PHYSIOLOGY, GROWTH PATTERN AND FLOWERING OF TISSUE CULTURE BANANA *MUSA* (AAB) 'NENDRAN'

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled "**Physiology, growth pattern and flowering of tissue culture banana *Musa* (AAB) 'Nendran'**" 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 to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

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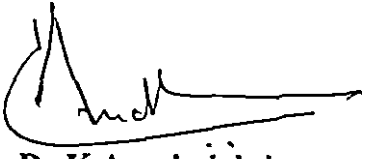
CERTIFICATE

Certified that the thesis entitled "**Physiology, growth and flowering of tissue culture banana *Musa* (AAB) `Nendran'**" is a record of research work done independently by **Mrs.Deepa Jacob Mavelil** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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DEEPA JACOB MAVELIL

To my family

Whose Prayers are

Always for and with me

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Introduction

INTRODUCTION

Banana, one of the most important tropical fruits of the world, is also named as "Adams fig" and "Apple of Paradise" because of its antiquity. Banana occupies a place of pride and ranks third in importance. In India it is grown in an area of 3.84 lakh hectares with an annual production of 77.9 lakh tons. This amounts to 11.67 per cent of the total area and 24.29 per cent of the total production of fruit crops in India (NRCB, 1993-94). It occupies an area of about 72,570 hectares in Kerala with a production of 5,74,260 tons (Farm Information Bureau, 1997). Unlike the other categories of banana like dessert (Poovan, Palayankodan etc.) and culinary types (Monthan, Batheesa etc.), the dual purpose variety, Nendran is very popular in Kerala and is cultivated on commercial basis. Nendran belongs to the French plantain group and its most important use is for making chips in addition to its use as table fruit.

The type of planting material has a marked effect on the performance of banana crop. Conventional method of propagation in Nendran is through suckers. Uniformity with respect to age and size of suckers is never achieved when bulk planting is done on large scale. Size and weight of rhizome are considered as important criteria for the selection of suckers, since it provides stored food for the initial growth of the plants. Usually suckers weighing 1.5 to 2.0 kg are used for planting and it results in variations in crop growth, yield and final duration of the crop as the size of the suckers is never indicative of its age. Also the spread of pests and diseases through the conventional suckers can cause economic loss and is thus a serious production constraint.

But with the standardisation of tissue culture techniques, the dearth of quality planting material is no more a problem. *In vitro* propagation has several advantages, like the ability to deliver large number of plants rapidly, hygienically and safely with 100 per cent establishment in the field. Therefore no replacements are

necessary except for the somaclonal variants observed after planting. Tissue culture plants can be established successfully in the field throughout the year unlike the conventional suckers and they will be free from pests and diseases since only elite plants will be used for the production of *in vitro* plants. The tissue culture plants of banana in field have shown better performance in terms of productivity, shorter crop cycle, increased plant vigour, uniformity of crop stand and shorter crop duration than the sucker derived plants, in spite of the fact that they lack a well developed rhizomatous portion and the whole plants weighed only 150 to 250 g . Eventhough the tissue culture plants are smaller in size than the suckers in the initial vegetative growth period, they will catch up with the sucker raised plants in the subsequent growth phase. When the sucker generated plants get an initial boost by stored food of rhizomes, the tissue culture plants have the merit of being true to type in characters of the elite plant selected for micropropagation.

Young *in vitro* plants are very tender and sensitive to stress during establishment. They have no nutrient or carbohydrate reserves and have to receive optimum management to ensure that neither the tender leaf area nor the root volume is damaged or stressed in any way. This entails extra attention and care at this critical stage. So the post-planting management of young *in vitro* plants is extremely important. The first five months after planting is the period when these plants are physiologicaly very active and when root and leaf growth is at a maximum. There must be no stress on the plant, or any constraints whatsover during this stage, otherwise the inherent advantages of tissue culture vigour could be lost to a large degree.

While the developmental processes in the banana plant are best described by morphological and phenological responses, the processes of growth (assimilation of dry matter) are described by physiological responses. This could be explained scientifically only by detailed studies with respect to the physiological attributes, dry matter partitioning etc. of both the group of plants at critical stages of the crop growth.

Tissue cultured plants produce more homogenous plant population, higher bunch weight and less variability in fruit size and shape, thus increasing the export potentiality of the fruit. In the present study, the performance of tissue culture banana plants is put to test against the conventional sucker-derived progenies, under varied fertilizer doses and methods of application, to ascertain superiority, if any, of the former over the latter and to attribute physiological reasons for the differences. The major objectives of the study were to compare the physiology, growth pattern, flowering and yield attributes of tissue culture banana plants with that of conventional planting material (suckers).

REVIEW OF LITERATURE

Banana is one of the most important, remunerative tropical fruit crops. Banana accounts for about 11.67 per cent of the area under fruits in India. Nendran is the most popular, commercial, dual purpose variety of banana grown extensively in Kerala. Though, Kerala ranks first in area under banana, the productivity is very low as compared to other states. Suckers, the conventional planting material in banana, cause variations in crop growth, yield and duration of the crop and hence considered as one major reason for the variations in productivity. More recently, banana planting material derived from *in vitro* techniques has been commercially used in some countries as an alternative to conventional planting material.

Tissue culture planting material is more than just a means of producing pest and disease free planting material or a technique for rapid and true multiplication of a mother plant with superior characteristics. Tissue cultured plants establish more quickly, are taller and have a shorter time to bunch emergence and harvest than conventional suckers. They have significantly higher yield in terms of bunch weight, which is a function of greater number of fingers and hands.

The developmental physiology, dry matter production and nutrient uptake in tissue cultured banana plants are different from the sucker propagated ones. This necessitated a comparative study to evaluate the field performance of tissue cultured plants and conventional propagules (suckers) of banana.

The review of research work on comparative evaluation of field performance of tissue cultured and sucker propagated bananas are highlighted here.

2.1 Vegetative/Biometrical characters

2.1.1 Height of plants

Hwang *et al.* (1984) recorded a height of 257 cm for sucker derived plants and 256 cm for tissue cultured plants at the shooting stage of cv. Giant Cavendish. Daniells (1988) reported that the tissue culture plants were about 30 cm taller than the plants grown from suckers. However, it should be recognized that the environmental conditions during the establishment phase would be the major controlling factor. Zamora *et al.* (1989) reported that the micropropagated banana plants grew faster than the sucker derived plants soon after establishment and at all times of plant growth the micropropagated plants were more taller. They also reached maximum heights earlier than sucker derived plants. Drew and Smith (1990) recorded that the tissue cultured plants commenced growth earlier, were taller throughout their life cycle than plants derived from conventional planting material. The tissue cultured plants which had a mean height of 205 mm at planting since already possessing an active root and shoot system were able to make better early growth. This difference in early growth was seen throughout the growth cycle. It was also reported that tissue cultured plants were about 236 cm at bunching whereas the suckers were only 220 cm.

A study conducted in Thailand by Hang (1991) on the growth of 'Grand Nain' banana plants, revealed that in the fourth month after planting, the height of tissue culture propagated plants was more than the plants derived from suckers.

Pradeep *et al.* (1992) evaluated the performance of tissue cultured and sucker propagated bananas and reported that tissue cultured plants progressively attained the height of sucker derived plants (286.8 and 296.6 cm respectively) at the

flowering stage, in spite of their smaller size at planting. Two months after planting tissue culture plants were 24.70 cm in height while the sucker plants were 78.75 cm in height.

Tissue cultured plants grew taller and thicker than conventional suckers, which in turn gave rise to a potential for carrying large bunches, as stated by Robinson and Anderson (1992). It was also established that the season of planting will influence the plant height. Robinson *et al.* (1993) observed that cultured plants were upto 300 mm taller than conventional suckers at flowering.

Anil (1994) reported that height of tissue culture Nendran banana plants varied at the critical growth stages. Three months after planting, the plants grew to 45.5 cm, at fifth month 144.4 cm and 227.4 cm at seventh month. At bunch emergence these plants were about 273 cm tall. Vuylsteke and Ortiz (1996) noticed that the tissue cultured plants grew vigorously and were taller than the sucker propagated plants of cv. Agbagba belonging to the False Horn plantain group.

2.1.2 Girth of plants

The pseudostem circumferences of micropropagated plants were significantly higher than those of sucker derived plants as reported by several workers (Hwang *et al.*, 1984; Zamora *et al.*, 1989; Drew and Smith, 1990 and Hang, 1991). Pradeep *et al.* (1992) reported that girth of pseudostem at flowering showed significant difference for tissue cultured (61.15 cm) and sucker derived plants (57.08 cm). Robinson (1992a) compared the conventional suckers with tissue culture plants and reported that the pseudostem circumference was about 69-77 cm for sucker derived plants and 72-84 cm for tissue cultured plants of Dwarf Cavendish bananas grown during different times of the year.

Anil (1994) reported variation in pseudostem thickness with increase in age. Pseudostem thickness of 16 cm was recorded at third month after planting whereas it was 43 cm and 68 cm at fifth month and flowering for tissue cultured Nendran.

2.1.3 Number of leaves

The tissue cultured plants gave rise to mature plants which retained more healthy leaves (13.2 leaves) than those originating from suckers (11.0) as reported by Hwang *et al.* (1984). Singh (1988) reported that the association of balbisiana genome (B) led to the production of leaves at wider intervals thus prolonging the vegetative phase leading to the production of more number of leaves. Robinson (1990) concluded that the number of leaves produced were more for tissue cultured plants than the sucker derived plants. Tissue culture plants produced on an average 47 leaves per plant compared with 41 leaves produced by suckers in Grand Nain.

Pradeep *et al.* (1992) reported that during the early vegetative growth phase the leaf production rate was 6.0-7.1 leaves per month, whereas in the late vegetative phase it was 4.7-5.1 leaves for tissue cultured plants. For the sucker derived plants, it was 5.0-7.0 and 3.8-4.0 leaves per month during the early and late vegetative phase respectively. Anil (1994) observed that the number of leaves and hence the leaf production rate was the lowest during one to two months after planting (1.8-3.1 leaves per month), which increased to 5.7-6.6 leaves per month during sixth and seventh month after planting and showed a declining trend in the late vegetative phase (4.8 leaves). Eckstein and Robinson (1995) noticed higher photosynthesis rate for tissue culture plants since it had more number of functional leaves than the sucker propagated plants. The tissue culture planting material had functional green leaves at planting while the conventional suckers had no leaf at this stage of development.

2.1.4 Phyllochrone and Leaf Emergence Rate (LER)

The leaf emergence rate (LER) is a useful index of the vegetative development rate of a banana plant and it has been proved experimentally that LER is closely related to temperature conditions (Turner and Hunt, 1983; Robinson and Nel, 1985). Singh (1988) reported that the result of phyllochrone (reciprocal of the rate of leaf production) clearly shows that the association of balbisiana (B) genome in cv. Manohar (ABB) and Kachkal (ABB) led them to produce leaves at wider intervals, thus prolonging the vegetative phase and hence led to the production of higher number of leaves. Singh and Bhattacharya (1992) confirmed phyllochrone as a good index of the vegetative growth rate of a banana plant and that a reduction in phyllochrone would exert considerable influence in reducing the overall crop duration in banana. Robinson (1996) reported that LER is very important since it indicates when management must be optimal, especially irrigation, fertilization, desuckering and weed control. Also the long duration between planting and flowering is due to lower leaf production rate.

2.2 Physiological characters

2.2.1 Leaf area, leaf area index and leaf area duration

Robinson and Nel (1985) found that the mean functional leaf area can be calculated using the formula L x W x 0.83 where L = maximum length of the lamina, W = maximum width of the lamina and 0.83 is an adjustment factor. These values were then used for calculating leaf area index (LAI). Hang (1991) reported that the plants grown from suckers weighing 4.0-8.0 kg weight produced the biggest leaves than the plants from suckers of 1.5-2.5 kg weight or from tissue cultured plants of 16.6 cm and 26.2 cm height.

Anil (1994) recorded that the leaf area of tissue cultured Nendran was 0.60 m^2, 2.96 m^2 and 6.75 m^2 in the third, fifth and seventh month, respectively. The total leaf area of the plant upto bunch emergence was 22.23 m^2. At bunch emergence the

functional leaf area was 12.23 m^2 whereas at harvest it was only 6.82 m^2. At bunch emergence the leaf area index was 3.06 and at harvest it was only 1.71. He also noted that the leaf area duration was 431.07.

Eckstein and Robinson (1995) reported that the tissue culture plants showed improved physiological efficiency which was consistent throughout the entire leaf profile. Seven months after planting tissue culture plants had 83.5 per cent larger mean functional leaf area than conventional suckers. The larger leaf area of tissue culture plants along with a vigorous root system enabled the tissue culture plants to reach full assimilation potential at an earlier stage of development, with a doubling of mean functional leaf area.

The maximum value for leaf area index as reported by Eckstein *et al.* (1995) in Williams banana was 2.27 and the LAI decreased to 1.56 at harvest. It was also concluded that the LAI increased until flowering.

2.2.2 Crop Growth Rate (CGR) and Net Assimilation Rate (NAR)

Robinson and Nel (1989a) studied the growth and development of tissue culture banana plants and noticed that NAR was more in plants grown in summer. Robinson and Anderson (1991) noted an increase in NAR and CGR during the months before harvest. Pradeep *et al.* (1992) reported that during the third and fourth month, the tissue culture plants recorded relative growth rate of 0.03 and 0.02 cms/cm/day whereas the sucker plants recorded 0.01 and 0.02 cms/cm/day respectively. The growth rate during the later periods declined indicating an exponential growth at early stages of growth and development and sigmoidal growth during later stages of tissue culture bananas.

Robinson (1992b) stated that CGR and NAR showed seasonal growth pattern. After planting, CGR increased, with a final rapid increase during the bunch

filling stage. CGR and NAR exhibited a pronounced increase before bunch harvest. This is because, during this period, the leaf area per plant remained constant yet the total dry matter increased substantially. Also an increase in mean temperature will result in a higher value for NAR and CGR.

Eckstein *et al.* (1995) reported that NAR and CGR increased rapidly after planting in tissue culture plants of 'Willaims' banana but when the average daily sunshine hours were very low, NAR and CGR declined rapidly. During the last two months prior to harvest, NAR and CGR decreased.

2.2.3 Flowering

Earliness in flowering and shorter crop duration of the tissue culture plants over that of conventional sucker derived ones were reported by several workers (Hwang *et al.*, 1984; Daniells, 1988; Robinson, 1989; Zamora *et al.*, 1989). Zamora *et al.* (1989) suggested that the micropropagated plants flowered earlier because they attained maximum growth earlier.

Drew and Smith (1990) concluded that the difference in early growth placed the conventional material about one month behind the tissue cultured plants in the growth cycle and this inturn resulted in early bunch emergence. Similar report was obtained by Novak *et al.* (1990) in Grand Nain banana regenerated from shoot tips.

Robinson (1990) in a comparative trial to evaluate the conventional suckers and *in vitro* derived banana plants reported that the tissue culture plants flowered two to three weeks earlier due to the presence of 14 leaves at six months after planting, when the first leaves from conventional suckers were seen.

In contrary, Pradeep *et al.* (1992) noticed that the number of days taken from planting to flowering was more in tissue culture Nendran banana. The sword suckers flowered 240 days after planting whereas the tissue culture plants took 268 days. Retention of all the functional leaves gave the shortest duration to flowering. Anil (1994) reported that the tissue cultured plants of Nendran took 234 days for bunch emergence.

2.2.4 Dry matter partioning

In all cases, dry matter production increased with the progressive development of the plant.

Twyford and Walmsley (1973) reported that at shot and harvest stages, an increase in dry matter content was discernible and that the dry matter production at shot and harvest stages were positively correlated with bunch weight. Buragohain (1986) recorded an increase in dry matter production with progressive development of the plant from 0.32 kg per plant at the sucker stage to 10.64 kg at harvest.

Robinson and Nel (1989b) found that the total dry matter increase was 66 times greater in summer than in winter. Sheela and Aravindakshan (1990) observed that dry matter production increased with the age of plant and it was most rapid between late vegetative phase and shooting time, the percentage increase being 699.52. Between shooting and harvest, the rate of increase of dry matter content was low and the increase in dry matter production was only nominal. The vegetative growth of plant showed a declining trend because of the mobilisation of nutrients to the developing bunches and resultant metabolic changes. During this period, the increase in dry matter production observed was due to bunch development.

Interactions between dry matter production and distribution were confirmed by the work done by Turner (1972) and Robinson and Anderson (1991a, 1991b). During the first three months after planting, leaves had the largest proportion of plant dry matter. Though LAI increased until flowering, percentage dry matter distribution to leaves decreased from three months after planting until harvest. Reason is that dry matter allocation to pseudostem increased, peaking at 39 per cent just before flowering.

Robinson (1992b) recorded a substantial increase in total dry matter content during the last two months before bunch harvest even when the leaf area per plant remained constant. A massive redistribution of assimulates took place from leaves, pseudostem and rhizome to the bunch and this favoured an increase in compensatory photosynthesis in the leaves.

Robinson and Anderson (1992) noticed that for the first five months of the crop cycle in Dwarf Cavendish banana, dry matter was apportioned preferentially to the leaves (40-50 per cent of the total). The products of photosynthesis were allocated to new leaves to further build up the source for future assimilates. The proportion of total dry matter in leaves decreased progressively from 50 to 12 per cent due to redistribution. Dry matter allocation to the rhizome remained at about 35 per cent of the total until flowering whereas to the pseudostem it was 27 per cent. From flowering till harvest, total dry matter apportioned to the bunch increased from 4 to 47 per cent, while that in the leaves, pseudostem and rhizome was correspondingly reduced.

Anil (1994) reported that the total dry matter production per plant was 7.28 kg. Of this 53.98 per cent was apportioned to the bunch, 32.43 per cent to the leaf, 5.32 per cent to leaf sheath and 4.68 and 3.71 per cent to the corm and pseudostem respectively. Eckstein and Robinson (1995) concluded that an increase in dry mass of tissue plants over suckers was observed for all plant parts except rhizome. Dry mass of tissue culture plants was evently distributed with 41 per cent in leaves, 31 per cent in

pseudostem and 27 per cent in rhizome. The subterranian storage organs (rhizome + suckers) of sucker derived plants contributed a higher percentage of total dry mass of the plant than with tissue culture plants (45.3 and 36.2 per cent respectively).

Eckstein *et al.* (1995) reported that during the first three months, dry matter was apportioned mainly to the leaves, reaching 44 per cent of plant mass, later it declined to 21 per cent at flowering and to only 9 per cent at harvest. At harvest, the bunch comprised 32 per cent of the total dry matter, equal to the sum of the rhizome and suckers, the sucker alone had only 10 per cent of dry matter thus emphasizing the great sink strength of the developing bunch.

2.2.5 Number of suckers produced

Daniells (1988) noticed that the tissue culture plants produce many more suckers than from conventional material and are usually quite uniform in size. These sucker characteristics would be related to the greater number of leaves and associated buds that tissue culture plants have. Examination of corms of tissue culture plants near flowering reveals they have many suckers coming from well underneath the bulkier part of the corm. Zamora *et al.* (1989) found that the micropropagated plants of Lakatan, Bungulan and Saba cultivars, particularly Lakatan suckered earlier than the control plants. Early and improved suckering in micropropagated plants may reflect either the initial advantage of their aseptic environment during propagation or a residual effect of growth regulators.

Drew and Smith (1990) reported that the sucker production on tissue cultured plants was significantly higher upto 8 months after planting, equal to conventional material from 8 months to harvest, and then significantly lower. Epsino *et al.* (1992) observed that early and uniform suckering and a greater number of suckers were produced in combination of tissue cultured plants + recommended practice

resulting in an earlier follower crop. Anil (1994) reported that the tissue culture plants of Nendran banana produced 5.8 suckers per plant and the total number of suckers per hectare amounted to 14500.

2.2.6 Crop duration

Hwang *et al.* (1984) reported that the harvesting period was shortened from the original 3 months to 1.5 months because of the uniform growth of plantlets and also the plantlets shooted 2 weeks earlier than those grown from suckers. Reuveni *et al.* (1985) found no differences between sucker and tissue culture derived plants of 'Williams' but Daniells (1988) reported taller plants with larger bunches from tissue cultured 'Williams' bananas although bunch emergence was about 3 weeks later. Yadav *et al.* (1988) observed that higher dose of potassium (300 g K_2O per plant) when applied in two splits reduced the time taken for harvest and thus the crop cycle was also shortened.

Tissue cultured plants established more quickly, and had a shorter time to bunch emergence and harvest of plant crop than conventional planting material (Drew and Smith, 1990).

Robinson (1990) in a field trial to compare the conventional planting material with *in vitro* derived plantlets observed that the latter flowered two to three weeks earlier and had only a shorter cycle to harvest. By contrary, Pradeep *et al.* (1992) reported that the days taken by tissue culture plants from planting to flowering and maturity was higher than the days taken by sword sucker plants. The days taken to attain maturity was 346 days and 314 days respectively in tissue culture and sucker derived plants.

Robinson (1992a) observed that the tissue cultured plants of Dward Cavendish banana came to maturity earlier than the sucker propagated ones. Robinson and Fraser (1992) obtained the same results with tissue cultured and sucker derived plants of banana cv. Grand Nain. The crop duration remained unaffected by various levels and frequencies of applications of fertilizers as observed by Natesh *et al.* (1993). Anil (1994) in an experiment with tissue culture 'Nendran' banana reported that the crop duration was 328 days. Eckstein and Robinson (1995) concluded that the faster development of tissue culture plants compared to conventional suckers would have contributed to the shorter crop cycles.

2.3 Nutritional studies

Being a heavy feeder, banana requires adequate amount of fertilizers throughout its growth phases for satisfactory yield.

2.3.1 Quantity and stage of fertilizer application

Obeifuna (1984) reported that the optimal dose of potassium was 300 g potassium per plant and should be applied at 19th/20th leaf stage (4-5 months old). Application later than 20th leaf stage (five months after planting) did not increase the bunches developed. Efficient utilisation of potassium was seen during the flower initiation stage.

Yadav *et al.* (1988) concluded that application of 200 g K_2O per plant gave signfiicantly higher yield. Among the frequencies, application of 1/2 or 2/3 at vegetative phase in two splits and 1/2 or 1/3 at shooting stage were found optimum for yield and bunch weight. Ram and Prasad (1989) reported that maximum plant growth was measured by the application of 300 g N, 120 g phosphorus and 200 g potassium in Dwarf Cavendish banana.

Garriga *et al.* (1989) reported that banana plants were grown in soil with low phosphorus and medium potassium content with the addition of 0-300 g nitrogen per plant annually along with 50 g P_2O_5 and 450 g K_2O per plant as basal dressing. In the first year all P and K and 50 per cent nitrogen were applied 45 days after planting, the remaining nitrogen was applied 135 days later. In the second year, N, P and K were applied when more than 50 per cent of the plants flowered.

Murthy and Iyengar (1990) reported that basal application at planting, either as full or half dose resulted in quicker absorption of fertilizer P, meeting the P requirement of Robusta banana during the early stages of growth. NPK application at the rate of 45:45:45; 180:180:180 and 270:270:270 g per plant when applied in three split doses was sufficient for the growth and development of Basrai banana (Dave *et al.*, 1991). It was also proved that nitrogen, potassium, magnesium, iron, zinc and manganese content showed higher degree of association with yield.

As per the package of practices recommendations (KAU, 1993), 190:115:300 g NPK per plant has to be applied for Nendran in six split doses - 40:65:60 g NPK/plant at planting, 30:50:60 g NPK one month after planting and 30:60 g N and K each at 2nd, 4th, 5th month after planting and just after complete emergence of bunch.

Natesh *et al.* (1993) reported that the recommended dose of fertilizers, viz. 190:115:300 g NPK per plant when applied in four splits for Nendran banana had favoured yield than when the same dose was applied in two splits; the four splits being at 2nd, 4th, 6th and 8th month after planting. Murthy *et al.* (1995) observed that the absorption of fertilizer N applied at early and late vegetative stages was faster but decreased gradually at harvest in Robusta banana. Nitrogen was applied in four equal

splits of 50 g each at early vegetative (45 days after planting), late vegetative (90 days), bud differentiation (115 days), and shooting stages of plant growth.

Sheela (1995) reported that the application of 300 g nitrogen and 450 g potash per plant gave the highest yield in tissue culture Nendran banana. It has been found that treatments with fertilizer application exceeding six splits had no effect no yield. The optimum nitrogen and potash dose was found to be 299.5 g and 465.5 g per plant respectively. Veeraraghavathatham *et al.* (1996) reported that for Nendran grown in wetland 160:50:390 g NPK per plant per year and for plants grown in garden land 150:90:300 g NPK per plant per year should be applied. Entire P should be applied in the 3rd month, the othernutrients to be applied in three split doses during 3rd, 5th and 7th month after planting.

Robinson (1996) reported that banana has high demand for nitrogen and particularly potassium. Nitrogen should be applied at short intervals during growth whereas potassium should be applied at planting and perhaps twice a year thereafter. Phosphate is required only at planting.

2.3.2 Effect of fertilizer application

Kohli *et al.* (1981) suggested that plants supplemented with nitrogenous fertilizers produced higher number of hands per bunch. Obeifuna (1984) observed that all plantains given potassium produced better yield than control. Application of 300 g K per plant at 4-5 months after planting (19/20th leaf stage) increased the bunch weight (73.9 per cent), number of marketable fingers (33.7 per cent) and finger weight (44.2 per cent) per plant over the control. Super optimal K applications decreased the yield.

Yadav *et al.* (1988) reported that significant effect of potassium level or frequency was not observed on growth. But yield and average bunch weight were

significantly affected by levels as well as frequency. Application of 200 g K_2O per plant gave significantly higher yield. Garriga *et al.* (1989) noticed that in banana yield was highest with 150 g nitrogen per plant each year. Nitrogen application increased the number of fruits per bunch and fruit length and also increased the fruit and pseudostem width.

Ram and Prasad (1989) reported that maximum growth was recorded with the application of 300; 120 and 200 g NPK per plant. Application of 200 g nitrogen resulted in early flowering but higher levels of nitrogen (300 g) delayed flowering. Sheela and Aravindakshan (1990) found that with increasing levels of potassium, the total dry matter production increased. Baruah and Mohan (1991) observed that the response of potassium application was seen with respect to yield attributing characters like weight of second hand, bunch weight and finger characters.

Kulasekharan (1993) reported that nitrogen induced growth of leaves and increased number of fruits per bunch. Requirement of P for banana is relatively lower and P_2O_5 did not show any significant effect on yield and maturity of banana. Potassium finds its role in improving quality, yield and shelf-life of fruits, helps the plant to tolerate adverse effects of drought, salinity, pests and diseases. Natesh *et al.* (1993) noticed that the morphological characters were not significantly influenced by the manurial dose and method of application whereas bunch weight, weight of hand and fingers were affected. A dose of 190:115:300 g NPK per plant per year in four splits favoured higher yield. Sheela (1995) recorded the highest yield with the application of 300 g N and 450 g potash per plant in tissue culture Nendran banana compared to plants from suckers.

2.3.3 Nutrient uptake

Buragohain (1986) noted a sharp increase in nitrogen uptake from 16.47 kg/ha at sucker stage to 310.82 kg/ha at shooting and declined to 267.53 kg/ha at harvest in Vayalvazhai (AAB). P uptake was 2.5 kg/ha, 60.68 and 55.6 kg/ha at sucker, shot and harvest stage respectively. There is massive uptake of potassium ie. from 28.29 kg/ha at sucker stage to 879.21 kg/ha at harvest. The calcium uptake rose to 397.87 kg/ha at harvest from the 3.47 kg/ha at the sucker stage. Similar results were reported by Montagut and Prevel (1965); Twyford and Walmsley (1973); Veerannah *et al.* (1974) and Ashok kumar (1977).

Stover and Simmonds (1987) reported that for a banana crop which produces 46 t/ha average yield removes 102:11:330 kg NPK. Sheela and Aravindakshan (1990) stated that the uptake of nitrogen increased progressively with the growth of banana cv. Palayankodan (AAB) till shooting irrespective of the amount of potassium applied but between shooting and harvest there was a decline. Total uptake decreased at harvest. Among the nutrients, potassium uptake was the highest compared to nitrogen and phosphorus.

Kulasekaran (1993) reported that from one hectare, by a 50 tons banana crop 320, 23 and 925 kg NPK were removed every year. Murthy *et al.*(1995) observed an increase in the uptake of fertilizer nitrogen with delayed application. The recovery (percentage utilization) also increased with the advanced stage of application and highest utilization was got from fertilizer nitrogen applied at shooting and the least from that applied at early vegetative phase.

2.3.4 Nutrient content at various stages of growth

Chattopadhyay (1981) found a decrease in the concentration of nitrogen at harvest. Lahav and Turner (1983) reported that the critical concentration of nutrients in

dry matter of D-leaf lamina was 2.6, 0.2 and 3.0% NPK and 0.5% calcium, 0.3 and 0.23 per cent magnesium and sulfur respectively.

Buragohain (1986) reported that the highest nitrogen content of the plant was observed during the sucker stage (2.04%), followed by shooting stage (1.93%) in Vayalvazhai banana (ABB) and after that nitrogen content decreased. Highest P content was seen in shooting stage (0.14%), followed by sucker stage (0.12%) and at harvest was 0.09 per cent. At all stages of growth, K content was higher than any other nutrient. The highest K content was seen at shot stage (3.04%) followed by shooting (2.99%) and large (2.95%) stages. At harvest K content fell down to 2.74 per cent. Calcium and magnesium content of banana plants increased gradually with the advancement of growth. High content of N, P and K at sucker and shooting stage was indicative of higher demand of these nutrients at these stages.

Ram and Prasad (1989) analysed the leaf samples of banana cv. Campierganj local (*Musa* ABB) before flowering and at fruit harvest. Studies have shown that leaf nitrogen content significantly increased (2.72%) with increasing level of nitrogen whereas it was reduced considerably at harvest. Maximum percentage of phosphorus in leaves (0.63%) was estimated before flowering which significantly reduced upto 0.41% at fruit harvest with 13 g P_2O_5 level. Whereas potassium concentration in leaves (4.60%) was highest at 300 g K_2O level and reduced (3.42%) at harvest. N, P and K content increased rapidly upto flowering and declined at fruit harvest.

Kulasekaran (1993) reported that leaf nutrient levels of 3.29 per cent N, 0.44 per cent P_2O_5, 3.11 per cent K_2O, 2.12 per cent Ca and 0.24 per cent Mg was optimum for increased yield in Robusta banana. The studies by Natesh *et al.* (1993) revealed that nitrogen and potassium concentration varied significantly at shooting and harvest whereas phosphorus concentration did not show significant variation at various growth stages. Anil (1994) reported that the N, P and K content of the corm was the highest

(1.34% N, 0.32% P and 6.30% K) followed by leaf sheath, pseudostem, leaf and fruit. The fruits contained 1.25, 0.34 and 1.70 percentage N, P and K respectively.

2.4 Bunch characters

Besides the bunch yield components, cycle time (harvest to harvest interval) is an important yield component of the banana plant system.

2.4.1 Bunch weight and yield

Hwang *et al.* (1984) reported that the fruit productivity was about the same between plants originating from plantlets and those originating from suckers. Daniells (1988) found that the bunch weight of tissue culture plants were greater when compared to sucker material and bunch emergence of the former was about 3 weeks later. Yadav *et al.* (1988) reported that significant effect of potassium level and frequency was observed on yield and average bunch weight in Dwarf Cavendish banana.

Drew and Smith (1990) noticed an increase in the yield of tissue culture plants when compared with suckers as measured by average bunch weight, average finger weight per bunch and average number of fingers and hands per bunch. Productivity (g/day) was also greater for micropropagated plants. Kwa and Ganry (1990) noticed that tissue culture plants had advantages like increased vigour, homogenous plant population and higher bunch weight.

Robinson (1990) reported that tissue culture plants of Williams, Dwarf Cavendish and Grand Nain produced 20 per cent more yield than conventional suckers due to larger bunches and a shorter cycle to harvest. Baruah and Mohan (1992) observed an increase in yield attributing characters like bunch weight, weight of D-hand

and fingers. The superiority in yield of tissue culture plants compared to plants grown from conventional sword suckers was reported by Pradeep *et al.* (1992) and recorded about 39 per cent yield increase. The average bunch weight of tissue culture plants were 13.2 kg, whereas that from suckers were 9.5 kg.

The trials conducted by Robinson (1992b) revealed that tissue plants produce higher yield in the plant crop compared with conventional suckers. The extent of yield increase vary with planting date and cultivar used. Robinson and Fraser (1992) found that average yield was 22 per cent higher with tissue culture plants than sucker planting material at all planting dates and this was associated with larger bunches and shorter crop cycle. Robinson *et al.* (1993) found that yields from tissue culture plants were 19.4, 15 and 13 per cent higher than from conventional suckers in Dwarf Cavendish, Williams and Grand Nain respectively. Anil (1994) reported that the tissue culture plants of Nendran banana yielded bunches weighing 9.25 kg average weight and the total bunch yield was 23.13 t/ha.

Eckstein *et al.* (1995) observed that after flowering, dry matter was mostly allocated to the developing bunch at the expense of all other plant parts. Sheela (1995) noticed that the tissue cultured plants of Nendran recorded an increase in yield of 25.63 per cent compared to plants from suckers. Vuylsteke and Ortiz (1996) reported that *in vitro* propagated plants of False Horn plantain cv. Agbagba did not manifest a consistently superior horticultural performance than conventional propagules. Higher yield was also not obtained in tissue cultured plants because of severe disease and suboptimal husbandry input.

2.4.2 Number of hands per bunch

The plants supplemented with nitrogenous fertilizers produced higher number of hands per bunch (Kohli *et al.*, 1981; Ram and Prasad, 1989). Zamora *et al.*

(1989) reported that micropropagated Lakatan banana had more number of hands per bunch than the suckers (6.3 vs 6.0 respectively). However, the sucker derived Bungulan banana plants yielded more hands per bunch (6.4) than the micpropagated plants (6.1). But for Saba, the number of hands per bunch was similar for both the types of planting material. Drew and Smith (1990) reported that the tissue culture plants of "New Guinea Cavendish" produced more number of hands per bunch than the conventional suckers. Baruah and Mohan (1992) observed an increase in the number of hands per bunch in response to potassium application.

Pradeep *et al.* (1992) found that the tissue culture nendran produced 5.8 hands per bunch whereas the sucker derived plants produced only 4.8 hands per bunch. Natesh *et al.* (1993) reported that the application of 190:115:300 g NPK per plant in 4 splits resulted in the production of bunches with 5.1 hands and those which received 300:140:450 g NPK in 4 splits produced 5 hands per bunch. Tissue culture Nendran plantlets produced 5.3 hands per bunch as reported by Anil (1994). Eckstein and Robinson (1995) reported that in field comparisons with suckers using the same general management, tissue culture plants had greater uniformity and upto 19 per cent higher production potential due to more number of fingers and hands, as well as shorter cycle times.

2.4.3 Length, girth, weight and size of fingers

Daniells (1988) reported that the greater bunch weight of tissue cultured banana cv. Williams than the sucker derived plants was due to the presence of more number of fingers per bunch. Yadav *et al.* (1988) observed that the number of fingers per bunch was significantly influenced by the different levels of potassium and frequency of application in Dwarf Cavendish banana. There were no significant differences for the number of fingers per hand for the micropropagated and sucker derived plants of Lakatan, Bungulan and Saba cultivars. But there was significant

difference in the number of fingers per bunch in the micropropagated and sucker derived plants of Lakatan and Bungulan whereas for Saba, there were more fruits per bunch in the sucker derived plants (154.2) than in the micropropagated plants (133.7) (Zamora *et al.*, 1989).

Ram and Prasad (1989) found that the size of fingers reduced significantly at the mid and distal end as compared to proximal to distal end of bunch, might be due to the less translocation of nutrients. Drew and Smith (1990) established that the tissue culture plants of Cavendish banana produced bunches with higher average finger weight and number of hands and finger than the suckers propagated plants. The benefits of *in vitro* propagation of bananas, as compared with the traditional methods of plant propagation include more homogenous plant population, higher bunch weight, more fingers and hands and less variability in fruit size and shape thus increasing the percentage of exportable fruits (Kwa and Ganry, 1990).

Baruah and Mohan (1992) observed that the total number of fingers per bunch, the length, circumference, and volume of fingers showed significant difference in response to different doses of potassium application in Dwarf Cavendish banana. The tissue cultured Nendran banana produced 62.8 fingers per bunch whereas the sword suckers had only 49.4 fingers (Pradeep *et al.*, 1992).

Natesh *et al.* (1993) studied the influence of biometric characters on yield and it is reported that number of fingers is having the maximum direct effect.It's also probable that the number of fingers is influenced more by the quantity of fertilizers upto a certain level than the time of application. Among the finger characters, only the weight of finger showed significant variation whereas the length and girth of finger remain unaffected. Anil (1994) reported that tissue culture Nendran banana produced 44.6 fingers per bunch and 8.37 fingers per hand. Eckstein and Robinson (1995)

noticed that the tissue culture plants of cv. Williams produced more number of fingers and hands per bunch than the conventional suckers.

2.5 Qualitative fruit characters

Vadivel and Shanmughavelu (1978) noticed an increase in the reducing, non-reducing and total sugars in banana with increase in rate of potassium supply.

Baruah (1986) in a study to find the response of potassium on fruit quality of Jahaji banana revealed that there was significant response to potassium in terms of quality of the fruits. Total soluble solids (TSS), total sugar, reducing and non-reducing sugars in the fruit increased with increasing levels of potassium whereas a reverse effect was observed with respect to titratable acidity. Sugar acid ratio was maximum at the highest level of potassium due to increase in sugar and reduction in acidity of fruit pulp.

Baruah and Mohan (1992) reported that the reducing, non-reducing and total sugars in banana increased with an increase in the rate of potassium supply in Dwarf Cavendish banana. Natesh *et al.* (1993) in a study to find out the effect of split application of fertilizers for banana revealed that among the qualitative characters, reducing and non-reducing sugars did not vary significantly. However, a significant increase in total soluble solids, total sugars and sugar/acid ratio was noticed with increase in fertilizer dose whereas acidity decreased with higher doses. Anil (1994) reported that the fruits of tissue culture Nendran banana had 26.13, 8.52 and 17.62 per cent of total sugar, reducing and non-reducing sugars respectively and the sugar acid ratio was 65.38, the titratable acidity being 0.40 per cent. The total soluble solid content was 21.2 per cent and the ascorbic acid content was 9.37 mg/100 g fruit.

Materials and Methods

MATERIALS AND METHODS

The present investigations on "Physiology, growth pattern and flowering of tissue culture banana *Musa* (AAB) 'Nendran'" were conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during 1996-'97. The location is situated at an altitude of 40 m above MSL at 10° 32" N latitude and 76° 16" E longitude. The area receives warm humid tropical climate. The soil type is laterite and well deep. The meteorological data are presented in Appendix I.

The planting materials included two months old, hardened plantlets produced through shoot tip culture of selected mother plants of ecotype 'Nedunendran' and uniform suckers weighing about 1.5-2.0 kg, were planted in August 1996. The plants were planted at a spacing of 2 m x 2 m and maintained by applying fertilizers at the rate of 190:115:300 g NPK/plant and 300:115:450 g NPK/plant applied in two and six split doses for various treatments.

The experimental design adopted was Factorial Randomized Block Design (Factorial RBD) with eight treatments, each with three replications. Twenty plants were planted in each plot which included the centrally located four experimental plants from which observations were recorded and four plants for periodical destructive sampling for uptake studies. A total of 480 plants were planted and the individual plot size was 80 m^2. The details of various treatments imposed are furnished below.

a) Planting material

T_1 - Tissue culture plants (60 days old), *Musa* (AAB) 'Nendran' cv. Nedunendran Plants were 20-25 cm tall with 6.0 cm girth and weighed 70-120 g.

T_2 - Suckers of 1.5 - 2.0 kg size *Musa* (AAB) 'Nendran' cv. Nedunendran

b) Fertilizer doses

M_1 - 190:115:300 g NPK/plant

M_2 - 300:115:450 g NPK/plant

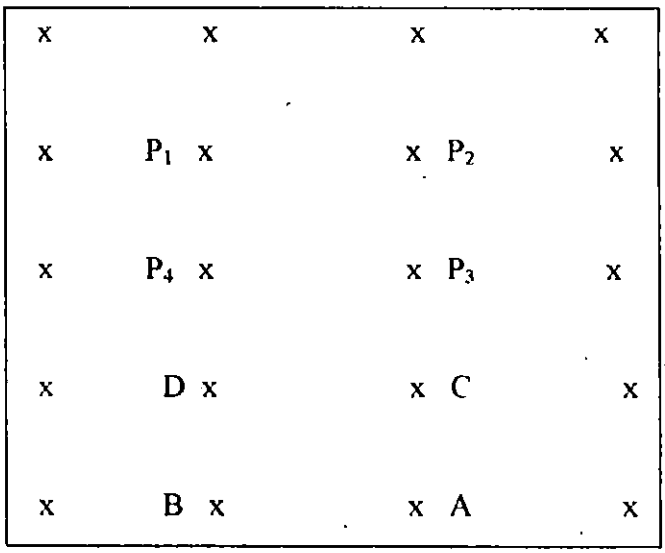
c) Method of application

S_1 - two splits at 2nd and 4th month

S_2 - six splits at 2nd, 3rd, 4th, 5th, 7th month and after flowering

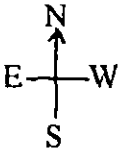
The eight treatments were $T_1M_1S_1$, $T_1M_1S_2$, $T_1M_2S_1$, $T_1M_2S_2$, $T_2M_1S_1$, $T_2M_1S_2$, $T_2M_2S_1$ and $T_2M_2S_2$.

Layout of the plot



P_1, P_2, P_3 and P_4 were the four experimental plants in a plot from which observations were recorded. The plants marked A, B, C and D were uprooted at 3rd, 5th, 7th month after planting and at flowering. After harvest, one of the experimental plants, from which observations were recorded was uprooted.

The layout of the experiment is as follows:



←——————————20 plants——————————→

$T_2M_1S_1$	$T_2M_2S_1$	$T_2M_1S_1$	$T_1M_2S_1$
$T_1M_1S_2$	$T_1M_2S_2$	$T_1M_1S_1$	$T_2M_2S_2$
$T_2M_1S_2$	$T_2M_2S_2$	$T_1M_1S_2$	$T_2M_2S_1$
$T_1M_1S_1$	$T_2M_1S_1$	$T_1M_2S_1$	$T_1M_2S_2$
$T_2M_2S_2$	$T_1M_1S_2$	$T_2M_2S_1$	$T_2M_1S_2$
$T_1M_2S_2$	$T_1M_2S_1$	$T_2M_1S_1$	$T_1M_1S_1$

R_3

R_2

R_1

24 plants

The following observations were taken to evaluate the effect of various treatments.

3.1 Vegetative characters

3.1.1 Height of the plant

Plant height was measured as the distance from ground level to the base of the unopened leaf and expressed in centimetre.

3.1.2 Girth of the plant

Girth of the plant at 10 cm above the ground level was recorded during the critical growth stages and expressed in centimetre.

3.1.3 Number of leaves per plant

The number of leaves produced was counted at critical stages of observation by labelling the leaves as and when they emerged and the total number of leaves produced by the plant was computed. The number of functional leaves at critical stages of growth were also recorded and expressed as mean number per plant.

3.1.4 Phyllochrone

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

3.1.5 Leaf area

Leaf area in banana was measured using the model suggested by Robinson and Nel (1985).

$$LA = 0.825 \times L \times B$$

where

LA_1 - leaf area per leaf, L - leaf length, B - leaf breadh and 0.825 is the constant.

3.1.6 Leaf Area Index (LAI)

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

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

3.1.7 Leaf Area Duration (LAD)

Leaf area duration was determined using the formula,

$$LAD = \frac{Li + (Li + 1)}{2} \times (t_2 - t_1)$$

where Li is Leaf Area Index (LAI) at time t_1 and Li + 1 is the LAI at time t_2. $(t_2 - t_1)$ is the time interval in days (Power *et al.*, 1967)

3.1.8 Crop Growth Rate (CGR) by Watson (1958)

$$CGR = \frac{W_2 - W_1}{P(t_2 - t_1)} \text{ g/m}^2\text{/day}$$

where W_1 and W_2 are the total plant dry weight at time t_1 and t_2, respectively. P is the spacing of banana.

3.1.9 Net Assimilation Rate (NAR) by Watson (1958)

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\text{Log}_e L_2 - \text{Log}_e L_1}{L_2 - L_1} \text{ g/m}^2\text{/day}$$

where W_1 and W_2 are the total plant dry weight and L_1 and L_2 are the total leaf area at time t_1 and t_2 respectively.

3.1.10 Dry matter partitioning (DMP)

For computing crop growth rate (CGR), net assimilation rate (NAR) and dry matter partitioning (DMP) one plant from each treatment was uprooted at the 3rd, 5th and 7th month after planting and immediately after harvest. During the vegetative phase the uprooted plants were separated into root, rhizome, pseudostem and leaves and their weights were recorded. After harvest, the uprooted plants were separated into root, rhizome, pseudostem, solid stem, leaves, peduncle and fruits and their weights were recorded. The bunches were separated into fingers and peduncle and their weights were recorded. These weights were then added to the total weight. Five hundred grams of each part was dried in hot air oven at 80°C until constant values are obtained, to

calculate the dry matter. Dry weight of senescent leaves and pruned suckers collected at different times were added to the total weight of the plant at harvest.

3.1.11 Number of days for shooting

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

3.1.12 Total crop duration

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

3.1.13 Number of suckers per plant

The time of emergence of suckers, the number of suckers at flowering and harvest, were recorded.

3.2 Yield characters

The following observations were noted.

3.2.1 Bunch weight at harvest

Bunches were weighed soon after harvest on a platform balance after cutting the top of peduncle at a distance of 30 cm from the first hand and apical tip pruned to 10 cm in all the treatments. The bunch weights were recorded in kilograms (kg).

3.2.2 Number of hands per bunch

3.2.3 Number of fingers in the D-hand and bunch

3.2.4. Length of the D-finger

The middle fruit in the top row of the second hand (Gottreich *et al.*, 1964) ie. the D-finger was used. Length was measured from the base of the finger, including the pedicel, along the outer curvature including the apex, using a twine and expressed in centimetre.

3.2.5 Girth of the D-finger

Girth was taken at the point of maximum thickness, using a twine. The corresponding length was obtained from a scale and expressed in centimetre.

3.2.6 Weight and volume of the D-finger

The weight of D-finger was taken on an electronic balance and expressed in grams. To find out the volume of the D-finger, it was immersed in a container full of water. The volume of water displaced was taken as the volume of the fruit.

3.2.7 Peel weight and pulp weight of fruits

The peel weight and pulp weight of the fully ripe fruits were recorded and expressed in grams. To calculate the pulp:peel ratio, the pulp weight was divided by the peel weight.

3.2.8 Colour of fruits

3.2.9 Shelf life of fruits

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

3.3 Qualitative fruit characters

Fully ripe D-finger from the bunches of each treatment were used for quality analysis. The middle fruit in the top row of the second hand was selected for quality analysis (Gottreich *et al.*, 1964). Samples were taken from top, middle and bottom portion of each fruit and these samples were then pooled and macerated in a waring blender.

3.3.1 Total soluble solids (TSS)

TSS was measured directly by using Erma refractometer (Pocket type) and expressed in degree brix.

3.3.2 Titratable acidity

Acidity was calculated by following the procedure proposed by A.O.A.C. (1980). Ten grams of the macerated sample was digested with boiling water and made upto 100 ml. An aliquot of the filtered solution was titrated against 0.1 N NaoH using phenolphthaleine as indicator. The results were expressed as per cent anhydrous citric acid.

3.3.3 Reducing sugars

Reducing sugars were estimated by Fehlings solution method (Lane and Eynon, 1943; A.O.A.C., 1980). To a known quantity of fruit juice, distilled water was added. After thorough mixing the solution was clarified with neutral lead acetate and potassium oxalate and made up to known volume. The solution was filtered and an aliquot of this solution was titrated against a mixture of Fehling's solution A and B using methylene blue as indicator. Reducing sugar was expressed in percentage.

3.3.4 Total sugars

The total sugars were determined as per the method described by A.O.A.C. (1980). This was expressed as percentage.

3.3.5 Non-reducing sugars

Non-reducing sugar content of the fruit samples were calculated using the formula,

Non-reducing sugar = (Total sugar - Reducing sugars)

3.3.6 Ascorbic acid

Ascorbic acid was estimated as per the method suggested by A.O.A.C. (1980). The results were expressed as mg per 100 g of fruit.

3.4 Other observations

3.4.1 Incidence of pests and diseases

The incidence of pests and diseases noted were recorded as and when they appeared.

3.4.2 Soil nutrient status

Soil samples were collected before planting and were analysed for available nitrogen, phosphorus and potassium following the method by Jackson (1973).

	R_1	R_2	R_3
Available N (kg/ha)	310.09	316.88	334.17
Available P (kg/ha)	25.34	14.08	19.71
Available K (kg/ha)	204.60	147.40	191.30

R_1, R_2 and R_3 are the 3 replications

3.4.3 Uptake of plant nutrients

To assess the nutrient uptake, plant samples were collected by uprooting the plants at the critical stages of growth and also at harvest. Sampling was done following the method of Twyford and Walmsley (1973). The plant parts used for analysis were root, rhizome, pseudostem, leaf, peduncle, peel and pulp of the freshly harvested plants. The samples were analysed for nitrogen, phosphorus, potassium, calcium and magnesium (Jackson, 1973).

3.4.4 Statistical analysis

The data collected on different characters were analysed by applying the technique of analysis of variance (ANOVA) for factorial RBD following Panse and Sukhatme (1978).

RESULTS

The results of the studies on "Physiology, growth pattern and flowering of tissue culture banana *Musa* (AAB) 'Nendran' " carried out at the Department of Pomology and Floriculture, College of Horticulture, Thrissur are presented here under. There was cent percentage field establishment for both, tissue culture and sucker progenies.

4.1 Vegetative characters

4.1.1 Height of the plant

The data presented in Table 1 revealed that tissue culture (28.04 cm) and sucker progenies (51.40 cm) differed significantly in plant height 45 days after planting. The data on mean height of plants at critical stages of growth are presented in Table 2.

During the third month after planting, tissue cultured plants recorded a height of 70.08 cm, which was on par with the height of 77.25 cm observed in sucker progenies. The effect due to fertilizer doses and method of application on height of plants did not differ significantly due to various treatments. Treatment $T_2M_2S_2$, recorded the highest height of 78.33 cm, which was 30 per cent more than the lowest value of 60.33 cm in $T_1M_2S_1$.

During the fifth month, the treatment effects showed significant differences. The mean values of plant height obtained for the two levels of planting material, fertilizer dose and method of application were found to be non-significant. $T_1M_1S_2$ recorded the highest value (155.00 cm) followed by $T_2M_1S_2$ and $T_1M_1S_1$, all three

Table 1. Biometric observations recorded 45 days after planting

Treatment	Plant height (cm)	Girth (cm)	Number of functional leaves	Leaf area of D-leaf (m^2)	Total leaf area (m^2)	Leaf area index
T_1	28.04	8.64	6.65	0.03	0.19	0.05
T_2	51.40	18.47	4.25	0.10	0.43	0.12
CD(0.05)	5.86	2.01	0.50	0.03	0.15	0.03
M_1	39.17	13.54	5.38	0.06	0.29	0.07
M_2	40.27	13.56	5.52	0.06	0.33	0.09
CD(0.05)	NS	NS	NS	NS	NS	NS
S_1	40.92	13.72	5.29	0.06	0.30	0.08
S_2	38.52	13.39	5.60	0.06	0.32	0.09
CD(0.05)	NS	NS	NS	NS	NS	NS
$T_1M_1S_1$	26.25	8.38	7.00	0.03	0.18	0.04
$T_1M_1S_2$	28.50	9.09	6.67	0.03	0.19	0.05
$T_1M_2S_1$	28.33	8.00	6.00	0.03	0.16	0.04
$T_1M_2S_2$	29.08	9.09	6.92	0.03	0.23	0.06
$T_2M_1S_1$	56.75	19.96	4.00	0.11	0.47	0.13
$T_2M_1S_2$	45.17	16.75	3.83	0.08	0.30	0.07
$T_2M_2S_1$	52.33	18.54	4.17	0.09	0.39	0.10
$T_2M_2S_2$	51.33	18.63	5.00	0.11	0.56	0.17
CD(0.05)	NS	NS	NS	NS	NS	0.06

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


P.G RESEARCH PROGRAMME
PHYSIOLOGY, GROWTH PATTERN AND FLOWERING OF
TISSUE CULTURE BANANA , MUSA (AAB)
NENDRAN
TREATMENTS - EIGHT - REPLICATION - THREE
PLANTING MATERIAL - T1 - TISSUE CULTURE PLANTS
T2 - SUCKERS
FERTILIZER DOSE -
METHOD OF APPLICATION -
NO. OF PLANTS/ PLOT - 20
TOTAL NO. OF PLANTS - 480
DESIGN - FACTORIAL RBD
LAY OUT & PLANTING - 27-6-99
R5
T1M2S1

being on par. The mean height of $T_1M_1S_2$ (155.00 cm) was 30 per cent more than the lowest height of 119.33 cm recorded in $T_2M_1S_1$.

Tissue cultured plants (T_1), lower level of fertilizer (M_1) and two split application (S_1) resulted in maximum plant height over the other level (312.50, 305.50 and 310.17 cm respectively) during the seventh month. Plant height was significantly influenced by the method of application, S_1 being more superior. The interaction effect of different treatments revealed that all treatments were on par. Plant height ranged from 292.67 cm in $T_2M_1S_2$ to 319.00 cm in $T_1M_1S_1$.

At flowering stage, tissue culture plants showed significant superiority (329.97 cm) over the sucker-derived ones (314.05 cm). But fertilizer doses and methods of application showed no significant difference in the character under consideration. At flowering stage, the maximum mean plant height was recorded in $T_1M_2S_2$ (337.08 cm) which was 10 per cent more than the lowest value of 308.14 cm in $T_2M_1S_2$. After bunch emergence there was no increase in plant height, in all the treatments.

4.1.2 Girth of the plant

The mean girth of plants at five critical stages of growth are presented in Table 2. The analysis of the data showed no significant difference in the girth of plants during the critical stages of growth. However, the sucker progenies (18.47 cm) showed significant superiority in girth over the tissue culture plants (8.64 cm) 45 days after planting (Table 1). The sucker propagated plants had more pseudostem circumference till fifth month whereas the girth was more for the tissue culture plants from the seventh month onwards.

Table 2. Effect of treatments on height and girth of plants at critical stages of growth

Treatment	Plant height (cm)				Girth (cm)			
	3 MAP	5MAP	7 MAP	Flowering	3 MAP	5 MAP	7 MAP	Flowering
T_1	70.08	143.83	312.50	329.97	20.75	40.75	56.17	57.98
T_2	77.25	142.92	291.17	314.05	25.75	42.75	52.00	53.88
CD(0.05)	NS	NS	14.08	9.21	3.03	NS	2.41	1.39
M_1	76.58	145.83	305.50	322.14	23.92	42.08	54.25	55.21
M_2	70.75	140.92	298.17	321.88	22.58	41.42	53.92	56.65
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
S_1	71.58	138.58	310.17	323.20	22.00	41.50	55.25	56.27
S_2	75.75	148.17	293.50	320.82	24.50	42.00	52.92	55.58
CD(0.05)	NS	NS	14.08	NS	NS	NS	NS	NS
$T_1M_1S_1$	76.67	154.33	319.00	335.88	21.33	40.67	58.67	58.58
$T_1M_1S_2$	75.33	155.00	302.67	329.17	22.67	41.00	51.67	56.78
$T_1M_2S_1$	60.33	127.67	317.33	317.78	17.67	41.00	56.67	57.42
$T_1M_2S_2$	68.00	138.33	311.00	337.08	21.33	40.33	57.67	59.14
$T_2M_1S_1$	73.00	119.33	307.67	315.42	24.00	42.33	54.67	53.58
$T_2M_1S_2$	81.33	154.67	292.67	308.14	27.67	44.33	52.00	51.89
$T_2M_2S_1$	76.33	153.00	296.67	323.75	25.00	42.00	51.00	55.50
$T_2M_2S_2$	78.33	144.67	297.67	308.89	26.33	42.33	50.33	54.33
CD(0.05)	NS	25.80	NS	NS	NS	NS	NS	NS

During the third month, sucker derived plants showed significant superiority (25.75 cm) over tissue culture plants (20.75 cm). Lower level of fertilizer (M_1) and six split application (S_2) resulted in plants with maximum girth at 10 cm above ground level (23.92 and 24.50 cm). The plant girth was maximum for $T_2M_1S_2$ treatment plants (27.67 cm) as against the least girth recorded in $T_1M_2S_1$ (17.67 cm).

During the fifth month, planting materials T_2 (suckers), M_1 level of fertilizer and six split application (S_2) recorded 42.75, 42.08 and 42.00 cm respectively and they recorded higher values over the other level T_1, M_2 and S_1. The interaction effect showed that all the eight treatments were on par, but the maximum girth was recorded in $T_2M_1S_2$ (44.33 cm). $T_1M_2S_2$ recorded the lowest value of 40.33cm for plant girth.

During the seventh month and flowering stage, tissue cultured plants showed significant superiority (56.17 and 57.98 cm respectively). The influence due to different levels of fertilizers and method of application were not statistically significant with respect to plant girth at both the stages. During the seventh month, $T_1M_1S_1$ recorded the highest value (58.67 cm) but at flowering stage, the highest value recorded was 59.14 cm in $T_1M_2S_2$ which was 14 per cent more than the lowest value of 51.89 cm in $T_2M_1S_2$.

4.1.3 Number of functional leaves

Data on the number of functional leaves produced by plants in different treatments are furnished in Table 3.

Table 3. Effect of treatments on leaf characters during different stages of growth

Treatment	Number of functional leaves				Phyllochrone (days)				Total No. of leaves
	3 MAP	5 MAP	7 MAP	Flowering	3 MAP	5 MAP	7 MAP	Flowering	
T_1	7.42	12.17	13.75	13.69	5.16	6.21	7.37	6.96	38.63
T_2	7.50	11.50	12.67	12.35	5.89	6.85	7.28	7.06	31.44
CD(0.05)	NS	NS	0.76	1.02	0.43	0.26	NS	NS	0.82
M_1	7.42	11.92	13.17	12.73	5.29	6.42	7.31	6.86	34.88
M_2	7.50	11.75	13.25	13.31	5.76	6.63	7.34	7.15	35.19
CD(0.05)	NS	NS	NS	NS	0.43	NS	NS	0.22	NS
S_1	7.17	11.50	13.50	13.02	5.79	6.61	7.27	6.95	35.13
S_2	7.75	12.17	12.92	13.02	5.25	6.45	7.38	7.06	34.94
CD(0.05)	NS	NS	NS	NS	0.43	NS	NS	NS	NS
$T_1M_1S_1$	7.33	12.00	14.00	13.67	5.04	5.82	7.31	6.64	38.33
$T_1M_1S_2$	7.00	12.33	13.67	12.92	4.73	6.00	7.31	6.77	38.17
$T_1M_2S_1$	7.33	12.00	14.33	13.67	5.92	6.97	7.07	7.11	39.00
$T_1M_2S_2$	8.00	12.33	13.00	14.50	4.93	6.04	7.79	7.31	39.00
$T_2M_1S_1$	7.33	11.00	12.33	12.00	5.54	6.88	7.31	6.77	31.17
$T_2M_1S_2$	8.00	12.33	12.67	12.33	5.83	7.00	7.31	7.26	31.83
$T_2M_2S_1$	6.67	11.00	13.33	12.75	6.67	6.75	7.39	7.28	32.00
$T_2M_2S_2$	8.00	11.67	12.33	12.33	5.51	6.75	7.09	6.91	30.75
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	0.43	NS

Tissue culture plants had 6.65 leaves 45 days after planting whereas the suckers had only 4.25, which was significantly different as evident from Table 1. The data revealed that the number of functional leaves were more for tissue culture plants during fifth month, seventh month and at flowering stage (12.17, 13.75 and 13.69 respectively) as compared to 11.50, 12.67 and 12.35 leaves respectively in sucker progenies. During the third month, sucker progenies had more functional leaves (7.50) than tissue culture plants (7.42). The different fertilizers doses and method of application did not significantly influence the number of functional leaves per plant. During third month the number of functional leaves was highest in $T_1M_2S_2$ (8.00) whereas during the fifth month, this was highest in $T_2M_1S_2$ (12.33). The tissue cultured plants had 14.5 leaves at flowering which was 20.83 per cent more than the lowest recorded value of 12.00 in treatment $T_2M_1S_1$. In the treatments with sucker derived plants, the number of functional leaves was almost the same.

From the above inferences, it was clear that the treatments imposed did not show any significant influence in the number of functional leaves per plant.

4.1.4 Total number of leaves produced

The total number of leaves (Table 3) produced was highest in tissue culture plants (38.63) as against 31.44 produced by sucker derived plants. Higher level of fertilizer (M_2) produced 35.19 leaves whereas lower level of method of application (S_1) produced 34.94 leaves. The interaction effect showed that number of leaves produced did not differ significantly in the various treatments. Treatments $T_1M_2S_1$ and $T_1M_2S_2$ recorded higher mean values (39.0) for total number of leaves, which was 27 per cent more than the lowest value of 30.75 in $T_2M_2S_2$.

4.1.5 Phyllochrone

A perusal of data presented in Table 3 revealed that the tissue culture plants had shorter time interval between the initiation of two successive leaves at all stages of growth.

The data showed that suckers took 5.9 days, higher level of fertilizer took 5.8 days and application of fertilizers in two splits (S_1) 5.8 days for the production of next leaf during the third month and all the three varied significantly over the other levels. During the third month, $T_2M_2S_1$ recorded a phyllochrone of 6.7 days whereas leaf production was fastest in $T_1M_1S_2$ which took only 4.7 days and all the treatments were on par.

During the fifth month, planting material T_1 (6.2) differed significantly from T_2 (6.8) whereas fertilizer dose and method of application did not influence significantly the character under study. Treatment $T_2M_1S_2$ recorded a mean value of 7.0 for phyllochrone while the lowest was observed in $T_1M_1S_1$ (5.8 days) and all the treatments were on par.

The statistical analysis of data showed that during the seventh month all the treatment effects were on par and the values ranged from 7.0 to 7.8.

At flowering stage, the treatments showed significant variation, the highest value being observed in $T_1M_2S_2$ (7.3) and lowest in $T_1M_1S_1$ (6.6). $T_1M_1S_1$, $T_1M_1S_2$, $T_2M_1S_1$ and $T_2M_2S_2$ were on par but differed significantly from $T_1M_2S_1$, $T_1M_2S_2$, $T_2M_1S_2$ and $T_2M_2S_1$ which were also on par. At flowering stage, tissue culture plants

(T_1), M_1 level of fertilizer and S_1 of method of application produced leaves at shorter intervals.

4.1.6 Leaf area of D-leaf

The sucker progenies had significantly larger values for leaf area 45 days after planting as depicted in Table 1. The data (Table 4) revealed that sucker derived progenies, lower level of fertilizer (M_1) and six split application (S_2) recorded higher values of 0.18, 0.16, 0.18 m^2 respectively for leaf area of third month, though not statistically significant. All the treatments were on par but $T_2M_2S_2$ recorded the highest value of 0.20 m^2 and $T_1M_2S_1$ the lowest of 0.10 m^2.

During the fifth month, all treatments except $T_1M_2S_1$ and $T_2M_1S_2$ were on par. $T_2M_1S_2$ was significantly superior over the others, recorded a leaf area of 0.76 m^2 which was 65 per cent more than the lowest of 0.46 m^2 obtained in $T_1M_2S_1$. Planting material, fertilizer dose and method of application did not influence significantly the leaf area of D-leaf however higher values were observed in T_2, M_1 and S_2.

The planting materials and fertilizer doses did not influence significantly the leaf area whereas leaf area was more (0.87 m^2) when fertilizers were applied in six splits. During the seventh month, all the treatments were statistically on par and the mean leaf area was highest for $T_2M_1S_1$ (0.95 m^2).

The effects due to planting material, fertilizer doses and method of application did not differ significantly with respect to leaf area of D leaf at flowering stage. The treatments T_1, M_2 and S_1 recorded higher values of 1.20 m^2 each. The effect due to treatment combinations differed significantly. Highest value of 1.31 m^2 in

Table 4. Effect of treatments on leaf area of plants

Treatment	Leaf area (D-leaf) m²				Total leaf area (m²)			
	3 MAP	5MAP	7 MAP	Flowering	3 MAP	5 MAP	7 MAP	Flowering
T_1	0.14	0.56	0.84	1.20	1.02	7.85	12.46	16.54
T_2	0.18	0.64	0.85	1.15	1.34	8.24	11.32	14.40
CD(0.05)	NS	NS	NS	NS	NS	NS	0.87	1.57
M_1	0.16	0.64	0.84	1.15	1.20	8.57	11.44	14.85
M_2	0.16	0.57	0.84	1.20	1.16	7.52	12.34	16.09
CD(0.05)	NS	NS	NS	NS	NS	1.26	0.87	NS
S_1	0.14	0.58	0.87	1.20	1.00	7.92	11.99	15.79
S_2	0.18	0.63	0.81	1.15	1.36	8.17	11.79	15.16
CD(0.05)	NS	NS	0.04	NS	0.35	NS	NS	NS
$T_1M_1S_1$	0.15	0.62	0.86	1.27	1.15	9.68	11.27	17.37
$T_1M_1S_2$	0.16	0.56	0.71	1.14	1.11	7.05	11.03	15.30
$T_1M_2S_1$	0.10	0.46	0.87	1.17	0.71	7.23	13.81	15.87
$T_1M_2S_2$	0.14	0.60	0.90	1.22	1.11	7.45	13.74	17.62
$T_2M_1S_1$	0.13	0.60	0.95	1.06	0.98	7.94	11.81	12.76
$T_2M_1S_2$	0.20	0.76	0.85	1.13	1.58	9.60	11.63	13.98
$T_2M_2S_1$	0.18	0.62	0.81	1.31	1.17	6.84	11.07	17.13
$T_2M_2S_2$	0.20	0.58	0.78	1.11	1.63	8.57	10.76	13.74
CD(0.05)	NS	0.15	NS	0.19	NS	NS	NS	3.30

$T_2M_2S_1$ was 23.4 per cent more than the lowest value of 1.06 m^2 in $T_2M_1S_1$. All treatments except $T_1M_1S_1$ (1.27 m^2) and $T_2M_2S_1$ (1.31 m^2) were on par.

4.1.7 Total leaf area

Total leaf area was more for sucker progenies (0.43 m^2) than tissue culture plants (0.19 m^2) 45 days after planting (Table 1). Data on total leaf area during the critical stages of plant growth are presented in Table 4.

During the third month, planting materials T_2 and M_1 level of fertilizer recorded higher values of 1.34 and 1.20 m^2 respectively for total leaf area but the effect was not significant. Six split application (S_2) resulted in higher values for leaf area (1.36 m^2) than S_1 (1.0 m^2). The treatment combinations did not differ significantly. $T_2M_2S_2$ recorded the highest value of 1.63 m^2 and $T_1M_2S_1$ the lowest (0.71 m^2).

Tissue cultured and sucker derived plants did not differ significantly in total leaf area during fifth month. M_1 level of fertilizer recorded higher value of 8.57 m^2 which was significantly superior over M_2 (7.52 m^2). Application of fertilizers in two and six splits did not influence the total leaf area significantly. All the treatments were statistically on par. Highest value of 9.68 m^2 observed in $T_1M_1S_1$ was 41 per cent more than the lowest value of 6.84 m^2 in $T_2M_2S_1$.

The total leaf area at seventh month differed significantly with the planting material and doses of fertilizer. Tissue cultured plants recorded total leaf area of 12.46 m^2 whereas higher level of fertilizer dose (M_2) recorded total leaf area of 12.34 m^2. Though application of fertilizers in two splits (S_1) recorded higher mean value for total leaf area (11.99 m^2), it did not differ significantly from S_2 which had a leaf area of

11.79 m^2. The treatment combinations did not differ significantly. Higher leaf area of 13.81 m^2 in $T_1M_2S_1$ was 28 per cent more than the lowest value of 10.76 m^2 in $T_2M_2S_2$.

Total leaf area was profoundly influenced by the treatments at flowering stage. Treatment $T_1M_2S_2$ recorded the highest value (17.62 m^2) which was 38 per cent more than the lowest value of 12.76 m^2 recorded in $T_2M_1S_1$. Tissue cultured plants (16.54 m^2) recorded significant superiority over the sucker progenies (14.40 m^2) in total leaf area. Fertilizer dose M_2 and method of application (S_1) recorded values of 16.09 and 15.79 m^2 respectively for total leaf area which was higher than the other levels.

4.2 Physiological characters

The data on leaf area index (LAI) and leaf area duration (LAD) are presented in Table 5.

4.2.1 Leaf area index (LAI)

Sucker derived plants had higher values for LAI 45 days after planting and during the third and fifth month (0.12, 0.34 and 2.06 respectively). But at seventh month and at flowering stage tissue cultured plants showed significant superiority over the sucker propagated ones. Lower level of fertilizer (M_1) resulted in higher LAI of 0.30 and 2.14 during third and fifth month respectively whereas M_2 recorded higher values of 3.09 and 4.02 for LAI during seventh month and at flowering. Method of application did not influence the LAI significantly during the critical stages except in the third month. Till fifth month S_2 recorded higher values and after that S_1.

Table 5. Leaf area index (LAI) and leaf area duration (LAD) at critical stages of plant growth

Treatment	Leaf area index				* Leaf area duration (days)			
	3 MAP	5MAP	7 MAP	Flowering	3 MAP	5 MAP	7 MAP	Flowering
T_1	0.26	1.96	3.12	4.13	6.76	66.53	152.52	217.68
T_2	0.34	2.06	2.83	3.60	10.14	71.84	146.67	192.21
CD(0.05)	NS	NS	0.21	0.39	2.12	NS	NS	13.38
M_1	0.30	2.14	2.86	3.71	8.36	73.29	150.03	197.17
M_2	0.29	1.88	3.09	4.02	8.54	65.08	149.16	212.72
CD(0.05)	NS	0.19	0.21	NS	NS	6.81	NS	13.38
S_1	0.25	1.98	3.00	3.95	7.32	66.92	149.36	208.74
S_2	0.34	2.04	2.95	3.79	9.59	71.45	149.83	201.55
CD(0.05)	0.086	NS	NS	NS	2.12	NS	NS	NS
$T_1M_1S_1$	0.29	2.42	2.82	4.34	7.29	81.17	157.09	214.82
$T_1M_1S_2$	0.28	1.76	2.76	3.82	7.35	61.24	135.64	197.46
$T_1M_2S_1$	0.18	1.81	3.46	3.97	4.86	59.54	147.93	222.73
$T_1M_2S_2$	0.28	1.86	3.45	4.41	7.54	64.18	159.45	235.71
$T_2M_1S_1$	0.24	1.99	2.95	3.19	8.40	66.87	148.13	184.30
$T_2M_1S_2$	0.40	2.40	2.91	3.50	10.40	83.89	159.28	192.11
$T_2M_2S_1$	0.29	1.71	2.77	4.28	8.72	60.10	134.31	211.49
$T_2M_2S_2$	0.41	2.14	2.69	3.43	13.06	76.50	144.95	180.92
CD(0.05)	NS	NS	NS	0.79	NS	NS	NS	26.75

* For computing LAD of 3rd month $t_2 - t_1$ is 45 days and for all other stages $t_2 - t_1$ is 60 days

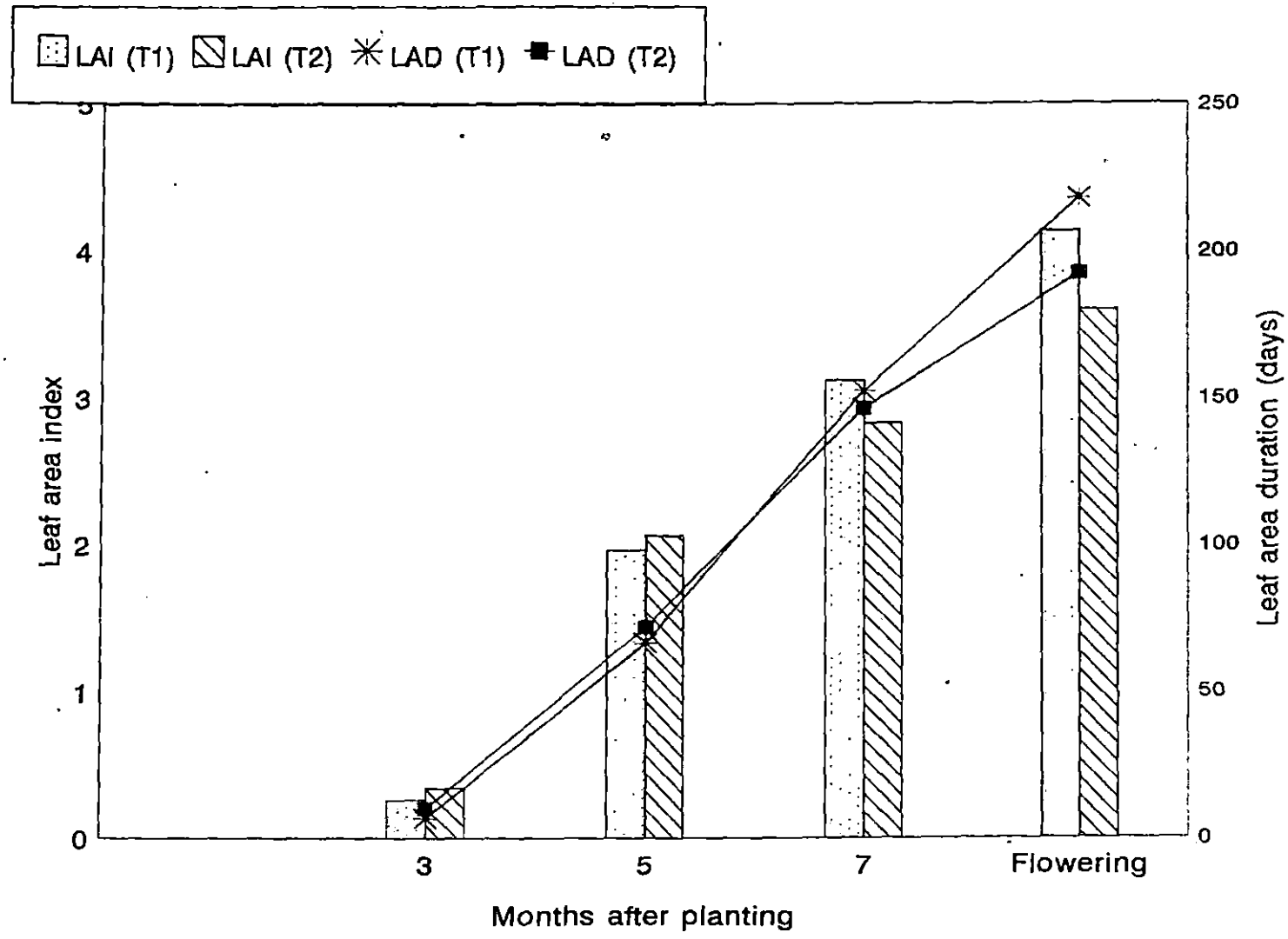


Fig.1. Effect of planting material on leaf area index (LAI) and leaf area duration (LAD) at critical stages of plant growth

The interaction effect showed that the treatments effects did not differ significantly in the LAI during third, fifth and seventh month. During third month, highest value was 0.41 in $T_2M_2S_2$ and lowest was 0.18 in $T_1M_2S_1$. The values for LAI ranged from 1.71-2.42 and 2.69-3.46 during the fifth and seventh month respectively. At flowering stage, $T_1M_2S_2$ recorded LAI of 4.41 which was the highest which was on par with $T_1M_1S_1$. Treatments $T_1m_1S_2$, $T_1M_2S_1$, $T_2M_1S_1$, $T_2M_1S_2$ and $T_2M_2S_2$ were on par.

4.2.2 Leaf area duration (LAD)

The leaf area duration was tabulated using standard formula and the data are furnished in Table 5.

During the third and fifth months after planting sucker derived plants recorded values of 10.14 and 71.84 days for LAD which was more than tissue culture plants. Fertilizer dose M_2 and method of application S_2 recorded higher values of 8.54 and 9.59 days respectively. All the treatments were on par when statistically analysed, highest value of 13.06 was in $T_2M_2S_2$ and lowest in $T_1M_2S_1$ (4.86 days). During fifth month, all the treatments were on par, but highest value observed in $T_2M_1S_2$ (83.89) was 41 per cent more than the lowest value of 59.54 days in $T_1M_2S_1$.

The difference in LAD due to difference in planting material, fertilizer doses and method of application was not statistically significant. Tissue culture plants recorded a value of 152.52 whereas suckers recorded LAD of 146.67 days. Highest value noticed in $T_1M_2S_2$ (159.45) was 18.7 per cent more than the lowest value of 134.31 days in $T_2M_2S_1$ and all the eight treatments were on par.

At flowering stage, planting material T_1 and fertilizer dose M_2 showed significant superiority as evident from Table 5. T_1 recorded LAD of 217.68 days and T_2 192.21 days. The difference due to method of application in LAD was not significant. The interaction effect due to treatments showed that the LAD for all treatments differed significantly. $T_1M_2S_2$ had the highest LAD of 235.71 which was 30.3 per cent more than the lowest value of 180.92 days in $T_2M_2S_2$. Treatments $T_1M_1S_2$, $T_2M_1S_1$, $T_2M_1S_2$ and $T_2M_2S_2$ were on par.

4.2.3 Crop Growth Rate (CGR)

The data (Table 6) presented revealed that crop growth rate (CGR) was influenced significantly by the different treatments during the third, fifth and seventh month. CGR was significantly influenced by planting material, fertilizer dose and methods of application at all stages of growth.

During the third and fifth month sucker progenies recorded higher values for CGR (0.34 and 4.47 g/m²/day respectively). During seventh month, CGR of tissue plants was 8.62 whereas that of sucker plants was 5.67 g/m²/day. Lower level of fertilizer (M_1) resulted in higher values for CGR during third, fifth and seventh month (0.36, 4.52 and 8.44 g/m²/day respectively. But at flowering, CGR of M_2 was 5.99 and that of M_1 was 2.82 g/m²/day. Method of application significantly influenced CGR at all stages with exception to that of seventh month. CGR was highest in S_1 (7.11) and S_2 (7.17 g/m²/day) during seventh month.

During third month, highest value observed in $T_2M_2S_2$ (0.34) was on par with $T_1M_1S_1$, $T_1M_1S_2$ and $T_1M_2S_2$. Lowest was in $T_2M_1S_1$ (0.08 g/m²/day). $T_2M_1S_2$ which recorded a CGR of 5.45 was the highest during fifth month was on par with

Table 6. Effect of treatments on physiological characters (CGR and NAR) at different stages of growth

Treatment	* Crop growth rate (g/m²/day)				* Net assimilation rate (g/m²/day)			
	3 MAP	5MAP	7 MAP	Flowering	3 MAP	5 MAP	7 MAP	Flowering
T_1	0.29	4.07	8.62	4.74	2.25	5.30	3.64	1.24
T_2	0.34	4.47	5.66	4.08	1.70	4.64	2.39	1.30
CD(0.05)	0.03	0.28	0.16	0.39	0.15	0.21	0.12	NS
M_1	0.36	4.52	8.44	2.82	2.32	5.12	3.62	0.85
M_2	0.27	4.02	5.85	5.99	1.63	4.83	2.40	1.69
CD(0.05)	0.03	0.28	0.16	0.39	0.15	0.21	0.12	0.13
S_1	0.22	4.46	7.11	5.95	1.55	5.78	2.93	1.73
S_2	0.41	4.09	7.17	2.86	2.40	4.16	3.10	0.81
CD(0.05)	0.03	0.28	NS	0.39	0.15	0.21	0.12	0.13
$T_1M_1S_1$	0.35	3.48	9.70	5.35	2.93	4.47	3.81	1.52
$T_1M_1S_2$	0.33	4.57	11.59	0.38	2.43	5.89	5.63	0.09
$T_1M_2S_1$	0.16	5.21	4.92	8.74	1.28	7.39	2.00	2.35
$T_1M_2S_2$	0.32	3.05	8.27	4.48	2.35	3.48	3.10	1.01
$T_2M_1S_1$	0.08	4.61	9.26	3.58	0.45	5.59	3.74	1.16
$T_2M_1S_2$	0.66	5.45	3.20	1.99	3.49	4.54	1.31	0.63
$T_2M_2S_1$	0.28	4.55	4.57	6.14	1.56	5.69	2.15	1.89
$T_2M_2S_2$	0.34	3.26	5.63	4.60	1.32	2.73	2.35	1.51
CD(0.05)	0.05	0.57	0.32	NS	0.30	0.42	0.25	NS

* For computing CGR and NAR of 3rd month $t_2 - t_1$ is 45 days and for all other stages $t_2 - t_1$ is 60 days

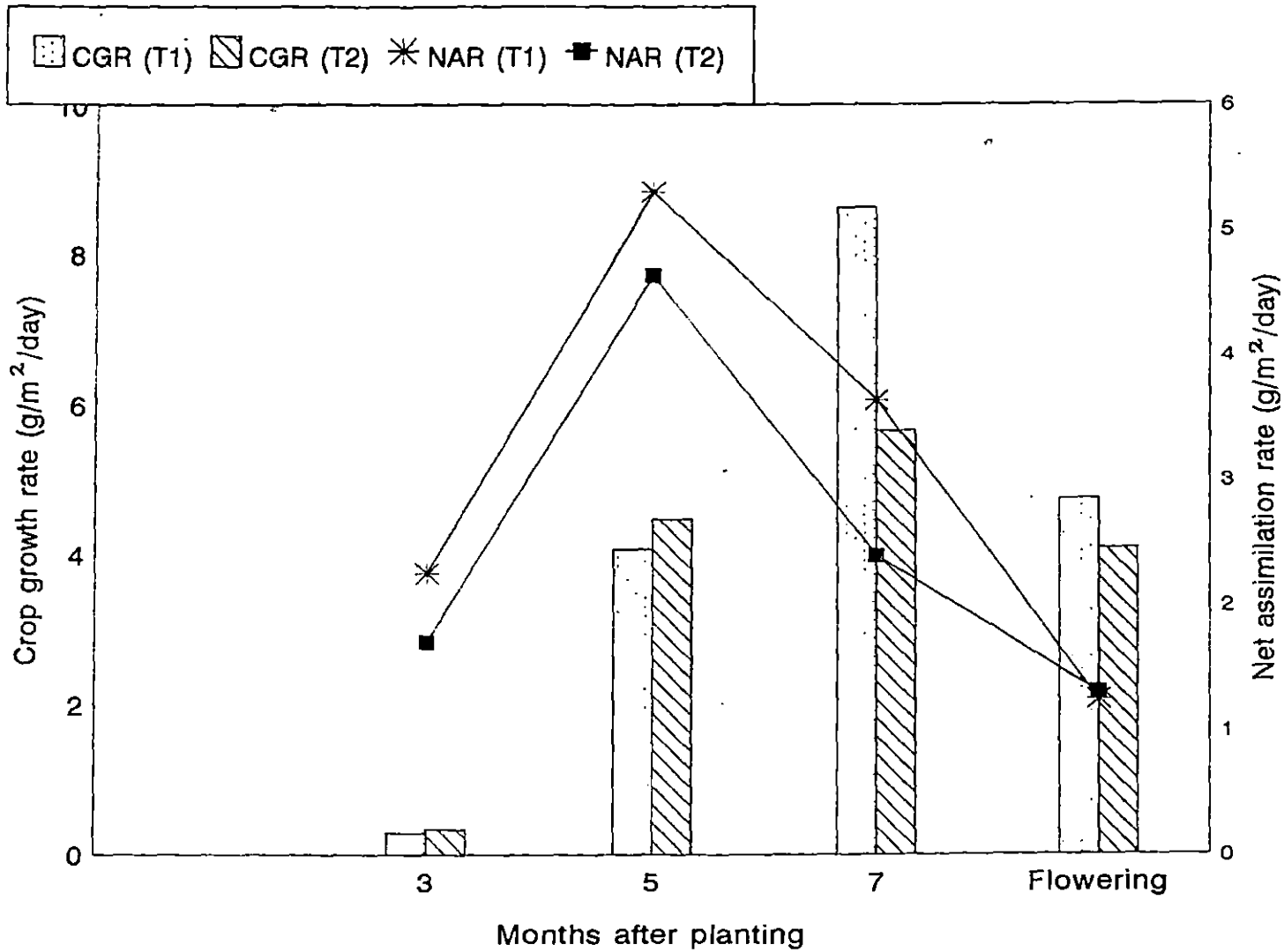


Fig.2. Effect of planting material on crop growth rate (CGR) and net assimilation rate (NAR) at critical stages of plant growth

$T_1M_2S_1$ (5.21 g/m²/day). Lowest value was noticed in treatment $T_1M_2S_2$ (3.05) and $T_1M_2S_2$ was on par with $T_1M_1S_1$ and $T_2M_2S_2$. During the seventh month $T_1M_1S_2$ recorded the highest value (11.59) and this was 26.3 per cent more than the lowest value of 3.2 g/m²/day observed in $T_2M_1S_2$. At flowering stage, the differences between treatment means were non-significant. Crop growth rate of 8.74 g/m²/day was observed in $T_1M_2S_1$ and the least value was obtained in $T_1M_1S_2$ (0.38).

4.2.4 Net Assimilation Rate (NAR)

From the data furnished in Table 6 it could be inferred that net assimilation rate (NAR) was influenced significantly by the different treatments at all critical stages of growth except at flowering stage.

NAR showed significant differences at all critical stages of growth. Tissue culture plants which were significantly superior over suckers recorded NAR of 2.25, 5.30 and 3.64 g/m²/day during third, fifth and seventh month. But at flowering stage, NAR had higher values in sucker propagated ones (1.30 g/m²/day). Similarly fertilizer dose M_1 manifested significant superiority in NAR during the first three stages whereas at flowering M_2 level was significantly superior. Two split application (S_1) resulted in higher values of NAR during fifth month and at flowering.

Data in Table 6 revealed that treatment $T_2M_1S_2$ recorded the highest value (3.49) for NAR whereas the lowest was in $T_2M_1S_1$ (0.45 g/m²/day) during the third month. At fifth month, values for NAR ranged from 2.73-5.89 g/m²/day and the highest was recorded in $T_1M_1S_2$. During seventh month $T_1M_1S_2$ recorded highest mean value (5.63), followed by $T_1M_1S_1$ (3.81) and $T_2M_1S_1$ (3.74). NAR was lowest in $T_2M_1S_2$

(1.31). At flowering stage, NAR was highest in $T_1M_2S_1$ (2.35) and least in $T_1M_1S_2$ (0.09 g/m²/day). At this stage all the treatments were on par.

4.2.5 Dry matter partitioning

The data on dry matter partitioning during critical stages of growth and at harvest are presented in Tables 7-9.

During the third month, dry weight of root, rhizome, pseudostem leaf and whole plant did not show significant variation due to treatments. Dry weight of root, rhizome, pseudostem and leaf ranged from 6.4-11.88, 5.61-129.87, 16.6-39.9 and 27.9-76.0 g per plant. Total plant dry weight was highest in $T_2M_2S_2$ (234.3) and lowest in $T_1M_2S_1$ (58.45 g).

Sucker derived plants recorded higher values for dry weight of diferent plant parts than the tissue culture plants during third month. M_1 level of fertilizer recorded higher dry matter content in different plant parts with exception to that of rhizome. Method of app lication also did not affect significantly the dry matter content but six split application recorded higher dry matter content in all parts except root.

During the fifth month, total dry matter production was highest in $T_2M_1S_2$ (1357.5 g) and lowest in $T_1M_2S_1$ (799.9 g), the former being 70 per cent more than the latter. Dry weight of root and leaves showed significant variation. Dry matter partitioning to the root was highest in $T_1M_2S_2$ (6.75%), to the rhizome this was highest in $T_2M_1S_1$ (33.22%) whereas to the pseudostem and leaves were highest in $T_2M_1S_1$ (30.24%) and $T_1M_1S_2$ (44.2%) respectively. Among the different plant parts, dry weight was highest for leaves and that too in treatment $T_2M_2S_1$ (487.5 g).

Table 7. Influence of treatments on dry matter partitioning (DMP) at third and fifth month after planting

Treatment	3 months after planting					5 months after planting				
	Root (g)	Rhizome (g)	Pseudostem (g)	Leaves (g)	Total (g)	Root (g)	Rhizome (g)	Pseudostem (g)	Leaves (g)	Total (g)
T_1	7.40(2.72)*	10.60(3.26)	23.70 (4.87)	37.99(6.16)	80.95(8.99)	49.86	241.79	234.68	367.17	893.50
T_2	9.67(3.11)	107.39(10.36)	36.52(6.04)	65.63(8.10)	215.53(14.68)	51.94	303.78	281.59	382.26	1027.93
CD(0.05)	NS	2.33	1.12	NS	NS	NS	NS	NS	NS	NS
M_1	8.54(2.92)	43.90(6.63)	29.82(5.46)	53.55(7.32)	141.02(11.88)	58.56	286.26	286.75	396.82	1036.72
M_2	8.44(2.91)	48.90(6.99)	29.70(5.45)	48.26(6.95)	139.29(11.80)	43.24	259.32	229.53	352.61	884.71
CD(0.05)	NS	NS	NS	NS	NS	14.56	NS	NS	NS	NS
S_1	8.93(2.99)	45.20(6.72)	26.42(5.14)	46.40(6.81)	129.87(11.40)	43.48	276.40	246.19	366.27	932.33
S_2	8.07(2.84)	47.55(6.90)	33.32(5.77)	55.55(7.45)	150.85(12.82)	58.31	269.17	270.09	283.17	989.10
CD(0.05)	NS	NS	NS	NS	NS	14.56	NS	NS	NS	NS
$T_1M_1S_1$	8.04(2.84)	10.25(3.28)	23.53(4.85)	39.80(6.31)	82.72(9.10)	53.32	278.52	250.39	402.13	984.36
$T_1M_1S_2$	7.69(2.77)	15.98(4.06)	27.64(5.26)	47.40(6.89)	99.54(9.98)	53.63	203.50	293.19	434.83	985.15
$T_1M_2S_1$	6.41(2.53)	5.61(2.47)	16.57(4.07)	27.88(5.28)	58.45(7.65)	38.18	250.78	198.45	312.48	799.89
$T_1M_2S_2$	7.54(2.75)	9.84(3.22)	28.03(5.29)	38.22(6.18)	85.93(9.27)	54.31	234.37	196.70	319.24	804.62
$T_2M_1S_1$	11.88(3.45)	94.04(9.72)	30.46(5.52)	54.23(7.36)	191.96(13.86)	36.71	272.34	247.93	262.93	819.91
$T_2M_1S_2$	6.96(2.64)	88.67(9.44)	38.66(6.22)	75.95(8.72)	212.37(14.57)	90.58	390.67	355.48	487.40	1357.46
$T_2M_2S_1$	9.85(3.14)	129.87(11.42)	37.43(6.12)	68.82(8.30)	224.64(14.99)	45.73	303.95	287.98	487.52	1125.18
$T_2M_2S_2$	10.28(3.21)	117.57(10.87)	39.92(6.32)	64.50(8.03)	234.30(15.31)	34.74	248.16	234.98	291.20	809.16
CD(0.05)	NS	NS	NS	NS	NS	29.12	NS	NS	189.94	NS

* Values in parentheses indicate square root transformed data

Table 8. Effect of treatments on dry matter partitioning at seventh month and at flowering

Treatment	Seventh month					Flowering					
	Root (g)	Rhizome (g)	Pseudostem (g)	Leaf (g)	Total (g)	Root (g)	Rhizome (g)	Pseudostem (g)	Leaf (g)	Flower buds (g)	Total (g)
T_1	117.42	636.10	884.87	1007.16	2650.88	183.87	820.60	1237.21	1280.79	79.01	3576.81
T_2	93.70	466.75	709.03	858.95	2128.39	114.50	629.22	899.35	1103.88	92.08	2837.58
CD(0.05)	12.60	42.89	63.05	53.11	46.90	19.59	62.55	47.50	26.81	NS	46.41
M_1	105.90	637.15	885.89	1047.24	2681.18	145.98	769.85	1052.28	1195.05	93.80	3230.48
M_2	105.23	465.69	708.00	818.87	2098.08	152.39	679.97	1084.28	1189.61	77.29	3183.90
CD(0.05)	NS	42.89	63.05	53.11	46.90	NS	62.55	NS	NS	15.89	46.41
S_1	101.24	466.84	869.14	972.30	2414.57	151.30	677.64	1274.83	1364.27	83.78	3527.17
S_2	109.89	636.00	724.75	893.80	2364.70	147.07	772.17	861.73	1020.40	87.32	2887.21
CD(0.05)	NS	42.89	63.05	53.11	46.90	NS	62.55	47.50	26.81	NS	46.41
$T_1M_1S_1$	87.82	573.73	1089.60	1121.85	2893.01	129.74	760.57	1401.95	1478.55	119.30	3790.11
$T_1M_1S_2$	147.07	875.64	967.94	1176.86	3167.52	188.37	873.24	1046.27	1055.84	81.07	3244.78
$T_1M_2S_1$	118.43	367.92	738.26	811.30	2035.90	250.90	654.72	1523.93	1411.85	29.36	3872.09
$T_1M_2S_2$	116.38	727.10	743.66	918.61	2507.08	166.47	993.85	976.69	1176.91	86.32	3400.24
$T_2M_1S_1$	86.62	576.46	849.69	1154.70	2667.48	118.70	854.50	1045.09	1416.04	89.02	3523.44
$T_2M_1S_2$	102.08	522.78	636.32	735.54	1196.73	147.11	591.09	715.83	829.77	85.81	2363.60
$T_2M_2S_1$	112.07	349.27	799.00	801.36	2061.87	105.88	440.76	1128.36	1150.63	97.42	2923.05
$T_2M_2S_2$	74.04	418.49	551.09	744.20	1787.49	86.32	630.52	708.13	1019.06	96.07	2540.21
CD(0.05)	NS	NS	NS	106.22	93.83	39.17	125.10	NS	53.63	31.78	92.83

Plate 2. Effect of treatments on root distribution pattern seven months after planting

Plate 2a. $T_1M_1S_1$ vs $T_2M_1S_1$

Plate 2b. $T_1M_2S_1$ vs $T_2M_2S_1$


T, M, S,
T, M, S,
7 M.A.P.


7 M.A.P.
T, M, S.
T, M, S.

Plate 2. Effect of treatments on root distribution pattern seven months after planting

Plate 2c. $T_1M_1S_2$ vs $T_2M_1S_2$

Plate 2d. $T_1M_2S_2$ vs $T_2M_2S_2$


T, M, S,
T, M, S,
7 M.A.P.


T, M, S,
T, M, S,
7 M.A.P.

In the seventh month dry weight of leaves and whole plant showed significant difference. Tissue culture plants recorded higher dry matter content in the different parts and was significantly superior than the sucker progenies. Lower level of fertilizer (M_1) resulted in higher values for dry weight of different plant parts. S_1 level of method of application recorded higher values for pseudostem, leaf and whole plant whereas S_2 recorded higher dry matter content in root and rhizome. Dry matter content of root, rhizome and pseudostem did not show significant variation. Dry matter content of root, rhizome, pseudostem and leaf ranged from 74.0-147.1, 349.3-875.6, 551.1-1089.6 and 735.5-1176.9 g respectively. Total dry weight of plant was highest in $T_1M_1S_2$ (3167.5) and lowest in $T_2M_2S_2$ (1787.5 g)

At flowering stage, dry matter content of all parts except flower bud recorded higher values in planting material T_1 (tissue culture plants). Fertilizer doses significantly influenced the dry weight of rhizome, flower bud and whole plant. Methods of fertilizer application significantly influenced the dry weight of rhizome, pseudostem, leaf and also of whole plant. Dry matter allocation to root, rhizome, leaf and flower bud showed significant difference. Regarding the dry matter content of pseudostem all the treatments were on par. Total plant dry weight recorded the highest value in $T_1M_2S_1$ (3872.1 g) and lowest in $T_2M_1S_2$ (2363.6 g). Dry weight of flower bud recorded the highest value in $T_1M_1S_1$ (119.3 g).

Data on dry matter partitioning at harvest revealed that the apportioning to rhizome, pseudostem, stem, leaf and bunch was significantly influenced by the different treatments. Among the different parts, dry matter allocation to the bunch was the highest (35-40%). total plant dry weight was highest in $T_1M_2S_1$ (7087.8 g) of which 243.8 g was apportioned to the root, 1400 g to the rhizome, 1373 g to pseudostem, 1747, 1976.5 and 347.4 g to the leaf, bunch and stem respectively. Dry matter content was lowest in $T_1M_1S_2$ (4173.5 g).

Table 9. Dry matter partitioning as influenced by the different treatments during harvest

Treatment	Dry matter partitioning at harvest						
	Root (g)	Rhizome (g)	Pseudostem (g)	Stem (g)	Leaf (g)	Bunch (g)	Total (g)
T_1	253.10	913.55	1235.10	308.44	1269.72	1911.19	5891.59
T_2	107.66	592.21	1021.34	251.00	1027.66	2052.79	5051.03
CD(0.05)	8.18	31.90	26.96	18.89	37.47	36.92	99.69
M_1	188.05	600.38	1235.42	252.73	961.22	1903.86	5142.19
M_2	172.71	905.38	1021.01	306.71	1336.16	2060.13	5800.43
CD(0.05)	8.18	31.90	26.96	18.89	37.47	36.92	99.69
S_1	186.01	794.15	1052.06	269.27	1236.65	1943.10	5481.77
S_2	174.75	711.61	1204.38	290.16	1060.73	2020.89	5460.85
CD(0.05)	8.18	31.90	26.96	18.89	37.47	36.92	NS
$T_1M_1S_1$	261.58	709.47	1295.30	270.85	1261.51	2179.27	5979.98
$T_1M_1S_2$	273.81	508.87	1015.03	221.85	618.31	1535.66	4173.53
$T_1M_2S_1$	243.81	1399.94	1373.11	347.41	1747.01	1976.49	7087.78
$T_1M_2S_2$	233.19	1035.93	1256.94	393.65	1452.03	1953.32	6325.06
$T_2M_1S_1$	115.15	446.40	890.02	198.25	912.98	1797.90	4360.83
$T_2M_1S_2$	101.65	736.78	1741.34	319.94	1052.10	2102.60	6054.42
$T_2M_2S_1$	123.50	620.77	649.80	260.59	1025.10	1818.72	4498.48
$T_2M_2S_2$	90.35	564.87	804.21	225.20	1120.47	2491.97	5290.40
CD(0.05)	NS	63.80	53.91	37.78	74.95	73.84	199.38

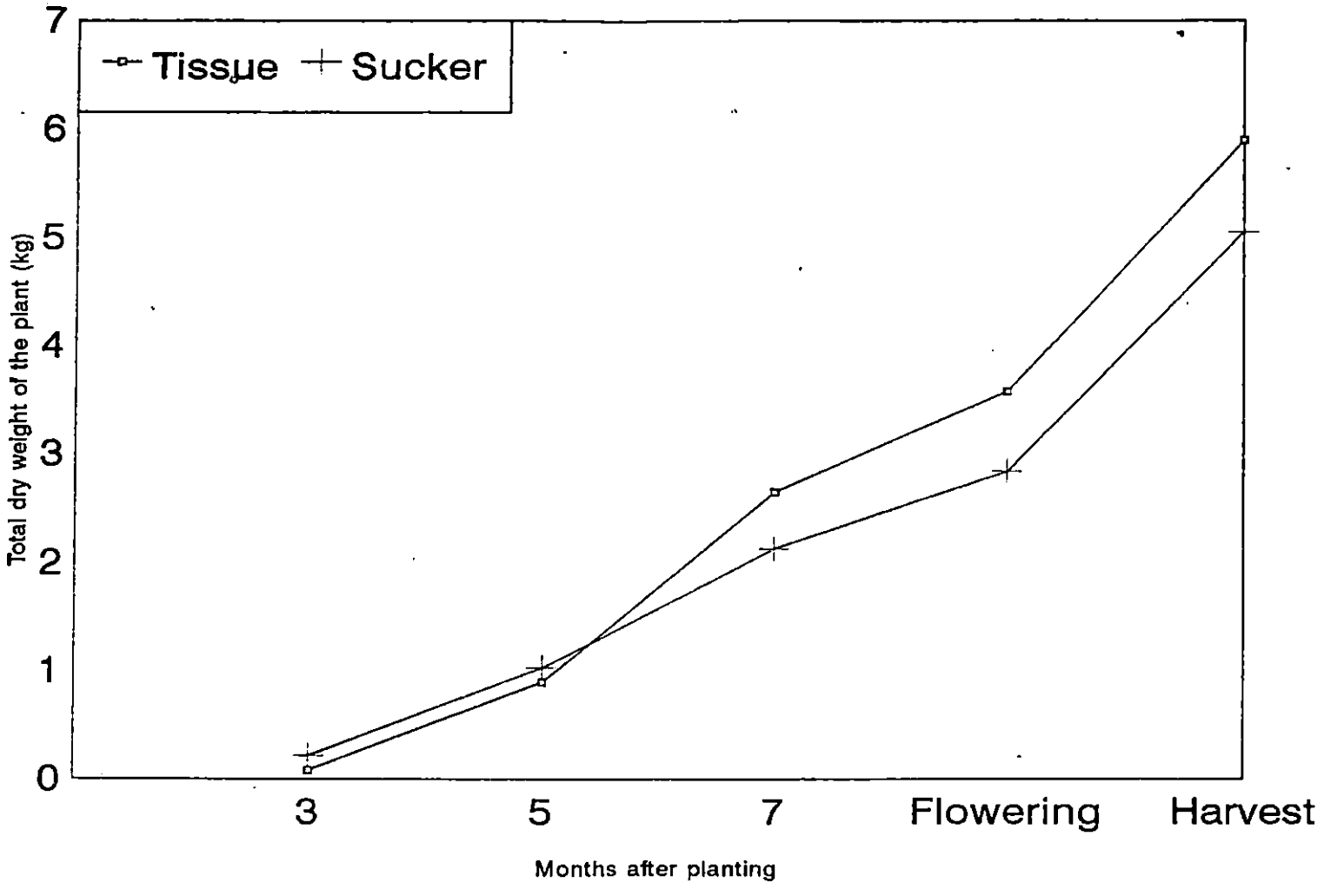


Fig.3. Total dry matter content in tissue culture and sucker progenies at critical stages of growth

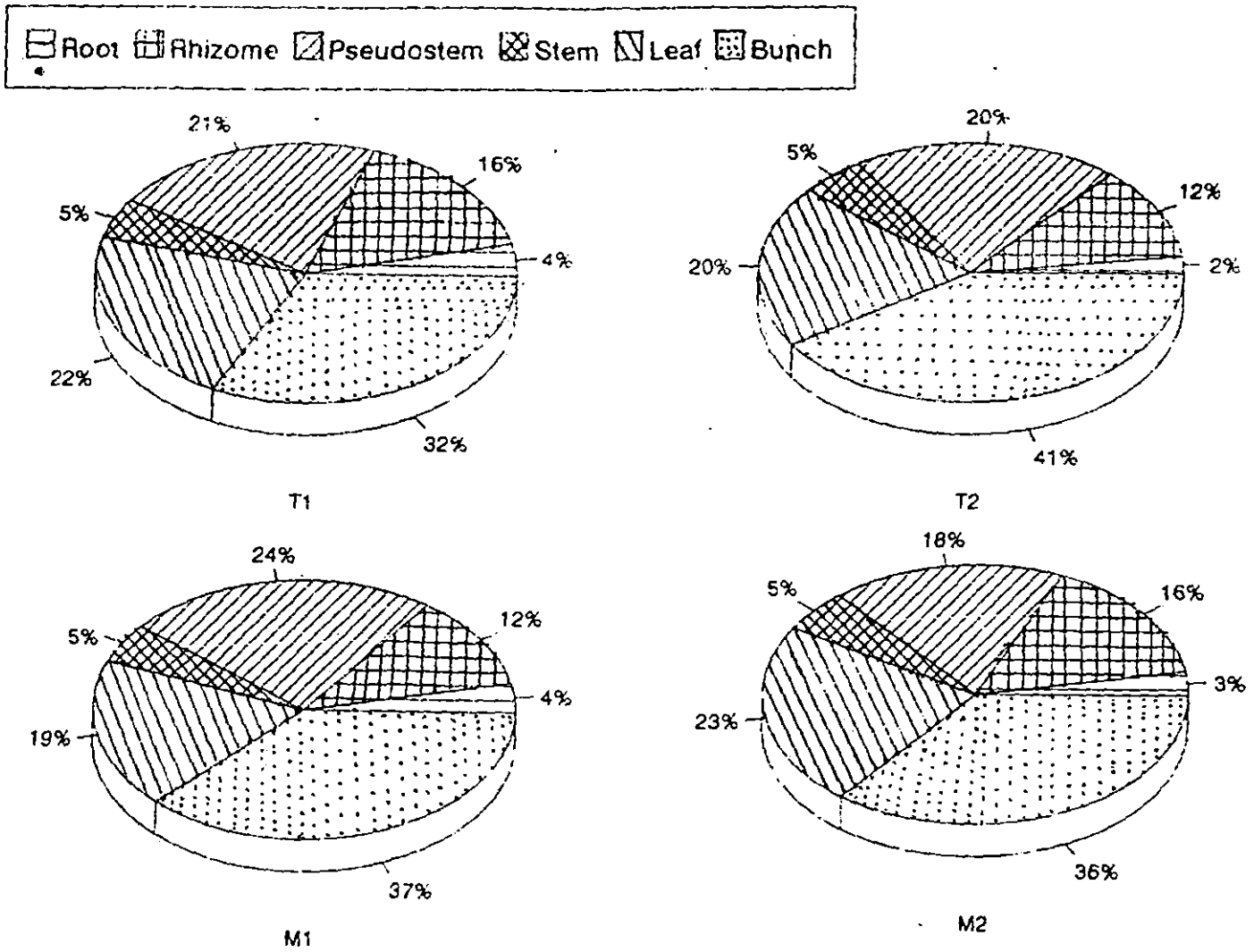


Fig. 4. Effect of planting materials and fertilizer doses on dry matter partitioning (DMP) during harvest

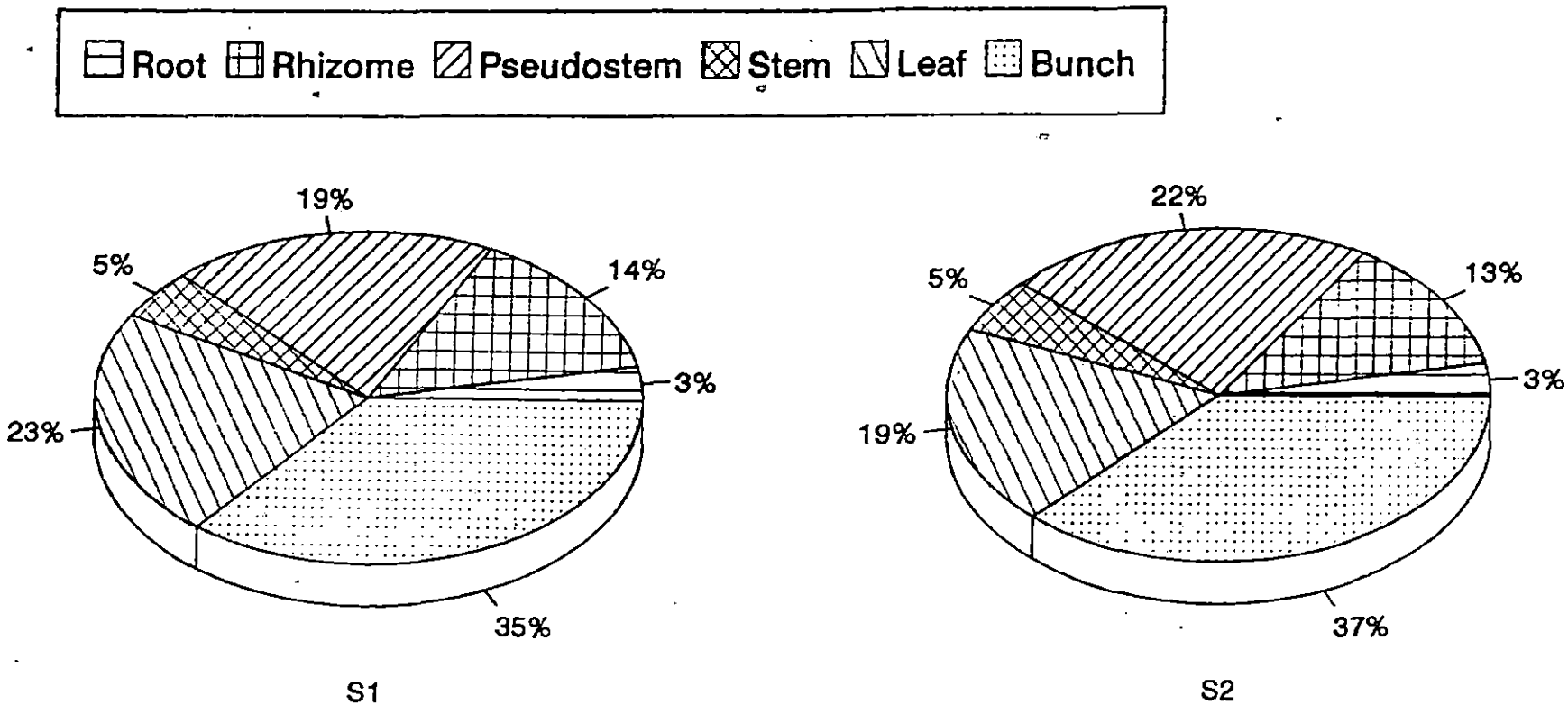


Fig. 5. Effect of methods of application on dry matter partitioning (DMP) during harvest

Data showed that at harvest stage dry matter content of root, rhizome, pseudostem, leaf and stem showed significant superiority in tissue culture plants over sucker propagated ones. Dry weight of bunch was significantly higher in sucker derived plants. Methods of fertilizer application and fertilizer doses resulted in significant difference in dry weight of different plant parts in different treatments.

4.2.6 Suckering Habit

The statistical analysis of data presented in Table 10 showed that with regard to the time of emergence of first sucker, the treatments differed significantly. Treatment $T_2M_1S_1$ produced suckers at the earliest (in 87.9 days) which was on par with $T_2M_1S_2$, $T_2M_2S_1$ and $T_2M_2S_2$. Tissue cultured plants took more days for the emergence of first sucker (140-150 days). When fertilizer was applied in two splits (S_1), time of emergence of first sucker was 111.9 days whereas S_2 resulted in emergence of first sucker 120.5 days after planting.

Number of suckers at flowering and harvest were more in tissue culture plants (8.1 and 8.8 respectively). Higher level of fertilizer (M_2) and two split application (S_1) resulted in the production of maximum number of suckers. The treatment combinations did not show significant difference with respect to the number of suckers at flowering and harvest and all the treatments were on par. Sucker production was maximum in $T_1M_2S_1$ (9.0) at flowering stage whereas at harvest, this was more in $T_1M_2S_2$ (9.5).

Table 10. Effect of treatments on suckering habit

Treatment	Suckering habit		
	Time of emergence of first sucker (DAP)	Number of suckers at flowering	Number of suckers at harvest
T_1	140.73	8.10	8.75
T_2	91.62	4.67	5.54
CD(0.05)	7.65	0.95	1.43
M_1	116.00	6.15	6.75
M_2	116.35	6.63	7.54
CD(0.05)	NS	NS	NS
S_1	111.88	6.44	7.42
S_2	120.47	6.33	6.88
CD(0.05)	7.65	NS	NS
$T_1M_1S_1$	141.97	7.17	9.00
$T_1M_1S_2$	141.27	8.50	8.17
$T_1M_2S_1$	121.37	9.00	8.33
$T_1M_2S_2$	158.33	7.75	9.50
$T_2M_1S_1$	87.87	4.42	4.83
$T_2M_1S_2$	92.92	4.50	5.00
$T_2M_2S_1$	96.33	5.17	7.50
$T_2M_2S_2$	89.36	4.58	4.83
CD(0.05)	15.29	NS	NS

4.2.7 Number of days for flowering

From the data presented in Table 11, it is clear that planting material T_2, lower level of fertilizer M_1 and six split application (S_2) resulted in early flowering the mean values being 233.3, 236.2 and 237.0 days respectively. In general sucker derived plants flowered earlier than tissue culture plants. Early flowering was noticed in $T_2M_2S_2$ (227.3 days) whereas flowering was delayed most in $T_1M_2S_2$ (245.17).

4.2.8 Total crop duration

Planting material, fertilizer dose and method of application significantly influenced the total duration of the crop. Sucker propagated plants which took 315 days for harvest were much more earlier than tissue culture plants (329.19 days) [Table 11]. M_1 level of fertilizer and S_2 level for application resulted in early harvest of the bunches. Statistical analysis of the data showed that all the treatments were on par. Shortest duration was noticed in $T_2M_2S_2$ (307.7 days) and longest in $T_1M_2S_2$) (334.3 days).

4.3 Yield characteristics

4.3.1 Bunch weight

Data presented in Table 12, showed that tissue culture plants were significantly superior than the sucker derived plants in bunch weight. Tissue culture plants recorded significantly the higher mean bunch weight (10.85 kg) than the sucker progenies (9.12 kg). Levels of fertilizers also influenced the bunch weight significantly as the bunch weight was maximum (10.41 kg) for level M_2 and 9.55 kg for M_1.

Table 11. Effect of treatments on the days for flowering and total crop duration

Treatment	Duration till flowering (days)	Total crop duration (days)
T_1	241.94	329.19
T_2	233.34	315.06
CD(0.05)	6.27	10.89
M_1	236.20	320.19
M_2	239.08	324.06
CD(0.05)	NS	NS
S_1	238.32	324.27
S_2	236.96	319.99
CD(0.05)	NS	NS
$T_1M_1S_1$	238.50	331.58
$T_1M_1S_2$	239.67	318.05
$T_1M_2S_1$	244.43	332.78
$T_1M_2S_2$	245.17	334.33
$T_2M_1S_1$	230.92	311.22
$T_2M_1S_2$	235.72	319.89
$T_2M_2S_1$	239.44	321.47
$T_2M_2S_2$	227.27	307.67
CD(0.05)	NS	NS

Similarly the method of application also influenced the bunch weight significantly. The overall mean of S_1 produced 9.7 kg bunches while that of S_2 was 10.26.

The combination effect of different treatments also showed significant difference. Treatment $T_1M_2S_2$ produced 12.2 kg bunches as compared to 8.5 kg bunches of $T_2M_1S_1$. There was an increase of 43 per cent in bunch weight due to the combined effect of planting material, fertilizer dose and method of application.

4.3.2 Number of hands

Sucker derived plants (5.19) had more number of hands than tissue culture plants (5.15). Similarly M_2 level of fertilizer and S_2 level of method of application recorded mean values of 5.28 and 5.21 respectively which was more than that of M_1 (5.07) and S_1 (5.14). However number of hands was not significantly influenced by planting materials, fertilizer doses or methods of application (Table 12).

Among the different treatment combinations, number of hands was highest in $T_2M_1S_2$ (5.39) which was 11 per cent more than the lowest value of 4.85 in $T_2M_1S_1$.

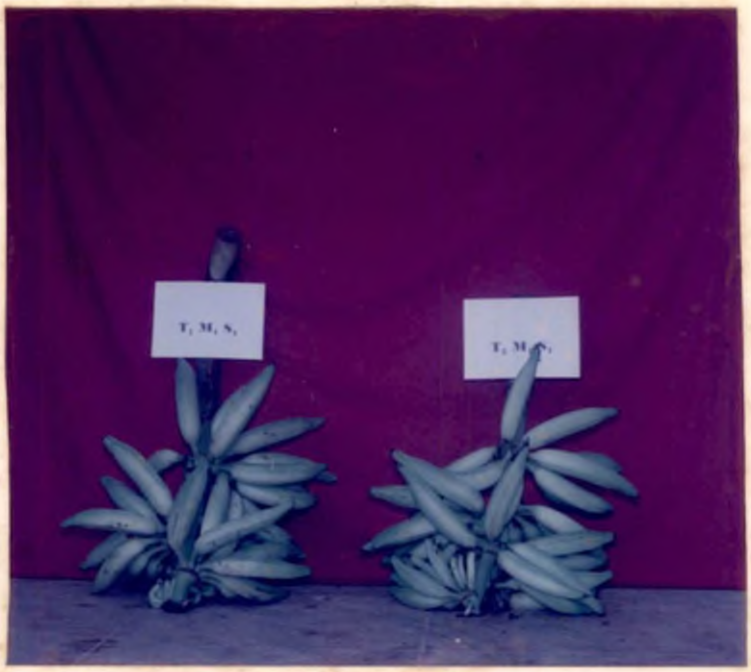
4.3.3 Number of fingers

From the data presented in Table 12, it was found that treatments showed significant variation. Number of fingers per bunch was more in tissue culture plants (48.69) whereas in sucker progenies it was only 44.25. Fertilizer doses and methods of application did not significntly influence the character under consideration but the mean values were more for level M_2 (48.09) and S_1 (47.69). Among the different treatments, $T_1M_2S_2$ recorded the highest of 51.42 which was 22 per cent more than the lowest of

Plate 3. Effect of treatments on bunch characters

Plate 3a. $T_1M_1S_1$ vs $T_2M_1S_1$

Plate 3b. $T_1M_2S_1$ vs $T_2M_2S_1$


T1 M1 S1


T2 M2 S1
T1 M2 S1

Plate 3. Effect of treatments on bunch characters

Plate 3c. $T_1M_1S_2$ vs $T_2M_1S_2$

Plate 3d. $T_1M_2S_2$ vs $T_2M_2S_2$


$T_2 M_1 S_2$
$T_1 M_1 S_2$

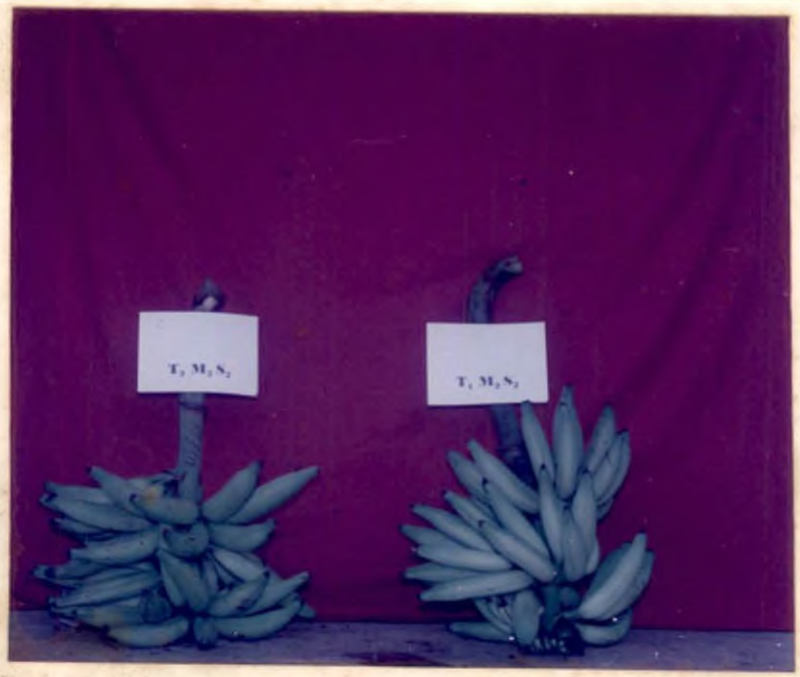

$T_2 M_2 S_2$
$T_1 M_2 S_2$

Table 12. Effect of treatments on bunch characters

Treatment	Bunch weight (kg)	Number of hands	Number of fingers	Peduncle weight (g)	Productivity (t ha^{-1})
T_1	10.85	5.15	48.69	897.83	27.12
T_2	9.11	5.19	44.25	909.17	22.49
CD(0.05)	0.52	NS	3.86	NS	1.52
M_1	9.55	5.07	44.85	911.75	23.60
M_2	10.41	5.28	48.09	895.25	26.02
CD(0.05)	0.52	NS	NS	NS	1.52
S_1	9.70	5.14	47.69	923.75	24.26
S_2	10.26	5.21	45.26	883.25	25.36
CD(0.05)	0.52	NS	NS	NS	NS
$T_1M_1S_1$	10.57	5.17	50.00	943.00	26.43
$T_1M_1S_2$	10.37	4.86	43.83	750.00	25.92
$T_1M_2S_1$	10.24	5.28	49.53	881.33	25.61
$T_1M_2S_2$	12.22	5.30	51.42	1017.00	30.54
$T_2M_1S_1$	8.54	4.85	42.25	986.33	21.34
$T_2M_1S_2$	8.73	5.39	43.33	967.67	20.70
$T_2M_2S_1$	9.46	5.25	48.97	884.33	23.65
$T_2M_2S_2$	9.71	5.28	42.44	798.33	24.28
CD(0.05)	1.04	NS	7.72	178.33	NS

Table 12a. Interaction effect of treatments on bunch characters

Treatment	Bunch weight (kg)	Number of hands	Number of fingers	Peduncle weight (g)	Weight of D-finger (g)
T_1M_1	10.47	5.01	46.92	846.50	151.13
T_1M_2	11.23	5.29	50.47	946.17	153.86
T_2M_1	8.63	5.12	42.79	977.00	143.09
T_2M_2	9.59	5.26	45.71	841.33	142.68
T_1S_1	10.41	5.22	49.76	912.17	149.45
T_1S_2	11.29	5.08	47.63	883.50	155.54
T_2S_1	9.00	5.05	45.61	935.33	148.60
T_2S_2	9.22	5.33	42.89	883.00	137.17
M_1S_1	9.55	5.01	46.13	964.67	154.17
M_1S_2	9.55	5.12	43.58	858.83	140.05
M_2S_1	9.85	5.26	49.25	882.83	143.88
M_2S_2	10.96	5.29	46.93	907.67	152.66
CD(0.05)	0.73	NS	NS	126.00	NS

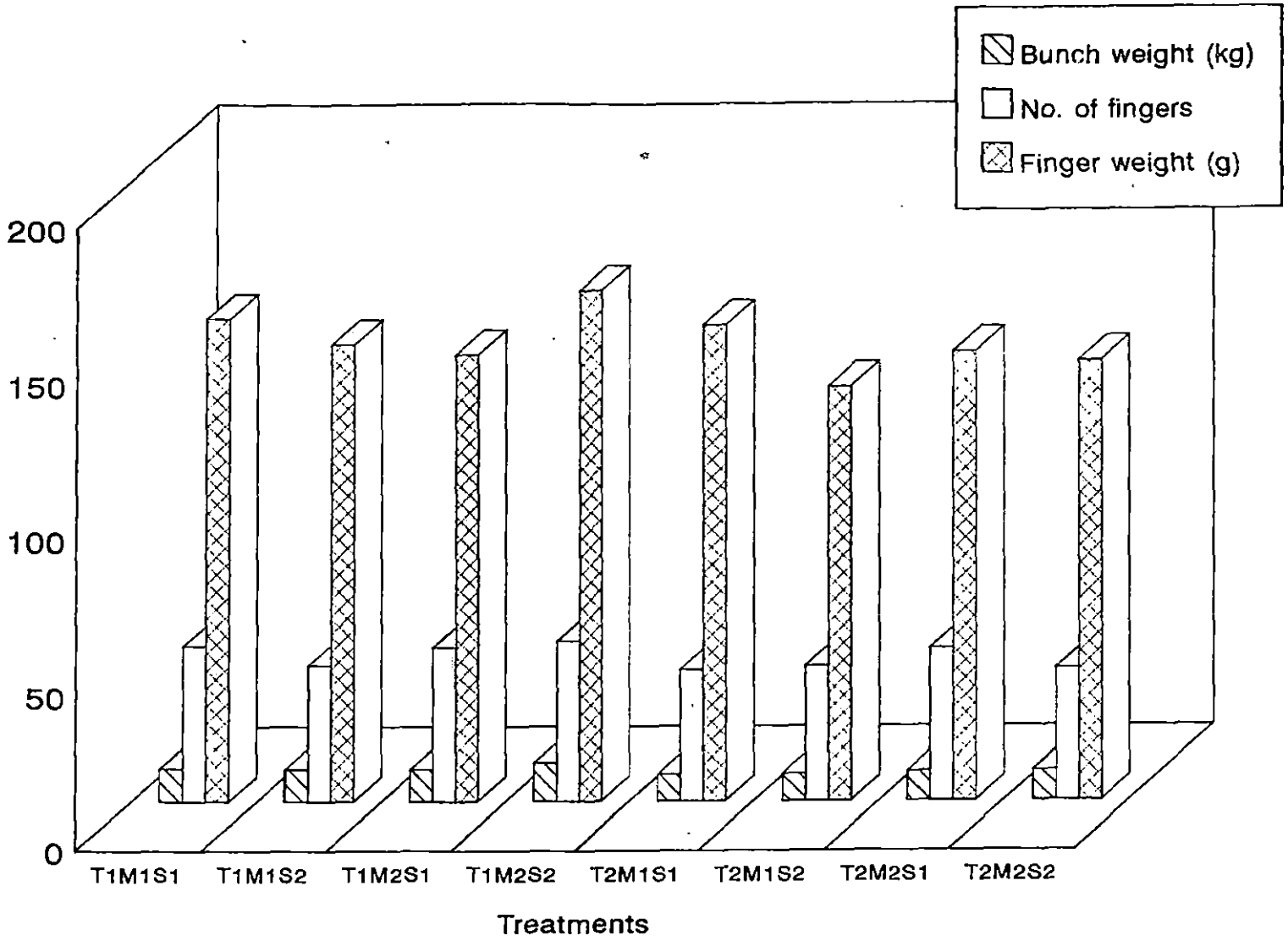


Fig.6. Effect of treatments on bunch weight, number of fingers and weight of D-finger

42.25 in $T_2M_1S_1$. $T_1M_1S_2$, $T_1M_2S_1$, $T_2M_1S_1$, $T_2M_1S_2$, $T_2M_2S_1$ and $T_2M_2S_2$ were statistically on par.

4.3.4 Peduncle weight

Peduncle weight (Table 12) which adds to the total bunch weight was also significantly influenced by the treatments. $T_1M_2S_2$ recorded highest peduncle weight (1017 g) which was on par with $T_1M_1S_1$, $T_1M_2S_1$,$T_2M_1S_1$, $T_2M_1S_2$ and $T_2M_2S_1$. Lowest peduncle weight in $T_1M_1S_2$ (750 g) was 36 per cent less than the highest value. However planting material T_2, M_1 level of fertilizer and method of application S_1 recorded values (909.17, 911.75 and 923.75 g respectively) more than that of T_1, M_2 and S_2 (897.83, 895.25 and 883.25 respectively).

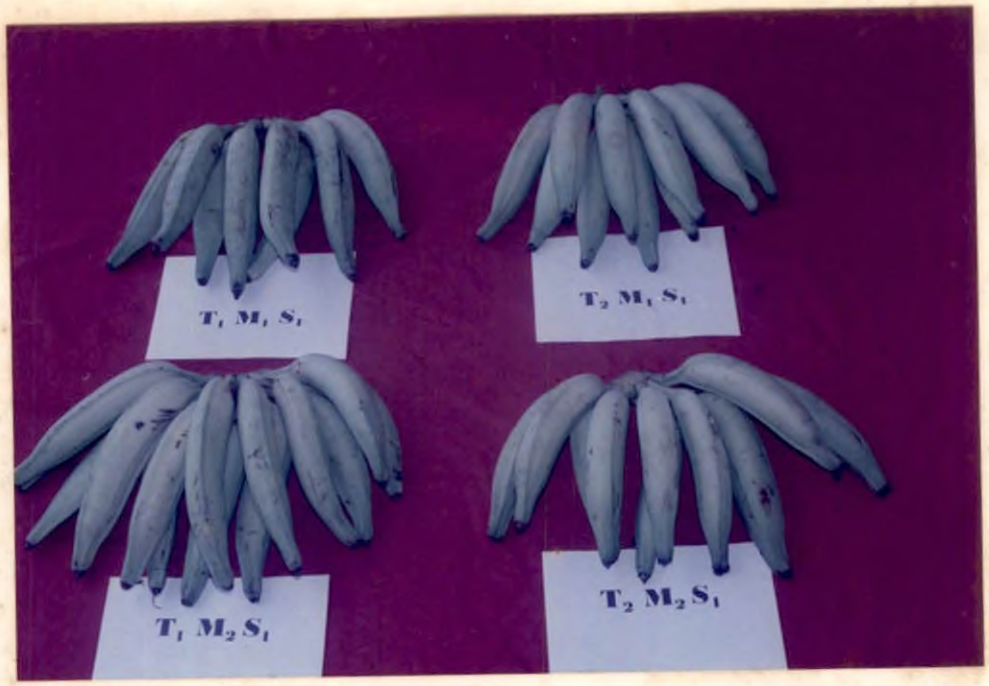
4.3.5 Productivity per hectare

Data presented in Table 12 showed that total bunch yield per hectare was more for tissue culture plants (27.12) than suckers (22.49 t ha^{-1}). Higher fertilizer dose M_2 recorded a productivity of 26.02 which was significantly superior over M_1 (23.6). Application of fertilizers in six splits (S_2) recorded a tonnage of 25.36 whereas S_1 recorded 24.26 tons per hectare. But the productivity per hectare was not significantly influenced by the different treatments. Bunch yield per hectare was highest in $T_1M_2S_2$ (30.54) and this was 47.5 per cent more than the lowest of 20.70 t ha^{-1} in $T_2M_1S_1$.

4.3.6 Fruit characters

The data on fruit characters under the influence of different treatments are given in Table 13.

Plate 4. Effect of treatments on the size of D-hand


$T_1 M_1 S_1$
$T_2 M_1 S_1$
$T_1 M_2 S_1$
$T_2 M_2 S_1$

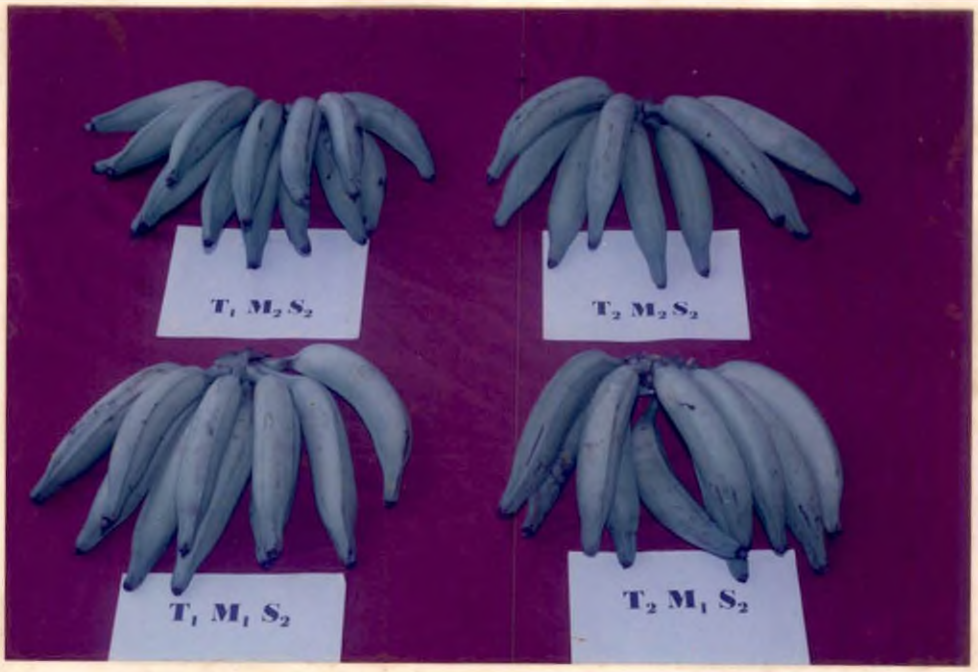

$T_1 M_2 S_2$
$T_2 M_2 S_2$
$T_1 M_1 S_2$
$T_2 M_1 S_2$

Table 13. Effect of treatments on fruit characters

Treatment	Length (cm)	Girth (cm)	Weight (g)	Volume (ml)	Shelf life (days)	Pulp peel ratio
T_1	22.34	12.55	152.50	153.72	5.92	3.03
T_2	21.65	12.43	142.89	144.52	5.58	3.17
CD(0.05)	NS	NS	NS	NS	0.32	NS
M_1	22.18	12.41	147.11	148.18	5.67	2.90
M_2	21.80	12.50	148.27	150.06	5.83	3.30
CD(0.05)	NS	NS	NS	NS	NS	NS
S_1	22.19	12.50	149.02	150.53	5.67	3.08
S_2	21.80	12.47	146.36	147.71	5.83	3.12
CD(0.05)	NS	NS	NS	NS	NS	NS
$T_1M_1S_1$	22.68	12.36	155.30	156.67	5.67	3.16
$T_1M_1S_2$	22.54	12.46	146.96	147.78	6.50	2.92
$T_1M_2S_1$	22.08	12.57	143.60	144.58	5.50	3.19
$T_1M_2S_2$	22.04	12.79	164.13	165.83	6.00	2.85
$T_2M_1S_1$	21.91	12.52	153.03	153.00	5.33	2.84
$T_2M_1S_2$	21.60	12.30	133.14	135.28	5.17	2.68
$T_2M_2S_1$	22.08	12.55	144.17	147.86	6.17	3.14
$T_2M_2S_2$	21.02	12.34	141.20	141.95	5.67	4.03
CD(0.05)	NS	NS	NS	NS	NS	NS

The data revealed that mean length of individual finger was highest in $T_1M_1S_1$ (22.68 cm) and lowest in $T_2M_2S_2$ (21.02) and all treatments were on par. Lower levels of planting material, manurial dose and method of application recorded higher values for finger length than the higher level. There was no significant variation between treatments in the girth of fruits. Tissue culture plants recorded higher values (12.55) than the sucker derived plants (12.43 cm). Higher level of fertilizer dose and two split application resulted in more values for girth of fruits. Lowest value for fruit girth was recorded in $T_2M_1S_2$ (12.30) and highest in $T_1M_2S_2$ (12.79 cm).

Data showed that there was no significant superiority between the different treatments regarding the weight and volume of D-finger. However planting material T_1 (tissue culture plants), higher fertilizer dose (M_2) and two split application (S_1) resulted in larger values for weight and volume of the fruits. Individual fruit weight was highest in $T_1M_2S_2$ (164.13) and lowest in $T_2M_1S_2$ (133.14 g). The former was 23 per cent more than the latter. Similar results were also obtained for the volume of fruit, highest (165.8) and lowest (135.3 ml) being observed in $T_1M_2S_2$ and $T_2M_1S_2$ respectively.

Though the shelf-life of fruits did not show significant difference, mean value was highest in $T_1M_1S_2$ (6.5 days) and lowest in $T_2M_1S_1$ (5.3). Fruits from tissue culture plants had higher keeping quality (5.9 days) than sucker progenies (5.6). Higher levels of fertilizer and methods of application recorded a shelf-life of 5.8 days whereas in both, the lower level had a shelf-life of 5.7 days.

Eventhough the analysed data in Table 13 revealed no significant superiority, pulp peel ratio was highest in $T_2M_2S_2$ (4.03), which was 50 per cent more than the lowest value of 2.68 observed in $T_2M_1S_2$. The ratio was more in higher levels of planting material (3.17), fertilizer dose (3.30) and method of application (3.12).


$T_1 M_1 S_1$
$T_2 M_1 S_1$
$T_1 M_1 S_2$
$T_2 M_1 S_2$
$T_1 M_2 S_1$
$T_2 M_2 S_1$
$T_1 M_2 S_2$
$T_2 M_2 S_2$

4.3.6.1. Qualitative fruit characters

The effect of different treatments on the quality characteristics of fruits are presented in Table 14.

Titratable acidity was more in the fruits of tissue culture plants (0.41%) than sucker progenies (0.39%). Similarly lower levels of fertilizer dose and method of application had more acidity (0.41 and 0.40% respectively). Acidity was highest in $T_1M_2S_2$ and $T_2M_1S_1$ (0.43) and lowest in $T_2M_2S_1$ (0.35%), the difference between highest and lowest being 23 per cent.

In general tissue cultured plants produced sweeter fruits and the percentage values reported for total and reducing sugars were 20.53 and 15.39 per cent respectively. Highest mean value for total sugar was 21.58 is $T_1M_2S_1$ and for reducing sugar was 16.48. Total sugar recorded the lowest value in $T_2M_1S_1$ (19.07) and reducing sugar in $T_1M_2S_2$ (14.37%). Application of fertilizers in two splits (S_1) recorded higher values for total (20.41) and reducing sugar (15.41). Total sugar recorded higher value of 20.18 per cent in M_2 level of fertilizer whereas reducing sugar was more (15.72) when lower level of fertilizer (M_1) was applied. Non-reducing sugar content was more in $T_1M_2S_1$ (7.11%), but it did not differ significantly from the lowest recorded value of 3.28% in $T_2M_1S_1$. Non reducing sugar was more in tissue culture plants (5.15%) than sucker derived plants (4.48%). Higher level of fertilizer (M_2) recorded non-reducing sugar content of 5.24 per cent whereas lower level (S_1) of method of application recorded 5.00 per cent cent.

Total soluble solids (TSS) content of fruits did not show significant variation between treatments. Highest value was in $T_2M_2S_1$ (30.03) and lowest in $T_2M_1S_1$

Table 14. Effect of treatments on qualitative characters of fruits

Treatment	Acidity (%)	TSS (°Brix)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid mg/ 100g fruit
T_1	0.41	29.13	20.53	15.39	5.15	3.07
T_2	0.39	28.76	19.75	15.27	4.48	3.60
CD(0.05)	NS	NS	NS	NS	NS	NS
M_1	0.41	28.72	20.10	15.72	4.38	3.63
M_2	0.39	29.17	20.18	14.94	5.24	3.04
CD(0.05)	NS	NS	NS	NS	NS	NS
S_1	0.40	29.07	20.41	15.41	5.00	2.97
S_2	0.40	28.82	19.87	15.25	4.62	3.71
CD(0.05)	NS	NS	NS	NS	NS	0.72
$T_1M_1S_1$	0.40	29.23	20.71	16.25	4.46	2.83
$T_1M_1S_2$	0.38	29.73	20.52	16.48	4.05	3.81
$T_1M_2S_1$	0.42	29.10	21.58	14.46	7.11	2.20
$T_1M_2S_2$	0.43	28.43	19.33	14.37	4.96	3.46
$T_2M_1S_1$	0.43	27.90	19.07	15.80	3.28	3.73
$T_2M_1S_2$	0.41	28.00	20.10	14.38	5.73	4.16
$T_2M_2S_1$	0.35	30.03	20.30	15.15	5.15	3.11
$T_2M_2S_2$	0.38	29.10	19.52	15.77	3.75	3.39
CD(0.05)	NS	NS	NS	NS	NS	NS

(27.90°Brix). All the treatments were statistically on par. Tissue culture plants had TSS of 29.13°B whereas M_1 and M_2 recorded values 28.72 and 29.17°B respectively. Two split application (S_1) resulted in TSS content of 29.07 whereas six split (S_2) recorded 28.82°Brix.

Treatment $T_2M_1S_2$ had the highest ascorbic acid content of 4.16 mg/100 g fruit. This was 90 per cent more than the lowest value of 2.20 obtained in $T_1M_2S_1$. It was evident from the data presented in Table 14, that the sucker derived plants had more ascorbic acid (3.60), when nourished with M_1 level of fertilizer (3.63) in six split doses (3.71 mg/100 g fruit). Among the three different factors viz. planting material, fertilizer dose and method of application, only the latter showed significant variation in the ascorbic acid content of the fruit.

4.4 Plant nutrient concentrations

Nutrient levels in different plant parts of banana under different treatments were analysed at critical growth stages so as to infer conclusions on the distribution of nutrients and their effect on crop performance. The data generated are presented in Tables 15 to 18. Significant changes were observed in the nutrient concentration in different plant parts due to the effect of planting material, fertilizer doses and method of application. Results are summarised here under.

4.4.1 Nutrient concentration at third month

Further growth and development of the plant depends on the growth attained during this period because a good start is very important. Physiological

importance of this stage is that the leaf production rate is relatively faster and there is steady increase in leaf area.

4.4.1.1 Nitrogen levels at third month (Table 15)

Tissue culture plants had more nitrogen in the different parts viz. root, rhizome, pseudostem and leaf than the sucker progenies and the content was highest in the leaf (3.54). Higher dose of nitrogen (M_2) did not result in concomittent increase of its content in the root, rhizome and pseudostem but resulted in an increase of its content in the leaf. Application of fertilizers in six splits (S_2) produced more nitrogen in the root, rhizome and pseudostem. But the nitrogen content in the leaf was highest when fertilizers were applied in two splits (S_1). The nitrogen content in the root, rhizome, pseudostem and leaf varied from 1.48-1.93, 1.10-1.96, 1.92-2.23 and 3.23-3.75 per cent respectively. Nitrogen content in root, rhizome and pseudostem was not significantly varied by the treatments but in the leaf, the content showed significant variation. Highest value of 3.75 per cent in leaf was recorded in $T_1M_2S_1$.

4.4.1.2 Phosphorus level at third month

No significant variation in the phosphorus content of different plant parts was observed when different levels of planting material, fertilizer dose and method of application was tried (Table 15). The phosphorus content in the root ranged from 0.11-0.17, the highest being in $T_1M_1S_1$, and that of rhizome was 0.07-0.13 per cent. Highest value of 0.18 per cent was noted in $T_2M_1S_2$ and $T_1M_1S_1$ in case of pseudostem. The phosphorus content in the leaf was 0.14-0.18 per cent, the highest value being observed in $T_1M_2S_2$ and the lowest in $T_2M_2S_1$ but all the treatments were on par.

Table 15. Nutrient concentrations in different plant parts during third month

Treatment	Root (%)					Rhizome (%)					Pseudostem (%)					Leaves (%)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	1.81	0.14	2.06	0.17	0.28	1.77	0.11	2.84	0.49	0.33	2.07	0.17	3.96	0.31	0.26	3.54	0.17	2.69	1.09	0.50
T_2	1.60	0.14	1.78	0.16	0.29	1.25	0.09	2.32	0.19	0.28	2.05	0.15	3.54	0.51	0.23	3.41	0.15	3.26	1.14	0.40
CD(0.05)	NS	NS	0.20	NS	NS	0.20	NS	0.38	0.13	0.03	NS	NS	0.33	0.05	NS	0.07	NS	NS	NS	0.06
M_1	1.69	0.15	1.87	0.17	0.29	1.51	0.10	2.69	0.36	0.28	2.08	0.17	3.61	0.46	0.24	3.43	0.16	3.10	1.02	0.42
M_2	1.72	0.13	1.97	0.16	0.27	1.50	0.11	2.47	0.32	0.32	2.05	0.15	3.90	0.36	0.25	3.52	0.16	2.84	1.22	0.47
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.03	NS	NS	NS	0.05	NS	0.07	NS	NS	0.16	NS
S_1	1.64	0.14	1.75	0.15	0.28	1.37	0.09	2.44	0.24	0.25	2.02	0.15	3.80	0.34	0.24	3.52	0.16	2.78	1.21	0.45
S_2	1.77	0.14	2.09	0.18	0.29	1.64	0.11	2.73	0.43	0.36	2.11	0.17	3.70	0.48	0.26	3.43	0.17	3.16	1.03	0.44
CD(0.05)	NS	NS	0.20	NS	NS	0.20	0.019	NS	0.13	0.03	NS	NS	NS	0.05	NS	0.07	NS	NS	0.16	NS
$T_1M_1S_1$	1.80	0.17	1.92	0.20	0.29	1.66	0.11	2.81	0.36	0.22	1.92	0.18	4.02	0.29	0.24	3.25	0.16	3.47	1.09	0.49
$T_1M_1S_2$	1.81	0.13	2.04	0.18	0.33	1.96	0.12	3.28	0.60	0.34	2.15	0.16	3.92	0.35	0.25	3.67	0.17	2.34	0.95	0.46
$T_1M_2S_1$	1.71	0.11	1.99	0.13	0.23	1.58	0.11	3.06	0.34	0.33	2.03	0.15	3.86	0.23	0.30	3.75	0.16	2.49	1.26	0.51
$T_1M_2S_2$	1.93	0.15	2.30	0.18	0.27	1.87	0.10	2.22	0.64	0.43	2.20	0.17	4.05	0.36	0.24	3.51	0.18	2.45	1.07	0.54
$T_2M_1S_1$	1.48	0.16	1.73	0.14	0.30	1.10	0.07	1.81	0.13	0.24	2.23	0.14	3.78	0.41	0.19	3.50	0.16	2.49	1.12	0.39
$T_2M_1S_2$	1.68	0.13	1.78	0.16	0.27	1.33	0.10	2.87	0.32	0.34	2.03	0.18	2.71	0.80	0.27	3.32	0.15	4.12	0.92	0.37
$T_2M_2S_1$	1.58	0.11	1.34	0.12	0.29	1.15	0.08	2.07	0.14	0.21	1.92	0.13	3.55	0.45	0.21	3.57	0.14	2.69	1.37	0.41
$T_2M_2S_2$	1.65	0.16	2.25	0.22	0.30	1.41	0.13	2.54	0.16	0.31	2.04	0.16	4.13	0.39	0.27	3.23	0.16	3.78	1.16	0.44
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.66	0.10	NS	0.15	NS	NS	NS	NS

4.4.1.3 Potassium levels at third month

The potassium content in the root, rhizome and pseudostem showed significant superiority in the tissue culture plants (2.06, 2.84 and 3.96% respectively) over the sucker progenies but in the leaf, content was more in suckers (3.26) than the tissue culture plants (2.69). M_1 level of fertilizer resulted in more content of potassium in the rhizome and leaf whereas M_2 level resulted in more of its content in the root and pseudostem as evident in Table 15. Application of fertilizers in six splits (S_2) produced more potassium in the root, rhizome and leaf (2.09, 2.73 and 3.16% respectively). On the contrary, S_1 level resulted in higher content of potassium in the pseudostem (3.80).

Potassium content in the root, rhizome, pseudostem and leaf were 1.34-2.30, 1.81-3.28, 2.71-4.13 and 2.34-3.78 per cent respectively. $T_2M_2S_2$ recorded the highest values for potassium content in the pseudostem and leaf. Potassium content of the pseudostem showed significant variation and all treatments except $T_2M_1S_2$ were on par.

4.4.1.4 Calcium levels at third month

Tissue culture plants recorded higher values for calcium content in the root and rhizome whereas the calcium content of pseudostem and leaf were more in sucker progenies as evident in Table 15. Fertilizer dose did not significantly influence the content of calcium in the root and rhizome, but M_1 level showed significant superiority in case of calcium content of pseudostem and M_2 showed superiority in case of leaf. Application of fertilizers in six splits (S_2) resulted in higher values for calcium in the root, rhizome and pseudostem whereas S_1 resulted in more calcium in the leaf (1.21%). Calcium content in the root, rhizome, pseudostem and leaf varied from 0.12-0.22, 0.21-0.43, 0.23-0.80 and 0.92-1.37 per cent respectively.

4.4.1.5 . Magnesium levels at third month

Tissue culture plants recorded higher values for magnesium in the rhizome and leaf whereas sucker progenies had more magnesium in the root and pseudostem. In general M_2 level of fertilizer and S_2 level of method of application resulted in higher values for magnesium in the different plant parts. Magnesium content in the root and rhizome varied from 0.23-0.33 and 0.21-0.43 per cent respectively. Highest content of magnesium was seen in leaf (0.37-0.54%) in treatment $T_1M_2S_2$. Magnesium content of pseudostem ranged from 0.19-0.30 per cent.

4.4.2 Nutrient concentration at five months after planting (Table 16)

At this growth stage, leaf area is almost maximum and also the stem girth. Fast development of the rhizome is seen.

4.4.2.1 Nitrogen levels at fifth month

Data presented in Table 16 depicted that the nitrogen content in the root and rhizome were more for tissue culture plants whereas the sucker-derived plants had more nitrogen in the pseudostem and leaf. Similarly M_2 level of fertilizer resulted in higher content of nitrogen in the root and rhizome whereas M_1 resulted in higher nitrogen content in the pseudostem and leaf. Application of fertilizers in two splits (S_1) resulted in higher content of nitrogen in the pseudostem and leaf whereas six split application (S_2) produced more nitrogen in the root and rhizome. Nitrogen content in root, rhizome, pseudostem and leaf varied from 1.32-1.98, 0.98-1.63, 1.30-2.17 and 2.95-3.62 per cent respectively.

4.4.2.2 Phosphorus levels at fifth month

Phosphorus content in rhizome and leaves of tissue culture and sucker derived plants did not show significant difference but sucker progenies showed higher phosphorus content in the root whereas in the pseudostem, tissue culture plants had higher phosphorus content. M_1 level of fertilizer resulted in significant superiority with respect to phosphorus content of root, pseudostem and leaves whereas M_2 level produced more phosphorus in the rhizome. Application of fertilizers in six splits (S_2) resulted in higher phosphorus content of root and rhizome whereas S_1 recorded higher content in the pseudostem. Phosphorus content was highest in the root (0.09-0.19), and the highest content was noticed in $T_2M_1S_2$. Phosphorus content of rhizome, pseudostem and leaf ranged from 0.04-0.15, 0.10-0.15 and 0.11-0.18 per cent respectively.

4.4.2.3 Potassium levels at fifth month

In general the sucker derived plants recorded higher potassium content in different parts with exception to that of root where tissue culture plants had higher potassium. The application of higher dose of fertilizers (M_2), that too in two splits (S_1) resulted in higher content of potassium in the different parts of the plant.

Potassium content was highest in the pseudostem and the content varied from 4.53-8.43 per cent and the highest was observed in $T_1M_2S_2$. Content of potassium in the root, rhizome and leaf was 4.40-7.17, 3.80-6.27 and 3.30-4.87 per cent respectively.

4.4.2.4 Calcium levels at fifth month

Tissue culture plants had higher calcium content in the root, rhizome and pseudostem whereas the content of calcium in leaves was more in sucker derived plants. M_2 level of fertilizer when enforced resulted in more calcium in the rhizome, pseudostem and leaf. Method of application did not significantly influence the calcium content of rhizome and leaves.

The content of calcium in the root rhizome and pseudostem were 0.20-0.51, 0.11-0.59 and 0.38-0.71 per cent respectively. Calcium content was highest in the leaf (0.30-0.84) and the highest value of 0.84 per cent was noted in $T_2M_1S_1$.

4.4.2.5 Magnesium levels at fifth month

Magnesium content of root, pseudostem and leaves were more in tissue culture plants but content of magnesium in the rhizome was more in sucker derived plants. Similarly M_1 level of fertilizer and S_2 level of method of application resulted in higher content of magnesium in the different plant parts but S_1 resulted in higher content in the leaves.

The magnesium content of different plant parts are as follows, root - 0.24 to 0.34; rhizome - 0.17 to 0.34; pseudostem 0.13 to 0.26 and in leaf - 0.20 to 0.34 per cent.

Table 16. Nutrient concentrations in different plant parts during fifth month

Treatment	Root (%)					Rhizome (%)					Pseudostem (%)					Le		
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K
T_1	1.62	0.12	6.06	0.40	0.29	1.20	0.09	4.33	0.33	0.21	1.78	0.13	6.71	0.63	0.21	3.24	0.15	4.33
T_2	1.71	0.14	5.08	0.32	0.26	1.29	0.10	4.83	0.33	0.28	1.71	0.12	7.57	0.53	0.15	3.20	0.15	4.46
CD(0.05)	NS	0.01	0.11	0.01	0.01	0.05	NS	0.12	NS	0.01	NS	0.009	0.24	0.02	0.01	NS	NS	NS
M_1	1.56	0.16	5.46	0.37	0.28	1.11	0.09	4.42	0.27	0.22	1.77	0.13	6.60	0.49	0.19	3.33	0.16	4.27
M_2	1.78	0.12	5.68	0.35	0.27	1.37	0.11	4.75	0.39	0.27	1.72	0.12	7.68	0.67	0.17	3.10	0.14	4.52
CD(0.05)	0.14	0.01	0.11	0.01	NS	0.05	0.01	0.12	0.02	0.01	NS	0.009	0.24	0.02	0.01	0.11	0.01	0.15
S_1	1.60	0.12	5.83	0.31	0.25	1.20	0.09	4.96	0.33	0.22	1.89	0.13	7.44	0.53	0.17	3.26	0.15	4.56
S_2	1.73	0.15	5.31	0.42	0.30	1.28	0.11	4.21	0.33	0.27	1.61	0.12	6.83	0.62	0.19	3.17	0.15	4.23
CD(0.05)	NS	0.01	0.11	0.01	0.01	0.05	0.01	0.12	NS	0.01	0.07	0.009	0.24	0.02	0.01	NS	NS	0.15
$T_1M_1S_1$	1.32	0.16	7.17	0.47	0.28	1.25	0.09	5.07	0.39	0.19	1.95	0.14	6.40	0.38	0.26	3.21	0.18	4.87
$T_1M_1S_2$	1.74	0.15	5.10	0.43	0.31	1.24	0.13	4.23	0.37	0.25	1.30	0.14	4.53	0.71	0.21	3.38	0.14	3.30
$T_1M_2S_1$	1.81	0.09	5.83	0.35	0.24	1.03	0.04	4.23	0.23	0.18	1.90	0.11	7.47	0.69	0.14	3.15	0.12	4.33
$T_1M_2S_2$	1.61	0.12	6.13	0.37	0.34	1.27	0.12	3.80	0.32	0.23	1.97	0.14	8.43	0.73	0.23	3.22	0.15	4.80
$T_2M_1S_1$	1.56	0.13	4.40	0.20	0.26	0.98	0.06	4.27	0.11	0.17	2.17	0.15	8.40	0.44	0.13	3.62	0.17	4.73
$T_2M_1S_2$	1.61	0.19	5.17	0.36	0.27	0.98	0.07	4.10	0.20	0.27	1.67	0.11	7.07	0.43	0.16	3.13	0.15	4.17
$T_2M_2S_1$	1.71	0.12	5.90	0.22	0.25	1.55	0.15	6.27	0.59	0.34	1.52	0.10	7.50	0.62	0.15	3.09	0.11	4.30
$T_2M_2S_2$	1.98	0.14	4.83	0.51	0.28	1.63	0.12	4.70	0.43	0.32	1.49	0.12	7.30	0.62	0.17	2.95	0.17	4.63
CD(0.05)	0.28	0.01	0.22	0.01	0.02	NS	0.02	0.24	0.03	0.02	NS	NS	0.48	0.03	0.02	0.21	NS	0.31

4.4.3 Nutrient concentration at seventh month

Yet another destructive sampling and chemical analysis was performed at this growth stage which synchronises with late vegetative or flowering stage of the crop. Here again the marked effects of treatments were obtained. Relevant data is available in Table 17.

4.4.3.1 Nitrogen levels at seventh month

Significantly higher N concentrations were observed in all the plant parts where suckers were used as planting material (T_2). Higher dose of N did not result in concomittent increases of its contents in the pseudostem and leaf but resulted in higher levels in the root and rhizome. The decrease was significant in pseudostem whereas the increase was significant in rhizome. The effect of method of application was also not consistent with respect to plant parts while in root and pseudostem the levels increased significantly with six splits whereas application at two splits recorded higher levels of nitrogen in the rhizome and leaf though the effect was not significant in the case of leaf.

The range of N in the root, rhizome, pseudostem and leaf were 0.99 to 1.76, 0.71 to 1.35, 0.61 to 1.37 and 2.19 to 2.87 per cent respectively, in response to the applied treatment combinations. However the three factor interactions were not significant with respect to nitrogen concentrations in the root, pseudostem and leaf. The treatment $T_2M_2S_1$ (two splits of higher dose where planting material was sucker) recorded significantly higher concentration of nitrogen in the rhizome compared to all other treatments.

4.4.3.2 Phosphorus levels at seventh month

Phosphorus was found to be present in very low concentrations compared to other nutrients but the tissue culture plants had higher P content in different parts and content was found to be significantly high in leaf and root. Higher level of fertilizer (M_2) had more P content, which was significantly superior to the lower level (M_1). Comparing the method of application, P was present in higher concentration in treatments receiving fertilizers in six splits.

The range of phosphorus content in the root was 0.07 to 0.16 per cent and the treatments were found to be significantly different, the highest concentration (0.16%) being in $T_1M_2S_2$. Phosphorus content in rhizome, pseudostem and leaf were 0.04 to 0.34, 0.07 to 0.13 and 0.14 to 0.19 per cent respectively and all were found to be non-significant.

4.4.3.3 Potassium levels at seventh month

The different parts of sucker derived plants had significantly higher level of potassium than the tissue culture plants. Potassium content of root was more in plants receiving M_1 level of fertilizer dose whereas in the rhizome, pseudostem and leaf, potassium content was more in M_2 level. In plants receiving fertilizers in two splits (S_1), potassium content was more in root and rhizome whereas it was more in the pseudostem and leaves, when the method of application was six split.

Among the different nutrients, potassium concentration was found to be the highest in different plant parts which is well pointed out in Table 17. Potassium level

was more in the pseudostem (3.60 to 7.67%) and root (5.07 to 7.60%) when compared to rhizome and leaf (2.63 to 4.53% and 3.50 to 4.47% respectively).

4.4.3.4 Calcium levelsat seventh month

The data presented in Table 17, revealed that calcium content was more in tissue culture plants in the root and rhizome whereas it was present in significantly higher amounts in the pseudostem and leaf of sucker derived plants. The calcium content was more in treatments M_1 (lower level of fertilizer) and S_1 (two split application) over the other levels M_2 and S_2.

The root, rhizome, pseudostem and leaf contained 0.17 to 0.39, 0.19 to 0.48, 0.30 to 0.54 and 0.23 to 0.57 per cent calcium respectively.

4.4.3.5 Magnesium levels at seventh month

No general idea could be inferred regarding the magnesium content in different parts of the plant during the seventh month when we compare the tissue culture and sucker derived plants. The plants receiving treatment M_1 and M_2, and also S_1 and S_2 did not very much in their magnesium concentrations in the different parts. The concentration of magnesium in the root and rhizome were more in $T_2M_2S_1$ (0.24 and 0.26% respectively). Leaf had the highest magnesium content (0.24%) in treatment $T_2M_1S_1$.

Table 17. Nutrient concentrations in different plant parts during seventh month

Treatment	Root (%)					Rhizome (%)					Pseudostem (%)					Leaves (%)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	1.14	0.11	5.33	0.29	0.22	0.75	0.13	3.28	0.40	0.22	0.68	0.10	4.18	0.38	0.16	2.37	0.16	4.07	0.36	0.24
T_2	1.40	0.12	6.23	0.21	0.22	0.97	0.06	4.07	0.39	0.22	0.99	0.09	6.53	0.41	0.19	2.70	0.14	4.11	0.44	0.22
CD(0.05)	0.14	0.005	0.11	0.02	NS	0.05	NS	0.15	NS	NS	0.04	NS	0.27	0.01	0.005	0.11	0.01	NS	0.01	0.01
M_1	1.22	0.10	5.98	0.25	0.21	0.81	0.06	3.48	0.40	0.22	0.86	0.08	5.03	0.37	0.18	2.59	0.15	3.99	0.43	0.23
M_2	1.32	0.12	5.58	0.25	0.23	0.91	0.13	3.88	0.39	0.22	0.81	0.10	5.68	0.33	0.17	2.49	0.16	4.18	0.38	0.22
CD(0.05)	NS	0.005	0.11	NS	0.01	0.05	NS	0.15	NS	NS	0.04	0.01	0.27	0.01	0.005	NS	NS	0.11	0.01	NS
S_1	1.16	0.09	5.97	0.27	0.22	0.92	0.14	3.88	0.43	0.21	0.73	0.09	5.31	0.41	0.17	2.57	0.13	3.98	0.47	0.23
S_2	1.38	0.13	5.59	0.23	0.22	0.80	0.05	3.47	0.37	0.23	0.94	0.10	5.39	0.38	0.18	2.50	0.16	4.20	0.34	0.22
CD(0.05)	0.14	0.005	0.11	0.02	NS	0.05	NS	0.15	0.02	NS	0.04	NS	NS	0.01	0.005	NS	0.01	0.11	0.01	NS
$T_1M_1S_1$	1.18	0.07	5.30	0.39	0.22	0.74	0.07	3.17	0.31	0.18	0.62	0.07	3.60	0.45	0.18	2.45	0.16	3.50	0.45	0.23
$T_1M_1S_2$	1.17	0.10	5.13	0.17	0.22	0.80	0.05	3.03	0.40	0.24	0.67	0.09	3.70	0.41	0.15	2.19	0.15	4.13	0.37	0.24
$T_1M_2S_1$	0.99	0.07	5.80	0.26	0.22	0.76	0.34	4.30	0.48	0.18	0.82	0.13	4.77	0.37	0.15	2.51	0.15	4.17	0.40	0.24
$T_1M_2S_2$	1.20	0.16	5.07	0.33	0.23	0.71	0.04	2.63	0.41	0.25	0.61	0.11	4.63	0.30	0.18	2.35	0.19	4.47	0.23	0.23
$T_2M_1S_1$	1.15	0.09	7.60	0.23	0.21	0.83	0.08	3.53	0.45	0.22	0.77	0.08	5.20	0.54	0.20	2.85	0.15	4.07	0.57	0.24
$T_2M_1S_2$	1.40	0.14	5.90	0.21	0.18	0.87	0.05	4.17	0.46	0.21	1.37	0.12	7.60	0.46	0.22	2.87	0.16	4.27	0.32	0.23
$T_2M_2S_1$	1.31	0.12	5.17	0.20	0.24	1.35	0.06	4.53	0.47	0.26	0.69	0.09	7.67	0.30	0.16	2.50	0.14	4.17	0.47	0.22
$T_2M_2S_2$	1.76	0.12	6.27	0.19	0.24	0.81	0.06	4.03	0.19	0.19	1.13	0.08	5.63	0.36	0.18	2.61	0.16	3.94	0.42	0.21
CD(0.05)	NS	0.01	0.23	0.04	NS	0.10	NS	NS	0.04	0.02	NS	NS	0.23	0.02	0.01	NS	NS	NS	0.02	NS

4.4.4 Nutrient concentrations at harvest (Table 18)

The duration of the vegetative, floral and bunching phase determines the total duration of the crop and the former is largely dependent on gene or variety and environmental factors especially temperature.

4.4.4.1 Nitrogen levels at harvest

Nitrogen levels present in root, rhizome, pseudostem and stem were significantly superior in sucker progenies compared to tissue culture plants whereas the latter had more nitrogen in peduncle, peel and pulp of the fruit and was reported to be non-significant. The leaf contained more nitrogen than the other parts. Nitrogen concentration was more in the root, pseudostem, leaf, peduncle and peel in treatment M_2. Fertilizer application in two splits resulted in higher levels of nitrogen in root, rhizome, and stem whereas pseudostem, leaf, peduncle and peel had more nitrogen when six split application was followed.

Nitrogen levels in root, rhizome, pesudostem and stem varied from 0.98 to 1.29, 0.68 to 1.01, 0.35 to 1.15 and 0.14 to 0.25 per cent respectively. Leaf had highest nitrogen level of 1.88 to 4.24 per cent, the former being reported in $T_1M_2S_2$. Nitrogen content in peel, pulp and peduncle were 0.80 to 1.38, 0.40 to 0.56 and 0.70 to 1.82 per cent respectively.

4.4.4.2 Phosphorus levels at harvest

The root, rhizome, pseudostem and stem of sucker derived plants contained more phosphorus whereas the tissue cultured plants had more phosphorus in the leaf, peduncle and peel. The phosphorus concentration in the pulp was more or less the same in both the planting materials. The phosphorus content remained the same in all plant parts irrespective of the level of fertilizer with exception to that of root. Similar trend was noticed in case of method of application in rhizome, pseudostem, stem and pulp of fruit. Two split application (S_1) resulted in higher phosphorus levels in the root, leaf, peduncle and peel.

There was not much significant variation in the phosphorus concentration of different parts of the plant and the mean value observed was 0.04 to 0.16 per cent. Highest P concentration of 0.42 per cent was noticed in the roots in treatment $T_2M_2S_1$.

4.4.4.3 Potassium levels at harvest

Potassium is the element to be found in highest concentration in the different plant parts. Potassium levels in the root, pseudostem, leaf, peduncle, peel and pulp were more for tissue culture planting material. Lower level of method of application (S_1) resulted in higher potassium concentration in the rhizome, pseudostem, stem and leaf whereas application of fertilizers in six splits (S_2) produced more amount of these nutrient in the root, peduncle, peel and pulp of the fruit. M_2 level of fertilizer when applied produced more potassium in the root, rhizome, stem, peduncle and fruit pulp.

Potassium concentration in the root varied from 2.83 to 7.87 per cent, the latter being reported in $T_1M_2S_2$, in the rhizome 2.97 to 7.20, in the pseudostem, stem

and leaf was 2.13 to 4.53, 4.27 to 8.00 and 2.37 to 3.40 per cent respectively. Potassium concentration was highest in the peduncle (4.93 to 9.17%), the levels in peel and pulp being 3.5 to 5.47 per cent and 0.59 to 1.37 per cent.

4.4.4.4 Calcium levels at harvest

Calcium was found to be present more in higher level of planting material and fertilizer dose and in higher level of method of application in all the different plant parts at harvest stage.

Calcium content of root, rhizome, pseudostem, stem and leaf were 0.11 to 0.67, 0.10 to 0.71, 0.23 to 1.19, 4.27 to 8.00 and 0.98 to 1.35 per cent respectively. Calcium concentration in the bunch averaged from 0.68 to 0.85 per cent in the peduncle, 0.21 to 0.64 per cent in the peel to 0.06 to 0.48 per cent in the pulp.

4.4.4.5 Magnesium levels at harvest

Tissue culture planting material (T_1) in general had higher magnesium content than the suckers (T_2) in the different plant parts and the former, was found to be significantly superior over the latter. Similarly application of lower level of fertilizer dose (M_1), in two splits (S_1) resulted in higher magnesium concentrations in the different plant parts over the other levels of fertilizer dose and method of application.

Magnesium was found to be in more or less the same concentration in the various plant parts, the average value being 0.09 to 0.25 per cent.

Table 18. Nutrient concentrations in different plant parts at harvest

Treatment	Root (%)					Rhizome (%)					Pseudostem (%)					Stem (%)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	1.04	0.10	5.52	0.26	0.26	0.69	0.04	3.71	0.24	0.22	0.40	0.04	3.98	0.61	0.20	0.72	0.07	5.38	0.23	0.23
T_2	1.19	0.18	3.93	0.32	0.22	0.86	0.06	5.53	0.37	0.26	0.60	0.05	3.05	0.76	0.17	0.88	0.07	6.01	0.44	0.22
CD(0.05)	0.07	NS	0.32	0.03	0.01	0.03	0.01	0.18	0.02	0.02	0.03	0.004	0.19	0.10	0.01	0.03	NS	0.17	0.02	NS
M_1	1.11	0.10	3.90	0.33	0.25	0.80	0.06	4.44	0.36	0.25	0.44	0.05	3.71	0.70	0.22	0.83	0.07	5.65	0.28	0.23
M_2	1.13	0.18	5.55	0.25	0.23	0.75	0.05	4.80	0.25	0.22	0.55	0.05	3.32	0.67	0.16	0.77	0.06	5.74	0.40	0.21
CD(0.05)	NS	NS	0.45	0.03	0.01	0.03	NS	0.18	0.02	0.02	0.03	NS	0.19	NS	0.01	0.03	0.008	NS	0.02	NS
S_1	1.12	0.17	4.31	0.25	0.24	0.82	0.06	4.65	0.34	0.24	0.37	0.05	3.67	0.81	0.19	0.92	0.07	5.83	0.25	0.24
S_2	1.11	0.11	5.14	0.33	0.23	0.73	0.05	4.60	0.27	0.23	0.62	0.05	3.36	0.56	0.19	0.68	0.07	5.56	0.43	0.21
CD(0.05)	NS	NS	0.45	0.03	NS	0.03	NS	NS	0.02	NS	0.03	NS	0.19	0.10	NS	0.03	NS	0.17	0.02	NS
$T_1M_1S_1$	1.12	0.12	5.20	0.39	0.29	0.70	0.04	4.27	0.10	0.22	0.39	0.06	3.50	0.52	0.25	1.09	0.07	1.57	0.19	0.22
$T_1M_1S_2$	0.98	0.09	3.23	0.41	0.27	0.70	0.06	4.20	0.37	0.23	0.52	0.03	3.60	0.91	0.24	0.12	0.09	5.30	0.28	0.23
$T_1M_2S_1$	0.98	0.07	5.77	0.10	0.24	0.68	0.04	2.97	0.25	0.18	0.32	0.04	4.53	0.80	0.14	0.79	0.06	4.50	0.23	0.33
$T_1M_2S_2$	1.10	0.14	7.87	0.12	0.22	0.69	0.03	3.40	0.24	0.23	0.35	0.04	4.27	0.23	0.17	0.86	0.05	5.17	0.24	0.15
$T_2M_1S_1$	1.11	0.08	2.83	0.39	0.20	1.01	0.06	4.17	0.71	0.31	0.39	0.05	4.30	0.74	0.19	0.92	0.06	4.27	0.27	0.25
$T_2M_1S_2$	1.21	0.12	4.33	0.11	0.22	0.79	0.05	5.13	0.24	0.26	0.47	0.04	3.43	0.64	0.18	1.17	0.07	6.47	0.38	0.23
$T_2M_2S_1$	1.29	0.42	3.43	0.11	0.25	0.89	0.08	7.20	0.29	0.26	0.38	0.05	2.33	1.19	0.17	0.88	0.08	8.00	0.32	0.15
$T_2M_2S_2$	1.16	0.07	5.13	0.67	0.21	0.72	0.06	5.63	0.23	0.20	1.15	0.07	2.13	0.46	0.14	0.55	0.06	5.30	0.81	0.22
CD(0.05)	0.14	NS	0.63	0.05	NS	NS	NS	0.37	0.04	NS	0.06	NS	0.37	NS	0.02	0.07	NS	0.34	0.04	NS

Contd.

Table 18. Continued

Treatment	Leaf (%)					Peduncle (%)					Peel (%)					Pulp (%)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	2.74	0.15	2.95	1.25	0.26	1.34	0.10	8.31	0.74	0.19	1.25	0.11	4.46	0.54	0.18	0.50	0.06	1.16	0.32	0.12
T_2	2.11	0.12	2.55	1.19	0.21	1.20	0.08	6.43	0.79	0.16	1.14	0.10	4.05	0.43	0.14	0.49	0.06	1.12	0.42	0.12
CD(0.05)	0.06	0.01	0.11	NS	0.02	NS	0.01	0.16	0.02	0.01	NS	NS	0.12	0.02	0.01	NS	NS	NS	0.02	NS
M_1	2.09	0.12	2.77	1.21	0.25	1.23	0.09	6.98	0.76	0.18	1.19	0.12	4.83	0.50	0.14	0.50	0.06	0.95	0.41	0.12
M_2	2.76	0.14	2.73	1.23	0.22	1.32	0.09	7.75	0.77	0.16	1.20	0.10	3.68	0.48	0.17	0.48	0.06	1.33	0.33	0.11
CD(0.05)	0.06	0.01	NS	NS	0.02	NS	NS	0.16	NS	0.01	NS	0.01	0.12	NS	0.01	NS	NS	0.21	0.02	0.009
S_1	2.15	0.15	2.90	1.14	0.23	1.07	0.10	6.84	0.75	0.18	1.08	0.12	3.95	0.48	0.18	0.49	0.06	1.15	0.35	0.11
S_2	2.70	0.12	2.60	1.30	0.24	1.47	0.08	7.89	0.77	0.18	1.31	0.10	4.56	0.51	0.14	0.49	0.06	1.32	0.40	0.13
CD(0.05)	0.06	0.01	0.11	0.07	NS	0.17	0.01	0.16	NS	NS	0.18	0.01	0.12	0.02	0.01	NS	NS	NS	0.02	0.009
$T_1M_1S_1$	2.14	0.16	3.40	1.08	0.25	1.45	0.12	7.05	0.66	0.19	1.38	0.14	5.10	0.64	0.15	0.49	0.06	0.67	0.42	0.12
$T_1M_1S_2$	2.14	0.13	2.37	1.36	0.22	1.40	0.09	7.97	0.75	0.19	1.24	0.10	5.47	0.52	0.14	0.43	0.07	1.30	0.44	0.12
$T_1M_2S_1$	2.44	0.21	3.00	1.37	0.09	1.22	0.11	9.03	0.73	0.17	1.09	0.09	3.50	0.05	0.03	0.51	0.07	1.37	0.06	0.09
$T_1M_2S_2$	4.24	0.09	3.03	1.21	0.26	1.30	0.08	9.17	0.82	0.22	1.29	0.11	3.77	0.54	0.13	0.56	0.07	1.32	0.37	0.13
$T_2M_1S_1$	1.88	0.09	2.70	1.14	0.23	0.70	0.08	6.33	0.77	0.18	0.80	0.12	3.60	0.21	0.15	0.57	0.07	1.23	0.43	0.13
$T_2M_1S_2$	2.22	0.12	2.60	1.28	0.28	1.36	0.07	6.57	0.85	0.17	1.33	0.09	5.17	0.60	0.14	0.50	0.04	0.59	0.37	0.12
$T_2M_2S_1$	2.13	0.13	2.60	0.98	0.15	0.93	0.01	4.93	0.84	0.15	1.07	0.10	3.60	0.57	0.13	0.40	0.05	1.33	0.48	0.11
$T_2M_2S_2$	2.21	0.12	2.40	1.35	0.17	1.82	0.06	7.87	0.68	0.14	1.38	0.10	3.83	0.34	0.14	0.47	0.07	1.32	0.42	0.13
CD(0.05)	0.11	0.01	0.22	0.14	NS	NS	NS	0.31	0.05	0.02	NS	NS	0.25	0.03	0.02	NS	0.01	0.42	0.05	NS

4.5 Uptake of nutrients by plants

There was a sharp increase in the uptake of nutrients from third month till harvest because of the increased dry matter production with progressive development of the plant.

4.5.1 Nutrient uptake at third month

Uptake of plant nutrients at third month (Table 19) was indicative of the growth as uptake is a measure of the percentage availability of nutrients and dry matter production.

4.5.1.1 Nitrogen uptake at third month

There was not any significant influence in nitrogen uptake by roots by planting material, fertilizer dose and method of application. The nitrogen uptake by the rhizome, pseudostem and leaf was significantly influenced by planting material, higher values being observed in sucker progenies. The nitrogen uptake by rhizome and pseudostem was more when the level of fertilizer was M_2, whereas the uptake by leaf, was more in case of M_1. Application of nitrogen in six splits recorded higher values for uptake though the influence was not significant.

The nitrogen uptake by root, rhizome, pseudostem and leaf was in the range of 0.11 to 0.18, 0.12 to 1.68, 0.34 to 0.85 and 1.05 to 2.64 per cent respectively. The highest uptake was noticed in treatment $T_2M_2S_2$.

4.5.1.2 Phosphorus uptake during third month

In general, phosphorus uptake was more by sucker progenies, though the effect was not significant. The uptake of phosphorus by different plant parts remained the same irrespective of the levels of the fertilizer dose and method of application tried.

The uptake of phosphorus was in the range of 0.01 to 0.15 per cent in rhizome, 0.03 to 0.06 per cent in pseudostem and 0.05 to 0.13 per cent in leaf. The uptake was lowest in the roots (0.01 to 0.02%).

4.5.1.3 Potassium uptake during third month

The uptake of nutrients recorded higher values in different parts of sucker derived plants. The fertilizer dose M_2 resulted in higher values for potassium uptake, eventhough the effect was not significant. Six split application (S_2) resulted in more uptake of nutrients by the different plant parts.

Potassium uptake by roots varied from 0.13 to 0.24, 0.23 to 3.15 per cent in rhizome. Uptake of potassium recorded a value of 0.66 to 1.64 per cent in pseudostem and 0.69 to 3.17 per cent in the leaf.

4.5.1.4 Uptake of calcium in third month

Calcium uptake was generally more when higher level of planting material, fertilizer dose and method of application was tried. The calcium uptake by root, rhizome, pseudostem and leaf ranged from 0.01 to 0.02, 0.03 to 0.28, 0.04 to 0.33 and 0.35 to 0.96 per cent respectively.

Table 19. Nutrient uptake by different plant parts during third month (dry weight basis)

Treatment	Root (g/plant)					Rhizome (g/plant)					Pseudostem (g/plant)					Leaf (g/plant)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	0.15	0.01	0.17	0.02	0.03	0.23	0.01	0.36	0.07	0.04	0.51	0.04	0.98	0.08	0.06	1.40	0.07	1.04	0.43	0.20
T_2	0.16	0.01	0.18	0.02	0.03	1.33	0.10	2.52	0.20	0.32	0.77	0.06	1.32	0.20	0.09	2.30	0.10	2.25	0.75	0.27
CD(0.05)	NS	NS	NS	NS	NS	0.42	0.04	0.88	0.08	0.15	NS	NS	NS	0.07	NS	0.66	0.03	0.76	0.21	NS
M_1	0.15	0.01	0.17	0.02	0.03	0.67	0.05	1.26	0.14	0.17	0.64	0.05	1.01	0.16	0.07	1.93	0.09	1.76	0.65	0.23
M_2	0.15	0.01	0.19	0.02	0.03	0.89	0.07	1.62	0.12	0.19	0.65	0.05	1.20	0.12	0.08	1.77	0.08	1.53	0.62	0.23
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S_1	0.15	0.01	0.16	0.01	0.03	0.71	0.05	1.26	0.09	0.14	0.57	0.04	1.06	0.10	0.06	1.73	0.08	1.34	0.60	0.21
S_2	0.16	0.01	0.19	0.02	0.03	0.85	0.07	1.62	0.17	0.22	0.72	0.06	1.24	0.18	0.09	1.97	0.10	1.94	0.58	0.25
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.07	NS	NS	NS	NS	NS	NS
$T_1M_1S_1$	0.16	0.02	0.16	0.02	0.02	0.23	0.01	0.41	0.05	0.03	0.49	0.05	1.04	0.07	0.06	1.40	0.07	1.35	0.49	0.22
$T_1M_1S_2$	0.15	0.01	0.17	0.02	0.03	0.31	0.02	0.52	0.10	0.05	0.59	0.04	1.11	0.11	0.07	1.75	0.08	1.14	0.45	0.21
$T_1M_2S_1$	0.11	0.01	0.14	0.01	0.02	0.12	0.01	0.23	0.03	0.02	0.34	0.03	0.66	0.04	0.05	1.05	0.05	0.69	0.35	0.14
$T_1M_2S_2$	0.17	0.02	0.21	0.02	0.03	0.25	0.01	0.29	0.08	0.06	0.64	0.05	1.13	0.10	0.07	1.38	0.07	0.96	0.42	0.22
$T_2M_1S_1$	0.17	0.02	0.21	0.02	0.04	1.00	0.07	1.60	0.12	0.24	0.67	0.05	1.14	0.12	0.06	1.92	0.09	1.35	0.61	0.21
$T_2M_1S_2$	0.13	0.01	0.13	0.01	0.02	1.14	0.10	2.51	0.28	0.37	0.80	0.07	1.10	0.33	0.11	2.64	0.13	3.17	0.70	0.29
$T_2M_2S_1$	0.16	0.01	0.14	0.01	0.03	1.51	0.10	2.81	0.18	0.29	0.78	0.05	1.39	0.17	0.08	2.54	0.10	1.98	0.96	0.29
$T_2M_2S_2$	0.18	0.02	0.24	0.02	0.03	1.68	0.15	3.15	0.21	0.39	0.85	0.06	1.64	0.16	0.10	2.09	0.10	2.48	0.74	0.84
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.90	NS	NS	NS	NS	NS	NS	NS

4.5.1.5 Magnesium uptake during third month

Magnesium uptake in all the plant parts were more with T_2 level of planting material, M_2 and S_2 levels of fertilizer dose and method of application. The magnesium uptake by root, rhizome and pseudostem varied from 0.02 to 0.04, 0.02 to 0.38 and 0.04 to 0.33 per cent respectively whereas that of leaf was 0.04 to 0.84 per cent. Magnesium uptake by rhizome and leaf was highest in treatment $T_2M_2S_2$.

4.5.2 Nutrient uptake at fifth month

The data presented in Table 20 give an idea about the uptake of the nutrients during the fifth month.

4.5.2.1 Nitogen uptake at fifth month

The nitrogen uptake in the different plant parts were more for sucker derived plants than the tissue culture plants though the effect was not significant. Lower level of fertilizer (M_1) and application of fertilizers in six splits (S_2) resulted in larger values for nutrient uptake in the different parts.

Nitrogen uptake in root, rhizome, pseudostem and leaf were 0.69 to 1.41, 2.5 to 4.72, 3.51 to 5.94 and 8.60 to 15.29 g per plant respectively. Treatment $T_2M_2S_1$ recorded higher values for nitrogen uptake in the rhizome and leaf.

4.5.2.2 Phosphorus uptake at fifth month

Uptake of phosphorus in different parts was more in planting material T_2 (suckers) but T_1 and T_2 did not show significant vartiation in the uptake pattern. M_1 level of fertilizer resulted in higher phosphorus uptake by root, pseudostem and leaves. Application of fertilizers in six splits (S_2) resulted in higher values for phosphorus uptake by different parts.

The phosphorus uptake by root and rhizome was significantly influenced by the treatments under study. Uptake of phosphorus by root, rhizome, pseudostem and leaf ranged from 0.03 to 0.17, 0.10 to 0.46, 0.22 to 0.41 and 0.38 to 0.72 g per plant respectively. The uptake of phosphorus by leaves recorded the highest value and the highest value of 0.72 g per plant was observed in $T_1M_1S_1$.

4.5.2.3 Potassium uptake at fifth month

Potassium uptake by rhizome, pseudostem and leaves were more in sucker-derived plants but uptake by roots was more in tissue culture plants. Lower dose of fertilizer (M_1) and method of application (S_1) resulted in higher values for potassium uptake by different parts of the plant. Potassium uptake by roots and leaves were significantly influenced by the different reatments. With respect to the uptake pattern by roots, treatments $T_1M_1S_2$, $T_1M_2S_1$, $T_2M_1S_1$, $T_2M_2S_1$ and $T_2M_2S_2$ were on par.

Potassium uptake by root, rhizome, psedostem and leaf recorded a value of 1.61 to 4.69, 8.62 to 19.06, 13.36 to 25.17 and 12.31 to 21.03 g per plant respectively.

Table 20. Nutrient uptake by different plant parts during fifth month (dry weight basis)

Treatment	Root (g/plant)					Rhizome (g/plant)					Pseudostem (g/plant)					Leaf (g/plant)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	0.80	0.07	3.02	0.20	0.15	2.87	0.21	10.54	0.78	0.50	4.05	0.31	15.28	1.47	0.49	11.91	0.54	15.68	1.57	1.00
T_2	0.86	0.08	2.67	0.17	0.14	3.84	0.30	14.60	0.97	0.84	4.80	0.32	21.14	1.46	0.43	12.13	0.55	16.80	2.52	0.90
CD(0.05)	NS	NS	NS	NS	NS	NS	0.07	3.97	NS	0.19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M_1	0.90	0.10	3.21	0.22	0.16	3.15	0.23	12.57	0.72	0.64	4.99	0.37	18.78	1.40	0.54	13.10	0.62	16.60	2.07	1.06
M_2	0.76	0.05	2.48	0.15	0.11	3.56	0.28	12.57	1.03	0.70	3.87	0.26	17.64	1.52	0.39	10.94	0.47	15.88	2.02	0.85
CD(0.05)	NS	0.02	NS	0.06	0.04	NS	NS	NS	0.25	NS	NS	0.10	NS	NS	0.12	NS	NS	NS	NS	NS
S_1	0.69	0.06	2.59	0.14	0.11	3.37	0.24	13.84	0.92	0.61	4.58	0.31	18.33	1.29	0.42	11.85	0.52	16.62	2.13	0.93
S_2	0.97	0.09	3.11	0.24	0.17	3.34	0.27	11.30	0.83	0.73	4.28	0.33	18.09	1.63	0.51	12.19	0.57	15.86	1.96	0.98
CD(0.05)	0.25	0.02	NS	0.06	0.04	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$T_1M_1S_1$	0.70	0.09	3.81	0.25	0.14	3.49	0.22	13.99	1.07	0.52	4.86	0.36	15.92	0.94	0.64	12.92	0.72	19.48	1.51	1.14
$T_1M_1S_2$	0.93	0.08	2.74	0.23	0.16	2.52	0.25	8.62	0.76	0.51	3.78	0.41	13.36	2.09	0.60	14.63	0.61	14.30	2.02	1.23
$T_1M_2S_1$	0.69	0.03	2.23	0.13	0.09	2.52	0.10	10.67	0.54	0.46	3.70	0.22	15.15	1.40	0.27	9.84	0.38	13.67	0.93	0.75
$T_1M_2S_2$	0.87	0.07	3.33	0.20	0.18	2.93	0.27	8.87	0.75	0.52	3.87	0.27	16.68	1.44	0.45	10.25	0.47	15.28	1.82	0.90
$T_2M_1S_1$	0.57	0.05	1.61	0.08	0.10	2.74	0.17	11.65	0.30	0.46	5.36	0.35	20.67	1.03	0.33	9.56	0.45	12.31	2.62	0.83
$T_2M_1S_2$	1.41	0.17	4.69	0.33	0.25	3.85	0.28	16.03	0.77	1.07	5.94	0.37	25.17	1.54	0.57	15.29	0.71	20.33	2.13	1.02
$T_2M_2S_1$	0.78	0.06	2.71	0.10	0.11	4.72	0.46	19.06	1.78	1.02	4.40	0.30	21.60	1.80	0.43	15.08	0.54	21.03	3.44	0.98
$T_2M_2S_2$	1.69	0.05	1.68	0.18	0.10	4.06	0.30	11.67	1.06	0.80	3.51	0.27	17.13	1.46	0.40	8.60	0.49	13.51	1.88	0.77
CD(0.05)	NS	0.05	1.61	0.12	0.07	NS	0.13	NS	0.50	0.38	NS	NS	NS	NS	0.24	NS	NS	8.67	NS	NS

Uptake of potassium was highest in pseudostem and this was in treatment $T_2M_1S_2$ (25.17).

4.5.2.4 Calcium uptake at fifth month

The uptake of calcium in different parts of the plant was not significantly influenced by planting material. However, the uptake by rhizome and leaf were more in sucker derived plants. Calcium uptake by rhizome, pseudostem and leaf were more when lower level of fertilizer (M_1) was applied. Application of fertilizers in two splits (S_1) resulted in higher values for calcium uptake by rhizome and leaf whereas six split application (S_2) resulted in higher values for uptake by root and pseudostem.

The calcium uptake by root, rhizome, pseudostem and leaf ranged from 0.08 to 0.33 , 0.30 to 1.78, 0.94 to 2.09 and 0.93 to 3.44 g per plant respectively. Calcium uptake by pseudostem and leaf was not significantly influenced by the different treatments.

4.5.2.5 Magnesium uptake at fifth month

Magnesium uptake by root, pseudostem and leaf were more in planting material, T_1 whereas the uptake by rhizome was more in T_2 (sucker). Uptake by root, pseudostem and leaf were more when M_1 level of fertilizer was applied. Application of fertilizers in six splits (S_2) resulted in higher values for magnesium uptake by the different plant parts.

The uptake of magnesium by root, rhizome and pseudostem was significantly influenced by the different treatments and the values ranged from 0.09 to 0.25, 0.46 to

1.07 and 0.27 to 0.64 g per plant respectively. Magnesium uptake by leaf was highest in $T_1M_1S_2$ (1.23) and lowest in $T_1M_2S_1$ (0.75).

4.5.3 Nutrient uptake at seventh month

The uptake of nutrients by different plant parts during the seventh month was furnished in Table 21.

4.5.3.1 Nitrogen uptake at seventh month

Nitrogen uptake by root, rhizome and leaf was highest in tissue culture plants but the highest value of 6.76 in pseudostem was noticed in sucker progenies (T_2). Uptake of nitrogen by the different plant parts except root was highest when M_1 level of fertilizer was applied. Application of fertilizers in six splits (S_2) recorded higher values for nitrogen uptake by root, rhizome and pseudostem. Highest uptake was noticed in leaf when S_1 level of method of application was followed (25.17 g per plant).

Nitrogen uptake by root, rhizome, pseudostem and leaf ranged from 1.00 to 1.72, 2.78 to 7.02, 4.55 to 6.79 and 19.39 to 32.86 g per plant respectively. The nitrogen uptake by different parts were however not influenced by the treatments.

4.5.3.2 Phosphorus uptake at seventh month

Among the different plant parts, leaf had the highest mean value for phosphorus uptake (1.28 in suckers and 1.62 in tissue culture plants). Phosphorus uptake was more in tissue culture plants (T_1). Higher level of fertilizer (M_2) resulted in larger values for uptake of phosphorus by different parts with exception to that of

pseudostem. Application of fertilizers in two splits (S_1) recorded higher values in rhizome and pseudostem whereas S_2 resulted in higher uptake by root and leaf.

The uptake of phosphorus was not significantly influenced by the treatments in case of rhizome, pseudostem and leaf and the values ranged from 0.21 to 1.16, 0.45 to 0.92 and 1.09 to 1.81 g per plant respectively. Uptake by root was significantly influenced by the different treatments. $T_1M_1S_2$, $T_2M_1S_2$ and $T_2M_2S_1$ recorded the highest value (0.15, 0.14 and 0.14) and these three were on par. Lowest value of 0.06 was observed in $T_1M_1S_1$.

4.5.3.3 Potassium uptake at seventh month

Tissue culture plants recorded higher values for potassium uptake by root, rhizome and leaf. In the case of pseudostem, highest value was noticed in planting material, T_2 (sucker). Application of lower dose of fertilizer (M_1) resulted in higher values for uptake by the different parts. S_1, the lower level of method of application resulted in higher uptake of potassium by pseudostem and leaf whereas S_2 recorded higher values for potassium uptake by root and rhizome.

Potassium uptake by root, rhizome, pseudostem and leaf ranged from 4.64 to 7.55, 15.84 to 26.54, 30.98 to 61.20 and 29.24 to 48.67 g per plant respectively. Potassium uptake by root, pseudostem and leaves were significantly influenced by the different treatments. Highest value of 61.20 is pseudostem was noticed in $T_2M_2S_1$ and that of leaf (48.67) was in $T_1M_1S_2$.

Table 21. Nutrient uptake by different plant parts during seventh month (dry weight basis)

Treatment	Root (g/plant)					Rhizome (g/plant)					Pseudostem (g/plant)					Leaf (g/plant)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	1.33	0.13	6.24	0.32	0.26	4.80	0.57	19.92	2.53	1.42	5.96	0.82	36.14	3.44	1.45	23.79	1.62	40.70	3.70	2.35
T_2	1.30	0.11	5.76	0.20	0.20	4.35	0.29	18.72	1.86	1.03	6.76	0.65	46.17	2.96	1.32	23.34	1.28	35.24	3.95	1.94
CD(0.05)	NS	NS	NS	0.05	0.04	0.41	NS	NS	0.28	0.11	0.57	0.07	2.90	0.30	0.11	NS	0.10	2.01	0.24	0.11
M_1	1.29	0.11	6.20	0.25	0.22	5.15	0.37	21.72	2.58	1.39	7.12	0.75	41.91	4.01	1.59	26.79	1.60	41.58	4.58	2.45
M_2	1.34	0.13	5.80	0.27	0.25	4.00	0.48	16.93	1.80	1.06	5.97	0.72	40.40	2.30	1.18	20.34	1.30	34.36	3.07	1.84
CD(0.05)	NS	0.01	NS	NS	NS	0.41	NS	1.86	0.28	0.11	0.57	NS	NS	0.30	0.11	1.57	0.10	2.01	0.24	0.11
S_1	1.18	0.09	5.98	0.27	0.23	4.13	0.55	17.55	1.95	0.98	6.23	0.77	44.90	3.64	1.50	25.17	1.44	38.34	4.65	2.26
S_2	1.45	0.14	6.03	0.25	0.24	5.03	0.31	21.10	2.44	1.47	6.49	0.70	37.41	2.76	1.28	21.95	1.46	37.60	2.99	2.03
CD(0.05)	0.18	0.01	NS	NS	NS	0.41	NS	1.86	0.28	0.11	NS	NS	2.90	0.30	0.11	1.57	NS	NS	0.24	0.11
$T_1M_1S_1$	1.04	0.06	4.65	0.34	0.20	4.26	0.38	18.17	1.80	1.06	6.79	0.75	39.33	4.89	1.92	27.47	1.74	39.29	5.01	2.53
$T_1M_1S_2$	1.72	0.15	7.55	0.26	0.32	7.02	0.42	26.54	3.53	2.12	6.45	0.83	35.83	3.96	1.44	25.72	1.81	48.67	4.38	2.79
$T_1M_2S_1$	1.18	0.08	6.86	0.31	0.27	2.78	1.16	15.84	1.76	0.68	6.06	0.92	34.94	2.71	1.12	20.36	1.24	33.78	3.26	1.98
$T_1M_2S_2$	1.38	0.19	5.89	0.38	0.27	5.16	0.32	19.16	3.02	1.84	4.55	0.79	34.47	2.20	1.33	21.60	1.71	41.07	2.12	2.10
$T_2M_1S_1$	1.00	0.08	6.59	0.20	0.18	4.78	0.43	20.37	2.59	1.27	6.54	0.71	44.15	4.60	1.66	32.86	1.70	46.96	6.60	2.81
$T_2M_1S_2$	1.42	0.14	6.02	0.22	0.18	4.56	0.27	21.83	2.42	1.11	8.71	0.73	48.34	2.95	1.37	21.09	1.16	31.40	2.32	1.66
$T_2M_2S_1$	1.48	0.14	5.81	0.23	0.27	4.70	0.21	15.84	1.64	0.92	5.54	0.69	61.20	2.35	1.30	20.04	1.09	33.34	3.75	1.73
$T_2M_2S_2$	1.29	0.10	4.64	0.14	0.18	3.37	0.24	16.87	0.79	0.80	6.25	0.45	30.98	1.95	0.97	19.39	1.16	29.24	3.14	1.54
CD(0.05)	NS	0.02	1.38	0.09	NS	NS	NS	NS	NS	NS	NS	NS	5.80	NS	0.22	3.14	NS	4.03	0.49	0.23

4.5.3.4 Calcium uptake at seventh month

Tissue culture plants (T_1) showed significant superiority over T_2 with respect to calcium uptake by root, rhizome and pseudostem. Uptake by leaves was more in suckers (3.95) than in tissue culture plants (3.70). M_1 level of fertilizer dose resulted in larger values for calcium uptake by rhizome, pseudostem and leaf whereas M_2 produced higher values for uptake by root. Application of fertilizers in two splits (S_1) recorded higher values for calcium in root, pseudostem and leaf. Similarly S_2 resulted in higher values in the rhizome. Calcium uptake by root and leaf showed significant variation. The data of calcium uptake by root when analysed showed that $T_1M_2S_2$ (0.38) and $T_1M_1S_1$ (0.34 g/plant) were on par which differed significantly from $T_2M_2S_2$, $T_2M_2S_1$, $T_2M_1S_2$ and $T_2M_1S_1$, the latter four were also on par. The uptake by rhizome, pseudostem and leaf ranged from 0.79 to 3.53, 1.95 to 4.89 and 2.12 to 6.60 g per plant respectively. Calcium uptake by leaves was highest in $T_2M_1S_1$ (6.60) and lowest in $T_1M_2S_2$ (2.12 g/plant).

4.5.3.5 Magnesium uptake at seventh month

Tissue culture planting material, T_1 showed significant superiority in the magnesium uptake by the different plant parts. M_1 level of fertilizer produced higher values for magnesium uptake by all parts except root. Application of fertilizers in two splits (S_1) resulted in larger values for uptake of this nutrient in the root and rhizome whereas S_2 resulted in larger values in the pesudostem and leaf.

Uptake of magnesium by root and rhizome was not significantly influenced by the treatments whereas the treatments differed significantly in the uptake of magnes-

ium by pseudostem and leaf. Magnesium uptake by root, rhizome, psuedostem and leaf were 0.18 to 0.32, 0.68 to 2.12, 0.97 to 1.92 and 1.54 to 2.81 g per plant respectively. Highest value for magnesium uptake was noticed in leaf, in the treatment $T_2M_1S_1$ (2.81 g/plant).

4.5.4 Nutrient uptake at harvest

Data on nutrient uptake at harvest was furnished in Table 22.

4.5.4.1 Nitrogen uptake at harvest

The nitrogen uptake by different plant parts was significantly influenced by the two planting materials, T_1 and T_2. T_1 recorded higher values for nitrogen uptake by root, rhizome, stem and leaf whereas T_2 recorded higher values in case of pseudostem and bunch. Among the different plant parts, uptake was highest in the bunch. Higher dose of fertilizer (M_2) resulted in larger values for uptake by rhizome, stem, leaf and bunch. M_1 recorded higher values for nitrogen uptake by root and pseudostem. Six split application (S_2) recorded higher values in case of pseudostem, stem, leaf and bunch whereas two split application (S_1) recorded higher values for root and rhizome.

The nitrogen uptake by all plant parts except bunch was significantly influenced by the treatments imposed. In root, highest value recorded was in $T_1M_1S_1$ (2.93) which was on par with $T_1M_1S_2$ and $T_1M_2S_2$ and the lowest was observed in $T_2M_2S_2$ (1.05). Uptake by rhizome, pseudostem, leaf and stem ranged from 3.58 to 9.51, 2.49 to 9.26, 13.18 to 61.63 and 6.64 to 12.66 g per plant respectively. The uptake by bunch recorded the highest value in $T_2M_2S_2$ (30.38) and lowest in $T_2M_2S_1$ (15.08) and all the eight treatments were on par.

4.5.4.2 Phosphorus uptake at harvest

Phosphorus uptake by different plant parts recorded highest value in planting material, T_1 (tissue culture plants) with exception to that of bunch, where the highest value was observed in sucker derived plants (1.76). Higher dose of fertilizer (M_2) resulted in higher values for phosphorus uptake by root rhizome, stem, leaf and bunch whereas application of fertilizers in two splits (S_1) recorded higher values in root, rhizomes, leaf and bunch.

Phosphorus uptake by root, rhizome and leaf varied from 0.07 to 0.53, 0.25 to 0.52 and 0.78 to 3.62 g per plant respectively. Pseudostem and stem recorded a value of 0.29 to 0.75 and 0.29 to 0.58 respectively. The uptake of phosphorus by bunch was not significantly influenced by the diferent treatments, the highest value was observed in $T_2M_2S_1$ (2.20) and the lowest in $T_2M_1S_2$ (1.27 g per plant).

4.5.4.3 Potassium uptake at harvest

Tissue cultured plants recorded higher values for potassium uptake in the root, pseudostem, stem, leaf and bunch. Similarly M_2 level of fertilizer resulted in higher values in root, rhizome, stem, leaf and bunch. Application of fertilizer in six splits (S_2) resulted in higher values for potassium uptake by roots, pseudostem, stem and bunch. Two split application (S_1) produced higher values for potassium uptake by rhizome and leaf.

The potassium content of all plant parts except bunch showed significant variation. Potassium uptake was highest in bunch, the mean value recorded was 57.14 ($T_2M_2S_1$) to 108.04 g per plant in $T_2M_2S_2$ and all the treatments were on par.

Table 22. Nutrient uptake by different plant parts at harvest

Treatment	Root (g/plant)					Rhizome (g/plant)					Pseudostem (g/plant)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	2.64	0.26	13.72	0.67	0.65	6.29	0.36	32.08	2.15	1.92	4.78	0.51	49.46	7.44	2.42
T_2	1.29	0.20	4.15	0.32	0.24	5.01	0.36	33.23	2.00	1.50	5.85	0.50	32.60	7.29	1.78
CD(0.05)	0.22	NS	0.63	0.05	0.03	0.36	NS	NS	NS	0.16	0.37	NS	2.73	NS	0.09
M_1	2.04	0.19	7.55	0.68	0.49	4.73	0.30	27.01	1.88	1.50	5.50	0.54	44.99	8.41	2.63
M_2	1.90	0.27	10.32	0.31	0.40	6.56	0.41	38.30	2.26	1.92	5.10	0.47	37.06	6.31	1.57
CD(0.05)	NS	NS	0.63	0.05	0.03	0.36	0.08	1.85	0.18	0.16	0.37	0.06	2.73	1.25	0.09
S_1	2.05	0.27	8.80	0.46	0.47	6.13	0.40	33.77	2.29	1.79	3.87	0.50	40.26	7.98	1.97
S_2	1.88	0.19	9.06	0.53	0.42	5.16	0.31	31.55	1.86	1.63	6.77	0.51	41.80	6.75	2.24
CD(0.05)	NS	NS	NS	0.05	0.03	0.36	0.08	1.85	0.18	NS	0.37	NS	NS	NS	0.09
$T_1M_1S_1$	2.93	0.30	13.61	1.02	0.75	4.96	0.31	30.25	0.70	1.58	5.11	0.71	45.35	6.74	3.21
$T_1M_1S_2$	2.69	0.23	8.86	1.14	0.75	3.58	0.32	21.37	1.90	1.16	5.24	0.29	36.52	9.20	2.45
$T_1M_2S_1$	2.39	0.17	14.07	0.25	0.60	9.51	0.52	41.52	3.50	2.56	4.35	0.58	62.27	10.91	1.88
$T_1M_2S_2$	2.56	0.33	18.33	0.27	0.51	7.10	0.27	35.18	2.49	2.38	4.42	0.45	53.68	2.89	2.14
$T_2M_1S_1$	1.28	0.10	3.31	0.45	0.23	4.52	0.25	18.59	3.17	1.38	3.50	0.42	38.28	6.54	1.67
$T_2M_1S_2$	1.23	0.12	4.41	0.11	0.23	5.86	0.34	37.83	1.77	1.89	8.17	0.75	59.81	11.15	3.20
$T_2M_2S_1$	1.59	0.53	4.24	0.13	0.30	5.53	0.52	44.71	1.77	1.63	2.49	0.30	15.12	7.72	1.11
$T_2M_2S_2$	1.05	0.07	4.64	0.60	0.19	4.08	0.32	31.80	1.29	1.11	9.26	0.54	17.19	3.73	1.16
CD(0.05)	0.43	NS	1.27	0.11	NS	0.72	NS	3.71	0.37	0.32	0.74	0.14	5.47	NS	0.19

Contd.

Table 22. Continued

Treatment	Stem (g/plant)					Leaf (g/plant)					Bunch (g/plant)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	9.94	0.45	13.63	1.27	0.84	36.12	1.93	38.48	15.88	3.35	19.73	1.72	87.51	10.20	3.08
T_2	7.97	0.37	11.10	1.58	0.62	21.76	1.20	26.13	12.24	2.15	21.32	1.76	77.84	11.14	3.18
CD(0.05)	0.68	0.05	1.10	NS	0.09	1.13	0.15	1.40	0.95	0.24	0.99	NS	4.60	0.30	NS
M_1	8.35	0.40	10.82	1.27	0.69	20.16	1.22	27.38	11.46	2.40	19.93	1.60	78.69	10.56	3.17
M_2	9.57	0.42	13.91	1.59	0.77	37.72	1.91	37.23	16.66	3.09	21.12	1.88	86.67	10.77	3.09
CD(0.05)	0.68	NS	1.10	NS	NS	1.13	0.15	1.40	0.95	0.24	0.99	NS	4.60	NS	NS
S_1	8.71	0.38	12.22	1.38	0.71	27.16	1.94	36.40	14.47	2.98	18.81	1.94	76.57	10.19	3.32
S_2	9.20	0.43	12.51	1.48	0.75	30.73	1.19	28.21	13.65	2.51	22.25	1.55	88.77	11.14	2.94
CD(0.05)	NS	NS	NS	NS	NS	1.13	0.15	1.40	NS	0.24	0.99	NS	4.60	0.30	NS
$T_1M_1S_1$	8.69	0.48	13.27	1.02	0.77	26.99	1.96	42.91	13.56	3.19	24.14	2.17	93.15	12.48	3.37
$T_1M_1S_2$	7.51	0.31	7.33	1.03	0.63	13.18	0.78	14.58	8.43	1.37	15.76	1.32	75.43	8.69	2.30
$T_1M_2S_1$	10.92	0.42	15.04	1.03	0.85	42.70	3.62	52.42	23.91	5.08	18.54	1.74	88.68	8.35	3.58
$T_1M_2S_2$	12.66	0.58	18.92	2.04	1.12	61.63	1.37	44.03	17.62	3.76	20.49	1.66	92.79	11.28	3.05
$T_2M_1S_1$	7.17	0.34	9.40	1.62	0.68	17.13	0.85	24.66	10.39	2.08	17.48	1.64	67.33	8.44	4.00
$T_2M_1S_2$	10.02	0.46	13.33	1.40	0.67	23.34	1.28	27.38	13.47	2.97	22.35	1.27	78.84	12.64	3.00
$T_2M_2S_1$	8.06	0.29	11.22	1.83	0.53	21.81	1.33	25.61	10.02	1.58	15.08	2.20	57.14	11.50	2.32
$T_2M_2S_2$	6.64	0.38	10.46	1.46	0.60	24.76	1.32	26.86	15.07	1.95	30.38	1.93	108.04	11.97	3.39
CD(0.05)	1.36	0.11	2.28	NS	NS	2.26	0.30	2.80	NS	0.48	NS	NS	NS	0.59	NS

Potassium uptake by root, rhizome, pseudostem, stem and leaf were 3.31 to 18.33, 18.59 to 44.71, 15.12 to 62.27, 7.33 to 18.92 and 14.58 to 52.42 g per plant respectively.

4.5.4.4 Calcium uptake at harvest

Calcium uptake by root, rhizome, pseudostem and leaf recorded higher values in planting material, T_1 whereas T_2 had higher values for uptake by stem and bunch. Method of application and fertilizer dose significantly influenced the calcium uptake by different plant parts. Higher dose, M_2 resulted in larger values for uptake by rhizome, stem, leaf and bunch. M_1 produced higher values for uptake in case of root and pseudostem. Calcium uptake by different parts showed that uptake by root, stem and bunch were more when the method of application was S_2 (six splits). S_1 resulted in higher values for uptake by rhizome, pseudostem and leaf.

Calcium uptake by root, rhizome and bunch showed significant differences under the influence of the imposed treatments. In case of root, uptake in treatment $T_1M_1S_2$ (1.14) differed statistically from $T_1M_1S_1$ (1.02) and also from $T_2M_2S_2$ (0.60). Lowest value was observed in $T_2M_1S_2$ (0.11) and $T_2M_2S_1$ (0.13). Uptake by pseudostem, stem and leaf ranged from 2.89 to 11.15, 1.02 to 2.14 and 8.43 to 23.91 g per plant respectively and that by the bunch was 8.35 to 12.64 g.

4.5.4.5 Magnesium uptake at harvest

In general the magnesium uptake by different plant parts were more in tissue culture plants and showed significant superiority over sucker progenies as shown in Table 22. Higher dose of fertilizer, M_2 resulted in significant superiority of the

treatment for magnesium uptake by rhizome, stem and leaf but M_1 had higher values for uptake by root, pseudostem and bunch. Two split application (S_1) was found to be more effective since it recorded larger values for uptake by root, rhizome, leaf and bunch whereas fertilizer application in six splits (S_2) had higher values for uptake by pseudostem and stem.

Magnesium uptake by all plant parts except stem and bunch showed significant differences. Uptake by root, rhizome, pseudostem, stem and leaf were 0.19 to 0.75, 1.11 to 2.56, 1.11 to 3.21, 0.53 to 1.12 and 1.37 to 5.08 g per plant respectively and that by bunch was 2.30 to 4.0 g.

4.6 Total nutrient uptake by the plant during different stages of growth (Table 23)

4.6.1 Total nutrient uptake during third month

The data presented in Table 23 revealed that sucker-derived plants absorbed more nitrogen than the tissue culture plants. Higher dose of fertilizer (M_2) when applied in six splits resulted in higher mean value for nitrogen uptake, though both did not show significant variation. The treatment $T_2M_2S_1$ had the highest uptake of fertilizer nitrogen (4.98), though non-significant, was much higher than the lowest value of 1.62 in $T_1M_2S_1$. All the eight treatments were found to be on par when statistically analysed.

It was evident from the data in Table 23, that the sucker-derived plants showed more uptake of phosphorus when the fertilizer was applied in six splits (S_2). The levels of fertilizer applied had no effect in phosphorus uptake by the plant. The phosphorus uptake by plants ranged from 0.09 to 0.34 g per plant, the highest being recorded in $T_2M_2S_2$.

Among the different nutrients, the uptake of potassium recorded the highest mean value. The sucker-derived plants recorded a mean value of 6.26 g per plant which was significantly superior over the tissue culture plants (2.54 g per plant). M_2 level of fertilizer and S_2 level of method of application though recorded higher mean values for potassium uptake, they are statistically on par with the other levels, S_1 and M_1 respectively.

The uptake of potassium by plants was the highest in $T_2M_2S_2$ (7.50 g per plant) and the lowest was in treatment $T_1M_2S_1$ (1.70 g per plant).

Tissue cultured and sucker derived plants showed significant variation with respect to the total uptake of calcium. Sucker derived progenies recorded a value of 1.16 and tissue cultured plants recorded 0.59 g per plant (Table 23).

Levels of fertilizer dose and method of application did not significantly influence the total uptake of calcium by plants. However the higher levels, M_2 and S_2 recorded a mean value of 0.88 and 0.94 g respectively which was more than M_1 and S_1 ,(0.87 and 0.81 g/plant respectively).

Total calcium uptake varied from 0.42 g in $T_1M_2S_1$ to 1.32 g in $T_2M_2S_1$. All the eight treatments were found to be on par when statistically analysed.

The data in Table 23 depicted that there was no significant variation in total uptake of magnesium by plants which received the different levels of fertilizer doses and method of application. But sucker derived plants (T_2) had more magnesium (0.71 g) than the tissue culture plants, T_1 (0.32 g/plant).

Table 23. Effect of treatments on total nutrient uptake by the plant during different stages of growth (dry weight basis)

Treatment	3rd month (g/plant)					5th month (g/plant)					7th month (g/plant)					Harvest (g/plant)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	2.28	0.14	2.54	0.59	0.32	19.62	1.13	44.52	4.02	2.14	35.58	3.14	103.01	9.98	5.49	79.49	5.22	234.87	37.61	12.26
T_2	4.56	0.28	6.26	1.16	0.71	21.64	1.25	55.22	5.12	2.31	35.75	2.32	105.89	8.97	4.49	63.20	4.39	185.04	34.56	9.48
CD(0.05)	1.28	0.09	1.88	0.30	0.24	NS	NS	NS	NS	NS	NS	0.53	NS	0.32	0.12	1.89	0.47	8.06	2.10	0.79
M_1	3.38	0.21	4.28	0.87	0.51	22.13	1.32	51.17	4.41	2.39	40.36	2.84	111.42	11.51	5.65	60.68	4.26	196.43	34.26	10.18
M_2	3.46	0.21	4.53	0.88	0.52	19.13	1.07	48.57	4.73	2.06	31.27	2.62	97.48	7.44	4.32	82.00	5.36	223.48	37.90	10.86
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.26	NS	3.39	0.32	0.12	1.89	0.47	8.06	2.10	NS
S_1	3.16	0.18	3.81	0.81	0.45	20.48	1.12	51.39	4.47	2.07	36.71	2.84	106.78	10.51	4.97	66.70	5.44	208.02	36.76	11.25
S_2	3.69	0.24	4.99	0.94	0.58	20.78	1.26	48.35	4.66	2.38	34.92	2.62	102.12	8.44	5.01	75.99	4.17	211.89	35.41	10.49
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.26	NS	3.39	0.32	NS	1.89	0.47	NS	NS	NS
$T_1M_1S_1$	2.27	0.15	2.95	0.63	0.33	21.97	1.38	53.19	3.76	2.44	39.56	2.92	101.43	12.04	5.70	72.73	5.94	238.49	35.51	12.87
$T_1M_1S_2$	2.80	0.15	2.94	0.67	0.36	21.86	1.35	39.01	5.09	2.50	40.90	3.21	118.59	12.12	6.67	47.95	3.24	164.08	30.39	8.66
$T_1M_2S_1$	1.62	0.09	1.70	0.42	0.23	16.75	0.73	41.72	3.01	1.57	30.38	3.40	91.43	8.04	4.04	88.43	7.05	274.00	47.96	14.54
$T_1M_2S_2$	2.43	0.15	2.59	0.63	0.37	17.92	1.08	44.16	4.21	2.06	32.68	3.01	100.59	7.72	5.54	108.86	4.65	262.92	36.59	12.96
$T_2M_1S_1$	3.76	0.22	4.30	0.87	0.54	18.23	1.02	46.24	4.02	1.72	45.17	2.91	118.06	13.99	5.92	51.09	3.61	161.56	30.61	10.04
$T_2M_1S_2$	4.71	0.30	6.91	1.31	0.79	26.48	1.52	66.23	4.77	2.90	35.79	2.30	107.59	7.90	4.31	70.98	4.23	221.60	40.54	11.96
$T_2M_2S_1$	4.98	0.26	6.31	1.32	0.69	24.98	1.35	64.40	7.11	2.55	31.73	2.12	116.19	7.96	4.23	54.57	5.16	158.03	32.96	7.55
$T_2M_2S_2$	4.80	0.34	7.50	1.13	0.81	16.86	1.11	43.99	4.58	2.06	30.29	1.94	81.73	6.02	3.49	76.17	4.57	198.98	34.12	8.40
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.52	NS	6.79	0.64	NS	3.78	NS	16.13	NS	1.58

Highest value for total uptake of magnesium was observed in $T_2M_2S_2$ (0.81 g) and the lowest in $T_1M_2S_1$ (0.23 g) and all the eight treatments were on par.

4.6.2 Total nutrient uptake during fifth month (Table 23)

Sucker derived plants recorded a higher mean value of 21.64 whereas in tissue culture plants, the total uptake of nitrogen was 19.62 g per plant. M_1 level of fertilizer resulted in higher values for nitrogen uptake (22.13) but did not show significant variation from M_2 (19.13). Similarly method of application showed no significant difference.

The highest value was recorded in $T_2M_1S_2$ (26.48), which is 58 per cent more than the lowest value of 16.75 g/plant in treatment $T_1M_2S_1$.

Phosphorus uptake was not significantly influenced by planting materials, fertilizer doses and method of application enforced. However higher values for uptake was noticed in suckers (T_2), lower dose of fertilizer (M_1) and six split application (S_2), the values being 1.25, 1.32 and 1.26 g per plant respectively. The interaction effect showed that there was no significant diferences between treatments and the highest value was observed in $T_2M_1S_2$ (1.52) and the lowest in $T_1M_2S_1$ (0.73 g/plant).

A perusal of data in Table 23 showed that potassium uptake was more in sucker derived plants (55.22) and also when lower level of fertilizer (M_1) was applied in two splits (S_1). Potassium uptake did not show significant variation under the influence of different treatments. The highest value of 66.23 noticed in $T_2M_1S_2$ was 70 per cent more than the lowest recorded value of 39.01 g/plant in $T_1M_1S_2$.

No significant difference was observed between treatments with respect to the total calcium and magnesium uptake by plant. Sucker derived plants recorded higher values (5.12 and 2.31) for calcium and magnesium. M_2 level of fertilizer resulted in higher values for calcium and magnesium uptake. Application of fertilizers in six splits (S_2) resulted in higher values of 4.66 and 2.38 g/plant for calcium and magnesium respectively.

Treatment $T_1M_1S_2$ and $T_2M_1S_2$ had higher values for calcium (5.09) and magnesium (2.90) uptake respectively. $T_1M_2S_1$ (3.01) recorded lowest value for calcium uptake whereas for magnesium it was in $T_1M_2S_1$ (1.57 g/plant).

4.6.3 Total nutrient uptake during seventh month (Table 23)

Among the different nutrients, potassium uptake was highest followed by nitrogen. Data presented in Table 23 revealed that tissue culture plants recorded higher values for uptake of nitrogen, phosphorus, calcium and magnesium. Potassium uptake was more in sucker derived plants.

Nitrogen uptake by plants ranged from 30.29 to 45.17 g per plant. $T_2M_2S_2$, $T_2M_2S_1$, $T_1M_2S_2$ and $T_1M_2S_1$ were on par differed significantly from $T_2M_1S_2$. Highest value (45.17) was observed in $T_2M_1S_1$. Phosphorus uptake by plants varied from 1.94 to 3.40 and all the treatments were on par, the highest value being noticed in $T_1M_2S_1$ and lowest in $T_2M_2S_2$. The uptake of potassium by plants showed significant difference. $T_1M_1S_2$ which recorded the highest value (118.59) was on par with $T_2M_1S_1$ (118.06) and $T_2M_2S_1$ (116.19) but differed significantly from others. Calcium uptake by plants recorded the highest value in $T_2M_1S_1$ (13.99 g) which differed significantly from $T_2M_2S_2$ which recorded the lowest value of 6.02 g. Magnesium uptake was highest in

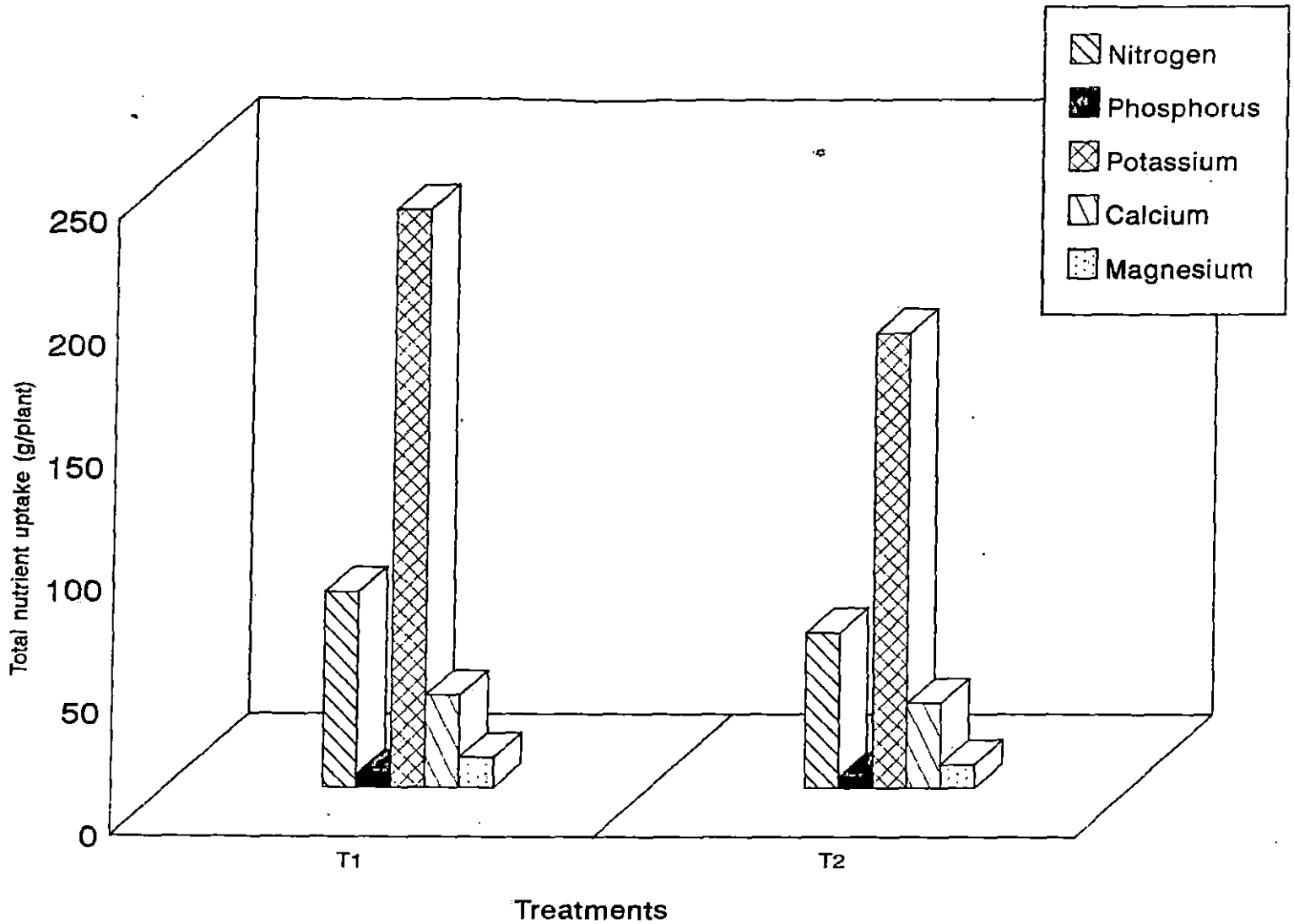


Fig.7. Effect of planting material on total nutrient uptake during harvest

$T_1M_1S_2$ (6.67 g) which was 91 per cent more than the lowest value of 3.49 g in $T_2M_2S_2$ but all the treatments were statistically on par.

4.6.4 Total nutrient uptake during harvest

Uptake of different nutrients by plants were the highest during this stage (Table 23). Tissue culture plants showed significant superiority over the sucker derived ones in the uptake of different nutrients. All nutrients except magnesium recorded the highest value for uptake when M_2 level of fertilizer was applied. Fertilizers when applied in six splits resulted in higher values for nitrogen and potassium uptake whereas two split application (S_1) resulted in higher values for uptake of phosphorus, calcium and magnesium.

The uptake of all nutrients except phosphorus and calcium showed significant difference between treatments. In the uptake of nitrogen, $T_1M_2S_2$ recorded the highest mean value of 108.86 g which differed significantly from $T_1M_2S_1$ (88.43 g). Lowest was recorded in $T_1M_1S_2$ (47.95 g). $T_1M_2S_1$ recorded the highest value (7.05) for phosphorus uptake and the lowest was in $T_1M_1S_2$ (3.24) but all the treatments were on par. Regarding the uptake of potassium, $T_2M_2S_1$ had the lowest value (158.03) and was on par with $T_2M_1S_1$ and $T_1M_1S_2$. $T_1M_2S_1$ differed significantly from other treatments and recorded a value of 274.00 g for potassium uptake. The treatments did not show significant difference in the uptake of calcium and the highest value of 47.96 g was observed in $T_1M_2S_1$ and lowest in $T_2M_1S_1$ (30.61). Magnesium uptake by plants ranged from 7.55 to 14.54 g per plant and the treatments showed significant difference. Highest value of 14.54 g/plant was noticed in $T_1M_2S_1$ and lowest in $T_2M_2S_1$.

Discussion

DISCUSSION

Musa (AAB) 'Nendran' is the most important commercial variety of banana grown in Kerala. More than 30 per cent of the area under banana is occupied by this variety (Farm Information Bureau, 1997). Conventionally Nendran banana is propagated through suckers. As large scale plantings are taken up during September-October months aiming at the harvest during next Onam festival season, farmers are forced to resort to planting with whatever suckers they get. The selection criteria of the suckers are never strictly adhered to due to non-availability of quality suckers of desired ecotype.

In commercial plantings, the uniformity of the planting material is as important as its quality to achieve target yield. The conventional propagation of banana through suckers has the limitation of low rate of multiplication. The *in vitro* propagation of banana has been standardised (Ma and Shii, 1972; Krikorian, 1982; Withers, 1980; Aravindakshan, 1989; Bhaskar, 1991 and Balachandran, 1993) and large scale propagation of selected mother plants are made possible in banana culture world over. The growth and development of tissue culture banana plants have been studied in detail by many workers (Daniells, 1988 and Eckstein and Robinson, 1995). However, information on physiology, growth pattern and nutritional requirement of tissue cultured Nendran banana is scarce. Before being advocating to the large scale cultivation of tissue culture Nendran banana to the farmers the detailed information regarding physiology, growth pattern, manurial requirement etc. are warranted. In the present study the physiology, growth pattern and flowering of tissue culture Nendran banana as compared to the conventional suckers under different manurial levels were studied and the results obtained are discussed here under.

The biometric observations, namely, height and girth recorded during critical stages of growth such as third, fifth, seventh month after planting and at flowering stages have revealed that the treatment effects were significant during the fifth month (Table 1). The growth of the tissue culture plants, though do not significantly differed from suckers, have recorded superior growth as compared to the latter. During the third month after planting, the tissue culture plants recorded a height of 70.08 cm which was on par with the height of 77.25 cm observed in sucker progenies. The effect due to the levels of fertilizer and method of application also did not show significant variation. The tissue culture plants attained comparable height and girth as that of sucker progenies at third month itself showed the increased rate of growth of the tissue culture plants from the very day of field planting as they have well established root system and canopy. Therefore, the growth potential of tissue culture plants is dependent on current assimilation, together with efficient water and nutrient uptake during early stages as compared to the stored food dependent growth of suckers. The present study also is in conformity with the earlier reports of Daniells, 1988; Robinson, 1989; Drew and Smith, 1990; Anil, 1994 and Eckstein and Robinson, 1995.

The height of the plant at fifth month has shown significant increase in tissue culture plants due to the combined effect of fertilizer dose and method of application as evident by the more height of 155 cm recorded in $T_1M_1S_2$ as against 119.33 cm recorded in $T_2M_1S_1$ (Table 2). The increased height attained by tissue culture plants can be attributed to the cumulative effect of favourable external growth factors and intensive management obtained from the day of planting. This trend of increased height of tissue culture plants over that of suckers persisted even during flowering stage.

The girth of the plants has shown significant difference between tissue culture and sucker progenies at all stages of growth except fifth month. Tissue culture plants recorded significantly increased girth over that of suckers. The present study is

in conformity with the works of Daniells, 1988; Robinson, 1989 and Drew and Smith, 1990 wherein increased height of tissue culture plants over suckers were reported and was attributed to the higher growth rate of tissue culture plants. Different levels of fertilizers and method of application did not differ significantly with respect to their effect on girth of plants.

The number of functional leaves at the critical stages of growth have shown (Table 3) that the tissue culture plants had more number of functional leaves at all the stages of growth, over that of sucker progenies. This character was persistent right from planting of tissue culture plants and might have attributed to increased assimilation rate and resultant growth rate. The delayed senescence of leaves and increased production of leaves may be the reason for recording more number of functional leaves in tissue culture banana. This fact has already been reported by Daniells, 1988; Robinson, 1989; Pradeep *et al.*, 1992; Sheela, 1995 and Eckstein and Robinson, 1995.

There was significant difference with respect to total number of leaves produced by the plants due to treatments. The tissue culture banana plants produced more number of leaves (38.63) as compared to 31.44 leaves of sucker progenies. Different levels of fertilizers and method of application could not significantly vary the total number of leaves produced, indicating that this character is genetically determined in each variety/ecotype of banana. With respect to tissue culture banana plants, the leaves right from the first to last is retained and while in sucker progenies 6-8 leaves are destroyed at the time of preparation of suckers for planting. This may be the reason for recording more number of leaves in tissue culture bananas from planting to flowering as compared to suckers belonging to same ecotype. It is evident from the data (Table 3) that 39 leaves are produced by Nedunendran ecotype of banana, before differentiation to flower bud is taking place, in the main apical bud of the plant. All the 39 leaves were

functional and added to the assimilate production in tissue culture plants whereas only 31.44 leaves were available for sucker progenies. The present work is in conformity with the conclusions made by Daniells (1988), Robinson (1989) and Pradeep *et al.* (1992).

The data on the interval between two successive leaves recorded at the critical stages of growth (phyllochrone) has revealed the increased growth rate of tissue culture plants as evidenced by shorter interval for phyllochrone. The significant difference in phyllochrone recorded during the third month can be attributed to the more quantity of fertilizer received in $T_1M_1S_2$ treatment (4.7 days) as compared to 6.7 days in $T_2M_2S_1$. This may be due to the combined effect of superior planting material in combination with the fertilizer received in adequate quantity at required intervals. During fifth month after planting the phyllochrone of tissue culture plants recorded 6.2 days which was significantly shorter than 6.8 days recorded for T_2. The interaction effect of treatments also influenced the phyllochrone. Treatment $T_2M_1S_2$ recorded 7.0 days for phyllochrone while in $T_1M_1S_1$ it was only 5.04 days. On perusal of the data furnished in Table 3, it has been found that the phyllochrone was the least at early vegetative phase, which gradually increased at the transition stage (5-7 months) and again reduced at late transition stage. In tissue culture plants the phyllochrone was shorter as compared to the sucker progenies. Corresponding values for phyllochrone during third, fifth, seventh month and flowering stage of tissue culture plants were 5.16, 6.21, 7.37 and 6.96 days respectively as against 5.89, 6.85, 7.28 and 7.06 days respectively. The reduced phyllochrone during the flowering phase can be attributed to the rapid growth of the flower stalk within the pseudostem to which the leaf petioles are directly attached. This is in conformity with the reports by Eckstein and Robinson (1995). However, the lowest phyllochrone of 6.64 days was recorded at flowering stage by the treatment $T_1M_1S_1$. Phyllochrone was the shortest (6.2 days) in $T_1M_1S_1$ and $T_1M_1S_2$ when averaged over the entire period of leaf production.

The data on leaf area of D-leaf revealed that the differential effects due to planting materials and fertilizer doses was not significant at third, fifth, seventh month after planting and at flowering. However there was significant difference between leaf area of tissue culture plants (0.03 m^2) at 45th days after planting as compared to 0.10 m^2 of sucker progenies (Table 1). The mean leaf area was more (0.87 m^2) during fifth month when fertilizers were applied in six splits. The effect due to treatment combinations at flowering stage differed significantly, $T_2M_2S_1$ recording 1.31 m^2 leaf area as against 1.06 m^2 in $T_2M_1S_1$. The study revealed that the leaf area did not differ significantly between tissue culture plants and suckers. This may be due to the fact that both the plants were of the same ecotype (Nedunendran) and the growing conditions were similar.

The data on leaf characters such as total leaf area, leaf area index (LAI) and leaf area duration (LAD) showed significant difference due to treatments (Table 5). Total leaf area per plant was maximum for sucker derived progeny during third and fifth month after planting being 1.34 m^2 and 8.24 m^2, respectively as against 1.02 and 7.85 m^2, respectively of tissue culture plants. During seventh month and at flowering, the total leaf area was significantly superior for tissue culture plants recording 12.46 and 16.54 m^2, respectively, while it was only 11.32 and 14.40 m^2 for sucker progenies. A similar trend in leaf area index and leaf area duration was observed (Table 5). During the third and fifth month, LAI was 0.34 and 2.06 respectively in sucker progenies whereas it was only 0.26 and 1.96 respectively in tissue culture plants. LAI of 3.12 and 4.13 was recorded for seventh month and flowering stage respectively for tissue culture plants while it was 2.83 and 3.60 respectively in sucker progenies. During the third and fifth, sucker progenies recorded the highest LAD of 10.14 and 71.84 days respectively whereas during the seventh month and flowering stage LAD was highest in tissue culture plants (152.52 and 217.68 days respectively).

Higher LAI and LAD of tissue culture plants was due to the cumulative effect of higher growth rate exhibited by the tissue culture plants during the late vegetative phase. Similar response of increased growth with respect to total number of leaves, total leaf area, LAI and LAD has been reported by Eckstein and Robinson (1995) and he has attributed that the larger leaf area of tissue culture plants along with a vigorous root system has enabled the tissue culture plants to reach full assimilation potential at an earlier stage of development, with a doubling of mean functional leaf area. At flowering stage the combination treatment $T_1M_2S_2$ recorded LAI of 4.41 and LAD of 235.71 days. This treatment was significantly superior in LAI and LAD over other treatments except $T_1M_1S_1$ (4.34 and 214.82 respectively). Tissue culture plants (T_1) supplied with higher levels of fertilizer (M_2) in six splits (S_2) resulted in higher LAI and LAD. This can be due to better response of tissue culture plants to improved management conditions over that of conventional suckers (Eckstein and Robinson, 1995).

The data on crop growth rate (CGR) revealed that the different treatments such as planting material, fertilizer dose and method of application significantly differed at all stages of plant growth. The crop growth rate was maximum for sucker progenies during third and fifth month after planting, while in the subsequent stages the tissue cultured plants recorded higher CGR. At seven months after planting the treatment combination $T_1M_1S_2$ recorded the highest CGR (11.59 g/m²/day) which was 26.3 per cent more than the lowest value recorded by $T_2M_1S_2$ (3.2 g/m²/day). At flowering stage, CGR reduced as compared to the seventh month. However the tissue culture plants receiving higher levels of fertilizer recorded more crop growth rate.

Net Assimilation Rate (NAR) also showed significant difference at all stages of crop growth and tissue culture plants recorded significant superior NAR at third (2.25 g/m²/day), fifth (5.30 g/m²/day) and seventh (3.64 g/m²/day) month over the

sucker propagated ones (Table 6). The increased number of leaves, leaf area and leaf area duration coupled with added inherent advantage of superior mother plant inherited to the tissue culture plants has resulted in the increased crop growth rate and net assimilation rate for tissue culture plants. This inturn has reflected in the dry matter accumulation as evidenced in Tables 7-9.

The sucker derived plants, though recorded higher dry matter accumulation in different plant parts than the tissue culture plants during third and fifth month after planting, the tissue culture plants recorded higher dry matter content during seventh month, flowering and at harvest. The dry matter partitioning to the different plant parts like root, rhizome, pseudostem and leaf as influenced by the treatments are depicted in Fig. 4. Dry matter partitioning (DMP) was maximum to the tune of 46.73 per cent in leaves of tissue culture plants while it was maximum in rhizome (51.11%) in suckers progenies during third month. In tissue culture plants DMP was maximum towards leaf in the fifth and seventh month while at flowering it was maximum in the pseudostem. In sucker progenies from the fifth month onwards, the DMP in rhizome decreased and that in the pseudostem and leaves increased. During seventh month, the maximum value was in leaf (40.16%), followed by pseudostem (33.23%). At flowering the DMP of tissue culture plants was maximum in leaves (35.66%), followed by pseudostem (34.33%), rhizome (23.28%), root (5.15%) and flower bud (2.23%). In sucker progeny also a similar trend was noticed.

The DMP of tissue culture plants was always maximum in leaves at all growth stages showing the increased assimilation potential of the plants over that of suckers. In addition it clearly indicates the strong sink prevalent in growing area namely leaves of the tissue culture plants while in sucker progenies the DMP was maximum in rhizome during early phases, which later changed to leaves and pseudostem. From the fifth month onwards, the increase in DMP of the pseudostem in tissue culture plants

show the physiological preparation of the plant in developing a strong trunk to bear the developing bunch. The better dry matter accumulation at growing point of the tissue culture plant during early growth stages of the plant can be attributed to less competition from the rhizomatous portion of the plant as it does not have a strong sink Similar results were reported by Robinson, 1992a; Robinson and Anderson, 1992 and Anil, 1994.

The total dry matter production at harvest stage recorded significant superiority of tissue culture plants over the sucker progenies (5891.56 g and 5051.03 g respectively (Table 9). The DMP at harvest stage has clearly showed that there exist competition between bunch and developing suckers in tissue culture plants as well as in sucker progenies. In tissue culture plants, 32.44 per cent of dry matter produced was apportioned to the bunch and 15.51 per cent to the developing suckers. While it was to the tune of 40.6 per cent to the bunch and 11.7 per cent to the sucker in sucker propagated plants. It can be noted that the mean number of suckers (8.10) produced by tissue culture plants was more than that of sucker progenies (4.67), that too at a later stage of vegetative growth of the mother plant have resulted in a strong sink in tissue culture plants as compared to that of reduced number of suckers in sucker progenies. The interaction effect of treatments in DMP was significant. The treatment $T_1M_2S_1$ resulted in maximum dry matter production (7087.8 g) followed by $T_1M_2S_2$ (6325.1 g). The least dry matter production was recorded in $T_1M_1S_2$ (4173.5 g) indicating that lower level of fertilizer at increased split are not congenial for better growth of tissue culture plants.

A vigorous root system (Plate 2) originating from juvenile rhizome tissue and the large initial leaf area, leaf number and leaf area duration coupled with ideal external inputs like fertilizer and irrigation ($T_1M_2S_2$) might have enabled the tissue culture plants to reach full assimilation potential at critical stages of development

resulting in increased dry matter production. The selection of ideal mother plant based on yield for *in vitro* multiplication also would have contributed to the preferential DMP towards bunch in tissue culture plants.

The number of days for flowering showed that the tissue culture plants came to flowering 18 days later than the sucker derived progeny, and the difference was statistically significant. This also showed that the planting material T_2, lower level of fertilizer M_1 and 6 split application S_2, resulted in early flowering, being 233.3, 236.2 and 237 days respectively. The interaction effect showed that $T_2M_2S_2$ came to flowering early (227.3 days) as against 245.2 days taken by $T_1M_2S_2$.. Total crop duration was also shortest in $T_2M_2S_2$ (307.7 days) and longest in $T_1M_2S_2$ (334.3 days). The delayed flowering and harvest in tissue culture plants observed in $T_1M_2S_2$ has resulted in increased yield of $T_1M_2S_2$ (12.22 kg per plant) over other treatments while the early flowering and harvest observed in other treatments has resulted in lower yield compared to $T_1M_2S_2$.

Earliness in flowering observed in sucker progeny may be due to the physiological ageing of the suckers at the time of planting as the uniformity of the size of suckers are never indicative of its age. The harvest interval in sucker (T_2) progenies was 13.8 days from the first to last harvest while it was only 16.28 days in tissue culture plants, the difference being negligible. However, the harvest interval observed in the experimental plants are more or less uniform compared to 45-60 days observed in farmer's field. This may be due to the criteria employed during selection of suckers and better management practices adopted. Similarly Daniells (1988) and Pradeep *et al.* (1992) reported late flowering of tissue culture plants.

The effect of treatments on yield and yield attributes differed significantly. The overall mean bunch weight of tissue culture plants was 10.85 kg while that of

suckers were 9.11 kg per plant the former was statistically superior. The combination effect of treatments showed that $T_1M_2S_2$ yielded heaviest bunches (12.22 kg) as compared to 8.54 kg bunches produced by $T_2M_1S_1$. The mean number of hands produced by the plants did not differ significantly due to the treatments and it was 5.19 for suckers and 5.15 for tissue culture plants. The number of fingers per bunch showed significant variation, the tissue culture plants producing more mean number of fingers (48.69) as against 44.25 of sucker progenies while the highest number of fingers per bunch (51.42) was produced by $T_1M_2S_2$. All the other tissue culture treatments irrespective of fertilizer doses and method of application were on par.

The productivity per hectare was maximum for tissue culture plants as compared to the sucker progenies (27.12 and 22.49 t ha^{-1} respectively) which showed an overall increase of 20.59 per cent. The increased level of fertilizer (M_2) resulted in 10.28 per cent increase in yield (26.06 t ha^{-1}) as compared to 23.6 t ha^{-1} in M_1. The effect due to method of application was non-significant. However, the combination effect of treatments showed that $T_1M_2S_2$ resulted in a productivity of 30.54 t ha^{-1} as compared to 24.28 t ha^{-1} from $T_2M_2S_2$. The increase in yield realised from $T_1M_2S_2$ can be attributed to better production potential of tissue culture plants coupled with better management practices.

$T_2M_2S_2$, though recorded highest yield among the other treatments with sucker progenies, was inferior to all the treatments with tissue culture plants. This definitely shows the superiority of tissue culture plants over that of randomly selected sucker progenies. It also shows that the mean productivity per hectare can be increased in a banana plantation by adopting planting with tissue culture plants derived from selected superior mother plants. Similar results of increased yield with tissue culture plants has already been reported by several workers (Daniells, 1988; Pradeep *et al.*, 1992; Robinson and Anderson, 1992 and Sheela, 1995). The increase in yield observed in

tissue culture plants will vary with cultivar, location and management practices. Pradeep *et al.* (1992) reported 39 per cent increase of yield in tissue culture plants over sucker progenies in Nendran banana.

Though the fruit characters (length, girth, weight and volume) did not differ significantly in tissue culture and sucker derived plants (Table 13) the significantly superior yield recorded in tissue culture plants can be pointed out to the presence of more number of fingers (48.69 fingers in tissue culture plants vs. 44.25 in sucker progenies) and increase in weight of individual finger (152.50 g in tissue culture and 142.89 g in suckers). The presence of more number of functional leaves together with the increased leaf area of tissue culture plants resulted in higher photosynthetic efficiency of the tissue culture plants over the sucker propagated ones and hence increase in weight of individual finger and bunch due to the increased carbohydrate accumulation in these parts which is the active sink. Similar reports on fruit characters were mentioned by Ram and Prasad (1989), Drew and Smith (1990) and Kwa and Ganry (1990).

The shelf life or storage life of fruits was significantly higher in tissue culture plants (5.92 days) as against 5.58 days in suckers. Pulp-peel ratio recorded the highest value of 4.03 in $T_2M_2S_2$. The mean value for pulp-peel ratio was more in sucker progenies (3.17) whereas in tissue culture plants it was 3.03. The results of studies on quality of fruits in relation to different treatments furnished in Table 14 showed that the tissue culture plants produced quality fruits than the suckers. Acidity was higher in treatments with tissue culture plants (T_1) and M_1 level of fertilizer. Total soluble solids (TSS), total sugars, reducing and non-reducing sugar content were more in tissue culture plants (29.13°B, 20.53 per cent, 15.39 and 5.15 per cent respectively) as against 28.76°B, 19.75 per cent, 15.27 and 4.48 per cent respectively in sucker

propagated ones. The sugar content was more when higher quatity of fertilizer (M_2) was applied in two splits (S_1).

The increase in sugar in tissue culture planting material source can be attributed to the increased carbohydrate content in fruits, consequent to the higher photsynthetic efficiency of tissue culture plants because of the presence of more number of functional leaves and increased leaf area. Potassium is the element which is the most important in fruit development. The increased sugar contents of fruits receiving higher dose of fertilizer can be due to the increase in rate of potassium supply. This was in conformity with the results reported by Vadivel and Shanmughavelu (1978), Baruah (1986), Baruah and Mohan (1992) and Natesh *et al.* (1993). Ascorbic acid content was more in sucker propagated plants (T_2) which received M_1 level of fertilizer in six splits (S_2).

The growth and development of the plant is dependent upon various external conditions prevalent during the growth phase. Plant nutrition plays a major role in the growth and development of the crop. It is reported that the availability of nutrients at critical stages of growth in sufficient quantities is to be assured for getting maximum yield, especially in banana. The growth and development of plants during the vegetative phase determine the size of bunch, number of hands and fingers in banana as the flower bud differentiation takes place within the plant itself at about 4.5-5.0 months after planting. The availability of major nutrients nitrogen, phosphorus and potassium and secondary elements calcium and magnesium are reported to play a major role in the growth and development of banana (Prevel, 1964 and Lahav, 1973).

In the present study two levels of fertilizer, namely, M_1 (190:115:300 g per plant) and M_2 (300:115:450 g/plant) under two different methods of application, two split (S_1) and six split (S_2) application were given to two different sets of planting

material, viz. tissue culture plants and suckers. The nutrient concentrations in different plant parts during third, fifth and seventh month and at flowering stage were found out. The nutrient uptake by the plants at different stages were also worked out. The objective of the study was to find out the nutrient absorption by the plants as influenced by the different treatments and to find out the best treatment for obtaining maximum yield.

Three months after planting nitrogen content in the root, rhizome and pseudostem was not significantly different whereas in the leaf, it was significantly different. The mean nitrogen content was more in $T_1M_2S_1$ (3.75%) in the leaves, which was significantly superior to other treatments, indicating that more nitrogen was available in the leaves of tissue cultured plants when applied with higher quantity of fertilizers in two splits. This was in conformity with the reports by Murthy *et al.* (1995). The phosphorus concentrations in plant were more or less constant in all treatments irrespective of plant parts and can be attributed to the same level of 115 g P_2O_5 applied to all plants as basal dose. There was significant difference in the potassium content of different plant parts due to the treatments, and the influence was more pronounced in the pseudostem. Potassium content was more in the pseudostem of tissue culture plants (3.96) than the suckers (3.54%). M_2 level of fertilizer when applied in two splits resulted in higher potassium content than other treatments. Calcium and magnesium content in different plants parts also did not show significant difference during third month.

However, the total nutrient uptake by different plant parts at third month after planting worked out on dry weight basis did not show significant variation due to the levels of fertilizer and method of application. The total uptake of nitrogen, phosphorus potassium, calcium and magnesium was higher in the leaves in sucker progenies (2.30, 0.10, 2.25, 0.75 and 0.27 g/plant respectively) as against 1.40, 0.07,

1.04, 0.43 and 0.20 g/plant respectively for tissue culture plants. Eventhough the nutrient concentration recorded higher values for tissue culture plants, the total nutrient uptake was more in sucker progenies because of the higher biomass content of the latter during the third month.

During the fifth month there was no significant difference in nitrogen concentration due to planting material whereas it different significantly due to the higher level of fertilizer applied in more number of splits (Table 16). The nitrogen content in leaves was maximum (3.62) in $T_2M_1S_1$ followed by 3.38 per cent in $T_1M_1S_2$ and 3.22 per cent in $T_1M_2S_2$. Phosphorus content in roots and rhizome significantly differed due to the interaction effect of treatments. The percentage potassium content in different plant parts differed significantly due to the treatments. Tissue culture plants supplied with M_2 level of fertilizer applied in two splits (S_1) resulted in more potassium concentration in all plant parts. This may be due to the higher availability of potassium for the plants. Percentage of potassium was maximum in the pseudostem as compared to other plant parts tested, indicating that the absorption of available potassium and its consequent storage in the pseudostem as reported by Anil, 1994 and Sheela, 1995.

Calcium and magnesium content differed significantly in root, rhizome and pseudostem during fifth month. Sucker supplied with higher level of fertilizer recorded more calcium in the root and rhizome. The total nutrient uptake during fifth month showed no significant difference between planting material treatments. This may be due to the increased nutrient concentration observed in tissue culture plants compensating the reduction in dry matter content. However, it can be noted that five months after planting, the tissue culture plants have attained biomass content equal to that of sucker progenies due to the increased rate of growth obtained under ideal conditions. The fertilizer dose M_2 resulted in constantly higher nutrient status in all plant parts. The nutrient partitioning during fifth month has revealed that all nutrients except potassium

was maximum in leaves while potassium was maximum in pseudostem followed by rhizome. This inturn reflects the higher physiological activity in leaves resulting in more dry matter production.

During the seventh month, the difference in nitrogen content was not significant between treatments in the different plant parts. The overall effect of planting material showed significant difference, the sucker progenies recording more nitrogen in the different parts. The total uptake by different plant parts worked out on dry weight basis showed that tissue cultured plants recorded higher values for all the nutrients due to the increased dry matter content. Though non-significant in difference, the nitrogen content in leaves due to various treatments showed variation from 2.19 in $T_1M_1S_2$ to 2.87 per cent in $T_2M_1S_2$.

Higher level of fertilizers applied resulted in more nutrient content in all plant parts irrespective of the method of application. When the method of application alone was considered there was significant difference in all nutrient concentrations in different plant parts, the more number of splits favouring higher concentration. The total nutrient uptake by different plant parts showed that there was no significant variation in the nitrogen content of root and leaves due to planting material treatment. However, the tissue cultured plants contained all the nutrients in higher quantities than sucker progenies, in all the plant parts tested (Table 23).

Nutrient concentrations in the different plant parts were worked out during harvest stage. It has revealed that the nutrient concentrations in different plant parts showed significant difference due to the effect of planting material. The different levels of nutrients supplied has also resulted in significant variation in nutrient content, the higher level of fertilizer resulted in higher concentration of nutrient in different plant parts. Among the split application levels, though they differed significantly, a common

trend in nutrient concentration in different plant parts was not observed. The combination effect of treatments (Table 23) showed that the total nitrogen content was maximum in $T_1M_2S_2$ (108.86 g per plant). Phosphorus content was highest in $T_1M_2S_1$ (7.05 g per plant). Potassium, calcium and magnesium content was highest in $T_1M_2S_1$ (274.00, 47.96 and 14.54 g/plant respectively). This clearly indicated that tissue culture planting material supplied with higher level of fertilizer showed better response in terms of better absorption of nutrient, finally resulting in more productivity. The increased dry matter production consequent to higher uptake of nutrient has been reported by Sheela and Aravindakshan (1990).

The total uptake of nutrients at critical stages of growth showed a gradual increase in tissue culture plants from vegetative to flowering stage, the incremental increase being significantly superior to that of sucker progenies. The two different levels of fertilizer applied though did not show significant variation in the uptake of nutrients during early vegetative phase resulted in significant variation in the nutrient uptake during seventh month and harvest. This indicates that the availability of nutrients in late vegetative phase has critical role in the total plant nutrient content.

The higher nutrient uptake as influenced by more split application was evident only in harvest stage, indicating that the late application of fertilizers affect bunch development positively. Murthy *et al.* (1995) has also reported similar results of increased productivity due to late application of fertilizers at bud differentiation and shooting stages. The nutrient concentrations increased rapidly upto flowering and declined at fruit harvest. This was in agreement with the earlier reports of Randhawa *et al.*, 1973; Ram and Prasad, 1989 and Natesh *et al.*, 1993.

Summary

SUMMARY

The investigations were carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1996-97 to study the physiology, growth pattern and flowering of tissue culture banana *Musa* (AAB) 'Nendran'. During the course of the experiment plant growth, yield and quality of the produce under the influence of different treatments enforced were critically observed. The salient findings of the investigations are summarised below.

From the fifth month onwards tissue culture plants recorded higher values for plant height. Tissue culture plants were 329.97 cm at flowering stage whereas the sucker progenies measured 314.05 cm for plant height. Treatment $T_1M_2S_2$ recorded the highest value of 337.08 cm.

Sucker derived plants recorded mean value of 53.88 cm for girth and tissue culture plants recorded 57.98 cm. Treatment combinations did not affect plant girth significantly.

During the early stages of plant growth, there was no significant difference between the treatments with respect to the number of functional leaves present. The number of functional leaves and the total number of leaves were more for tissue culture plants than sucker progenies. Manurial doses and methods of application also did not significantly influence the leaf number.

Tissue culture plants had shorter time interval between the initiation of two successive leaves at all stages of growth.

The leaf area of D-leaf was more in sucker progenies at all stages except at flowering. But the total leaf area was more for tissue culture plants than suckers from the seventh month onwards.

Sucker derived plants had higher values for leaf area index (LAI) and leaf area duration (LAD) during the third and fifth month but at seventh month and at flowering stage tissue cultured plants showed significant superiority over the sucker propagated ones.

Crop growth rate (CGR) and net assimilation rate (NAR) was influenced significantly by the different treatments (planting material, fertilizer dose and method of application) at all stages of growth. However, the treatment combination did not differ significantly at flowering stage. $T_1M_2S_1$ recorded the highest value for CGR and NAR during flowering stage.

Observations on dry matter partitioning (DMP) showed that the dry weight of different plant parts did not show significant variation during third and fifth month. At harvest stage the dry matter content in different plant parts as well as the whole plant was more in tissue culture plants than the sucker derived ones.

Sucker progenies produced the first sucker 91.6 days after planting whereas for this the tissue culture plants took 140.7 days. In contrary, the number of suckers at flowering and harvest were more for tissue culture plants.

The time taken for bunch emergence, bunch maturity and consequently the crop duration were less in suckers than the tissue culture plants. Treatment $T_2M_2S_2$ recorded early flowering and harvest of bunches.

Leaves had higher concentration of nutrients than the other parts during the critical stages of growth. But potassium content showed much variation between the different plant parts tested.

Nutrient uptake pattern by different plant parts on dry weight basis showed that the uptake of all nutrients was highest in leaves since the nutrient concentration and dry weight was more in leaves. However, at harvest stage the uptake of potassium was highest in the bunch and that too in tissue culture plants.

The total nutrient uptake by the plant was more in sucker progenies during the third and fifth month. But during the later stages of growth, total nutrient uptake was more in tissue culture plants. In general manurial doses and methods of application did not significantly influence the total uptake of nutrients by plants.

The mean length, girth, weight and volume of D-finger did not show significant superiority between the treatments. Tissue culture plants had higher mean values for these characters. Higher level of fertilizer (M_2) and two split application (S_1) recorded higher values for D-finger characters. Shelf life was more in tissue culture plants whereas pulp-peel ratio was more in sucker derived progenies.

Tissue cultured plants produced sweeter fruits which was indicated from its higher values reported for total, reducing and non-reducing sugars. Ascorbic acid content was more in sucker derived plants. However, planting material, manurial doses and methods of application did not significantly influence these characters.

Bunch weight was significantly superior in tissue culture plants than sucker progenies, with higher level of fertilizer (M_2) and six split application (S_2). Treatment

$T_1M_2S_2$ recorded the highest value for bunch weight. Among the different treatments with suckers, bunch weight was highest in $T_2M_2S_2$.

The number of hands were more in sucker derived plants whereas the number of fingers per bunch was more in tissue culture plants.

The total bunch yield per hectare was more for tissue culture plants than suckers. Higher fertilizer dose (M_2) when applied in six splits (S_2) recorded the maximum value for bunch yield per hectare. Treatment $T_1M_2S_2$ recorded the highest tonnage.

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*Originals not seen

Appendix

APPENDIX-1

Weather data at monthly intervals during the experimental period (July 1996 to July 1997)

Months	Rainfall (mm)	Temperature °C		Relative humidity (%)	Sunshine (hrs)	Wind speed (km/h)
		Maximum	Minimum			
July 1996	588.7	28.8	23.1	89.5	2.7	2.7
August	310.0	29.1	23.6	86.5	3.7	3.0
September	391.6	29.2	23.7	84.0	4.3	2.7
October	219.3	30.1	22.9	81.5	6.0	2.0
November	22.1	31.5	23.6	71.5	7.1	3.7
December	60.4	30.5	21.8	67.5	6.8	6.4
January 1997	0.0	32.0	22.9	61.5	9.6	6.9
February	0.0	33.9	21.8	60.5	9.3	3.9
March	0.0	35.7	24.0	59.5	9.6	4.0
April	8.2	35.2	24.5	66.5	9.6	3.3
May	63.0	34.4	24.5	72.0	6.7	3.3
June	720.5	31.2	23.0	82.0	5.9	2.7
July	979.2	28.6	21.8	90.0	1.9	4.6

PHYSIOLOGY, GROWTH PATTERN AND FLOWERING OF TISSUE CULTURE BANANA *MUSA* (AAB) 'NENDRAN'

By

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ABSTRACT OF A THESIS

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ABSTRACT

The study entitled "Physiology, growth pattern and flowering of tissue culture banana *Musa* (AAB) 'Nendran'" was conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1996-97 inorder to compare the performance of tissue culture plants against the conventional suckers under varied fertilizer doses and methods of application, to ascertain superiority, if any, of the former over the latter.

During the early stages of growth, the vegetative characters recorded higher values for the sucker derived plants whereas during the later periods, the plant height, girth, number of functional leaves per plant and the total number of leaves were more in tissue culture plants.

Leaf area of D-leaf, total leaf area, leaf area index and leaf area duration showed significant superiority of the tissue culture plants over the sucker progenies. Crop growth rate and net assimilation rate was significantly influenced by the different treatments and they recorded higher values for the tissue culture plants. The time taken for bunch emergence and duration of the crop was less in sucker progenies. The number of suckers per plant was more in tissue culture plants.

Dry matter production by different plant parts as well as by the whole plant was higher in tissue culture plants and they produced heavier bunches than sucker progenies. However in both the planting materials, higher levels of fertilizer dose (M_2) and method of application (S_2) recorded superiority with respect to bunch weight per plant and bunch yield per hectare. Fruit quality was also more in tissue culture plants.

The nutrient concentration and nutrient uptake were significantly more in leaves during the critical stages of growth. The total nutrient uptake by the plant recorded higher values for the tissue culture plants. Manurial doses and methods of application did not significantly influence the total uptake of nutrients by plants.

The results of the study undoubtedly proved the superiority of tissue culture plants where in the highest yield of 12.22 kg obtained in $T_1M_2S_2$ was 43 per cent more than the lowest of 8.54 kg in $T_2M_1S_1$. Application of higher dose of fertilizers (300:115:450 g NPK per plant) recorded 9.0 per cent increase in yield over the recommended dose of 190:115:300 g NPK per plant. Percentage yield increase was 5.77 when six split application was resorted to instead of two splits.