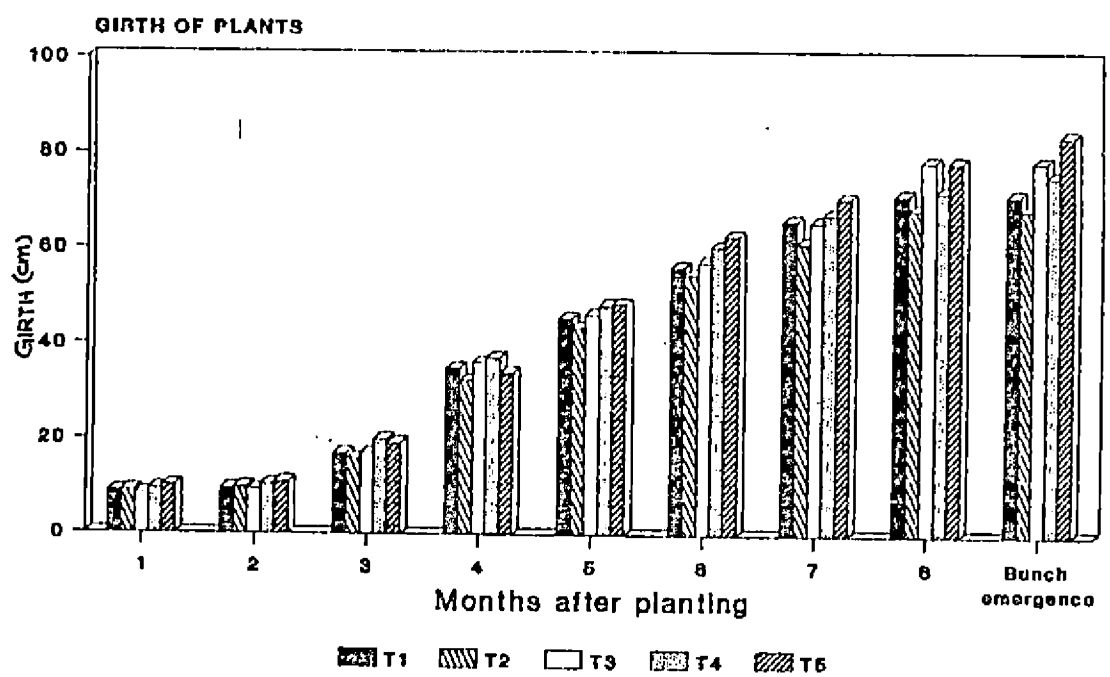


Fig. 1. Effect of spacing on height and girth of tissue culture Nendran banana

Data on plant growth pattern in the eighth month after planting also showed that the height of plants was the highest in T_5 (320.90 cm) followed by T_4 (308.70 cm) and T_3 (292.30 cm). The treatment T_5 did not differ significantly from T_4, while the latter was on par with T_3. The mean values for plant height was the lowest in T_1 (255.00 cm) followed by T_2 (273.90 cm); the two treatments being statistically on par, while the latter was on par with T_3.

During the ninth month after planting, the plants were the tallest in T_5 (335.70 cm) followed by T_4 (327.90 cm) and both the treatments were statistically on par, but significantly different from all other treatments. The lowest plant height was recorded in T_1 (255.00 cm) followed by T_2 (273.90 cm); both the treatments being statistically on par. However, T_3 (292.30 cm) which followed T_2 did not differ significantly from the latter.

After ninth month, since the bunch had emerged in all treatments there was no increase in the height of plants. Therefore, the data on height of plants at bunch emergence showed the same trend as in the observations recorded at ninth month after planting.

The data revealed that in the early growth stages the height of plants remained more or less unaffected by the treatments. However, from fifth month after planting, plant height varied significantly under the influence of various treatments imposed. During this period the plant height was found to increase with decrease in spacing.

4.1.2 Effect of spacing on the girth of tissue culture Nendran banana

The results of the study are presented in Table 2 and Fig 1. The data showed no significant difference in the girth of plants till eighth month after planting. However, the mean values showed that the girth of plants was higher in the closest spacings (T_4 and T_5) upto eighth month. During the ninth month after planting, there was significant difference in the girth of plants due to the difference in spacing. Between eighth and ninth months, there was no further increase in girth in treatments T_1, T_2 and T_3.

Between the ninth month after planting and the subsequent period till flowering in all the treatments, there was no further increase in plant girth. During the above growth period, the highest mean value (83.60 cm) was recorded in T_5 followed by T_3 (78.20 cm) and T_4 (75.20 cm); these treatments being statistically on par. The treatments T_3 and T_4 however did not differ significantly from T_1 (71.10 cm). The treatments T_4 and T_1 were statistically on par with T_2 (68.10 cm) which recorded the lowest mean value for girth of plants.

Table 2. Effect of spacing on the girth of tissue culture Nendran banana

Treat- ments	Plant girth (cm) Months after planting									
	1	2	3	4	5	6	7	8	9	At bunch emergence
T_1	8.75	9.36	16.97	34.86	45.60	56.17	65.65	71.10	71.10	71.10
T_2	8.89	9.78	15.95	32.45	43.61	54.72	61.15	68.10	68.10	68.10
T_3	8.39	9.24	17.02	36.28	46.39	57.20	65.36	78.20	78.20	78.20
T_4	9.38	10.38	19.99	37.13	48.27	60.37	66.95	71.80	75.20	75.20
T_5	9.99	10.89	19.26	33.94	48.55	62.48	70.42	78.10	83.60	83.60
F-test	NS	NS	NS	NS	NS	NS	NS	NS	*	*
CD(0.05)	-	-	-	-	-	-	-	-	9.728	9.728

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

From the above inferences it is evident that the treatments did not show any significant influence in the girth of plants till eighth month after planting, when bunch emergence had started in wider spacings. In the ninth month after planting and at bunch emergence time, the girth of plants was found to increase in closer spacings.

4.1.3 Effect of spacing on leaf production of tissue culture Nendran banana

The data on the effect of spacing on monthly leaf production are presented in Table 3.

During the first to fifth months after planting, there was no significant difference between the treatments in the rate of leaf production except in the second month. During the second month after planting, the highest number of leaves were produced in T_5 (4.5) followed by T_3 (4.4) and these two treatments were statistically on par, but significantly superior to all other treatments. The treatments T_4, T_2 and T_1 produced 3.2, 3.1 and 3.1 leaves respectively and these were statistically on par.

Table 3. Effect of spacing on the leaf production of tissue culture Nendran banana

Treatment	Monthly rate of leaf production										Total upto bunch emergence
	Months after planting										
	1	2	3	4	5	6	7	8	9	At bunch emergence	
T_1	1.9	3.1	5.1	5.8	5.8	6.0	6.4	3.9	-	-	38.0
T_2	1.8	3.1	4.6	5.4	5.7	6.0	6.6	4.8	-	-	38.0
T_3	1.3	4.4	5.4	5.7	5.7	5.9	6.3	5.6	1.6	-	41.9
T_4	2.3	3.2	5.1	5.0	5.4	4.5	5.2	5.6	6.0	0.7	43.0
T_5	1.70	4.5	5.6	5.7	6.2	4.6	5.6	5.7	5.9	1.4	46.9
F-test	NS	*	NS	NS	NS	**	**	*	**	**	**
CD(0.05)	-	1.118	-	-	-	1.054	0.586	1.211	0.437	0.437	1.336

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

During the sixth month after planting, the leaf production rate showed significant difference due to differences in spacing. The lowest number of leaves during the month were produced in T_4 (4.5) followed by T_5 (4.60); both the treatments were statistically on par, but significantly different from the other treatments. The highest number of leaves were produced in T_2 and T_1 (6.0 in each) followed by T_3 (5.9) and these treatments were statistically on par.

During the seventh month after planting the treatments showed significant difference in the number of leaves produced. The lowest number of leaves were produced in T_4 (5.2) followed by T_5 (5.6); both the treatments being statistically on par, but significantly different from other treatments. The highest number of leaves were produced in T_2 (6.6) followed by T_1 (6.4) and T_3 (6.3) and these three treatments were statistically on par.

The treatments differed in the number of leaves produced during eighth month after planting. The highest number of leaves were produced in T_5 (5.7) followed by T_3 and T_4 (5.6 each). All these treatments were statistically on par with T_2 (4.8). The treatment T_2 did not differ significantly from T_1 (3.9) which produced the lowest number of leaves.

During the ninth month after planting, no leaves were produced in T_1 and T_2 since bunch emergence had already occurred. The treatment T_3 produced the lowest number of leaves during the period (1.6) because bunch emergence was nearing in this treatment. Highest number of leaves were recorded in T_4 (6.0) followed by T_5 (5.9) and the two treatments were significantly superior to T_3.

During the month of visible bunch emergence in T_4 and T_5, flowering had already taken place in all other treatments. The treatments T_5 which recorded the higher mean value for the number of leaves (1.4) was significantly superior to T_4 (0.7).

Data on the total number of leaves produced in different treatments are furnished in Table 3. Among the five treatments, T_5 recorded the highest number of leaves (46.9) and it was significantly superior to all other treatments. The plants on treatments T_4 (43.0) and T_3 (41.9) followed T_5 and they were statistically on par, but significantly superior to T_1 and T_2 (38.0 each). The latter two treatments were statistically on par.

From the results, it becomes evident that the monthly rate of leaf production was not influenced by different spacings during the vegetative growth phase upto fifth month after planting. Thereafter, the rate of leaf production increased during sixth and seventh months in the wider spacings compared to closer spacings. The rate of leaf production decreased later in the treatments nearing flowering, which took place at different durations under the influence of the treatments. It was observed that the total number of leaves produced per plant were more in closer spacing compared to wider spacings.

4.1.4 Effect of spacing on the number of functional leaves in tissue culture Nendran banana

Data on the effect of spacings on the number of functional leaves are presented in Table 4 and Fig 2.

The data revealed that there was no significant difference between treatments till seventh month after planting. However, the mean values indicated that the number of functional leaves were more in closer spacings (T_4 and T_5) during third to sixth months after planting. In the seventh month after planting the number of functional leaves present were almost the same in all the treatments.

In the eighth month after planting, different treatments showed significant difference in the number of functional leaves present. The highest number of functional leaves were present in T_1 (11.60) followed T_2 (11.40), and T_3 (10.60); all the treatments being statistically on par. The lowest number of functional leaves were observed in T_4 (10.20) followed by T_5 (10.40) and these treatments were statistically on par with T_3. The treatment T_5 was on par with T_3 and T_2.

During the ninth month after planting, the highest number of functional leaves were recorded in T_5 (9.89) followed by T_4 (9.50); both the treatments being statistically on par, but significantly superior to other treatments. The treatments T_2 and T_1 followed the former in the number of functional leaves (8.10 and 8.00 respectively) and both the treatments were statistically on par and

Table 4. Effect of spacing on the total number of functional leaves of tissue culture Nendran banana

Treatment	Number of functional leaves per plant										
	Months after planting										
	1	2	3	4	5	6	7	8	9	At bunch emergence	At harvest
T_1	6.80	7.40	7.90	8.50	9.30	9.89	10.30	11.60	8.00	11.60	5.60
T_2	7.20	7.20	7.80	8.10	8.60	9.70	10.00	11.40	8.10	11.40	6.00
T_3	6.10	7.10	7.60	8.89	9.50	10.10	10.30	10.60	7.20	10.60	4.00
T_4	7.20	8.20	9.00	9.00	10.10	10.50	10.40	10.20	9.50	9.50	3.40
T_5	6.30	7.10	8.10	9.30	9.80	10.50	10.50	10.40	9.89	9.89	2.40
F-test	NS	NS	NS	NS	NS	NS	NS	*	**	**	**
CD(0.05)	-	-	-	-	-	-	-	1.018	0.478	0.841	0.632

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

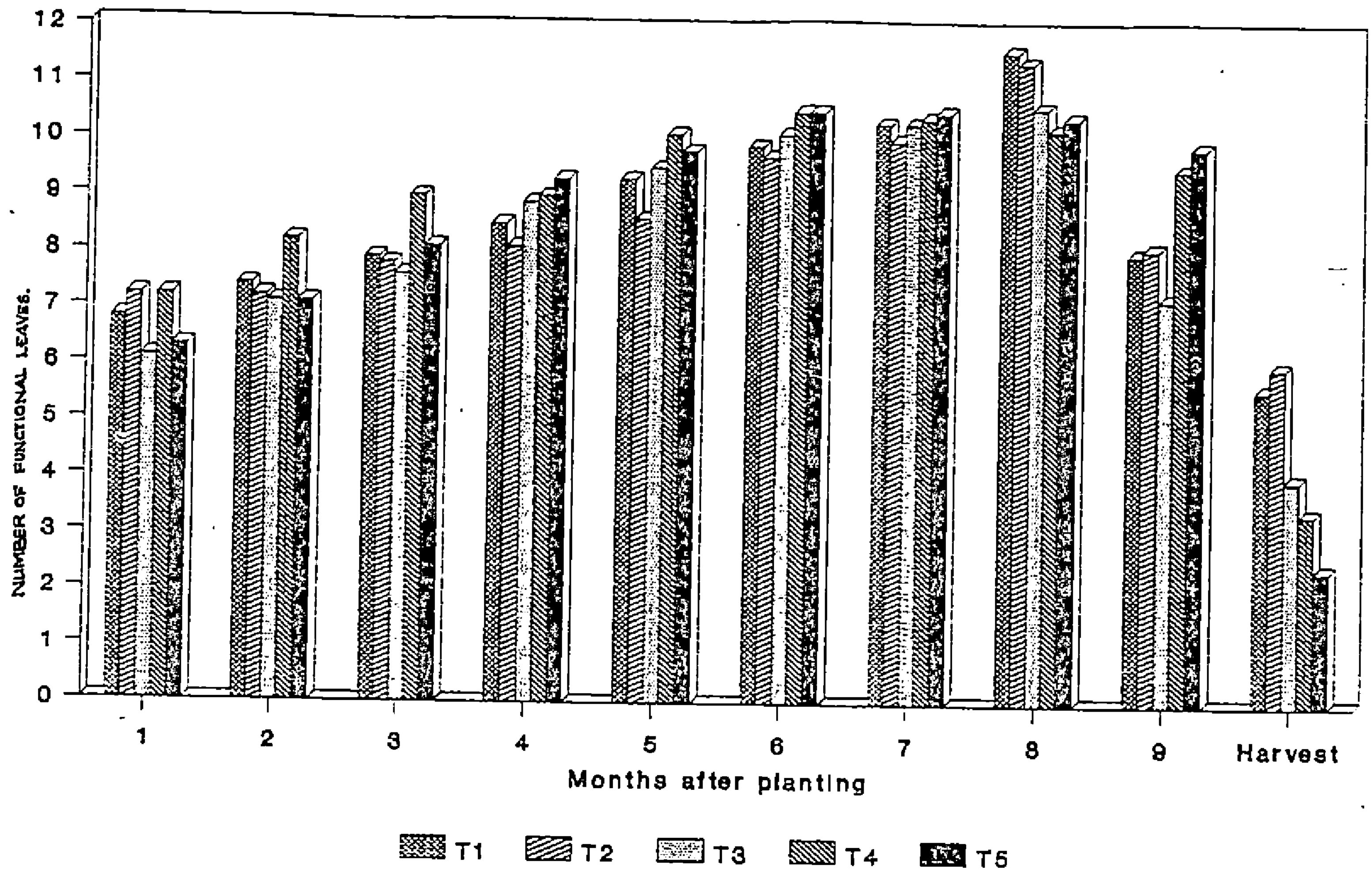


Fig. 2. Effect of spacing on total number of functional leaves of tissue culture Nendran banana

significantly superior to T_3. The lowest number of functional leaves were observed in T_3 (7.20).

At bunch emergence stage, highest number of functional leaves were present in T_1 (11.60) followed by T_2 (11.40) and these two treatments were significantly superior to all other treatments, but did not differ significantly between them. The treatment, T_3 which followed T_1 and T_2 had 10.60 functional leaves and this treatment was statistically on par with treatment T_5 (9.89). The lowest number of functional leaves at this stage was observed in T_4 (9.50), which did not differ significantly from T_5.

At harvest stage the treatment T_2 and T_1 which recorded the highest number of functional leaves (6.00 and 5.60 respectively) were significantly superior to all other treatments. The lowest number of functional leaves was recorded in T_5 (2.40) followed by T_4 (3.40) and T_3 (4.00). The treatments T_3 and T_4 were statistically on par, but significantly different from T_5.

The experiment revealed that in the early stages of plant growth, there was no significant difference between the treatments with respect to the number of functional leaves present; the wider spacings (T_2 and T_1) having more number of functional leaves than the closer spacings.

4.1.5 Effect of spacing on monthly increment in leaf area of tissue culture Nendran banana

The data on the monthly acquired leaf area under the influence of different spacings are presented in Table 5 and Fig 3.

It was observed that treatments did not show any significant difference in the monthly increment in leaf area between first to third month after planting. However, the mean values showed that the increment was less in wider spacings (T_1 and T_2) compared to the closer spacings (T_3, T_4 and T_5). In the fourth month after planting, the treatments differed significantly with respect to the leaf area increment. The highest leaf area was recorded in T_5 (3.190 m^2), which was significantly superior to all other treatments. The treatments T_3 (2.271 m^2) and T_4 (2.062 m^2) did not differ significantly from one another. The lowest leaf area was recorded in T_2 (1.467 m^2) and T_1 (1.739 ^{2}) and these treatments were statistically on par with T_4.

Table 5. Effect of spacing on monthly increment in leaf area of tissue culuture Nendran bana

Treatment	Total leaf area produced per month (m^2. plant $^{-1}$) Months after planting: 1	2	3	4	5	6	7	8	9	10	Upto bunch emergence
T_1	0.081	0.194	0.744	1.739	2.762	5.007	6.928	4.236	0	0	21.691
T_2	0.130	0.172	0.595	1.467	2.962	4.420	6.746	5.792	0	0	22.225
T_3	0.053	0.328	0.953	2.271	3.498	5.546	7.840	8.268	1.701	0	30.657
T_4	0.085	0.220	0.963	2.062	3.658	4.510	7.062	8.882	10.393	0	37.834
T_5	0.059	0.331	1.322	3.190	5.594	5.388	8.829	11.215	11.142	2.200	49.271
F-test	NS	NS	NS	**	**	NS	*	**	**	**	**
CD(0.05)	-	-	-	0.7525	1.1402	-	1.3545	1.9598	1.097	0.3565	3.9357

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

During the fifth month after planting, the treatment T_5 recorded the highest value for leaf area (5.594 m^2) which was significantly superior to all other treatments. This was followed by T_4 (3.658 m^2) and T_3 (3.498 m^2). The lowest values were recorded in T_1 (2.762 m^2) followed by T_2 (2.962 m^2). All these four treatments were statistically on par.

During the sixth month after planting, there was no significant difference between treatments in the monthly acquired leaf area, however, the mean value showed that the treatment T_5 recorded the highest leaf area (5.388 m^2).

During the seventh month after planting, the highest leaf area increment was observed in T_5 (8.829 m^2) followed by T_3 (7.840 m^2); both the treatments being statistically on par. The lowest values were recorded in T_2 (6.746 m^2) followed by T_1 (6.928 m^2) and T_4 (7.062 m^2); the three treatments being statistically on par with T_3.

During the eighth month after planting, the treatment T_5 recorded significantly higher leaf area increment (11.215 m^2). This was followed by T_4 (8.882 m^2) and T_3 (8.268 m^2); the latter two being statistically on par. The lowest values were recorded in T_1 (4.236 m^2)

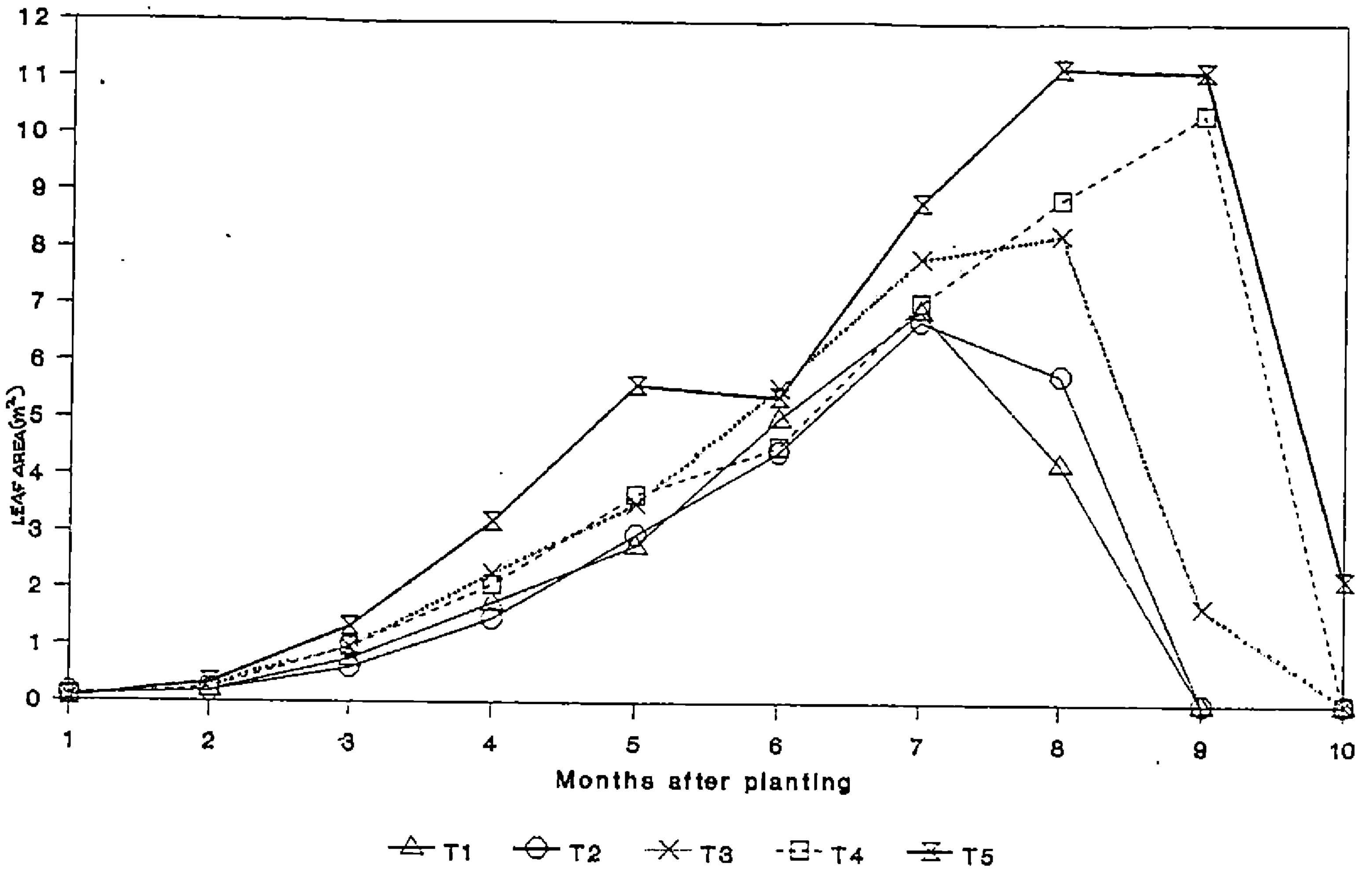


Fig. 3. Effect of spacing on monthly increment in leaf area of tissue culture Nendran banana

followed by T_2 (5.792 m^2) and these two treatments did not differ significantly from one another.

During the ninth month after planting, there was no new leaf production in T_1 and T_2, because bunch had already emerged. The treatments T_5 (11.142 m^2) and T_4 (10.393 m^2) recorded the highest leaf area. These two treatments were significantly superior to T_3 (1.701 m^2).

The data recorded on the increment in leaf area upto bunch emergence revealed that the highest values were in T_5 (49.271 m^2) followed by T_4 (37.834 m^2) and T_3 (30.657 m^2). These treatments were significantly different from one another. The lowest values were recorded in T_1 (21.691 m^2) followed by T_2 (22.225 m^2); both of them being statistically on par.

In general it was observed that the differences in for spacing did not influence the increment in the monthly leaf area during the initial periods of first to third month after planting and sixth month after planting. In other growth stages, the treatments showed significant influence on leaf area increment. The general trend observed was that leaf area increment was lesser with increase in the spacing. The total leaf area produced upto bunch emergence also showed the same trend.

4.1.6 Effect of spacing on functional leaf area of tissue culture Nendran banana

The data (Table 6 and Fig 4) revealed that between first and third month after planting, there was no significant difference in the functional leaf area of individual plants. However, the mean values showed that during this period, functional leaf area was more in closer spacings compared to the wider spacings in T_1 and T_2.

During the fourth month after planting the highest functional leaf area was recorded in T_5 (4.358 m^2) followed by T_3 (3.052 m^2) and these two treatments were significantly superior to other treatments. The treatment T_2 recorded the lowest functional leaf area (1.846 m^2) followed by T_1 (2.103 m^2); both the treatments being statistically on par. The treatment T_4 (2.831 m^2) which followed T_1 did not differ significantly from the former.

During the fifth month after planting, the treatment T_5 which recorded the highest functional leaf area was significantly superior to all other treatments. This was followed by T_4 (5.514 m^2) and T_3 (5.145 m^2) and these two

Table 6. Effect of spacing on the functional leaf area of tissue culture Nendran banana

Treatment	Functional leaf area (m^2 $plant^{-1}$)										
	Months after planting										
	1	2	3	4	5	6	7	8	9	At bunch emergence	At harvest
T_1	0.128	0.287	1.010	2.103	3.790	6.429	9.811	12.468	8.921	12.470	6.228
T_2	0.124	0.285	0.881	1.846	3.853	6.714	9.615	12.234	9.090	12.234	6.821
T_3	0.137	0.407	1.343	3.052	5.145	8.349	11.932	14.161	9.717	12.383	5.265
T_4	0.136	0.341	1.200	2.831	5.514	8.181	11.561	15.180	15.151	15.151	4.939
T_5	0.127	0.425	1.505	4.358	8.051	11.385	14.591	18.724	18.710	18.817	3.898
F-test	NS	NS	NS	**	**	**	**	**	**	**	**
CD(0.05)	-	-	-	0.8829	1.3037	1.5489	1.6695	1.3489	1.0013	1.7293	0.8828

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

treatments were statistically on par. The lowest functional leaf area during this period was recorded in T_1 (3.790 m^2) followed by T_2 (3.583 m^2). These two treatments were statistically on par, whereas T_2 was on par with T_3.

During the sixth month after planting also the treatment T_5 recorded the highest functional leaf area (11.385 m^2) which was significantly superior to all other treatments. The treatments T_3 and T_4 (8.349 m^2 and 8.181 m^2 respectively) which followed T_5 did not differ significantly from one another. The lowest functional leaf area was observed in T_1 (6.429 m^2) followed by T_2 (6.714 m^2); both the treatments being statistically on par with T_4.

During the seventh month after planting, the treatment T_5 showed significantly higher functional leaf area (14.591 m^2) compared to the other treatments. Treatment T_3 (11.932 m^2) and T_4 (11.561 m^2) followed T_5 and the latter two were statistically on par. The lowest functional leaf area was recorded in T_2 (9.615 m^2) followed by T_1 (9.811 m^2); both being statistically on par.

During the eighth month after planting, T_5 recorded highest functional leaf area as observed in previous growth stages (18.727 m^2) which was significantly superior to all other treatments. The treatments T_4 (15.180 m^2) and T_3

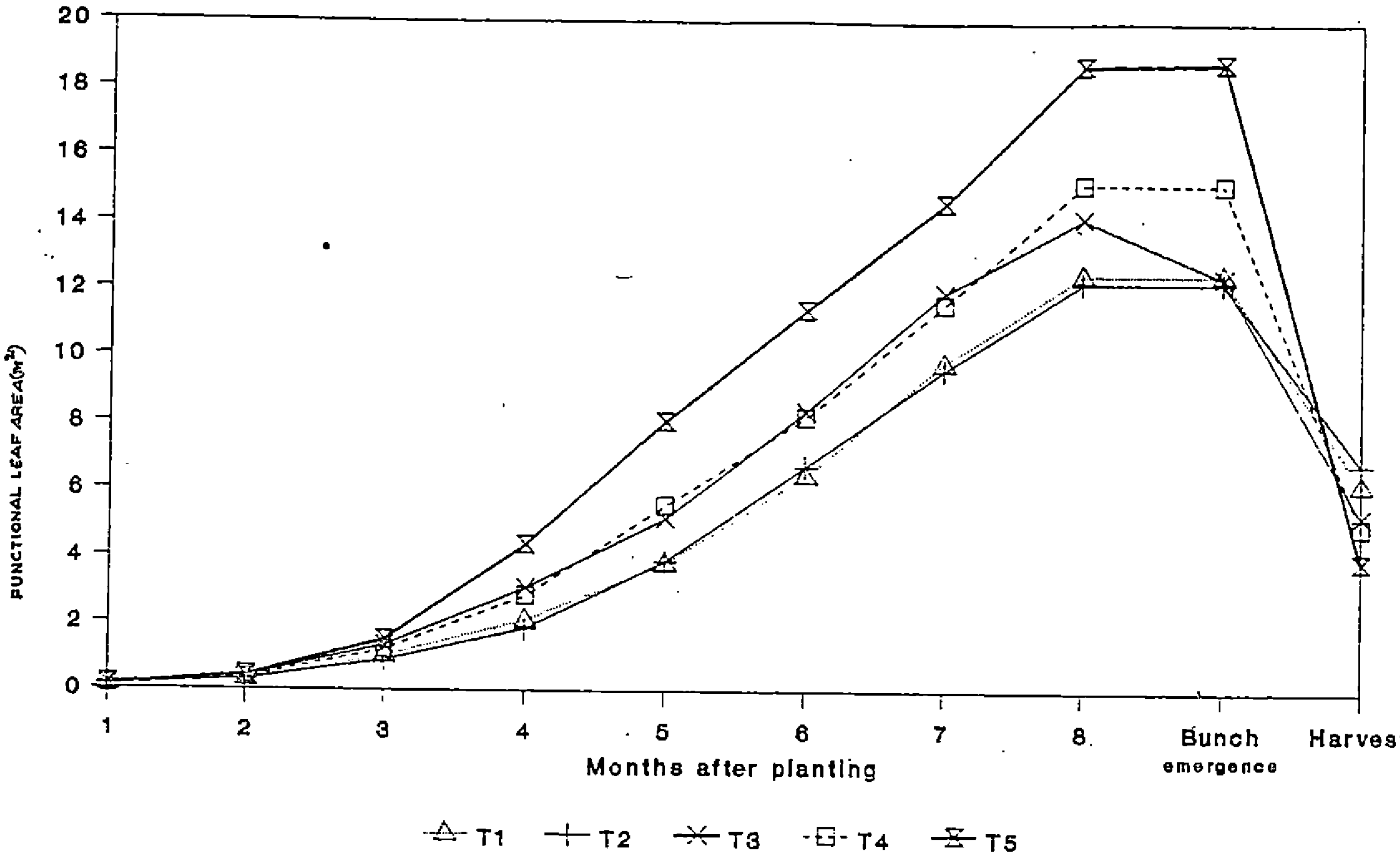


Fig. 4. Effect of spacing on functional leaf area of tissue culture Nendran banana

(14.161 m^2) which followed T_5 did not differ significantly from one another. The treatment T_2 (12.234 m^2) and T_1 (12.468 m^2) which were statistically on par, recorded the lowest functional leaf area in the order.

During the ninth month after planting, the treatment T_5 showed significantly superior value for functional leaf area (18.710 m^2) followed by T_4 (15.151 m^2); the latter two being superior to all the treatments except T_5. The lowest value for functional leaf area was observed in T_1 (8.921 m^2) followed by T_2 (9.090 m^2) and T_3 (9.717 m^2). These three treatments were statistically on par.

At bunch emergence also, the treatment T_5 (18.817 m^2) recorded the highest functional leaf area followed by T_4 (15.151 m^2); both the treatments being significantly superior to all other treatments, but significantly different from one another. The lowest values for functional leaf area were recorded in T_2 (12.234 m^2) followed by T_3 (12.383 m^2) and T_1 (12.470 m^2); the treatments being statistically on par.

At harvest stage the functional leaf area was the highest in T_2 (6.821 m^2) followed by T_1 (6.228 m^2); both the treatments being statistically on par, but significantly superior to all other treatments. The lowest functional leaf area at harvest was observed in T_5 (3.898 m^2). This treatments differed significantly from all other treatments. The treatments T_4 (4.939 m^2) and T_3 (5.265 m^2) which followed T_5 did not differ significantly between them.

In,general, it was observed that the functional leaf area decreased with increase in spacing during all stages of growth except at harvest.

4.1.7 Effect of spacing on leaf area index and leaf area duration of tissue culture Nendran banana

Data on leaf area index during different growth stages are presented in Table 7.

The data revealed that leaf area index (LAI) was influenced by the treatments in all the stages. In the first month after planting, the treatment T_5 recorded the highest value for LAI (0.081) followed by T_4 (0.060) and T_3 (0.044) and all the three treatments were statistically on par. The lowest values were recorded in T_1 (0.025) followed by T_2 (0.030) and these two treatments were statistically on par with T_3 and T_4.

During the second month after planting, the treatment T_5 recorded significantly higher LAI (0.272). The

Table 7. Effect of spacing on leaf area index (LAI) and leaf area duration (LAD) of tissue culture Nendran banana

Treatment	Leaf area index (LAI) Months after planting											LAD
	1	2	3	4	5	6	7	8	9	At bunch emergence	At harvest	
T_1	0.025	0.057	0.199	0.415	0.749	1.272	1.938	2.463	1.762	2.463	1.230	331.322
T_2	0.030	0.071	0.220	0.462	0.963	1.679	2.404	3.058	2.272	3.058	1.705	431.068
T_3	0.044	0.133	0.438	0.997	1.680	2.726	3.897	4.624	3.173	4.044	1.719	698.914
T_4	0.060	0.152	0.533	1.254	2.451	3.636	5.316	6.658	6.734	6.734	2.195	1190.972
T_5	0.081	0.272	0.963	2.789	5.152	7.287	9.337	11.982	11.976	12.042	2.494	2198.916
F-test	*	**	**	**	**	**	**	**	**	**	**	**
CD(0.05)	0.0386	0.0563	0.1706	0.4049	0.5695	0.5526	0.5884	0.5476	0.4368	0.6255	0.3477	143.358

* - Significant at 5% level

** - Significant at 1% level

treatments T_4 (0.152) and T_3 (0.133) were statistically on par and followed T_5. The lowest LAI was observed in T_1 (0.057) followed by T_2 (0.071); both the treatments being statistically on par. In the third month after planting also the same trend observed in the second month after planting prevailed. T_5 recorded the highest LAI (0.963) followed by T_4 (0.533), T_3 (0.438), T_2 (0.220) and T_1 (0.199). The same trend continued in the fourth month after planting also; the highest leaf area index being T_5 (2.789), followed by T_4 (1.254), T_3 (0.997), T2 (0.462) and T_1 (0.415).

During the fifth month after planting, the treatment T_5 which recorded a LAI value of 5.152 was significantly superior to all other treatments, followed by T_4 (2.451) which was significantly superior to other treatments except T_5 and T_3 (1.680) which was significantly superior to T_1 and T_2. The treatment T_1 recorded the lowest LAI (0.749) followed by T_2 (0.963); the two treatments being statistically on par. The trend observed in the fifth month prevailed in sixth month also. The leaf area index values were the highest in T_5 (7.287) followed by T_4 (3.636) and T_3 (2.726). The lowest values were recorded in T_1 (1.272) followed by T_2 (1.679). The same trend continued during seventh month after planting also, where T_5 recorded the highest LAI (9.337) followed by T_4 (5.316) and T_3 (3.897).

The lowest LAI was observed in T_1 (1.938) followed by T_2 (2.404).

During the eighth month after planting, it was observed that the LAI was higher in the closer spacings. All the treatments were significantly different from one another. The LAI values in the descending order are T_5 (11.982), T_4 (6.658), T_3 (4.624), T_2 (3.058) and T_1 (2.463). The same trend continued in the ninth month after planting also; the values recorded being T_5 (11.976), T_4 (6.734), T_3 (3.173), T_2 (2.272) and T_1 (1.672).

At bunch emergence, the highest leaf area index was observed in T_5 (12.042) followed by T_4 (6.734) and T_3 (4.044). These three treatments were significantly different from one another and superior to T_1 (2.463) and T_2 (3.058); the latter two being statistically on par.

At harvest stage the highest leaf area index value recorded in T_5 (2.494) was statistically on par with that of T_4 (2.195). The treatment T_1 recorded the lowest LAI (1.230) followed by T_2 (1.705) and T_3 (1.719); the latter two being statistically on par, but significantly superior to T_1.

The observations indicated that the LAI increased with the increase in population density. The closest spacings recorded the highest LAI.

Data on leaf area duration (LAD) presented in Table 7 revealed that the LAD was the highest in T_5 (2198.916) followed by T_4 (1190.972) and T_3 (698.914). These three treatments were significantly different from one another and superior to T_1 (331.322) and T_2 (431.068); the latter two being statistically on par. It was noted that leaf area duration increased with decrease in spacing, and closer spaced plants recorded higher leaf area duration values.

4.1.8 Effect of spacing on the interval of leaf production in tissue culture Nendran banana

The data on the effect of spacing on interval of leaf production (phylacron) are presented in Table 8, which showed that from the first to fifth months after planting, there was no significant difference between treatments. A clear cut relationship between phylacron and spacing could not be established during this period.

Table 8. Effect of spacing on the interval of leaf production in tissue culture Nendran banana

Treatments	Interval of leaf production (days)								
	Months after planting								
	1	2	3	4	5	6	7	8	9
T_1	17.40	10.21	5.99	5.18	5.24	5.00	4.69	4.96	-
T_2	18.80	10.01	6.60	5.58	5.30	5.03	4.56	5.11	-
T_3	26.40	7.17	5.62	5.35	5.30	5.18	4.84	5.50	4.44
T_4	13.80	10.23	5.96	6.20	5.68	6.73	5.87	5.55	5.00
T_5	20.40	7.11	6.01	5.29	4.86	6.96	5.41	5.30	5.20
F-test	NS	NS	NS	NS	NS	*	**	NS	**
CD(0.05)	-	-	-	-	-	1.436	0.597	-	0.389

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

During the sixth month after planting, the treatment T_5 recorded the highest interval for leaf production (6.96 days) followed by T_4 (6.73 days); both the treatments being statistically on par, but significantly superior to all other treatments. The interval of leaf production was the shortest in T_1 (5.00 days) followed by T_2 (5.03 days) and T_3 (5.18 days; the treatments being statistically on par.

During the seventh month after planting, treatment T_4 recorded the longest interval of leaf production (5.87 days) followed by T_5 (5.41 days), but the two treatments did not differ significantly from one another. The treatment T_3 (4.84 days) which followed T_5 was statistically on par with the latter. The shortest interval for leaf production was observed in T_2 (4.56 days) followed by T_1 (4.69 days); both being on par with T_3.

There was no significant difference between the treatments in the eighth month after planting. The treatments T_4 recorded the highest interval of leaf production (5.55 days) followed by T_3 (5.50 days), T_5 (5.30 days), T_2 (5.10 days) and T_1 (4.96 days).

During the ninth month after planting, leaf production had stopped in treatment T_1 and T_2 consequent to bunch emergence. Among the other treatments, T_5 recorded the highest interval of leaf production (5.20 days) followed by T_4 (5.00 days); both the treatments being statistically on par, but significantly superior to T_3 (4.44 days).

Eventhough the spacings did not significantly influence the interval of leaf production, the effect was observed in the later stages of plant growth. In general it was observed that interval of leaf production increased with decrease in spacing.

4.1.9 Effect of spacing on time taken for bunch emergence, bunch maturity and crop duration of tissue culture Nendran banana

The data (Table 9) indicated that the time taken for bunch emergence was influenced by different spacings tried. The treatment T_1 recorded the shortest duration for bunch emergence (233.30 days), followed by T_2 (234.00 days). These two treatments were statistically on par but significantly superior to other treatments. The longest duration for bunch emergence was observed in T_5 (276.70 days) followed by T_4 (273.60 days); both the treatments being

Table 9. Effect of spacing on time taken for bunch emergence, bunch maturity and crop duration of tissue culture Nendran banana

Treatment	Time taken for bunch emergence (days)	Time taken for bunch maturity (days)	Crop duration (days)
T_1	233.30	92.80	326.10
T_2	234.00	94.00	328.00
T_3	245.20	101.00	346.20
T_4	273.60	104.00	377.60
T_5	276.70	99.40	376.10
F-test	**	**	**
CD(0.05)	7.3906	6.2408	11.5947

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

statistically on par, but significantly different from T_3 (245.50 days) which followed T_4.

The maturity period of bunch was also influenced by different spacings. The bunches matured early in T_1 (92.80 days) and T_2 (94.00 days); both the treatments being statistically on par and significantly superior to other treatments. The longest bunch maturity period was observed in T_4 (104.00 days) followed by T_3 (101.00 days) and T_5 (99.40 days); the treatments being statistically on par.

The crop duration also followed the pattern of time taken for bunch emergence. Crop duration was the shortest in T_1 (326.10 days) and T_2 (328.00 days) and these two treatments did not differ significantly from one another. The longest duration was recorded in T_5 (376.10 days) followed by T_4 (377.60 days); the treatments being statistically on par, but differing significantly from T_3 (346.20 days).

In general, it was observed that the time taken for bunch emergence, time taken for bunch maturity and consequently the crop duration were significantly influenced by the different spacings tried. The general trend observed was that the time taken for all the above three characters increased with closer spacings.

4.1.10 Effect of spacing on the number of suckers produced by tissue culture Nendran banana

The data on the effect of different spacings on the sucker production presented in Table 10 revealed that the highest number of suckers per plant (6.35) were present in T_1 followed by T_2 (5.80); both the treatments being significantly different form one another and superior to all other treatments. The lowest number of suckers per plant was observed in T_5 (3.35). The treatment T_4 (4.65) and T_3 (4.85) which followed T_1 did not differ significantly from one another, but were superior to T_1. The same data expressed in terms of sucker production per hectare, indicated that the highest number of suckers were produced in T_5 (21440.0) followed by T_4 (20664.6). Both the treatments significantly differed from one another and were superior to all other treatments. The lowest number of suckers per hectare was recorded in T_1 (12541.4) followed by T_2 (14500.0) and these two treatments were statistically on par, while T_3 (15835.4) which followed T_2 did not differ significantly from it.

The general trend observed was that the number of suckers produced per plant decreased with decrease in spacing, but on per hectare basis the trend was the reverse. Here the total number of suckers per hectare was more in closer spacings.

Table 10. Effect of spacing on the number of suckers produced by tissue culture Nendran banana

Treatment	Number of suckers per plant	Number of suckers per hectare
T_1	6.35	12541.40
T_2	5.80	14500.00
T_3	4.85	15835.40
T_4	4.65	20664.60
T_5	3.35	21440.00
F-test	**	**
CD(0.05)	0.5111	2228.869

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

4.1.11 Effect of spacing on the biomass production in tissue culture Nendran banana

The effect of spacings on the biomass production given in Table 11 and Fig 5, revealed that the character was influenced by the treatments imposed.

The weight of corms was the highest in T_1 (6.70 kg) followed by T_2 (6.56 kg); both the treatments being statistically on par and significantly superior to other treatments. The lowest fresh weight of corms was recorded in T_5 (4.75 kg) followed by T_4 (5.00 kg) and T_3 (5.20 kg). These three treatments were statistically on par.

The fresh weight of pseudostem was not found to be significantly influenced by different spacings. However, the mean values indicated that the fresh weight of pseudostem was more in wider spacings. Fresh weight of leaves also was not significantly influenced by different treatments, but the leaf weight increased with increase in spacing as indicated by the mean values. Fresh weight of leaf sheath also followed the same pattern. Eventhough not significant, the highest fresh weight of leaf sheath was recorded in wider spacing.

Table 11. Effect of spacing on the biomass production in tissue culture Nendran banana

Treatment	Fresh weight (kg)						Total	
	corm	pseudostem	leaf	leafsheath	sucker	bunch	per plant (kg)	per hectare (t)
T_1	6.70	9.70	9.56	10.40	2.15	9.50	48.01	94.82
T_2	6.56	9.60	9.30	10.00	1.75	9.25	46.46	116.45
T_3	5.20	8.60	8.90	9.13	1.50	9.00	42.33	138.19
T_4	5.00	8.67	8.26	9.00	1.00	6.70	38.63	169.87
T_5	4.75	8.52	8.12	8.75	0.80	6.05	36.97	236.61
F-test	**	NS	NS	NS	NS	**	**	**
CD(0.05)	1.1696	-	-	-	0.3359	1.379	3.6476	10.6575

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

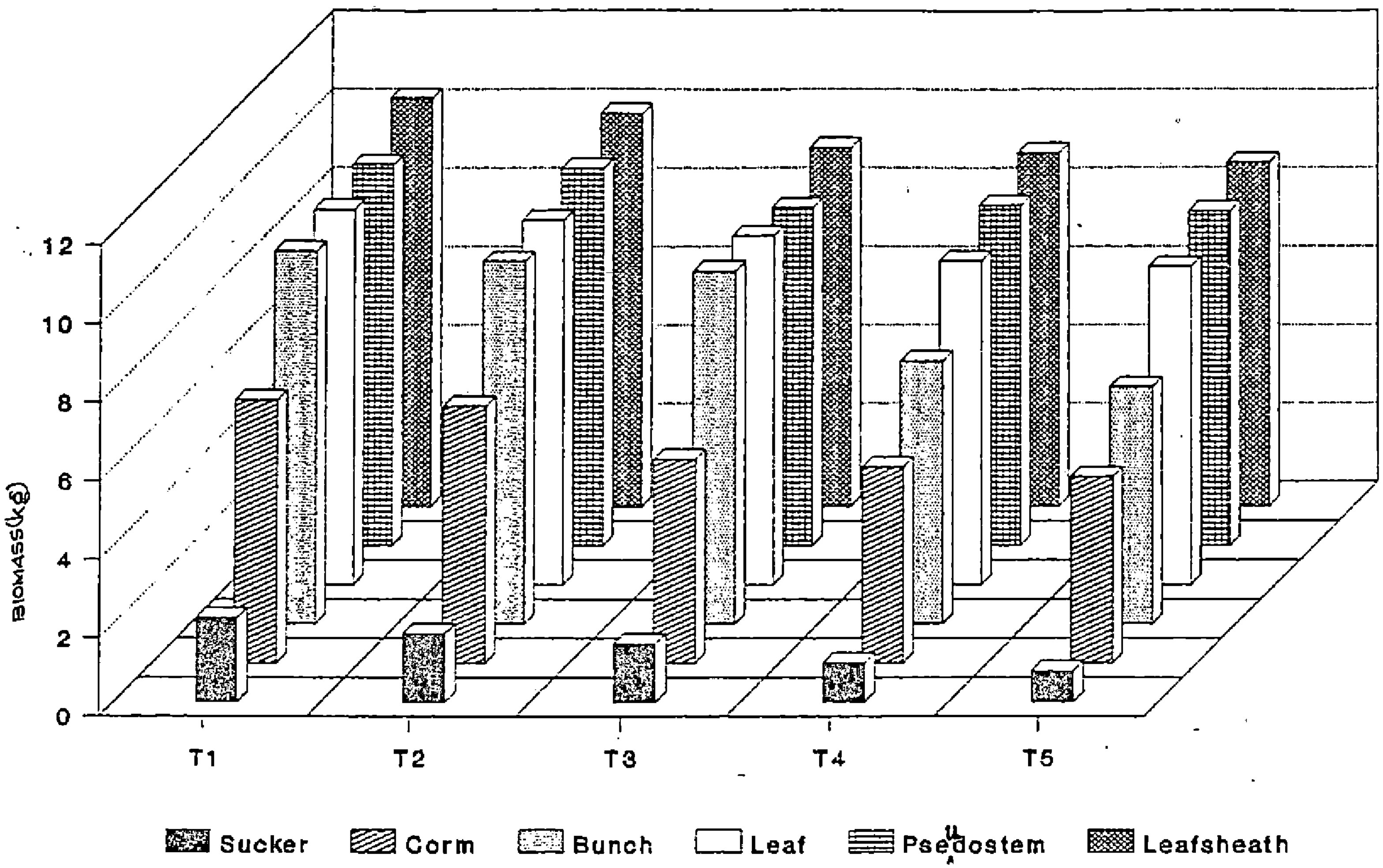


Fig. 5. Effect of spacing on biomass production in tissue culture Nendran banana

Fresh weight of suckers was found to be influenced by different spacings. The highest sucker weight recorded in T_1 (2.15 kg) was significantly superior to all other treatments. The treatment T_2 (1.75 kg) and T_3 (1.50 kg) which followed T_1 did not differ significantly between them. The lowest sucker weight were recorded in T_5 (0.80 kg) and T_4 (1.00 kg); the treatments being statistically on par. Fresh weight of bunches also showed significant variation. The highest bunch weight was recorded in T_1 (9.50 kg) followed by T_2 (9.25 kg) and T_3 (9.00 kg); the treatments being statistically on par but superior to other treatments. The lowest bunch weight was recorded in T_5 (6.05 kg) followed by T_4 (6.70 kg); both the treatments being statistically on par.

Total plant weight was also influenced by the treatments. The highest plant weight was observed in T_1 (48.01 kg) followed by T_2 (46.46 kg); the two treatments being statistically on par, but significantly superior to other treatments. The lowest plant weight was observed in T_5 (36.97 kg) and T_4 (38.63 kg). These two treatments were statistically on par but significantly different from T_3 (42.33 kg).

The biomass production per hectare was also influenced by various treatments. The highest biomass production on per hectare basis was observed in T_5 (236.61 t) followed by T_4 (169.87 t) and T_3 (138.19 t). These three treatments differed significantly from one another. The lowest biomass production per hectare was recorded in T_1 (94.82 t) followed by T_2 (110.15 t); the treatments being statistically on par, but significantly different from others.

It was observed from the data that the weight of corms, bunches and plants were significantly influenced by different spacings. The biomass accumulation in different plant parts was higher at wider spacings compared to closer ones. However, on per hectare basis, the total biomass production was found to be higher in closer spacings.

4.1.12 Effect of spacing on the dry matter production in tissue culture Nendran banana

Data on the influence of different spacings on dry matter production are presented in Table 12.

Table 12. Effect of spacing on the drymatter production in tissue culture Nendran banana

Treatment	Plant parts (Dry weight)					Total dry weight (kg plant^{-1})	Total drymatter production (t ha^{-1})
	Corm (g)	Pseudostem (g)	Leaf (kg)	Leaf sheath (g)	Bunch (kg)		
T_1	368.00	272.57	2.427	401.44	4.03	7.48	14.78
T_2	340.73	269.76	2.361	386.00	3.93	7.28	18.06
T_3	270.09	241.66	2.259	352.22	3.75	6.88	22.45
T_4	259.70	245.06	2.097	347.40	2.79	5.74	25.52
T_5	246.72	238.85	2.061	337.75	2.32	5.21	33.33
F-test	**	NS	NS	NS	**	**	**
CD(0.05)	55.28	-	-	-	0.6165	0.68179	2.8627

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

The dry weight of corms was found to be influenced significantly by the treatments; the highest being in T_1 (368.00 g) followed by T_2 (340.73 g); both being statistically on par and significantly superior to other treatments. The lowest values were recorded in T_5 (246.72 g) followed by T_4 (259.70 g) and T_3 (270.09 g) and these three treatments were statistically on par.

The peudostem weight was not significantly influenced by different spacings. However, higher values were recorded in wider spacings. The dry weight of leaves also remained unaffected significantly by the treatments. In this case also the wider spacings recorded more leaf weight. Similar pattern was observed in the case of leaf sheath also; the highest values being in wider spacings.

The dry weight of bunches computed showed significant variation under the influence of the different spacing. The highest bunch dry weight was recorded in T_1 (4.03 kg) followed by T_2 (3.93 kg) and T_3 (3.75 kg) and all these treatments were statistically on par but significantly superior to other treatments. The lowest bunch dry weight values were recorded in T_5 (2.32 kg) followed by T_4 (2.79 kg); the two treatments being statistically on par.

Total dry weight of plants followed the same pattern of bunch dry weight. The highest dry weight per plant was observed in T_1 (7.48 kg) followed by T_2 (7.28 kg) and T_3 (6.88 kg); the three treatments being statistically on par and significantly superior to others. The lowest values were recorded in T_5 (5.21 kg) and T_4 (5.74 kg) and these two treatments were statistically on par.

The total dry matter production expressed on per hectare basis showed that the treatments influenced this character significantly. The highest drymatter production was observed in T_5 (33.33 t) followed by T_4 (25.52 t) and T_3 (22.45 t). These three treatments differed significantly from one another but were superior to the other treatments. The lowest values recorded in T_1 (14.78 t) and T_2 (18.06 t) did not differ significantly from one another.

In general, it was observed that the dry matter production by different plant parts as well as the whole plant increased with wider spacing. However, the dry matter production per hectare was higher in the closer spacing.

4.2 Yield characters

4.2.1 Effect of spacing on mean bunch weight, number of hands and fingers of tissue culture Nendran banana

The data on the influence of spacings on bunch weight, number of hands and fingers are presented in Table 13 , Fig 6 and Plates 1 and 3.

The number of hands per bunch was the highest in T_3 (5.50) followed by T_1 (5.40) and T_2 (5.30). The three treatments were statistically on par and significantly superior to T_5 (4.10) and T_4 (4.40), which recorded the lowest number of hands per bunch in the order. The latter two treatments were statistically on par. The number of fingers per bunch also showed a similar trend. The highest number of fingers was recorded in T_3 (45.70) followed by T_2 (44.60) and T_1 (44.00); the three treatments being statistically on par. The treatment T_5 (31.00) which recorded the lowest number of fingers per bunch did not differ significantly from T_4 (34.00).

The number of fingers per hand did not show any significant difference in different treatments. However, the mean value showed that the highest number of fingers per hand was observed in T_2 (8.37) followed by T_3 (8.29), T_1 (8.16), T_4 (7.75) and T_5 (7.62).

Table 13. Effect of Spacing on mean bunch weight, number of hands and fingers of tissue culture Nendran banana

Treatment	Number of hands per bunch	Number of Fingers per bunch	Number of fingers per hand	Mean bunch weight (kg $plant^{-1}$)	Total bunch yield (t ha^{-1})
T_1	5.40	44.00	8.16	9.50	18.76
T_2	5.30	44.60	8.37	9.25	23.13
T_3	5.50	45.70	8.29	9.00	29.39
T_4	4.40	34.00	7.75	6.70	29.78
T_5	4.10	31.00	7.62	6.05	38.72
F-test	**	**	NS	**	**
CD(0.05)	0.4668	3.9311	-	1.3790	5.8704

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

The mean bunch weight per plant was also influenced by the different spacings. The highest bunch weight was recorded in T_1 (9.50 kg) followed by T_2 (9.25 kg) and T_3 (9.00 kg). These three treatments did not differ significantly from one to another, but were significantly superior to others. The bunch weight was the lowest in T_5 (6.05 kg) followed by T_4 (6.70 kg) and these two treatments did not show significant difference between them.

The total bunch yield per hectare also was significantly influenced by treatments. The highest tonnage recorded in T_5 (38.72 t) was significantly superior to all other treatments. This was followed by T_4 (29.78 t) and T_3 (29.39 t); both the treatments being statistically on par and significantly superior to T_1 and T_2. The treatment T_1 recorded the lowest tonnage (18.76 t) followed by T_2 (23.13 t), the two treatments being statistically on par.

The bunch characters discussed above showed a trend of increase in the economic part with increase in spacing tried. However, the total yield per unit area increased significantly with decrease in spacing.

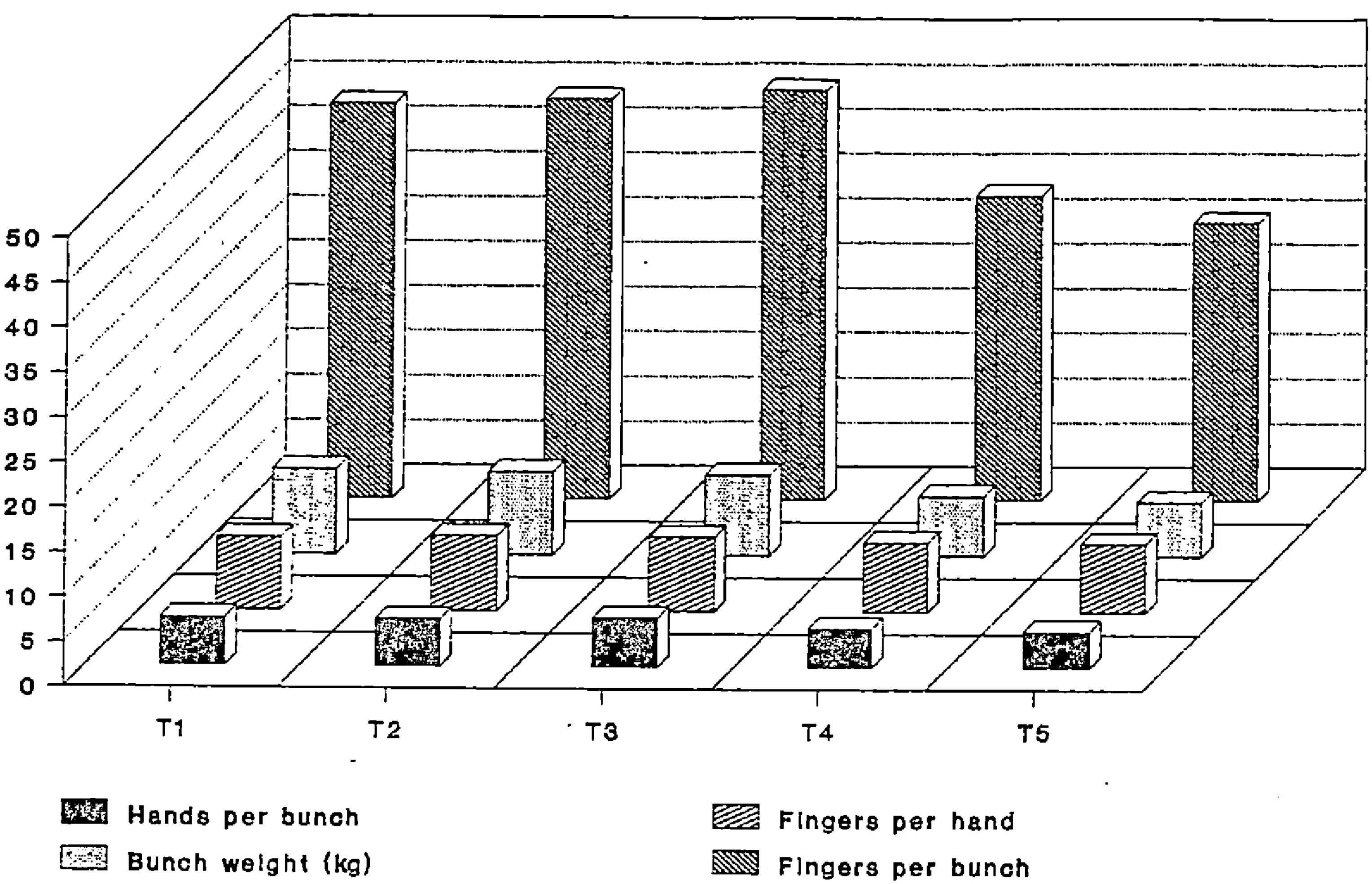


Fig. 6. Effect of spacing on mean bunch weight, number of hands and fingers of tissue culture Nendran banana

Plate 1. Effect of spacing on bunch yield of tissue culture Nendran banana

Plate 2. Effect of spacing on fruit characters of tissue culture Nendran banana


T1
2.25 x 2.25 m
T2
2.0 x 2.0 m
T5
1.25 x 1.25 m

Plate 3. Effect of spacing on bunch characters of selected treatments


T_1
2.25 x 2.25m


T_2
2.0 x 2.0m


T_5
1.75 x 1.75m

4.2.2 Effect of spacing on fruit characters of tissue culture Nendran banana

The data on fruit characters under the influence of different spacings are given in Table 14, Fig 7 and Plate 2.

The data revealed that the mean length of individual finger was significantly higher in T_3 (25.49 cm) followed by the treatment T_1 (23.18 cm) and T_2 (22.81 cm) and latter two were statistically on par. The shortest finger leength was observed in T_5 (17.40 cm) followed by T_4 (18.93 cm) and these two treatments differed significantly from one another. The mean girth of individual finger was highest in T_3 (13.45 cm) which again was significantly superior to all other treatments. The treatment T_1 (12.42 cm) and T_2 (12.01 cm) followed T_3 and were statistically on par. The lowest mean value for finger girth was observed in T_5 (10.57 cm) followed by T_4 (11.13 cm) and these two were statistically on par.

The mean weight of individual finger was the highest in T_2 (193.66 g) followed by T_3 (189.88 g) and T_1 (178.95 g). The three treatments were statistically on par.

Table 14. Effect of spacing on fruit characters of tissue culture Nendran banana

Treatment	Finger length (cm)	Finger girth (cm)	Finger weight (g)	Pulp weight (g)	Peel weight (g)	Pulp/peel ratio
T_1	23.18	12.42	178.95	139.71	39.24	3.58
T_2	22.81	12.01	193.66	139.35	45.49	3.11
T_3	25.49	13.45	189.88	137.13	52.73	2.61
T_4	18.93	11.13	156.05	105.70	50.35	2.09
T_5	17.40	10.57	151.87	97.78	54.09	1.81
F-test	**	**	*	**	**	**
CD(0.05)	1.47624	0.8518	32.7502	19.5423	7.6449	0.4283

* - Significant at 5% level

** - Significant at 1% level

The lowest finger weight was observed in T_5 (151.87 g) followed by T_4 (156.05 g) and these two treatments were statistically on par with T_1.

Fruit shape showed variation in its angularity and smoothness. Fruits produced from plants of wider spacing were fully filled and uniform. The angles of fruits or the ridges were rarely seen on fruits produced by wider spaced plants. The ridges were prominent in fruits of closer spaced plants. Moreover, fruits of plants with wider spacing were more smooth in texture than those with closer spaced plants.

The mean weight of pulp of individual fruit was highest in T_1 (139.71 g) followed by T_2 (139.35 g) and T_3 (137.13 g); the three treatments being statistically on par. The lowest weight of pulp was recorded in T_5 (97.78 g) followed by T_4 (105.70 g); the two treatments being statistically on par.

The mean peel weight of individual fruits in T_5 was the highest (54.09 g) followed by T_3 (52.73 g) and T_4 (50.35 g). These three treatments were statistically on par while T_3 and T_4 did not differ significantly from T_2 (45.49 g).

The lowest peel weight recorded in T_1 (39.24 g) did not differ significantly from T_2.

The pulp/peel ratio values were the highest in T_1 (3.58) followed by T_2 (3.11) and T_3 (2.61). These three treatments differ from one another statistically. The lowest pulp/peel ratio recorded in T_5 (1.81) did not differ significantly from T_4 (2.09).

The observations revealed that the closer spacings T_4 and T_5 had lesser finger size and weight compared to the wider spacings. The treatments T_3 showed comparable finger size with wider spacings, T_1 and T_2.

4.3 Quality characteristics of fruits

4.3.1 Effect of spacing on fruit quality of tissue culture Nendran banana

The effect of different spacings observed on quality of fruits in tissue culture Nendran banana are presented in Table 15 and Fig 8.

The data revealed that the treatments did not significantly influence the dry matter content of fruits. However, the mean values showed that the dry matter content was the highest in T_1 (42.482 per cent) followed by T_2 (42.426 per cent), T_3 (41.684 per cent), T_4 (41.580 per cent) and T_5 (38.432 per cent); indicating that drymatter content of fruits increased with increase in spacing.

Acidity of fruits was significantly influenced by different treatments. The acidity was the highest in T_5 (0.528 per cent) followed by T_4 (0.518 per cent) and these two treatments were statistically on par, but significantly superior to others. The lowest acidity values were observed in T_1 (0.390 per cent), T_2 (0.403 per cent) and T_3 (0.415 per cent); the three treatments being statistically on par.

The TSS content of fruit was also affected by the treatments. The highest TSS (24.50 per cent) was observed in T_1 followed by T_2 (21.20 per cent), T_3 (19.60 per cent), T_4 (18.30 per cent) and T_5 (17.40 per cent). All those treatments differed significantly from one another.

The total sugar content of fruit also showed variation in different treatments. The highest total sugar content was observed in T_1 (26.802 per cent) followed by T_2 (26.134 per cent); the treatments being statistically on par

Table 15. Effect of spacing on fruit quality of tissue culture Nendran banana

Treatment	Drymatter content (%)	Acidity (%)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars(%)	Ascorbic acid (mg/100g)	Sugar/acid ratio
T_1	42.482	0.390	24.50	26.802	8.702	18.100	9.364	68.74
T_2	42.426	0.403	21.20	26.134	8.518	17.616	9.370	65.38
T_3	41.684	0.415	19.60	22.000	8.554	13.446	9.898	53.19
T_4	41.580	0.518	18.30	18.910	7.864	11.046	13.894	36.46
T_5	38.432	0.528	17.40	17.740	7.002	10.738	14.108	33.67
F-test	NS	**	**	**	**	**	**	**
CD(0.05)	-	0.03547	0.6538	1.1909	0.8322	3.729	1.559	10.9607

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

The data revealed that the treatments did not significantly influence the dry matter content of fruits. However, the mean values showed that the dry matter content was the highest in T_1 (42.482 per cent) followed by T_2 (42.426 per cent), T_3 (41.684 per cent), T_4 (41.580 per cent) and T_5 (38.432 per cent); indicating that drymatter content of fruits increased with increase in spacing.

Acidity of fruits was significantly influenced by different treatments. The acidity was the highest in T_5 (0.528 per cent) followed by T_4 (0.518 per cent) and these two treatments were statistically on par, but significantly superior to others. The lowest acidity values were observed in T_1 (0.390 per cent), T_2 (0.403 per cent) and T_3 (0.415 per cent); the three treatments being statistically on par.

The TSS content of fruit was also affected by the treatments. The highest TSS (24.50 per cent) was observed in T_1 followed by T_2 (21.20 per cent), T_3 (19.60 per cent), T_4 (18.30 per cent) and T_5 (17.40 per cent). All those treatments differed significantly from one another.

The total sugar content of fruit also showed variation in different treatments. The highest total sugar content was observed in T_1 (26.802 per cent) followed by T_2 (26.134 per cent); the treatments being statistically on par

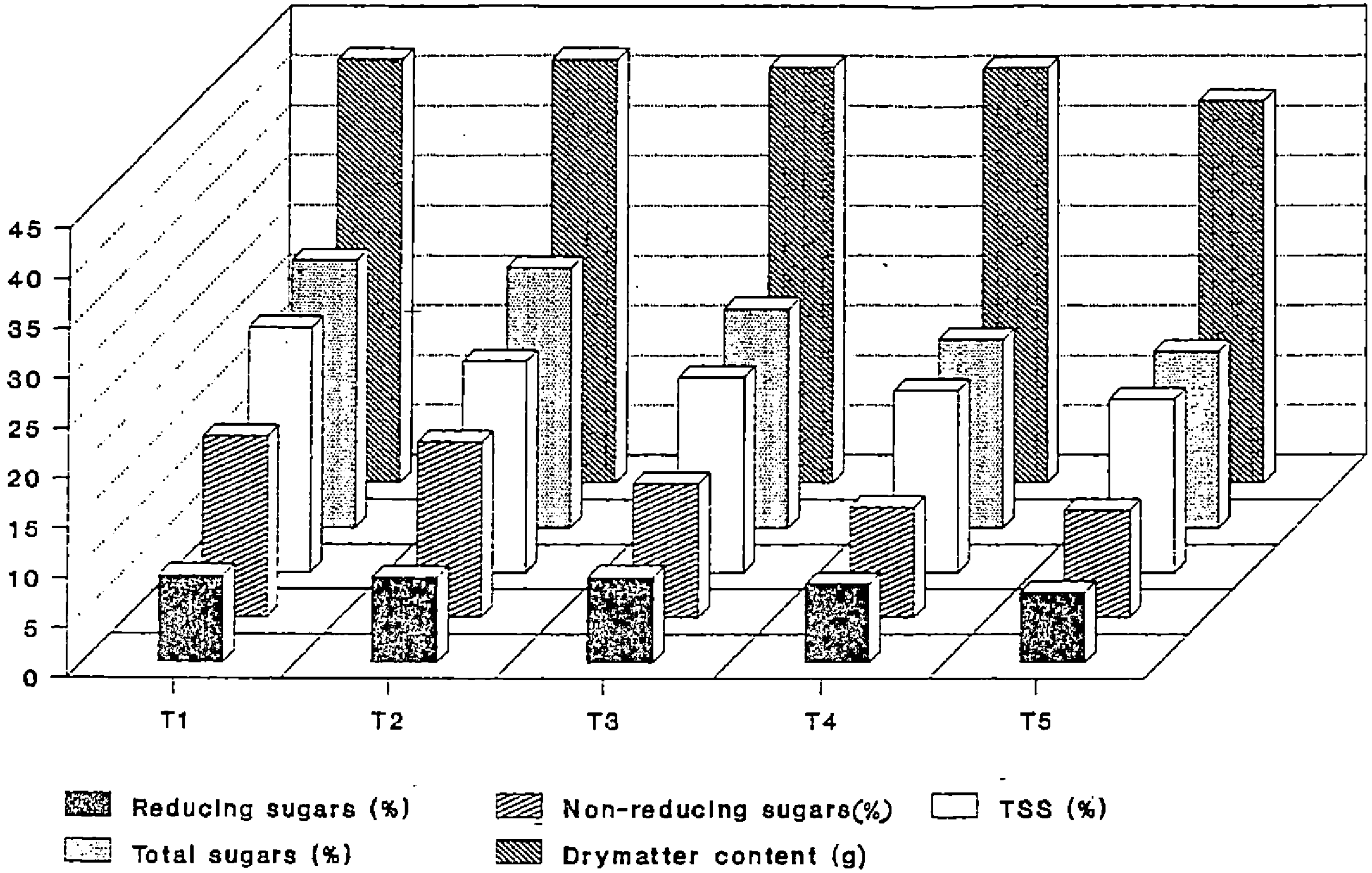


Fig. 8. Effect of spacing on fruit quality of tissue culture Nendran banana

and significantly superior to other treatments. These treatments were followed by T_3 (22.00 per cent), T_4 (18.910 per cent) and T_5 (17.740 per cent), the latter two being statistically on par.

The reducing sugar content of fruits was the highest in T_1 (8.702 per cent) followed by T_3 (8.554 per cent) and T_2 (8.518 per cent) and these three treatments were statistically on par. The treatment T_4 (7.864 per cent) which followed these treatments was statistically on par with T_2 and T_3. The lowest reducing sugar content was observed in T_5 (7.002 per cent).

The non-reducing sugar content of the fruits was the highest in T_1 (18.100 per cent) followed by T_2 (17.616 per cent); the two treatments being statistically on par and significantly superior to others. The lowest content of non-reducing sugar was observed in T_5 (10.738 per cent) followed by T_4 (11.046 per cent) and T_3 (13.446 per cent) and these three treatments were statistically on par.

The ascorbic acid content of of fruits (mg/ 100g) showed significant variation between treatments. The highest ascorbic acid content was observed in T_5 (14.108) followed by T_4 (13.894); both the treatments being statistically on par and significantly superior to others. The lowest levels of ascorbic acid was noted in T_1 (9.364) followed by T_2 (9.370) and T_3 (9.898) and these treatments did not show any significant difference among them.

The sugar/acid ratio was the highest in T_1 (68.74) followed by T_2 (65.38); the two treatments being statistically on par and significantly superior to others. The lowest values were recorded in T_5 (33.67) followed by T_4 (36.46) and these two treatments were statistically on par but differed significantly from T_3 (53.19).

It was observed from the data that the drymatter content, TSS, total sugars, reducing sugars, non-reducing sugars and sugar/acid ratio increased with increase in spacing. But the acidity and ascorbic acid content decreased with increase in spacing.

4.3.2 Effect of spacing on time taken for ripening and storage life of fruits of tissue culture Nendran banana

The data presented in Table 16 revealed that the time taken for ripening of fruits was significantly influenced by the different spacings adopted. The fruits

Table 16. Effect of spacing on time taken for ripening and storage life of fruits of tissue culture Nendran banana

Treatment	Time taken for ripening of fruits (days)	Storage life of fruits (days)
T_1	3.73	6.13
T_2	3.80	6.27
T_3	4.40	6.00
T_4	4.73	6.33
T_5	5.20	6.13
F-test	**	NS
CD(0.05)	0.51107	-

NS - Not significant

** - Significant at 1% level

from T_1 ripened in the shortest period of time (3.73 days) when kept at room temperature followed by T_2 (3.80 days). These two treatments were statistically on par, but differed significantly from other treatments. The longest period for ripening was observed in T_5 (5.20 days) followed by T_4 (4.73 days) and T_3 (4.40 days). Treatment T_5 was statistically on par with T_4 and T_4 in turn was statistically on par with T_3.

The storage life of fruits kept at room temperature did not vary significantly with treatments. In all treatments, the fruits ripened after six days of storage as observed in the data in Table 16.

It was observed from the data that the time taken for ripening of fruits decreased with the spacings adopted while the storage life at room temperature remained unaffected by the various spacings adopted.

4.4 Other observations

4.4.1 Effect of spacing on the cost of cultivation, net profit and benefit/cost ratio of tissue culture Nendran banana

The detailed cost of cultivation in Appendix - II and its abstract presented in Table 17 revealed that the

Table.17 Effect of spacing on the cost of cultivation, net profit and benefit/cost ratio of tissue culture Nendran banana (Abstract)

Treatment	Cost of cultivation (Rs.ha^{-1})	Income (Rs.ha^{-1})	Profit (Rs.ha^{-1})	Benefit/cost ratio
T_1	95,768.42	Fruits : 150100.00 Suckers: 50165.00 Total : 200265.00	104496.58	2.09
T_2	117870.39	Fruits : 185000.00 Suckers: 58000.00 Total : 243000.00	125129.61	2.06
T_3	147053.55	Fruits : 235080.00 Suckers: 63341.00 Total : 298421.00	151367.45	2.03
T_4	194725.91	Fruits : 238198.40 Suckers: 82658.40 Total : 320856.80	126130.89	1.65
T_5	272862.65	Fruits : 309760.00 Suckers: 85760.00 Total : 395520.00	122657.35	1.45

cultivation cost ranged from Rs. 95,768.42 in T_1 to Rs. 2,72,862.65 in T_5. The income per hectare ranged between Rs. 2,00,265.00 to Rs. 3,95,520.00 between this treatment. And net profit per hectare showed a range of Rs. 1,04,496.58 to Rs. 1,22,657.35 between the widest spacing and the closest one. The benefit/cost ratio showed a range of 2.09 to 1.45 between these levels of treatments. The data also indicated that the highest net profit was obtained in the treatments T_3 (Rs. 1,51,367.45 $.ha^{-1}$) followed by T_2 (Rs. 1,25,129.61 $.ha^{-1}$) and T_1 (Rs. 1,04,496.58 $.ha^{-1}$). The lowest net profit was obtained from T_5 (Rs. 1,22,657.35 $.ha^{-1}$) followed by T_4 (Rs. 1,26,130.89 ha^{-1}). Thus the results indicated that for the best profits and the net returns, the treatment T_3 is adaptable.

4.4.2 Effect of spacing on incidence of pests and diseases in tissue culture Nendran banana

The data on the incidence of Sigatoka leaf spot disease and banana rhizome weevil are presented in Table 18. The data revealed that the incidence of leaf spot disease was severe in closer spacings. In T_5 most severe incidence of the disease was observed affecting 33.00 per cent of leaf area followed by T_4 where 30.53 per cent of the leaf area was affected. There was a drastic reduction in the leaf area

Table 18. Effect of spacing on the incidence of pests and diseases in tissue culture Nendran banana

Treatment	Number of rhizome weevils per plant	Sigatoka leaf spot disease incidence	
		Disease index	leaf area infected (percentage)
T_1	3.50	2	10.97
T_2	3.50	2	11.11
T_3	3.75	2	14.14
T_4	9.25	3	30.53
T_5	9.50	3	33.00
F-test	-	**	
CD(0.05)	-	2.00676	

** - Significant at 1% level

Note : -

Disease index	Leaf area infected (percentage)
negligible	0 - 5
1	6 - 10
2	11 - 25
3	26 - 30
4	31 - 40
5	41 - 50
6	51 - 75
7	76 and above.

infected (14.14 per cent) in T_3. These treatments differed significantly from one another in the extent of leaf area affected. The least severe incidence was noted in T_1 followed by T_2, where the leaf area infected were 10.97 per cent and 11.11 per cent respectively. Both these treatments were statistically on par but significantly superior to other with respect to incidence of leaf spot disease. It was also found that the severity of leaf spot disease was more in closer spaced plants especially in T_4 and T_5 compared to wider spaced ones T_1, T_2 and T_3.

It was noted that incidence of banana rhizome weevil (Cosmopolitus sordidus) was more in closer spaced plants (T_4 and T_5), which accounted an average of 9.25 and 9.50 weevils per plant, while it was lesser in wider spaced plants (T_1, T_2 and T_3) recorded 3.50, 3.50 and 3.75 weevils respectively. The incidence of weevil attack was more or less the same in the spacings T_1, T_2 and T_3, while it was almost three times more in T_4 and T_5.

4.4.3 Effect of spacing on soil nutrient status after harvest of tissue culture Nendran banana

The data presented in Table 19 showed the status of major nutrients (N, P and K) from different treatments before and after harvest of bunches. The initial nutrient content

Table 19. Effect of Spacing on soil nutrient status after harvest of tissue culture Nendran banana

Treatments	Soil nutrient status after harvest (kg ha^{-1})			Per cent increase/ decrease of nutrients		
	N	P	K	N	P	K
T_1	85.406	45.450	132.016	13.36	22.99	16.68
T_2	80.142	44.252	127.980	7.66	20.91	14.05
T_3	71.592	40.676	121.556	-3.36	13.95	9.51
T_4	63.404	33.412	117.232	-17.54	-4.75	6.17
T_5	56.229	26.815	109.532	-31.60	-30.52	-0.43
F-test	**	**	**	-	-	-
CD(0.05)	6.3233	3.8773	6.0429	-	-	-

Note : - Pre - harvest values for composite soil sample

Levels - N = 74 kg ha^{-1}, P_2O_5 = 35 kg ha^{-1} and K_2O = 110 kg ha^{-1}

Rating (Low) (High) (Medium)

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

of the experimental plot, from the analysis of a composite sample, was found to be N 74 kg ha^{-1}, P_2O_5 35 kg ha^{-1} and K_2O 110 kg ha^{-1}. The data showed that the available nitrogen content of the soil after harvest was the lowest in T_5 (56.229 kg ha^{-1}) followed by T_4 (63. 404 kg ha^{-1}) and T_3 (71.592 kg ha^{-1}). These three treatments differed statistically from one another and from the other treatments. The highest available nitrogen content observed in T1 (85.406 kg ha^{-1}) was on par with that of T_2 (80.142 kg ha^{-1}).

The available phosphorus content of the soil also exhibited the same pattern of nitrogen. The lowest available P_2O_5 was observed in T_5 (26.815 kg ha^{-1}) followed T_4 (33.412 kg ha^{-1}) and T_3 (40.676 kg ha^{-1}); the treatments being significantly different from one another. The highest P_2O_5 content recorded in T_1 (45.450 kg ha^{-1}) didnot differ significantly from treatment T_2 (44.252 kg ha^{-1}).

The available K_2O in the soil after harvest of bunches showed variation in different treatments. The lowest K_2O content was observed in T_5 (109.532 kg ha^{-1}) followed by T_4 (117.232 kg ha^{-1}) and T_3 (121.556 kg ha^{-1}); the latter two being statistically on par, but significantly different from T_5 and the other treatments. The highest K_2O content of

132.016 kg ha^{-1} was observed in T_1 and it was statistically on par with that of T_2 (127. 980 kg ha^{-1}).

The general trend in the changes in soil nutrient content was that, the nutrient removal was more in case of all the three major nutrients, when the plant stand increased and consequently the spacing decreased.

A comparison of the nutrient status of the experimental plots prior to the planting and after the harvest was computed on percentage with reference to the pre-planting values for major nutrients. The rating indicated that nitrogen content was low, phosphorus content was high and potassium content was medium in the soil of the experimental plot. The data indicated that with decrease in spacing there is a progressive decline in the soil nutrient status with respect to all the major plant nutrients. Negative values for nitrogen was obtained at T_3 level (-3.36 per cent), for phosphorus at T_4 level (-4.75 per cent) and for potassium at T_5 level (-0.43 per cent). This indicated that supplementary doses of nutrients above the recommended level were required at the above stages to maintain the soil fertility when population go above T_3 level. Except a slight increase in nitrogen level, the recommended dozes appeared to be sufficient to the plant population at T_3.

4.4.4 Effect of spacing on nutrient content in tissue culture Nendran banana

Table 20 shows the content of major nutrients in different parts of the plants in different spacing treatments at harvest stage, expressed as percentage dry weight.

The data revealed that the nitrogen content in corms was the highest in T_1 (1.542 per cent) which was significantly superior to all other treatments. This was followed by T_2 and T_3 with 1.338 and 1.240 per cent respectively. The latter two treatments didnot differ significantly, while T_3 was on par with T_4 (1.050 per cent). The lowest nitrogen content (0.876 per cent) recorded in T_5 didnot differ significantly from that of T_4.

The nitrogen content of pseudostem recorded in T_1 (1.154 per cent) was the highest, which was significantly superior to all other treatments. The treatments T_2 (1.002 per cent) and T_3 (0.892 per cent) which followed T_1 were

Table 20. Effect of spacing on nutrient content in tissue culture Nendran banana

Nutrient content (percentage dry wt)		T_1	T_2	T_3	T_4	T_5	F-test	CD(0.05)
	N	1.542	1.338	1.240	1.050	0.876	**	0.1933
Corm	P	0.372	0.316	0.250	0.198	0.162	**	0.0515
	K	6.436	6.304	5.992	5.744	5.480	**	0.1321
	N	1.154	1.002	0.892	0.718	0.614	**	0.14257
Pseudostem	P	0.334	0.297	0.238	0.206	0.174	**	0.03687
	K	5.052	4.672	4.476	3.956	3.760	**	0.1955
	N	1.426	1.332	1.284	1.186	1.050	**	0.1191
Leaf	P	0.324	0.304	0.264	0.174	0.134	**	0.0593
	K	3.862	3.748	2.924	2.862	2.700	**	0.1262
	N	1.172	1.154	1.112	0.964	0.874	**	0.0839
Leafsheath	P	1.404	1.382	1.338	1.282	1.256	**	0.0378
	K	5.452	5.320	5.048	4.852	4.724	**	0.293
	N	1.304	1.246	1.228	1.062	1.068	**	0.0990
Fruit	P	0.362	0.340	0.304	0.268	0.224	**	0.0367
	K	1.756	1.704	1.594	1.456	1.440	**	0.1397

** - Significant at 1% level.

statistically on par. The lowest nitrogen content of the pseudostem recorded in T_5 (0.614 per cent) didnot differ significantly from that of T_4 (0.718 per cent).

The nitrogen content of the leaf tissues was the highest in T_1 (1.426 per cent) which was statistically on par with T_2 (1.332 per cent) while T_2 didnot differ significantly from T_3 (1.284 per cent). The lowest nitrogen content was observed in T_5 (1.050 per cent) which differed significantly from all other treatments. The treatments T_4 (1.186 per cent) which followed T_5 was statistically on par with T3.

The nitrogen content of the leafsheath was highest in T_1 (1.172 per cent) which was significantly superior to all other treatments. The treatments T_2 (1.154 per cent) and T_3 (1.112 per cent) which followed T_1 were statistically on par. The lowest nitrogen content was recorded in T_5 (0.874 per cent) followed by T_4 (0.964 per cent); both the treatments being significantly different from others.

The nitrogen content of the fruits was highest in T_1 (1.304 per cent) followed by T_2 (1.246 per cent) and T_3

(1.228 per cent). These three treatments were statistically on par. The lowest nitrogen content was observed in T_4 (1.062) per cent) followed by T_5 (1.068 per cent), but these two treatments were statistically on par.

The phosphorus content of the corms was the highest in T_1 (0.372 per cent) followed by T_2 (0.316 per cent) and T_3 (0.250 per cent), these three treatments differed significant from one another. The lowest phosphorus content observed in T_5 (0.162 per cent) followed by T_4 (0.198 per cent) didnot differ significantly from one another.

The phosphorus content of the pseudostem was the highest in T_1 (0.334 per cent) followed by T_2 (0.297 per cent); both the treatments being statistically on par. The lowest values were obtained in T_5 (0.174 per cent) followed by T_4 (0.206 per cent); both the treatments being statistically on par, while T_3 (0.238 per cent) was on par with T_4.

The highest phosphorus content of the leaves observed in T_1 (0.324 per cent) was statistically on par with that of T_2 (0.304 per cent) while T_2 was on par with T_3

(0.264 per cent). The lowest nitrogen content recorded in T_5 (0.134 per cent) was statistically on par with T_4 (0.174 per cent). In the leaf sheath phosphorus content was the highest in T_1 (1.404 per cent) followed by T_2 (1.382 per cent); both the treatments being statistically on par but significantly superior to others including T_3 (1.338 per cent) which followed them. The lowest phosphorus content observed in T_5 (1.256 per cent) was statistically on par with that of T_4 (1.282 per cent). The phosphorus content of fruits was the highest in T_1 (0.362 per cent) followed by T_2 (0.340 per cent) and T_3 (0.304 per cent). T_1 was statistically on par with T_2, while T_2 was with T_3. The lowest phosphorus content observed in T_5 (0.224 per cent) differed significantly from all other treatments while T_4 (0.268 per cent) which followed T_5 was on par with T_3.

The potassium content of corms was the highest in T_1 (6.436 per cent) followed by T_2 (6.304 per cent) both the treatments being statistically on par. The lowest potassium content was observed in T_5 (5.480 per cent) followed by T_4 (5.744 per cent) and T_3 (5.992 per cent). These three treatments differed significantly from one another. In the pseudostem, the potassium content was the highest in T_1

(5.052 per cent) which was significantly higher than others. Treatment T_2 (4.672 per cent) and T_3 (4.476 per cent) did not significantly differ from one another. The lowest potassium content (3.760 per cent) observed in T_5 didnot differ significantly from that of T_4 (3.956 per cent). In the leaves the highest potassium content was observed in T_1 (3.862 per cent) followed by T2 (3.748 per cent); both the treatments being statistically on par. The lowest potassium content observed in T_5 (2.700 per cent) differed significantly from all other treatments. The treatment T_4 (2.862 per cent) and T_3 (2.924 per cent) which followed T_5 were statistically on par. The potassium content of leaf sheath was the highest in T_1 (5.452 per cent), which did not differ significantly from that of T_2 (5.320 per cent). The lowest potassium content observed in T_5 (4.724 per cent) was statistically on par with T_4 (4.852 per cent) while T_4 was statistically on par with T_3 (5.048 per cent). In the fruits; the potassium content was the highest in T_1 (1.756 per cent) followed by T_2 (1.704 per cent), T_3 (1.594 per cent) T_4 (1.456 per cent) and T_5 (1.440 per cent). T_1 was statistically on par with T_2, T_2 with T_3, T_3 with T_4 and T_4 with T_5.

The general trend observed was that the content of the major nutrients decreased in the tissues with decrease in spacing. It was also observed from the data that among the different plant parts, the highest nitrogen content was in corms followed by leaf, fruit, leaf sheath and pseudostem. Phosphorus content was the highest in leaf sheath followed by corm, fruit, pseudostem and leaf. The potassium content was the highest in corm, followed by leaf sheath, pseudostem, leaf and fruit.

4.4.5 Effect of spacing on the uptake and partitioning of major nutrients in tissue culture Nendran banana

The result of the study are presented in Table 21. The data revealed that the nitrogen (expressed as gram per plant on dry weight basis) content of the corms varied significantly between treatments; the highest being in T_1 (5.408 g) which was statistically on par with T_2 (4.610 g). The lowest nitrogen content of corm was noted in T_5 (2.190 g) followed by T_4 (2.732 g) and T_3 (3.330 g). In the pseudostem also nitrogen was the highest in T_1 (3.152 g) followed by T_2 (2.676 g). Both the treatments were significantly different from one another and superior to others. The lowest nitrogen

Table 21. Effect of spacing on the uptake and partitioning of major nutrients in tissue culture Nendran banana

Nutrient content (on dry wt. basis)		Treatments						
		T_1	T_2	T_3	T_4	T_5	F test	CD(0.05)
Corm (g)	N	5.408	4.610	3.330	2.732	2.190	**	1.2360
	P	1.318	1.072	0.672	0.488	0.404	**	0.3267
	K	22.438	21.500	16.198	14.918	13.782	**	3.9383
Pseudostem (g)	N	3.152	2.676	2.146	1.766	1.466	**	0.4641
	P	0.906	0.786	0.576	0.504	0.416	**	0.14007
	K	13.770	12.602	10.786	9.704	8.992	**	1.5007
Leaf (g)	N	34.692	31.476	29.068	24.768	21.676	**	5.4993
	P	7.866	7.168	5.946	3.666	3.176	**	1.5202
	K	91.114	88.586	66.132	60.088	55.784	**	15.091
Leafsheath (g)	N	4.696	4.448	3.896	3.782	2.960	**	0.7210
	P	5.634	5.330	4.710	4.458	4.220	**	0.6999
	K	21.762	20.612	17.844	16.790	15.960	**	2.8789
Fruit (g)	N	52.328	48.674	45.960	31.082	26.296	**	5.2052
	P	14.610	13.258	11.418	7.576	5.180	**	1.7999
	K	69.928	66.522	59.862	40.090	34.260	**	9.7710
Total g $Plant^{-1}$	N	100.308	91.884	84.420	64.130	54.588	**	6.2402
	P	30.324	27.614	23.322	16.692	13.396	**	2.4901
	K	219.010	209.822	170.822	141.590	130.784	**	19.3146
Total kg ha^{-1}	N	196.606	229.714	275.658	285.222	349.362	**	32.4585
	P	59.898	69.038	76.154	74.188	85.736	**	8.5697
	K	432.612	524.556	557.782	629.288	706.452	**	62.6059

** - Significant at 1% level

content was observed in T_5 (1.466 g) followed by T_4 (1.766 g) and T_3 (2.146 g); the three treatments being statistically on par. The nitrogen content of leaf was the highest in T_1 (34.692 g) which was significantly superior to all other treatments. The treatment T_2 (31.476 g) was statistically on par with T_3 (29.068 g). The lowest nitrogen content observed in T_5 (21.676 g) did not differ significantly from T_4 (24.768 g) while T_4 was statistically on par with T_3. In leaf sheath also the nitrogen content was the highest in T_1 (4.696 g) followed by T_2 (4.448 g) and both these treatments were statistically on par. The treatments T_3 (3.896 g) and T_4 (3.782 g) followed T_2 and these were statistically on par. The lowest nitrogen content was observed in T_5 (2.960 g). The nitrogen content of the fruits did not differ significantly between T_1 (52.328 g) and T_2 (48.674 g), while T_2 was statistically on par with T_3 (45.960 g). The lowest nitrogen content recorded in T_5 (26.296 g) was statistically on par with T_4 (31.082 g).

The phosphorus content of the corms was the highest in T_1 (1.318 g) followed by T_2 (1.072 g). Both the treatments were statistically on par , but superior to others. The lowest phosphorus content recorded in T_5 (0.404 g) didnot differ significantly from T_4 (0.488 g) and T_3 (0.672 g). In pseudostem also the highest phosphorus content was recorded in T_1 (0.906 g) followed by T_2 (0.786 g); both the treatments being statistically on par, but superior to other treatments. The lowest phosphorus content recorded in T_5 (0.416 g) followed by T_4 (0.504 g) and T_3 (0.576 g) were statistically on par. The phosphorus content of the leaf was the highest in T_1 (7.866 g) followed by T_2 (7.168 g) and these two treatments were statistically on par and significantly different from others. The lowest phosphorus content observed in T_5 (3.716 g) did not differ significantly from T_4 (3.666 g), but these were significantly lower to T_3 (5.946 g). The highest phosphorus content in leaf sheath were recorded in T_1 (5.634 g) followed by T_2 (5.330 g) and T_3 (4.710 g). The treatment T_1 was statistically on par with T_2 while T_2 was on par with T_3. The lowest phosphorus content of leaf sheath recorded in T_5 (4.220 g) didnot differ significantly from that of T_4 (4.458 g) and T_3. In the fruits the highest phosphorus content was recorded in T_1 (14.610 g) followed by T_2 (13.258 g); both the treatments being statistically on par, but superior to others. The lowest phosphorus content in fruits was recorded in T_5 (5.180 g) followed by T_4 (7.576 g) and T_3 (11.418 g) and these treatments differed significantly from one another.

The values for potassium in corms was the highest in T_1 (22.438 g) followed by T_2 (21.500 g); both the treatments being statistically on par, but significantly superior to others. The lowest potassium levels observed in T_5 (13.782 g) did not differ significantly from that in T_4 (14.918 g) and T_3 (16.198 g) which followed T_5. In the pseudostem potassium was the highest in T_1 (13.770 g) followed by T_2 (12.602 g) and T_3 (10.786 g). The treatment T_1 was statistically on par with T_2 while T_2 was on par with T_3. The lowest quantity of potassium observed in T_5 (8.992 g) was statistically on par with that of T_4 (9.704 g) while T_4 was statistically on par with T_3. In the leaf, potassium was the highest in T_1 (91.114 g) followed by T_2 (88.586 g); both the treatments being statistically on par, but significantly superior to others. The lowest potassium content noted in T_5 (55.784 g) didnot differ significantly from T_4 (60.088 g) or T_3 (66.132 g). In the leaf sheath potassium was the highest in T_1 (21.762 g) followed by T_2 (20.612 g). The two treatments were statistically on par while T_3 (17.844 g) was statistically on par with T_2. The lowest potassium content observed in T_5 (15.960 g) didnot differ significantly from T_4 (16.790 g) and T_3. The highest potassium content in the fruits were recorded in T_1 (69.928 g) followed by T_2 (66.522 g) and T_3 (59.862 g); all the treatments being statistically on par but significantly superior to others. The lowest potassium content recorded in

T_5 (34.266 g) was statistically on par with that of T_4 (40.090 g).

The computed values for the major nutrient content in the plant as a whole showed that the highest nitrogen content was in T_1 (100.308 g) followed by T_2 (91.884 g), T_3 (84.420 g), T_4 (64.130 g) and T_5 (54.588 g). All the treatments differed significantly from one another.

In the case of phosphorus content also all the treatments differed significantly from one another. The highest phosphorus content was in T_1 (30.324 g) followed by T_2 (27.614 g), T_3 (23.322 g), T_4 (16.692 g) and T_5 (13.396 g).

In the case of potassium content the highest values were observed in T_1 (219.010 g) followed by T_2 (209.822 g); both the treatments being statistically on par but significantly superior to others. This was followed by T_3 (170.822 g) which was significantly different from T_5 (130.784 g) which recorded the lowest potassium content followed by T_4 (141.590 g).

The above data expressed in per hectare basis also showed variation in the uptake of nutrients in various treatments. The highest nitrogen uptake was in T_5 (349.362 kg ha^{-1}) followed by T_4 (285.222 kg ha^{-1}) and T_3 (275.658 kg ha^{-1}); the latter two being statistically on par. The lowest nitrogen uptake was noted in T_1 (196.606 kg ha^{-1}) followed by T_2 (229.714 kg ha^{-1}).

The uptake of phosphorus was the highest in T_5 (85. 736 kg ha^{-1}). The treatment was significantly superior to all other treatments and was followed by T_3 (76.154 kg ha^{-1}), T_4 (74.188 kg ha^{-1}), and T_2 (69.038 kg ha^{-1}); the three treatments being statistically on par but significantly different from T_1 (59.898 kg ha^{-1}) which recorded the lowest phosphorus uptake.

The uptake of potassium was the highest in T_5 (706.452 kg ha^{-1}) followed by T_4 (629.288 kg ha^{-1}). The two treatments differed significantly from one another. T_5 was significantly superior to all other treatments while T_4 was superior to others except T_5. The uptake of potassium observed in T_1 (432.612 kg ha^{-1}) was significantly the lowest among all the treatments. This was followed by T_2 (524.556 kg ha^{-1}) and T_3 (557.782 kg ha^{-1}) which were statistically on par.

The data presented in Table 21 showed that the content of nitrogen, phosphorus and potassium in the plants were lesser when the spacing decreased. The trend was clear with individual organs or the plant as a whole. However, on per hectare basis the nutrient content in plants per unit area increased with decrease in spacing. The uptake pattern of the major nutrients showed that the highest nitrogen and phosphorus content was in fruits followed by leaf, leaf sheath, corm and pseudostem. However the potassium content was the highest in leaf followed by fruits, corm, leaf sheath and pseudostem.

DISCUSSION

DISCUSSION

The banana (*Musa* spp.) is a fruit plant of tropical origin, but commercially grown from the equator to a latitude of 30^{o} or more. In fruit crops like pineapple and banana which are perennial but monocarpic in growth habit, high density planting has been tried with varying success. Waithaka and Puri (1971), Patil *et al*. (1978), Chundawat *et al*. (1981 a and b), Reddy (1982), Kohli (1986), Robinson and Nel (1988 and 1989) and Rajeevan and Geetha (1989) have shown the feasibility of increasing yields by many folds through high density planting in banana.

Optimum planting density for banana is derived from a complex integration of many factors, all of which must be evaluated for each individual plantation. Simmonds (1966) highlighted eight such factors namely, cultivar, soil fertility, sucker selection, management level, weed suppression, wind speed, topography and economic considerations. When climatic variations are added to these, it becomes obvious that responses to a particular density may differ substantially. Thus Turner (1982) reported a four fold variation in yield at 2000 plants ha^{-1} depending on climatic zone and cultivars.

In the present farming situation where arable land is a limiting factor, peasants always look forward for more income from available land. In this context, the concept of high density planting pronounces its own importance. However, the jurisdiction of such a space management lies at a level where total yield is maximum while quality of produce is at optimum level, thus enhancing the marketable yield and net returns per unit area.

The present investigations were designed to develop a viable space management system for tissue culture Nendran banana by manipulating the crop stand above and below the recommended level of 2500 plants ha^{-1}. This recommendation developed by the Kerala Agricultural University providing a spacing of 2 x 2 m for 'Nendran' is well accepted and practiced by banana growers. During the course of the experiment, plant growth, yield and quality of the produce under different spacings were critically observed and the results obtained are discussed below:

5.1 Vegetative characters

5.1.1 Effect of spacing on height of tissue culture Nendran banana

The results of the study (Table 1) indicated that there was no notable difference in plant height in different spacings till fourth month after planting. However, from the fifth month onwards, the plant height increased with decrease in spacing. Maximum plant height at these stages of growth was always associated with the lowest spacing of 1.25 x 1.25 m and the minimum in 2.25 x 2.25 m. However, the increment in height was more in 1.75 x 1.75 m (T_3) towards the stage of cessation of vegetative growth and bunch emergence.

One of the reasons for increase in plant height under closer spacings appears to be the competition for light as the plants occupied the ground space with each increment in growth rate. In the early vegetative growth stage upto fourth month after planting, the plants did not occupy complete space available and therefore, light was not a limiting factor. This may be the reason why there was little or no significant difference in the plant height in different treatments at this stage. Studies on different cultivars of banana (Moreau, 1965; Ahmed and Mannan, 1970, Irizarry et al., 1975, Chattopadhyay et al., 1980 and 1984, Reddy, 1982, Kohli et al., 1986, Robinson and Nel, 1988 and 1989, Robinson et al., 1989 and Rajeevan and Geetha, 1989) agree that height of banana plants increased with decrease in spacing.

The competition for light might not have affected the populations tried in this study in the early growth stage up to a level of population because banana has the mechanism to carryout photosynthesis even at lower light intensities than the normal requirement. This view is supported by Brún (1960) who observed that on the lower surface of the banana leaves photosynthesis and transpiration were initiated even at low light intensity of 100 fc, while on the upper surface of leaves, sometimes 2000-3000 fc of white fluorescent light is required to initiate the process. The total leaf area per plant (Table 5) and functional leaf area upto bunch emergence (Table 6) as well as leaf area duration (Table 7) were higher in closer spacings and these factors also might have contributed to the higher efficiency of photosynthetic system.

The second reason that can be attributed for increased plant height is the increase in the number of roots produced per plant with increase in plant density as observed in the studies of Beugnon and Champion (1966) as well as Mohan and Rao (1984). They observed that with increase in plant density, the number of roots produced per plant increased, eventhough the total length of large roots decreased. In the present experiment individual plants in all treatments were provided with the recommended doze of fertilizers and water. Therefore, the probable increase in the number of roots might have enhanced the foraging capacity of the plants instead of leading to inter and intramat competition which may be experienced when nutrients and moisture are limited.

Yet another possible factor which had enhanced the plant height in closer spacings may be the longer duration for completion of vegetative phase by the plants. It was observed (Table 9) that the duration for flowering varied between the treatments; the longest being in the closest spacing and vice-versa. There was a difference of 43.4 days in the time taken for flowering between T_1 and T_5. This extended vegetative growth period also might have contributed to the increase in plant height in the closer spacings. Similar observations were recorded by Reddy (1982) and Rajeevan and Geetha (1989) in 'Robusta' under different spacings.

The relationship between height of the plants and number of leaves produced have also been well established in banana. According to Summerville (1944), the height of plant has a bearing on the number of leaves, since the petiole elongates sufficiently to permit the full opening of the lamina. In the present investigation (Table 3) the total number of leaves produced per plant was significantly higher in the closer spacings.

An overview of the results obtained gives an impression that the plant height increased with closer spacings upto the levels tried in this experiments. It was also noted that the plant height in T_3 (1.75x1.75 m), the spacing level just below the recommended one ie, T_2 (2.0 x 2.0 m), was always comparable with that of the wider spacings in statistical terms. From early vegetative growth till bunch emergence the treatment T_3 did not show any significant difference in the plant height from that of T_2. At bunch emergence stage the plant height differed only by a mean value of 18.40 cm between T_2 and T_3.

5.1.2 Effect of spacing on the girth of tissue culture Nendran banana

Results of the study (Table 2) revealed that upto eighth month after planting there was no significant difference between treatments with respect to the girth of plants. In the ninth month after planting and at harvest time, there was significant difference in plant girth. The monthly increment in girth was more in T_3 towards the cessation of vegetative growth and emergence of bunch. The general trend observed was that with decrease in spacing, the girth of plants increased; the highest plant girth being in T_5. Reddy (1982) also observed the same trend in the girth of the 'Robusta' plants under high density planting. However, the reports from Banana Research Station, Kannara with 'Nendran' cultivar showed no significant difference in plant girth between different spacings, though the mean values were slightly higher in closer spacings. While Bhan and Majumdar (1961) and Irizarry *et al*. (1975) did not observe significant difference in plant girth of banana in response to closer spacings, Robinson and Nel (1988) noted a reduction in plant girth in response to closeness of spacing. These differences in different reports may be due to the fact that in the latter studies the spacings tried would not have been sufficient to ensure a satisfactory vegetative growth. The results of the present study is in agreement with the former two reports.

The reasons for the increased girth of plants in closer spacings in the present investigation may be traced back to the satisfactory photosynthetic rate, higher efficiency of the forage system and extended duration of vegetative phase discussed earlier under the effect of spacing on height of plants. The increased number of total leaves per plant^{-1} discussed earlier also might have contributed to higher plant girth in closer spacings, since the leaf sheaths form majority of the bulk of pseudostem. The results also showed that at the harvesting stage, the treatment T_3 was only second to T_5 in the plant girth and it was on par with T_5 and T_4 which recorded higher plant girth.

5.1.3 Effect of spacing on leaf production in tissue culture Nendran banana

The results of the study (Table 3) indicated that the monthly rate of leaf production was not influenced by different spacings during the early vegetative growth phase up to fifth month after planting. There after, during the sixth and seventh month after planting, the monthly rate of leaf production increased significantly in the wider spacing. During and after ninth month, the bunches emerged in different treatments resulted in stoppage of further leaf production, the total number of leaves produced, however, was significantly higher in the closer spacing compared to wider spaced ones. The extended vegetative growth period might have given more time for further leaf production to add to the total number of leaves produced in the closer spacings.

The results of the present study are in agreement with the findings of Reddy (1982), Kohli et al. (1986), Rajeevan and Geetha (1989) and Robinson et al. (1989) in different cultivars of banana. Leaf production in banana is found to be related to several agroclimatic and genetic factors as reported by Turner (1970), the prolonged vegetative growth (Ticho, 1960), increased availability of soil moisture (Krishnan et al., 1978) and increased plant growth rate (Barker and Steward, 1962 a and b), Pillai and

Shanmughavelu, 1978 a and b, Reddy, 1982 and Sathyanarayana, 1985).

In the present experiment also in the earlier stages, the growth parameters, namely, plant height and girth were not significantly different resulting in the similar response in the number of leaves produced per month. The mutual shading of plants had not taken place in this growth period, since the small planting materials had not covered all the land area available. Therefore difference in soil moisture levels, temperature inside and beneath the canopy did not differ markedly enough to bring notable changes in the microclimate.

Another factor which has a bearing on monthly rate of leaf production is the interval of leaf production which has not differed significantly between different spacings (Table 8). This also might have contributed to the more or less uniform rate of leaf production in the early vegetative growth stage. During the latter part of growth, eight months after planting, bunch emergence had taken place in wider spacings resulting in no further leaf production in those treatments. But the leaf production went on uninterrupted in the close ones for a few more period.

The results also gave a noteworthy inference that the total number of leaf produced increased with closer spacings. The treatment T_3 had a total number of 41.9 leaves which was comparable with that of T_4 and was statistically on par with it.

5.1.4 Effect of spacing on the number of functional leaves in tissue culture Nendran banana

The data (Table 4) revealed that there was no significant difference in the number of functional leaves till seventh month after planting. During the period between the eighth month after planting and harvest, the wider spacings (T_2 and T_1) had higher number of functional leaves and this was significantly higher during the ninth month after planting to harvest time also. One of the reasons for lower number of functional leaves in closer spacings may be the faster rate of leaf senescene in closely spaced banana than the wider spaced ones as observed by Ludlow et al. (1974). The enhanced rate of leaf senescence can be correlated to the decrease in dark respiration rate also. The changes in spectral quality of light intercepted by lower canopy has also been mentioned as the reason for fastor leaf senescene by Holmes and Smith (1975) which prevents the older leaves lying in shaded parts becoming parasitic. Another reason for the decrease in number of functional leaves may the incidence of sigatoka leaf spot diseases, which was severe under closer spacings (Table 18). The reduction in the number of functional leaves between bunch emergence and harvest stage was very drastic in all the treatments. During this period the rains received (Appendix I) might have contributed a congenial condition for the spread of the sigatoka leaf spot disease, which drastically reduced the number of functional leaves. Added to the enhanced rate of leaf senescence discussed in the earlier part, the disease might have resulted in reduction in number of functional leaves in the closer spaced treatments.

5.1.5 Effect of spacing on monthly increment in leaf area in tissue culture Nendran banana

The results of the study indicated that during the initial period of vegetative growth upto the third month after planting, the treatments did not affect significantly the monthly increment in total leaf area. From fourth month onwards there was significant difference in this parameter with the treatments imposed, except in the sixth month after planting. It was observed that, in general the leaf area increment was higher in closer spacing and vise-versa. The total leaf area acquired upto bunch emergence also showed the same trend. The reasons for the increase in monthly increment in leaf area may be the higher number of leaves per unit area in closer spaced plots as well as larger size of individual leaves. Computations made to assess the mean individual leaf size using total number of leaves (Table 3) and total area (Table 5) at bunch emergence stage showed that individual leaf area was higher in closer spacings. These findings are in agreement with the reports of Reddy (1982) and Robinson and Nel (1985 and 1988).

5.1.6 Effect of spacing on functional leaf area of tissue culture Nendran banana

The results of the study (Table 6) revealed that there was no significant difference in the functional leaf area during the early vegetative growth period upto three months after planting. The period between the fourth month after planting and bunch emergence showed an increase in functional leaf area in the closer spacings and T_5 had significantly higher value during this period. However, at harvest stage, it was the wider spacing that had the highest functional leaf area.

The trend observed in the functional leaf area seems to be related to the number of functional leaves present during different growth periods (Table 4). It was observed that the number of functional leaves was not significantly affected by the different treatments in the early stages of growth. But from the fourth month after planting the number of functional leaves present was higher in the closer spacings, contributing to the corresponding increase in the functional leaf area also. Eventhough the functional leaf area was higher in closer spacings at bunch emergence, it decreased drastically in these treatments towards harvest. From the above inferences it becomes apparent that between bunch emergence and harvest period the rate of senescence of the functional leaves is faster in closer spacings. This is in agreement with the reports of Ludlow <u>et al</u>. (1974) and Holmes and Smith (1975) who related the decreased dark respiration rate and changes in spectral quality of penetrating radiation in the lower canopies to faster rate of deterioration of banana leaves under shade. They attributed this as an in built mechanism of plants to prevent parasitism of less effective or functional older leaves remaining on the lower portion of the canopy. In the current experiment, the fruit maturity period underwent a rainy season when the chances of leaf spot disease was more under the agroclimatic condition prevailing in the experimental tract. This also might have contributed to the lower functional leaf area in closer spacings where the micro-climate is more favourable for disease incidence and spread. The weather data provided in Appendix I and the rate of disease incidence furnished in Table 18 also support this view.

5.1.7 Effect of spacing on leaf area index and leaf area duration in tissue culture Nendran banana

The study (Table 7) indicated that the leaf area index increased with decrease in spacing and the resultant increase in the plant density. The closest spacing recorded higher leaf area index. Davidson and Donald (1958) observed that the period of low leaf area index can be shortened by increasing the number of plants per unit area, so that the time taken for crop plants to reach the critical value of leaf area index can be shortened.

In the present study also this was achieved in closer spacings. The total number of leaves per unit area, the total leaf area during the crop cycle and the functional leaf area were higher in the closer spacings and these governed the determinant components of leaf area index directly and indirectly. The increase in leaf area under high density planting in relation to decrease in plant spacing and soil temperature in banana has been explained by Robinson and Alberts (1987) also.

The leaf area duration was the highest in closer spacings; the closest spacing recording more than six times the leaf area duration value of the wider spacings tried. The leaf area duration being a function of the leaf area index and time, the higher leaf area index values might have reflected in correspondingly higher leaf area duration values also. This view is supported by the findings of Reddy (1982), Stover (1984) and Robinson and Nel (1986).

5.1.8 Effect of spacing on the interval of leaf production in tissue culture Nendran banana

The interval of leaf production (Table 8) was not significant in the early growth period upto fifth month after planting. Thereafter the differences in spacing influenced the interval of leaf production till bunch emergence. During the eighth month after planting when the bunch emergence was nearing, the interval of leaf production did not show significant difference between treatments and after this period the leaf production had totally stopped in the treatments (T_1 and T_2) where bunch emergence occured. In general it was observed that interval of leaf production increased with decrease in spacing. The results obtained are in agreement with earlier reports of Oppenheimer and Gottriech (1960), based on similar experiments in banana. Effects of shade in reduction of plant growth parameters were reported by Murray (1960) in banana and Ludlow et al. (1974) in other monocot species. In the early stages of growth, the mutual shading has not set in due to availability of sufficient space for growth and hence the treatments did not influence the interval of leaf production. The significant difference in interval of leaf production in the later part of vegetative growth phase may be due to the reduction in temperature in microclimate in closer spaced plots. Such effects of low temperature on interval of leaf production was reported by Summerville (1944), Smirin (1960), Ticho (1960), Cann (1964), Turner (1972) and Turner and Hunt (1984). The present studies also showed that the interval of leaf production was high during the first and second month after planting in all treatments compared to the later stages of growth. This effect of plant age in reduction of interval of leaf production is supported by Oppenheimer and Gottriech (1960) also.

5.1.9 Effect of spacing on time taken for bunch emergence, bunch maturity and crop duration in tissue culture Nendran banana

The data furnished in Table 9 indicated that the time taken for bunch emergence, bunch maturity period and consequently the crop duration were significantly influenced by various treatments. The duration for all the above characters increased in closer spacings. Delayed flowering in banana due to closer spacing was observed by Berrill (1963), Ahmed and Mannan (1970), Irizarry et al. (1975 and 1978), Chattopadhyay et al. (1980 a and 1984), Reddy (1982), Anonymous (1985 b) as well as Rajeevan and Geetha (1989).

Oppenheimer and Gottriech (1960) observed that flowering in wider spacing was early due to more frequent unfurling of leaves. Such differences in frequency of leaf unfurling were observed in the present experiment also (Table 8) and has been discussed earlier.

Summerville (1944) regarded flowering in banana as a function of several leaf characters including exposure of each leaf to sufficient hours of daylight and mean temperature during the functional life of each leaf. The functional leaf area till bunch emergence was observed to be the highest in wider spacings in the present experiment also. This has been discussed earlier in relation to total number of functional leaves (Table 4). However, it was noted that the total number of leaves per plant was the highest in closer spacings (Table 5). This character might not have influenced the flowering time. Israeli and Bluemenfeld (1986) have also reported that the relation between total number of leaves and flowering time is vague.

The time taken for bunch maturity was significantly influenced by different spacings; the longest duration of bunch maturity being in closer spacings and vice-versa. Increased bunch maturity period in closer spaced banana was reported by Kebby and Green-halgh (1959), Moreau (1965), Razvi and Jagirdhar (1966), Ahmed and Mannan (1970), Chattopadhyay et al. (1980 a), Chundawat et al. (1981 a and b), Reddy (1982) and Anonymous (1985 b). The slow rate of bunch development in association with decreased photosynthetic efficiency of individual leaves was observed by Turner (1984), which might be applicable to the results obtained in the present experiment also, where the functional leaf area underwent drastic reduction during bunch maturity period (Table 6). The decreased photosynthetic efficiency due to severe incidence of leaf spot disease during bunch development period discussed earlier has contributed to the reduction in photosynthetically active leaf area.

The total crop duration was also significantly influenced by the various spacings. The duration was longest in closer spacings. This may be due to the delay in flowering and fruit maturity period in closer spacings as observed by Oppenheimer and Gottriech (1960), Ahmed and Mannan (1970), Alagiamanavalan and Balakrishnan (1976), Irizarry et al. (1978), Reddy (1982), Robinson and Nel (1986) and Rajeevan and Geetha (1989). The progressive inhibition of floral initiation by continuous leaf production may also prolong the crop cycle, since flower inititiation is more related to age of the plant in banana rather than temperature or photoperiod (Turner, 1970). In the present study also a variation observed in the total leaf number from 38 to 46.9 with decrease in spacing (Table 3) might have kept the plants in vegetative phase resulting in delayed crop cycle in closer spacing. The low temperature and high relative humidity within the canopy of close planted plots also might have affected the interval of leaf production as observed in the earlier part of the study which in turn affected the crop cycle. Such phenomena in banana has been observed by Daudin (1955) and Arscott et al. (1965).

The data on the duration of reproductive phase also revealed that eventhough the time taken for bunch emergence showed a difference of 43.4 days between the closest and widest spacings. The treatment T_3 differed only by 11.2 days from T_2 with respect to this character. Similarly, the time taken for bunch maturity showed a difference of 11.2 days, while T_3 differed only by 7 days from T_2. It was also observed that there was a difference of 50 days between the crop cycle of various treatments while T_3 was only 18 days longer in total duration than T_2.

5.1.10 Effect of spacing on the number of suckers produced by tissue culture Nendran banana

The general trend observed was that the number of suckers produced per plant decreased with dicrease in spacing, but on per hectare basis the trend was the reverse. Berrill (1963), Jagirdhar et al. (1963), Moreau (1965), Caro-costas (1968), Ahmed and Mannan (1970), Irizarry et al.

(1975), Chattopadhyay *et al*. (1980), Reddy (1982) and Rajeevan and Geetha (1989) also observed the same trend in sucker production of banana.

The decreased rate of sucker production of individual plants in closer spacing can be attributed to the differences in the temperature level inside the canopy due to varying plant densities. Higher temperature can be expected in the microclimate of wider spaced plots and this may favour higher number of suckers in these treatments. Such relationship between temperature and sucker production was reported by Chakraborthy and Rao (1980). Earliest sucker production was observed at fifth month after planting in wider spacing, whereas in the dense planting by which time the plants might have grown to the levels to decrease the temperature in the microclimate due to shading of the interspaces and thereby inhibiting earlier sucker production in dense planting. Eventhough sucker production by individual plants decreased the total number of suckers per ha was significantly higher in closer spacings. This is due to the more crop stand per unit area in closer spacings. It was also observed that the average sucker production in the treatment T_3 was comparatively high on per plant as well as on per hectare basis.

5.1.11 Effect of spacing on the biomass production in tissue culture Nendran banana

The studies on biomass production presented in Table 9 revealed that in pseudostem, leaf and leaf sheath, there was no significant difference in the biomass accumulation due to the treatment effect. However, in general it was observed that biomass accumulation in these plant parts were more in wider spaced plants. In corms, suckers and bunches there were significant differences in the biomass accumulation due to the treatment effect. The total biomass accumulation per plant also differed significantly between treatments. However, on per hectare basis, the biomass production was more in closer spacings which may be due to more number of plants per unit area.

The present results are in agreement with the reports of Reddy (1982) and Turner (1984). The biomass production in banana is correlated with the photosynthatic rate (Brun, 1961 and Gietema, 1970). They found that photosynthatic contribution of lower leaf surface is more and also that 80 per cent of photosynthates come from the top two to five leaves. Even in the closest spacing, in the early growth stages the plants have not grown to cause mutual shading to result in a reduction in the photosynthatic efficiency. This may be the reason for the little differences in the biomass production in various plant parts.

However, during the late growth stages, mutual shading would have lowered the rate of photosynthasis in closer spacings. The reduction in photosynthatic apparatus due to disease incidence during later part of the crop cycle would also have contributed to the reduction in biomass accumulation, though the vegetative growth was more in closer spacing. The data further revealed that the percentage of biomass accumulated in the bunch is more in the first three wider spacings; T_3 being most efficient in diverting more biomass towards bunch. The bunch weight, weight of corms and weight of suckers of the plants in this treatment were comparable with that of T_2. Thus it seems that T_3 strikes a balance in the biomass partitioning among the economic parts instead of supporting excess non-productive vegetative growth.

5.1.12 Effect of spacing on the drymatter production in tissue culture Nendran banana

The drymatter production also followed the same trend of the biomass production and it was observed that dry matter production in the individual plants increased with increase in spacing. However, on per hectare basis highest drymatter production was observed in closer spacing. The same trend was observed by Reddy (1982) and Turner (1984) in banana. Loomis and Williams (1963) have observed that with increase in leaf area index, there is a corresponding increase in light absorption and drymatter production. This report is in agrement with the trend in drymatter production observed on per hectare basis, as the computed values of leaf area index on per hectare basis was higher in closer spacings due to high plant density. Since the biomass accumulation and drymatter production are related (Turner 1972), the trend observed in the former case can be applicable to the latter also.

5.2 Yield characters

5.2.1 Effect of spacing on bunch weight, number of hands and fingers in tissue culture Nendran banana

The yield characters, namely, bunchweight, number of hands and fingers showed significant variation with respect to the spacings tried (Table 13). Significant increase in bunch weight per plant was observed in wider spacings. The number of hands and number of fingers per bunch also followed the same trend. The number of fingers per hand did not vary significantly. However, the total yield on per hectare basis was significantly higher in closer spacings. It was also observed that the number of hands and number of fingers per bunch had influence on the bunch weight of individual plants.

The trend observed with respect to the number of hands per bunch is supported by similar studies by Ahmed and Mannan (1970), Chattopadhyay et al. (1980 and 1984), Robinson and Alberts (1987), Mustaffa (1988 a), Rajeevan and Geetha (1989) and Robinson et al. (1989). However, Bhan and Majumdar (1961) and Missinghan (1963) observed no significant influence in the number of hands and fingers with changes in spacing. This may be due to the fact that the planting distance tried by them would not have been sufficient enough for changes in the character.

The present studies showed decrease in the number of fingers per hand as well as per bunch under closer spacings. Similar results were reported by Ahmed and Mannan (1970), Irizarry et al. (1975), Chattopadhyay et al. (1980 and 1984), Chundawat et al. (1981 a and 1983), Mustaffa (1983), Daniells et al. (1987) and Rajeevan and Geetha (1989) in different cultivars of banana.

The increase in mean bunch weight with wider spacing observed in this experiment is in agreement with reports of Baghadadi et al. (1959), Kebby and Green-halgh (1959), Ahmed and Mannan (1970), Azouz et al. (1971), Robinson and Singh (1974), Chattopadhyay et al. (1980 and 1984), Chundawat et al. (1981 a, b and 1983), Reddy (1982), Mustaffa (1983), Robinson and Nel (1986) and Robinson et al. (1989). The lack of significant influence on the bunch weight between different spacings as reported by Bhan and Majumdar (1961) and Caro-costas (1968) may be due to the sufficient space available for the growth and development of plants in the spacings they had tried.

In banana, the number of total leaf produced per plant, leaf size, total leaf area, phylacron, number of functional leaves and functional leaf area have been considered as determinants of growth and productivity by Barker and Steward (1962 a and b), Simmonds (1966), Turner (1970), Pillai and Shanmugavelu (1976, 1977, 1978 a and b), Chakraborthy and Rao (1980), Reddy (1982) and Sathyanarayana (1985). All these factors seem to be in a favourable position in treatment T_3 for the production of a reasonably good bunch with fruit size and bunch weight comparable to that of T_2. This advantage might have been backed up by the efficient biomass partitioning in this treatment as observed earlier.

The advantage of lowest plant densities with respect to the higher total yield per hectare is apparently due to the population effect. Similar increase in tonnage under high density planting were observed by Berrill (1963), Ahmed and Mannan (1970), Azouz et al. (1971), Randhawa et al. (1973), Anonymous (1978), Patil et al. (1978), Venero and Marquez (1979), Chattopadhyay et al. (1980), Reynolds and

Robinson (1985), Robinson and Nel (1986 and 1989), Skikh et al. (1986) Daniells et al. (1987), Morales as well as and Rodriguez (1988).

5.2.2 Effect of spacing on fruit characters of tissue culture Nendran banana

The data on fruit characters furnished in table 14 showed that there was significant difference between treatments with respect to fruit characters. The length, girth and weight of fingers, pulp weight and pulp/peel ratio were higher in wider spacings, while peel weight was higher in closer ones. Similar observations were reported by Chattopadhyay et al. (1980 and 1984), Reddy (1982), Mustaffa (1983), Daniells et al. (1987), Robinson and Alberts (1987) Robinson and Nel (1989) and Rajeevan and Geetha (1989). Progressive increase in the peel weight and decrease in pulp weight was associated with closeness of spacings which inturn affected the pulp/peel ratio. This view is in agreement with the reports of Chattopadhyay et al. (1980) and Reddy (1982). The treatment T_3 had shown superiority or equalness in fruit length, girth, weight and pulp/peel ratio to the wider spaced plants, especially the treatment T_2. This shows that the fruits in the bunches of treatment T_3 have equal market acceptability as those of T_2.

5.3 Quality characterestics

5.3.1 Effect of spacing on fruit quality of tissue culture Nendran banana

The results of studies on quality of fruits in relation to spacing furnished in Table 15 showed significant differences in various quality aspects of fruits. The drymatter content did not show significant difference between treatments. Acidity was significantly higher in closer spacing of T_4 and T_5. The TSS content showed significantly higher levels in wider spacings. Total sugars, reducing sugars and non-reducing sugars decreased significantly in closer spacings. Ascorbic acid content showed significant increase in closer spacings. Sugar/ acid ratio was significantly high in wider spacings.

Decrease in fruit quality in relation to closeness of spacing was reported (Anon., 1978), when the plant population density varied from 4000 to 7000 plants ha^{-1}. In Maricongo plantains, decrease in fruit quality with respect to sugar, TSS and sugar/acid ratio was reported by Irizarry et al. (1978). Similar reduction in fruit quality in relation to plant densities was also reported by Chundawat et al. (1983) and Morales and Rodriguez (1988). These reports are in agreement with the present observations also. However, Missinghan (1963), Robinson and Singh (1974), Chattopadhyay et al. (1980) and Reddy (1982) did not find any significant difference in fruit quality with respect to different banana cultivars, probably due to the fact that the population tried were not dense enough to create a stress which may reflect in fruit quality.

The slight difference in drymatter content in T_3 may be due to the lesser amount of total biomass production, but this might have been nullified by the better efficiency of the treatment in diversion of biomass to bunches as observed in the results presented in Table 11. In terms of acidity and reducing sugars as well as ascorbic acid content, the treatment was statistically on par with wider spacings. In TSS content T_3 showed a slight difference from T_2. The total sugars, non-reducing sugars and sugar/ acid ratio were lower in this treatment. This might have slightly reduced the fruit quality of the treatment (T_3) compared to wider spacings, but at the same time keeping its position fairly high above the more closer spacings.

5.3.2 Effect of spacing on time taken for ripening and storage life of fruits of tissue culture Nendran banana

The results of the studies on the effect of spacing on fruit ripening period and storage life of fruits presented in Table 16 revealed that the time taken for ripening increased with decrease in spacing. With increase in spacing, there was significant reduction in time taken for ripening of fruits showing a difference of 1.47 days between the longest and shortest duration, while the difference between T_2 and T_3 was only 0.6 days. This indicates that decrease in spacing increase the fruit development process in the same pattern as that of other characters like time taken for bunch emergence time taken for harvest maturity and total crop cycle which have been discussed earlier. Similar reduction in fruit ripening period in different cultivars of banana was observed by Irizarry et al. (1975), Chattopadhyay et al. (1980), Chundawat et al. (1981 a), Reddy (1982) and Mustaffa (1983) also. However, the storage life of fruits at room temperature was not affected by different spacings tried. The shortest duration recorded in T_3 was 6.0 days while the longest duration of only 6.33 days was recorded in T_4. This finding is in agreement with the above discussed reports as well as the reports of Caro - costas (1968).

The above finding indicates that the treatment T_3 did not show much difference either in the time taken for ripening or the total shelf-life of fruits from that of T_2 and T_1, to be considered as important from the practical point of view.

5.4 Other observations

5.4.1 Effect of spacing on the cost of cultivation, netprofit and benefit/cost ratio of tissue culture Nendran banana

The abstract of economics of cultivation presented in Table 17 and the details in Appendix II indicated that the cost of cultivation increased correspondingly with decrease in spacing. The net profit per hectare increased upto the treatment T_3 and thereafter decreased with decrease in spacing. The benefit /cost ratio showed a decreasing trend with decrease in spacing. However, it was farely high and comparable at T_3. A negligible decrease in the number of hands per bunch, number of fingers per hand and number of fingers per bunch were observed in T_3 compared to T_2 and T_1. At the same time in T_3, the individual fruit size was higher in terms of length, girth and almost equal to treatment T_2. These determinants have reflected in comparable bunch yield in the treatment T_3 with respect to recommended spacing T_2 (2.0 x 2.0 m) and still wider spacing of T_1 (2.25 x 2.25 m). Added to this, the higher efficiency of biomass diversion of the plants and the crop stand in unit area in T_3 discussed earlier might have made this treatment more production efficient. Eventhough cost of cultivation was higher in this treatment (T_3) compared to wider spacings, the benefit/cost ratio was at a favourable level because of the higher net profit per unit area governed by the increased income from bunches as well as from the suckers. Similar high returns from optimum level of planting density were reported by Moreau (1965), Caro - costas (1968), Sharma and Roy (1972), Alagiamanavalan and Balakrishnan (1967), Reddy (1982), Rajeevan and Geetha (1989) and Thomas et al. (1989) in banana. In other crops like pineapple, Chadha et al. (1973 and 1975), Singh and Singh (1974), Dutta (1975), Bose (1984) and in mango, Ram (1993) observed higher net profit when the plant population was increased to a plant stant of proper balance.

Taking into consideration the present research results and previous reports in the similar lines it seems possible to increase the plant population in tissue culture Nendran banana from 2500 to 3265 plants ha^{-1} in square method of planting without affecting the yield and quality to a very severe extend.

5.4.2 Effect of spacing on the incidence of pests and diseases in tissue culture Nendran banana

Data on the incidence of various pests and diseases presented in Table 18 revealed that with decrease in spacing the sererity of the major pest, the banana rhizome weevil and the major disease, the sigatoka leaf spot increased. The severity of indence of rhizome weevil was more or less same in wider spacing upto T_3, but in other spacings, it was almost three fold in terms of the number of weevils present in the rhizome. According to Sherif and Thomas (1988) the damages due to the banana weevil are severely manifested in the post-flowering phase of the crop. The flowered plants and those nearing flowering were worst affected. The same trend was observed in the present experiment also. Similarly in case of sigatoka leaf spot also the severity of disease was more or less same upto T_3 while in the other treatment it was almost three fold. The faster rate of pest and disease incidence in the closer spaced plots may be due to the high relative humidity, lower temperature and lesser exposure of the soil and interspace to direct sunlight which provided a favourable microclimate for the incidence of pests and diseases. Similar severe incidence of diseases in banana under closer spacings were reported by Bunting and Dade (1926), Anon., (1957) Chundawat et al. (1981a), Anon., (1985 b) and Reddy and Singh (1993). However shade to certain level is found to be favourable in decreasing the severity of leaf spot diseases as observed by Vincente-chandler (1966) in banana. They have observed that less than 50 per cent shade was found to lower the incidence of leaf spot diseases. This may be the reason why in the present studies wider spacing upto T_3 had lesser incidence of leaf spot diseases and rhizome weevil attack.

The above discussed results indicate that the incidence of major pests and diseases of banana were comparatively less in spacing upto T_3. Therefore decreasing the spacing upto T_3 level may not invite crop hazards by means of pest and disease incidence to cause severe crop loss.

5.4.3 Effect of spacing on soil nutrient status after harvest of tissue culture Nendran banana

The general trend in the changes in soil nutrient content was that the nutrient removal was more with respect to all the three major nutrients, when the plant stand increased and consequently the spacing decreased. The data indicated that the nitrogen content of soil at pre-planting stage was low while phosphorus content was high and potassium content was medium. The percentage increase or decrease in the major nutrient content in soil after harvest showed that the nitrogen, phosphorus and potassium reaches the depletion rate beyond T_3 and additional dozes of nitrogen is required at least at a slighter quantity above T_2 level.

The changes in the soil nutrient status due to different spacings are in harmony with the difference in the total uptake of nutrients (Table 21). The growth rate in terms of plant height and girth are high in closer spacings as observed early. The extended crop cycle in closer spacings also is partly at the expense of the soil nutrient so as to maintain satisfactory level of metabolic activities for a prolonged period. The data also indicated that nitrogen and potassium are required at a higher levels compared to phosphorus. Similar observations were recorded by Fawcett (1921), Jacob and Uexkull (1960), Martin-pervel (1984), Sheela and Aravindakshan (1990) and Kulasekaran (1993). Shading in closer spaced plots also might have been one of the reasons for high growth rate and consequent nutrient uptake by plant.

From the results obtained in the current experiment and pervious experiments in the similar lines, it becomes evident that potassium followed by nitrogen are required in higher quantities compared to phosphorus for banana. It is also seen that with decrease in spacing, the crop removal of the major nutrients is at a rapid rate. The treatment T_3 appears to be the optimum population level which can be supported by the present fertilizer management practice, beyond which additional dozes of fertilizers are required to support the population.

5.4.4 Effect of spacing on uptake and partitioning of major plant nutrients by tissue culture Nendran banana

The content of major plant nutrients in various plant parts were analysed after harvest and the data are presented in Table 21. The results indicated that the nutrient content in various plant parts decreased with decrease in spacing. The trend was clear when the nutrient content in individual plant organs were observed seperately, or the plant as a whole . The increase in nutrient content on per hectare basis is only because of the higher plant density in closer spacing. These inferences are in agreement with the earlier findings of Martin-prevel (1964) and Reddy (1982) who observed similar decrease in the total nutrient content of the plant with increase in plant population density. However on per hectare basis, the nutrient content in plants increased with decrease in spacing.

The high growth rate interms of plant height, girth, number of leaves per plant etc., as well as enhanced crop cycle period in closer spacing might have resulted in more utilization of the nutrient resulting in lesser residual nutrient content in the plant body after harvest. The higher rate of depletion of the soil nutrient content in closer spacing also indicates that the plant puts forth efforts to maintain these elements in required levels for growth and production.

The nutrient content in various plant parts also found to vary. The highest nitrogen and phosphorus content was in fruits followed by leaf, leaf sheath, corm and pseudostem. However, the potassium content was the highest in the leaf followed by fruit, corm, leaf sheath and pseudostem. This indicates that the leaf and fruit maintain a high level of all the three major nutrients compared to leaf sheath, corm and pseudostem. This may be due to the selective diversion of these nutrients to the priority areas, namely, fruits and leaves where the development activities are aimed more towards the reproduction function. The drymatter accumulation in various plant parts (Table 12) also shows that leaves and bunches are the priority organs for drymatter accumulation.

The present study also indicated that the content of the potassium was the highest in various plant parts followed by nitrogen and phosphorus. The same trend were also observed by Fawcett (1921), Jacob and Uexkull (1960), Sheela and Aravindakshan (1990) and Kulasekaran (1993).

SUMMARY

SUMMARY

The present investigation on "Standardisation of spacing for tissue culture banana cv. Nendran (AAB group)" was conducted at the Department of Horticulture, College of Agriculture, Vellayani, Thiruvananthapuram during 1992-'93, to find out the optimum spacing for tissue culture planting materials of Nendran banana, so as to increase the number of marketable bunches from unit land area without affecting the size and quality of fruits. During the course of the experiment, plant growth, yield and quality of the produce under different spacings were critically observed and the important findings are summarised below.

From the fifth month after planting, plant height varied significantly under the influence of various treatments imposed. During this period the plant height was found to increase with decrease in spacing. However, the plant height in T_3 (1.75 x 1.75 m) was always comparable with that of the wider spacings T_1 and T_2.

The treatments did not have any significant influence on the girth of the plants till eighth month after planting. In the ninth month after planting and at bunch

emergence time, the girth of plants was found to be more in closer spacings.

The monthly rate of leaf production was not influenced by different spacings during the vegetative phase upto fifth month after planting. The rate of leaf production increased during the later vegetative phase, but decreased in treatments nearing flowering. The total number of leaves produced per plant were more in closer spacings. The rate of leaf production in treatment T_3 was comparable with wider spaced plants.

In the early stages of plant growth, there was no significant difference between the treatments with respect to the number of functional leaves present; the wider spacings had more number of functional leaves than the closer spacings.

The treatments showed significant influence on leaf area increment except during the initial periods of first to third month and sixth month after planting. However, the leaf area increment and total leaf area produced upto bunch emergence were lesser with increase in spacing.

The functional leaf area decreased with increase in spacing during all stages except at harvest.

The leaf area index (LAI) increased with increase in plant population density; the closest spacings recording the highest leaf area index (LAI) at all stages of growth. Leaf area duration (LAD) increased with decrease in spacing. Closer spaced plants recorded the highest leaf area duration.

The spacings did not significantly influence the interval of leaf production during the early stages of plant growth, but the effect was observed in the later stages. In general, the interval of leaf production increased with decrease in spacing.

The time taken for bunch emergence, time taken for bunch maturity and consequently the crop duration were significantly influenced by different spacings tried. The widest spacing recorded the shortest duration for bunch emergence and vice-versa. The bunch maturity period was longer in closer spacings. Crop duration was the shortest in wider spacing and longest in closer spacings. The general trend observed was that the time taken for all the above three characters increased with decrease in spacings.

The number of suckers produced per plant decreased with decrease in spacing, but on per hectare basis the trend was the reverse. Total number of suckers was more in closer spacings.

Observations on biomass partitioning showed that weight of corms, bunches and weight of plants were significantly influenced by different spacings. The biomass accumulation in different plant parts was higher at wider spacings compared to closer ones. However, on per hectare basis, the total biomass production was found to be higher in closer spacings.

The drymatter production by different plant parts as well as the whole plant increased with increase in spacing. However, the drymatter production per hectare was the highest in the closer spacings.

The mean bunch weight was influenced by different spacings tried. The bunch weight recorded in T_3 (9.00 kg) was comparable with that of the wider spaced plants in T_2 (9.25 kg). However, bunch weight in the closer spaced plants was lesser than those in wider spaced ones. The number of hands per bunch was the lowest in closer spacings compared to wider ones. The number of fingers per hand did not show any significant difference with respect to different spacings.

Yield per unit area increased with decrease in spacing; highest in closer spacing and lowest in wider spacing. The treatment T_3 produced higher yield per hectare (29.39 t ha^{-1}) compared to wider spacings of T_2 (23.13 t ha^{-1}) and T_1 (18.76 t ha^{-1}).

The bunch characters in general showed a trend of increase in economic part with increase in spacing tried. However, the total yield per unit area increased significantly with decrease in spacing.

Finger size and weight were lesser with closer spacings compared to the wider spacings. The treatment T_3 showed comparable finger size with the widest spacing.

The drymatter content, TSS, total sugars, reducing sugars, non-reducing sugars and sugar/acid ratio increased with increase in spacing. But the acidity and ascorbic acid content decreased with increase in spacing.

The time taken for ripening of fruits decreased with increase in spacing, while the storage life at room temperature remained unaffected by the various spacings adopted.

The cost of cultivation increased with decrease in spacing and was the lowest in the widest spacing and highest in the closest spacing. The total income also increased with decrease in spacing. But the net profit per hectare of land increased upto T_3 level and then decreased. The treatment T_3 recorded maximum net profit of Rs. 1,51,367.45 with a benefit/cost ratio of 2.03.

The intensity of incidence of pests and diseases in closer spaced plants was almost three times more than that in wider spaced plants. Decreasing the spacing upto T_3 did not invite hazards by means of pest and disease incidence to cause severe crop loss.

The changes in soil nutrient content showed that the nutrient removal was more, with respect to all the three major plant nutrients (nitrogen, phosphorus and potassium), when the plant stand per unit area increased.

The content of the major nutrients decreased in the plant tissues with decrease in spacing. Among the different plant parts, the highest nitrogen content was in corms followed by leaf, fruit, leafsheath and pseudostem. Phosphorus content was the highest in leaf sheath followed by corm, fruit, pseudostem and leaf. The potassium content was the highest in corm, followed by leaf sheath, pseudostem, leaf and fruit. However, on per hectare basis, the nutrient content in plants increased with decrease in spacing.

The uptake pattern of the major nutrients showed that the highest nitrogen and phosphorus content was in fruits followed by leaf, leaf sheath, corm and pseudostem. However, the potassium content was the highest in leaf followed by fruits, corm, leaf sheath and pseudostem.

The observations on growth, yield and quality of tissue culture Nendran plants under different spacing indicated the possibility of decreasing the spacing to 1.75 x 1.75 m in square method of planting from the recommended level of 2.0 x 2.0m. However, the experiment is to be repeated before drawing definite conclusions.

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* Orginals not seen

APPENDICES

APPENDIX - I

Weather data prevailed during the growth and development period of tissue culture Nendran banana

Month		Temperature (^{o}C)		Relative humidity (%)	Rain fall (mm)	Cumulative rain fall (mm)
		Maximum	Minimum			
August	1992	28.90	22.30	83.89	67.80	67.80
September	1992	29.30	23.20	81.72	76.30	144.10
October	1992	28.90	22.70	85.23	412.00	556.10
November	1992	29.17	23.00	83.18	281.00	837.10
December	1992	30.34	21.48	78.66	15.10	852.20
January	1993	30.30	20.56	77.15	Nil	852.20
February	1993	31.20	21.30	76.46	2.80	855.00
March	1993	32.39	23.10	75.55	36.30	891.30
April	1993	32.50	24.60	83.12	31.60	922.90
May	1993	32.09	25.00	88.00	223.20	1146.10
June	1993	29.97	24.12	86.80	391.30	1537.40
July	1993	28.75	22.47	87.24	224.20	1761.60
August	1993	29.80	23.30	84.62	33.20	1794.80

Effect of spacing on cost of cultivation, netprofit and benefit/cost ratio of tissue culture Nendran banana

Details	spacing :	2.25 x 2.25 m			2.0 x 2.0 m			1.75 x 1.75m			1.50 x 1.50m			1.25 x 1.25m		
	Rate	Number of Labourers (@ Rs.65/lbr.)	Quantity	Amount Rs ps	Labour	Quantity	Amount Rs Ps	Labour	quantity	amount Rs Ps	Labour	quantity	amount Rs Ps	Labour	quantity	amount Rs ps
1 Clearing of land	@280 m2/Lbr	36	-	2340 00	36	-	2340 00	36	-	2340 00	36	-	2340 00	36	-	2340 00
2 Earthing up	@200 m2/Lbr	50	-	3250 00	50	-	3250 00	50	-	3250 00	50	-	3250 00	50	-	3250 00
3 Making irrigation and drainage channels (22 channels)	@400 m/Lbr	6	-	390 00	6	-	390 00	6	-	390 00	6	-	390 00	6	-	390 00
4 Taking pits	@100/Lbr	21		1300 00	26		1690 00	34		2210 00	47		3055 00	67		4355 00
5 Planting materials (considering 5% mortality rate)	Rs. 6 per plant	-	2074	12444 00	-	2625	15750 00	-	3428	20568 00	-	4667	28002 00	-	6720	40320 00
6 Planting	200/Lbr	10	-	650 00	13	-	845 00	17	-	1105 00	23	-	1495 00	34	-	2210 00
7 Shading	200/Lbr	10	-	650 00	13	-	845 00	17	-	1105 00	23	-	1495 00	34	-	2210 00
8 Compost/dry cowdung (10 kg/plant)	@ Rs.300/t.	20.74t	-	6222 00	26.25t	-	7875 00	34.28t	-	10284 00	46.67t	-	14001 00	67.20t	-	20160 00
9 Gap filling	--	1	-	65 00	1	-	65 00	1	-	65 00	2	-	130 00	2	-	130 00
10 Cowdung (dry) application	@ 250/Lbr	8	-	520 00	10	-	650 00	14	-	910.00	19	-	1235 00	27	-	1755 00
11 Irrigation after planting (for 1 month) once in 3 days	@ 250/Lbr	83	-	5395 00	105	-	6825 00	137	-	8905 00	186	-	12090 00	268	-	17420 00
12 Cost of fertilizers																
Urea (190 g/plant)	@ Rs.2/90 per kg.	-	394kg.	1142 60	-	499kg.	1447 10	-	651kg.	1887 90	-	887kg.	2572 30	-	1277kg.	3703 30
SSP (115 g/plant)	@ Rs.5/40 per kg.	-	239kg.	1290 60	-	302kg.	1630 80	-	394kg.	2127 60	-	537kg.	2899 80	-	773kg.	4174 20
MOP (300 g/plant)	@ Rs.4/00 per kg.	-	623kg.	2492 00	-	788kg	3152 00	-	1029kg.	4116 00	-	1400kg.	5600 00	-	2016kg	8064 20
13 Fertilizer application (Lbr)	@ 150/Lbr															
1. at planning	@ 150/Lbr	14	-	910 00	18	-	1170 00	23	-	1495 00	31	-	2015 00	45	-	2925 00
2. 1 MAP	@ 150/Lbr	14	-	910 00	18	-	1170 00	23	-	1495 00	31	-	2015 00	45	-	2925 00
3. 2 MAP	@ 200/Lbr	10	-	650 00	13	-	845 00	17	-	1105 00	23	-	1495 00	34	-	2210 00
4. 4 MAP	@ 200/Lbr	10	-	650 00	13	-	845 00	17	-	1105 00	23	-	1495 00	34	-	2210 00

Details	spacing: Rate	2.25 x 2.25 m Number of Labourers (@ Rs.65/lbr)	Quantity	Amount Rs ps	2.0 x 2.0 m Labour	Quantity	Amount Rs Ps	1.75 x 1.75m Labour	quantity	amount Rs Ps	1.50 x 1.50m Labour	quantity	amount Rs Ps	1.25 x 1.25m Labour	quantity	amount Rs ps
5. 5 MAP	@ 200/Lbr	10	-	650 00	13	-	845 00	17	-	1105 00	23	-	1495 00	34	-	2210 00
6. After complete emergence	@ 200/Lbr	10	-	650 00	13	-	845 00	17	-	1105 00	23	-	1495 00	34	-	2210 00
14 Irrigation after fertilizer application (for 6 application)	@ 400/Lbr	31	-	2015 00	39	-	2535 00	51	-	3315 00	70	-	4550 00	100	-	6500 00
15 Irrigation during summer months (once in 2 days for 2 months)	@300/Lbr	207	-	13455 00	263	-	17095 00	343	-	22295 00	467	-	30355 00	672	-	43680 00
16 Clearing the channels	-	6	-	390 00	6	-	390 00	6	-	390 00	6	-	390 00	6	-	390 00
17 Weeding (band weeding) (4 times)	@ 500 m2/Lbr	100	-	6500 00	100	-	6500 00	50	-	3250 00	50	-	3250 00	50	-	3250 00
18 Desuckering	-	5	-	325 00	5	-	325 00	5	-	325 00	5	-	325 00	5	-	325 00
19 Phorate (75 g/plant)	@ Rs.55/kg	-	156kg.	8580 00	-	197kg	10835 00	-	257kg	14135 00	-	350kg	19250 00	-	504kg	27720 00
20 Application of Phorate (twice)	@ 500/Lbr	13	-	845 00	16	-	1040 00	21	-	1365 00	28	-	1820 00	40	-	2600 00
21 Propping	@ 100/Lbr	21	-	1365 00	26	-	1690 00	34	-	2210 00	47	-	3055 00	67	-	4355 00
22 Cost of propping materials	@ Rs.4/plant	-	-	8296 00	-	-	10500 00	-	-	13712 00	-	-	18668 00	-	-	26880 00
23 Bunch covering with dry leaves(wrapping)	@ 100/Lbr	21		1365 00	26		1690 00	34		2210 00	47		3055 00	67		4355 00
24 Irrigation/watering	-	6		390 00	6		390 00	6		390 00	6		330 00	6		390 00
25 Harvesting and transporting	@100/Lbr	21		1365 00	26		1690 00	34		2210 00	47		3055 00	67		4355 00
26 Interest on working capital	@ 10% per annum			8706 22			10715 49			13573 05			17997 81			25101 15
Total expenditure incurred		695		95768 42	861		117870 39	1060		147053 55	1369		194725 91	1880		272862 65

cont...

	spacing:	2.25 x 2.25 m			2.0 x 2.0 m			1.75 x 1.75m			1.50 x 1.50m			1.25 x 1.25m		
Returns	Rate	Yield pl^{-1}	Yield ha^{-1}	Amount Rs ps	Yield pl^{-1}	Yield ha^{-1}	Amount Rs Ps	Yield pl^{-1}	Yield ha^{-1}	amount Rs Ps	Yield pl^{-1}	Yield ha^{-1}	amount Rs Ps	Yield pl^{-1}	Yield ha^{-1}	amount Rs ps
1 Income from bunches	@8/-per kg.	9.500kg.	18762.5	150100 00	9.250kg.	23125kg.	185000 00	9.00kg.	29385kg.	235080 00	6.700kg.	29774.8kg.	238198 40	6.05kg.	38720kg.	309760 00
2 From Suckers	@ Rs.4/- per sucker	6.35	12541.25	50165 00	5.80	14500	58000 00	4.85	15835.25	63341 00	4.65	20664.60	82658 40	3.35	21440	85760 00
Total income				200265 00			243000 00			298421 00			320856 00			395520 00

	2.25 x 2.25 m	2.0 x 2.0 m	1.75 x 1.75m	1.50 x 1.50m	1.25 x 1.25m
A) total income	Rs 200265.00	Rs. 243000.00	Rs 298421.00	Rs 320856.80	Rs 395520.00
B) total expenditure	Rs 95768.42	Rs. 117870.39	Rs 147053.55	Rs 194725.91	Rs 272862.65
Net profit (A-B)	Rs 104496.58	Rs. 125129.61	Rs.151367.45	Rs 126130.89	Rs 122657.35
Benefit/Cost ratio(B/C Ratio)	2.09	2.06	2.02	1.65	1.45

Note Lbr = Labourer SSP = Single Super Phosphate MOP = Muriate of Potash MAP = Months After Planting

STANDARDISATION OF SPACING FOR TISSUE CULTURE BANANA cv. NENDRAN (AAB Group)

By

B. K. ANIL B.Sc. (Ag.) T. Tech.

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
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DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
VELLAYANI — THIRUVANANTHAPURAM
1994

ABSTRACT

The investigation on "Standardisation of spacing for tissue culture banana cv. Nendran (AAB group)" was conducted at the Department of Horticulture, College of Agriculture, Vellayani, Thiruvananthapuram during 1992-'93 inorder to study the effect of different spacings on growth, yield and fruit quality of Nendran banana. The results obtained are presented below:

In the early stages of growth, the vegetative characters were not influenced by the spacings tried. However, during later periods, the plant height, girth, number of leaves per plant, total and functional leaf area, interval of leaf production, LAI and LAD increased with decrease in spacing. The time taken for bunch emergence, maturity and duration of crop increased with decrease in spacing. The number of suckers per plant decreased with decrease in spacing, while total number of suckers per hectare increased with decrease in spacing.

The biomass and drymatter production per plant, bunch yield and fruit size were higher in wider spacing, while on per hectare basis it was the reverse. Drymatter content, TSS, reducing, non-reducing and total sugars and

sugar/acid ratio of fruits increased with increase in spacing, while acidity and ascorbic acid content decreased. The time taken for ripening of fruits decreased with increase in spacing, while shelf life remained unaffected. The benefit/cost ratio was most favourable in 1.75 x 1.75 m spacing. Incidence of pests and diseases ,were severe in closer spacings above 1.75 x 1.75 m.

Soil nutrient deplition was tolerable upto 1.75 x 1.75 m spacing, while uptake and partitioning of major nutrients by individual plants decreased with decrease in spacing. Fruits showed the highest nitrogen and phosphorus content followed by leaf, leaf sheath, corm and pseudostem. Potassium content was the highest in leaf followed by fruits, corm, leaf sheath and pseudostem.

In general spacing 1.75 x 1.75 m did not significantly affect the plant growth, yield and quality of fruits. However, the experiment has to be repeated to arrive at conclusive results.