WATER AND FERTILIZER USE EFFICIENCY IN DRIP FERTIGATED BANANA *Musa* (AAB) 'NENDRAN'

By

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DECLARATION

I hereby declare that this thesis entitled **Water and fertilizer use efficiency in drip fertigated 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 or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **Water and fertilizer use efficiency in drip fertigated banana *Musa* (AAB) 'Nendran'** is a record of research work done independently by **Ms. Deepa Thomas** 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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INTRODUCTION

1. INTRODUCTION

Banana is the succulent annual fruit crop of the tropics. Bestowed with a three-fold higher production capability compared to other fruit crops, it accounts for 33 per cent of the fruits produced in the country. 'Nendran' (AAB) is the intensively cultivated group of banana in Kerala. With multiple uses ranging from that of a valued food for infants and invalids, to culinary and table purposes as well as diverse processed products, Nendran occupies an integral part of the homesteads and way of life in the state. Inspite of this its mean yield remains very low at around 5.6 kg plant^{-1} (Farm Information Bureau, 2000), though instances of 15 to 20 kg yield per plant is not uncommon. Management inadequacies alone shall be the cause of this low yields as the vegetative propagation precludes interferences of genetic degradation in the yield process. The situation necessitates a reappraisal, as well as revised formulation of the present production technology of this crop.

Management aims at providing a support system to facilitate optimum growth, development and yield process. Basic components of any management system are nutrients and water for any crop and the success of the management system should be evaluated not merely on yields in relation to the level of components but also on the efficiency of each unit of component. Efficiency is actually governed not merely by the levels of application but also by the incidental losses, extent of absorption and utilisation and the factors affecting them as well as source specific characteristics.

Yield expression normally cannot directly be an exclusive function of applied inputs alone as the process of growth is dependent on several native components. Yield in banana is naturally a terminal product of interactions of these components. Reappraisal of the present system to formulate newer technology requires detailed investigations on the direct and interaction effects among management components. Being an annual crop this will have to be studied on temporal basis. Variability induction through variation in levels, methods and time of application is the means available for the purpose.

Supplemental application of water is a pre-requisite for banana in the monsoonic tract of Kerala characterised by alternating seasonal wet and dry spells of seven and five months. Conventional irrigation characterised by heavy doses at wider intervals lead to losses and reduced efficiency on one side and is liable to unfavourable elemental releases through reduced state of rhizosphere environment. Drip irrigation at surface or subsurface areas has the advantages of minimising these twin disadvantages of conventional irrigation. It has also the advantage of regulated temporal supply of nutrients in tune with demand of growth (FAI, 1995) which incidentally will reduce losses, physical and chemical inactivation as well as possible side effects of fertilizer elements. These aspects need investigation.

Adequacy for growth and compensation of removal from soil are the two pivots on which nutritional management is based. Conventional system of fertilizer application in few splits may fail to meet the requirement throughout the growth phases through problems of losses or inactivation. It is also likely to aggravate the release of native elements like iron and manganese which may suppress the effect of applied elements. Actual requirements to meet the two objectives shall be arrived at only through a method of near continuous system of application. Drip fertigation opened up possibilities for this, but crop response to such a management is yet to be known.

Combining high crop productivity and input use efficiency therefore rests on integrating the applied inputs with crop demand on one side and minimising induced ineffectiveness through lateral effects on the other. Development technology based on soil plant system characterization and response behaviour of the crop to inputs is the answer for this. This constituted the objective of the present study. The specific objectives intended to be studied in the context shall be listed as follows:

1. to estimate water and fertilizer use efficiency in drip fertigated banana var. Nendran.
2. to study the dynamics of nutrients applied through drip fertigation and conventional methods.
3. to study the rooting pattern of banana as influenced by the methods of irrigation and fertilizer application.
4. to study the loss of nutrients beyond root zone under excess water supply

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana is the most important tropical fruit crop of India. The cultivar Nendran (AAB) is grown commercially under various agroclimatic situations in Kerala for local as well as export marketing. This variety is known for its greater response to nutrients and water. a stress due to both reduce the yield drastically. Being scarce commodities. the efficient use of these resources are imperative.

The introduction of simultaneous micro irrigation and fertilization can enhance use efficiency of water and fertilizers by the crop and help to maintain a soil water nutrient environment favourable for higher productivity.

Results of the past studies pertinent to water and fertilizer management of banana particularly Nendran (AAB) are reviewed in this chapter. Attention is focused on crop response. water and nutrient distribution in soil and suitability to different nutrient sources under drip fertigation.

2.1 Growth and development of banana

Banana var. Nendran (AAB) is a herbaceous annual crop. The average duration of the crop extended to about 315 days of which the vegetative growth phase lasted for 233 days in a laterite belt of humid tropical environment (Mavelil, 1997).

2.1.1 Shoot

In the vegetative phase. leaves are formed in spiral succession from the outside of the meristem of the rhizome (Purseglove, 1972). Generally one leaf per week may be taken as rate of leaf production (Shanmugavelu *et al.*, 1992). Pradeep *et al.* (1992) reported that in the early vegetative phase, the leaf production was 5.0-7.0 per month, whereas it was 3.8-4.0 in the late vegetative phase. Mavelil (1997) observed that an average of 31.4 leaves were produced in Nendran prior to bunch emergence and the leaf production was not influenced by varying fertilizer levels.

The centre of meristem of the rhizome gets transformed to the inflorescence. In Nendran, the vegetative bud travelled upto a height of 26 cm in the transitional stage and after differentiation, the bunch ascended swiftly and shot out (Anbazhagan and Shanmugavelu, 1981).

2.1.2 Root

Banana, which is propagated vegetatively has got adventitious root system. According to Skutch (1937), these roots arise in groups of four each, at the junction between the central cylinder and the cortex of the corm. The secondary laterals originate in the protoxylem near the root tip.

The studies conducted by Shobhana (1985) using ^{32}P showed that Nendran banana has a shallow root system with the bulk of roots confined to the top 15 cm soil forming a dense surface mat. The roots were more active within 30 cm depth and 20 cm lateral distance. In another crop geometry study conducted by Ashokan (1986), it was revealed that in the cultivar Palayankodan (AAB), the active roots were distributed upto a radial distance of 30 to 35 cm and to a depth of 25 to 30 cm, at the peak vegetative phase.

Root distribution and soil moisture content was found to be related. The development of surface roots under irrigated condition and an extensive root system under unirrigated condition have been noticed by Krishnan and Shanmugavelu (1980) in the cultivar Robusta (AAA). The crop was irrigated when the available soil moisture was depleted by 20, 40 and 60 per cent. They observed a maximum vertical root spread of 324 cm at harvest under high soil moisture depletion levels. Lateral and vertical root spreads also increased with the decreasing available soil moisture.

Shobhana (1985) while working in Nendran banana under rainfed and irrigated conditions observed that the number, length, diameter and dry weight of roots were greater when grown under rainfed conditions than under irrigated conditions. Increase in length of roots was observed upto flowering, the rate of elongation being faster under rainfed conditions.

Root activity studies using ^{32}P indicated that maximum root activity of Nendran banana under irrigated conditions was at 5 cm depth and at 20 cm lateral distance whereas in rainfed crop, it was observed at 30 cm depth and 20 cm away from the plant. It was also reported that roots tended to be concentrated at a depth of 15-30 cm in rainfed condition. But under irrigated condition, the active root distribution was more uniform upto a depth of 60 cm (Shobhana *et al.*, 1989).

Eapen (1994) observed more number of roots in rainfed banana than in irrigated banana. Irrigated banana tended to develop a spreading root system while rainfed banana developed a compact root system.

2.2 Nutrient Management in banana

The banana plant is well known to be extremely demanding of nutrients and therefore addition of mineral fertilizers is of importance for its cultivation (Shanmugavelu *et al.*, 1992).

2.2.1 Rate and time of fertilizer application

Several suggestions are made with regard to the time and quantity of application of fertilizers to banana. Timing of fertilizer application on plant crop was studied by Obeifuna (1984) and it was shown that early applications were critical. When first application was delayed by three months irrecoverable nutritional stress was created and a delay of six months reduced the yield by 42 per cent despite normal fertilization practices after the delay.

Nair *et al.* (1990) studied the effect of NPK and their split application on the yield of Nendran banana grown in rice fields. Investigations revealed that application of 400 g N and 600 g K_2O per plant in six splits resulted in higher yields.

Natesh *et al.* (1993) reported that application of 190-115-300 g NPK per plant in four splits (2, 4, 6 and 8 MAP) was most effective under humid tropical conditions of Kerala. 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 was also found that fertilizer application exceeding six splits had not resulted in any additional yield advantage.

KAU (1996) recommended 190-115-300 g NPK per plant in six splits. the splits being 40-65-60 g NPK at planting. 30-50-60 g NPK at one month after planting (MAP) and 30-60 g NK each at second. fourth and fifth month after planting and just after complete emergence of bunch. In a later study. dose of 380-115-600 g NPK per plant in six splits was found to produce an yield of 38.95 t ha^{-1} which was 47.6 per cent increase over that of the plants receiving 190-115-300 g NPK (KAU. 1997).

2.2.2 Leaf nutrient standards

Based on the NPK concentrations on third. fifth and seventh leaf. Hewitt (1955) suggested that third youngest leaf should be considered as the index leaf (D-leaf) and sampled to estimate the nutrient status. He further registered that 2.6 per cent N. 0.45 per cent P_2O_5 and 3.3 per cent K_2O were the critical concentrations and that no increase in yield could be obtained by additional application of nutrients. Lahav and Turner (1983) reported that the critical concentrations of nutrients in the dry matter of D-leaf lamina were 2.6. 0.2 and 3.0 per cent N. P and K. respectively and 0.5 per cent Ca. 0.3 per cent Mg and 0.23 per cent sulphur.

Kulasekharan (1993) obtained maximum yield for Robusta, when the nutrient contents in the leaf were 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.

Natesh (1987) reported that nutrient concentrations were 2.16 per cent N. 0.67 per cent P and 3.98 per cent K at late vegetative phase and 3.82 per cent N, 0.67 per cent P and 3.18 per cent K at shooting stage in the index leaf of Nendran banana when 190-115-300 g NPK per plant was applied.

However, Mavelil (1997) observed a leaf nutrient content of 3.13, 0.15, 4.17, 0.44 and 0.21 per cent of N, P, K, Ca and Mg respectively at 5 MAP and 2.87, 0.16, 4.27, 0.32, 0.23 per cent N, P, K, Ca and Mg respectively at 7 MAP with a soil application of 190-115-300 g NPK which was found optimum for high yield in Nendran banana.

2.2.3 Growth and yield as affected by nutrient application

The direct effects of fertilizers are first manifested on the morphology and growth, which inturn reflect on the yield.

Mathew (1980) indicated that increasing level of nitrogen helped in increasing height and girth of pseudostem and petiole length. Garriga *et al.* (1989) obtained highest psuedostem girth with an application of 150g nitrogen per plant.

Higher levels of N application produced higher number of hands (Kohli *et al.*, 1981), number of fruits per bunch, fruit length and fruit width and finally the bunch weight (Garriga *et al.*, 1989). But higher levels of nitrogen was found to delay flowering (Ram and Prasad, 1989).

The effect of phosphorus on growth and yield of banana was not much conspicuous as in the case of nitrogen and potassium (Martin-Prevel, 1969 and Kulasekharan, 1993).

A significant positive correlation between potassium content and height and girth of pseudostem, number of functional leaves and total dry matter was established by many workers (Sheela, 1982; George, 1994; Sheela, 1995 and Thomas, 1998).

Sheela (1982) indicated that K application enhanced ripening of bunches. Obeifuna (1984) observed that the application of K at 300 g per plant at 4-5 MAP increased the bunch weight, number of marketable fingers and finger weight. However, super optimal K application decreased the yield.

Yadav *et al.* (1988) reported that the rate and frequency of potassium application had no effect on growth characters, but significantly affected the yield. Application of K also helped in improving the yield attributing characters like weight of second hand, bunch weight and finger characters (Baruah and Mohan, 1991) and in improving quality and shelf life of fruits (Kulasekharan, 1993). Thomas (1998) obtained increased number of fingers and bunch weight when 300 g K_2O per plant was applied and suggested that a fertilizer recommendation of 190-115-300 g NPK per plant could still be reduced by the addition of 17-20 kg organic manure per plant.

2.2.4 NPK interaction

Fertilizer experiments on banana conducted over a 13 year period in Jamaica revealed that economic response to fertilization could be expected only from the combined use of N, P and K (Butler, 1960).

Natesh *et al.* (1993) noticed that the morphological characters were not significantly influenced by the NPK fertilizer level or its application in split doses, but the bunch weight, weight of D-hand and D-fingers showed significant variation. Similarly Mavelil (1997) also reported that the height and girth of pseudostem and number of functional leaves were not affected by the doses of fertilizers tried, but the yield varied significantly.

2.2.5 Nutrient uptake and distribution in banana

Nutrients within a banana plantation are distributed throughout the soil and in the roots, rhizome, suckers, pseudostem, leaves and bunch. The nutrients in each site and the rate at which they move around are important in the nutrition of bananas (Robinson, 1996).

Burgohain and Shanmugavelu (1986) noted a sharp increase in nitrogen uptake from 16.47 kg ha^{-1} at sucker stage to 310.82 kg ha^{-1} at shooting which later declined to 267.53 kg ha^{-1} at harvest in banana Vayalvazhai (AAB). P uptake was 2.5, 60.68 and 55.6 kg ha^{-1} at sucker, shot and harvest stage respectively. There was a massive uptake of K by the banana plant which increased from 28.29 kg ha^{-1} at sucker stage to 879.91 kg ha^{-1} at harvest.

Sheela and Aravindakshan (1990) also obtained progressive increase in the uptake of nitrogen till shooting irrespective of the amount of potassium applied, but between flowering and harvest there was a decline. Among the nutrients applied, potassium uptake was the highest compared to nitrogen and phosphorus.

Kulasekharan (1993) reported that 320 kg N, 23 kg P and 925 kg K were removed by 50 t crop in one hectare.

Mavelil (1997) reported the uptake of nutrients increased with time and the highest uptake was recorded during harvest. The plant accumulated 70.97, 4.22, 221.6, 40.54, 11.96 g N, P, K, Ca and Mg per plant respectively at a fertilizer dose of 190-115-300 g NPK per plant in six splits.

Distribution of nutrients in different plant parts in different growth stages of banana var. Poovan (AAB) was studied by Balakrishnan (1980). During initial stages (fifth leaf stage) corm was found to be the largest repository of the nutrients. During fifteenth leaf stage pseudostem was the largest storehouse. In the flowering and harvest stages also pseudostem continued to be the largest reservoir of nutrients. The share of fruits to total nutrient content at harvest stage was also high.

But Thomas (1998) observed highest accumulation of nitrogen and calcium in leaves and phosphorus, potassium and magnesium in rhizome of banana at the harvest stage.

2.3 Water management in banana

Banana is a herbaceous plant which requires moist conditions for optimum growth and yield (Samson, 1980). Soil water deficits during cropping period adversely affected the growth of banana despite favourable temperature, relative humidity and sunshine hours (Bhattacharya and Rao, 1985).

2.3.1 Water requirement of banana

The evaporative demands of banana are very high and the estimates of the annual Et of banana vary from 1200 mm (Simmonds, 1966) to 1560 mm (Bhattacharya and Rao, 1985) and to 2690 mm (Young *et al.*, 1985). The widespread variations reported in the literature on the Et of bananas relative to the evaporation from Class A Pan (Eo) suggest that water requirement vary under different locality and seasonal conditions. Hence a standard summer crop coefficient for irrigation cannot be recommended (Robinson and Alberts, 1986). Stover and Simmonds (1987) stated that a tropical banana plantation could consume 900 to 1800 mm water in ten months from planting to harvest. This amounts to a consumptive use of three to six mm day^{-1} depending upon the leaf area, temperature, humidity, radiation and wind.

Krishnakumary *et al.* (1995) reported that increase in irrigation water levels from 100 CPE to 20 CPE (Cumulative Pan Evaporation) when irrigated to 20 mm depth enhanced growth, flowering and yield of Nendran banana.

As per package of practices recommendations of Kerala Agricultural University (KAU, 1996), 10 mm (40 litres) of water per plant once in two days during summer ensure higher bunch yield in Kerala.

2.3.2 Response of banana to moisture stress

Robinson and Alberts (1986) studied the growth of banana cultivar Williams at different Et/Eo levels (0.25, 0.5 and 0.75) and observed that at the lowest Et/Eo, a stress induced growth reduction occurred during the hot summer months. Though there was no difference in the total leaf production and leaf emergence rates between treatments, a substantial reduction was noticed in plant height, stem circumference, leaf length and leaf area index suggesting that the cell division and cell expansion might have been reduced at lower levels.

Robinson and Bower (1987) demonstrated that peak transpiration rate of banana leaves was reduced by about 15 per cent and 40 per cent at soil moisture potentials of 25 and 50 kPa indicating that bananas become sensitive to soil moisture potentials as low as 20 kPa.

Holder and Gumbs (1982) concluded that adequate irrigation between 120 and 180 days of growth incorporating flower initiation was essential for higher yields in the tropics. A higher water supply just prior to flower initiation increased subsequent growth and bunch mass, boosting yield by 33 per cent (Robinson and Alberts, 1986). Stress at flower initiation reduced the number of hands and fingers and thus sensitivity to an increasing water stress was greater at flower initiation stage than at fruit filling stage.

Watson and Daniells (1983) showed that water stress during bunch development caused reduced finger size as well as shortened green life and uneven fruit ripening. Hegde and Srinivas (1989) reported that decreasing frequency of irrigation delayed flowering and decreased nutrient uptake except potassium.

2.3.3 Methods of irrigation

Surface or basin irrigation is the conventional method of irrigation for banana and is still practiced universally.

New systems for applying water to bananas more effectively include sprinklers and micro-irrigation systems like microjet and drip. Though sprinkler is relatively inexpensive and improve the microclimate of the plantation, it does have several disadvantages like susceptibility to wind and evaporative losses, poor water distribution and unsuitability for tall banana cultivars (Robinson, 1996).

2.3.3.1 The concept of drip irrigation

Water is fast becoming an economically scarce resource in many areas of the world (Gregory, 1984). Micro irrigation techniques are, therefore, suggested to improve irrigation efficiency of crops (Batchelor *et al.*, 1996).

Drip irrigation ensures precise, slow application of water in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices called emitters located at selected points along water delivery lines (Reddi and Reddy, 1995). The drip emitter is generally a water energy reducer which dissipates the energy of the water flowing through it and thus reduces the flow rate to a given discharge (Bucks *et al.*, 1982).

In drip irrigation plants are irrigated frequently and with a volume of water approaching the consumptive use of the plants, directly to the root zone, thereby minimizing such conventional losses as deep percolation, run off and soil water evaporation (Michael, 1992). Reddi and Reddy (1995) also opined that as the plant does not experience any moisture stress and the loss of dissolved nutrients is reduced considerably, the plant can grow well and is likely to give higher yields.

When the emitters are placed below the soil, the system is termed as subsurface drip irrigation system (CWRDM, 1997). Subsurface irrigation was a concept so far, but revolutionary changes occurring in plasticulture, greatly improved its possibility.

2.3.3.2 Efficiency of drip irrigation

In many banana growing countries, there is a trend towards micro-irrigation systems instead of sprinklers. Drip irrigation is now almost universally adopted. In Israel, drip was reported to be the most successful system for bananas, especially when water is applied very frequently (Lahav and Kalmar, 1981). In Hawai Young *et al.* (1985) stated that drip irrigation of bananas produced double the yield than from a well managed sprinkler-irrigated plantation. Hegde and Srinivas (1989) demonstrated in India that drip irrigation was superior to basin irrigation in all aspects of growth, yield and water use efficiency.

Better efficiency of drip irrigation when compared to basin irrigation was reported by many researchers. Sivanappan and Padmakumari (1983) obtained

76 per cent saving of irrigation water in drip irrigation while Cevik *et al.* (1988) obtained a water saving of 50 per cent. Hegde and Srinivas (1990) could obtain optimum evaporation replenishment at 60 per cent pan evaporation for drip while it was at 80 per cent for basin irrigation. The field water use efficiency at this optimum replenishment was found to be 64 and 54 kg ha^{-1} cm^{-1} for drip and basin irrigation, respectively. The partial wetting of the soil and control of water penetration achieved through drip irrigation might have helped in increasing irrigation efficiency (Bravdo and Proebsting, 1993).

On comparing different methods of irrigation, Upadhyay (1995) obtained an yield increase of 52 per cent in banana under drip irrigation when compared to surface irrigation. Water consumption of surface method was 1760 mm and that by drip was 970 mm resulting in a water saving of 56 per cent.

Banana plantations in Cuba, when given trickle irrigation providing 10 litres per hour (lph) and irrigated for 1.5 hours per day during the first six months of cultivation provided banana plants with sufficient water (Sotolongo and Ruiz, 1992). A drip irrigation experiment with different quantity of water in Robusta banana conducted on a sandy loam soil at Bhavanisagar resulted higher water use efficiency at 16 litres per day and was recommended for banana production (Bosu *et al.*, 1995).

2.3.3.3 Fertilizer application to crops under drip irrigation

Crop growth and yields under drip irrigation could be lower than those achieved under conventional irrigation methods, if fertilizer placement is not modified to meet the needs of trickle irrigated crops (Miller *et al.*, 1976). So the fertilizer applied should be close to the water source (emitter), in order to use it effectively.

According to Bresler (1977), drip irrigation becomes an efficient method mainly due to the opportunity for combined application of water with appropriate concentration of nutrient elements to the plant root zone.

Keng *et al.* (1979) studied the effect of different fertilizer management practices in sweet pepper with drip irrigation in an oxisol. The three different methods of fertilizer application studied were fertigation of N and K and banded P; drip irrigation with banded N, P and K; and drip irrigation with broadcast N, P and K. The yields from broadcast fertilizer treatments were 15.8 per cent lower than fertigation and 12.3 per cent lower than from banded fertilizer indicating that fertigation could be a promising alternative. Fertilizer placement, timing, water application, frequency of irrigation all influence yield under drip irrigation (Csizinsky, 1979; Miller *et al.*, 1981).

Mullins *et al.* (1992) also evaluated the effect of drip irrigation and different rates of NPK on fruit yield and quality of tomato. It was observed that broadcast application of 450 kg ha^{-1} of 10:10:10 NPK mixture before planting in combination with drip irrigation produced yield equal to those with higher rates of fertilizer partly applied before planting and partly through irrigation system.

2.4 The concept of fertigation

Fertigation is defined as the application of solid or liquid mineral fertilizers via. pressurised irrigation systems, thus forming nutrient containing irrigation water (Magen, 1995). Eventhough combined irrigation and fertilization could be practiced under different irrigation systems like sprinkler, microjet etc. the control under drip irrigation system was superior (Bar – Yosef, 1999).

According to FAI (1995), fertigation enjoys various advantages like (i) higher use efficiency of water and fertilizers, (ii) minimum losses of nutrients due to prevention of leaching, (iii) optimization of nutrient balance by supplying nutrient directly to root zone in available form , (iv) control of nutrient concentration in soil solution to effect proper supply, (v) saving in application cost and (vi) improvement of soil physical and biological condition due to proper maintenance of soil moisture levels.

Bravdo and Proebsting (1993) also reported that unlike other irrigation methods, no interference between water availability and soil aeration appeared to exist in drip irrigated orchards. As in the case of water, there is a non uniform distribution of air in the root zone, thereby subjecting various parts of the root systems to a range of air concentrations.

2.4.1 Crop response to fertigation

Bar-Yosef (1977) observed a special advantage for drip fertigation in sandy soils where the accurate control of water and ions in the plant root volume was critical. Tomatoes grown in a field of fine sand was found to produce a fruit yield of 110 t ha^{-1} under drip fertigation. Later Kafkafi and Bar-Yosef (1980) obtained successful cropping of tomatoes with drip fertilization on a highly calcareous soil also.

Miller *et al.* (1981) could obtain better N content in tomatoes during most of the growing season, when the fertilizer N was applied through drip irrigation system. Only small differences in total tomato yield were observed among treatments although fertigation did enhance fruit maturity.

Stark *et al.* (1983) found a linear relationship among total N uptake by tomato with fertigation of nitrogen upto 300 kg ha^{-1}. He opined that adequate nitrogen could be applied to tomatoes using high frequency N fertilization without large denitrification losses. Bhella and Wilcox (1985) obtained the highest vegetative growth and total yield of Muskmelon with 150 g l^{-1} of N applied through drip irrigation.

Fitter and Manger (1985) reported that increasing irrigation efficiency reduced the leaching of nitrate N. Fresh market tomato production was significantly increased by N-rates of 130-200 kg ha^{-1} by increasing the number of large fruits which was due to reduced leaching of nutrients under trickle irrigation

(Karlen *et al.*, 1985). N feeding of rock melon cv. Early Dawn under trickle irrigation by Pryor and Kelly (1987) resulted in higher yields with 1:1 NK ratio (240:240 kg NK ha^{-1}) than with 2:1 ratio.

Haynes (1988) obtained increased vegetative growth in chilli when 75 kg ha^{-1} N was applied by fertigation compared to broadcast application.

Titulaer and Slangen (1990) suggested that application of N to trickle irrigated lettuce in tune with crop growth minimized the leaching losses and reduced the fertilizer costs.

N fertigation studies taken up in banana at various centres of the AICRP (Tropical fruits) have shown that fertigation could produce better growth and yield in banana (ICAR, 1993). Application of 200 g N through drip gave a higher bunch weight than 200 g N applied in soil in Nendran banana (KAU, 1997).

Several other studies have shown that crop yield response to N was stronger under microfertigation. Bar-Yosef and Sagiv (1982) obtained better response in lettuce, Assaf *et al.* (1983) in apples, Dasberg *et al.* (1988) in oranges and Bafna *et al.* (1993) in tomatoes.

Studies of phosphorus and potassium microfertigation showed improved crop response to these elements. Bar-Yosef *et al.* (1989) found that P fertigated sweet corn gave a significantly higher yield than drip irrigated sweet corn receiving pre-plant P fertilization.

Enhanced response to microfertigated K has also been reported for sugarcane (Ingram and Hilton, 1986) and grape fruit (Boman, 1996).

Liquid fertilizer was tested for garlic through drip on entisols at Rahuri, India by Pawar *et al.* (1993). The application of 100 per cent N and P_2O_5 through liquid fertilizer gave higher yield as well as maximum water use efficiency in drip irrigation system. The yield contributing characters were favourably influenced by the application of 100 per cent N and P through fertigation.

Use of liquid fertilizer for fertigation in banana was tried at Rahuri, India and the results indicated that a fertilizer saving of 25 per cent could be obtained by fertigation. The yield contributing characters were enhanced in fertigation treatments as compared to surface method (MPKV, 1998).

2.4.2 Frequency of fertigation

Drip irrigation is ideally suited for controlling the placement and supply rate of water soluble fertilizers (Goldberg *et al.*, 1976). Nitrogen fertilization is particularly attractive since N can be applied throughout the growing season at rates designed to meet the changing crop demand.

Fertigation of nutrients at almost every irrigation, but in very great dilution increased the fertilizer use efficiency far beyond the previously possible level (Menzel and Obe, 1990).

Ibrahim (1992) obtained increased yield with high fertigation frequency (two day intervals) than low fertigation frequency for tomatoes grown in sandy soils under arid conditions. However, Locascio *et al.* (1977) found no difference in the yield of strawberries when N and K were applied either daily or at weekly intervals with the trickle irrigation. Multiple application of nitrogenous fertilizers through trickle did not appear to improve the efficiency of fertilizer uptake by tomatoes over a single injection (Miller *et al.*, 1981).

Lahav and Kalmar (1988) also obtained slight but non-significant advantage for weekly fertilizer application over the continuous fertilizer injection into irrigation water in banana.

2.4.3 Efficiency of fertigation

High frequency application of N with trickle irrigation improved the efficiency of fertilizer use by potatoes more than two-fold over that of conventional fertilizer method (Rolston *et al.*, 1979). Similarly Miller *et al.* (1981) found that utilisation of N by tomato was more when applied through the trickle system than when banded and furrow irrigated or banded and trickle irrigated.

Feigin *et al.* (1982) obtained increased N uptake in celery with increasing rates of urea ammonium nitrate applied through drip system. Nitrogen uptake results were also consistent with N distributions in the soil which indicated greater leaching of soil applied fertilizer than given through irrigation water.

Compared to conventional fertilization, fertilizer savings under fertigation was found to be as high as 50 per cent in tomato (Goyal *et al.*, 1985), pepper (Haynes, 1988), peaches (Bussi *et al.*, 1991) and okra (Kadam *et al.*, 1993).

A field experiment conducted in fine textured heavy soil of Gujarat, India to explore the feasibility of nitrogen fertigation in banana revealed that drip fertigation at 80 per cent of recommended dose could give higher yield when compared with surface irrigation and normal fertilizer application (Parikh *et al.*, 1994). The fertilizer use efficiency was also better under drip fertigation (149 kg ha^{-1} per kg N) as against surface irrigation (101 kg ha^{-1} per kg N).

2.4.4 Rhizosphere changes under fertigation

High concentrations of mineral nutrients applied by drip fertigation may lead to localised salinity problems or changes in soil pH in the wetted zone. Changes in pH might not only affect root uptake but could significantly influence the solubility of mineral elements within the irrigated soil volume, possibly leading to deficiencies or toxic levels of certain elements (Haroon, 1991).

Edwards *et al.* (1982) found that fertigation with ammonium nitrate at the rate of 33 kg ha^{-1} on eleven occasions over a period of two years caused a decrease in soil pH from 6.2 to 3.7 in the zone wetted by emitter.

Haynes (1988) observed that the decrease in soil pH was greater in fertigation of N as urea followed by broadcast application. The decrease in pH was also greater in higher rate of urea application. In another study, Haynes (1990) concluded that fertigation with both ammonium sulphate and urea caused acidification in the wetted soil volume. Acidification was confined to the surface 20 cm of soil in the ammonium sulphate while it was upto a depth of 40 cm in urea due to its greater mobility. Such subsoil acidity is likely to be very difficult to ameliorate. Increasing the trickle discharge rates reduced the downward movement of urea and encouraged its lateral spread in the wetted soil. As a consequence, acidification was confined to the surface 20 cm soil.

Haroon (1991) observed that pH of the soil tended to increase, with daily drip fertigation at 4 l plant^{-1}, than with alternate day drip fertigation at the same rate.

Parchomchuk *et al.* (1993) studied the effect of drip fertigation of NH_4^+-N and P on the pH of the soil and observed that soil acidification began within one year in a zone extending approximately 60 cm vertically and horizontally from the drip source. Acidification was most severe at 20-30 cm directly beneath the emitter where the soil pH decreased from 5.8 to 4.5 after one year and to 3.7 after three seasons of fertigation. As with decline in pH, greatest changes in Ca and Mg concentrations occurred at the 20-30 cm depth with Ca decreasing to 27 per cent and Mg to 33 per cent of its original concentration after three years. At the periphery of the acidified soil zone Ca and Mg levels remained unchanged or increased due to displacement from regions of lower pH. Potassium was displaced more rapidly than Ca and Mg probably due to the replacement by NH_4^+, at exchange sites in the early stage of experiment.

2.4.5 Soil moisture distribution in drip fertigation

The pattern of wetting front was found varying under drip irrigation for different soils due to variations in soil texture, permeability, presence or absence of impermeable layers etc. Besides, emitter discharge rate, emitter spacing and total water added also influenced the extent of wetted soil volume (Warrick, 1986).

Howell *et al.* (1981) reported that when the point of application was isolated in a drip system, the soil was wetted in an axillary symmetric pattern just like a bulb, rather than in a one dimensional fashion. However, the wetted parts of the surface would cross together if the emitters were placed sufficiently close to each other. Later Bravdo and Proebsting (1993) also reported that the water distribution under each dripper formed a bulb shaped zone.

Sivanappan *et al.* (1987) studied the water movement pattern for a drip discharge rate of 8 lph and observed it up to 30 cm and 40 cm distance in horizontal and vertical directions, respectively.

Carmi and Plant (1988) reported that most of the available water supplied by drip irrigation was found at 0-30 cm depth, but infiltration depth increased as evaporation rate decreased. Studies conducted by Randall and Locascio (1988) in trickle irrigated cucumber and tomato showed that discharge rate of 8 lph resulted in higher water content in top 20 cm of soil than the lower application rate of 2 lph.

Gupta *et al.* (1990) reported that in a sandy clay loam soil, the horizontal advance was highly correlated to the elapsed time than the vertical advance. The advance front increased with increase in discharge rates.

Isomoisture lines drawn to study the horizontal and vertical movement of water showed that in the beginning, the water at higher application rate (12 lph) saturated the soil near the dripper and infiltration was slower, whereas the water penetration increased with lower application rate (4 lph) because of availability of more time for infiltration (Goel *et al.*, 1993).

Increase in radial spread and reduction in spread in vertical direction, with increase in discharge rate in a sandy clay loam soil was also reported by Dahiwalkar *et al.* (1994).

Maheswarappa *et al.* (1997) studied the moisture movement in littoral sandy soil under drip irrigation and it was observed that vertical movement was greater than the lateral due to the highly porous nature of the soil. The horizontal wetted area increased with increase in discharge rate.

2.4.6 Root growth and distribution in soil under drip irrigation

Physical and chemical conditions that prevail in the soil under drip irrigated condition influences the growth and distribution of roots. Goldberg *et al.* (1971) reported that the root system of annual crops that develop under drip system are often shallow relative to the depth of the wetted soil.

Goldberg *et al.* (1976) found that root weight of pepper (*Capsicum annum* L.) at about 30 cm depth and 30 cm away from the drippers was only two per cent of the total weight and 80 per cent of roots were within the first 20 cm.

Root development and distribution in sandy soil was studied by Bar-Yosef *et al.* (1980). The results proved that the main factor contributing to the different response of the plants to the irrigation treatments was the root weight and distribution. As the irrigation frequency was increased from one to three irrigations per day, there was an increase in root weight and ultimately drymatter and fresh fruit yield.

Drip irrigation experiments conducted with cucumber and tomato grown on a coarse textured soil in a green house proved that water application at 2 or 8 lph per emitter did not influence root density, distribution or plant water status. Drip irrigation at 0.5 times pan evaporation resulted in higher soil water content, root density and plant water status than the one at 0.25 times pan evaporation. Further, mature plants had root systems that were well adaptable to the different soil water distributions (Randall and Locascio, 1988).

Safadi and Battikhi (1988) observed no significant difference between drip irrigations at different soil moisture tensions with regard to vertical and horizontal root growth and root dry weight of squash.

The root length densities of tomato determined at three trickle irrigation treatments, trickle irrigation at 35, 70 and 105 per cent ET showed a decrease with soil depth. Greater root length and density was found in irrigation at 35 than at 70 or 105 per cent ET (Sanders *et al.*, 1989).

A high concentration of small rootlets in the confined volume of irrigated soil under the dripper might have a tremendous capacity to supply water to the above ground canopy due to increased root surface area, relatively low dependence on water movement in the soil, continuous provision of at least part of the system to optimal soil water potential and transfer of water between wet and dry roots (Bravdo and Proebsting, 1993).

Studies conducted by Agarwal and Narda (1994) on root distribution on furrow and drip irrigated tomatoes revealed that furrow irrigated tomatoes had higher rooting densities at all depths compared to drip irrigated ones. The rooting density trend, however, remained the same with maximum occurring in 0-15 cm layer and decreasing with depth.

Root distributions of drip fertigated high yielding pepper, tomato, muskmelon and sweet corn were studied by Bar-Yosef (1999). All root systems were restricted to a soil cylinder 40 cm in radius which coincided with the horizontal water front position.

The smaller soil volume is often considered beneficial because it minimises losses of water and agrochemicals but rapid alterations of environment could be produced by plant activity in the small rooting volume. Sub-optimal soil volume might be detrimental to growth because of excessively low root weight, even if the active root surface area were sufficient for uptake (Vaadia and Itai. 1968). A restricted irrigated and fertilized soil volume also decreased the capacity of the soil for water and nutrients which inturn raised the probability of stress when the application of nutrients or water was delayed for even short periods of time (Bar-Yosef *et al.*, 1980).

2.4.7 Subsurface drip irrigation

With recent advances in quality of fertilizer products and filtration devices which could reduce the emitter clogging problems, subsurface drip irrigation is gaining importance. Moreover, location of emitters at the appropriate depth avoids deterioration of drip lines by exposure to solar radiation and animals like rats and dogs (Bar-Yosef. 1999).

The volume of irrigation water typically lost to evaporation. deep percolation and surface runoff in the furrow irrigation method could potentially be reduced during subsurface drip method (Phene, 1990). But when the water table is shallow. the subsurface drip should be managed to decrease deep percolation (Phene *et al.*, 1989).

When emitters are placed below the soil surface in accordance with soil hydraulic properties, the top three to five cm soil layer could be kept dry during the whole season. This could prevent weed germination. Subsurface drip irrigation given to tomato at 10-18 inches below the soil led to remarkably lower weed population, early fruit maturity and significantly higher yield compared to furrow irrigation (Grattan *et al.*, 1988).

Bar-Yosef *et al.* (1991) found delayed growth of tomato plants in a loamy soil when emitters were placed 40-50 cm below the soil surface as compared with 20-25 cm. The inhibited growth was attributed to the extra time the roots needed to pass through the relatively dry top soil layer and reach the centre of the wetted soil volume.

Roots were found to grow deeper into the soil under subsurface than under surface drip fertigation (Hernandez *et al.*, 1991).

Ghali and Svehlik (1988) studied the soil water dynamics under surface and subsurface trickle irrigated conditions which revealed that the saturated width around a subsurface source was smaller than that resulting from a surface source indicating an apparent advantage in reducing surface evaporation under subsurface method.

Amali *et al.* (1997) reported that use of the subsurface drip system resulted in very non-uniform soil water contents above the depth of the emitters, whereas the variability below the emitter depth was comparable to the surface irrigation systems.

The subsurface drip irrigation method has been shown by Styles and Barnasconi (1994) to be more profitable than the surface irrigation methods under some circumstances, while the surface irrigation methods could offer more profit under other circumstances or soil conditions.

2.4.8 Subsurface drip fertigation

In subsurface drip fertigation, nutrients are applied to the centre of the root system where water content is relatively high and steady with time (Phene and Howell, 1984) and root activity is maximal.

Nutrients introduced by subsurface tricklers could move in a spherical volume around the emitter while nutrient transport in surface application is bound within a hemisphere below the point source (Phene *et al.*, 1986).

Bar-Yosef *et al.* (1991) opined that the differences in the uptake rates of mobile elements between surface and subsurface fertigation systems would be smaller than in those of immobile elements as mobile elements were distributed and exploited from a considerably larger soil volume. Empirical results of P and N distribution in soil under surface and subsurface fertigation showed deeper P distribution under subsurface than under surface P fertigation, but there was only smaller differences in N and water distribution between the two systems (Hernandez *et al.*, 1991).

2.4.9 Fertigation of major nutrients

Fertigation can be effected by using single or multiple nutrient fertilizers, in their solid or liquid form. Applying all nutrients in their soluble and available form to plant can have distinct advantages under certain conditions, especially in the case of phosphorus and potassium. These two elements undergo precipitation and adsorption processes in the soil that reduce their availability. Hence by the repeated and often continuous supply of these elements in irrigation water, these negative phenomenon could be minimized (Magen, 1995).

2.4.9.1 N fertigation

Nitrogen, the plant nutrient most commonly deficient for crop production is often applied in drip irrigation system. In general, all N fertilizers cause few clogging and precipitation problems with the exception of ammonium sulphate, which may cause precipitation of $CaSO_4$ in hard calcium rich water (Magen, 1995).

2.4.9.1.1 Distribution of nitrogen in soil

Bacon and Davey (1982) obtained increased NH_4^+ concentration (7.1 to 13.5 ppm) during irrigation in the surface six cm depth of soil extending upto a distance of 30 to 60 cm from the outlet. Ammonium concentration decreased rapidly as the soil dried out and eight hours after irrigation, it fell from 13.5 to 8.5 ppm. As there was no change in NO_3^- concentration in this region, the NH_4^+ might have immobilised rather than nitrified.

The highly mobile NO_3^- ions moved with the wetting front and accumulated at the periphery of the wetted soil volume (Haynes, 1985) whereas the applied NH_4^+ was found concentrated in the surface 10 cm of soil immediately below the emitter and little lateral movement was observed (Haynes, 1990).

Urea is relatively mobile and it is not strongly adsorbed by soil colloids. It therefore tends to be more evenly distributed within the wetted profile than does applied ammonium. Haynes (1990) observed more or less uniform distribution of urea and nitrate down the soil below the emitter and had moved laterally in the profile to 15 cm radius from the emitter.

Bravdo and Proebsting (1993) reported that NO_3^--N moved with the water and tended to accumulate at the edges of the wetted zone, whereas NH_4^+-N did not move well in the soil and tended to accumulate in the vicinity forming decreasing gradients towards the margins of the wetted soil volume.

2.4.9.2 Phosphorus fertigation

Application of phosphorus to irrigation water may cause precipitation of phosphate salts. Bucks *et al.* (1982) opined that the precipitation of insoluble dicalcium phosphate and dimagnesium phosphate under high soil pH and Fe-P compounds in low pH might occur in irrigation pipes and drip emitters. Reducing the pH of irrigation water significantly reduced the risk of Ca-P compounds precipitation and hence the use of phosphoric acid was recommended by Magen (1995).

2.4.9.2.1 Distribution of phosphorus in soil

P distribution in sandy and clayey soils were experimentally determined by Bar-Yosef and Sheikholslami (1976) after applying given amounts of P and water through a point source. When NO_3^- movement in both soils extended to a distance of 20 cm from the source. P movement was restricted to distances of 12 and 7 cm from the emitter in the sandy and clayey soils, respectively. Large application rates of water and P increased the distance of water from the emitter, but not that of P.

Rauschkolb *et al.* (1976) showed that ortho-phosphate applied through trickle irrigation moved to a much greater distance into a clayey soil than had previously been observed for comparable application rates spread uniformly on the soil surface. This was because in point source fertigation all P was applied over the small surface area of the solution entry zone, so that soil adsorption sites became saturated and the extent of P migration was greater than with broadcast P application. The distance of P movement was proportional to the application rate and at 39 kg P ha^{-1} it moved 25 cm horizontally and 30 cm vertically in the profile.

O'Neill *et al.* (1979) found that P was spread to greater soil volume when applied as phosphoric acid through a trickle system than triple super phosphate applied beneath each emitter.

Bacon and Davey (1982) studied the distribution of Bray No.1-P in the sandy loam soil that had been under drip irrigation for five years. The results revealed that trickle irrigation caused both horizontal and vertical movement of native soil P near the outlet and that P fertilizer applied 50 to 80 cm away from the outlet, remained near the soil surface and above the root zone.

Phosphorus when applied as urea phosphate moved in a calcareous loam soil to a depth of 30 cm (Mikkelsen and Jarrel, 1987).

But, the placement of small quantities of superphosphate near the trickle outlet was a satisfactory alternative to broadcasting (Bacon and Davey, 1989).

Papadopoulos (1992) also obtained greatest P accumulation in the surface 0-15 cm layer and even after three potato growing seasons, soil P was significantly higher in the surface 15 cm in comparison with the initial values.

2.4.9.3 Potassium fertigation

Application of K fertilizers does not cause any precipitation of salts, except when using K_2SO_4 with irrigation water containing high concentration of Ca. Common K sources are readily soluble in water. Potassium ion moved freely into the soil and was adsorbed at the cation exchange sites of soil colloids (Magen, 1995).

Raiscos *et al.* (1996) carried out studies to examine the effect of different sources of potassium (K_2SO_4, KNO_3 and $K_2SO_4 + KNO_3$) applied through trickle fertigation in a plantation of Grand Naine banana variety. KNO_3 was found to increase average bunch weight, number of hands and fruit weight.

2.4.9.3.1 Distribution of potassium in soil

Potassium is less mobile than nitrate, but distribution in the wetted volume might be more uniform due to interaction with binding sites (Haynes, 1985).

Most workers have detected considerable lateral and downward movement of trickle applied K (Goode *et al.*, 1978; Keng *et al.*, 1979; Kafkafi and Bar-Yosef, 1980).

Bar-Yosef and Sagiv (1985) suggested that at the time of maximum K uptake in high K demanding crops, it must be applied even if its concentration in the soil is sufficient, because the rate of sorbed K release to the soil solution becomes a rate limiting step in K uptake. Bar-Yosef (1999) considered this important particularly under drip fertigation where plant root volumes are restricted.

2.4.10 Water soluble fertilizers for fertigation

Magen (1995) listed out the criteria for the chemicals applied through drip irrigation system such as full solubility (<0.02% insoluble in water); quick dissolution in irrigation water, fine grained product, insolubles of non-clogging mineral and bacterial type; high nutrient content in the saturated solution; no chemical interactions between the fertilizer and irrigation water and minimum content of conditioning agents.

The NPK content of common fertilizers suitable for fertigation in their solid and saturated liquid forms were listed by Ashwanikumar (1992). The solubility of the fertilizers was reduced when two or three fertilizers were mixed together. The compatability of different soluble fertilizers were presented by Shah (1998).

2.4.10.1 Prepared liquid fertilizers

Clear liquid fertilizers used for fertigation include urea, ammonium nitrate and ammonium sulfate either individually or in combination with orthophosphates, KH_2PO_4, KCl, K_2SO_4 etc. A correct rate and concentration of application is desired and same should be selected to avoid over fertigation. Most crop needs may be met at a concentration of 100 mg l^{-1} in the irrigated water (Ashwanikumar, 1992).

Different agencies have developed water soluble fertilizers to meet a wide range of requirements. Kemira has developed about 60 different grades to suit recommendations of different crops at different stages (Ulf Inberg, 1992).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field investigations on the water and fertilizer use efficiency in drip fertigated banana var. Nendran were conducted during 1997-1999 at Banana Research Station, Kannara, Kerala. The details of the experimental materials used and methods adopted in the conduct of the experiments as well as in the evaluation of the results are presented hereunder.

3.1 Location

The Banana Research Station, Kannara functioning under Kerala Agricultural University is located at 10°N latitude and 70°E longitude at an altitude of 55.6 m above mean sea level.

3.2 Weather and climate

The experimental area enjoys a warm humid tropical climate. Mean weather data showed that the summer was hot, dry and rainless, the dry spell extending from December to May. The mean maximum and minimum temperature experienced were 31°C and 26°C respectively. Southwest monsoon concentrated during the months of June, July and August with a mean average rainfall of 2500 mm.

The study was conducted for two consecutive years from October 1997 to October 1999. Weather conditions prevailed during the period are presented in Appendix 1 and 2 and Fig.3.1a and 3.1b.

Fig. 3.1a. Weather parameters prevailed during 1997-98

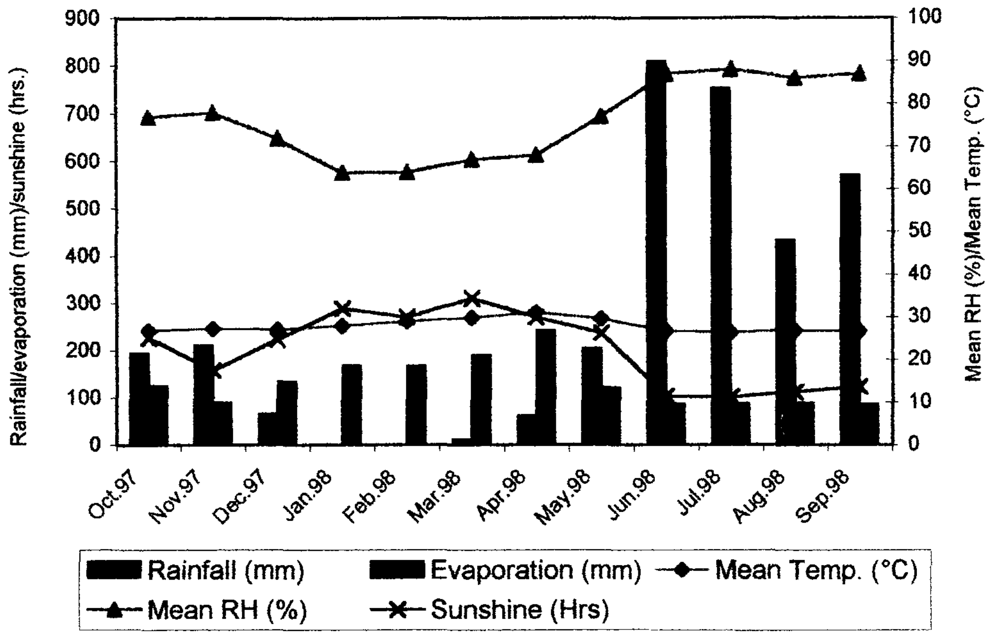
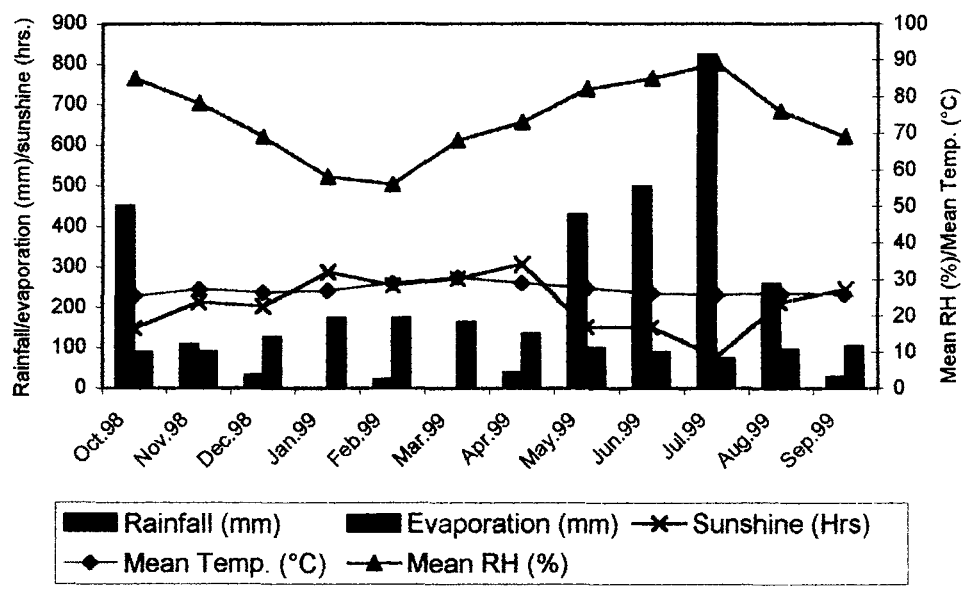


Fig. 3.1b. Weather parameters prevailed during 1998-99



3.3 Soil

The soil of the experimental field was deep well drained lateritic sandyclay of order Oxisol. The physico-chemical characteristics of the soil prior to the experiment are furnished in Table 3.1.

Table 3.1. Physico-chemical characteristics of the soil prior to the experiment

(a) Physical properties		
(i) Structure	Medium subangular blocky	
(ii) Texture	Sandy clay	
(iii) Field capacity (%)	18.5	
(iv) Permanent wilting point (%)	11.0	
(v) Bulk density (g cc^{-1})	1.1	
(b) Chemical properties	Experiment I	Experiment II
Organic carbon (%)	0.45	0.48
Available N (kg ha^{-1})	234.08	210.00
Available P (kg ha^{-1})	18.20	18.20
Available K (kg ha^{-1})	325.00	250.00
EDTA extractable Ca (%)	0.04	0.04
EDTA extractable Mg (%)	0.03	0.03
DTPA extractable Fe (ppm)	37.80	41.20
DTPA extractable Mn (ppm)	86.90	50.40
DTPA extractable Cu (ppm)	2.84	2.71
DTPA extractable Zn (ppm)	1.03	0.70

3.4 Experiment details

The study consisted of three individual experiments.

Experiment 1

Nutrient dose and application frequency in drip fertigated banana.

Design : Split plot

Replications : Three

Treatments

I year (1997-98)

Main plot : Irrigation methods and frequencies of fertilizer application

1. Conventional irrigation @ 48 litres once in 3 days; fertilizer in 6 splits (C_6)
2. Drip fertigation @ 16 litres day^{-1}; fertilizer in 6 splits (D_6)
3. Drip fertigation @ 16 litres day^{-1}; fertilizer in 24 splits (D_{24})

Subplot - Nutrient doses (g NPK per plant)

1. 100-60-150 (F_{50})
2. 200-115-300 (F_{100}) (present recommended dose)
3. 300-175-450 (F_{150})
4. 400-230-600 (F_{200})
5. 500-290-750 (F_{250})

II year (1998-99)

Based on the observations made in the first year experiment, the quantity of water used in the main plot treatment was changed from a fixed quantity to varying quantities calculated based on the daily pan evaporation. The quantity of irrigation given during the summer months is given in Appendix 3. In the subplot treatments, a lower dose of F_{25} was introduced and the highest dose F_{250} was left out.

Main plot - Irrigation methods and frequencies of fertilizer application

1. Conventional irrigation at 100 per cent cumulative pan evaporation (CPE) compensation once in three days; fertilizers in six splits (C_6)

2. Drip fertigation at 100 per cent daily pan evaporation compensation (PEC); fertilizers in six splits (D_6)
3. Drip fertigation at 100 per cent daily PEC; fertilizers in 24 splits (D_{24})

Subplot - Nutrient doses (g NPK per plant)

1. 50-30-75 (F_{25})
2. 100-60-150 (F_{50})
3. 200-115-300 (F_{100})
4. 300-175-450 (F_{150})
5. 400-230-600 (F_{200})

Experiment 2

Water use efficiency as influenced by methods and levels of irrigation

Design : Split plot

Replications : Three

Treatments

I year (1997-98)

Main plot - Irrigation methods

1. Surface drip (S)
2. Subsurface drip (SS)
3. Conventional method (C)

Subplot - Levels of irrigation

1. 8 litres day^{-1} (I_{50})
2. 12 litres day^{-1} (I_{75})
3. 16 litres day^{-1} (I_{100})

The nutrients were supplied at F_{200} level (400-230-600 g NPK per plant) in six splits through drip for drip irrigated plants and in basins for conventionally irrigated plants.

II year (1998-99)

Based on the observations made in the first year, the subplot treatments were changed. The quantity of irrigation water was calculated based on the daily pan evaporation instead of a fixed volume.

Main plot - Irrigation methods

1. Surface drip (S)
2. Subsurface drip (SS)
3. Conventional method (C)

Subplot - Levels of irrigation

1. Daily irrigation at 50 per cent of daily PEC
2. Daily irrigation at 75 per cent daily PEC.
3. Daily irrigation at 100 per cent daily PEC.

The nutrients were given at F_{100} (200-115-300 g NPK per plant) in six splits through drip for drip irrigated plants and in basins for conventionally irrigated plants.

Experiment 3

Leaching loss of nutrients under different levels of irrigation.

The experiment was conducted at College of Horticulture, Vellanikkara during 1998-99. The suckers were planted in cement tanks of size of 1.5 m diameter and 80 cm depth and having provisions for the collection of leachate at the base. The tanks were filled with soil ten months before the start of experiment maintaining a bulk density similar to that of the field. Banana suckers were planted at the centre of the tank in 30 x 30 x 30 cm pits. The fertilizers were supplied to these plants at 200-115-300 g NPK per plant in six splits.

Design : CRD

No. of replication : Four

Treatments

1. Flooding at 100 per cent CPE compensation once in three days
2. Flooding at 200 per cent CPE compensation once in three days
3. Flooding at 300 per cent CPE compensation once in three days

The leachate was collected for three consecutive irrigations after every fertilizer application and analysed for available nutrients.

3.5 Crop culture

3.5.1 Planting of suckers

Uniform sword suckers were selected for planting. The suckers were dipped in cowdung slurry and dried for three days before planting. Pits of size 50 x 50 x 50 cm were made at a spacing of 2 x 2 m and suckers were planted in the centre of the pit. Furadan (Carbofuran 3% G) was applied at 20 g plant^{-1} around the rhizomes at the time of planting. The planting was done on November 3, 1997 and November 5, 1998, during the first year and second year respectively. Mulching of the suckers with green leaves was also done. Farm yard manure was applied at

10 kg plant^{-1} fifteen days after and was incorporated into the soil along with the mulch.

3.5.2 Installation of drip irrigation system

Drip irrigation system was laid out under the supervision of Jain Irrigation Systems, Palakkad. Pond water was used for irrigation. Mains and submains were placed at a depth of 20 cm and the laterals were drawn on the surface of the soil for every row of the plant. Two emitters each having discharge rate of 8 lph were given for every plant at a distance of 30 cm from the plant on either side.

For subsurface irrigation, the surface drip system was modified to apply the water at 30 cm depth directly in the root zone. The emitters were connected to the laterals through microtubes and the emitters were placed in PVC pipes of 30 cm length to ensure that the irrigation was given below the soil at a depth of 30 cm (Plate 1).

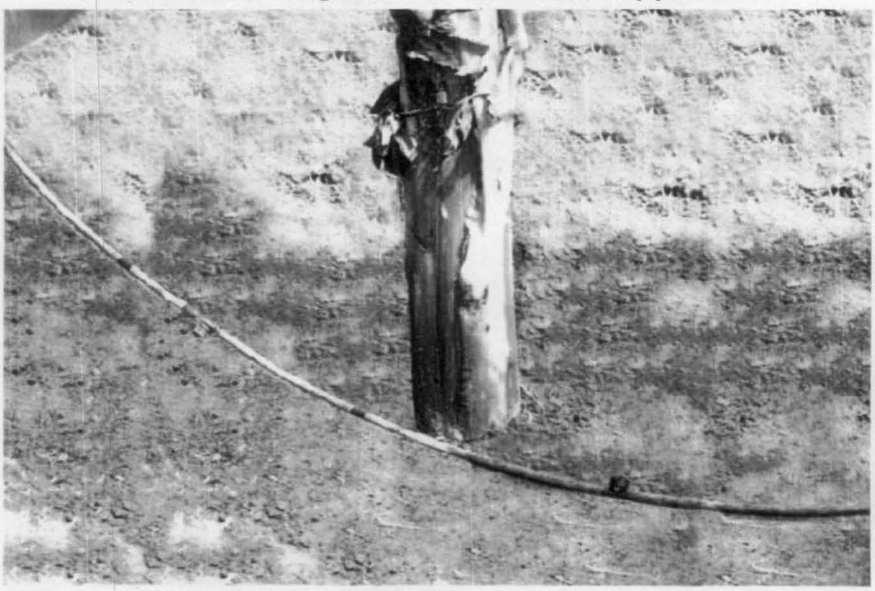
3.5.3 Imposition of treatments

3.5.3.1 Irrigation

Irrigation was started two months after planting (MAP), during the month of January. A uniform irrigation was given initially to all the plants to bring the soil to field capacity.

Fixed quantities of water as per the treatments was given as irrigation in the first year. But in the second year, the quantity of irrigation was determined

Plate 1 Surface drip, Subsurface drip and Conventional methods of irrigation and fertilizer application



a. Surface drip

b. Subsurface drip

c. Conventional basin method

based on daily evaporation data collected from USWB Class A Pan Evaporimeter located in the meteorological observatory, College of Horticulture, Vellanikkara. For drip irrigated plants, daily evaporation loss was compensated by irrigation whereas in basin irrigated plants, irrigation was given at cumulative pan evaporation once in three days.

3.5.3.2 Fertilizer

Urea (46 per cent N), Single superphosphate (16 per cent P_2O_5) and Muriate of potash (60 per cent K_2O) were used as the sources of nitrogen, phosphorus and potassium respectively. In experiment 1, N and K fertilizers were given at 2, 3, 4, 5, 6 and 7 MAP and on every week of these months for plants having fertilization or fertigation in 6 splits (C_6 and D_6) and 24 splits (D_{24}) respectively. P fertilizer application was limited to two splits for C_6 and D_6 and to eight splits for D_{24} and the application was done during second and third months after planting.

For experiment 2, fertilizers were applied exactly as in the case of C_6 and D_6 of experiment 1, for basin irrigated plants and drip irrigated plants respectively.

3.5.3.3 Preparation of fertilizer solution for fertigation

Saturated solution of NPK was used for fertigation in the first two months of fertilizer application. Single superphosphate being sparingly soluble was mixed with water and was kept overnight to settle the undissolved salts. The amount of water required to dissolve the entire water soluble fraction of P_2O_5 was determined. The decanted solution was filtered and analysed for P_2O_5 content for confirmation. To this solution urea and MOP were added.

Saturated N and K solutions were prepared by dissolving required quantity of urea and MOP in water according to the treatments.

3.5.4 Weed control

The plants were given directed spraying of paraquat (Grammaxone 24%) at 0.6 kg ai ha^{-1} at two months interval for the control of weeds. No intercultural operations were done two months after planting.

3.5.5 Desuckering

Side suckers produced till the emergence of flowers were removed by cutting them with sickles from the base close to the surface.

3.5.6 Plant protection

The incidence of bacterial rot in both the years was controlled by drenching streptocycline @ 0.05 g l^{-1}. The severely affected plants were cut and removed and the basins were drenched. Neighbouring plants also were drenched with streptocycline.

Sigatoka leaf spot incidence during Southwest monsoon was controlled by spraying 1.0 per cent Bordeaux mixture.

Furadan (Carbofuran 3% G) at 20 g $plant^{-1}$ was applied twice at the time of planting and 75 days after planting (DAP). Sevin (Carbaryl 50% WP) at 0.2 per cent was applied on the pseudostem and leaf axils after removing the dried outer sheaths as a prophylatic measure against pseudostem weevil.

The general view of the experimental field is given in Plate 2.

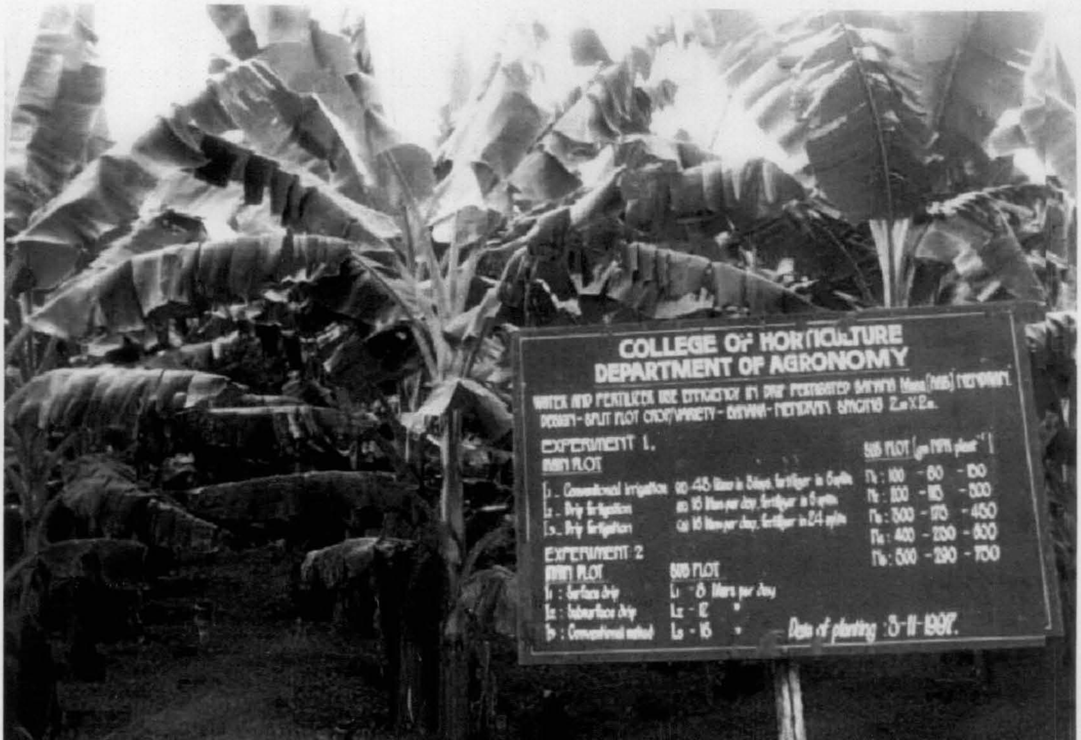
3.6 Soil moisture distribution studies

The soil moisture content under surface drip, subsurface drip and daily conventional irrigation was determined at weekly intervals during the month of April, 1998 and April, 1999. Soil moisture content was analysed both from the drip line and its opposite diagonal. Four samples were collected from each line, 30 and 60 cm away from the plant at two depths of 0-30 cm and 30-60 cm. The wet weight of these samples were taken and were kept in an oven at 105°C until constant values were obtained. The dry weights also were recorded and the moisture contents were determined on dry weight basis.

3.7 Root distribution studies

The root distribution pattern under different methods of irrigation was studied using excavation method. Lateral and vertical spread of roots at 30, 60 and 90 cm away from the plant at 30 and 60 cm depth were determined at 6MAP for the treatment plants under surface drip, subsurface drip and conventional method of irrigation, given at 16 litres per day per plant in the first year and at 100 per cent PEC in the second year. Trenches were made around the plant and the roots were slowly separated from the soil. The total length and weight of the roots in each zone were recorded.

Plate 2 General views of the experimental plot



3.8 Nutrient analysis

3.8.1 Soil

Soil samples for the determination of nutrient contents were collected at 5 MAP exactly as in the case of soil moisture distribution study but only from the drip side. The samples collected in polythene covers were labelled and transported to the laboratory. In the laboratory, the samples were dried, clods were broken using a wooden mallet, sieved through 2 mm sieve and were stored in containers. During the second year, NH_4^+-N and NO_3^--N were determined using wet samples, simultaneously determining its moisture content. Nutrient contents were expressed on dry weight basis. The methods used for analyses are given in Table 3.2.

3.8.2 Plant

Third fully opened leaf from the apex which was considered as the index leaf, was used for analysis. Samples of leaf lamina from either side of the middle portion of index leaf were collected at monthly intervals from 3 MAP to flowering. The samples were dried in a hot air oven at 70°C for 72 hours. The dried samples were analysed for nutrient contents.

3.8.3 Biomass

After harvest the plants were uprooted and separated into rhizome, root, pseudostem, leaves, peduncle and bunch. The male buds were removed 45 days after flowering. Sample collected from each portion was weighed and was dried first under shade and then in a hot air oven at 70°C. The dried samples were analysed for nutrient contents.

Table 3.2. Methods used for analysis of soil, plant and leachate samples

Characters	Method	Reference
I. Physical analysis of soil		
1. Bulk density	Keen-Raczkowksi brass cup method	Piper, 1966
2. Field capacity	Field method	Misra and Ahmed, 1993
3. Permanent wilting point	Field method	Misra and Ahmed, 1993
4. Mechanical composition	International Pipette method	Piper, 1966
II. Chemical analysis		
a. Soil		
1. Organic carbon	Walkely-Black method	Jackson, 1958
2. Available N	Alkaline permanganate method	Subbiah and Asija, 1956
3. Ammoniacal and nitrate nitrogen	2 m KCl extract distilled in a macrokjeldhal	Tandon, 1993
4. Available P_2O_5	Ascorbic acid reduced molybdophosphoric blue colour method	Watanabe and Olsen, 1965
5. Available K_2O	Neutral normal NH_4OAC extract method using Flame Photometer	Jackson, 1958
6. Exchangeable Ca, Mg	Neutral normal NH_4OAC extract titration with EDTA	Jackson, 1958
7. Available Fe, Mn, Cu, Zn	DTPA extract method using Atomic Absorption Spectrophotometry	Lindsay and Norvell, 1978

Contd.

Table 3.2. Continued

Characters	Method	Reference
b. Plant		
1. N	Microkjeldhal method	Jackson, 1958
2. P	Diacid extract estimated Colorimetrically in a Spectronic-20 Spectrophotometer by Vanadomolybdophosphoric yellow colour method	Jackson, 1958
3. K	Diacid extract method using a flame photometer	Jackson, 1958
4. Ca, Mg, Fe, Mn, Cu, Zn	Diacid extract method using atomic absorption spectrophotometer	Jackson, 1958
c. Leachate		
1. Ammoniacal nitrogen	Macrokjeldhal distillation (Titration after distilling NH_3 in boric acid)	Tandon, 1993
2. Nitrate nitrogen	Macrokjeldhal distillation (Titration after distilling NH_3 in boric acid	Tandon, 1993
3. Phosphorus	Blue colour method	Tandon, 1993
4. Potassium	Flame photometry	Tandon, 1993

3.8.4 Leachate

Leachate collection in Experiment 3, was done for three consecutive irrigations after every fertilizer application. From every 10 litres of leachate collected from each treatment pot, 100 ml of sample was taken and these samples were mixed together to obtain a composite sample. The subsample drawn was analysed for NH_4^+-N, NO_3^--N, P_2O_5 and K content.

3.9 Biometric observations

The observations on vegetative characters were recorded from 3 MAP to flowering and yield and yield attributes were recorded after the harvest of the crop.

3.9.1 Vegetative characters

3.9.1.1 Height of the plant

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

3.9.1.2 Girth of the plant

Girth of the plant at 30 cm above the ground level was measured in centimeters.

3.9.1.3 Number of leaves per plant

The number of functional leaves was counted and recorded.

3.9.1.4 Area of the index leaf

Area of the index leaf was measured using the method suggested by Robinson and Nel (1985).

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

where

LA - area of the leaf, L - length, B - breadth and 0.825 is the constant.

3.9.1.5 Leaf area index (LAI)

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

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

3.9.2 Number of days for flowering

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

3.9.3 Total crop duration

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

3.9.4 Number of suckers per plant

The number of suckers at flowering and harvest were recorded.

3.9.5 Root characters

3.9.5.1 Root length

The total length of primary, secondary and tertiary roots were measured and expressed in centimeters.

3.9.5.2 Root weight

The root samples were collected in polythene covers and fresh weight was taken and expressed in grams.

3.9.6 Bunch characters

3.9.6.1 Bunch weight

Matured bunches were harvested and the weight of the bunches were taken after cutting the top of peduncle from the ring above the first hand. Bunch weights were recorded in kilograms.

3.9.6.2 Number of hands and fingers per bunch

3.9.6.3 Number of fingers in the D-hand

The middle fruit in the top row of the second hand (Gottreich *et al.*, 1964) was considered as the D-finger.

3.9.6.4 Length of the D-finger

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 centimetres.

3.9.6.5 Girth of the D-finger

Girth was taken at the point of maximum thickness and expressed in centimeters.

3.9.6.6 Weight and volume of the D-finger

The weight of the D-finger was taken and expressed in grams. The volume was estimated by water displacement method and expressed in cc.

3.9.6.7 Biomass yield

The plant uprooted after harvest were separated into rhizome, root, pseudostem, leaves, peduncle and fruit and their weights were recorded. The male bud from every plant was removed from the inflorescence 45 days after flowering and its fresh weight was taken. The total biomass was calculated and expressed in kilograms.

3.9.7 Fertilizer use efficiency (FUE)

The yield (kg) produced per kilogram of nutrient was determined for N, P and K using the equation

$$\text{FUE} = \frac{\text{Yield}}{\text{Quantity of nutrient applied}}$$

3.9.8 Water use efficiency

Yield produced (kg) per hectare per millimeter of water was determined and expressed as kg ha^{-1} mm^{-1}

3.9.9 Statistical analysis

The data collected on different characters were analysed by applying the technique analysis of variance (ANOVA) as per the design adopted in each experiment (Panse and Sukhatme, 1978). Intercorrelation analysis and Path

Coefficient analysis (Singh and Choudhary, 1977) were also done to work out the relationship between different parameters. The package MSTATC was used for computation.

RESULTS

4. RESULTS

Plant yield is largely influenced by the external inputs like fertilizer and water independently or more by their interactions. The effective management in terms of quantity, frequency and timing is important for higher yield and cost effectiveness. In the project entitled "Water and fertilizer use efficiency in drip fertigated banana *Musa* (AAB) Nendran", two experiments were conducted at Banana Research Station, Kannara, Thrissur, Kerala, during 1997-98 and repeated during 1998-99 for confirmation of results. The morphological, physiological and nutritional influence of the treatments on plant growth and yield and the altered rhizosphere environment in relation to nutrient and water management were studied in detail and results are presented here. A pot culture study to estimate the leaching loss of nutrients through irrigation was conducted at College of Horticulture, Vellanikkara and the results are also presented hereunder.

Experiment 1

4.1 Growth attributes

4.1.1 Plant height

The plant height as influenced by the method, frequency and level of fertilizer application is given in Tables 4.1 and 4.2 for the first and second year respectively.

During the first year, conventional (C_6) and drip method (D_6) where fertilizer application was in six splits, behaved similarly with regard to plant height till 6 MAP, but conventional basin irrigation resulted in significantly taller plants

Table 4.1. Effect of methods of irrigation, frequencies and levels of fertilizer application on plant height (cm) of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	156.66	182.87	203.82	219.20	269.07
D_6	159.01	177.10	191.78	225.40	252.20
D_{24}	151.11	195.77	202.22	232.67	275.50
CD (0.05)	NS	8.488	NS	9.937	8.650
F_{50}	149.38	181.06	198.58	229.17	263.94
F_{100}	157.10	187.33	205.92	233.44	269.39
F_{150}	162.97	182.83	202.94	233.28	270.11
F_{200}	157.29	189.22	195.06	221.56	259.44
F_{250}	154.61	185.78	193.86	211.33	265.06
CD (0.05)	4.068	NS	6.136	11.11	NS
C_6F_{50}	151.75	165.83	200.08	230.50	264.17
C_6F_{100}	163.56	176.83	213.92	235.00	270.00
C_6F_{150}	167.33	186.50	207.67	221.50	287.50
C_6F_{200}	159.00	191.67	197.83	202.00	266.67
C_6F_{250}	141.67	193.50	199.58	207.00	257.00
D_6F_{50}	152.17	179.25	189.08	228.00	261.33
D_6F_{100}	159.42	198.42	209.17	231.17	264.67
D_6F_{150}	162.83	166.67	201.00	236.67	253.50
D_6F_{200}	156.98	178.92	183.83	237.83	236.83
D_6F_{250}	163.67	162.25	175.83	193.33	244.67
$D_{24}F_{50}$	144.22	198.08	206.58	229.0	266.33
$D_{24}F_{100}$	148.33	186.75	194.67	234.17	273.50
$D_{24}F_{150}$	158.58	195.33	200.17	241.67	269.33
$D_{24}F_{200}$	155.9	197.08	203.50	224.83	274.83
$D_{24}F_{250}$	158.50	201.58	206.17	233.67	293.50
CD (0.05)	7.047	10.62	10.63	19.24	NS

Table 4.2. Effect of methods of irrigation, frequencies and levels of fertilizer application on plant height (cm) of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	71.69	135.50	187.37	226.35	263.33
D_6	71.25	140.03	201.33	240.39	270.67
D_{24}	70.35	135.87	200.97	243.81	283.33
CD (0.05)	NS	NS	2.21	5.26	8.26
F_{25}	63.11	125.72	177.78	219.71	251.11
F_{50}	69.56	138.56	193.22	231.48	266.11
F_{100}	73.64	139.94	200.33	240.62	280.56
F_{150}	74.70	135.89	202.61	241.28	281.67
F_{200}	74.47	145.56	208.83	251.17	282.78
CD (0.05)	3.99	3.88	6.46	9.40	8.70
C_6F_{25}	70.00	126.83	176.17	216.97	243.33
C_6F_{50}	65.67	139.67	182.00	221.43	260.00
C_6F_{100}	76.77	140.33	196.33	237.00	280.00
C_6F_{150}	75.33	132.17	201.00	236.83	273.33
C_6F_{200}	70.66	138.50	181.33	219.50	260.00
D_6F_{25}	63.33	133.67	188.50	227.67	250.00
D_6F_{50}	72.83	138.50	194.00	232.83	261.67
D_6F_{100}	72.32	139.83	203.17	241.47	271.67
D_6F_{150}	73.78	135.17	190.33	236.00	283.33
D_6F_{200}	74.00	153.00	230.67	264.00	286.67
$D_{24}F_{25}$	56.00	116.67	168.67	214.50	260.00
$D_{24}F_{50}$	70.17	137.50	203.67	240.17	276.67
$D_{24}F_{100}$	71.83	139.67	201.50	243.40	290.00
$D_{24}F_{150}$	75.00	140.33	216.50	251.00	288.33
$D_{24}F_{200}$	78.77	145.17	214.50	270.00	301.67
CD (0.05)	6.925	6.718	11.19	16.29	NS

at 7 MAP than D_6. However, drip fertigation in 24 splits (D_{24}) produced significantly taller plants at 4, 6 and 7 MAP. During the second year also, the same trend was observed except a statistically similar plant height both in the C_6 and D_6 treatments at 7 MAP.

With regard to the fertilizer dose, application of the present fertilizer recommendation for Nendran (F_{100}) and a 50 per cent higher dose (F_{150}) resulted in taller plants than the lower (F_{50}) or higher (F_{200} or F_{250}) doses, but the difference levelled off by 7 MAP during the first year. In the second year at 7 MAP, the height of plants were significantly higher in F_{100}, F_{150} and F_{200} than F_{25} or F_{50}.

The effect on plant height due to combination of different levels, methods and frequencies of fertilizer application was not significantly different at 7 MAP during both the years. However during first year at 6 MAP, application in 24 splits through drip produced plants of similar height irrespective of fertilizer dose. The highest dose (F_{250}) in six splits through drip resulted in significantly lesser height than its lower doses. In the conventional basin irrigation with fertilizer application in six splits, a dose higher than F_{150} caused significant reduction in plant height.

In the second year at 6 MAP, F_{150} and F_{200} through drip in 24 splits resulted in significantly tallest plants. Lower doses irrespective of methods reduced the height of plants. The observed heights during 3, 4 and 5 MAP were almost agreeable with this trend.

A notable difference in plant height in the initial stages was observed between the first year and second year. The plant height at 3 MAP and 4 MAP was notably lesser in the second year than that in the first year irrespective of the treatment differences. However, the difference levelled off during 5 and 6 MAP and attained uniformity during 7 MAP.

4.1.2 Girth of the pseudostem

There was a proportionate increase in girth of the pseudostem with advance in age. A general improvement in the girth was noticed with the crop in the second year over first year (Tables 4.3 and 4.4).

Significant difference in girth was noticed between conventional and drip irrigated banana particularly in later months during both the years. Between D_6 and D_{24} a significant reduction in D_6 was observed only at 7 MAP in the first year crop.

Lower (F_{50}) or higher (F_{200} or F_{250}) doses of fertilizers were found to reduce the girth than F_{100} or F_{150} till 6 MAP during the first year. However F_{200} recorded the maximum girth from 4 MAP in the second year, though it was at par with F_{150} and even with F_{100} at 4 and 5 MAP.

Analysis of the combined effect of method, frequency and dose of fertilizer application in general showed that a fertilizer application through drip irrespective of dose is better in improving girth than conventional method. In the second year, spectacular improvement in girth was obtained with the use of higher

Table 4.3. Effect of methods of irrigation, frequencies and levels of fertilizer application on plant girth (cm) of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	25.88	39.85	46.23	51.23	54.70
D_6	23.38	43.18	51.18	54.20	55.47
D_{24}	25.05	42.83	51.67	55.97	58.73
CD (0.05)	NS	1.557	2.976	2.116	2.417
F_{50}	25.58	40.55	47.97	51.61	54.17
F_{100}	26.08	44.34	50.97	55.22	56.44
F_{150}	23.21	44.44	51.92	56.78	57.50
F_{200}	24.90	40.44	49.33	52.11	56.89
F_{250}	24.08	40.00	48.28	53.28	56.50
CD (0.05)	1.771	2.816	2.160	2.368	4.476
C_6F_{50}	26.83	40.92	42.17	50.00	52.83
C_6F_{100}	28.75	41.75	49.17	53.33	53.67
C_6F_{150}	25.67	42.66	49.00	53.67	55.17
C_6F_{200}	24.75	38.75	45.33	48.00	56.50
C_6F_{250}	23.42	35.17	45.50	51.17	55.33
D_6F_{50}	23.08	38.42	50.92	51.67	55.00
D_6F_{100}	26.83	48.17	52.67	55.83	56.50
D_6F_{150}	21.12	47.67	53.75	57.17	56.83
D_6F_{200}	24.28	40.33	50.00	53.83	55.33
D_6F_{250}	21.58	41.33	48.58	52.50	53.67
$D_{24}F_{50}$	26.83	42.32	50.83	53.17	54.67
$D_{24}F_{100}$	22.67	43.10	51.08	56.50	59.17
$D_{24}F_{150}$	22.83	43.00	53.00	59.50	60.50
$D_{24}F_{200}$	25.67	42.23	52.67	54.50	58.83
$D_{24}F_{250}$	27.25	43.50	50.75	56.17	60.50
CD (0.05)	3.068	4.877	NS	4.101	7.752

Table 4.4. Effect of methods of irrigation, frequencies and levels of fertilizer application on plant girth (cm) of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	24.42	38.27	50.27	52.74	57.50
D_6	24.28	39.67	52.80	56.07	60.03
D_{24}	25.82	41.17	51.87	56.37	60.83
CD (0.05)	NS	NS	NS	2.299	2.432
F_{25}	23.44	37.22	48.94	51.58	54.67
F_{50}	24.33	40.50	50.50	53.89	58.67
F_{100}	25.07	40.67	52.22	54.62	60.11
F_{150}	25.36	38.72	52.72	57.22	51.56
F_{200}	26.00	41.39	53.83	57.99	62.28
CD (0.05)	NS	2.45	3.169	2.022	1.913
C_6F_{25}	23.99	35.67	50.17	51.67	52.83
C_6F_{50}	24.32	40.33	49.17	52.50	58.17
C_6F_{100}	25.10	40.67	53.67	55.07	61.00
C_6F_{150}	24.45	37.33	49.67	53.00	59.17
C_6F_{200}	24.22	37.33	48.67	51.47	56.33
D_6F_{25}	25.00	39.50	50.33	52.57	55.83
D_6F_{50}	25.00	39.83	51.67	54.00	58.33
D_6F_{100}	24.11	39.00	51.33	53.13	58.67
D_6F_{150}	23.30	36.67	53.50	59.33	62.50
D_6F_{200}	24.00	43.33	57.17	61.33	64.83
$D_{24}F_{25}$	21.33	36.50	46.33	50.50	55.33
$D_{24}F_{50}$	23.67	41.33	50.67	55.17	60.67
$D_{24}F_{100}$	26.00	42.33	51.67	55.67	60.67
$D_{24}F_{150}$	28.33	42.17	55.00	59.33	63.00
$D_{24}F_{200}$	29.77	43.50	55.67	61.17	65.67
CD (0.05)	3.52	NS	NS	3.503	3.313

fertilizer dose through drip over conventional method. F_{150} and F_{200} behaved similarly with either 6 or 24 splits of drip fertigation during 6 and 7 MAP.

4.1.3 Number of functional leaves

Number of functional leaves retained in the plant at different months after planting is presented in Tables 4.5 and 4.6 respectively for the first year and second year.

Comparing the effect of conventional and drip methods, drip fertigation was found better and D_{24} was significantly superior to C_6 during 5, 6 and 7 MAP during the first crop. Though D_6 was similar to C_6 during 6 and 7 MAP, at 5 MAP a significantly higher number of functional leaves was obtained for D_6.

In the second year, significant difference between drip (D_{24}) and conventional method was obtained only at 3 MAP and 6 MAP, but at 7 MAP, they were on par.

With regard to the fertilizer dose, any dose over F_{50} in the first year and over F_{25} in the second year behaved similarly at 6 and 7 MAP.

No significant difference in the number of leaves was observed in the first year and second year due to any combination of method, frequency and level of fertilizer application.

A general observation is that number of functional leaves was relatively more in all the treatments in the first year than in the second year in the later stages.

Table 4.5. Effect of methods of irrigation, frequencies and levels of fertilizer application on number of leaves of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	11.30	13.82	13.87	17.07	16.00
D_6	10.40	14.47	15.23	17.77	16.40
D_{24}	11.17	14.35	15.30	18.70	17.47
CD (0.05)	NS	NS	1.171	0.938	0.646
F_{50}	11.22	14.38	15.39	16.50	15.61
F_{100}	11.64	14.37	14.83	18.83	16.72
F_{150}	10.28	14.14	15.00	18.00	17.11
F_{200}	10.64	14.34	14.39	18.17	16.61
F_{250}	11.00	13.83	14.39	17.72	17.06
CD (0.05)	NS	NS	NS	1.254	1.047
C_6F_{50}	11.33	13.50	14.67	16.33	15.33
C_6F_{100}	12.00	13.83	13.83	18.50	16.00
C_6F_{150}	11.00	13.77	13.67	16.50	15.33
C_6F_{200}	10.83	14.00	13.67	16.67	16.17
C_6F_{250}	11.33	14.00	13.50	17.33	17.17
D_6F_{50}	10.58	14.00	16.17	16.00	15.67
D_6F_{100}	11.83	15.17	15.17	18.50	16.83
D_6F_{150}	9.08	14.50	16.00	18.33	17.00
D_6F_{200}	10.33	15.00	14.33	18.67	16.50
D_6F_{250}	10.17	13.67	14.50	17.33	16.00
$D_{24}F_{50}$	11.75	15.63	15.33	17.17	15.83
$D_{24}F_{100}$	11.08	14.10	15.50	19.50	17.33
$D_{24}F_{150}$	10.75	14.17	15.33	19.17	19.00
$D_{24}F_{200}$	10.75	14.01	15.17	19.17	17.17
$D_{24}F_{250}$	11.50	13.83	15.17	18.50	18.00
CD (0.05)	NS	NS	NS	NS	NS

Table 4.6. Effect of methods of irrigation, frequencies and levels of fertilizer application on number of leaves of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	10.80	13.37	14.73	14.23	12.87
D_6	10.83	12.57	14.03	14.63	12.23
D_{24}	11.62	13.37	13.67	14.33	13.07
CD (0.05)	0.525	NS	NS	0.308	0.733
F_{25}	10.97	12.56	13.78	13.61	11.94
F_{50}	11.04	13.50	14.22	14.39	12.89
F_{100}	11.04	13.22	13.89	15.06	13.00
F_{150}	11.29	12.78	14.39	14.39	13.28
F_{200}	11.09	13.44	14.44	14.56	12.50
CD (0.05)	NS	NS	NS	0.731	0.795
C_6F_{25}	10.57	12.83	14.50	13.17	11.83
C_6F_{50}	10.44	13.67	14.67	14.33	13.33
C_6F_{100}	10.11	13.67	14.50	14.50	13.00
C_6F_{150}	10.89	13.00	14.67	14.33	13.33
C_6F_{200}	10.99	13.67	15.00	14.50	12.83
D_6F_{25}	11.17	12.83	14.00	14.17	12.00
D_6F_{50}	11.33	13.33	14.50	15.17	11.83
D_6F_{100}	10.67	12.17	12.83	15.17	12.83
D_6F_{150}	10.32	11.33	14.17	14.67	13.00
D_6F_{200}	10.67	13.17	14.67	14.00	11.50
$D_{24}F_{25}$	11.17	12.00	12.83	13.50	12.00
$D_{24}F_{50}$	11.33	13.50	13.50	13.67	13.50
$D_{24}F_{100}$	11.33	13.83	14.33	15.50	13.17
$D_{24}F_{150}$	12.67	14.00	14.00	13.83	13.50
$D_{24}F_{200}$	11.60	13.50	13.67	15.17	13.17
CD (0.05)	NS	NS	NS	NS	NS

4.1.4 Area of index leaf (m^2)

Data on the area of the index leaf at different stages of growth during first year and second year are depicted in Tables 4.7 and 4.8 respectively. Fertilizer application through drip in six splits significantly decreased the size of the index leaf than by the same in 24 splits, which was at par with C_6 at all stages during the first year crop. However, in the second year significant difference was observed only at 7 MAP where D_{24} was significantly superior to C_6 and on par with D_6.

In the first year, fertilizer dose did not show significant difference on leaf area of index leaf except at 3 MAP where a dose higher than F_{100} reduced the leaf area. In the second year a dose higher than F_{50} at 5 MAP and F_{100} at 6 MAP did not bring any significant addition to leaf area.

The effect of combination of method, frequency and dose of fertilizer was found significant only at 3 and 4 MAP in the first year where the effect of C_6 and D_{24} were comparable.

A general observation was that the size of index leaf was greater for the first year in the initial stages (3 MAP and 4 MAP). But the trend was not the same in the later months as the leaves of the crop in the second year possessed a relatively larger size during 5, 6 and 7 MAP.

4.1.5 Leaf area index

In general, leaf area index (LAI) reached its peak at 6 MAP and then declined.

Table 4.7. Effect of methods of irrigation, frequencies and levels of fertilizer application on area of index leaf (m^2) of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	0.345	0.743	0.734	0.844	0.772
D_6	0.257	0.676	0.593	0.710	0.591
D_{24}	0.312	0.746	0.753	0.841	0.750
CD (0.05)	0.0453	NS	0.0453	0.0321	0.0785
F_{50}	0.331	0.727	0.704	0.790	0.715
F_{100}	0.337	0.704	0.693	0.803	0.685
F_{150}	0.260	0.727	0.712	0.826	0.694
F_{200}	0.298	0.733	0.694	0.786	0.710
F_{250}	0.297	0.717	0.666	0.792	0.716
CD (0.05)	0.0043	NS	NS	NS	NS
C_6F_{50}	0.392	0.789	0.719	0.821	0.754
C_6F_{100}	0.397	0.727	0.758	0.848	0.776
C_6F_{150}	0.323	0.795	0.047	0.868	0.749
C_6F_{200}	0.299	0.729	0.757	0.861	0.730
C_6F_{250}	0.315	0.674	0.689	0.822	0.852
D_6F_{50}	0.255	0.680	0.657	0.659	0.712
D_6F_{100}	0.315	0.712	0.611	0.747	0.544
D_6F_{150}	0.213	0.671	0.564	0.771	0.570
D_6F_{200}	0.282	0.689	0.593	0.651	0.610
D_6F_{250}	0.218	0.629	0.542	0.721	0.518
$D_{24}F_{50}$	0.345	0.713	0.734	0.889	0.680
$D_{24}F_{100}$	0.298	0.672	0.709	0.814	0.735
$D_{24}F_{150}$	0.245	0.717	0.825	0.840	0.764
$D_{24}F_{200}$	0.312	0.781	0.733	0.828	0.791
$D_{24}F_{250}$	0.359	0.849	0.767	0.833	0.779
CD (0.05)	0.0754	0.1066	NS	NS	NS

Table 4.8. Effect of methods of irrigation, frequencies and levels of fertilizer application on leaf area of index leaf (m^2) of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	0.257	0.548	0.789	0.977	1.095
D_6	0.265	0.536	0.802	1.065	1.125
D_{24}	0.268	0.578	0.843	1.045	1.158
CD (0.05)	NS	NS	NS	NS	0.045
F_{25}	0.253	0.503	0.717	0.916	1.131
F_{50}	0.292	0.569	0.800	0.966	1.083
F_{100}	0.262	0.561	0.828	1.070	1.134
F_{150}	0.264	0.564	0.865	1.091	1.136
F_{200}	0.246	0.573	0.846	1.102	1.146
CD (0.05)	NS	NS	0.069	0.081	0.044
C_6F_{25}	0.242	0.515	0.761	0.909	1.157
C_6F_{50}	0.261	0.539	0.762	0.970	1.066
C_6F_{100}	0.278	0.602	0.846	0.997	1.045
C_6F_{150}	0.256	0.574	0.824	1.086	1.096
C_6F_{200}	0.247	0.508	0.750	0.922	1.112
D_6F_{25}	0.269	0.508	0.738	1.011	1.084
D_6F_{50}	0.290	0.553	0.770	0.999	1.091
D_6F_{100}	0.249	0.500	0.771	1.156	1.193
D_6F_{150}	0.255	0.501	0.836	1.053	1.120
D_6F_{200}	0.261	0.619	0.896	1.107	1.136
$D_{24}F_{25}$	0.248	0.486	0.651	0.829	1.151
$D_{24}F_{50}$	0.325	0.615	0.868	0.927	1.092
$D_{24}F_{100}$	0.259	0.581	0.868	1.057	1.165
$D_{24}F_{150}$	0.280	0.616	0.935	1.136	1.193
$D_{24}F_{200}$	0.229	0.591	0.893	1.276	1.191
CD (0.05)	NS	NS	NS	0.141	NS

Table 4.9. Effect of methods of irrigation, frequencies and levels of fertilizer application on leaf area index of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	0.98	2.57	2.53	3.60	3.12
D_6	0.70	2.45	2.28	3.16	2.44
D_{24}	0.90	2.68	2.92	3.94	3.29
CD (0.05)	0.139	NS	0.375	0.195	0.287
F_{50}	0.94	2.61	2.76	3.25	2.81
F_{100}	1.02	2.53	2.55	3.78	2.86
F_{150}	0.71	2.60	2.62	3.74	3.03
F_{200}	0.80	2.63	2.50	3.54	2.97
F_{250}	0.83	2.49	2.47	3.51	3.09
CD (0.05)	0.177	NS	NS	NS	NS
C_6F_{50}	1.11	2.66	2.79	3.31	2.88
C_6F_{100}	1.19	2.52	2.40	3.92	3.10
C_6F_{150}	0.89	2.74	2.55	3.62	3.03
C_6F_{200}	0.81	2.55	2.59	3.58	2.93
C_6F_{250}	0.90	2.37	2.32	3.56	3.67
D_6F_{50}	0.69	2.38	2.67	2.63	2.83
D_6F_{100}	0.93	2.70	2.32	2.44	2.29
D_6F_{150}	0.57	2.43	2.12	3.55	2.42
D_6F_{200}	0.74	2.58	2.13	3.05	2.60
D_6F_{250}	0.56	2.17	2.18	3.12	2.07
$D_{24}F_{50}$	1.01	2.79	2.81	3.81	2.72
$D_{24}F_{100}$	0.95	2.37	2.94	3.99	3.19
$D_{24}F_{150}$	0.66	2.54	3.18	4.05	3.63
$D_{24}F_{200}$	0.85	2.74	2.78	3.99	3.39
$D_{24}F_{250}$	1.03	2.95	2.91	3.86	3.52
CD (0.05)	NS	NS	NS	NS	NS

Table 4.10. Effect of methods of irrigation, frequencies and levels of fertilizer application on leaf area index (LAI) of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
C_6	0.69	1.84	2.93	3.50	3.50
D_6	0.72	1.70	2.82	3.90	3.43
D_{24}	0.77	1.93	2.78	3.76	3.86
CD (0.05)	NS	NS	NS	NS	0.261
F_{25}	0.70	1.59	2.48	3.12	3.38
F_{50}	0.81	1.93	2.78	3.50	3.46
F_{100}	0.73	1.88	2.78	4.03	3.69
F_{150}	0.75	1.80	3.10	3.92	3.77
F_{200}	0.66	1.93	3.08	4.02	3.67
CD (0.05)	NS	NS	0.256	0.329	0.265
C_6F_{25}	0.64	1.66	2.76	2.99	3.42
C_6F_{50}	0.69	1.85	2.80	3.55	3.45
C_6F_{100}	0.77	2.07	3.08	3.62	3.42
C_6F_{150}	0.69	1.87	3.09	3.98	3.65
C_6F_{200}	0.68	1.74	2.91	3.34	3.57
D_6F_{25}	0.76	1.64	2.58	3.59	3.26
D_6F_{50}	0.82	1.84	2.79	3.80	3.24
D_6F_{100}	0.67	1.54	2.47	4.38	3.82
D_6F_{150}	0.66	1.42	2.95	3.85	3.64
D_6F_{200}	0.70	2.04	3.28	3.87	3.17
$D_{24}F_{25}$	0.70	1.46	2.09	2.79	3.46
$D_{24}F_{50}$	0.93	2.08	2.76	3.16	3.69
$D_{24}F_{100}$	0.73	2.02	2.72	4.10	3.83
$D_{24}F_{150}$	0.89	2.10	3.27	3.93	4.03
$D_{24}F_{200}$	0.62	2.00	3.05	4.84	4.26
CD (0.05)	NS	NS	0.443	0.569	NS

In the crop grown in first year, the highest LAI of 3.94 was observed with drip fertigation in 24 splits, significantly greater than the other two treatments (Table 4.9). Reduction in the frequency of fertigation to six (D_6) significantly reduced LAI, even significantly lower than fertilizer application in six splits in conventional method (C_6). At 5 MAP also, D_{24} had the highest LAI, and D_6 and C_6 were on par.

During the second year, the effect was found to be significant only at 7 MAP and maximum LAI was accounted with D_{24}. D_6 and C_6 were on par (Table 4.10). All the fertilizer doses above F_{50} behaved similarly with regard to LAI and F_{100} at 6 MAP registered the maximum LAI in both the years.

The combined effect of methods, frequencies and levels of fertilizer application did not show any significant effect in the first year. In the second year, at 6 MAP, the highest LAI of 4.84 was associated with $D_{24}F_{200}$, which was reduced to 3.87 in D_6F_{200} and 3.34 in C_6F_{200}.

4.2 Yield and yield attributes

The bunch yield and the characters related to it are presented in Tables 4.11 and 4.12 for the first and second year respectively.

4.2.1 Yield

In the first year, no significant difference in bunch yield was obtained between conventional method (C_6) and drip fertigation (D_6) where fertilizers are

Table 4.11. Effect of methods of irrigation, frequencies and levels of fertilizer application on yield and bunch characters, days to flower and total duration of banana var. Nendran during first year

Treatment	Yield (kg/plant)	Peduncle length (cm)	No. of hands	No. of fingers per bunch	Days to flower	Duration of the crop (days)
C_6	5.89	59.97	4.50	40.90	218.07	298.97
D_6	5.63	65.90	4.10	37.70	210.63	295.87
D_{24}	5.94	61.53	4.50	41.80	201.63	291.30
CD (0.05)	NS	NS	NS	2.167	9.153	1.855
F_{50}	5.25	65.50	4.33	40.56	191.94	288.22
F_{100}	6.22	65.44	4.39	39.94	213.56	295.00
F_{150}	6.39	59.53	4.44	41.94	209.11	291.72
F_{200}	6.08	66.20	4.44	39.94	214.72	299.33
F_{250}	5.16	55.66	4.22	38.28	221.22	302.62
CD (0.05)	0.555	6.243	NS	NS	9.963	7.898
C_6F_{50}	5.36	63.00	4.67	44.17	207.33	295.67
C_6F_{100}	6.30	67.67	4.67	39.67	219.33	296.83
C_6F_{150}	6.97	56.27	4.33	40.67	215.00	296.50
C_6F_{200}	5.48	61.60	4.67	42.83	219.33	302.50
C_6F_{250}	5.32	51.30	4.17	37.17	229.33	303.33
D_6F_{50}	5.87	70.50	4.33	41.00	195.17	292.00
D_6F_{100}	6.17	69.67	4.00	38.33	210.17	296.17
D_6F_{150}	5.62	57.00	4.17	39.00	199.50	277.50
D_6F_{200}	5.55	70.33	4.00	35.00	220.50	302.50
D_6F_{250}	4.97	62.00	4.00	35.17	227.83	311.17
$D_{24}F_{50}$	4.53	63.00	4.00	36.50	173.33	277.00
$D_{24}F_{100}$	4.53	63.00	4.00	36.50	173.33	292.00
$D_{24}F_{150}$	6.20	59.00	4.50	41.83	211.17	292.00
$D_{24}F_{200}$	6.58	65.33	4.83	46.17	212.83	301.17
$D_{24}F_{250}$	5.20	53.67	4.50	42.50	206.50	293.33
CD (0.05)	0.961	10.81	NS	NS	NS	13.68

Table 4.12. Effect of methods of irrigation, frequencies and levels of fertilizer application on yield and bunch characters, days to flower and total duration of banana var. Nendran during second year

Treatment	Yield Kg plant $^{-1}$	Peduncle length (cm)	No. of hands	Total fingers	Days to flower	Total duration (days)
C_6	9.16	40.80	4.97	46.87	242.07	324.40
D_6	10.07	27.22	5.23	50.78	246.60	328.33
D_{24}	10.52	31.50	5.13	47.93	240.47	324.87
CD (0.05)	0.567	0.655	NS	NS	NS	NS
F_{25}	7.80	35.33	4.89	42.39	250.11	332.78
F_{50}	9.57	32.33	5.06	47.11	250.56	334.00
F_{100}	10.45	34.11	5.17	53.22	248.89	329.00
F_{150}	10.90	34.33	5.00	47.17	236.44	320.00
F_{200}	10.87	29.75	5.44	52.75	229.22	313.56
CD (0.05)	0.648	2.206	NS	3.753	10.34	6.164
C_6F_{25}	7.92	42.50	4.33	38.50	250.00	324.00
C_6F_{50}	8.95	36.00	5.17	45.33	252.33	333.00
C_6F_{100}	9.93	44.50	5.17	51.33	241.33	321.67
C_6F_{150}	9.57	43.00	5.17	45.50	220.67	317.33
C_6F_{200}	9.43	38.00	5.00	53.67	246.00	326.00
D_6F_{25}	7.70	27.00	5.33	41.33	254.67	338.33
D_6F_{50}	9.85	25.00	5.00	47.67	259.67	336.00
D_6F_{100}	10.46	30.33	5.00	54.33	250.33	332.67
D_6F_{150}	11.44	29.50	5.00	54.00	243.67	321.00
D_6F_{200}	10.91	24.25	5.83	56.58	224.67	336.00
$D_{24}F_{25}$	7.77	36.50	5.00	47.33	245.67	336.00
$D_{24}F_{50}$	9.92	36.00	5.00	48.33	239.67	333.00
$D_{24}F_{100}$	10.95	27.50	5.33	54.00	255.00	332.67
$D_{24}F_{150}$	11.70	30.50	4.83	42.00	245.00	321.67
$D_{24}F_{200}$	12.27	27.00	5.00	48.00	217.00	301.00
CD (0.05)	1.123	3.822	NS	6.501	17.90	10.68

given in six splits. Drip fertigation in 24 splits (D_{24}) tended to improve the yield, though not significant.

The fertilizer doses of F_{100} and F_{150} resulted in the highest, but comparable bunch yields. The lowest as well as the highest dose found to decrease the yield.

Significant interaction was observed when the effect of same dose of fertilizer through various methods and frequencies of application was analysed. With double the recommended fertilizer dose (F_{200}), the highest yield was obtained in 24 splits, but the same dose in six splits either through drip or conventional method resulted in a yield lower by 22 and 24 per cent, respectively.

In the second year significant yield increase was obtained for drip fertigation over conventional irrigation and fertilizer application methods. Among the two frequencies of fertigation, though statistically similar, twenty four splits performed better than six splits.

The fertilizer dose of F_{100} or above produced significantly higher yield than that F_{25} or F_{50}. Drip fertigation of F_{200} in 24 splits produced the highest significant yield than that in six splits, and the same fertilizer dose through conventional method in six splits resulted in further yield reduction. When a fertilizer dose higher than F_{100} was given through conventional method in six splits, it resulted in similar yields. Progressive yield increase with increase in fertilizer dose was obtained when it was applied through drip, the yield being highest at F_{150} when in six splits and at F_{200} when in twenty four splits.

The bunch yield in the second year was notably higher than the first year irrespective of the treatment differences.

4.2.2 Peduncle length

Data depicted in the Table 4.11 showed that in the first year, peduncle length was not affected by the method of irrigation and frequency of fertigation. But in the second year, conventional method (C_6) could produce longer peduncles (40.80 cm) than D_6 (27.22) and D_{24} (31.50 cm).

In all the fertilizer levels except the highest level, the length of the peduncle was similar in both the years.

A notable difference in peduncle length was observed between the first and second year crops. The length of the peduncle of the bunches of the first year was almost double than that of the second year, irrespective of the treatments.

4.2.3 Number of hands

Either the method of irrigation, frequency of fertilizer application or different levels of fertilizers did not bring out any significant variation in the number of hands in both the crops. No response was obtained for the combination of methods and levels of fertilizer application as the number of hands ranged from 4.0 to 4.83 in the first year and 4.33 to 5.83 in the second year.

4.2.4 Total number of fingers per bunch

Drip fertigation in 24 splits (D_{24}) produced highest number of fingers in the first year, which was at par with conventional method (C_6) (Table 4.11).

Drip in 6 splits (D_6) recorded the lowest number of fingers. Levels of fertilizers or its interaction with different methods of fertilization did not bring any significant influence.

In the second year, method of fertilization had no effect, but the levels of fertilizers influenced the number of fingers produced. The highest number of fingers was manifested in F_{100} (53.22) and F_{200} (52.75). F_{25} was significantly inferior.

4.2.5 Days to flowering

From the data presented in the Table 4.11, it is clear that in the first year, drip fertigation with 24 splits (D_{24}) resulted in early flowering followed by D_6. But in the second year (Table 4.12), method of irrigation and fertigation frequency did not influence the flowering date.

The levels of fertilizer also had significant effect on flowering. In the first year, early flowering was noticed with F_{50}. It took only 191.9 days which was 30 days less than F_{250}. In the second year unlike in the first year F_{150} and F_{200} recorded early flowering compared to their lower doses.

Interaction effect analysis of the methods of irrigation, fertigation frequencies and levels of fertilization showed that in the second year, plants in

$D_{24}F_{200}$ treatment came to flower 38 days earlier than $D_{24}F_{100}$ and 29 days earlier than C_6F_{200}.

4.2.6 Total duration

The total duration of the crop raised during the first year and second year are furnished in Tables 4.11 and 4.12, respectively.

In the first year, early harvesting of the bunch was recorded in drip fertigation with 24 splits (D_{24}), followed by D_6. C_6 took maximum days for harvesting. In the second year, the duration of the crop was not affected by the method of irrigation or frequency of fertigation.

Increasing the fertilizer levels resulted in higher number of days for harvest in the first year, whereas in the second year, higher fertilizer doses helped in early harvesting of the bunches. Combined effect of irrigation methods and fertilizer dose showed that at low fertilizer levels, drip fertigation (D_{24} and D_6) resulted in longer duration and at higher fertilizer dose D_6 and D_{24} took less number of days for harvesting than conventional irrigation and fertilizer application.

4.3 D-finger characteristics

Data on the D-finger characters are presented in Tables 4.13 and 4.14 for the first year and second year respectively.

Table 4.13. Effect of methods of irrigation, frequencies and levels of fertilizer application on D-finger characters of banana var. Nendran during first year

Treatment	No. of fingers in D- hand	D- finger weight (g)	D- finger Length (cm)	D- finger Girth (cm)
C_6	10.07	120.71	19.61	11.91
D_6	9.02	110.83	19.93	11.81
D_{24}	10.23	125.17	20.68	12.29
CD (0.05)	NS	NS	NS	NS
F_{50}	9.67	111.74	20.89	12.34
F_{100}	9.33	122.53	20.21	11.69
F_{150}	10.00	121.24	20.04	12.24
F_{200}	9.39	126.44	20.06	11.68
F_{250}	10.47	112.57	19.17	12.04
CD (0.05)	NS	6.686	NS	NS
C_6F_{50}	10.00	110.08	20.90	12.53
C_6F_{100}	9.33	125.28	18.90	11.97
C_6F_{150}	11.00	127.64	18.90	11.50
C_6F_{200}	9.00	122.04	20.00	11.73
C_6F_{250}	11.00	118.50	19.63	11.80
D_6F_{50}	9.67	110..07	20.33	12.30
D_6F_{100}	8.67	113.01	20.67	10.57
D_6F_{150}	9.00	111.27	21.00	12.93
D_6F_{200}	9.00	113.58	18.80	10.93
D_6F_{250}	8.75	106.22	18.87	10.93
$D_{24}F_{50}$	9.33	115.05	21.43	12.20
$D_{24}F_{100}$	10.00	129.29	21.36	12.53
$D_{24}F_{150}$	10.00	124.82	20.23	12.30
$D_{24}F_{200}$	10.17	143.71	21.37	12.37
$D_{24}F_{250}$	11.67	112.99	19.02	12.03
CD (0.05)	NS	11.58	NS	NS

Table 4.14. Effect of methods of irrigation, frequencies and levels of fertilizer application on D-finger characters of banana var. Nendran during second year

Treatment	Fingers in D-hand	D-finger weight(g)	D-finger length(cm)	D-finger girth(cm)	D-finger volume(cc)
C_6	10.00	177.88	20.05	13.59	144.93
D_6	10.62	189.70	21.54	13.41	154.33
D_{24}	10.40	197.39	21.97	13.37	157.67
CD (0.05)	NS	15.51	NS	NS	NS
F_{25}	10.11	165.10	20.48	13.39	142.00
F_{50}	10.89	189.04	19.96	13.86	143.78
F_{100}	10.28	204.96	22.01	13.76	164.67
F_{150}	10.11	190.86	21.69	13.12	154.56
F_{200}	10.31	191.65	21.80	13.17	156.56
CD (0.05)	NS	15.38	1.232	NS	NS
C_6F_{25}	9.50	166.05	20.13	14.53	166.33
C_6F_{50}	11.17	194.98	16.87	13.40	130.67
C_6F_{100}	10.17	212.15	23.23	14.27	173.00
C_6F_{150}	9.00	163.05	19.90	12.93	130.67
C_6F_{200}	10.17	153.18	20.10	12.83	124.00
D_6F_{25}	11.00	156.23	21.43	12.83	121.00
D_6F_{50}	10.67	186.30	22.50	14.17	148.00
D_6F_{100}	10.00	211.20	21.17	14.00	173.00
D_6F_{150}	11.33	187.83	20.83	12.97	154.67
D_6F_{200}	10.08	206.94	21.77	13.10	175.00
$D_{24}F_{25}$	9.83	173.00	19.87	12.80	138.67
$D_{24}F_{50}$	10.83	185.84	20.50	14.00	152.67
$D_{24}F_{100}$	10.67	191.54	21.63	13.00	148.00
$D_{24}F_{150}$	10.00	221.72	24.33	13.47	178.33
$D_{24}F_{200}$	10.67	214.84	23.53	13.57	170.67
CD (0.05)	NS	26.64	2.134	NS	29.49

4.3.1 Number of fingers in D-hand

The fingers in D-hand also followed a similar trend as in the case of number of hands. The method of irrigation, frequency of fertigation, and level of fertilizers or their interactions did not influence the finger number in D-hand in both the years. The number of fingers varied from 8.67 to 11.67 in the first year and from 9.0 to 11.33 in the second year.

4.3.2 D-finger weight

D-finger weight in the first year was not affected by the method of irrigation and fertilizer application. But the increase in level of fertilizer up to F_{200} increased the weight of the index finger. F_{250} registered a lower fruit weight which was comparable with that of F_{50}

In the second year, there was an increase in the weight of the D- finger, when drip fertigation was adopted, compared to that in conventional method. Increasing the frequency of fertilizer application from 6 to 24 also helped in gaining more fruit weight.

A fertilizer level of F_{100} registered the highest fruit weight and increasing the level still further resulted only in comparable fruit weight.

4.3.3 D-finger length

In the first year, D-finger length did not vary significantly with the method of irrigation, frequency and level of fertilization or with their combined effect. In the second year, the levels of fertilizer had significant influence, but not the method of irrigation and frequency of fertilization. Increasing fertilizer level up to F_{100} increased the length of fruits and fertilizer doses higher than F_{100} produced fruits with same length.

Analysis of the combined effect of methods of fertilization and levels of fertilizer showed that $D_{24}F_{150}$ and $D_{24}F_{200}$ could produce the longest fruits. In drip fertigation in six splits (D_6), the length of the fruits were similar in fertilizer levels beyond F_{100}, but in conventionally treated plants, the length of fruits was found decreasing beyond F_{100}. The lowest length was observed for C_6F_{50}, but when F_{50} was combined with D_6 or D_{24}, significant increase was observed.

4.3.4 D- finger girth

Tables 4.13 and 4.14 showed that the girth of the fruit was not influenced by methods of irrigation, frequencies of fertilization, levels of fertilizers or their interactions in both the years.

4.3.5 D-finger volume

The method of irrigation, frequency of fertigation and level of fertilization did not influence the volume of D-finger in the second year (Table 4.14). The interaction of these factors indicated that F_{25} was significantly inferior in both D_6 and D_{24} and all other levels were on par. In conventional method, levels above F_{100} resulted in reduced volume.

4.4 Suckering habit

The number of suckers present in the mat at the time of flowering and harvesting are presented in Table 4.15.

In the first year, drip fertigation with 24 splits (D_{24}) registered more number of suckers at flowering than D_6 and conventional. But at harvest the variation was non-significant. In the second year also, the treatments had no influence on sucker production.

Fertilizer levels produced significant effect on number of suckers at harvesting in both the years. In the first year fertilizer levels above F_{100} behaved similarly whereas in the second year, sucker production increased with fertilizer level.

Interaction effect was non-significant in both the years. Number of suckers both at flowering and harvesting was considerably more in the first year than in the second year.

4.5 Biomass production

The biomass accumulation by each part and the whole plant in the first year and second year are furnished in Tables 4.16 and 4.17 respectively.

In the first year, the total biomass produced by drip fertigation in 24 splits (60.06 kg) was comparable with that of conventionally treated plants. Rhizome, which accounted for major share of biomass also followed the same trend. The biomass of pseudostem, leaf, male bud and bunch was not affected

Table 4.15. Effect of methods of irrigation, frequencies and levels of fertilizer application on sucker production of banana var. Nendran

Treatment	I year		II year	
	No. of suckers		No. of suckers	
	At flowering	At harvest	At flowering	At harvest
C_6	7.84	9.87	7.10	6.20
D_6	7.62	11.67	6.77	7.73
D_{24}	10.38	10.20	7.71	7.87
CD (0.05)	1.156	NS	NS	NS
F_{25}	-	-	7.69	5.56
F_{50}	8.44	7.22	6.00	6.33
F_{100}	8.63	12.00	7.94	6.89
F_{150}	8.51	11.00	7.06	8.44
F_{200}	8.63	10.67	7.28	9.11
F_{250}	8.84	12.00	-	-
CD (0.05)	NS	2.659	NS	1.628
C_6F_{25}	-	-	8.00	5.67
C_6F_{50}	6.53	6.00	6.17	5.67
C_6F_{100}	6.40	13.67	7.17	6.33
C_6F_{150}	7.43	10.33	6.17	6.33
C_6F_{200}	8.83	9.00	8.00	7.00
C_6F_{250}	10.00	10.33	-	-
D_6F_{25}	-	-	5.83	5.00
D_6F_{50}	8.17	9.67	5.83	6.33
D_6F_{100}	8.87	12.00	8.67	6.00
D_6F_{150}	8.00	12.33	7.33	10.67
D_6F_{200}	6.73	13.67	6.17	10.67
D_6F_{250}	6.33	10.67	-	-
$D_{24}F_{25}$	-	-	9.23	6.00
$D_{24}F_{50}$	10.63	6.00	6.00	7.00
$D_{24}F_{100}$	10.63	10.33	8.00	8.33
$D_{24}F_{150}$	10.10	10.33	7.67	8.33
$D_{24}F_{200}$	10.33	9.33	7.67	9.67
$D_{24}F_{250}$	10.20	15.00	-	-
CD (0.05)	NS	NS	NS	NS

Table 4.16. Effect of methods of irrigation, frequencies and levels of fertilizer application on biomass production (kg $plant^{-1}$) of banana var. Nendran during first year

Treatment	Rhizome	Pseudo-stem	Leaf	Peduncle	Male bud	Bunch	Total
C_6	36.12	21.69	1.98	0.62	0.24	5.89	66.52
D_6	35.18	18.47	1.53	0.75	0.29	5.63	61.84
D_{24}	41.62	18.37	2.15	0.71	0.29	5.94	69.06
CD (0.05)	5.717	NS	NS	0.045	NS	NS	4.142
F_{50}	36.89	17.65	2.09	0.78	0.26	5.25	62.92
F_{100}	40.89	22.22	2.00	0.69	0.32	6.22	72.35
F_{150}	37.36	18.98	1.70	0.66	0.23	6.39	65.31
F_{200}	36.22	19.74	1.89	0.73	0.21	6.08	64.87
F_{250}	36.83	18.89	1.77	0.59	0.34	5.16	63.59
CD (0.05)	NS	2.999	NS	0.087	0.053	0.555	4.469
C_6F_{50}	32.77	19.84	2.17	0.60	0.27	5.36	61.01
C_6F_{100}	45.00	23.50	2.33	0.61	0.27	6.30	78.01
C_6F_{150}	30.82	18.75	1.90	0.63	0.22	6.97	59.29
C_6F_{200}	33.83	20.00	1.83	0.69	0.19	5.48	62.03
C_6F_{250}	38.17	26.33	1.67	0.56	0.23	5.32	72.28
D_6F_{50}	37.86	18.83	1.99	1.03	0.15	5.87	65.731
D_6F_{100}	39.17	20.33	1.67	0.80	0.37	6.17	68.50
D_6F_{150}	40.67	20.33	1.50	0.63	0.22	5.62	68.97
D_6F_{200}	31.33	17.83	1.33	0.67	0.27	5.55	56.93
D_6F_{250}	26.83	15.00	1.17	0.60	0.50	4.97	49.07
$D_{24}F_{50}$	40.04	14.28	2.10	0.70	0.36	4.53	62.03
$D_{24}F_{100}$	38.50	22.83	2.00	0.67	0.32	6.20	70.52
$D_{24}F_{150}$	40.59	17.85	1.69	0.72	0.26	6.58	67.68
$D_{24}F_{200}$	43.49	21.38	2.50	0.85	0.22	7.20	75.64
$D_{24}F_{250}$	45.50	15.33	2.49	0.62	0.29	5.20	69.43
CD (0.05)	6.864	5.195	NS	0.151	0.092	0.961	7.740

Table 4.17. Effect of methods of irrigation, frequencies and levels of fertilizer application on biomass production (kg plant^{-1}) of banana var. Nendran during second year

Treatment	Rhizome	Pseudostem	Leaf	Peduncle	Male bud	Fruit	Total
C_6	30.67	29.90	1.55	0.562	0.487	9.16	72.32
D_6	27.70	32.00	1.84	0.585	0.632	10.07	72.83
D_{24}	30.23	32.42	1.77	0.595	0.737	10.52	76.28
CD (0.05)	2.211	0.878	0.2565	NS	0.0717	0.567	3.053
F_{25}	20.12	21.14	1.43	0.538	0.594	7.80	51.63
F_{50}	27.54	26.84	1.51	0.635	0.488	9.57	66.59
F_{100}	30.13	29.26	1.80	0.647	0.667	10.45	72.96
F_{150}	33.94	38.66	2.17	0.558	0.724	10.90	86.95
F_{200}	35.92	41.30	1.69	0.525	0.619	10.87	90.92
CD (0.05)	1.636	1.902	0.240	0.069	0.031	0.648	3.18
C_6F_{25}	18.55	19.73	1.25	0.550	0.470	7.92	48.47
C_6F_{50}	26.40	30.53	1.38	0.625	0.388	8.95	68.27
C_6F_{100}	33.90	30.63	1.80	0.660	0.482	9.93	77.41
C_6F_{150}	35.47	34.70	1.55	0.525	0.499	9.57	82.31
C_6F_{200}	39.00	33.90	1.77	0.450	0.595	9.43	85.15
D_6F_{25}	20.05	22.70	1.55	0.545	0.698	7.70	52.24
D_6F_{50}	23.92	25.40	1.90	0.640	0.500	9.85	62.21
D_6F_{100}	24.86	27.20	1.35	0.670	0.763	10.46	65.31
D_6F_{150}	40.20	40.10	3.15	0.500	0.810	11.44	96.20
D_6F_{200}	29.45	44.60	1.25	0.568	0.388	10.91	87.17
$D_{24}F_{25}$	21.77	21.00	1.50	0.520	0.615	7.77	53.18
$D_{24}F_{50}$	32.30	24.60	1.25	0.640	0.575	9.92	69.29
$D_{24}F_{100}$	31.63	29.95	2.25	0.610	0.748	10.95	76.16
$D_{24}F_{150}$	26.15	41.17	1.80	0.650	0.863	11.70	82.39
$D_{24}F_{200}$	39.30	45.40	2.07	0.557	0.875	12.27	100.45
CD (0.05)	2.834	3.294	0.416	NS	0.0531	1.123	5.51

significantly by the method of fertilization. However, peduncle weight increased when drip fertigation was adopted.

In the second year, significantly higher biomass was obtained from D_{24}, followed by D_6 and C_6 which were on par with each other. Drip fertigation, irrespective of the frequency of fertilization was superior to conventional methods in producing the above ground portion. But the conventional method resulted in more biomass accumulation in the rhizome.

Comparison of different levels of fertilizers on biomass production showed that in the first year maximum biomass was produced when a fertilizer level of F_{100} was provided. All other levels were inferior to F_{100}, but on par with each other. Similarly the pseudostem biomass also was highest in F_{100}, but on par with F_{200}. The weight of peduncle did not follow a definite pattern and F_{50} and F_{200} had comparable weight.

In the second year increase in the weight of rhizome, pseudostem and leaf were noticed with the increase in fertilizer level. The higher peduncle and bunch weight were recorded by F_{100} and levels beyond F_{100} registered lesser values for peduncle weight but comparable for bunch weight.

Interaction effect analysis also showed that C_6F_{100} and $D_{24}F_{100}$ registered comparable biomass as that of C_6F_{250} and $D_{24}F_{200}$. Similar trend was present in the rhizome and pseudostem which form the major components. In the second year

D_6F_{150} and $D_{24}F_{200}$ recorded the maximum biomass, which were statistically higher than C_6F_{200}. Similarly $D_{24}F_{100}$ was superior to D_6F_{100} in biomass production.

Rhizome contributed much to the total biomass in the first year, due to higher sucker production. But in the second year, number of suckers produced was lesser and the weight of the pseudostem was found increased.

4.6 Nutrient content in the plant

4.6.1 Nitrogen

4.6.1.1 Nitrogen in the index leaf at different growth stages

The nitrogen content in the index leaf of banana at different growth stages, and that in different plant parts at harvest during the first year and second year are furnished in Tables 4.18 and 4.19 respectively.

In the first year, the nitrogen content in the leaf sample remained statistically similar in all methods of fertilizer application and frequencies of fertigation tried. In the second year, the content varied significantly with method of fertilization. At fifth and seventh months, drip fertigation in 24 splits (D_{24}) and conventional method (C_6) could produce similar nitrogen content. D_6 remained significantly inferior.

Comparison of different levels of fertilizer also revealed that the contents were the same in the first year in all the treatments at 3 MAP. The response increased up to F_{150} at 4 MAP and up to F_{250} in 5 MAP. At flowering, all levels above F_{100} resulted in similar nutrient content. Fertilizer dose of F_{100} was

Table 4.18. Effect of methods of irrigation, frequencies and levels of fertilizer application on N content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	3.10	3.27	3.38	3.63	2.78	1.814	1.12	1.12	1.13	0.47	2.29	1.31
D_6	3.65	3.27	3.46	3.63	2.73	1.692	1.07	1.19	1.31	0.50	2.30	1.33
D_{24}	3.38	3.30	3.41	3.92	2.82	1.870	1.18	1.35	1.41	0.55	2.26	1.42
CD(0.05)	NS	NS	NS	NS	NS	0.106	NS	0.132	0.160	0.056	NS	NS
F_{50}	3.40	2.94	3.17	3.66	2.68	1.830	1.06	1.01	1.12	0.44	2.36	1.31
F_{100}	3.17	3.20	3.28	3.77	2.82	1.72	1.09	1.31	1.37	0.56	2.27	1.26
F_{150}	3.24	3.58	3.43	3.74	2.84	1.83	1.12	1.20	1.30	0.56	2.27	1.38
F_{200}	3.44	3.31	3.42	3.85	2.89	1.77	1.11	1.26	1.26	0.50	2.27	1.33
F_{250}	3.62	3.38	3.77	3.63	2.64	1.81	1.23	1.34	1.35	0.46	2.22	1.49
CD(0.05)	NS	0.285	0.232	0.044	0.185	NS	NS	0.131	0.107	0.075	NS	0.087
C_6F_{50}	2.88	3.42	3.11	3.81	2.69	1.85	1.06	0.98	1.01	0.42	2.33	1.18
C_6F_{100}	2.91	2.93	3.28	3.56	2.88	1.90	1.04	1.204	1.20	0.50	2.21	1.23
C_6F_{150}	3.11	3.58	3.53	3.56	2.88	1.85	1.12	1.008	1.17	0.56	2.44	1.37
C_6F_{200}	3.36	3.29	3.30	3.53	2.91	1.79	1.16	1.17	1.12	0.45	2.30	1.34
C_6F_{250}	3.22	3.14	3.67	3.72	2.53	1.69	1.20	1.26	1.15	0.40	2.16	1.44
D_6F_{50}	3.72	3.02	3.36	3.98	2.63	1.85	1.06	0.92	1.16	0.45	2.40	1.42
D_6F_{100}	3.05	3.16	3.25	3.56	2.69	1.57	1.12	1.32	1.40	0.56	2.30	1.31
D_6F_{150}	3.84	3.58	3.36	3.30	2.72	1.79	1.01	1.26	1.32	0.50	2.16	1.29
D_6F_{200}	3.58	3.16	3.47	3.81	2.88	1.57	0.98	1.20	1.26	0.50	2.27	1.20
D_6F_{250}	4.06	3.42	3.84	3.53	2.72	1.68	1.18	1.26	1.40	0.48	2.36	1.43
$D_{24}F_{50}$	3.58	2.38	3.05	3.19	2.72	1.79	1.06	1.12	1.20	0.45	2.35	1.33
$D_{24}F_{100}$	3.56	3.50	3.30	4.20	2.88	1.68	1.12	1.40	1.51	0.62	2.30	1.26
$D_{24}F_{150}$	2.79	3.56	3.39	4.34	2.91	1.85	1.23	1.32	1.43	0.62	2.21	1.48
$D_{24}F_{200}$	3.36	3.47	3.47	4.20	2.88	1.96	1.18	1.40	1.40	0.56	2.27	1.44
$D_{24}F_{250}$	3.58	3.58	3.81	3.64	2.69	2.07	1.32	1.57	1.57	0.50	2.16	1.59
CD(0.05)	NS	0.494	NS	0.250	NS	NS	NS	NS	NS	NS	NS	0.151

Table 4.19. Effect of methods of irrigation, frequencies and levels of fertilizer application on N content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	3.54	3.86	3.68	3.35	3.13	1.30	1.35	0.76	1.60	0.78	2.93	1.23
D_6	3.47	3.56	3.31	3.25	2.86	1.00	1.13	0.73	1.28	0.75	2.47	1.20
D_{24}	3.62	4.06	3.75	3.36	3.14	1.08	1.09	0.95	1.60	0.72	2.47	1.25
CD(0.05)	NS	0.160	0.132	NS	0.192	0.167	0.045	0.003	0.101	NS	0.106	NS
F_{25}	3.32	3.38	3.19	3.21	2.92	0.94	1.02	0.86	1.44	0.77	2.61	1.14
F_{50}	3.52	3.83	3.57	3.26	2.63	1.13	1.08	0.83	1.47	0.73	2.64	1.24
F_{100}	3.48	3.92	3.59	3.32	3.34	1.28	1.36	0.82	1.60	0.69	2.59	1.26
F_{150}	3.75	3.76	3.72	3.49	3.16	1.01	1.17	0.82	1.39	0.71	2.59	1.25
F_{200}	3.64	4.18	3.83	3.31	3.16	1.27	1.30	0.74	1.56	0.85	2.69	1.24
CD(0.05)	0.141	0.23	0.111	0.182	0.187	0.157	0.075	0.062	0.138	0.062	NS	0.062
C_6F_{25}	3.23	3.33	3.20	3.20	3.24	1.02	1.02	0.74	1.74	0.87	2.78	1.18
C_6F_{50}	3.57	3.97	3.62	3.44	2.46	1.26	1.11	0.74	1.79	0.75	2.69	1.21
C_6F_{100}	3.74	4.04	3.80	3.58	3.44	1.59	1.62	0.79	1.62	0.56	3.14	1.27
C_6F_{150}	3.72	3.91	3.86	3.49	3.23	1.12	1.32	0.81	1.37	0.78	2.80	1.24
C_6F_{200}	3.46	4.06	3.90	3.03	3.19	1.49	1.66	0.73	1.46	0.92	3.25	1.24
D_6F_{25}	3.38	3.06	3.02	3.16	2.69	0.99	1.07	0.71	1.22	0.78	2.38	1.07
D_6F_{50}	3.45	3.46	3.46	3.09	2.32	0.94	1.05	0.74	1.20	0.78	2.44	1.20
D_6F_{100}	3.18	3.86	3.04	3.00	3.23	1.17	1.29	0.78	1.23	0.84	2.38	1.28
D_6F_{150}	3.72	3.44	3.49	3.59	2.95	0.93	1.12	0.74	1.29	0.63	2.58	1.23
D_6F_{200}	3.60	3.99	3.51	3.40	3.10	0.99	1.10	0.64	1.46	0.70	2.58	1.22
$D_{24}F_{25}$	3.36	3.74	3.35	3.28	2.84	0.82	0.98	1.12	1.34	0.64	2.69	1.16
$D_{24}F_{50}$	3.53	4.06	3.61	3.25	3.10	1.19	1.10	1.01	1.40	0.64	2.80	1.30
$D_{24}F_{100}$	3.53	4.08	3.92	3.39	3.37	1.07	1.17	0.88	1.95	0.67	2.24	1.24
$D_{24}F_{150}$	3.80	3.93	3.81	3.39	3.20	0.99	1.08	0.90	1.51	0.73	2.38	1.27
$D_{24}F_{200}$	3.86	4.48	4.07	3.49	3.20	1.31	1.15	0.84	1.76	0.92	2.24	1.27
CD(0.05)	0.244	NS	0.192	0.315	0.324	NS	0.131	0.107	0.238	0.107	0.238	0.107

found superior at 6 and 7 MAP of the second year and increasing the dose further resulted only in comparable contents. At 5 MAP, maximum response was obtained at F_{200}.

Interaction of the methods and levels of fertilization had no significant effect during the first year. In the second year, at 5 MAP C_6F_{200} and $D_{24}F_{100}$ were found to be at par.

The leaf N content gradually increased from 3 MAP to 6 MAP in the first year and to 5 MAP in the second year and then declined afterwards. Corresponding increase in leaf N content was observed with increasing fertilizer dose. At 4 MAP, it increased from 2.94 of F_{50} to 3.38 of F_{250} during first year and from 3.38 of F_{25} to 4.18 of F_{200} during second year.

4.6.1.2 N content of different plant parts at harvest

The N content of various plant parts at harvest during first and second year are also given in Tables 4.18 and 4.19 respectively.

4.6.1.2.1 Rhizome

The nitrogen content in the rhizome was influenced only by the method of fertilization. The level of fertilizer alone or in combination with the method of fertilizer application had no effect during the first year. Drip fertigation in 24 splits (D_{24}) resulted in more content than D_6, but conventional method (C_6) could produce the same effect as D_{24}.

In the second year, the method of irrigation, frequency of fertilization and levels of fertilizer had significantly influenced the N content. Though the N content varied from 0.82 to 1.49 per cent, the difference was not statistically significant in the combination treatments. Drip fertigation (D_6 or D_{24}) resulted in lesser N content than C_6 and among the levels, dose above F_{25} could produce comparable content in the rhizome.

4.6.1.2.2 Root

The effect of treatments directly or in combination had no significant effect in the first year. In the second year, conventional method registered more content than drip fertigation. The content was found increasing with increase in fertilizer level also, and the contents ranged from 1.02 to 1.36 per cent.

4.6.1.2.3 Pseudostem

Among various vegetative parts, the pseudostem contained the lowest N and ranged from 0.64 to 1.12 per cent in the second year. The N content was significantly influenced by the method of fertilization, in both the years. In both the years, drip fertigation in 24 splits (D_{24}) was superior to drip fertigation in six splits (D_6) or conventional method in six splits (C_6).

Fertilizer levels of F_{100} and above could produce comparable contents in the first year whereas in the second year, the highest fertilizer level (F_{200}) registered the lowest content. Fertilizer dose below F_{200} resulted in higher contents which were on par.

4.6.1.2.4 Peduncle

The nitrogen content in the peduncle was significantly higher under drip fertigation in the first year, whereas in the second year, conventionally treated plants registered higher content in the peduncle than D_6.

Levels above F_{100} resulted in statistically similar N contents in the peduncle in the first year. In the second year, the treatments though differed significantly had no definite pattern.

4.6.1.2.5 Fruit

Nitrogen content in the fruit of the first year crop was found increasing, when drip fertigation was adopted. The highest N content of 0.55 per cent was obtained under drip fertigation in 24 splits. But in the second year, the content was not affected by the method of irrigation and fertilization.

Increased response of the plants to fertilizer levels, with regard to the nitrogen content in the fruit was manifested only up to a level of F_{100} in the first year and levels of F_{100}, F_{150} and F_{200} registered comparable contents. Lowest and highest fertilizer levels recorded less N content in fruit. In the second year, the content was found decreasing with increase in fertilizer level except in F_{200}, which registered the highest N content.

The lowest fertilizer level (F_{25}), when applied with conventional irrigation resulted in significantly higher N content (0.87 per cent) than the same with drip fertigation in six splits (0.78 per cent) or in 24 splits (0.64 per cent).

It was also observed that the fruit N content was notably higher during second year compared to the first year.

4.6.1.2.6 Male bud

Among the reproductive parts, the male bud contained higher percentage of N and it varied from 2.16 to 2.44 in the first year and from 2.24 to 3.25 per cent in the second year.

In the first year, the effect of treatments, on the N content in male bud was not significant. But in the second year, significantly more content in male bud was observed under conventional method. The levels of fertilizer had no significant influence.

4.6.1.2.7 Leaf

Methods of irrigation and fertilizer application did not influence the nitrogen content in the leaf at harvest in both the years.

Appreciable increase in the N content with increase in fertilizer dose was observed in the first year while the content was found increasing only to a level of F_{50} in the second year. All other levels (F_{100} to F_{200}) were found comparable.

Analysis of combination of methods and levels of fertilization showed that in the first year irrespective of methods, the contents increased with fertilizer dose. In the second year the contents were found increasing with increase in fertilizer dose from F_{25} to F_{50} only in drip fertigated condition. In conventional method, all levels were on par.

4.6.2 Phosphorus

4.6.2.1 P content in the index leaf at different growth stages

The P content in the index leaf was significantly affected by the treatments in the first year (Table 4.20), though followed different trend in different stages. In the initial five months, P content was highest for drip fertigation in 6 splits, whereas at 7 MAP, conventional method resulted in a higher content than drip fertigation. In the second year, the response was significant only at fourth and seventh months, and drip fertigation in 24 splits and 6 splits respectively performed better in these cases (Table 4.21).

With regard to the response to fertilizer levels, in the first year the P content in the plant continued to increase till 7 MAP. The corresponding increase with increasing fertilizer dose was initially observed up to F_{100}, gradually changing to F_{150} at 4 MAP and to F_{250} at 5 MAP. In the second year also, the response increased from F_{50} to F_{150} as the crop reached 6 MAP stage. At 7 MAP, there was a decline in the P content in the index leaf when fertilized above F_{100}.

A scrutiny of the combination effects showed that in the first year the response in terms of plant P content increased with increase in fertilizer level and maximum content at 5MAP was produced in D_6F_{250}. In the second year also, at 5 MAP, the P content in D_{24} increased with increase in fertilizer level and $D_{24}F_{150}$ followed by $D_{24}F_{200}$ recorded higher contents than others. But for conventional

Table 4.20. Effect of methods of irrigation, frequencies and levels of fertilizer application on P content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	0.249	0.222	0.279	0.303	0.313	0.091	0.074	0.140	0.182	0.045	0.432	0.112
D_6	0.300	0.280	0.298	0.276	0.293	0.096	0.092	0.116	0.179	0.059	0.368	0.124
D_{24}	0.259	0.246	0.268	0.311	0.283	0.085	0.082	0.098	0.217	0.061	0.296	0.119
CD(0.05)	0.032	0.018	0.012	0.018	0.015	0.012	0.012	0.032	0.005	NS	0.003	NS
F_{50}	0.268	0.213	0.228	0.282	0.295	0.074	0.007	0.080	0.143	0.053	0.329	0.108
F_{100}	0.308	0.213	0.269	0.353	0.031	0.096	0.078	0.099	0.182	0.061	0.301	0.117
F_{150}	0.249	0.271	0.278	0.299	0.309	0.091	0.089	0.125	0.231	0.051	0.346	0.118
F_{200}	0.247	0.287	0.268	0.299	0.309	0.091	0.089	0.125	0.231	0.051	0.346	0.123
F_{250}	0.275	0.264	0.365	0.255	0.281	0.097	0.078	0.133	0.216	0.058	0.458	0.126
CD(0.05)	0.022	0.031	0.031	0.031	0.002	0.011	0.011	0.017	0.006	NS	0.003	NS
C_6F_{50}	0.235	0.263	0.238	0.373	0.353	0.080	0.075	0.068	0.146	0.042	0.348	0.107
C_6F_{100}	0.241	0.142	0.251	0.357	0.319	0.100	0.089	0.093	0.181	0.047	0.312	0.104
C_6F_{150}	0.270	0.207	0.254	0.273	0.308	0.079	0.080	0.140	0.207	0.054	0.450	0.107
C_6F_{200}	0.263	0.235	0.299	0.258	0.298	0.094	0.068	0.221	0.178	0.042	0.493	0.106
C_6F_{250}	0.263	0.263	0.353	0.252	0.290	0.100	0.057	0.178	0.198	0.039	0.576	0.134
D_6F_{50}	0.363	0.235	0.261	0.232	0.280	0.090	0.061	0.093	0.135	0.064	0.312	0.102
D_6F_{100}	0.398	0.263	0.273	0.271	0.287	0.109	0.064	0.113	0.178	0.073	0.303	0.124
D_6F_{150}	0.270	0.363	0.283	0.273	0.306	0.100	0.097	0.117	0.185	0.055	0.348	0.137
D_6F_{200}	0.242	0.313	0.260	0.312	0.293	0.090	0.143	0.146	0.193	0.042	0.430	0.135
D_6F_{250}	0.228	0.228	0.413	0.294	0.298	0.093	0.097	0.109	0.202	0.064	0.449	0.124
$D_{24}F_{50}$	0.207	0.142	0.185	0.241	0.254	0.053	0.075	0.080	0.149	0.054	0.327	0.113
$D_{24}F_{100}$	0.313	0.235	0.283	0.430	0.324	0.079	0.082	0.090	0.186	0.064	0.287	0.112
$D_{24}F_{150}$	0.207	0.242	0.296	0.352	0.315	0.093	0.091	0.117	0.301	0.044	0.259	0.110
$D_{24}F_{200}$	0.235	0.313	0.245	0.313	0.270	0.100	0.083	0.089	0.201	0.075	0.259	0.129
$D_{24}F_{250}$	0.335	0.300	0.329	0.220	0.255	0.099	0.081	0.113	0.249	0.071	0.348	0.121
CD(0.05)	0.038	0.053	0.053	0.053	0.011	0.019	0.017	0.029	0.011	NS	0.005	NS

Table 4.21. Effect of methods of irrigation, frequencies and levels of fertilizer application on P content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	0.224	0.209	0.197	0.166	0.153	0.067	0.088	0.060	0.259	0.089	0.454	0.174
D_6	0.210	0.197	0.175	0.172	0.189	0.061	0.072	0.068	0.197	0.074	0.445	0.138
D_{24}	0.218	0.221	0.199	0.158	0.154	0.048	0.080	0.069	0.246	0.081	0.481	0.114
CD(0.05)	NS	0.018	NS	NS	0.032	0.007	0.002	NS	NS	0.012	NS	NS
F_{25}	0.23	0.178	0.153	0.157	0.141	0.054	0.069	0.056	0.224	0.066	0.380	0.106
F_{50}	0.208	0.210	0.188	0.163	0.144	0.077	0.091	0.064	0.220	0.092	0.451	0.189
F_{100}	0.219	0.209	0.197	0.152	0.200	0.046	0.091	0.072	0.261	0.083	0.484	0.122
F_{150}	0.219	0.227	0.281	0.165	0.153	0.062	0.082	0.068	0.232	0.088	0.505	0.127
F_{200}	0.207	0.220	0.194	0.191	0.190	0.056	0.068	0.068	0.231	0.078	0.480	0.147
CD(0.05)	NS	0.031	0.010	0.020	0.020	0.010	0.010	NS	NS	0.015	0.003	NS
C_6F_{25}	0.242	0.216	0.151	0.149	0.121	0.050	0.071	0.042	0.298	0.047	0.420	0.110
C_6F_{50}	0.226	0.226	0.208	0.160	0.100	0.071	0.089	0.042	0.256	0.103	0.420	0.365
C_6F_{100}	0.277	0.197	0.224	0.178	0.231	0.071	0.106	0.079	0.250	0.085	0.449	0.131
C_6F_{150}	0.133	0.195	0.203	0.167	0.121	0.074	0.082	0.071	0.259	0.106	0.484	0.115
C_6F_{200}	0.242	0.209	0.200	0.178	0.193	0.071	0.094	0.067	0.230	0.105	0.498	0.149
D_6F_{25}	0.231	0.115	0.124	0.146	0.178	0.071	0.064	0.064	0.180	0.077	0.300	0.097
D_6F_{50}	0.177	0.204	0.177	0.198	0.182	0.113	0.071	0.071	0.180	0.087	0.484	0.106
D_6F_{100}	0.211	0.245	0.207	0.158	0.192	0.013	0.072	0.066	0.210	0.077	0.506	0.128
D_6F_{150}	0.300	0.229	0.205	0.178	0.202	0.055	0.082	0.067	0.195	0.677	0.498	0.145
D_6F_{200}	0.133	0.191	0.160	0.182	0.192	0.053	0.071	0.071	0.221	0.054	0.437	0.162
$D_{24}F_{25}$	0.229	0.202	0.184	0.175	0.124	0.041	0.072	0.062	0.195	0.074	0.410	0.110
$D_{24}F_{50}$	0.22	0.201	0.180	0.135	0.149	0.043	0.112	0.079	0.225	0.087	0.449	0.097
$D_{24}F_{100}$	0.168	0.186	0.160	0.121	0.178	0.053	0.094	0.071	0.323	0.087	0.498	0.107
$D_{24}F_{150}$	0.225	0.258	0.247	0.150	0.135	0.056	0.082	0.067	0.243	0.081	0.534	0.122
$D_{24}F_{200}$	0.247	0.260	0.22	0.213	0.185	0.043	0.039	0.067	0.243	0.074	0.506	0.131
CD(0.05)	0.053	0.053	0.017	0.034	0.034	0.017	0.017	NS	0.053	0.026	0.003	0.206

method and drip in six splits, there was a decrease beyond F_{100}. After 5 MAP, there was a decrease in P content in the leaf and hence the content did not follow a definite pattern after six months.

The leaf P content of the second year was very less compared to the first crop after five months. The content in the first year decreased considerably at 4 MAP and then continued to increase till 7 MAP. In the second year, the content was decreasing progressively till 7MAP. At 7 MAP the leaf P content of the plants in the first year in conventional irrigation was 0.313, while it was only 0.153 in the second year.

4.6.2.2 P content in different plant parts at harvest

The P content of the various plant parts at harvest are given in Tables 4.20 and 4.21 for the first year and second year respectively.

4.6.2.2.1 Rhizome

The P content varied from 0.053 to 0.1 per cent during the first year and from 0.013 to 0.113 during the second year. Drip fertigation in six splits recorded the highest P content in rhizome in the first year and conventional method tended to remain comparable with D_6. The plants behaved similarly in the second year also.

Only F_{50} resulted in a comparatively lower P content and all other levels registered comparable contents in the first year. In the second year, the response increased up to F_{50} and decreased thereafter.

4.6.2.2.2 Root

In general, P content in roots was more than that of rhizome. The treatment effect on root P content was similar to that of rhizome. In the first year, higher P content was observed under drip method and in the second year, conventional method resulted in a higher content.

With regard to the fertilizer levels, in the first year, the P content increased with fertilizer dose up to F_{200} and further increase declined the P content. In the second year, maximum content was recorded in F_{50} and further increase resulted in comparable contents.

4.6.2.2.3 Pseudostem

The P content in pseudostem irrespective of the treatments was notably higher in the first year when compared to that in the second year.

Conventional basin irrigation and fertilizer application resulted in a higher content in the first year, with a comparable P content in D_6. But in the second year, the effect was non-significant, but drip fertigation tended to have a higher content.

The response of plants in terms of P content of pseudostem to different levels of fertilizer was found increasing up to a level of F_{250} in the first year. In the second year, fertilizer levels had no significant effect. Highest content was recorded in C_6F_{200} and the contents ranged from 0.068 per cent in C_6F_{50} to 0.221

per cent in C_6F_{200} in the first year. In the second year, the interaction effect was found non-significant as the contents ranged from 0.042 to 0.079 per cent.

4.6.2.2.4 Peduncle

The P content in the peduncle ranged from 0.135 to 0.301 in the first year and from 0.180 to 0.323 in the second year.

In the first year, drip fertigation in 24 splits resulted in a higher content of phosphorus in peduncle while drip fertigation in six splits had the lowest content. A fertilizer level of F_{150} had the highest P content and the contents decreased with further increase in fertilizer dose.

The effect of methods and levels of fertilization was not significant in the second year. However, significant variation was observed in combination treatments though no definite pattern was followed. $D_{24}F_{100}$ recorded the highest content (0.323 per cent) which was on par with C_6F_{25} (0.298 per cent), suggesting a higher content in the conventional method even at lower fertilizer levels.

4.6.2.2.5 Fruit

The P content in fruit varied from 0.039 to 0.075 and from 0.047 to 0.106 during the first year and second year respectively.

Methods and levels of fertilization did not exert any significant influence on the phosphorus content in the first year. In the second year, among the methods of fertilizer application, conventional method (C_6) had the highest content and drip fertigation in 24 splits (D_{24}) tended to be on par with C_6. Comparison of different fertilizer levels showed that the P content in fruit increased only to a level of F_{50} and further increase in level could produce only comparable contents.

4.6.2.2.6 Male bud

Among various plant parts, the male bud accumulated highest concentration of P and it ranged from 0.259 to 0.576 per cent in the first year and from 0.300 to 0.534 in the second year.

In the first year, conventional method registered the highest P content in male bud among different methods of irrigation and fertilizer application. In the second year, drip fertigation could register highest content, though not significant.

Effect of different fertilizer levels was found increasing with increase in dosage in the first year, while the contents remained comparable beyond F_{50} in the second year.

4.6.2.2.7 Leaf

The P content in the leaf was unaffected by the methods of fertilization and levels of fertilization in both the years. But the interaction between the methods and levels of fertilization was significant in the second year. Higher contents were recorded with higher fertilizer doses in conventionally treated plants where fertilizers were applied in six splits (D_6). But in (D_{24}), the contents were statistically similar in all fertilizer levels.

4.6.3 Potassium

4.6.3.1 K content in the index leaf at different growth stages

The concentration of potassium in various growth stages as influenced by the treatments are presented in Tables 4.22 and 4.23 for the first year and second year respectively. In general, the content of leaf decreased with growth from 3 MAP to 7 MAP in all the treatments and the variation was from 4.55 to 5.8 per cent at 3 MAP and from 3.60 to 4.80 per cent at 7 MAP in the first year.

In both the years in the initial stages, drip fertigation methods resulted in higher leaf contents, but the difference levelled off in subsequent months and conventionally treated plants registered higher K content in leaves at 7 MAP.

Response to the higher fertilizer levels was noticed only in the later stages of growth during the first year. At 6 MAP, F_{200} and F_{250} had the highest K content. In the second year, the increase in response up to 6 MAP was observed. The K content increased with fertilizer level up to F_{150} at 4 MAP and up to F_{200} at 6 MAP.

Analysis of combination of methods and levels of fertilization showed that in the initial stages (3 and 5 MAP) of the first year drip in 6 splits (D_6) was better than drip fertigation in 24 splits (D_{24}), if the fertilizer applied is at a lower dose (F_{50}).

Table 4.22. Effect of methods of irrigation, frequencies and levels of fertilizer application on K content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	4.60	4.30	4.94	5.31	4.40	10.42	5.28	9.28	10.17	1.40	6.20	1.19
D_6	5.47	4.25	4.88	4.80	4.28	9.04	5.72	8.00	8.92	1.42	5.39	1.17
D_{24}	5.44	4.56	4.57	4.26	3.92	8.64	4.80	7.55	9.18	1.44	4.82	0.95
CD (0.05)	0.192	0.160	0.056	0.071	0.428	1.066	0.229	0.412	0.611	0.198	0.483	NS
F_{50}	5.13	4.33	4.51	4.443	3.97	8.07	5.07	7.42	8.15	1.27	5.43	0.74
F_{100}	5.18	4.57	5.10	4.73	4.10	8.27	4.57	8.23	8.90	1.43	5.27	1.17
F_{150}	5.03	4.15	4.93	4.79	4.17	8.83	4.90	7.40	10.07	1.37	5.64	1.22
F_{200}	5.28	4.37	4.57	5.00	4.43	11.17	6.33	9.77	9.43	1.43	5.00	1.78
F_{250}	5.22	4.43	4.87	5.00	4.33	10.50	5.47	8.57	10.57	1.60	6.00	1.19
CD(0.05)	0.195	0.199	0.097	0.199	0.178	0.176	0.499	0.545	0.576	0.087	0.462	0.192
C_6F_{50}	4.60	4.0	5.90	4.50	4.00	10.00	6.00	8.80	9.05	1.30	6.10	0.77
C_6F_{100}	4.60	4.00	4.80	5.40	4.50	8.50	4.40	9.50	9.20	1.40	5.80	1.23
C_6F_{150}	4.60	4.00	5.20	5.47	4.40	9.60	4.60	7.60	10.90	1.40	6.00	1.27
C_6F_{200}	4.65	4.50	4.70	5.60	4.50	11.70	5.80	11.50	10.20	1.50	6.30	1.40
C_6F_{250}	4.55	4.40	5.10	5.50	4.60	12.30	5.60	9.00	11.50	1.40	6.80	1.27
D_6F_{50}	5.50	4.40	4.60	4.40	3.80	8.60	4.60	8.50	7.80	1.20	4.00	0.90
D_6F_{100}	5.45	4.40	5.20	5.00	4.20	7.50	4.80	7.40	8.60	1.40	6.00	1.27
D_6F_{150}	5.50	4.25	5.40	4.60	4.00	9.50	5.60	7.80	9.30	1.50	6.93	1.30
D_6F_{200}	5.59	4.10	4.50	5.20	4.80	9.60	8.40	8.50	8.70	1.40	4.20	1.27
D_6F_{250}	5.30	4.10	4.70	4.80	4.60	10.00	5.20	7.80	10.20	1.60	5.80	1.10
$D_{24}F_{50}$	5.30	4.00	4.03	4.30	4.10	5.60	4.60	4.95	7.60	1.30	6.20	0.57
$D_{24}F_{100}$	5.50	5.30	5.30	3.80	3.60	8.80	4.50	7.80	8.90	1.50	4.00	1.00
$D_{24}F_{150}$	5.00	4.20	4.20	4.30	4.10	7.40	4.50	6.80	10.00	1.20	4.00	1.10
$D_{24}F_{200}$	5.60	4.50	4.50	4.20	4.00	12.20	4.80	9.30	9.40	1.40	4.50	0.87
$D_{24}F_{250}$	5.80	4.80	4.80	4.70	3.80	9.20	5.60	8.90	10.00	1.80	5.40	1.20
CD(0.05)	0.337	0.345	0.169	0.345	0.306	2.038	0.864	0.944	0.998	0.151	0.799	NS

Table 4.23. Effect of methods of irrigation, frequencies and levels of fertilizer application on K content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	4.93	5.36	5.16	3.60	4.19	10.93	2.06	10.37	10.86	1.84	7.28	1.99
D_6	5.33	5.14	5.19	3.52	3.96	7.70	2.25	8.20	9.07	1.76	7.33	2.26
D_{24}	5.77	5.19	5.32	3.41	3.97	8.93	2.49	7.69	10.16	2.02	6.68	2.59
CD(0.05)	0.072	0.116	0.072	NS	NS	0.794	NS	1.282	0.314	NS	0.200	0.213
F_{25}	4.89	5.12	4.90	3.50	3.70	7.67	2.39	8.07	8.75	1.73	6.50	2.24
F_{50}	4.93	5.02	5.14	3.37	4.16	9.70	2.23	7.41	9.68	1.89	7.01	2.30
F_{100}	5.80	5.18	5.30	3.53	3.97	9.19	2.30	10.30	10.62	1.78	7.00	2.08
F_{150}	5.32	5.31	5.23	3.41	4.06	8.61	2.40	8.93	10.53	1.97	7.27	2.34
F_{200}	5.77	5.52	5.53	3.75	4.32	10.77	2.00	9.07	10.57	2.00	7.71	2.43
CD(0.05)	0.154	0.290	0.157	0.202	0.177	0.311	0.195	0.121	0.578	NS	0.493	0.151
C_6F_{25}	4.80	5.17	5.00	3.35	3.80	7.80	1.90	8.80	10.30	1.40	6.80	1.80
C_6F_{50}	4.50	5.50	5.20	3.40	4.07	9.60	2.40	9.17	11.50	2.20	7.30	1.97
C_6F_{100}	5.50	6.10	5.40	3.95	4.50	12.37	1.90	11.50	11.50	1.60	7.40	1.67
C_6F_{150}	4.13	5.03	5.00	3.90	4.18	11.70	2.20	10.50	10.50	2.00	7.40	2.17
C_6F_{200}	5.70	5.00	5.20	3.40	4.40	13.20	1.90	11.90	10.50	2.00	7.50	2.33
D_6F_{25}	4.73	5.15	4.80	3.95	3.60	7.40	2.10	7.80	7.80	2.00	6.30	2.37
D_6F_{50}	4.50	4.50	5.03	3.40	4.20	9.50	1.97	7.40	8.70	1.60	6.43	2.23
D_6F_{100}	6.00	4.60	5.10	3.65	3.80	7.40	2.40	9.40	9.33	1.80	7.80	2.07
D_6F_{150}	5.80	5.60	5.40	3.15	4.00	6.80	2.20	8.50	9.30	1.80	7.80	2.27
D_6F_{200}	5.60	5.85	5.60	3.45	4.20	7.40	2.57	7.90	10.20	1.60	8.82	2.37
$D_{24}F_{25}$	5.13	5.05	4.90	3.20	3.70	7.80	3.17	7.60	8.15	1.80	6.40	2.57
$D_{24}F_{50}$	5.80	5.05	5.20	3.30	4.20	10.00	2.33	5.67	8.83	1.87	7.30	2.70
$D_{24}F_{100}$	5.90	4.85	5.40	3.00	3.60	7.80	2.60	10.00	11.03	1.95	6.30	2.50
$D_{24}F_{150}$	6.03	5.30	5.30	3.17	4.00	7.33	2.80	7.80	11.80	2.10	6.60	2.60
$D_{24}F_{200}$	6.00	5.70	5.80	4.40	4.37	11.70	1.53	7.40	11.00	2.40	6.80	2.60
CD(0.05)	0.266	0.503	0.272	0.349	0.306	0.538	0.337	2.102	1.001	0.373	0.854	0.261

4.6.3.2 K content in different plant parts at harvest

4.6.3.2.1 Rhizome

The content of potassium was very high in all the plant parts and in rhizome the contents ranged from 5.60 to 12.30 per cent in the first year and from 6.8 to 13.20 per cent in the second year. Conventional method resulted in more content in both the years. Fertilizer levels of F_{200} and F_{250} had significantly higher contents than their lower doses.

Among the combination treatments, significant variation was observed in K content. In the first year in C_6F_{50} treatment, the K content was 10 per cent whereas in D_6F_{50} and $D_{24}F_{50}$, it was 8.60 and 5.60 respectively. In the second year, there was no definite pattern.

4.6.3.2.2 Root

The K content and the effect of treatments on it was notably different in two years.

In the first year, the K content ranged from 4.80 to 5.72 per cent among the different methods of irrigation and fertilization, and drip fertigation in six splits (D_6) had higher content than conventional method in six splits (C_6). In the second year, irrespective of the method, the contents were less (2.06-2.49 per cent) and the effect of method of irrigation and fertilization was non significant.

At higher fertilizer levels, (F_{200} and F_{250}) the content in root increased significantly in the first year, whereas the content decreased in the second year at a fertilizer level of F_{200}.

4.6.3.2.3 Pseudostem

Compared to other major nutrients, the accumulation of K in pseudostem was higher in all the treatments and it ranged from 4.95 to 11.5 per cent in the first year and from 5.67 to 11.90 in the second year.

Conventionally treated plants (C_6) registered higher potassium content in the pseudostem in both the years.

Comparison of different levels of fertilizers showed that the contents increased with increasing fertilizer dose in the first year. But in the second year, the highest level was recorded by F_{100} and levels above and below F_{100} registered lower values.

4.6.3.2.4 Peduncle

As in the case of pseudostem, conventional irrigation and fertilization resulted in higher potassium content in the peduncle in both the years and D_6 registered the lowest K content. Among different fertilizer levels a level of F_{150} and F_{100} respectively produced the highest K content in the first year and the second year and levels above them registered statistically similar K contents.

4.6.3.2.5 Fruit

The K content of fruit ranged from 1.2 to 1.8 per cent and 1.4 to 2.4 per cent in the first year and second year respectively.

Drip fertigation or conventional irrigation and fertilization did not differ significantly and the K content in the fruit was not affected by these treatments.

Variation in K content in the fruit due to variation in fertilizer dose was significant only in the first year and the contents were found increasing with increase in fertilizer levels.

4.6.3.2.6 Male bud

In male bud also, higher K content was obtained in conventionally treated plants but in second year, drip fertigation in six splits could produce comparable K content as conventionally irrigated and fertilized plants.

Increased fertilizer levels increased the K content in the male bud and the effect was more pronounced in the second year. When the highest fertilizer level was applied through D_{24} F_{200}, it resulted in lesser K content in male buds than that applied through C_6 or D_6 treatments.

4.6.3.2.7 Leaf

In the first year the K content in the leaf at harvest was not influenced by the method of irrigation and fertilizer application and frequency of fertigation. In the second year, the effect was significant and a higher content was observed in the leaves in drip fertigated plants. Comparing the frequencies of fertigation, a higher content was found when frequency of fertilizer application was 24.

Response to higher levels of fertilizers in terms of K content in leaves was observed at harvest in both the years. Highest content was observed in F_{200} in both the first year and second year.

Though not significant in the first year, in the second year higher K contents were observed in drip fertigation in 24 splits. In the second year, even the lowest level ($D_{24}F_{25}$) under drip fertigation in 24 splits registered a higher content than D_6 and C_6 at F_{200}.

4.6.4 Calcium

4.6.4.1 Ca content in the index leaf at different growth stages

The calcium content present in the index leaf during different growth stages of the crop in the first year and second year are furnished in Tables 4.24 and 4.25 respectively.

The effect of method of irrigation and frequency of fertilization was significant only in the first five months of growth in the first year. Drip fertigation in six splits resulted in the highest content in general. Unlike in the first year, conventionally treated plants had higher calcium content in the index leaf, during the second year except at 3 MAP and 7 MAP. Drip fertigation in six splits and 24 splits did not vary significantly.

There was a decrease in calcium content with increase in fertilizer level and at 5 MAP, the highest content was recorded with F_{50}. In the second year also, similar trend was obtained, though not significant in the initial five months.

Analysis of the combined effect of irrigation and fertilizer application showed that in the first year irrespective of the method, application of major nutrients in six splits (either C_6 or D_6) resulted in greater concentration of absorbed native calcium in leaf up to 7 MAP, than application in 24 splits (D_{24}).

Table 4.24. Effect of methods of irrigation, frequencies and levels of fertilizer application on Ca content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	0.75	0.82	0.58	0.88	0.88	0.89	0.78	0.63	0.34	0.25	0.26	1.51
D_6	0.94	0.91	0.65	0.90	0.90	0.84	0.65	0.63	0.35	0.29	0.26	1.63
D_{24}	0.59	0.58	0.55	0.90	0.94	0.53	0.63	0.70	0.33	0.28	0.25	1.70
CD (0.05)	0.143	0.106	0.045	NS	NS	0.064	0.120	0.032	NS	NS	NS	NS
F_{50}	0.85	0.87	0.71	1.04	0.96	0.89	0.70	0.78	0.34	0.26	0.31	1.77
F_{100}	0.82	0.87	0.63	0.99	0.87	0.82	0.71	0.61	0.36	0.27	0.24	1.65
F_{150}	0.74	0.87	0.58	0.89	0.93	0.74	0.69	0.77	0.35	0.29	0.24	1.65
F_{200}	0.66	0.65	0.52	0.91	0.92	0.63	0.68	0.50	0.32	0.26	0.28	1.58
F_{250}	0.74	0.61	0.52	0.65	0.85	0.70	0.65	0.61	0.33	0.28	0.20	1.43
CD (0.05)	0.102	0.075	0.031	0.107	0.061	0.075	NS	0.061	NS	NS	0.044	0.182
C_6F_{50}	0.89	0.87	0.68	1.05	0.95	0.98	0.77	0.52	0.29	0.21	0.31	1.62
C_6F_{100}	0.63	1.00	0.77	0.95	0.83	0.91	0.73	0.51	0.34	0.24	0.27	1.55
C_6F_{150}	0.70	0.83	0.55	0.91	0.93	0.94	0.76	1.01	0.38	0.26	0.25	1.25
C_6F_{200}	0.80	0.73	0.53	0.93	0.89	0.81	0.80	0.50	0.36	0.29	0.28	1.60
C_6F_{250}	0.73	0.70	0.37	0.59	0.83	0.83	0.83	0.63	0.34	0.24	0.17	1.55
D_6F_{50}	0.93	0.99	0.80	1.22	0.99	1.10	0.60	0.92	0.39	0.30	0.31	1.93
D_6F_{100}	1.18	0.96	0.60	0.79	0.83	0.93	0.76	0.55	0.37	0.29	0.27	1.80
D_6F_{150}	0.91	1.17	0.57	0.96	0.93	0.73	0.73	0.60	0.34	0.32	0.17	1.70
D_6F_{200}	0.70	0.80	0.48	0.99	0.96	0.66	0.60	0.46	0.32	0.26	0.29	1.50
D_6F_{250}	0.99	0.65	0.81	0.57	0.79	0.80	0.58	0.65	0.32	0.29	0.25	1.23
$D_{24}F_{50}$	0.72	0.77	0.67	0.86	0.96	0.60	0.73	0.90	0.34	0.26	0.32	1.77
$D_{24}F_{100}$	0.65	0.65	0.52	1.23	0.96	0.62	0.65	0.79	0.36	0.28	0.18	1.60
$D_{24}F_{150}$	0.62	0.62	0.62	0.81	0.93	0.55	0.58	0.69	0.32	0.30	0.30	2.0
$D_{24}F_{200}$	0.48	0.41	0.55	0.81	0.91	0.43	0.65	0.55	0.29	0.24	0.26	1.65
$D_{24}F_{250}$	0.51	0.48	0.39	0.79	0.95	0.47	0.56	0.57	0.33	0.31	0.19	1.49
CD (0.05)	0.177	0.131	0.053	0.185	0.107	0.131	0.131	0.107	0.075	0.053	0.074	0.315

Table 4.25. Effect of methods of irrigation, frequencies and levels of fertilizer application on Ca content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	0.34	0.41	0.44	0.45	0.41	0.58	0.55	0.74	0.24	0.22	0.29	1.00
D_6	0.36	0.26	0.36	0.41	0.50	0.57	0.49	0.61	0.31	0.32	0.31	0.94
D_{24}	0.32	0.26	0.32	0.38	0.88	0.66	0.41	0.75	0.34	0.28	0.25	0.90
CD(0.05)	0.032	0.045	0.045	0.003	0.184	0.055	0.101	0.072	0.003	0.003	0.003	NS
F_{25}	0.35	0.32	0.37	0.43	0.52	0.66	0.44	0.74	0.36	0.24	0.27	0.94
F_{50}	0.38	0.31	0.36	0.38	0.68	0.62	0.51	0.81	0.32	0.24	0.27	0.93
F_{100}	0.34	0.30	0.38	0.44	0.60	0.54	0.58	0.63	0.27	0.26	0.31	0.96
F_{150}	0.31	0.32	0.40	0.43	0.56	0.57	0.47	0.69	0.25	0.32	0.29	1.00
F_{200}	0.32	0.30	0.37	0.38	0.62	0.64	0.40	0.62	0.28	0.28	0.29	0.89
CD(0.05)	0.031	NS	NS	0.044	0.087	0.053	0.044	0.069	0.031	0.044	NS	NS
C_6F_{25}	0.33	0.44	0.44	0.49	0.45	0.62	0.47	0.79	0.35	0.13	0.26	0.90
C_6F_{50}	0.33	0.41	0.41	0.38	0.32	0.47	0.52	1.03	0.21	0.14	0.27	0.95
C_6F_{100}	0.37	0.38	0.47	0.50	0.42	0.52	0.72	0.52	0.20	0.29	0.29	1.05
C_6F_{150}	0.34	0.40	0.43	0.47	0.32	0.64	0.60	0.80	0.22	0.35	0.34	1.09
C_6F_{200}	0.36	0.42	0.46	0.43	0.53	0.65	0.43	0.58	0.24	0.17	0.32	1.00
D_6F_{25}	0.34	0.22	0.32	0.40	0.44	0.68	0.44	0.57	0.33	0.42	0.30	1.01
D_6F_{50}	0.41	0.26	0.37	0.43	0.46	0.70	0.54	0.63	0.36	0.31	0.30	0.83
D_6F_{100}	0.36	0.26	0.34	0.37	0.54	0.39	0.52	0.60	0.34	0.26	0.34	0.96
D_6F_{150}	0.33	0.34	0.44	0.46	0.54	0.39	0.48	0.58	0.22	0.27	0.29	0.97
D_6F_{200}	0.36	0.20	0.32	0.35	0.52	0.72	0.47	0.69	0.29	0.34	0.31	0.90
$D_{24}F_{25}$	0.38	0.31	0.34	0.40	0.68	0.69	0.40	0.88	0.40	0.19	0.25	0.89
$D_{24}F_{50}$	0.40	0.26	0.31	0.33	1.26	0.68	0.48	0.79	0.40	0.26	0.26	1.02
$D_{24}F_{100}$	0.30	0.25	0.34	0.45	0.84	0.70	0.52	0.78	0.27	0.24	0.29	0.86
$D_{24}F_{150}$	0.26	0.22	0.32	0.36	0.81	0.69	0.33	0.70	0.29	0.35	0.24	0.95
$D_{24}F_{200}$	0.25	0.27	0.32	0.37	0.83	0.55	0.31	0.60	0.32	0.35	0.23	0.75
CD(0.05)	0.053	0.075	0.053	0.075	0.151	0.092	0.075	0.119	0.053	0.075	NS	NS

4.6.4.2 Ca content in different plant parts at harvest

4.6.4.2.1 Rhizome

The concentration of Ca ranged from 0.43 to 1.1 per cent in the first year and from 0.39 to 0.72 per cent in the second year.

Drip fertilization in 24 splits (D_{24}) resulted in comparatively lower Ca content in the rhizome than C_6 or D_6, in the first year. But in the second year, a reverse result was obtained and the highest content was registered in D_{24}.

Comparison of fertilizer levels on the content of calcium showed that with the increase in fertilizer levels, the Ca content in the rhizome decreased and the plants behaved similarly in both the years, except in F_{200} of the second year.

Analysis of the combination treatments showed that in the first year, the highest level of fertilizer (F_{250}) when applied through drip as D_{24} resulted in lower Ca accumulation (0.47 per cent) whereas the same when applied through drip as D_6 or in basins resulted in a better content and the contents were 0.8 and 0.83 per cent respectively. A similar trend was observed during the second year also in the highest fertilizer levels.

4.6.4.2.2 Root

Conventional irrigation and fertilization resulted in more Ca content in the root in first year. In the second year, the content in C_6 was similar to that of D_6 and D_{24} recorded the lowest value.

Differences in fertilizer levels did not affect the Ca content in root significantly in the first year. In the second year F_{100} registered the highest value and levels above and below F_{100} had significantly lower values.

Ca content in rhizome and root were comparatively higher in the first year than in the second year.

4.6.4.2.3 Pseudostem

Drip fertigation in 24 splits (D_{24}) resulted in better Ca content in the pseudostem while this was on par with that in C_6 in the second year. Higher levels of fertilizers also were found decreasing the content in both the years.

D_6 treatment invariably resulted in lower calcium concentration in pseudostem and this became more evident in the analysis of combination treatments in both the years.

4.6.4.2.4 Peduncle

The effect of methods of irrigation, frequencies and levels of fertilization on Ca content in the peduncle was not significant in the first year. In the second year, higher content was registered in D_{24} followed by D_6 and then C_6. Higher fertilizer dose also could result in lower Ca content in the peduncle in the second year.

Lower fertilizer levels applied through drip in 24 splits resulted in higher Ca content than higher fertilizer levels applied through drip or in basins in six splits.

4.6.4.2.5 Fruit

Calcium content of fruits ranged from 0.21 to 0.32 per cent in the first year and 0.13 to 0.42 in the second year.

Methods of irrigation and fertilizer application had no marked influence in the first year. In second year, higher calcium content was recorded in drip fertigation particularly drip fertigation in 6 splits.

Calcium content in fruit remained statistically similar in the first year, irrespective of the fertilizer dose. But in the second year, higher contents were registered with higher fertilizer levels.

4.6.4.2.6 Male bud

Calcium content in male bud was found unaffected by the method of fertilization and irrigation in the first year. In the second year, drip fertigation in six splits registered the highest content, but was statistically on par with conventional method.

Response to levels of fertilizers was significant in the first year, though the response was negative. Highest content was recorded in the lowest fertilizer level. In the second year, the effect was non-significant.

Irrespective of the irrigation methods and fertilizer application frequency, the lowest level resulted in significantly higher Ca content whereas higher fertilizer levels behaved differently in the first year. In the second year such a significant variation could not be observed.

4.6.4.2.7 Leaf

Calcium content in the leaf was not affected by the method of irrigation and fertilizer application and frequency of fertigation in both the years.

In the first year comparison of different fertilizer levels showed that beyond F_{50}, there was a decreasing trend and the lowest value was recorded in F_{250}. In the second year the content was unaffected by the levels of fertilizer or by its interaction with methods of fertilizer application.

4.6.5 Magnesium

4.6.5.1 Mg content in the index leaf at different growth stages

Drip fertigation in six splits registered the highest Mg content in all the stages of growth of the first crop. In the second year, same trend was noticed at 3 MAP, but at 4 MAP and 5 MAP, conventional method resulted in the highest Mg content (Tables 4.26 and 4.27).

As in the case of calcium, Mg content also decreased with increase in fertilizer dose in both the years. Notable decrease in the leaf Mg content was observed in the second year than the first year irrespective of the irrigation method or quantity and frequency of fertilizer application at all stages.

4.6.5.2 Mg content in different plant parts at harvest

4.6.5.2.1 Rhizome

Methods of irrigation and fertilization did not bring any significant influence on the Mg content of rhizome in both years. In the first year, among

Table 4.26. Effect of methods of irrigation, frequencies and levels of fertilizer application on Mg content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	0.486	0.493	0.387	0.398	0.401	0.584	0.256	0.381	0.173	0.178	0.202	0.237
D_6	0.516	0.521	0.416	0.432	0.394	0.527	0.292	0.387	0.188	0.162	0.229	0.276
D_{24}	0.451	0.397	0.379	0.400	0.375	0.589	0.361	0.296	0.164	0.164	0.208	0.264
CD (0.05)	0.016	0.032	0.010	0.016	NS	NS	0.006	0.020	0.210	NS	0.023	0.010
F_{50}	0.533	0.477	0.428	0.496	0.442	0.920	0.428	0.394	0.186	0.155	0.221	0.281
F_{100}	0.480	0.475	0.397	0.421	0.429	0.435	0.304	0.329	0.166	0.159	0.196	0.298
F_{150}	0.449	0.535	0.390	0.389	0.378	0.436	0.265	0.428	0.170	0.176	0.228	0.230
F_{200}	0.474	0.461	0.370	0.382	0.373	0.471	0.253	0.288	0.174	0.180	0.223	0.244
F_{250}	0.487	0.403	0.384	0.362	0.329	0.572	0.264	0.334	0.178	0.169	0.198	0.242
CD (0.05)	0.010	0.031	0.014	0.010	0.062	0.081	0.006	0.017	0.006	0.014	0.014	0.031
C_6F_{50}	0.510	0.490	0.477	0.556	0.495	0.868	0.263	0.229	0.172	0.161	0.203	0.310
C_6F_{100}	0.424	0.521	0.407	0.408	0.536	0.397	0.274	0.253	0.158	0.177	0.235	0.340
C_6F_{150}	0.478	0.526	0.400	0.369	0.343	0.548	0.240	0.537	0.182	0.175	0.204	0.156
C_6F_{200}	0.561	0.475	0.377	0.301	0.341	0.632	0.280	0.316	0.157	0.195	0.199	0.218
C_6F_{250}	0.460	0.451	0.303	0.356	0.291	0.474	0.221	0.570	0.195	0.181	0.169	0.160
D_6F_{50}	0.587	0.482	0.400	0.561	0.482	0.88	0.356	0.405	0.191	0.162	0.198	0.335
D_6F_{100}	0.582	0.449	0.417	0.367	0.347	0.361	0.243	0.361	0.186	0.149	0.199	0.242
D_6F_{150}	0.456	0.673	0.411	0.412	0.394	0.376	0.298	0.519	0.162	0.187	0.245	0.267
D_6F_{200}	0.469	0.548	0.369	0.460	0.387	0.400	0.263	0.392	0.204	0.164	0.270	0.267
D_6F_{250}	0.480	0.451	0.482	0.361	0.363	0.616	0.299	0.261	0.199	0.150	0.235	0.268
$D_{24}F_{50}$	0.503	0.460	0.437	0.372	0.349	1.009	0.664	0.548	0.195	0.143	0.262	0.197
$D_{24}F_{100}$	0.433	0.455	0.367	0.487	0.405	0.548	0.394	0.375	0.154	0.150	0.155	0.311
$D_{24}F_{150}$	0.413	0.405	0.357	0.386	0.397	0.383	0.257	0.228	0.167	0.167	0.233	0.268
$D_{24}F_{200}$	0.392	0.361	0.363	0.386	0.391	0.381	0.215	0.156	0.162	0.182	0.200	0.247
$D_{24}F_{250}$	0.513	0.0307	0.368	0.368	0.335	0.626	0.273	0.171	0.140	0.177	0.190	0.300
CD (0.05)	0.017	0.053	0.024	0.017	0.107	0.141	0.011	0.029	0.011	0.024	0.024	0.053

Table 4.27. Effect of methods of irrigation, frequencies and levels of fertilizer application on Mg content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	0.267	0.282	0.274	0.227	0.152	265	0.249	0.157	0.116	0.124	0.245	0.160
D_6	0.281	0.240	0.246	0.229	0.210	0.264	0.219	0.185	0.150	0.184	0.254	0.209
D_{24}	0.260	0.261	0.240	0.228	0.199	0.249	0.196	0.185	0.151	0.138	0.234	0.217
CD(0.05)	0.016	0.010	0.010	NS	0.010	NS	0.003	NS	0.016	0.010	0.003	0.010
F_{25}	0.275	0.313	0.288	0.252	0.203	0.259	0.262	0.206	0.180	0.162	0.271	0.212
F_{50}	0.303	0.265	0.271	0.237	0.227	0.279	0.231	0.186	0.155	0.133	0.241	0.217
F_{100}	0.274	0.261	0.254	0.235	0.191	0.211	0.213	0.224	0.154	0.133	0.241	0.182
F_{150}	0.247	0.250	0.245	0.221	0.183	0.277	0.227	0.123	0.082	0.189	0.253	0.194
F_{200}	0.248	0.215	0.210	0.195	0.131	0.271	0.175	0.138	0.123	0.128	0.192	0.172
CD(0.05)	0.022	0.017	0.015	0.022	0.014	0.031	0.014	NS	0.015	0.022	0.006	0.010
C_6F_{25}	0.259	0.370	0.348	0.259	0.173	0.249	0.260	0.177	0.172	0.110	0.269	0.153
C_6F_{50}	0.278	0.282	0.282	0.235	0.153	0.289	0.237	0.153	0.136	0.100	0.250	0.173
C_6F_{100}	0.316	0.300	0.273	0.255	0.189	0.237	0.254	0.142	0.104	0.143	0.260	0.143
C_6F_{150}	0.236	0.243	0.242	0.204	0.140	0.266	0.262	0.143	0.052	0.213	0.242	0.187
C_6F_{200}	0.248	0.214	0.225	0.182	0.105	0.282	0.233	0.169	0.117	0.054	0.206	0.146
D_6F_{25}	0.288	0.240	0.262	0.234	0.247	0.281	0.260	0.175	0.177	0.246	0.282	0.223
D_6F_{50}	0.333	0.265	0.285	0.275	0.265	0.356	0.256	0.186	0.160	0.184	0.282	0.243
D_6F_{100}	0.244	0.225	0.237	0.208	0.184	0.173	0.213	0.357	0.189	0.143	0.258	0.199
D_6F_{150}	0.272	0.258	0.241	0.229	0.204	0.228	0.196	0.085	0.081	0.160	0.237	0.196
D_6F_{200}	0.267	0.212	0.205	0.201	0.150	0.284	0.172	0.121	0.142	0.188	0.209	0.184
$D_{24}F_{25}$	0.279	0.330	0.253	0.262	0.190	0.246	0.266	0.267	0.190	0.130	0.261	0.260
$D_{24}F_{50}$	0.298	0.247	0.246	0.200	0.262	0.191	0.199	0.217	0.169	0.109	0.262	0.235
$D_{24}F_{100}$	0.262	0.258	0.251	0.242	0.198	0.223	0.171	0.175	0.170	0.114	0.206	0.204
$D_{24}F_{150}$	0.232	0.249	0.251	0.231	0.207	0.337	0.223	0.141	0.114	0.195	0.281	0.199
$D_{24}F_{200}$	0.230	0.219	0.200	0.202	0.140	0.249	0.120	0.123	0.111	0.143	0.161	0.187
CD(0.05)	0.038	0.029	0.027	0.038	0.024	0.053	0.024	NS	0.027	0.038	0.018	0.017

different fertilizer levels the highest content was noticed in F_{50}, the lowest level tried and the content decreased with increase in fertilizer. In the second year, all levels except F_{100} could produce contents which were on par with each other and F_{100} recorded the lowest content.

The Mg content in the rhizome was widely varying in the first year and it ranged from 0.361 to 1.009 per cent while in second year, it remained with in the range of 0.173 to 0.356 per cent.

4.6.5.2.2 Root

Highest Mg content was recorded in drip fertigation in the first year and in conventional method in the second year.

Mg content was found decreasing with increase in the fertilizer levels in the two years of study.

4.6.5.2.3 Pseudostem

Increasing the frequency of fertigation decreased the Mg content in the first year, while in drip fertigation and conventional methods where fertilizers were given in six splits produced comparable contents. In the second year, the effect of method of irrigation and fertilization was non-significant.

A fertilizer level of F_{150} recorded the highest Mg content in pseudostem in the first year and increasing the dose further decreased the content. In the second year also, the plants responded similarly to all the treatments with regard to Mg content in pseudostem.

4.6.5.2.4 Peduncle

Higher Mg content was recorded in drip fertigation in six splits (D_6) in both the years. In the second year D_{24} also produced contents which were on par with D_6.

The Mg content in the peduncle was found to decrease with increase in the fertilizer level, and the highest content was registered in the lowest level in both years. A comparatively higher content of Mg was observed in the peduncle of first year crop, than that of second year.

4.6.5.2.5 Fruit

Conventional method in the first year and drip fertigation in the second year registered the highest Mg content in D-finger, though the variation was non-significant in the first year.

An increase in the content up to F_{150} was noticed among different fertilizer levels in both years. Levels above F_{150} registered similar contents in the first year and lower contents in the second year.

Generally, higher Mg content, was noticed in the first year when compared to that in second year, as it was ranging from 0.145 to 0.195 per cent in the first year and from 0.054 to 0.246 in the second year.

4.6.5.2.6 Male bud

Drip fertigation in six splits (D_6) registered the highest Mg content in male bud in both years though the content was comparable with that in D_{24} in the first year.

The effect of levels of fertilizer, though significant was not in definite pattern in the first year. But in the second year, the content was found decreasing with increase in fertilizer level.

4.6.5.2.7 Leaf

Mg content in leaf at harvest was significantly higher in drip fertigated banana than in the conventionally irrigated plants in both the years. Increasing fertilizer dose decreased the Mg content in both first year and second year.

4.6.6 Iron

4.6.6.1 Fe content in the index leaf at different growth stages

Iron content in the index leaf of the crop during 3 MAP to 7 MAP are given in Tables 4.28 and 4.29 respectively for the first year and second year.

In the first year, highest Fe content was registered in drip fertigation in 24 splits (D_{24}) at 3 MAP. Thereafter the variation was non-significant. In the final stages (7 MAP), D_6 also was on par with D_{24}. Conventional method had the lowest content.

As against in the first year, the Fe content in the leaf during second year was lowest in drip fertigation in 24 splits. Drip in six splits was higher or comparable with conventional method.

Comparison of different levels of fertilizers influencing the Fe content showed that increasing fertilizer dose to a level of F_{150} decreased the Fe content in all the months except 5 MAP, during the first year. But in the second year, Fe

Table 4.28. Effect of methods of irrigation, frequencies and levels of fertilizer application on Fe content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	324	360	229	193	190	2229	2593	610	353	130	144	433
D_6	229	297	200	208	213	2012	2648	704	330	185	243	451
D_{24}	405	337	205	196	206	2110	2627	718	340	203	243	612
CD(0.05)	38.50	37.7	NS	NS	7.9	146.5	NS	53.67	8.9	12.3	9.1	42.9
F_{50}	349	455	210	215	207	2379	2623	612	245	156	241	438
F_{100}	319	367	157	204	190	2342	2421	731	265	161	217	448
F_{150}	294	273	213	182	193	1785	2458	625	348	159	193	481
F_{200}	309	277	228	211	219	1827	2724	659	405	205	194	541
F_{250}	325	283	250	183	206	2251	2886	759	441	183	204	587
CD(0.05)	17.7	45.6	46.9	15.8	10.7	137	161.5	42.5	16.4	7.8	13.1	27.5
C_6F_{50}	318	443	281	235	192	1937	2050	708	267	150	135	363
C_6F_{100}	310	444	145	186	179	2238	2608	565	271	112	121	391
C_6F_{150}	336	253	237	178	183	1962	2324	759	360	94	110	463
C_6F_{200}	341	328	271	178	186	2464	2573	397	413	167	194	453
C_6F_{250}	316	330	212	189	210	2542	3410	619	451	127	158	493
D_6F_{50}	363	365	204	224	220	2693	2484	480	258	159	290	404
D_6F_{100}	228	320	167	193	179	2040	2611	917	256	196	227	436
D_6F_{150}	177	283	195	163	187	1680	2571	726	321	140	292	377
D_6F_{200}	219	285	173	252	250	1477	3052	686	381	221	203	485
D_6F_{250}	159	230	260	209	230	2170	2520	712	432	208	203	556
$D_{24}F_{50}$	367	557	144	187	210	2508	3336	649	211	158	297	546
$D_{24}F_{100}$	420	338	158	232	212	2748	2044	712	267	176	304	519
$D_{24}F_{150}$	370	284	206	204	208	1712	2480	390	363	241	177	603
$D_{24}F_{200}$	366	217	240	204	220	1540	2546	893	420	227	185	685
$D_{24}F_{250}$	500	288	277	152	178	2041	2727	947	441	213	252	710
CD(0.05)	30.6	78.9	81.3	27.4	18.5	237.4	279.7	73.7	28.4	13.5	22.7	47.7

Table 4.29. Effect of methods of irrigation, frequencies and levels of fertilizer application on Fe content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	281	250	229	214	192	1037	2519	642	209	193	108	619
D_6	347	229	232	233	205	1009	2589	590	248	143	125	585
D_{24}	260	131	184	180	173	1329	2931	574	329	168	134	643
CD(0.05)	51.64	NS	3.802	NS	4.248	88.47	331.1	42.40	53.40	NS	10.96	42.6
F_{25}	263	239	214	247	172	1129	2245	641	255	177	142	561
F_{50}	305	245	210	206	161	1322	2606	648	302	194	123	580
F_{100}	305	305	250	210	156	1204	2680	545	236	106	118	681
F_{150}	365	235	233	191	222	927	2792	634	259	175	129	601
F_{200}	242	160	169	189	238	1044	3077	541	258	187	101	655
CD(0.05)	36.91	35.15	15.60	25.98	15.18	166.7	180.2	37.38	42.56	40.60	12.31	47.6
C_6F_{25}	252	270	214	185	173	847	1962	640	217	102	128	620
C_6F_{50}	271	282	242	215	162	744	2160	520	224	259	94	567
C_6F_{100}	379	285	279	262	191	1523	3172	636	224	118	107	753
C_6F_{150}	245	258	242	221	213	868	2262	720	192	173	109	481
C_6F_{200}	259	158	168	188	225	1204	3040	696	187	215	104	673
D_6F_{25}	314	202	245	333	220	1236	2621	624	256	173	171	517
D_6F_{50}	333	209	216	257	158	1078	2484	703	242	120	106	548
D_6F_{100}	294	322	220	173	136	680	2250	424	229	99	118	674
D_6F_{150}	543	243	294	208	193	774	3040	685	212	177	138	571
D_6F_{200}	252	173	186	193	318	1281	2554	514	300	147	92	616
$D_{24}F_{25}$	223	246	183	224	123	1304	2153	661	293	159	128	545
$D_{24}F_{50}$	312	245	173	148	163	2144	3174	720	440	202	167	626
$D_{24}F_{100}$	243	309	252	196	141	1410	2618	576	254	103	129	616
$D_{24}F_{150}$	307	206	163	146	267	1139	3076	497	372	176	141	751
$D_{24}F_{200}$	215	150	153	188	173	649	3637	414	289	200	107	675
CD(0.05)	63.93	NS	27.01	45.01	26.29	288.7	312.1	64.75	73.71	NS	21.33	82.4

content was found to increase with fertilizer dose initially, but tended to decrease gradually with increasing fertilizer levels. At 3 MAP, the highest content was registered for F_{150}, but at 5 MAP and 6 MAP, it was for F_{100} and F_{25} respectively.

Fe content during 7 MAP was higher in D_6F_{200}, $D_{24}F_{100}$ and $D_{24}F_{200}$ whereas the content in C_6F_{200} and C_6F_{100} were considerably lower in the first year. In the second year, the contents in $D_{24}F_{200}$ and $D_{24}F_{100}$ were considerably lower.

4.6.6.2 Fe content in different plant parts at harvest

The Fe content of the plant parts at harvest are given in Tables 4.28 and 4.29 for the first year and second year respectively.

4.6.6.2.1 Rhizome

The Fe content of rhizome ranged from 1477 to 2748 ppm in the first year and from 649 to 2144 ppm in the second year.

Conventional method of irrigation and fertilization resulted in a higher Fe content in the rhizome in the first year, but this was on par with drip fertigation in 24 splits. In the second year, the content was the highest under D_{24} and both C_6 and D_6 were statistically similar.

Among different fertilizer levels, F_{50} registered the highest Fe content in both the years. Fertilizer doses above F_{50} resulted in a lower or comparable content of iron in the rhizome.

4.6.6.2.2 Root

The method of irrigation and fertilization had no effect on the Fe content in root in the first year, but the levels of fertilizers had significant influence. There was an increasing trend with increase in fertilizer dose.

In the second year, drip fertigation in 24 splits (D_{24}) recorded the highest content followed by C_6 and D_6. As in the case of first year, the content was found increasing with increasing dose of fertilizer.

Fe accumulation in roots was in general more than that in rhizome, irrespective of treatments.

4.6.6.2.3 Pseudostem

In the first year, drip fertigation resulted in a higher Fe content in the pseudostem than conventional method and D_6 and D_{24} did not vary significantly among themselves. Contrary to this, in the second year, C_6 recorded the highest Fe content and D_6 and D_{24} were on par.

Increasing fertilizer levels in the first year increased the Fe content in the pseudostem also. However, F_{100} also had a higher Fe content. But in the second year F_{100} and F_{200} recorded the lowest content. Under higher fertilizer levels, drip fertigation decreased the Fe content in pseudostem, the lower contents being with D_{24}. Under lower fertilizer levels, the reverse trend was observed.

4.6.6.2.4 Peduncle

In peduncle, the Fe content was higher in C_6 than D_6 or D_{24} in the first year. Unlike this, in the second year, D_{24} resulted in the higher content. The effect of fertilizer in increasing the Fe content was noticed in the first year in peduncle also. In the second year F_{50} also recorded a higher Fe content.

4.6.6.2.5 Fruit

An increased Fe content in the fruit was recorded in the first year when drip fertigation was adopted and drip fertigation in 24 splits (D_{24}) resulted in further increase in Fe content than drip fertigation in six splits. In the second year, the effect of fertilization methods was non-significant.

The Fe content in the fruit was significantly affected by the level of fertilizer also, but did not follow a definite pattern. F_{200} recorded the highest content in the first year and the levels below F_{200} were on par. In the second year F_{100} recorded the lowest content and all other levels were comparable.

The Fe content in F_{200} and F_{250} combined with D_6 and D_{24} was significantly higher than those combined with C_6 in the first year.

4.6.6.2.6 Male bud

In both the years, the Fe content in male bud was higher in drip fertigated plants and the difference between D_6 and D_{24} was non-significant. Similarly, increasing fertilizer dose also tended to decrease the Fe content. In the first year it ranged between 193 ppm and 241 ppm and in the second year it was between 101 and 142ppm, the highest content being in the lowest fertilizer levels.

4.6.6.2.7 Leaf

Drip fertigation in 24 splits resulted in the highest Fe content in the leaf at harvest in both the years, but conventional method also attained statistically similar Fe content in the second year.

Higher fertilizer levels enhanced the Fe content in the leaf at harvest. In the second year, F_{100} also could result in contents which were statistically on par with F_{200}

In general, a higher the content in the leaves was recorded in the second year (481 to 751 ppm) than in the first year (363 to 710 ppm).

4.6.7 Manganese

4.6.7.1 Mn content in the index leaf at different growth stages

In the initial five months of the first year, conventional method of fertilization (C_6) resulted in higher Mn content in the index leaf than drip fertigation (Table 4.30). The frequency of drip fertigation (D_6 and D_{24}) did not vary among themselves. After six months, the content in D_{24} increased extensively. In the second year also, conventional method continued to maintain a higher Mn content in the index leaf in all months (Table 4.31). This was followed by D_6 and D_{24} recorded the lowest values.

Table 4.30. Effect of methods of irrigation, frequencies and levels of fertilizer application on Mn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	2027	1873	2100	2670	2273	1287	792	1098	1100	528	961	6153
D_6	1559	1535	1870	2424	2165	856	835	993	1117	451	1384	6061
D_{24}	1439	1539	2049	3370	2457	860	963	996	1297	410	1043	7076
CD(0.05)	NS	227.7	173.8	551.1	179.8	114.1	NS	NS	NS	73.90	163.1	198.9
F_{50}	1101	1167	1383	1890	1746	841	850	733	906	517	964	5790
F_{100}	1756	1678	1939	2833	2164	927	733	678	867	483	1067	6032
F_{150}	1737	1798	1960	2983	2422	1021	911	830	1289	450	1172	6254
F_{200}	1783	1750	1983	3250	2639	1039	808	1307	1467	389	1333	6936
F_{250}	1998	1854	2767	3150	2521	1178	1014	1598	1344	478	1111	7137
CD(0.05)	165.2	184.2	209.8	221.9	218.6	89.2	144	162.6	156.4	70.2	180.8	295
C_6F_{50}	1300	1267	1450	2100	1837	1000	783	940	867	550	1020	6075
C_6F_{100}	2233	2100	2250	2850	2400	1017	817	800	950	600	850	5704
C_6F_{150}	2083	1950	1700	2400	2367	1200	700	750	1083	523	1000	5807
C_6F_{200}	2217	1950	2500	2850	2550	1650	733	1350	1250	450	1200	6284
C_6F_{250}	2300	2100	2600	3150	2213	1567	927	1650	1400	517	733	6895
D_6F_{50}	1037	1100	1450	2070	1767	817	517	800	950	500	1005	5454
D_6F_{100}	1417	1450	1450	2200	2060	867	650	600	750	450	1500	5830
D_6F_{150}	1810	1893	1950	2550	2100	870	1433	907	1233	423	1217	5545
D_6F_{200}	1550	1650	1800	2900	2367	683	773	1207	1350	367	1800	6249
D_6F_{250}	1983	1583	2700	2400	2533	1047	800	1450	1300	517	1400	7225
$D_{24}F_{50}$	967	1133	1250	1500	1633	707	1250	460	900	500	867	5840
$D_{24}F_{100}$	1617	1483	2117	3450	2033	897	733	633	900	400	850	6563
$D_{24}F_{150}$	1317	1550	2230	4000	2800	993	600	830	1550	400	1300	7409
$D_{24}F_{200}$	1583	1650	1650	4000	3000	783	917	1363	1800	350	1000	8276
$D_{24}F_{250}$	1710	1880	3000	3900	2817	920	1317	1693	1333	400	1200	7291
CD(0.05)	286.2	319.1	363.4	384.3	378.6	154.5	249.4	282	271	121.5	313.2	511

Table 4.31. Effect of methods of irrigation, frequencies and levels of fertilizer application on Mn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	1504	1269	1553	2102	1608	861	927	1157	538	360	992	4372
D_6	1035	806	1166	1274	917	539	666	981	542	380	761	2630
D_{24}	983	789	1026	970	1185	781	853	910	557	340	686	3427
CD(0.05)	83.88	303	175.5	112	145	81.7	76.1	102.7	NS	262	932	438.8
F_{25}	883	647	771	920	991	600	652	883	469	339	667	2650
F_{50}	1043	817	1006	1055	1014	834	853	1047	582	367	783	3100
F_{100}	1152	1012	1258	1509	1256	713	848	1010	532	400	842	4447
F_{150}	1315	1216	1562	1851	1352	723	907	1072	561	356	834	3559
F_{200}	1477	1082	1644	1910	1571	763	814	1068	583	340	940	3624
CD(0.05)	60.42	104.1	91.49	84.4	102.3	71.5	118.1	71.25	62.3	NS	81.3	466.0
C_6F_{25}	1025	740	707	1087	1050	683	620	1077	423	267	867	2607
C_6F_{50}	1365	1050	1377	1680	1180	947	787	1173	500	417	933	3633
C_6F_{100}	1475	1507	1583	2287	1627	1057	1105	1000	517	400	990	6546
C_6F_{150}	1645	1750	2107	2767	1837	790	1050	1133	650	383	905	4466
C_6F_{200}	2010	1300	1990	2690	2347	830	1070	1400	600	333	1267	4607
D_6F_{25}	950	650	727	1035	857	583	717	800	433	433	683	2513
D_6F_{50}	760	630	857	885	747	477	623	833	612	267	633	2239
D_6F_{100}	1030	820	1057	1255	1010	300	653	1057	547	400	780	3350
D_6F_{150}	1194	1020	1547	1775	1103	617	687	1200	483	433	773	2612
D_6F_{200}	1240	910	1643	1420	870	717	650	1017	633	367	937	2434
$D_{24}F_{25}$	675	550	880	635	1067	533	620	773	550	317	400	2830
$D_{24}F_{50}$	1005	770	783	600	1117	1080	1150	1133	633	417	783	3427
$D_{24}F_{100}$	950	710	1133	987	1130	783	787	973	533	400	757	3444
$D_{24}F_{150}$	1105	877	1033	1010	1117	763	983	883	550	250	823	3600
$D_{24}F_{200}$	1180	1037	1300	1620	1495	743	723	787	517	317	617	3832
CD(0.05)	104.6	180.4	158.5	146.2	177.2	123.9	204.6	123.4	107.9	118.8	1407	807.1

There was an increase in Mn content with increase in fertilizer level for the first five months of the first year. At 6 MAP, the contents increased at a faster rate irrespective of the treatments and levels above F_{150} had higher but comparable content. In the second year also, the content increased with increase in fertilizer level in all the stages.

Analysis of combined effect of irrigation methods, frequencies and levels of fertilizer application showed that in the second year a higher fertilizer application in basin (C_6F_{150} and C_6F_{200}) could maintain fairly higher content in all the stages whereas higher levels through drip ($D_{24}F_{150}$, $D_{24}F_{200}$, D_6F_{150} and D_6F_{200}) had lesser content in the later stages.

Concentration of Mn in leaves was higher in the first year than in the second year, irrespective of different treatments.

4.6.7.2 Mn content in different plant parts at harvest

Distribution of Manganese in different plant parts was studied by determining the content at harvest in those plant parts. The data are presented in Tables 4.30 and 4.31 for the first year and second year respectively.

4.6.7.2.1 Rhizome

Conventional method had a reasonably higher Mn content in the rhizome than drip fertigation in the first year, while in the second year, the variation was not much pronounced. Both C_6 and D_{24} resulted in comparable contents and D_6 had a lower content.

Increase in the fertilizer levels increased the Mn content in rhizome in the first year: while in the second year the highest content was recorded in F_{50} and even F_{200} resulted in content which was on par with F_{50}.

A higher content compared to that in the second year, was noticed in the first year irrespective of the treatments. The contents varied from 683 to 1650 ppm in the first year and from 300 to 1080 ppm in the second year.

4.6.7.2.2 Root

The effect of methods of irrigation and fertilization was not significant in the first year. However in the second year C_6 and D_{24} had a higher content than D_6.

As in the case of Mn content in rhizome, in the roots also the contents increased with increased fertilizer levels in the first year. In the second year, F_{50} and levels above it had comparable contents.

4.6.7.2.3 Pseudostem

Drip fertigation and conventional basin application of fertilizers did not bring any variation in Mn content in pseudostem in the first year. In the second year conventional method resulted in a significantly higher Mn content in the pseudostem.

Variations due to different levels of fertilizers was more pronounced in the first year; where the content increased with increasing fertilizer levels. In the second year, the contents were increased only up to a level of F_{50}.

4.6.7.2.4 Peduncle

Only the different levels of fertilizers could produce significant variation on the Mn content in the peduncle. In the first year, the response was more prominent and the content increased progressively with increase in fertilizer levels. In the second year, the enhanced response was only to a level of F_{50}.

4.6.7.2.5 Fruit

Conventional method registered a higher Mn content in the first year while in the second year, both conventional (C_6) and drip fertigation in six splits (D_6) had comparable contents.

The variation in Mn content due to different fertilizer levels was not pronounced in both the years, but a higher content was recorded in lower fertilizer levels.

4.6.7.2.6 Male bud

In the first year, Mn content in male bud due to drip fertigation was higher than that due to conventional method. But in the second year, the pattern was just the opposite. But in both the years, the effect of fertilizer levels was the same and the content increased with increase in fertilizer levels.

A comparatively higher Mn content was observed in the first year than in the second year.

4.6.7.2.7 Leaf

Mn content in the leaf at harvest was very high compared to that in other plant parts. It varied from 5454 to 8276 ppm in the first year and from 2239 to 6546 ppm in the second year. This also means that the content in the leaf in the first year was much more than that in the second year. Drip fertigation in 24 splits resulted in a higher Mn content in the first year whereas conventional method produced more content in the second year.

Increasing fertilizer dose increased the Mn content in the first year, but in the second year F_{100} produced the highest content and further increase in fertilizer dose decreased the Mn content.

4.6.8 Copper

4.6.8.1 Cu content in the index leaf at different growth stages

The copper content in the index leaf of banana during the first year and second year are given in Tables 4.32 and 4.33 respectively.

In the first year, the content for the first four months was not affected by the method of irrigation, frequency of fertigation and level of fertilization. Later, the treatments influenced significantly and conventional method resulted in a higher content followed by drip fertigation. In the second year also, the treatments did not produce any significant influence in the copper content, except at 7 MAP, where also conventional method recorded a higher content than drip fertigation.

Table 4.32. Effect of methods of irrigation, frequencies and levels of fertilizer application on Cu content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	14.67	10.73	12.33	14.67	11.47	14.80	11.27	13.67	19.60	6.73	12.40	10.60
D_6	12.33	11.20	12.13	10.87	9.13	10.80	12.90	19.40	17.40	6.33	14.73	10.13
D_{24}	14.93	11.40	10.40	12.20	9.93	17.07	14.60	35.80	21.80	6.60	13.27	9.60
CD(0.05)	NS	NS	1.631	0.973	0.605	1.237	0.842	4.563	1.07	NS	1.335	NS
F_{50}	14.00	11.11	10.44	12.67	9.78	16.00	11.11	16.44	14.11	5.33	11.89	10.00
F_{100}	14.67	10.44	10.44	12.33	10.78	14.33	11.67	19.44	18.00	4.89	12.44	10.56
F_{150}	12.78	11.33	10.44	13.00	9.89	13.44	12.33	23.78	22.00	7.67	12.78	9.33
F_{200}	13.11	10.78	13.33	13.22	10.22	13.89	14.67	28.22	21.67	7.00	15.22	9.56
F_{250}	15.33	11.89	13.44	11.67	10.22	13.44	14.67	26.89	22.22	7.89	15.00	11.11
CD(0.05)	0.981	NS	1.026	NS	NS	1.063	0.808	2.342	1.504	1.142	1.522	1.13
C_6F_{50}	14.00	10.33	11.67	17.00	12.00	17.00	12.00	10.67	15.00	5.67	10.33	11.00
C_6F_{100}	13.00	0.33	11.00	13.67	12.00	15.00	12.00	14.00	18.67	5.67	11.67	11.67
C_6F_{150}	16.00	11.00	11.67	15.00	10.00	16.00	10.67	17.00	21.00	8.33	11.00	10.00
C_6F_{200}	16.33	10.00	14.00	13.67	11.67	14.00	11.67	15.33	20.00	6.33	15.00	9.67
C_6F_{250}	14.00	12.00	13.33	14.00	11.67	12.00	10.00	11.33	23.33	7.67	14.00	10.67
D_6F_{50}	14.00	11.00	10.00	12.00	9.00	15.00	10.33	21.67	13.33	5.00	14.33	10.00
D_6F_{100}	16.00	11.00	9.33	10.00	8.33	10.33	13.00	19.67	16.33	4.33	12.67	9.33
D_6F_{150}	9.67	12.67	9.67	10.33	9.00	9.00	10.67	20.33	11.00	7.33	13.00	8.67
D_6F_{200}	7.00	11.00	16.67	12.00	9.00	8.33	17.00	16.33	19.00	7.00	17.67	9.67
D_6F_{250}	15.00	10.33	15.00	10.00	10.33	11.33	13.00	19.00	20.33	8.00	16.00	13.00
$D_{24}F_{50}$	14.00	12.00	9.67	9.00	8.33	16.00	11.00	17.00	14.00	5.33	11.00	9.00
$D_{24}F_{100}$	15.00	10.00	11.00	13.33	12.00	17.67	10.00	24.67	19.00	4.67	13.00	10.67
$D_{24}F_{150}$	12.67	10.33	10.00	13.67	10.67	15.33	15.67	34.00	27.00	7.33	14.33	9.33
$D_{24}F_{200}$	16.00	11.33	9.33	14.00	10.00	19.33	15.33	53.00	26.00	7.67	13.00	9.33
$D_{24}F_{250}$	17.00	13.33	12.00	11.00	8.67	17.00	21.00	50.00	23.00	8.00	15.00	9.67
CD(0.05)	1.699	1.851	1.776	2.562	1.880	2.548	1.399	4.056	2.605	NS	2.079	1.95

Table 4.33. Effect of methods of irrigation, frequencies and levels of fertilizer application on Cu content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	11.47	10.73	10.87	9.13	9.93	11.93	22.47	13.67	6.20	7.87	11.27	7.20
D_6	10.00	10.53	11.07	8.33	8.20	9.47	17.40	10.27	6.73	6.33	11.33	7.53
D_{24}	9.60	9.93	10.27	8.47	8.93	8.47	21.27	11.27	9.60	4.67	10.87	6.80
CD(0.05)	NS	NS	NS	NS	1.447	1.791	1.929	1.309	1.875	2.132	NS	NS
F_{25}	10.67	9.89	9.89	8.11	8.56	9.89	16.67	8.11	6.33	5.33	9.78	6.44
F_{50}	9.78	9.56	10.56	8.00	8.67	10.67	18.67	11.22	8.44	6.67	10.67	6.89
F_{100}	11.44	11.00	11.33	8.78	9.44	11.22	22.22	15.00	7.67	5.00	11.89	7.44
F_{150}	10.22	11.11	10.67	9.11	9.67	9.33	24.00	12.11	8.00	8.33	12.67	7.22
F_{200}	9.67	10.44	11.22	9.22	8.78	8.67	20.33	12.22	7.11	6.11	10.78	7.89
CD(0.05)	1.048	NS	NS	NS	NS	1.618	1.419	1.730	NS	1.417	1.345	NS
C_6F_{25}	12.00	12.00	10.67	8.00	7.00	10.00	20.00	10.00	6.33	5.67	10.00	7.0
C_6F_{50}	10.33	10.00	9.67	9.00	9.67	11.00	21.33	11.67	7.00	9.67	11.00	6.67
C_6F_{100}	13.67	10.33	11.33	9.00	11.33	16.00	20.00	13.00	5.67	5.67	10.67	7.33
C_6F_{150}	10.67	11.00	10.67	9.67	10.33	10.67	26.00	16.00	6.67	10.67	12.00	7.33
C_6F_{200}	10.67	10.33	12.00	10.00	11.33	12.00	25.00	17.67	5.33	7.67	12.67	7.67
D_6F_{25}	11.67	9.00	8.67	8.00	9.00	9.67	14.00	8.00	6.33	5.00	11.00	6.67
D_6F_{50}	11.00	10.33	11.00	8.00	7.00	12.00	16.67	11.00	7.00	5.33	10.00	7.33
D_6F_{100}	9.67	10.33	11.67	9.00	9.00	8.00	20.00	16.00	7.67	5.67	15.00	7.33
D_6F_{150}	9.00	13.00	12.33	8.00	8.00	11.00	19.33	9.33	6.00	10.00	12.00	8.33
D_6F_{200}	8.67	10.00	11.67	8.67	8.00	6.67	17.00	7.00	6.67	5.67	8.67	8.00
$D_{24}F_{25}$	8.33	8.67	10.33	8.33	9.67	10.00	16.00	6.33	6.33	5.33	8.33	5.67
$D_{24}F_{50}$	8.00	8.33	11.00	7.00	9.33	9.00	18.00	11.00	11.33	5.00	11.00	6.67
$D_{24}F_{100}$	11.00	12.33	11.00	8.33	8.00	9.67	26.67	16.00	9.67	3.67	10.00	7.67
$D_{24}F_{150}$	11.00	9.33	9.00	9.67	10.67	6.33	26.67	11.00	11.33	4.33	14.00	6.00
$D_{24}F_{200}$	9.67	11.00	10.00	9.00	7.00	7.33	19.00	12.00	9.33	5.00	11.00	8.00
CD(0.05)	1.816	2.275	2.017	NS	2.373	2.803	2.458	2.996	NS	2.455	2.330	1.78

Increasing the fertilizer level increased the Cu content significantly in the third and fifth months after planting in the first year, whereas the effect was significant only at 3 MAP of the second year. But unlike in the first year, the higher content was registered with lower fertilizer levels.

4.6.8.2 Cu content in different plant parts at harvest

4.6.8.2.1 Rhizome

In the first year drip fertigation in 24 splits recorded a higher Cu content in the rhizome than conventional method. But in the second year, conventional method of fertilization tended to increase the content, than D_6 or D_{24}.

The effect of fertilizers on Cu accumulation in the rhizome was found decreasing with increase in the fertilizer level. In the first year, the highest content was obtained from F_{50} and all other higher levels were on par. In the second year, the decrease was observed only at a level of F_{150} and above.

4.6.8.2.2 Root

As in the case of rhizome in the first year the content was more in root under drip fertigation. In the second year, conventional method resulted in a higher content, but D_{24} was on par. D_6 had a lesser content.

Cu content in root increased with increasing fertilizer levels. In the first year, F_{200} and F_{250} had the highest Cu content whereas in the second year F_{150} registered highest concentration.

4.6.8.2.3 Pseudostem

In both the years, the Cu content in psuedostem also followed the same trend as that of Cu content in rhizome and root. Drip fertigation resulted in a higher content in the first year and a lower content in the second year than conventional method.

The content was as high as 35.8 ppm with D_{24} in the first year, but it was 19.4 and 13.67 ppm in D_6 and C_6 respectively.

The positive effect of fertilizers on Cu content was more pronounced in the first year and at F_{200}, the content in the pseudostem was 28.22 ppm. In the second year, F_{100} recorded the highest content (15.0 ppm) and higher fertilizer levels registered only lower contents (12.11 and 12.22 ppm at F_{150} and F_{200} respectively.

4.6.8.2.4 Peduncle

The Cu content of peduncle ranged from 11.00 to 27.0 ppm in the first year, but it was only 5.33 to 11.33 ppm during second year.

Drip fertigation in 24 splits resulted in the highest Cu content in the peduncle followed by D_6 and C_6 in both the years. Enhanced response to fertilizers was obtained only to a fertilizer level of F_{150} and levels above F_{150} had comparative contents in the first year. However no significant influence due to varying fertilizer levels was observed in the second year.

4.6.8.2.5 Fruit

Cu content in the fruit in the first year remained unaffected by the method of irrigation and fertilization. In the second year, significant difference existed between C_6 and D_{24}, the higher content being in C_6.

Comparison of fertilizer levels showed that Cu content increased up to a level of F_{150} and levels above F_{150} resulted in comparable contents. In the second year, the highest content was registered in F_{150}, but plants behaved differently to other fertilizer levels.

4.6.8.2.6 Male bud

Drip fertigation in six splits resulted in high Cu content in the first year, but no significant variation was observed in the second year.

Fertilizers had significant positive effect and increasing the level to F_{200} in the first year and to F_{150} in the second year increased the Cu content in male bud.

4.6.8.2.7 Leaves

Method of irrigation and fertilizer application had no significant effect on the copper content in the leaves in both years.

Comparison of fertilizer levels showed that increased fertilizer dose enhanced the copper content in the first year. But in the second year, the content remained unaffected by the treatments.

Higher copper content (8.67 to 13.0 ppm) was recorded in the first year than that in the second year (5.67 to 8.3 ppm).

4.6.9 Zinc

4.6.9.1 Zinc content in the index leaf at different growth stages

The influence of methods of irrigation and fertilizer application and frequency of fertilization with regard to Zn content followed different trend in different months (Tables 4.34 and 4.35). In the first year at 3 MAP the effect was non significant but at 4 MAP and 7 MAP higher leaf Zn content was observed in the D_6 and C_6 treatments. In the second year also drip fertigation method resulted in higher content in the initial stages, but later conventionally treated plants had more Zn content.

The influence of levels of fertilizer was significant in both the years, but did not follow a definite pattern. The Zn content varied from 13.33 to 29.67 ppm at 3 MAP while the range was only 12.67 to 14.67 ppm at 7 MAP due to various treatments in the second year.

4.6.9.2 Zinc content in different plant parts at harvest

4.6.9.2.1 Rhizome

Zn content varied from 16.67 to 41.67 ppm in the first year and from 10.67 to 21.33 ppm in the second year. Zn accumulation in rhizome was more under conventional method of fertilization in both years. Comparison of different levels of fertilizers showed that the variation was more pronounced in the second year than in the first year. In the first year levels above F_{100} were on par, whereas in the second year, the contents increased with increase in fertilizer level up to F_{200}.

Table 4.34. Effect of methods of irrigation, frequencies and levels of fertilizer application on Zn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	17.27	16.33	16.47	18.60	16.93	37.53	21.53	25.80	15.93	8.80	22.87	13.93
D_6	18.30	20.00	16.60	15.80	15.13	27.47	20.60	34.67	11.33	8.20	39.27	13.67
D_{24}	17.20	15.40	14.73	17.07	15.20	21.60	22.60	39.40	10.73	9.07	38.00	15.93
CD(0.05)	NS	1.723	0.807	0.881	0.991	4.784	NS	3.578	1.941	NS	2.787	1.368
F_{50}	17.06	16.78	15.22	18.00	15.22	25.33	20.22	37.56	11.44	8.11	38.89	13.33
F_{100}	17.89	18.33	14.33	18.20	15.11	29.22	19.33	30.44	11.89	7.78	29.67	15.00
F_{150}	17.22	19.44	16.44	16.22	16.00	28.67	23.22	37.00	11.33	8.56	35.11	13.11
F_{200}	17.22	16.33	16.33	17.78	16.78	30.78	21.89	28.00	13.33	9.22	34.11	14.78
F_{250}	18.56	15.33	17.33	15.56	15.67	30.33	23.22	23.44	15.33	9.78	29.11	16.33
CD(0.05)	NS	1.84	1.476	1.317	1.196	1.999	2.006	4.592	1.852	1.393	2.399	2.097
C_6F_{50}	15.33	14.00	15.00	20.00	15.00	32.67	27.33	23.00	13.00	7.67	29.33	14.00
C_6F_{100}	18.00	20.67	15.00	19.67	16.67	37.67	22.00	26.33	14.33	7.33	24.00	15.00
C_6F_{150}	19.00	15.33	19.00	17.67	16.30	37.33	20.00	25.67	14.67	9.67	28.00	12.33
C_6F_{200}	17.33	17.00	17.00	19.33	18.00	38.33	18.67	23.67	17.67	10.33	20.00	13.33
C_6F_{250}	16.67	14.67	16.33	16.33	18.67	41.67	19.67	30.33	20.00	9.00	13.00	15.00
D_6F_{50}	19.83	18.67	15.00	19.00	15.33	20.33	17.67	44.00	13.00	6.00	50.33	12.67
D_6F_{100}	19.00	19.00	14.00	15.00	16.33	25.67	18.00	29.00	11.00	9.00	30.00	13.00
D_6F_{150}	18.33	28.33	16.33	13.00	13.00	24.67	21.00	29.33	10.00	7.67	41.33	12.67
D_6F_{200}	17.67	18.00	18.00	17.00	16.67	37.33	24.00	31.33	9.67	9.67	42.33	14.33
D_6F_{250}	16.67	16.00	19.67	15.00	14.33	29.33	22.33	39.67	13.00	8.67	32.33	15.67
$D_{24}F_{50}$	16.00	17.67	15.67	15.00	15.33	23.00	15.67	45.67	8.33	10.67	37.00	13.33
$D_{24}F_{100}$	16.67	15.33	14.00	20.00	12.33	24.33	18.00	36.00	10.33	7.00	35.00	17.00
$D_{24}F_{150}$	14.33	14.67	14.00	18.00	18.62	24.00	28.67	56.00	9.33	8.33	36.00	14.33
$D_{24}F_{200}$	16.67	14.00	14.00	17.00	15.67	16.67	23.00	29.00	12.67	7.67	40.00	16.67
$D_{24}F_{250}$	22.33	15.33	16.00	15.33	14.00	20.00	27.67	30.33	13.00	11.67	42.00	18.33
CD(0.05)	2.476	3.188	2.556	2.282	2.071	3.463	3.474	7.954	3.207	2.413	4.155	3.632

Table 4.35. Effect of methods of irrigation, frequencies and levels of fertilizer application on Zn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
C_6	16.73	14.43	19.07	20.77	13.80	18.60	36.93	53.60	10.93	8.73	36.13	14.40
D_6	22.53	15.07	17.47	18.60	13.53	14.53	23.67	32.27	11.20	8.13	31.87	13.47
D_{24}	14.73	15.70	16.87	17.97	13.30	17.20	23.80	42.87	11.67	8.57	38.80	15.00
CD(0.05)	5.294	0.997	1.538	2.164	NS	0.778	1.296	6.438	NS	NS	2.135	NS
F_{25}	18.56	15.67	17.22	18.89	13.38	16.89	25.22	37.11	11.44	7.78	31.44	12.89
F_{50}	16.22	14.72	17.56	17.67	14.00	16.00	26.44	49.44	9.78	8.89	35.67	13.44
F_{100}	18.11	15.05	17.89	19.56	13.00	15.11	29.78	49.89	10.33	7.67	38.22	14.78
F_{150}	20.56	15.33	18.89	21.22	13.78	16.56	26.44	42.33	12.67	8.50	36.00	14.78
F_{200}	16.56	14.56	17.44	18.22	13.56	19.33	32.78	35.78	12.11	9.56	36.67	15.56
CD(0.05)	2.548	0.782	1.043	1.150	0.668	1.038	1.600	6.873	1.046	0.981	2.064	1.540
C_6F_{25}	16.33	14.33	17.00	16.67	13.00	19.33	30.67	51.33	10.33	9.33	33.67	15.00
C_6F_{50}	17.00	15.50	18.67	17.50	13.67	21.33	43.33	74.00	9.33	6.67	37.33	12.33
C_6F_{100}	17.00	14.83	21.00	22.33	13.67	15.33	39.00	36.67	10.00	9.00	40.33	14.00
C_6F_{150}	16.33	14.17	19.33	25.67	14.33	16.33	30.00	50.67	12.00	8.67	33.67	15.00
C_6F_{200}	17.00	13.33	19.33	21.67	14.33	20.67	41.67	55.33	13.00	10.00	35.67	15.67
D_6F_{25}	24.67	18.33	16.33	20.50	14.00	13.00	19.00	26.67	8.67	7.67	30.00	11.00
D_6F_{50}	18.33	14.67	18.00	19.33	14.67	10.67	16.33	33.67	10.67	10.00	33.00	12.67
D_6F_{100}	21.33	13.83	18.00	19.83	12.67	15.00	30.33	60.00	9.67	8.00	32.33	14.33
D_6F_{150}	29.67	15.50	18.33	18.50	14.00	14.67	19.67	24.00	14.00	8.67	32.00	13.33
D_6F_{200}	18.67	13.00	16.67	14.83	12.33	19.33	33.00	17.00	13.00	6.33	32.00	16.00
$D_{24}F_{25}$	14.67	14.33	18.33	19.50	13.17	18.33	26.00	3.33	15.33	6.33	30.67	12.67
$D_{24}F_{50}$	13.33	14.00	16.00	16.17	13.67	16.00	19.67	40.67	9.33	10.00	36.67	15.33
$D_{24}F_{100}$	16.00	16.50	14.67	16.50	12.67	15.00	20.00	53.00	11.33	6.00	42.00	16.00
$D_{24}F_{150}$	15.67	16.33	19.00	17.50	13.00	18.67	29.67	52.33	12.00	8.17	42.33	16.00
$D_{24}F_{200}$	14.00	17.33	16.33	18.17	14.00	18.00	23.67	35.00	10.33	12.33	42.33	15.00
CD(0.05)	4.414	1.354	1.807	1.992	1.158	1.798	2.772	11.90	1.812	1.699	3.078	NS

4.6.9.2.2 Root

The effect of methods of fertilization was not significant in the first year, but in the second year, a higher content was recorded in the conventionally treated plants.

Zn content in the root was found increasing with increase in fertilizer dose and highly significant content was noticed in F_{150} in the first year and F_{200} in the second year.

4.6.9.2.3 Pseudostem

Influence of methods of irrigation and fertilization on the Zn content in pseudostem were contradictory in both the years. In the first year highest content was recorded in drip fertigation (D_{24}) while in the second year the content was lesser in D_{24} and more in conventional method.

The effect of fertilizers though significant in both the years did not follow a definite pattern.

4.6.9.2.4 Peduncle

Conventional basin irrigation and fertilizer application resulted in a higher Zn content in peduncle in the first year, while in the second year the content in peduncle remained unaffected.

Among different fertilizer levels, F_{250} alone could produce significantly higher content in the first year. In the second year also, the increasing trend with increase in fertilizer levels was observed.

4.6.9.2.5 Fruit

Method of irrigation and fertilization did not exert any significant effect with regard to the Zn content in fruit, in both the years. But the application of fertilizers in different levels produced effect on Zn content in fruit, and with the increase in fertilizer dose, the content increased.

4.6.9.2.6 Male bud

Drip fertigation either in 6 splits or 24 splits (D_6 or D_{24}) recorded higher content than conventionally treated plants. In the second year also, the dominance of D_{24} remained, while D_6 had the lowest content.

Comparison of different levels of fertilizers showed that F_{50}, the lowest level in the first year registered the highest content and the content decreased with increase in fertilizer levels. A similar trend could not be observed during the second year.

4.6.9.2.7 Leaf

Drip fertigation in 24 splits recorded a higher Zn content in leaf in the first year at harvest, but in the second year , the influence was not significant.

Response to fertilizers was found increasing to a level of F_{100} and increasing the dose further did not increase the content but resulted in comparable Zn contents.

4.7 Fertilizer use efficiency

Use efficiency of nutrients estimated based on the yield produced per unit of nutrient applied is presented for nitrogen, phosphorus and potassium in Table 4.36 for both the years.

The effect of method of irrigation and fertilization had no significant influence on the efficiency of fertilizer nitrogen in the first year. But in the second year, drip fertigation performed better than conventional method.

With regard to the levels of fertilizers, highest efficiency was obtained at the lowest level and increase in fertilizer level gradually decreased the efficiency.

Analysis of the combined effect of levels of fertilizers and irrigation methods showed that at lower fertilizer levels (F_{50} in first year and F_{100} in second year), drip fertigation resulted in better efficiency though marginal, than conventional method.

Phosphorus and potassium use efficiency also followed the same pattern as that of nitrogen in both the years.

Better use efficiency of fertilizers was obtained in the second year when compared to that in the first year.

Table 4.36. Use efficiency of N, P and K as influenced by different methods of irrigation, frequencies and levels of fertilizer application in banana var. Nendran.

Treatment	Nitrogen		Phosphorus		Potassium	
	I year	II year	I year	II year	I year	II year
C_6	26.58	70.60	45.73	118.99	17.69	47.07
D_6	26.37	74.04	44.96	124.89	17.60	49.37
D_{24}	25.33	75.81	43.27	127.93	16.89	50.54
CD(0.05)	NS	3.23	NS	5.478	NS	2.153
F_{25}	-	155.96	-	259.67	-	103.94
F_{50}	52.53	95.74	87 57	159.61	35.04	63.86
F_{100}	31.11	52.24	51.13	90.90	20.72	34.79
F_{150}	21.22	36.30	36.48	62.25	14.18	24.20
F_{200}	15.19	27.17	26.44	47.28	10.15	18.15
F_{250}	10.32	-	17.82	-	6.86	-
CD(0.05)	2.461	5.114	4.171	11.56	1.642	3.409
C_6F_{25}	-	158.40	-	163.74	-	105.37
C_6F_{50}	53.60	89.50	89.36	149.20	35.75	59.70
C_6F_{100}	31.50	49.65	54.81	86.39	20.98	33.07
C_6F_{150}	23.20	31.86	39.78	54.63	15.47	21.24
C_6F_{200}	13.71	23.58	23.85	41.04	9.16	15.75
D_6F_{250}	10.63	-	18.34	-	7.07	-
CD(0.05)	-	154.00	-	256.41	-	102.64
D_6F_{50}	58.67	98.54	97.80	164.26	39.13	65.72
D_6F_{100}	30.83	52.32	53.65	91.03	20.54	34.84
D_6F_{150}	18.54	38.10	32.07	65.32	12.47	25.40
D_6F_{200}	13.88	27.27	24.14	47.44	9.27	18.21
D_6F_{250}	9.93	-	17.14	-	6.61	-
$D_{24}F_{25}$	-	155.47	-	258.85	-	103.62
$D_{24}F_{50}$	45.33	99.20	75.57	165.37	30.24	66.17
$D_{24}F_{100}$	31.00	54.75	53.94	95.27	20.65	36.47
$D_{24}F_{150}$	21.92	38.96	37.59	66.81	14.62	25.97
$D_{24}F_{200}$	18.00	30.67	31.32	53.36	12.02	20.49
$D_{24}F_{250}$	10.40	-	17.94	-	6.92	-
CD(0.05)	4.262	8.858	7.225	20.03	2.844	5.905

4.8 Total Nutrient uptake

The total uptake of the nutrients (g $plant^{-1}$) by the plant at harvest as influenced by methods and levels of fertilizer application in the first year and second year are presented in Tables 4.37 and 4.38 respectively. The mean uptake in various plant parts are also furnished in Table 4.39.

4.8.1 Nitrogen

Drip fertigation in 24 splits (D_{24}) resulted in the highest uptake of nitrogen in both years. Application of fertilizers in six splits either in basins (C_6) or through drip (D_6) performed similarly in the first year, while C_6 was better than D_6 in the second year.

Increased uptake due to higher fertilizer dose was noticed only to a level of F_{100} in the first year and all higher levels were comparable. But in the second year, the effect was more significant and response increased up to a level of F_{200}. In the first year, response to fertilizers decreased beyond F_{100} in conventional method and beyond F_{150} in drip in 6 splits. But in D_{24}, the response increased up to F_{200}. In the second year, the uptake increased in all methods with increasing levels.

Rhizome accumulated the highest share of N uptake followed by pseudostem in the first year. But in the second year, bunch also became a major sink and the share of rhizome decreased, compared to that in the first year.

Table 4.37. Effect of methods of irrigation, frequencies and levels of fertilizer application on total uptake of nutrients (g plant^{-1}) in banana var. Nendran during first year

Treatment	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
C_6	60.76	5.28	333.14	34.3	19.02	5.28	7.19	0.06	0.12
D_6	55.98	4.44	271.41	31.87	16.81	4.85	5.27	0.05	0.10
D_{24}	70.50	4.57	294.54	30.54	19.45	5.77	5.89	0.09	0.11
CD (0.05)	7.51	NS	30.60	NS	1.20	0.428	NS	0.006	0.104
F_{50}	57.36	3.58	248.82	35.71	24.59	5.51	5.73	0.06	0.10
F_{100}	68.00	4.93	305.70	36.49	17.10	6.21	6.30	0.07	0.12
F_{150}	63.23	4.56	276.83	32.85	16.60	4.59	5.97	0.07	0.11
F_{200}	62.02	4.96	347.42	27.62	15.78	4.71	6.90	0.07	0.11
F_{250}	61.46	5.79	316.76	28.52	18.06	5.49	7.32	0.07	0.11
CD (0.05)	6.328	0.92	32.71	3.092	1.569	0.557	0.941	0.006	0.105
C_6F_{50}	53.97	3.33	288.37	32.89	21.02	4.39	6.34	0.06	0.10
C_6F_{100}	74.90	4.99	348.37	39.69	17.27	6.23	7.36	0.07	0.14
C_6F_{150}	56.57	4.33	265.61	35.11	18.14	4.34	6.12	0.06	0.11
C_6F_{200}	56.66	5.17	359.63	30.02	18.28	5.17	7.50	0.06	0.12
C_6F_{250}	61.68	8.59	394.83	33.80	20.41	6.28	8.64	0.06	0.14
D_6F_{50}	59.89	4.33	279.92	43.54	24.98	6.12	5.69	0.06	0.10
D_6F_{100}	61.78	5.35	265.37	36.38	14.72	5.65	5.38	0.05	0.10
D_6F_{150}	63.98	4.81	314.56	32.47	17.30	4.70	5.36	0.06	0.10
D_6F_{200}	49.35	4.05	265.31	23.49	13.58	3.77	4.69	0.04	0.11
D_6F_{250}	44.91	3.64	231.88	23.45	13.46	4.03	5.23	0.05	0.09
$D_{24}F_{50}$	58.23	3.06	178.16	30.69	27.79	6.03	5.15	0.06	0.10
$D_{24}F_{100}$	67.32	4.44	303.35	33.40	19.30	6.78	6.17	0.08	0.11
$D_{24}F_{150}$	69.14	4.52	250.30	30.96	14.36	4.72	6.42	0.08	0.13
$D_{24}F_{200}$	80.04	5.67	417.32	29.34	15.50	5.20	8.64	0.12	0.09
$D_{24}F_{250}$	77.79	5.24	323.56	28.31	20.31	6.16	8.07	0.10	0.10
CD (0.05)	10.09	1.599	56.65	5.356	2.72	0.964	1.28	0.01	0.018

Table 4.38. Effect of methods of irrigation, frequencies and levels of fertilizer application on total uptake of nutrients (g $plant^{-1}$) in banana var. Nendran during second year

Treatment	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
C_6	59.16	5.27	403.98	29.74	10.54	3.41	6.83	0.06	0.14
D_6	54.15	4.97	310.60	31.05	12.79	3.02	5.41	0.05	0.10
D_{24}	61.85	5.18	353.00	34.33	11.90	3.72	5.91	0.05	0.13
CD (0.05)	2.442	NS	33.90	1.869	1.06	0.253	0.216	0.008	0.011
F_{25}	41.62	3.26	219.60	23.44	9.42	2.46	3.72	0.03	0.08
F_{50}	53.35	5.29	308.90	29.93	10.89	3.58	4.65	0.05	0.12
F_{100}	60.23	5.21	372.30	29.74	11.58	3.36	6.06	0.06	0.13
F_{150}	64.09	6.20	407.90	38.07	14.06	3.66	7.31	0.07	0.15
F_{200}	72.63	5.76	470.6	37.34	12.76	3.84	8.52	0.06	0.15
CD (0.05)	4.574	0.615	22.25	2.383	1.685	0.313	0.638	0.005	0.013
C_6F_{25}	42.24	2.58	207.39	19.37	7.28	2.09	3.84	0.05	0.10
C_6F_{50}	53.63	5.45	345.30	28.99	9.56	2.68	5.35	0.06	0.17
C_6F_{100}	63.14	5.74	456.70	29.77	11.16	4.30	7.40	0.07	0.12
C_6F_{150}	62.30	6.09	469.70	39.04	14.00	3.50	8.30	0.08	0.15
C_6F_{200}	74.49	6.35	540.7	31.51	10.72	4.46	9.24	0.08	0.17
D_6F_{25}	41.38	3.77	226.70	26.53	11.40	2.57	3.83	0.03	0.07
D_6F_{50}	50.05	5.53	275.00	29.17	13.25	2.83	4.15	0.05	0.09
D_6F_{100}	57.01	4.21	296.10	24.36	12.48	1.97	4.77	0.05	0.13
D_6F_{150}	65.78	6.46	398.20	35.45	13.18	3.98	7.03	0.08	0.12
D_6F_{200}	56.54	4.85	356.80	39.73	13.65	3.76	7.28	0.05	0.09
$D_{24}F_{25}$	41.26	3.42	224.8	24.44	9.59	2.73	3.40	0.03	0.08
$D_{24}F_{50}$	56.37	4.86	306.40	31.62	9.87	5.23	4.41	0.05	0.11
$D_{24}F_{100}$	60.58	5.71	363.90	35.10	11.10	3.81	6.01	0.06	0.14
$D_{24}F_{150}$	64.17	5.89	355.70	39.72	15.02	3.50	6.67	0.05	0.17
$D_{24}F_{200}$	86.91	6.09	514.20	40.79	13.92	3.31	9.05	0.07	0.17
CD (0.05)	7.922	1.066	38.55	4.128	NS	0.542	1.104	0.008	0.023

Table 4.39. Mean uptake of nutrients by different plant parts (g plant^{-1}) of banana var. Nendran as influenced by methods of irrigation, frequencies and levels of fertilizer application.

Nutrients	Rhizome	Pseudostem	Peduncle	Bunch	Male bud	Leaf
I Year						
N	34.74	12.13	0.99	8.62	0.44	5.49
P	1.75	1.18	0.15	1.13	0.07	0.47
K	179.67	82.77	7.23	23.88	1.07	4.47
Ca	14.30	6.42	0.26	4.58	0.05	6.62
Mg	10.79	3.55	0.14	2.84	0.04	1.07
Fe	4.08	0.67	0.03	0.29	0.004	0.21
Mn	1.91	1.02	0.09	0.78	0.02	2.62
Cu	0.03	0.02	0.001	0.01	0.0002	0.004
Zn	0.05	0.03	0.001	0.01	0.001	0.006
II year						
N	17.39	12.84	0.97	21.49	1.13	4.55
P	0.89	1.06	0.15	2.34	0.20	0.49
K	143.11	140.3	6.55	54.31	3.07	8.26
Ca	9.01	11.03	0.19	7.88	0.12	3.48
Mg	3.88	2.65	0.09	4.28	0.10	0.72
Fe	1.71	0.94	0.02	0.481	0.01	0.23
Mn	1.55	1.77	0.08	1.31	0.05	1.29
Cu	0.02	0.02	0.001	0.02	0.001	0.003
Zn	0.03	0.07	0.001	0.02	0.001	0.01

4.8.2 Phosphorus

Methods and frequencies of fertilization did not influence the uptake of P by the plant in both the years. But the uptake was found increasing with increasing the fertilizer dose up to F_{200} in the first year and up to F_{150} in the second year.

In the first year, there was an increase in the uptake of P in the conventional method with increase in fertilizer dose and C_6 F_{250} registered the highest uptake. But under drip fertigation, the uptake remained comparable. In the second year, contrary to this, F_{150} had the highest uptake for D_6 and D_{24} and in C_6 levels above F_{50} were on par.

The total content in rhizome and pseudostem decreased and that in the bunch increased in the second year.

4.8.3 Potassium

Conventional method (C_6) resulted in a higher accumulation of K in the plant than drip fertigation and the plants behaved similarly in both the years. Increasing the frequency of application increased K uptake only in the second year, while in the first year, the effect was comparable.

Increasing the dose of fertilizers, increased the uptake of potassium and F_{200} resulted in the highest K accumulation.

In the first year, rhizome was the major reservoir of potassium applied. In the second year, the content in pseudostem and bunch increased appreciably and that in the rhizome decreased.

4.8.4 Calcium

The variation in Ca uptake due to methods and frequencies of fertilizer application was not marked in the first year. But in the second year, drip fertigation in 24 splits resulted in higher uptake than D_6 or C_6.

There was a decrease in Ca uptake with increase in fertilizer dose in the first year. But contrary to this, the uptake increased to a level of F_{150} in the second year.

The share of the rhizome decreased and that of the pseudostem and bunch increased appreciably in the second year.

4.8.5 Magnesium

Drip fertigation in 24 splits (D_{24}) and basin application (C_6) were comparable in Mg uptake in the first year, but in the second year, both D_6 and D_{24} registered higher uptake than C_6.

Increased fertilizer dose decreased the uptake of Mg also in the first year. But in the second year, as in the case of Ca, F_{150} resulted in the highest Mg uptake.

The total Mg uptake by the plants were comparatively lesser in the second year, than that in the first year.

4.8.6 Iron

Drip fertigation is 24 splits (D_{24}) resulted in a higher iron uptake than conventional method in both the years. D_6 registered the lowest Fe uptake though the variation from C_6 was non-significant in the first year.

Increasing fertilizer dose above F_{100} resulted in a lower Fe uptake in the first year. In the second year, levels from F_{50} to F_{200} registered comparable contents.

Fe uptake, in general, was lesser in the second year.

4.8.7 Manganese

Drip fertigation and conventional method (basin irrigation and fertilizer application) were statistically similar with respect to Mn uptake in the first year. But in the second year, Mn uptake was more in C_6, followed by D_{24}.

Mn accumulation was found increasing with the fertilizer dose in both the years and C_6F_{250} and C_6F_{200} registered the higher Mn uptake in the first year and second year respectively.

4.8.8 Copper

Comparison of different methods of fertilizer application showed that drip fertigation in 24 splits (D_{24}) in the first year and conventional method (C_6) in the second year registered the highest Cu accumulation.

The uptake of Cu increased with fertilizer dose to a level of F_{100} in the first year and to F_{150} in the second year. The uptake of Cu ranged from 0.04 to 0.12 g plant^{-1} in the first year and from 0.03 to 0.08 g plant^{-1} in the second year.

4.8.9 Zinc

Conventional method (C_6) favoured more uptake of Zn in the first year, but in the second year drip fertigation in 24 splits (D_{24}) also was comparable with C_6.

The response to fertilizers was only up to F_{100} in the first year. In the second year, the response increased to F_{150}.

The content in the rhizome decreased drastically and that in the pseudostem, and bunch increased in the second year.

EXPERIMENT 2

4.9 Water use efficiency as influenced by methods and levels of irrigation

The experiment was conducted for two years during 1997-98 and 1998-99 where efficiency of three methods of irrigation and fertilizer application such as surface drip fertigation, subsurface drip fertigation and conventional basin application in six splits at monthly intervals was tested at three levels of irrigation. The irrigation levels were fixed at 16 l day^{-1} plant^{-1}, 12 l day^{-1} and 8 l day^{-1} in the first year. In the second year, the irrigation per plant was changed from fixed quantities to quantities determined based on daily pan evaporation and the 100 per cent PEC (I_{100}) was considered the highest level. Lower levels were fixed as I_{75} and I_{50} where 75 per cent and 50 per cent of the evaporation were compensated through irrigation.

In the first year, the fertilizer was applied at the F_{200} level (400-230-600 g NPK plant^{-1}) of the experiment 1. But in the second year, the quantity of the fertilizer was further reduced to F_{100} level (200-115-300 g NPK plant^{-1}).

The change in volume of irrigation water in the second year directly resulted in a high rate of water application (Appendix 3) and a corresponding decrease in the concentration of fertilizer in the soil solution. The results of the experiment are presented herewith.

4.9.1 Growth attributes

4.9.1.1 Plant height

The influence of methods and levels of irrigation on the height of the plant during the first year and second year are presented in Tables 4.40and 4.41 respectively.

In the first year, though surface drip method significantly increased plant height at 4 MAP, conventional method was found favouring the increase in plant height during 6 MAP and 7 MAP. But in the second year, drip fertigation particularly surface drip was found to result in taller plants with a significant difference during 5 MAP.

With regard to the levels of irrigation, the lower levels always resulted in reduced height except at the early stages (3 MAP) and the highest level (I_{100}) was always found best. In the second year, I_{75} and I_{100} behaved similarly in most of the times of observation.

Analysis of the combined effect of methods and levels of irrigation showed that higher levels through conventional basin irrigation was better for plant growth in the first year. In the second year, significant reduction in plant height was observed only at the lowest level when applied through conventional basin method, all other combinations behaving similarly at 6 MAP.

Table 4.40. Effect of methods and levels of irrigation on plant height (cm) of banana var. Nendran during first year

Variables	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	161.33	198.17	207.94	220.94	240.11
SS	147.42	175.39	192.72	219.06	246.22
C	152.50	190.39	206.17	236.50	286.06
CD(0.05)	NS	7.151	NS	13.94	29.30
I_{50}	147.67	180.42	197.42	208.33	255.89
I_{75}	154.61	185.17	197.72	229.11	250.00
I_{100}	158.97	198.36	211.69	239.06	266.50
CD(0.05)	NS	9.745	7.229	15.30	NS
SI_{50}	159.58	198.33	208.83	204.93	230.67
SI_{75}	156.33	186.17	200.72	220.67	241.00
SI_{100}	168.08	210.00	214.25	237.33	248.67
SSI_{50}	152.92	175.75	194.92	218.83	259.00
SSI_{75}	144.67	172.75	188.08	214.33	232.67
SSI_{100}	144.67	177.67	195.17	224.00	247.00
CI_{50}	130.50	167.17	188.50	201.33	278.00
CI_{75}	162.83	196.58	204.33	252.33	276.33
CI_{100}	164.17	207.42	225.67	255.83	303.83
CD(0.05)	21.04	16.88	12.52	26.50	NS

Table 4.41. Effect of methods and levels of irrigation on plant height (cm) of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	74.44	120.64	190.94	227.94	267.22
SS	68.28	123.67	186.61	225.44	263.33
C	69.00	117.22	180.22	217.78	260.00
CD (0.05)	NS	NS	7.016	NS	NS
I_{50}	64.39	104.33	174.44	210.56	252.22
I_{75}	73.67	121.87	187.78	227.62	265.56
I_{100}	73.67	135.33	195.44	233.00	272.78
CD (0.05)	4.95	6.191	7.036	8.638	8.531
SI_{50}	66.50	105.67	181.33	220.00	256.67
SI_{75}	83.38	123.93	193.83	230.17	268.33
SI_{100}	73.00	132.33	197.67	233.67	276.67
SSI_{50}	67.00	106.33	175.00	220.00	260.00
SSI_{75}	68.33	126.67	189.83	226.00	261.67
SSI_{100}	69.50	138.00	195.00	230.33	268.33
CI_{50}	59.67	101.00	167.00	191.67	240.00
CI_{75}	68.83	115.00	179.67	226.67	266.67
CI_{100}	78.50	135.67	193.67	235.00	273.33
CD (0.05)	8.574	NS	NS	14.96	NS

4.9.1.2 Girth

A perusal of the data (Tables 4.42 and 4.43) shows that in the first year, methods and levels of irrigation had no influence on the girth of the plant except at 6 MAP. At 6 MAP, conventional basin irrigation at 16 l day^{-1} (CI_{100}) found better than other treatments. In the second year also, significant variations among different methods of irrigation was noticed only in the later stages. Subsurface drip fertigation was comparable with conventional, but inferior to surface drip in all the stages. Surface drip fertigation resulted in maximum thickness in the later stages. Evaporation compensation of 75 per cent was found sufficient for producing high plant girth as I_{75} and I_{100} were found comparable at 5 MAP and 7 MAP.

In the first year, the combination of different methods and levels of irrigation had no effect at 3 MAP. At 4 MAP and 5 MAP, conventional method at I_{50} (CI_{50}) was inferior and all other treatments were comparable. At 6 MAP, the thickness of subsurface drip at I_{50} and I_{75} (SSI_{50} and SSI_{75}) also registered low values as CI_{50}.

Different methods at different levels of irrigation did not produce any significant variation in the second year.

4.9.1.3 Number of leaves

Tables 4.44 and 4.45 show that the number of leaves produced in both the years was not influenced by method and level of irrigation or their interaction. But irrespective of treatments there was a remarkably higher leaf production during 6 MAP in the first year and this increase did not occur in the second year.

Table 4.42. Effect of methods and levels of irrigation on plant girth (cm) of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	26.37	44.42	50.33	54.00	53.06
SS	25.64	42.92	46.58	51.00	53.39
C	25.70	40.72	48.25	54.50	56.89
CD (0.05)	NS	NS	NS	0.912	NS
I_{50}	25.86	41.47	46.31	50.94	54.00
I_{-5}	25.93	43.36	48.83	52.56	54.50
I_{100}	25.92	43.22	50.03	56.00	54.83
CD (0.05)	NS	NS	NS	2.736	NS
SI_{50}	27.92	44.00	50.50	53.33	50.33
SI_{-5}	25.68	43.92	49.08	52.50	55.17
SI_{100}	25.50	45.33	51.42	56.17	53.67
SS I_{50}	25.25	43.75	46.08	50.33	54.83
SS I_{-5}	25.58	43.83	46.33	48.17	51.67
SS I_{100}	26.08	41.17	47.33	54.50	53.67
CI_{50}	24.42	36.67	42.33	49.17	56.83
CI_{-5}	26.52	42.33	51.08	57.00	56.67
CI_{100}	26.17	43.17	51.33	57.33	57.17
CD (0.05)	NS	3.861	5.043	4.738	NS

Table 4.43. Effect of methods and levels of irrigation on plant girth (cm) on banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	24.44	34.56	51.72	55.83	60.06
SS	22.50	37.11	49.33	52.67	56.28
C	23.28	34.33	50.11	53.06	57.50
CD (0.05)	NS	NS	1.738	2.428	1.703
I_{50}	22.06	31.00	47.61	50.17	54.61
I_{75}	24.72	38.11	51.72	54.44	58.72
I_{100}	23.44	36.89	51.83	56.94	60.50
CD (0.05)	2.108	4.832	2.330	1.425	1.857
SI_{50}	23.83	31.00	49.50	51.83	56.83
SI_{75}	26.83	36.67	52.83	56.67	61.17
SI_{100}	23.17	36.00	52.83	59.00	62.17
SSI_{50}	21.33	31.67	47.33	50.00	54.00
SSI_{75}	22.67	39.67	51.33	53.00	56.50
SSI_{100}	23.50	40.00	49.33	55.00	58.33
CI_{50}	21.00	30.33	46.00	48.67	53.00
CI_{75}	25.17	38.00	51.00	53.67	58.50
CI_{100}	23.67	34.67	51.33	56.83	61.00
CD (0.05)	NS	8.369	NS	NS	NS

Table 4.44. Effect of methods and levels of irrigation on number of leaves of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	11.25	13.61	14.11	18.56	15.56
SS	11.17	12.94	13.67	17.88	17.44
C	11.23	12.89	14.00	18.78	16.61
CD (0.05)	NS	NS	NS	NS	0.735
I_{50}	11.42	12.83	13.78	17.78	16.72
I_{75}	11.28	12.94	13.78	18.16	16.61
I_{100}	10.94	13.67	14.22	19.28	16.28
CD (0.05)	NS	NS	NS	1.119	NS
SI_{50}	11.92	13.17	14.17	17.17	15.00
SI_{75}	11.08	13.50	13.33	18.50	16.00
SI_{100}	10.75	14.17	14.83	20.00	15.67
SS I_{50}	10.83	13.50	12.33	18.50	18.17
SS I_{75}	11.42	12.17	14.00	17.13	17.33
SS I_{100}	11.25	13.17	14.67	18.00	16.83
CI_{50}	11.50	11.83	14.83	17.67	17.00
CI_{75}	11.35	13.17	14.00	18.83	16.50
CI_{100}	11.35	13.67	13.17	19.83	16.33
CD (0.05)	NS	NS	1.775	NS	NS

Table 4.45. Effect of methods and levels of irrigation on number of leaves of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	11.33	12.00	13.94	13.44	12.22
SS	10.44	13.22	14.62	14.44	12.83
C	10.33	12.11	14.22	14.06	12.94
CD (0.05)	NS	NS	NS	NS	NS
I_{50}	10.44	11.67	14.06	12.94	12.56
I_{75}	11.00	13.33	14.22	14.39	12.72
I_{100}	10.67	12.33	14.50	14.61	12.72
CD (0.05)	NS	1.144	NS	0.7056	NS
SI_{50}	11.67	11.00	13.67	12.00	12.00
SI_{75}	11.67	13.00	13.83	14.17	12.17
SI_{100}	10.67	12.00	14.33	14.17	12.50
SSI_{50}	9.33	13.00	15.00	14.00	12.00
SSI_{75}	10.83	13.67	14.17	14.17	13.50
SSI_{100}	11.17	13.00	14.67	15.17	13.00
CI_{50}	10.33	11.00	13.50	12.83	13.67
CI_{75}	10.50	13.33	14.67	14.83	12.50
CI_{100}	10.17	12.00	14.50	14.50	12.67
CD (0.05)	NS	NS	NS	NS	NS

4.9.1.4 Area of the index leaf

In the first year (Table 4.46) conventional method of irrigation resulted in significantly higher leaf area and both surface and subsurface drip fertigation remained on par. Area of the index leaf in the second year (Table 4.47) was unaffected by the method of irrigation.

An irrigation level of 12 l day^{-1} (I_{75}) produced comparable leaf area as that of 16 l day^{-1} (I_{100}) at 5 MAP and in all other months, the effect of irrigation level was not significant, in the first year. In the second year, 75 per cent PEC (I_{75}) was sufficient at 5 MAP, but as it reached 6 MAP, 100 per cent PEC (I_{100}) was required.

Analysis of different methods at various levels of irrigation in the first year showed that CI_{75} and CI_{100} are superior and at lower levels, drip fertigation especially subsurface drip failed to produce sufficient leaf area. Contrary to this, in the second year, at lower levels of irrigation, conventional method was found inferior to drip fertigation.

The size of the index leaf was relatively small in the first year compared to that in second year. It varied from 0.53 to 0.86 m^2 in the first year and 0.89 to 1.23 m^2 in the second year at 7 MAP. Also it was noticed that there was a reduction in leaf size at 7 MAP in the first year, while it was found increasing in the second year.

Table 4.46. Effect of methods and levels of irrigation on area of index leaf (m^2) of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	0.32	0.78	0.80	0.81	0.58
SS	0.31	0.70	0.74	0.76	0.67
C	0.33	0.71	0.87	0.91	0.81
CD (0.05)	NS	NS	0.083	0.093	0.137
I_{50}	0.31	0.67	0.75	0.80	0.72
I_{75}	0.33	0.76	0.80	0.81	0.66
I_{100}	0.31	0.75	0.85	0.86	0.69
CD (0.05)	NS	NS	0.065	NS	NS
SI_{50}	0.36	0.73	0.85	0.80	0.53
SI_{75}	0.32	0.78	0.73	0.81	0.59
SI_{100}	0.30	0.82	0.83	0.81	0.62
SS I_{50}	0.28	0.71	0.67	0.73	0.76
SS I_{75}	0.31	0.71	0.79	0.71	0.56
SS I_{100}	0.32	0.68	0.75	0.85	0.70
CI_{50}	0.30	0.57	0.74	0.88	0.86
CI_{75}	0.36	0.79	0.90	0.92	0.83
CI_{100}	0.33	0.76	0.96	0.94	0.75
CD (0.05)	NS	NS	0.113	NS	NS

Table 4.47. Effect of methods and levels of irrigation on area of the index leaf (m^2) of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	0.21	0.51	0.78	1.05	1.10
SS	0.25	0.44	0.73	1.10	1.15
C	0.22	0.48	0.73	0.94	1.10
CD (0.05)	NS	NS	NS	0.117	NS
I_{50}	0.19	0.44	0.66	0.90	1.03
I_{75}	0.25	0.48	0.77	1.04	1.18
I_{100}	0.25	0.51	0.81	1.14	1.13
CD (0.05)	0.032	NS	0.056	0.080	NS
SI_{50}	0.19	0.50	0.75	0.89	0.89
SI_{75}	0.25	0.55	0.79	1.06	1.23
SI_{100}	0.20	0.48	0.82	1.19	1.16
SSI_{50}	0.23	0.39	0.66	1.00	1.14
SSI_{75}	0.26	0.39	0.76	1.13	1.17
SSI_{100}	0.25	0.55	0.79	1.16	1.12
CI_{50}	0.14	0.43	0.58	0.82	1.07
CI_{75}	0.23	0.51	0.76	0.92	1.13
CI_{100}	0.29	0.51	0.83	1.06	1.11
CD (0.05)	NS	NS	0.097	NS	NS

4.9.1.5 Leaf area index (LAI)

Leaf area index, a function of number of leaves and area of the index leaf obtained during the first year and second year are furnished in Tables 4.48 and 4.49 respectively.

In the first year, the influence of the methods and levels of irrigation was pronounced only six months after planting. At 6 MAP, conventional irrigation was better than others. But at 7 MAP, LAI due to subsurface drip fertigation became on par with that of conventional method. Supplying 16 l day^{-1} and 12 l day^{-1} produced comparable leaf area at 6 MAP.

In the second year also, the influence of method of irrigation was significant only after six months growth and subsurface drip fertigation was noticed to be superior over other methods. After five months, I_{75} and I_{100} were statistically similar, but at 6 MAP, variation between treatments became significant and 100 per cent replenishment resulted in the highest LAI.

4.9.2 Yield and yield attributing characters

The bunch yield and associated characters obtained during the first year and second year are furnished in Tables 4.50 and 4.51 and respectively.

4.9.2.1 Bunch weight

In the first year conventional daily basin irrigation resulted in the production of heavier bunches than drip irrigation. Surface and subsurface drip that were inferior to basin produced about 28 per cent less yield over conventional

Table 4.48. Effect of methods and levels of irrigation on leaf area index of banana var. Nendran during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	0.93	2.64	2.85	3.72	2.25
SS	0.85	2.26	2.64	3.44	2.96
C	1.03	2.30	3.04	4.28	3.37
CD (0.05)	NS	NS	NS	0.554	0.522
I_{50}	0.90	2.16	2.73	3.56	3.03
I_{75}	0.94	2.46	2.77	3.71	2.74
I_{100}	0.98	2.58	3.02	4.17	2.81
CD (0.05)	NS	NS	NS	0.459	NS
SI_{50}	1.08	2.38	3.03	3.40	1.98
SI_{75}	0.90	2.62	2.43	3.76	2.37
SI_{100}	0.81	2.91	3.10	3.99	2.40
SS I_{50}	0.77	2.39	2.43	3.39	3.48
SS I_{75}	0.90	2.16	2.74	3.04	2.41
SS I_{100}	0.90	2.23	2.76	3.88	2.97
CI_{50}	0.85	1.70	2.74	3.88	3.63
CI_{75}	1.01	2.59	3.16	4.34	3.43
CI_{100}	1.22	2.60	3.21	4.63	3.07
CD (0.05)	NS	NS	NS	NS	NS

Table 4.49. Effect of methods and levels of irrigation on LAI of banana var. Nendran during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
S	0.60	1.56	2.72	3.55	3.62
SS	0.65	1.47	2.67	3.96	3.64
C	0.59	1.47	2.60	3.30	3.64
CD (0.05)	NS	NS	NS	0.346	NS
I_{50}	0.51	1.32	2.34	2.93	3.43
I_{75}	0.68	1.61	2.73	3.73	3.76
I_{100}	0.65	1.58	2.93	4.16	3.70
CD (0.05)	0.117	NS	0.241	0.380	NS
SI_{50}	0.56	1.48	2.55	2.67	3.68
SI_{75}	0.71	1.77	2.72	3.76	3.59
SI_{100}	0.54	1.43	2.90	4.21	3.59
SSI_{50}	0.52	1.28	2.47	3.47	3.30
SSI_{75}	0.71	1.34	2.68	4.02	3.97
SSI_{100}	0.72	1.78	2.86	4.40	3.65
CI_{50}	0.45	1.19	1.99	2.64	3.32
CI_{75}	0.61	1.70	2.80	3.42	3.78
CI_{100}	0.70	1.52	3.02	3.85	3.85
CD (0.05)	NS	NS	NS	NS	NS

Table 4.50. Effect of methods and levels of irrigation on yield and bunch characters, days to flower and total duration of banana var. Nendran during first year

Treatment	Yield (kg plant^{-1})	Peduncle length (cm)	No. of hands	Total No. of fingers	Days to flower	Total duration (days)
S	5.53	62.79	4.22	37.89	203.83	291.78
SS	5.42	68.74	4.56	38.44	204.53	293.69
C	7.06	54.17	4.72	47.33	220.94	303.86
CD (0.05)	0.452	2.092	NS	1.654	14.17	4.226
I_{50}	5.34	61.9	4.17	37.94	213.64	299.66
I_{75}	5.89	62.47	4.61	41.06	210.11	296.94
I_{100}	6.77	61.33	4.72	44.67	205.56	292.72
CD (0.05)	0.768	NS	NS	NS	NS	5.326
SI_{50}	4.72	67.20	3.83	35.83	203.00	296.33
SI_{75}	5.45	64.33	4.50	36.17	206.33	290.17
SI_{100}	6.42	56.83	4.33	41.67	202.17	288.83
SSI_{50}	4.87	60.67	4.67	39.17	206.77	292.89
SSI_{75}	5.17	73.23	4.33	35.67	205.67	297.33
SSI_{100}	6.22	72.33	4.67	40.50	201.17	290.83
CI_{50}	6.43	57.83	4.00	38.83	231.17	309.75
CI_{75}	7.07	49.83	5.00	51.33	218.33	303.33
CI_{100}	7.67	54.83	5.17	51.83	213.33	298.50
CD (0.05)	NS	11.56	NS	NS	NS	NS

Table 4.51. Effect of methods and levels of irrigation on yield and bunch characters, days to flower and total duration of banana var. Nendran in the second year

Treatment	Yield Kg $plant^{-1}$	Peduncle length (cm)	No. of hands	Total No. of fingers	Days to flower	Total duration (days)
S	9.72	31.00	5.17	51.83	242.67	326.33
SS	10.44	27.83	5.28	51.00	245.78	325.56
C	8.82	37.00	5.00	53.00	248.22	337.78
CD (0.05)	0.414	5.684	NS	NS	NS	NS
I_{50}	8.63	33.67	5.00	48.28	258.00	341.00
I_{75}	9.83	34.67	5.22	51.50	244.11	332.44
I_{100}	10.51	27.50	5.22	56.06	234.56	316.22
CD (0.05)	0.312	1.914	NS	4.598	7.642	9.162
SI_{50}	9.08	33.50	5.17	53.83	253.00	335.67
SI_{75}	9.92	32.50	5.00	46.97	242.33	328.33
SI_{100}	10.17	27.00	5.33	55.00	232.67	315.00
SSI_{50}	9.58	32.50	5.33	47.00	258.67	333.00
SSI_{75}	10.33	33.00	5.17	49.67	246.67	329.67
SSI_{100}	11.40	18.00	5.33	56.33	232.00	314.00
CI_{50}	7.23	35.00	4.50	44.00	262.33	354.33
CI_{75}	9.25	38.50	5.50	58.17	243.33	339.33
CI_{100}	9.97	37.50	5.00	56.83	239.00	319.67
CD (0.05)	0.540	3.315	NS	7.964	NS	NS

irrigations. But in the second year. subsurface drip (10.44 kg) was superior to surface drip (9.72 kg) and basin irrigation (8.82). which was 18.38 per cent higher than the conventional method.

Variation in yield was recorded due to different levels of irrigation also. In both the years I_{100} gave the highest yield. I_{50} and I_{75} resulted in comparable yields in the first year, whereas in the second year, there was a decrease in yield with I_{50}, compared to I_{75}.

Variation in the yield for combinations of different methods and levels of irrigation was more pronounced in the second year. Yield obtained by subsurface drip fertigation at I_{75} (10.33 kg) was statistically similar to surface drip at I_{100} (10.17 kg). Similarly the yield obtained from conventional irrigation at 100 per cent PEC was also on par with surface drip at 75 per cent PEC. At lower levels of irrigation also drip irrigation performed better. Conventional irrigation at lowest level (C_{50}) produced bunches weighing 7.23 kg whereas surface and subsurface drip at the same level of irrigation resulted in bunches weighing 9.08 and 9.58 kg respectively.

4.9.2.2 Peduncle length

Peduncle length manifested more variation due to the method of irrigation in the first year (Table 4.50). Conventionally irrigated plants had the lowest peduncle length followed by surface drip. Subsurface irrigation recorded the maximum peduncle length. Contrary to this, in the second year, conventional method resulted the longest peduncle.

The length of the peduncle was found decreasing with increase in irrigation water in both years, though non-significant in the first year. The interaction of levels and methods of irrigation resulted in longer peduncles with surface and subsurface drip at low irrigation levels.

The peduncle length was notably less in the second year than in the first year.

4.9.2.3 Number of hands

Variation in number of hands produced as influenced by different levels, methods of irrigation or methods at different levels were not statistically significant (Tables 4.50 and 4.51). However, it was observed that the number of hands varied from 3.83 to 5.17 per bunch in the first year while the variation was from 4.5 to 5.5 in the second year. The number of hands produced in the first year were 4.22, 4.56 and 4.72 for surface, subsurface and conventional methods respectively while it was 5.17, 5.28 and 5.0 in the second year.

Increasing irrigation levels increased the number of hands in both years.

4.9.2.4 Total number of fingers

The total number of fingers ranged from 35.67 to 51.83 in the first year and from 44.00 to 58.17 in the second year. In the first year conventional method of irrigation resulted in more number of fingers compared to drip fertigation. Surface and subsurface drip were non-significant among themselves. In the second year, different methods of irrigation had no effect on the total number of fingers produced, but the levels of irrigation did produce significant influence. More fingers were produced by I_{100}, but comparable with I_{75}. I_{50} was significantly inferior.

Different levels of irrigation or methods of irrigation at varying levels did not influence the total number of fingers produced, in the first year. In the second year analysis of combination treatments revealed that subsurface drip at I_{75} and I_{100} were on par with basin irrigation at I_{75} and I_{100}. But subsurface drip at I_{75} could produce statistically same number of fruits as that of surface drip at I_{100}. At lower levels of irrigation, drip irrigation was found to be better than conventional method.

4.9.2.5 Days to flower

Flowering of the plants in the first year was influenced significantly by the methods of irrigation. Drip fertigation resulted in early flowering, but subsurface drip and surface drip did not vary among themselves. Quantity of irrigation given through different methods could not bring any significant effect.

In the second year, it was the level of irrigation and not the method of irrigation that produced difference in days to flowering. Higher the level of irrigation, earlier was the flowering. The combination of treatments had no significant effect. It took relatively lesser number of days during first year than second year.

4.9.2.6 Total duration

Total duration of the crop in the first year also was higher for conventionally treated plants than drip fertigated plants, but surface and subsurface drip did not vary significantly. Providing 16 l day^{-1} and 12 l day^{-1} resulted in simultaneous harvesting of the crop. But in the second year the response to irrigation increased and supplying I_{100} resulted in early maturity and harvesting of the crop. Total duration of the crop was comparatively lesser in the first year than in the second year. It varied from 288.8 to 309.8 days in the first year, whereas it was from 314.0 to 339.3 days in the second year.

4.9.2.7 D-finger characteristics

D-finger characters, contributing to the total bunch weight in the first year and second year are presented in Tables 4.52 and 4.53 respectively.

4.9.2.7.1 Number of fingers in D-hand

In the first year the number of fingers produced in D-hand was higher for conventional daily irrigation (10.94) but was comparable with surface drip (9.61). Methods of irrigation at different levels of irrigation did not influence the number of fingers in D-hand.

In the second year, fingers in D-hand was not statistically different due to the levels and methods of irrigation.

4.9.2.7.2 D- finger weight

The weight of the finger was significantly influenced by the methods and levels of irrigation, but not by their interaction effect.

Conventional method of irrigation and fertilization resulted in a higher D- finger weight in the first year. In the second year, it was subsurface drip, that

Table 4.52. Effect of methods and levels of irrigation on D- finger characters of banana var. Nendran during first year

Treatment	Fingers in D-hand	D- finger weight (g)	D- finger length (cm)	D- finger girth (cm)
S	9.61	107.73	19.27	11.93
SS	8.62	111.36	19.51	12.56
C	10.94	127.87	19.80	12.03
CD (0.05)	1.588	10.21	NS	NS
I_{50}	9.73	104.27	18.69	12.13
I_{75}	10.00	119.23	19.42	11.74
I_{100}	9.44	125.46	20.47	12.64
CD (0.05)	NS	9.118	0.979	0.615
SI_{50}	10.17	100.41	18.00	12.30
SI_{75}	9.17	108.34	18.90	11.03
SI_{100}	9.50	114.43	20.90	12.47
SSI_{50}	9.03	104.41	19.63	12.83
SSI_{75}	8.33	118.09	19.20	11.97
SSI_{100}	8.50	117.58	19.70	12.87
CI_{50}	10.00	107.98	18.43	11.27
CI_{75}	12.50	131.26	20.17	12.23
CI_{100}	10.33	144.37	20.80	12.60
CD (0.05)	NS	NS	1.696	NS

Table 4.53. Effect of methods and levels of irrigation on D-finger characters of banana var. Nendran during second year

Treatment	Fingers in D-hand	D-finger weight (gm)	D-finger length (cm)	D-finger girth (cm)	D-finger volume (cc)
S	10.78	153.98	21.03	12.44	123.67
SS	11.00	164.53	21.99	13.02	144.56
C	10.17	145.79	20.27	12.50	125.00
CD (0.05)	NS	10.97	NS	NS	NS
I_{50}	10.17	141.31	20.23	12.18	118.11
I_{75}	10.72	152.55	21.57	12.91	131.78
I_{100}	11.06	170.43	21.49	12.88	143.33
CD (0.05)	NS	8.242	NS	NS	11.60
SI_{50}	11.17	135.55	20.43	12.50	113.67
SI_{75}	11.00	153.45	21.27	12.53	125.00
SI_{100}	10.17	172.94	21.40	12.30	132.33
SSI_{50}	10.00	152.82	20.40	12.10	132.67
SSI_{75}	11.00	165.57	22.87	13.83	143.67
SSI_{100}	12.00	175.19	22.70	13.13	157.33
CI_{50}	9.33	135.57	19.87	11.93	108.00
CI_{75}	10.17	138.62	20.57	12.37	126.67
CI_{100}	11.00	163.18	20.37	13.20	140.33
CD (0.05)	NS	NS	NS	NS	20.09

could result in more finger weight. Surface drip was on par with both subsurface drip and basin irrigation.

Increasing the quantity of irrigation increased the fruit weight in both the years, but the effect was more prominent in the second year. In the first year, I_{75} and I_{100} resulted in fruit weights that were on par, whereas in the second year, there was a progressive increase from I_{50} to I_{100}.

4.9.2.7.3 Length of D-finger

Length of the D-finger in first year was not affected by the method of irrigation, but variation was obtained between different levels of irrigation. Evaporation compensation to 100 per cent (I_{100}) produced longest fruits and I_{50} and I_{75} resulted in comparable fruit length. The interaction of levels and methods was non-significant. In the second year, the levels and methods of irrigation and their interaction did not bring any significant influence.

4.9.2.7.4 D- finger girth

Neither the different methods of irrigation nor its interaction with various irrigation levels had significant effect on the girth of the D- finger in both the years.

4.9.2.7.5 D-finger volume

In the second year, crop response in terms of D-finger volume was significant only to the levels of irrigation and increase in irrigation water increased the fruit volume to a level of I_{75}. The methods of irrigation or its interaction with levels of irrigation did not bring any significant variation.

4.9.3 Sucker production

The sucker production in the first year was higher than that in the second year, irrespective of the treatments (Table 4.54). In the first year, sucker production was not affected by the method of irrigation, whereas in the second year, basin irrigation was found to produce lesser number of suckers than surface drip irrigation. Subsurface drip fertigation also produced lesser number which was on par with conventional irrigation.

With regard to the effect of levels of irrigation, increasing the irrigation from 8 l day^{-1} to 12 l day^{-1} in the first year was found increasing the sucker production, but further increase did not result in increased sucker production. In the second year, the effect of irrigation level was non-significant.

Levels of irrigation given through different methods had no influence during both the years. The suckers at harvest also was not affected by levels, methods or their combination in the first year, but in the second year, basin irrigation resulted in lesser number of suckers at harvest also.

4.9.4 Biomass production

The biomass accumulated during the first year and second year respectively are depicted in Tables 4.55 and 4.56. In the first year the total biomass did not vary significantly with the method of irrigation, but the individual

Table 4.54. Effect of methods and levels of irrigation on sucker production of banana var. Nendran

Treatment	I year		II year	
	No. of suckers		No. of suckers	
	At flowering	At harvest	At flowering	At harvest
S	9.78	9.78	8.33	10.67
SS	10.50	10.56	6.11	9.11
C	12.06	8.28	6.28	6.56
CD (0.05)	NS	NS	1.578	2.959
I_{50}	7.61	9.06	7.00	9.11
I_{75}	11.67	9.28	6.50	8.67
I_{100}	13.06	9.28	7.22	8.56
CD (0.05)	1.949	NS	NS	NS
SI_{50}	5.33	10.00	9.67	11.00
SI_{75}	11.00	8.67	7.17	12.33
SI_{100}	13.00	10.67	8.17	8.67
SSI_{50}	7.50	9.67	6.00	9.00
SSI_{75}	12.50	10.67	5.17	7.00
SSI_{100}	11.50	8.33	7.17	11.33
CI_{50}	10.00	7.50	5.33	7.33
CI_{75}	11.50	8.50	7.17	6.67
CI_{100}	14.67	8.83	6.33	5.67
CD (0.05)	NS	NS	2.663	2.232

Table 4.55. Effect of methods and levels of irrigation on biomass production (kg plant^{-1}) of banana var. Nendran during first year

Treatment	Rhizome	Pseudo-stem	Leaf	Peduncle	Male bud	Bunch	Total
S	32.19	17.75	1.51	0.69	0.30	5.53	57.98
SS	35.63	19.68	1.80	0.80	0.34	5.42	63.67
C	27.74	21.47	1.69	0.57	0.23	7.06	58.77
CD (0.05)	5.001	2.887	NS	0.101	0.072	0.452	NS
I_{50}	30.24	18.29	1.58	0.61	0.35	5.34	56.40
I_{75}	32.98	19.54	1.54	0.68	0.29	5.89	60.92
I_{100}	32.36	21.07	1.88	0.77	0.25	6.77	63.08
CD (0.05)	NS	1.707	NS	NS	0.046	0.768	3.062
SI_{50}	31.42	19.70	1.83	0.69	0.34	4.72	58.70
SI_{75}	30.67	15.55	1.20	0.59	0.27	5.45	53.73
SI_{100}	34.50	18.00	1.50	0.78	0.31	6.42	61.51
SS I_{50}	30.97	17.83	1.40	0.58	0.45	4.87	56.10
SS I_{75}	38.33	22.33	1.83	0.94	0.32	5.17	68.93
SS I_{100}	37.60	18.87	2.17	0.87	0.26	6.22	65.98
CI_{50}	28.33	17.33	1.50	0.55	0.26	6.43	54.41
CI_{75}	29.93	20.73	1.60	0.52	0.27	7.07	60.12
CI_{100}	24.97	26.33	1.97	0.65	0.17	7.67	61.75
CD (0.05)	5.130	2.957	NS	NS	0.080	NS	5.303

Table 4.56. Effect of methods and levels of irrigation on biomass production (kg plant $^{-1}$) of banana var. Nendran during second year

Treatment	Rhizome	Pseudo-stem	Leaf	Peduncle	Male bud	Bunch	Total
S	41.42	35.40	2.45	0.58	0.74	9.72	90.31
SS	34.17	34.46	1.84	0.59	0.58	10.44	82.08
C	30.58	35.15	1.23	0.54	0.57	8.817	77.89
CD (0.05)	3.831	NS	0.219	NS	0.059	0.041	2.957
I_{50}	30.45	31.68	2.22	0.56	0.65	8.63	74.18
I_{75}	36.76	35.05	2.23	0.568	0.64	9.83	85.09
I_{100}	38.95	38.28	2.07	0.59	0.61	10.51	91.01
CD (0.05)	0.708	1.467	NS	NS	NS	0.312	2.053
SI_{50}	35.25	33.70	2.45	0.60	0.68	9.08	81.76
SI_{75}	43.40	34.50	2.65	0.517	0.89	9.92	91.88
SI_{100}	45.60	38.00	2.25	0.63	0.66	10.17	97.30
SSI_{50}	26.15	26.83	1.80	0.58	0.36	9.58	65.30
SSI_{75}	38.10	35.95	1.75	0.62	0.66	10.33	87.41
SSI_{100}	38.25	40.60	1.98	0.58	0.73	11.40	93.53
CI_{50}	29.95	34.50	2.40	0.50	0.90	7.23	75.48
CI_{75}	28.78	34.70	2.30	0.57	0.37	9.25	75.98
CI_{100}	33.00	36.25	1.98	0.57	0.44	9.97	82.21
CD (0.05)	1.226	2.542	NS	NS	0.080	0.540	3.556

components were influenced. Rhizome contributed maximum to the total biomass and subsurface had the highest rhizome weight. The pseudostem which forms the major above ground portion was more in conventional method. The peduncle and male bud also were heavy under drip irrigation.

In the second year, the total biomass was higher for surface drip followed by subsurface drip fertigation, and pseudostem contributed to 39 per cent of total biomass under surface drip fertigation. Rhizome, leaves and male bud weight also were more for surface drip than other methods.

Comparison of different levels of irrigation showed that increase in the irrigation water increased the total biomass yield. Providing 12 l day^{-1} and 16 l day^{-1} were comparable with each other, but superior to 8 l day^{-1}. Similar pattern was noticed in the component parts other than rhizome, peduncle and male bud. As in the case of first crop, increasing the quantity of irrigation increased the weight of rhizome and pseudostem in the second year and thereby the total biomass production. The effect of levels of irrigation on leaf, peduncle and male bud was non-significant.

Analysis of the combined effect of irrigation at different methods and levels of irrigation showed that subsurface drip at 12 l day^{-1} was superior to surface drip at 16 l day^{-1} in producing rhizome, pseudostem and thereby total biomass. Conventional method at 12 l day^{-1} and 16 l day^{-1} produced more pseudostem, but rhizome weight was lesser than that of subsurface drip at 16 l day^{-1} and hence the total biomass was more for subsurface fertigation at 16 and 12 l day^{-1}. In the second year, maximum pseudostem weight was gained in subsurface drip at I_{100}, followed by subsurface drip at I_{75}. The pseudostem weight of subsurface at I_{75} (SSI_{75}) was comparable with that of CI_{100} and SI_{100}. But weight of rhizome was more in SI_{100}, followed by SI_{75} resulting in a higher total biomass in SI_{100} and SI_{75}.

4.9.4.1 Intercorrelation analysis

Intercorrelation among biomass production by vegetative parts and whole plant and to the bunch yield are presented in Tables 4.57 and 4.58 for the first year and second year respectively.

In the first year, only the weight of the pseudostem had a positive significant correlation with the bunch yield, while the biomass of male bud and rhizome were significantly and negatively correlated to yield, highest negative correlation being for male bud. Peduncle weight also was negatively correlated, though non-significant.

The total biomass inturn was highly correlated to the rhizome weight, which had a negative relation with yield. Besides the rhizome weight was highly correlated to the peduncle weight, which also affected the yield negatively.

Contrary to this, the pseudostem weight which had a positive correlation with yield was negatively related to weight of male bud and rhizome and negligibly to peduncle weight.

Table 4.57 . Interrelation of biomass of different plant parts and yield of banana var. Nendran in the first year

	Pseudostem	Leaf	Peduncle	Male bud	Rhizome	Total biomass	Yield
Pseudostem	1.0						
Leaf	0.333	1.0					
Peduncle	0.072	0.106	1.0				
Male bud	-0.409	-0.124	0.027	1.0			
Rhizome	-0.222	0.081	0.665	0.228	1.0		
Total biomass	0.527	0.390	0.626	-0.173	0.690	1.0	
Yield	0.404	0.127	-0.182	-0.622	-0.362	0.131	1.0

Table 4.58. Interrelation of biomass of different plant parts and yield of banana var. Nendran in the second year

	Pseudostem	Leaf	Peduncle	Male bud	Rhizome	Total biomass	Yield
Pseudostem	1.0						
Leaf	0.109	1.0					
Peduncle	0.020	0.071	1.0				
Male bud	0.351	0.439	-0.206	1.0			
Rhizome	0.568	0.261	0.215	0.538	1.0		
Total biomass	0.807	0.211	0.174	0.498	0.941	1.0	
Yield	0.425	-0.411	0.176	-0.181	0.465	0.559	1.0

In the second year, the correlation between total biomass and yield increased, and the weight of pseudostem and rhizome which contributed mainly to the total biomass also were positively correlated to yield.

The positive correlation between rhizome and peduncle decreased drastically in the second year. Similarly the negative correlation of pseudostem to rhizome and male bud also changed to positive significant correlation. The bunch weight was significantly and negatively correlated to the leaf weight in the second year.

4.9.5 Nutrient content in plant parts at different stages

The nutrient content in the index leaf of the plant at different growth stages and in different plant parts at harvest stage are presented here.

4.9.5.1 Nitrogen (Tables 4.59 and 4.60)

Method of irrigation and fertilizer application significantly influenced the foliar nitrogen content in the critical stages of growth. Basin application remained superior to drip fertigation in all these stages but surface drip and subsurface drip did not vary among themselves. In the second year also the same trend was followed. At 5 MAP, the N content was 3.49 under conventional whereas it was 3.11 and 3.22 per cent under surface drip and subsurface drip respectively in the first year. In the second year, it was 3.63 per cent under conventional and 3.51 and 3.62 per cent under surface and subsurface drip respectively.

Table 4.59. Effect of methods and levels of irrigation on N content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	3.59	2.56	3.11	3.74	2.49	1.87	1.15	1.34	1.26	0.42	2.27	1.39
SS	3.63	2.66	3.22	3.62	2.65	1.98	1.11	1.40	1.32	0.45	2.45	1.30
C	3.67	2.68	3.49	3.32	3.00	1.92	1.17	1.35	1.28	0.62	2.50	1.40
CD (0.05)	NS	0.059	0.230	NS	0.211	NS	NS	NS	NS	0.166	NS	0.059
I_{50}	3.60	2.56	3.17	3.92	2.62	1.87	1.17	1.16	1.19	0.42	2.43	1.35
I_{75}	3.78	2.63	3.14	3.53	2.69	1.85	1.13	1.34	1.28	0.50	2.36	1.38
I_{100}	3.51	2.71	3.49	3.23	2.83	2.05	1.14	1.59	1.39	0.57	2.43	1.37
CD (0.05)	NS	NS	0.250	NS	NS	0.181	NS	0.169	0.046	0.033	NS	NS
SI_{50}	3.33	2.46	2.97	3.84	2.38	1.68	1.18	1.20	1.21	0.36	2.40	1.46
SI_{75}	3.86	2.52	3.11	3.75	2.46	1.85	1.16	1.32	1.32	0.42	2.27	1.41
SI_{100}	3.58	2.69	3.25	3.64	2.63	2.07	1.12	1.51	1.26	0.48	2.13	1.31
SSI_{50}	3.64	2.58	3.30	4.09	2.38	1.85	1.12	1.12	1.19	0.40	2.67	1.22
SSI_{75}	3.89	2.69	2.99	3.02	2.69	1.90	1.06	1.40	1.37	0.45	2.30	1.36
SSI_{100}	3.36	2.72	3.36	3.75	2.88	2.18	1.15	1.68	1.42	0.50	2.40	1.33
CI_{50}	3.84	2.63	3.25	3.84	3.11	2.07	1.20	1.15	1.18	0.50	2.21	1.37
CI_{75}	3.58	2.69	3.33	3.81	2.91	1.79	1.17	1.32	1.15	0.62	2.52	1.38
CI_{100}	3.58	2.72	3.88	3.30	2.97	1.90	1.15	1.57	1.50	0.73	2.77	1.46
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.080	0.056	0.232	0.125

Table 4.60. Effect of methods and levels of irrigation on N content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	3.58	4.19	3.51	3.39	3.13	1.06	1.09	0.73	1.48	0.61	2.70	1.24
SS	3.36	4.33	3.62	3.34	3.33	1.03	1.11	0.68	1.90	0.76	2.90	1.26
C	3.65	4.41	3.63	3.58	3.28	1.36	1.59	0.75	1.65	0.68	2.8	1.24
CD (0.05)	0.131	NS	0.041	0.131	NS	NS	0.072	NS	0.271	0.092	0.101	NS
I_{50}	3.45	4.26	3.47	3.39	3.30	1.05	1.29	0.64	1.40	0.58	3.06	1.19
I_{75}	3.60	4.27	3.55	3.46	3.31	1.24	1.31	0.74	1.52	0.67	2.58	1.27
I_{100}	3.55	4.39	3.73	3.45	3.12	1.16	1.19	0.78	2.10	0.79	2.80	1.29
CD (0.05)	0.108	NS	0.073	0.065	0.149	NS	0.046	0.033	0.159	0.073	0.334	0.033
SI_{50}	3.69	4.09	3.28	3.41	3.16	0.91	0.99	0.71	1.01	0.56	3.25	1.20
SI_{75}	3.58	4.21	3.43	3.40	3.16	1.17	1.17	0.74	1.62	0.50	2.44	1.24
SI_{100}	3.49	4.27	3.81	3.35	3.07	1.09	1.11	0.74	1.79	0.76	2.43	1.29
SSI_{50}	3.29	4.29	3.42	3.19	3.30	1.02	1.20	0.53	1.40	0.67	2.80	1.20
SSI_{75}	3.54	4.36	3.64	3.39	3.41	1.10	1.15	0.71	1.74	0.76	2.52	1.29
SSI_{100}	3.26	4.33	3.81	3.44	3.30	0.97	0.98	0.78	2.57	0.84	3.39	1.29
CI_{50}	3.37	4.40	3.72	3.58	3.45	1.22	1.66	0.67	1.79	0.50	3.14	1.15
CI_{75}	3.68	4.25	3.58	3.60	3.38	1.44	1.61	0.76	1.20	0.76	2.77	1.27
CI_{100}	3.89	4.58	3.58	3.58	3.00	1.42	1.48	0.83	1.95	0.78	2.58	1.29
CD (0.05)	0.187	NS	0.126	0.113	NS	NS	0.080	0.056	0.276	0.126	0.579	NS

Irrigation levels could produce effect on plant nitrogen content only at 5 MAP in the first year. Application of 16 l day^{-1} (I_{100}) resulted in the highest nitrogen content at 5 MAP. In the second year water requirement increased with advance of growth till 7 MAP.

At 3 MAP in the second year, CI_{100} resulted in the highest N content (3.89), but at 5 MAP, subsurface and surface drip at I_{100} recorded the highest N content. CI_{100} resulted in a lesser value than drip fertigation at 100 per cent PEC. Subsurface drip at I_{50} and I_{75} were better than surface drip at 5 MAP. Besides subsurface drip at I_{50} was statistically similar to surface drip at I_{75}.

At harvest of the crop in first year only the N content in fruit and leaf were significantly affected by the method of irrigation. Conventional method recorded the highest content (0.62 per cent) in fruit followed by drip method. Both surface and subsurface drip were on par. Increase in quantity of irrigation increased the content in rhizome, pseudostem, peduncle and fruit.

In the second year, rhizome, pseudostem and leaf remained unaffected by the method of irrigation, but all other parts were significantly influenced. Conventional method and subsurface drip method produced comparable nitrogen contents in peduncle, fruit and male bud, but subsurface drip was inferior to conventional method, in terms of nitrogen content in root. Irrigation at I_{100} resulted in a higher content in pseudostem, peduncle, fruit and leaf but lower levels resulted in more content in root.

4.9.5.2 Phosphorus (Tables 4.61 and 4.62)

The P content in the index leaf of conventionally irrigated and fertilizer applied and subsurface drip fertigated plants were comparable at 3 MAP, but when it reached 7 MAP, subsurface drip had significantly higher content. Surface drip recorded the lowest value. There was a decrease in the P content, in general, as the crop reached 7 MAP.

In the second year, the effect of method of irrigation and fertilizer application was not significant in any of the growth stages, though conventional method tended to have a higher P content.

P content decreased with increase in water level at 6 MAP of the first year. But in the second year, providing irrigation to compensate for 75 per cent evaporation was sufficient at 3 MAP, but at 4 MAP, 100 per cent PEC resulted in better uptake. At 7 MAP, highest content was recorded by 50 per cent PEC.

The P content in the index leaf was very much lesser in the second year than that in the first year.

At harvesting stage of the crop in first year, P content in the peduncle and male bud alone were significantly influenced by the methods of irrigation and fertilizer application. In peduncle it was conventional method that resulted in highest content but in male bud more content was registered under surface drip fertigation. The content in the pseudostem and peduncle increased with increase in

Table 4.61. Effect of methods and levels of irrigation on P content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	0.205	0.223	0.265	0.292	0.267	0.103	0.081	0.086	0.129	0.041	0.356	0.11
SS	0.273	0.240	0.279	0.316	0.297	0.084	0.090	0.082	0 137	0.059	0.300	0.12
C	0.258	0.223	0.272	0.376	0.284	0.084	0.077	0.094	0.184	0.070	0.289	0.12
CD (0.05)	0.041	NS	NS	0.021	0.007	NS	NS	NS	0.004	NS	0.007	NS
I_{50}	0.232	0.226	0.251	0.343	0.272	0.094	0.091	0.083	0.137	0.050	0.312	0.11
I_{75}	0.246	0.21	0.288	0.338	0.291	0.086	0.085	0.084	0.147	0.059	0.328	0.12
I_{100}	0.258	0.240	0.277	0.303	0.286	0.091	0.071	0.096	0.166	0.068	0.306	0.11
CD (0.05)	NS	NS	NS	0.015	0.005	NS	0.010	0.010	0.02	0.003	0.006	0.010
SI_{50}	0.170	0.22	0.176	0.322	0.273	0.109	0.089	0.085	0.138	0.047	0.327	0.10
SI_{75}	0.204	0.185	0.342	0.285	0.269	0.100	0.080	0.080	0.121	0.042	0.394	0.11
SI_{100}	0.242	0.263	0.278	0.269	0.261	0.099	0.075	0.094	0.128	0.054	0.348	0.11
SSI_{50}	0.285	0.249	0.280	0.339	0.305	0.080	0.094	0.054	0.149	0.052	0.282	0.12
SSI_{75}	02.63	0.249	0.296	0.295	0.290	0.079	0.100	0.079	0.135	0.062	0.307	0.13
SSI_{100}	0.270	0.221	0.260	0.315	0.297	0.094	0.075	0.113	0.128	0.064	0.312	0.11
CI_{50}	0.242	0.207	0.298	0.368	0.238	0.093	0.091	0.109	0.124	0.052	0.327	0.12
CI_{75}	0.270	0.228	0.225	0.434	0.314	0.080	0.075	0.094	0.185	0.072	0.282	0.13
CI_{100}	0.263	0.235	0.293	0.325	0.299	0.079	0.064	0.080	0.242	0.085	0.257	0.11
CD (0.05)	0.056	0.036	0.056	0.025	0.008	0.006	NS	0.018	0.004	0.264	0.010	0.018

Table 4.62. Effect of methods and levels of irrigation on P content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	0.222	0.182	0.176	0.137	0.199	0.067	0.072	0.046	0.191	0.056	0.434	0.130
SS	0.190	0.161	0.228	0.144	0.183	0.044	0.088	0.050	0.228	0.071	0.047	0.127
C	0.250	0.193	0.192	0.150	0.196	0.069	0.076	0.059	0.220	0.077	0.383	0.131
CD (0.05)	NS	NS	NS	0.021	NS	0.001	0.007	0.004	NS	0.013	NS	NS
I_{50}	0.191	0.161	0.239	0.154	0.202	0.064	0.078	0.053	0.209	0.056	0.380	0.123
I_{75}	0.237	0.173	0.149	0.132	0.185	0.058	0.070	0.053	0.181	0.066	0.421	0.132
I_{100}	0.234	0.262	0.208	0.145	0.191	0.048	0.088	0.049	0.250	0.081	0.484	0.133
CD (0.05)	0.033	0.018	NS	NS	0.010	0.015	0.009	NS	0.033	0.010	0.033	NS
SI_{50}	0.204	0.193	0.194	0.135	0.221	0.074	0.071	0.052	0.208	0.047	0.348	0.129
SI_{75}	0.229	0.162	0.142	0.124	0.185	0.074	0.064	0.046	0.127	0.054	0.449	0.134
SI_{100}	0.232	0.190	0.191	0.151	0.192	0.053	0.082	0.041	0.239	0.067	0.506	0.127
SSI_{50}	0.139	0.139	0.380	0.124	0.178	0.045	0.089	0.043	0.195	0.054	0.484	0.119
SSI_{75}	0.231	0.152	0.115	0.150	0.185	0.047	0.082	0.042	0.208	0.068	0.420	0.125
SSI_{100}	0.200	0.192	0.189	0.157	0.185	0.041	0.094	0.064	0.282	0.092	0.498	0.136
CI_{50}	0.231	0.151	0.142	0.202	0.207	0.074	0.074	0.063	0.225	0.068	0.307	0.121
CI_{75}	0.251	0.205	0.191	0.121	0.185	0.053	0.064	0.071	0.208	0.077	0.394	0.136
CI_{100}	0.269	0.225	0.244	0.128	0.196	0.049	0.089	0.042	0.228	0.085	0.449	0.137
CD (0.05)	NS	0.031	NS	0.056	0.018	0.025	0.016	0.006	0.056	0.006	0.056	NS

quantity of irrigation, but in male bud and root lower levels produced more content.

In the second year, drip registered more P content than conventional method in rhizome and root whereas the content in fruit was more under conventional method. Increasing the quantity of irrigation water increased the P content in peduncle, fruit and male bud but, lower quantities resulted more P content in rhizome.

4.9.5.3 Potassium

Potassium content in the index leaf of the crop in both the years (Tables 4.63 and 4.64) was significantly influenced by the method of irrigation. A gradual decline in foliar leaf content was observed from 3 MAP to 7 MAP irrespective of all treatments, in the second year. In the first year, there was an increase till 6 MAP, and at 7 MAP, the content was found decreasing.

Drip irrigation resulted in a higher content than conventional method at 3 MAP, but at 4 MAP, conventional method resulted in a higher content. Hence a definite pattern was not followed. In the second year, subsurface resulted in higher K content in the index leaf in the third, fifth and seventh month after planting. Basin irrigation remained on par with subsurface at 3 MAP, but after five months, subsurface drip was significantly superior. At 7 MAP, K content in the surface drip also became comparable to subsurface drip fertigation.

Significantly highest potassium content in the index leaf was observed with I_{75} during first year. In the second year, the effect of quantity of irrigation was

Table 4.63. Effect of methods and levels of irrigation on K content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhizome	Root	Pseudostem	Peduncle	Fruit	Male bud	Leaf
S	5.40	4.50	4.43	4.93	4.23	9.43	5.00	9.57	8.90	1.40	5.13	1.28
SS	5.21	4.40	5.10	4.63	3.97	8.87	5.00	9.30	9.23	1.40	5.44	1.03
C	4.6	4.9	4.9	4.8	4.6	7.93	6.00	10.30	9.47	1.47	5.00	1.20
CD (0.05)	0.379	0.377	0.117	0.117	0.155	0.149	0.388	0.944	NS	NS	NS	0.149
I_{50}	4.8	4.3	4.8	4.9	4.3	7.73	6.33	10.27	9.13	1.37	4.60	1.17
I_{75}	5.12	4.83	4.77	4.80	4.43	8.77	5.17	9.47	9.03	1.37	5.44	1.22
I_{100}	5.30	4.72	4.87	4.67	4.10	9.73	4.50	9.43	9.43	1.53	5.53	1.12
CD (0.05)	0.142	0.339	NS	NS	0.156	0.663	0.356	NS	NS	NS	0.425	NS
SI_{50}	5.20	4.50	4.10	5.00	4.00	7.90	5.20	9.70	9.10	1.30	3.60	1.20
SI_{75}	5.45	4.67	4.50	5.00	4.50	8.20	5.00	9.40	8.90	1.50	6.00	1.47
SI_{100}	5.55	4.33	4.70	4.80	4.20	12.20	4.80	9.60	8.70	1.40	5.80	1.17
SSI_{50}	4.89	4.37	5.00	4.70	3.80	6.80	5.60	9.60	9.10	1.60	5.00	0.80
SSI_{75}	5.30	4.23	5.10	5.20	4.00	10.20	4.90	9.00	9.20	1.20	5.33	1.10
SSI_{100}	5.45	4.60	5.20	4.00	4.10	9.60	4.50	9.30	9.40	1.40	6.00	1.20
CI_{50}	4.40	4.00	5.30	5.00	5.00	8.50	8.20	11.50	9.20	1.20	5.20	1.50
CI_{75}	4.60	5.60	4.70	4.20	4.80	7.90	5.60	10.00	9.00	1.40	5.00	1.10
CI_{100}	4.90	5.23	4.70	5.20	4.00	7.40	4.20	9.40	10.20	1.80	4.80	1.00
CD (0.05)	NS	0.587	0.232	0.464	0.270	1.147	0.616	NS	NS	0.298	0.736	0.365

Table 4.64. Effect of methods and levels of irrigation on K content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	5.02	5.14	5.11	3.39	3.47	7.93	2.62	6.53	10.00	2.07	6.70	1.78
SS	5.36	5.16	5.33	3.13	3.47	9.57	2.40	6.56	10.23	1.90	6.96	1.54
C	5.32	4.87	5.04	3.57	3.23	9.13	2.30	8.31	8.67	1.68	6.33	2.13
CD (0.05)	0.262	NS	0.176	0.321	0.072	0.671	NS	0.644	0.679	NS	NS	0.275
I_{50}	5.16	5.04	4.88	3.27	3.00	8.53	2.56	7.00	10.24	1.68	6.23	1.72
I_{75}	5.23	5.03	5.14	3.13	3.43	8.37	2.23	7.38	9.30	1.88	6.62	1.78
I_{100}	5.31	5.09	5.47	3.69	3.73	9.73	2.53	7.02	9.37	2.10	7.13	1.94
CD (0.05)	NS	NS	0.187	0.130	0.263	0.615	0.279	NS	0.504	0.230	0.388	0.178
SI_{50}	5.07	5.25	4.90	2.90	3.00	8.20	2.67	6.80	11.00	1.70	6.20	1.73
SI_{75}	5.00	5.05	5.03	3.50	3.60	7.80	2.60	6.80	9.40	2.30	6.60	1.60
SI_{100}	5.00	5.13	5.40	3.77	3.80	7.80	2.60	6.00	9.60	2.20	7.30	2.00
SSI_{50}	5.00	4.80	5.00	3.20	3.20	7.80	2.60	6.80	9.80	1.70	6.30	1.60
SSI_{75}	5.20	5.27	5.40	2.80	3.60	9.50	2.20	6.80	9.90	1.70	7.27	1.60
SSI_{100}	5.87	5.40	5.60	3.40	3.60	11.40	2.40	6.07	11.00	2.30	7.30	1.43
CI_{50}	5.40	5.08	4.73	3.70	2.80	9.60	2.40	7.40	9.93	1.60	6.20	1.83
CI_{75}	5.50	4.78	5.00	3.10	3.10	7.80	1.90	8.53	8.60	1.63	6.00	2.17
CI_{100}	5.07	4.75	5.40	3.90	3.80	10.0	2.60	9.00	7.50	1.80	6.80	2.40
CD (0.05)	0.323	0.548	NS	0.225	0.351	1.066	NS	0.836	0.873	NS	NS	0.308

pronounced only after five months. Compensating 100 per cent pan evaporation (I_{100}) recorded the highest content followed by I_{75}.

In the first year at 4 MAP, increased K content due to increased irrigation from 8 l day^{-1} to 12 l day^{-1} was observed only in conventional method, while in drip methods, the contents remained almost same. But at 5 MAP, higher content was noticed in drip fertigation at higher irrigation levels.

In the second year the effect of drip fertigation was progressive and finally at 7 MAP drip fertigation at I_{75} was comparable to basin irrigation and fertilization at I_{100}. CI_{75} was also on par with surface and subsurface drip at I_{50}.

K content in rhizome at harvest of the crop in the first year was more under drip methods than conventionally treated plants and increasing the irrigation quantity increased the content. In the second year, subsurface drip accumulated more K in the rhizome, however comparable with conventional irrigation. At I_{100}, the K content in rhizome was 11.40 per cent for subsurface drip and 10.0 and 7.80 for conventional and surface drip respectively. K content in the pseudostem was more in basin irrigated plants, but the quantity of irrigation did not influence the content. K content in the peduncle was found to vary significantly only in the second year with a significantly higher accumulation in drip methods. Increasing levels of irrigation decreased the K content in the peduncle whereas in fruit, male bud and leaf, increasing the levels of irrigation, increased the K content.

4.9.5.4 Calcium

In both the years (Tables 4.65 and 4.66), the leaf Ca content increased with advancing growth. The content was relatively more in the first year than in the second year irrespective of treatments and growth stages.

The effect of methods of irrigation and fertilization on Ca content in the index leaf, though significant in the both the years behaved differently in different growth stages. In the second year at 3 MAP, subsurface fertigation resulted in more calcium content and at 5 MAP it was on par with conventional method and towards flowering stage, the content in surface drip reached the level of conventional methods.

As regards the effect of levels of irrigation on Ca content, it was observed that providing 12 l day^{-1} and 16 l day^{-1} resulted in comparable content, in the initial five months. In the later stages, higher contents were registered when irrigation was at lower rates. In the second year difference in Ca content was observed only in the later stages and it was seen that the calcium contents at I_{100} was lower while I_{50} and I_{75} were on par.

Besides, in the first year, conventional method had a higher content at lower irrigation levels. At 16 l day^{-1}, drip fertigation produced more content than conventional method. With surface drip and conventional basin method, the highest level (I_{100}) significantly reduced the leaf Ca content at 6 MAP (0.686 and 0.605 per cent respectively) than the subsurface method (0.990 per cent) during

Table 4.65. Effect of methods and levels of irrigation on Ca content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	0.717	0.677	0.517	0.839	0.885	0.687	0.627	0.711	0.338	0.214	0.269	1.48
SS	0.743	0.697	0.535	0.932	0.957	0.703	0.697	0.812	0.298	0.195	0.337	1.42
C	0.663	0.528	0.727	1.104	0.663	0.587	0.570	0.534	0.307	0.253	0.243	1.34
CD (0.05)	NS	0.377	0.041	0.207	0.143	0.083	NS	0.059	NS	0.038	0.072	NS
I_{50}	0.652	0.529	0.530	1.027	0.921	0.599	0.585	0.636	0.346	0.227	0.281	1.51
I_{75}	0.757	0.692	0.608	1.087	0.852	0.680	0.655	0.692	0.315	0.222	0.283	1.48
I_{100}	0.715	0.682	0.640	0.760	0.732	0.698	0.654	0.729	0.281	0.214	0.285	1.26
CD (0.05)	0.056	0.073	0.033	0.169	0.086	NS	NS	0.046	0.033	NS	NS	NS
SI_{50}	0.620	0.507	0.425	0.855	0.924	0.447	0.425	0.432	0.340	0.230	0.230	1.47
SI_{75}	0.800	0.755	0.535	0.977	0.960	0.725	0.645	0.690	0.335	0.210	0.280	1.67
SI_{100}	0.730	0.770	0.590	0.686	0.770	0.890	0.810	1.010	0.338	0.203	0.298	1.30
SSI_{50}	0.605	0.550	0.465	0.995	0.985	0.730	0.730	0.785	0.338	0.210	0.355	1.57
SSI_{75}	0.825	0.780	0.550	0.810	0.977	0.725	0.770	0.840	0.290	0.195	0.320	1.40
SSI_{100}	0.800	0.760	0.590	0.990	0.910	0.655	0.592	0.810	0.265	0.180	0.335	1.30
CI_{50}	0.730	0.530	0.700	1.231	0.855	0.620	0.600	0.690	0.360	0.240	0.257	1.50
CI_{75}	0.645	0.540	0.740	1.475	0.620	0.590	0.550	0.545	0.320	0.260	0.250	1.37
CI_{100}	0.615	0.515	0.740	0.605	0.515	0.550	0.560	0.368	0.240	0.260	0.220	1.17
CD (0.05)	0.974	NS	NS	0.292	NS	0.149	0.281	0.095	0.56	0.056	0.006	0.409

Table 4.66. Effect of methods and levels of irrigation on Ca content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	0.339	0.246	0.318	0.344	0.560	0.673	0.489	0.664	0.274	0.264	0.311	1.01
SS	0.368	0.273	0.389	0.409	0.410	0.666	0.526	0.762	0.280	0.268	0.315	0.91
C	0.331	0.292	0.409	0.488	0.542	0.715	0.612	0.564	0.232	0.253	0.296	1.05
CD (0.05)	0.004	0.004	0.041	NS	0.059	0.041	0.041	0.131	0.004	NS	NS	NS
I_{50}	0.343	0.278	0.390	0.449	0.556	0.800	0.545	0.803	0.256	0.246	0.317	1.04
I_{75}	0.357	0.266	0.382	0.444	0.526	0.658	0.537	0.574	0.267	0.257	0.288	1.00
I_{100}	0.338	0.266	0.343	0.348	0.431	0.596	0.554	0.612	0.263	0.282	0.317	0.93
CD (0.05)	NS	NS	NS	0.325	0.056	0.032	NS	0.133	NS	NS	NS	NS
SI_{50}	0.357	0.263	0.320	0.347	0.550	0.675	0.476	0.442	0.237	0.260	0.300	1.00
SI_{75}	0.357	0.263	0.320	0.347	0.550	0.675	0.476	0.442	0.237	0.260	0.300	1.05
SI_{100}	0.333	0.228	0.298	0.325	0.540	0.700	0.520	0.540	0.335	0.265	0.337	0.97
SSI_{50}	0.370	0.309	0.398	0.468	0.458	0.935	0.540	0.780	0.305	0.261	0.320	1.00
SSI_{75}	0.387	0.242	0.407	0.436	0.438	0.675	0.520	0.730	0.335	0.250	0.305	0.96
SSI_{100}	0.345	0.268	0.363	0.325	0.335	0.388	0.518	0.775	0.200	0.292	0.320	0.78
CI_{50}	0.330	0.277	0.438	0.520	0.621	0.820	0.625	0.620	0.213	0.210	0.335	1.28
CI_{75}	0.325	0.295	0.420	0.550	0.590	0.625	0.615	0.550	0.228	0.260	0.260	0.98
CI_{100}	0.338	0.304	0.370	0.394	0.417	0.700	0.595	0.522	0.255	0.290	0.293	1.05
CD (0.05)	NS	NS	NS	0.056	NS	0.056	0.006	0.232	0.006	NS	NS	NS

first year. Such a difference could not be observed in the second year where increasing levels reduced Ca content in all the methods.

At harvest stage of the crop in first year, calcium content in the rhizome, pseudostem and male bud were higher under drip fertigated conditions than under basin irrigation and fertilizer application. The content in fruit was more when conventional method of irrigation was adopted. Contrary to this, in the second year, conventional method resulted in more content in rhizome and root; but the content in pseudostem was more under drip fertigated conditions.

Irrigation at 16 l day^{-1} and 12 l day^{-1} resulted in comparable calcium content in pseudostem and male bud whereas in peduncle the content was highest at 8 l day^{-1}. Surface drip at I_{100} registered the highest content in all plant parts except male bud. In the second year, the content in the rhizome and pseudostem decreased with increase in irrigation level. In all other parts, the effect was non-significant.

4.9.5.5 Magnesium

In the first year (Table 4.67), subsurface drip fertigation recorded the highest Mg content in the index leaf in all the months of observation except at 6 MAP. At 6 MAP, conventional method had significantly higher content. In the second year (Table 4.68), it was noticed that different methods of irrigation had effect on Mg content only five months after planting, and drip fertigation resulted in a higher content than conventional method.

Table 4.67. Effect of methods and levels of irrigation on Mg content (%) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	0.469	0.507	0.369	0.415	0.373	0.417	0.379	0.261	0.182	0.158	0.171	0.15
SS	0.536	0.566	0.365	0.427	0.389	0.439	0.358	0.362	0.190	0.162	0.248	0.19
C	0.32	0.377	0.327	0.444	0.336	0.408	0.317	0.163	0.176	0.142	0.179	0.16
CD (0.05)	0.001	0.013	0.021	0.001	0.010	0.021	0.002	0.013	NS	NS	0.029	0.021
I_{50}	0.439	0.459	0.354	0.472	0.384	0.422	0.397	0.227	0.179	0.162	0.221	0.18
I_{75}	0.438	0.484	0.369	0.429	0.369	0.408	0.359	0.295	0.183	0.160	0.207	0.17
I_{100}	0.451	0.507	0.337	0.385	0.345	0.433	0.299	0.264	0.187	0.140	0.169	0.15
CD (0.05)	0.009	0.016	0.016	0.009	0.009	0.016	0.016	0.015	0.006	0.009	0.021	0.025
SI_{50}	0.478	0.435	0.295	0.482	0.388	0.261	0.378	0.091	0.132	0.205	0.143	0.15
SI_{75}	0.454	0.542	0.439	0.375	0.375	0.423	0.388	0.379	0.195	0.160	0.182	0.15
SI_{100}	0.475	0.544	0.372	0.389	0.356	0.567	0.372	0.313	0.221	0.109	0.189	0.14
SSI_{50}	0.529	0.560	0.353	0.498	0.402	0.536	0.437	0.377	0.207	0.151	0.326	0.21
SSI_{75}	0.556	0.540	0.397	0.379	0.381	0.402	0.369	0.362	0.167	0.167	0.233	0.19
SSI_{100}	0.522	0.599	0.344	0.403	0.384	0.377	0.268	0.349	0.195	0.168	0.184	0.18
CI_{50}	0.311	0.383	0.415	0.435	0.360	0.469	0.376	0.213	0.196	0.131	0.194	0.17
CI_{75}	0.304	0.371	0.272	0.534	0.352	0.400	0.319	0.145	0.187	0.152	0.207	0.16
CI_{100}	0.355	0.377	0.294	0.363	0.294	0.355	0.258	0.130	0.146	0.143	0.135	0.14
CD (0.05)	0.016	0.028	0.028	0.016	0.016	0.028	0.028	0.025	0.011	0.016	0.036	0.031

Table 4.68. Effect of methods and levels of irrigation on Mg content (%) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	0.254	0.246	0.267	0.208	0.206	0.424	0.204	0.166	0.126	0.141	0.265	0.21
SS	0.321	0.277	0.287	0.244	0.192	0.459	0.174	0.138	0.127	0.162	0.244	0.20
C	0.302	0.253	0.243	0.205	0.199	0.284	0.215	0.084	0.092	0.168	0.272	0.22
CD (0.05)	NS	NS	0.008	0.007	0.008	0.059	0.021	0.006	0.021	0.006	0.012	0.021
I_{50}	0.295	0.253	0.278	0.223	0.214	0.482	0.216	0.163	0.117	0.166	0.270	0.22
I_{75}	0.290	0.264	0.268	0.206	0.210	0.360	0.190	0.110	0.122	0.157	0.271	0.22
I_{100}	0.292	0.259	0.251	0.209	0.173	0.326	0.188	0.115	0.105	0.149	0.240	0.19
CD (0.05)	NS	NS	0.014	0.009	0.018	0.056	0.009	0.005	0.009	0.006	0.009	0.010
SI_{50}	0.269	0.253	0.251	0.214	0.207	0.469	0.236	0.239	0.114	0.147	0.268	0.20
SI_{75}	0.244	0.235	0.271	0.192	0.228	0.409	0.157	0.111	0.143	0.154	0.291	0.23
SI_{100}	0.247	0.250	0.280	0.218	0.184	0.393	0.219	0.147	0.121	0.123	0.235	0.19
SSI_{50}	0.307	0.260	0.361	0.222	0.208	0.666	0.192	0.173	0.155	0.163	0.259	0.22
SSI_{75}	0.319	0.290	0.288	0.237	0.199	0.362	0.173	0.130	0.130	0.141	0.261	0.20
SSI_{100}	0.337	0.282	0.256	0.213	0.169	0.350	0.156	0.111	0.096	0.182	0.212	0.18
CI_{50}	0.309	0.246	0.266	0.232	0.228	0.310	0.219	0.077	0.084	0.187	0.282	0.25
CI_{75}	0.306	0.267	0.247	0.188	0.203	0.308	0.239	0.089	0.093	0.175	0.262	0.22
CI_{100}	0.291	0.245	0.296	0.195	0.166	0.235	0.188	0.086	0.100	0.143	0.272	0.20
CD (0.05)	0.025	0.025	0.025	0.016	0.031	0.097	0.015	0.008	0.016	0.011	0.016	0.018

Comparison of different levels of irrigation revealed that 16 l day^{-1} produced highest Mg in the index leaf in the initial four months. But towards flowering, 8 l day^{-1} resulted in the highest content because of the considerable decrease in Mg content after five months. In the second year also, Mg content followed this pattern in the later stages.

In the first year, at harvest, Mg content was the lowest under conventional method of irrigation and fertilizer application except in male bud, and subsurface drip fertigation recorded the highest Mg content except in root. But in the second year, conventional method of irrigation resulted in the highest content in root, fruit, male bud and leaf while subsurface drip fertigation produced highest content in rhizome and peduncle.

Among different levels of irrigation, in the first year, I_{100} registered the lowest Mg content in rhizome and root. The decreasing trend was noticed in the case of above ground portion also. The same pattern was followed in the second year also.

4.9.5.6 Iron

Fe content in the index leaf in the first year (Table 4.69), was higher under surface drip conditions in all stages of growth except at 4 MAP where the effect was not significant. This was followed by subsurface drip fertigation and the least content was recorded by basin irrigation. In the second year (Table 4.70), methods of irrigation and fertilizer application influenced the Fe content in the index leaf only at 3 MAP. Conventional method recorded the lowest content.

Table 4.69. Effect of methods and levels of irrigation on Fe content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	320.89	232.67	272.67	287.78	280.33	2802.0	2731.7	599.40	291.89	259.89	300.44	587
SS	296.11	259.67	243.33	238.44	241.00	2885.3	3515.0	728.30	368.78	293.00	291.89	607
C	238.11	258.00	172.78	281.11	221.33	2373.1	2438.6	521.89	233.44	169.67	272.56	571
CD (0.05)	20.33	NS	71.20	29.32	15.02	130.3	NS	7429.0	31.51	7.459	8.702	NS
I_{50}	305.22	233.67	204.44	308.22	257.67	2945.1	3268.7	593.3	293.67	266.00	328.00	596
I_{75}	285.33	244.33	282.56	225.89	248.33	2514.3	2983.0	629.11	291.44	239.00	277.78	566
I_{100}	264.56	272.33	201.78	273.22	236.67	2601.0	2433.6	627.20	309.00	217.56	259.11	603
CD (0.05)	30.53	NS	37.47	26.86	12.80	168.00	368.2	NS	NS	4.455	13.03	NS
SI_{50}	298.00	204.00	233.00	334.67	298.00	2980.0	3170.0	508.3	231.67	269.00	376.00	586
SI_{75}	345.00	231.00	399.00	217.00	269.00	2727.0	3104.0	590.00	284.00	264.60	252.33	566
SI_{100}	319.67	263.00	186.00	311.67	274.00	2699.0	1921.0	700.00	360.00	246.00	273.00	609
SSI_{50}	348.33	240.00	195.00	248.00	249.00	3052.0	3692.0	769.67	366.30	325.00	303.33	617
SSI_{75}	284.00	228.00	269.00	218.00	234.00	2644.0	3781.0	694.33	347.00	290.30	313.00	565
SSI_{100}	256.00	311.00	266.00	249.33	240.00	2960.0	3072.0	721.0	393.00	263.67	259.33	638
CI_{50}	269.33	257.00	185.33	342.00	226.00	2803.3	2944.0	502.00	283.00	204.00	304.67	584
CI_{75}	227.00	274.00	179.67	242.67	242.00	2172.0	2064.0	603.0	243.33	162.00	268.00	567
CI_{100}	218.00	243.00	153.33	258.67	196.00	2144.0	2307.7	460.67	174.00	143.00	245.00	563
CD (0.05)	52.87	NS	64.90	46.53	22.17	29.10	637.8	145.20	52.68	7.717	22.57	NS

Table 4.70. Effect of methods and levels of irrigation on Fe content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	304	233	179	147	208	566	2963	521	320	157	119	472
SS	383	209	196	211	211	476	2914	289	287	178	111	484
C	258	200	193	180	215	951	2826	484	245	170	119	503
CD (0.05)	21.54	NS	NS	NS	NS	87.35	NS	121.1	50.16	NS	6.877	NS
I_{50}	345	214	203	199	222	784	2988	515	326	188	133	464
I_{75}	319	220	192	175	214	604	3022	395	281	173	113	479
I_{100}	280	298	174	164	198	605	2693	384	246	143	103	516
CD (0.05)	30.94	NS	18.86	NS	14.95	106.0	262.1	58.54	46.45	34.25	9.958	NS
SI_{50}	338	211	193	165	220	653	2845	752	397	159	139	405
SI_{75}	323	254	182	124	196	510	3136	384	310	144	104	475
SI_{100}	251	236	163	153	210	535	2910	426	255	168	116	537
SSI_{50}	414	221	212	242	238	480	3074	301	249	190	120	458
SSI_{75}	391	210	184	198	222	410	2969	312	321	240	116	466
SSI_{100}	344	196	193	194	173	540	2700	256	292	103	96	526
CI_{50}	285	210	205	191	209	1221	3045	491	332	214	141	527
CI_{75}	243	196	210	203	224	893	2962	490	212	135	120	496
CI_{100}	246	195	166	147	212	740	2471	471	193	160	98	485
CD (0.05)	0.025	NS	NS	NS	25.90	183.6	NS	101.4	80.45	59.32	17.25	NS

A decrease in the foliar Fe content during 3, 5 and 7 MAP was noticed with an irrigation of 16 l day^{-1} in the first year. Irrigation water of 8 l day^{-1} and 12 l day^{-1} were comparable in the initial and final stages (3 MAP and 7 MAP). In the second year also, irrigation reduced the Fe content only when 100 per cent of the evaporation was compensated. I_{50} and I_{75} were on par.

Interaction of methods and levels of irrigation resulted in a considerably lesser content under conventional method of irrigation even when 8 l day^{-1} was provided. At 3 MAP, only subsurface drip fertigation at 16 l day^{-1} could record a lower content which was comparable with CI_{50} or CI_{100}. At 5 MAP, surface drip at I_{100} (SI_{100}) recorded a lower content which was on par with CI_{50} and CI_{100}. At 7 MAP, subsurface drip at I_{75} and I_{100} resulted in lower levels, but surface drip recorded considerably higher content. In the second year, subsurface drip at I_{100} resulted in the lowest Fe content followed by subsurface drip at I_{75}, surface drip at I_{100} and basin irrigation at I_{100}.

The content in different parts at harvest showed that in the first year, a fairly higher content of Fe was present in all parts especially in rhizome, when compared to that in second year. Subsurface drip fertigation could exert significant influence on increased Fe absorption by the plant in the first year. In the second year, conventional method resulted in a higher content in the rhizome and surface drip produced higher content in the above ground portions except in leaf where the effect of methods of irrigation was non significant.

In both years, increasing the quantity of irrigation water reduced the content of Fe in all plant parts.

4.9.5.7 Manganese

The foliar Mn content at different growth stages and the content in different parts at harvest for the first year and second year are presented in Tables 4.71 and 4.72, respectively.

A reasonably higher content of Mn was present in the first year in all the stages of growth and in all parts at harvest, when compared to that in the second year. Conventional method of irrigation and fertilization resulted in a higher Mn content in all the stages of growth. When the quantity of irrigation water was reduced, the Mn content in the index leaf was found increasing. The same trend was noticed in both the years.

At harvest, surface drip resulted in the highest content in all the parts except in leaf in the first year. In the second year, more Mn content due to surface drip was noticed only in rhizome and peduncle. Conventional method produced higher content in pseudostem, root and peduncle.

Among different irrigation levels, I_{100} recorded the lowest Mn content in all parts in the first year, whereas in the second year, I_{75} was comparable with I_{50} in Mn content in peduncle, fruit and male bud and higher contents in root.

Table 4.71. Effect of methods and levels of irrigation on Mn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhizome	Root	Pseudostem	Peduncle	Fruit	Male bud	Leaf
S	1272	1317	1950	3033	2322	1422	1141	1294	1800	478	1678	6661
SS	1400	1178	1678	3417	2598	1271	1078	1181	1216	489	1156	7011
C	2206	2367	2360	3539	2371	809	827	883	1017	433	1104	6232
CD (0.05)	455.1	2478	115.0	125.5	NS	193.9	NS	169.7	383.3	NS	279.1	NS
I_{50}	1789	1867	2310	3606	2778	1360	1260	1322	1500	494	1378	7034
I_{75}	1622	1628	2050	3433	2461	1138	906	1083	1283	483	1360	5891
I_{100}	1467	1367	1629	2950	2052	1004	880	953	1250	422	1200	6979
CD (0.05)	149.9	165.6	211.2	251.3	188.7	119.3	262.5	168.6	101.8	NS	NS	1010
SI_{50}	1250	1300	1500	3400	2433	1517	1250	1300	1850	467	1400	7783
SI_{75}	1283	1450	2250	2900	2200	1400	967	1350	1750	517	2083	5405
SI_{100}	1283	1200	2100	2800	2333	1350	1206	1233	1800	450	1550	6794
SSI_{50}	1550	1300	2000	3400	3033	1550	1383	1467	1450	550	1217	7462
SSI_{75}	1483	1333	1900	3350	2800	1200	1000	1100	1200	483	1050	6027
SSI_{100}	1167	900	1367	3500	1960	1063	850	977	1000	433	1200	7545
CI_{50}	2567	3000	3430	4017	2867	1013	1146	1200	1200	467	1517	5856
CI_{75}	2100	2100	2000	4050	2383	813	750	800	900	450	947	6240
CI_{100}	1950	2000	1650	2550	1863	600	583	650	950	383	850	6600
CD (0.05)	259.6	286.8	365.8	435.3	326.8	NS	NS	NS	176.3	NS	405.4	NS

Table 4.72. Effect of methods and levels of irrigation on Mn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	1233	826	954	1023	888	861	810	867	511	306	1017	3336
SS	1017	637	1076	1087	1055	619	793	963	589	406	927	3648
C	1665	1358	1502	2306	1315	714	912	1348	578	311	852	2941
CD (0.05)	174.1	331.2	120	186.6	31.25	107.7	32.90	NS	33.3	70.12	56.6	487
I_{50}	1364	989	1303	1524	1218	749	844	1178	628	422	988	3385
I_{75}	1241	909	1174	1662	1152	724	907	991	561	344	982	3298
I_{100}	1310	922	1054	1229	927	721	763	1010	489	256	826	3242
CD (0.05)	48.9	NS	89.73	76.7	48.49	NS	42.94	NS	67.4	88.95	51.2	NS
SI_{50}	1155	773	1110	947	895	987	683	883	500	417	987	3643
SI_{75}	1190	917	953	1193	980	783	963	719	533	267	1150	3301
SI_{100}	1355	787	800	930	790	813	783	1000	500	233	913	3065
SSI_{50}	1105	767	1157	1177	1140	533	870	950	683	483	1033	4136
SSI_{75}	940	563	1000	1147	1010	690	790	1020	583	467	967	3438
SSI_{100}	1005	580	1070	937	1015	633	720	920	500	267	780	3370
CI_{50}	1830	1427	1643	2450	1620	727	980	1700	700	367	943	2377
CI_{75}	1595	1247	1570	2647	1467	700	970	1233	567	300	830	3156
CI_{100}	1570	1400	1293	1820	975	717	787	1110	467	267	783	3293
CD (0.05)	84.65	165.3	155.4	132.9	83.99	120	74.38	NS	NS	NS	88.63	NS

4.9.5.8 Copper

The data presented in the Tables 4.73 and 4.74 for the first year and second year respectively showed that methods of irrigation in general did not bring significant variation in foliar Cu content in different growth stages. Different levels of irrigation also had no significant effect except in the initial and final stages in the first year. But in the second year, the influence was pronounced in the initial stages.

At harvest of the first year crop, rhizome, pseudostem and leaf had higher Cu content when the plants were basin irrigated. But higher contents in peduncle, fruit and male bud was recorded under drip fertigation. In the second year, methods of irrigation and fertilization had no significant effect on Cu content. In leaf subsurface drip registered a higher content while surface drip and conventional method remained at par.

Increased quantity of irrigation reduced the content in pseudostem in the first year and all parts in the second year.

4.9.5.9 Zinc

Tables 4.75 and 4.76 showed that in the first year, the effect of method of irrigation on the foliar Zn content was significant only in the final stage (7 MAP), where drip fertigation recorded the highest content.

In the second year, though conventional method had a lower content than subsurface at 3 MAP, during 5 MAP and 6 MAP, conventional method

Table 4.73. Effect of methods and levels of irrigation on Cu content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhizome	Root	Pseudostem	Peduncle	Fruit	Male bud	Leaf
S	12.00	11.67	10.56	14.00	11.89	17.22	13.33	16.11	14.78	6.11	12.89	10.00
SS	14.22	11.00	12.33	13.33	11.44	12.67	13.67	19.44	20.44	7.11	13.56	9.67
C	12.11	12.22	14.44	14.22	12.00	16.78	13.67	22.56	12.44	4.78	10.56	10.89
CD (0.05)	NS	NS	NS	NS	NS	2.409	NS	2.872	0.872	1.661	1.380	0.908
I_{50}	12.00	11.67	12.78	14.44	12.56	16.67	13.44	21.33	15.67	6.22	12.11	9.44
I_{75}	12.67	12.33	12.67	13.89	11.78	14.11	14.56	20.56	15.89	5.67	12.56	11.00
I_{100}	13.67	10.89	11.89	13.22	11.00	15.89	12.67	16.22	16.11	6.11	12.33	10.11
CD (0.05)	1.169	NS	NS	NS	0.815	1.064	NS	2.409	NS	NS	NS	1.074
SI_{50}	14.00	11.00	9.00	15.33	11.67	16.00	12.33	15.00	15.00	6.67	14.00	10.00
SI_{75}	12.00	12.00	11.67	11.67	11.00	17.00	14.67	19.67	14.67	5.00	13.67	9.33
SI_{100}	10.00	12.00	11.00	15.00	13.00	18.00	13.00	13.67	14.67	6.67	11.00	10.67
SSI_{50}	12.67	11.00	12.67	12.33	12.00	14.67	12.00	22.33	17.67	7.67	11.67	8.33
SSI_{75}	14.00	12.00	12.00	15.00	12.33	8.33	15.00	20.00	20.67	6.33	14.00	11.00
SSI_{100}	16.00	10.00	12.33	12.67	10.00	15.00	14.00	16.00	23.00	7.33	15.00	9.67
CI_{50}	9.00	13.00	16.67	15.67	14.00	19.00	16.00	26.67	14.33	4.33	10.67	10.00
CI_{75}	12.00	13.00	14.33	15.00	12.00	17.00	14.00	22.00	12.33	5.67	10.00	12.67
CI_{100}	15.00	10.67	12.33	12.00	10.00	14.00	11.00	19.00	10.67	4.33	11.00	10.00
CD (0.05)	2.025	2.082	2.271	2.124	1.412	1.844	3.024	4.172	2.551	1.327	2.097	1.860

Table 4.74. Effect of methods and levels of irrigation on Cu content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	9.33	9.00	9.33	8.33	8.00	7.67	18.22	9.00	7.33	6.33	11.33	7.22
SS	9.556	10.10	9.78	9.00	8.22	9.33	23.11	9.89	8.56	7.22	11.33	8.33
C	11.33	12.11	10.67	10.11	8.44	10.11	20.56	10.33	7.22	7.89	11.00	7.00
CD (0.05)	0.252	NS	NS	NS	NS	NS	1.140	NS	NS	NS	NS	0.504
I_{50}	10.56	11.00	10.89	9.33	8.33	10.67	20.78	9.67	8.78	7.56	12.67	8.56
I_{75}	10.33	9.88	10.44	9.00	8.22	8.89	19.56	10.78	8.44	7.89	11.33	7.44
I_{100}	9.33	10.33	8.44	9.11	8.11	7.56	21.56	8.78	5.89	6.00	9.67	6.56
CD (0.05)	0.988	0.859	0.014	NS	NS	1.723	NS	1.250	1.064	NS	1.186	1.384
SI_{50}	9.00	9.67	9.00	7.00	9.00	10.00	17.33	8.67	7.33	6.33	12.00	8.67
SI_{75}	10.67	8.33	11.00	9.00	8.00	7.00	19.33	10.00	9.00	7.33	11.00	6.67
SI_{100}	8.33	9.00	8.00	9.00	7.00	6.00	18.00	8.33	5.67	5.33	11.00	6.33
SSI_{50}	11.00	10.67	11.00	9.67	7.67	10.67	23.33	9.67	8.67	6.33	13.00	9.33
SSI_{75}	9.33	9.63	10.00	8.33	8.00	9.67	19.33	11.33	9.67	9.00	12.00	8.67
SSI_{100}	8.33	10.00	8.33	9.00	9.00	7.67	26.67	8.67	7.33	6.33	9.00	7.00
CI_{50}	11.67	12.67	12.67	11.33	8.33	11.33	21.67	10.67	10.33	10.00	15.00	7.67
CI_{75}	11.00	11.67	10.33	9.67	8.67	10.00	20.00	11.00	6.67	7.33	11.00	7.00
CI_{100}	11.33	12.00	9.00	9.33	8.33	9.00	20.00	9.33	4.67	6.33	9.00	6.33
CD(0.05)	1.712	NS	NS	1.37	NS	NS	3.166	NS	1.144	NS	NS	2.397

Table 4.75. Effect of methods and levels of irrigation on Zn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during first year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	14.00	14.22	17.33	17.72	16.22	37.33	22.67	29.89	13.44	10.44	31.56	15.33
SS	16.89	14.00	16.22	19.00	17.22	34.67	23.56	30.78	14.56	12.56	30.44	15.22
C	17.56	14.00	15.33	19.11	14.44	36.67	20.00	33.22	15.44	11.22	30.89	16.44
CD (0.05)	NS	NS	NS	NS	1.623	8.398	1.868	NS	NS	NS	NS	NS
I_{50}	16.33	14.22	15.89	20.22	14.89	41.89	26.00	32.78	15.11	11.67	32.44	15.67
I_{75}	16.56	13.56	16.22	18.61	17.11	35.00	21.00	32.44	15.11	11.56	31.11	15.67
I_{100}	15.56	14.44	16.78	17.00	15.89	31.78	19.22	28.67	13.22	11.00	29.33	15.67
CD (0.05)	NS	NS	NS	1.398	1.423	3.389	1.932	2.915	1.569	NS	2.384	NS
SI_{50}	13.67	14.67	13.00	19.00	13.33	46.67	27.00	27.33	12.00	11.67	32.00	14.67
SI_{75}	13.67	13.67	19.33	19.50	19.00	34.33	21.67	30.67	16.00	10.67	32.00	15.67
SI_{100}	14.67	14.33	19.67	14.67	16.33	31.00	19.33	31.67	12.33	9.00	30.67	15.67
SSI_{50}	15.67	14.00	18.00	20.00	16.33	39.33	28.33	36.67	15.67	10.00	32.67	14.67
SSI_{75}	18.00	13.00	14.67	16.67	20.00	35.67	22.00	31.33	13.33	12.67	30.67	15.33
SSI_{100}	17.00	15.00	16.00	20.33	15.33	29.00	20.33	24.33	14.67	15.00	28.00	15.67
CI_{50}	19.67	14.00	16.67	21.67	15.00	39.67	22.67	34.33	17.67	13.33	32.67	17.67
CI_{75}	18.00	14.00	14.67	19.67	12.33	35.00	19.33	35.33	16.00	11.33	30.67	16.00
CI_{100}	15.00	14.00	14.67	16.00	16.00	35.33	18.00	30.00	12.67	9.00	29.33	15.67
CD (0.05)	2.193	NS	2.574	2.421	2.480	5.870	3.346	5.049	2.717	2.445	NS	NS

Table 4.76. Effect of methods and levels of irrigation on Zn content (ppm) in the index leaf at different growth stages and in different plant parts at harvest during second year

Treatment	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	Rhi-zome	Root	Pseu-dostem	Ped-uncle	Fruit	Male bud	Leaf
S	14.56	16.33	16.67	17.06	13.33	22.56	32.22	21.78	12.56	13.33	37.78	13.00
SS	18.56	15.28	18.11	18.33	13.00	24.56	35.33	23.78	19.89	12.44	36.78	14.00
C	15.78	15.67	19.11	20.72	13.56	22.22	29.33	17.56	14.44	14.00	35.67	13.00
CD (0.05)	2.462	NS	0.796	0.701	NS	1.154	NS	1.054	3.633	0.796	NS	NS
I_{50}	17.00	15.62	17.67	18.61	14.22	27.89	37.67	21.78	16.89	15.33	39.78	13.00
I_{75}	15.11	17.06	17.22	17.83	13.00	23.67	32.89	18.33	15.56	12.56	37.89	13.00
I_{100}	16.78	14.62	19.00	19.67	12.67	17.79	26.33	23.00	14.44	11.89	32.56	14.00
CD (0.05)	1.512	0.988	0.815	0.778	0.577	2.011	2.581	1.996	NS	1.074	1.479	NS
SI_{50}	15.00	15.83	15.67	17.33	14.33	22.33	30.67	28.67	15.00	15.67	37.00	13.00
SI_{75}	14.33	18.00	16.67	16.33	13.00	26.00	36.00	16.00	11.67	13.33	40.33	13.00
SI_{100}	14.33	15.17	17.67	17.50	12.67	19.33	30.00	20.67	11.00	11.00	36.00	14.00
SSI_{50}	20.00	15.0	17.00	18.00	13.67	33.67	47.00	21.00	18.33	13.33	42.33	14.00
SSI_{75}	16.67	16.00	17.33	17.33	12.33	26.00	35.67	21.33	17.67	10.33	36.33	12.00
SSI_{100}	19.00	14.33	20.00	19.67	13.00	14.00	23.00	29.00	23.67	13.67	31.67	14.00
CI_{50}	16.00	15.50	20.33	20.50	14.67	27.67	35.33	15.67	17.33	17.00	40.00	12.00
CI_{75}	14.33	17.17	17.67	19.83	13.67	19.00	27.00	17.67	17.33	14.00	37.00	13.00
CI_{100}	17.00	14.33	19.33	21.83	12.33	20.00	25.67	19.33	8.67	11.00	30.00	14.00
CD (0.05)	NS	NS	1.412	NS	NS	3.483	4.470	3.458	3.843	1.860	2.562	NS

recorded the highest content. Drip fertigation differed among themselves and subsurface drip recorded a higher content.

Foliar Zn content in the first year was found decreasing with increase in irrigation water only at 6 MAP and in the initial five months the effect was non-significant. At 7 MAP, 12 l day^{-1} and 16 l day^{-1} recorded higher content than 8 l day^{-1}.

In the second year, levels of irrigation did not produce a definite pattern of significance in the Zn content.

At harvesting stage of the crop, in the first year only the Zn content in root was significantly affected by methods of irrigation and fertilizer application and drip fertigation resulted in a higher Zn content. In the second year, Zn content in all parts except root, male bud and leaf was influenced by the treatments and the highest content was recorded in subsurface drip fertigation.

There was a decrease in the Zn content in all parts with increasing irrigation quantity. This was observed in both the years.

4.9.6 Water use efficiency

Data on bunch weight produced per unit of water applied through different methods and levels of irrigation are furnished in Table 4.77. It can be seen that in the first year, conventional method registered the highest water use efficiency followed by surface drip and subsurface drip methods. But in the second

Table 4.77. Water use efficiency (kg ha^{-1} mm^{-1} of water) as influenced by methods and levels of irrigation in banana var. Nendran

Treatment	I year	II year
S	390	550
SS	350	570
C	510	470
CD (0.05)	32.2	46.4
I_{50}	500	660
I_{75}	400	500
I_{100}	350	400
CD (0.05)	36.2	57.1
SI_{50}	480	690
SI_{75}	370	500
SI_{100}	330	390
SSI_{50}	370	730
SSI_{75}	350	530
SSI_{100}	320	440
CI_{50}	650	550
CI_{75}	480	470
CI_{100}	390	380
CD (0.05)	40.9	52.3

year an opposite trend was observed, with subsurface drip having the highest water use efficiency.

Increasing the level of water from I_{50} to I_{100} decreased the efficiency of water applied in both the years

The water use efficiency obtained in the second year was very much higher than that observed in the first year. At I_{100}, the efficiency obtained in the sub surface drip was the highest while conventional method and surface drip remained comparable.

4.9.7 Nutrient uptake at harvest

The data on total uptake of nutrients by the plants as influenced by the methods and levels of irrigation are furnished in Tables 4.78 to 4.80 for the first year and second year.

4.9.7.1 Nitrogen

The total uptake of nitrogen by the plant was not affected by the method of irrigation in both the years. But increasing the quantity of irrigation favoured the uptake and the effect was remarkable in the second year. In the first year I_{75} and I_{100} were on par, but in the second year, I_{100} was significantly superior to I_{75}.

Though the fertilizer applied in the second year was only half the dose given in the first year the uptake in general was almost the same in both the years. Rhizome had a higher share of the total nitrogen accumulated in both the years.

Table 4.78. Effect of methods and levels of irrigation on total uptake of nutrients ($g\ plant^{-1}$) in banana var. Nendran during first year

Treatment	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
S	55.89	3.71	278.46	26.31	12.31	5.80	6.79	0.06	0.11
SS	60.89	3.97	293.0	29.82	15.05	6.70	7.11	0.06	0.12
C	61.53	4.36	266.28	24.22	11.18	4.51	5.33	0.06	0.12
CD (0.05)	NS	NS	NS	2.304	1.804	0.576	NS	NS	NS
I_{50}	52.40	3.50	247.36	24.03	11.78	5.75	6.77	0.06	0.12
I_{75}	59.33	3.91	280.26	27.53	13.26	5.50	5.93	0.06	0.12
I_{100}	66.58	4.61	310.13	28.79	13.51	5.76	6.53	0.06	0.11
CD (0.05)	7.371	0.325	32.46	2.054	0.650	NS	NS	NS	NS
SI_{50}	51.46	3.82	255.52	20.70	8.65	5.94	7.91	0.06	0.13
SI_{75}	51.03	3.16	238.26	24.92	12.73	5.34	5.65	0.05	0.10
SI_{100}	65.19	4.10	341.60	33.32	15.56	6.11	6.79	0.06	0.11
SS I_{50}	50.23	3.01	227.49	26.81	14.91	6.21	7.01	0.07	0.12
SS I_{75}	66.99	4.21	336.27	32.55	15.52	6.66	6.89	0.06	0.13
SS I_{100}	65.46	4.71	315.25	30.10	14.72	7.23	7.44	0.06	0.12
CI_{50}	55.55	3.68	259.07	24.58	11.78	5.10	5.39	0.06	0.12
CI_{75}	59.98	4.37	266.25	25.14	11.58	4.51	5.26	0.07	0.12
CI_{100}	69.1	5.03	273.53	22.95	10.24	3.93	5.35	0.06	0.11
CD (0.05)	NS	0.563	56.22	3.558	1.125	0.843	NS	NS	0.013

Table 4.79. Effect of methods and levels of irrigation on total uptake of nutrients (g $plant^{-1}$) in banana var. Nendran during second year

Treatment	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
S	61.75	4.87	362.94	39.28	17.18	2.83	6.08	0.06	0.13
SS	60.67	4.71	358.95	36.47	15.85	2.08	5.51	0.06	0.13
C	60.59	4.85	353.41	33.17	11.40	3.03	5.77	0.06	0.11
CD (0.05)	NS	NS	NS	2.26	1.24	0.276	NS	NS	0.005
I_{50}	49.14	4.16	305.68	36.69	15.36	2.80	5.86	0.06	0.13
I_{75}	63.26	4.89	360.39	35.16	14.55	2.54	5.79	0.06	0.12
I_{100}	70.61	5.38	490.22	37.07	14.51	2.61	5.70	0.05	0.13
CD (0.05)	2.43	0.562	18.53	NS	0.649	NS	NS	0.006	NS
SI_{50}	51.67	4.46	328.72	41.46	17.75	3.12	6.40	0.06	0.14
SI_{75}	62.89	5.12	377.50	36.51	17.05	2.51	5.75	0.06	0.13
SI_{100}	70.70	5.83	382.59	39.72	16.75	2.86	6.09	0.05	0.13
SS I_{50}	45.93	3.41	258.86	34.53	16.81	1.78	5.01	0.05	0.12
SS I_{75}	54.35	4.54	376.71	37.97	14.62	2.29	5.99	0.07	0.13
SS I_{100}	71.72	6.19	441.27	36.92	16.13	2.18	5.54	0.06	0.14
CI_{50}	49.83	4.62	329.47	33.93	11.53	3.48	6.18	0.06	0.12
CI_{75}	62.55	5.01	326.97	30.99	11.99	2.80	5.63	0.06	0.11
CI_{100}	69.39	4.92	403.81	34.59	10.67	2.80	5.49	0.05	0.11
CD (0.05)	NS	0.974	32.10	NS	1.125	0.448	0.818	0.011	0.009

Table 4.80. Mean uptake of nutrients by different plant parts (g plant^{-1}) of banana var. Nendran as influenced by methods and levels of irrigation

Nutrients	Rhizome	Pseudostem	Peduncle	Bunch	Male bud	Leaf
I Year						
N	30.35	13.69	1.00	8.97	0.5	4.93
P	1.48	0.56	0.11	1.06	0.07	0.41
K	144.97	96.88	7.08	25.08	1.07	4.17
Ca	10.85	6.68	0.35	3.91	0.06	5.03
Mg	6.89	2.53	0.14	2.66	0.04	0.59
Fe	4.39	0.61	0.02	0.41	0.01	0.59
Mn	1.93	1.08	0.01	0.80	0.03	2.49
Cu	0.03	0.02	0.001	0.01	0.0003	0.004
Zn	0.06	0.03	0.001	0.02	0.001	0.01
II year						
N	20.59	12.91	1.07	19.33	1.27	5.82
P	1.03	0.92	0.14	1.92	0.19	0.60
K	150.89	126.6	6.19	53.23	2.99	8.53
Ca	12.22	11.72	0.17	7.4	0.14	4.66
Mg	6.99	2.27	0.07	4.38	0.12	0.98
Fe	1.17	0.76	0.02	0.47	0.01	0.23
Mn	1.34	1.88	0.04	0.95	0.04	1.54
Cu	0.02	0.02	0.001	0.02	0.001	0.0003
Zn	0.04	0.04	0.001	0.04	0.002	0.01

But the share in rhizome decreased in the second year and content in the bunch was found increasing.

4.9.7.2 Phosphorus (g $plant^{-1}$)

As in the case of nitrogen, the effect of different methods of irrigation and fertilizer application was not significant in the case of P uptake also. But the variation due to quantity of irrigation was significant. P uptake increased with increase in quantity, and in second year I_{75} and I_{100} were on par. Conventional method of irrigation (basin) at I_{100} resulted in the highest P uptake in the first year, but in the second year, it was subsurface drip at I_{100} that registered highest P uptake.

More P got accumulated in the rhizome, followed by pseudostem in both the years, but the content in rhizome decreased in the second year.

4.9.7.3 Potassium

The uptake of potassium also followed the same pattern as that of nitrogen and phosphorus. The uptake of K was the highest among all the nutrients applied.

4.9.7.4 Calcium

Subsurface drip fertigation resulted in a higher uptake of calcium than surface drip or conventional method in the first year. In the second year, it was surface drip, that recorded the highest uptake. Increasing quantity of irrigation to I_{75} resulted in a higher uptake, only in the first year. Increasing the irrigation further did not favour the uptake. In the second year. the variation due to difference in irrigation water was non-significant.

4.9.7.5 Magnesium

Mg uptake by the plant also was in the same pattern as that of calcium. Subsurface drip in the first year and surface drip in the second year resulted in higher uptake of Mg. I_{75} and I_{100} had comparable contents in both years, but I_{50} (the lowest level) had the highest uptake of Mg the second year.

In conventional irrigation. the uptake was found decreasing with increase in irrigation in the first year. but in surface drip. the uptake was increasing with quantity of irrigation. In subsurface drip. the variation was non-significant. In the second year. also conventional method registered the lowest uptake. and all levels of irrigation were comparable.

4.9.7.6 Iron

Drip fertigation especially subsurface drip resulted in a higher uptake of Fe than conventional irrigation in the first year. In the second year, both surface drip and basin irrigation resulted in similar Fe uptake. Subsurface drip resulted in the lowest Fe content.

The effect of different levels of irrigation in the uptake of Fe was non-significant in both the years. But in basin irrigation, there was a decrease with increase in quantity of irrigation. In the second year, this trend was seen in surface drip irrigated condition also.

The uptake was more (almost double) in the first year than in the second year. But major part of the element taken up was accumulated in the rhizome, and this was remarkably less in the second year.

4.9.7.7 Manganese

Manganese uptake by the plant was not influenced by the methods and levels of irrigation in both the years. Besides the Mn uptake in the second year was slightly lesser than that in the first year, but the content in the peduncle was comparatively higher in the first year than in the second year.

4.9.7.8 Copper

The uptake of Cu by the plant remained unaffected by the methods and levels of irrigation in the first year. In the second year, though the variation due to quantity of irrigation was significant, it did not follow a definite pattern.

4.9.7.9 Zinc

Though Zn uptake in the first year was not influenced by the methods and levels of irrigation, in the second year, drip fertigation could result in a higher Cu accumulation than basin irrigation. The effect of levels of irrigation was non significant in the second year also.

4.9.8 Rhizosphere moisture distribution

Soil moisture content was determined during three consecutive weeks of the peak dry season, in both the years (April 1998 and 1999) to study the influence of methods and levels of irrigation on soil moisture distribution.

The rhizosphere was divided into four zones viz., two diagonally opposite wet zones where the emitters are placed and the other two non-drip zones where the wetting was limited. Moisture content was determined at 30 and 60 cm lateral distance (*l*) from the base of the plant and at depths (*d*) of 0-30 and 30-60 cm. The results are presented hereunder.

It can be seen that the moisture content, in general, was very low in the first year and some points it was below permanent wilting point (PWP). The field capacity and permanent wilting points were worked out to be 18.5 and 11.0 per cent respectively.

4.9.8.1 Drip zone

Among different methods of irrigation, in the first year (Table 4.81) the effect was significant only at 30 *l* x 30 *d* zone, and conventional method resulted in a higher content, but on par with surface drip.

But in the second year (Table 4.82), the top layer near the emitter (30 *l* x 30 *d*) resulted in equal contents in all the methods of irrigation. In the lower layer (30 *l* x 60 *d*), subsurface drip fertigation resulted in a higher moisture content; followed by conventional. The lateral spread of moisture in the surface layers (60 *l* x 30 *d*) of drip zone under surface drip was comparable with that in the conventional method.

The moisture content was found increasing with increase in the quantity of irrigation water in both the years, irrespective of the treatments.

Table 4.81. Effect of methods and levels of irrigation on moisture content (%) in different layers of rhizosphere of banana var. Nendran in the first year

Treatment	Moisture content (%)							
	Drip zone				Non- drip zone			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	14.78	14.04	10.22	12.13	10.80	12.08	8.72	11.20
SS	11.92	14.22	10.91	12.25	8.37	10.92	7.26	10.39
C	16.25	15.78	12.92	11.41	16.00	15.46	12.60	11.34
CD (0.05)	2.834	NS	NS	NS	2.13	2.669	3.797	NS
I_{50}	12.56	13.07	9.52	10.38	10.71	12.34	8.05	9.95
I_{75}	14.17	15.24	11.52	12.12	11.81	12.56	10.07	11.36
I_{100}	16.22	15.73	13.0	13.27	12.65	13.57	10.45	11.61
CD (0.05)	1.251	1.694	1.69	2.01	1.69	NS	1.507	1.285
SI_{50}	12.42	11.58	8.49	10.80	11.24	11.80	7.33	9.40
SI_{75}	14.83	14.53	11.38	12.08	10.03	10.57	10.57	11.96
SI_{100}	17.10	16.01	10.78	13.46	11.12	13.85	8.24	12.23
SSI_{50}	11.22	13.18	10.45	10.71	7.12	11.24	7.09	10.77
SSI_{75}	10.69	14.84	10.48	12.61	8.66	11.21	7.68	10.46
SSI_{100}	13.85	14.65	11.80	13.42	9.33	10.32	7.00	9.94
CI_{50}	14.03	14.44	9.64	9.63	13.76	13.97	9.71	9.70
CI_{75}	16.99	16.36	12.71	11.67	16.72	15.88	11.96	11.66
CI_{100}	17.71	16.54	16.41	12.93	17.50	16.53	16.12	12.65
CD (0.05)	NS	2.935	NS	NS	2.93	NS	2.61	NS

Table 4.82. Effect of methods and levels of irrigation on moisture content (%) in different layers of rhizosphere of banana var. Nendran in the second year

Treatment	Moisture content (%)							
	Drip zone				Non- drip zone			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	16.81	15.26	11.8	10.58	10.24	9.76	7.82	9.20
SS	16.54	17.43	9.06	11.15	10.44	12.28	7.44	9.88
C	16.15	16.24	13.32	13.78	15.81	15.83	13.12	13.44
CD (0.05)	NS	0.479	2.016	1.856	2.09	2.03	3.99	3.02
I_{50}	14.29	14.61	10.07	10.22	11.64	11.81	8.41	8.92
I_{75}	16.51	15.81	10.83	11.53	12.05	12.82	9.45	11.26
I_{100}	18.69	18.50	13.30	13.76	12.81	13.25	10.52	12.17
CD (0.05)	1.214	1.709	1.348	1.114	NS	NS	1.44	1.69
SI_{50}	14.64	14.33	10.31	9.88	10.21	10.49	7.46	8.33
SI_{75}	15.87	12.95	11.01	9.32	9.36	9.69	7.63	9.65
SI_{100}	19.92	12.95	11.01	9.32	9.36	9.69	7.63	9.65
SSI_{50}	14.38	15.84	9.00	10.86	11.16	11.55	7.08	8.80
SSI_{75}	17.11	17.74	8.42	10.94	10.47	12.51	7.79	10.21
SSI_{100}	18.13	18.69	7.76	11.65	9.70	12.79	7.46	10.62
CI_{50}	13.85	13.68	10.88	9.92	13.54	13.37	10.70	9.63
CI_{75}	16.55	16.74	13.08	14.33	16.31	16.25	12.94	13.93
CI_{100}	18.03	18.31	16.01	17.09	17.59	17.56	15.72	16.74
CD (0.05)	NS	NS	NS	1.929	2.834	NS	NS	2.271

It can be seen that the downward movement was higher than the lateral movement in both surface drip and conventional method, but conventional method had a higher moisture content in the 60 *l* x 30 *d* zone. Subsurface drip could maintain only very low moisture content in the surface layers in the first year compared to the other methods, but in the second year, a comparable content was obtained in the 30 *l* x 30 *d* layer.

4.9.8.2 Non-drip zone

Conventional method, which was wetted almost uniformly in every zone recorded a higher moisture content. Among surface drip and subsurface drip, in the first year surface drip had a higher moisture content in the top (30 *l* x 30 *d*) layer, but such difference was not observed in the second year. But away from the emitter (60 *l*) the moisture contents were the same in both the methods. At 60 *l*, the moisture contents were higher in the lower layers than in the top layers.

Varying quantities of irrigation did not bring any effect on the movement of moisture to the non-drip zone.

4.9.9 Root distribution studies

Excavation studies done to study the root distribution in terms of root length and root weight in different zones around the plant, under different methods of irrigation and fertilizer application are presented here under. The roots of the plant provided with I_{100} was estimated. The basin of the plant was divided into four zones exactly as in the case of moisture estimation and the root distribution in each layer was studied. In addition to the four different layers, another layer, 60-90 *l* x 30 *d* was also included.

4.9.9.1 Root length

In the first year (Table 4.83) surface drip resulted in a higher total root length (24459 cm) when compared to conventional method (21769 cm) and subsurface drip had very less (18736 cm) compared to the other two methods of irrigation. But the length of primary roots of surface drip (13542 cm) and conventional (13585 cm) were the same, and it was the length of secondary and tertiary roots, that were more in surface drip irrigated plants. Subsurface drip also had more secondary roots and tertiary roots, but the length of primary roots was very low.

Table 4.84 shows that in the first year under surface drip fertigated condition, 64.41 per cent of the roots accumulated in the drip zone, which included 71.53 per cent or primary roots. But more secondary and tertiary roots, compared to primary roots were present in the non-drip zone.

In the case of subsurface drip, lesser percentage of roots were present in the drip zone (56.77) compared to surface drip (64.41).

Comparing root length in different depths and lateral spreads in drip zone, 30 *l* x 30 *d* accumulated the maximum roots in all the methods of irrigation. But in subsurface drip, more primary roots (16.35 per cent) were present in a lower depth (30 *l* x 60 *d*) than in the 30 *l* x 30 *d* layer, but more secondary and tertiary

Table 4.83. Length of Primary, secondary and tertiary roots (cm plant^{-1}) in the drip zone and non-drip zone of banana basin during first year at 6 MAP

Zone	Lateral Distance from plant	Soil Depth (cm)	Surface Drip				Subsurface Drip				Conventional irrigation			
			Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total
Drip Zone	30	30	4312	1450	182	5944	573	796	1092	2461	4269	1148	465	5882
	30	60	2691	627	462	3780	676	349	409	1434	1302	563	313	2178
	60	30	2043	946	971	3960	452	759	2117	3328	1099	624	829	2552
	60	60	617	401	907	1925	471	1162	783	2416	912	417	496	1825
	90	30	23	56	75	154	193	157	646	996	86	83	159	328
Total			9686	3480	2597	15763	2365	3223	5047	10635	7668	2835	2262	12765
Non Drip	30	30	1518	555	362	2435	448	319	1302	2069	2355	617	181	3153
	30	60	876	563	334	1773	695	415	369	1479	1575	239	137	1951
	60	30	794	494	961	2249	362	1034	1463	2859	605	542	710	1857
	60	60	632	665	781	2078	246	345	830	1421	1336	296	170	1802
	90	30	36	57	74	161	19	167	87	273	46	71	124	241
Total			3856	2328	2512	8696	1770	2280	4051	8101	5917	1765	1322	9004
Drip + Non -Drip Total			13542	5805	5109	24459	4135	5503	9098	18736	13585	4600	3584	21769

Table 4.84. Percentage of length of primary, secondary and tertiary roots in the drip zone and non-drip zone of banana basin during first year at 6 MAP.

Zone	Lateral Distance from plant	Soil Depth (cm)	Surface Drip				Subsurface Drip				Conventional irrigation			
			Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total
Drip Zone	30	30	31.85	24.96	3.57	24.30	13.86	14.47	12.0	13.15	31.42	24.96	12.97	27.02
	30	60	19.87	10.79	9.04	15.45	16.35	6.34	4.50	7.65	9.58	12.24	8.73	10.01
	60	30	15.09	16.29	19.01	16.19	10.94	13.79	23.17	17.76	8.08	13.56	23.12	11.72
	60	60	4.55	6.91	17.75	7.87	11.39	21.12	8.61	12.89	6.72	9.08	13.84	8.38
	90	30	0.17	0.96	1.47	0.63	4.66	2.85	7.10	5.32	0.63	1.81	4.44	1.51
Total			71.53	59.91	50.84	64.41	57.20	58.57	55.38	56.77	56.43	61.65	63.10	58.64
Non - Drip	30	30	11.20	9.56	7.09	9.96	10.83	5.80	14.30	11.04	17.34	13.41	5.05	14.48
	30	60	6.48	9.69	6.53	7.25	16.80	7.54	4.05	7.89	11.59	5.2	3.83	8.96
	60	30	5.86	8.52	18.81	9.19	8.76	18.79	16.08	15.26	4.46	11.79	19.8	8.53
	60	60	4.66	11.44	15.29	8.50	5.95	6.27	9.13	7.58	9.84	6.42	4.75	8.28
	90	30	0.27	0.88	1.44	0.66	0.46	3.03	0.96	1.46	0.34	1.53	3.47	1.11
Total			28.47	40.09	49.16	35.56	42.80	41.43	44.52	43.23	43.57	38.35	36.9	41.36

roots were present in the surface layers. In the non-drip zone also, the trend was the same.

In the second year (Table 4.85) contrary to the first year the total root was lower than that in the first year and subsurface drip resulted in the maximum root length. Also primary and secondary roots were higher in the subsurface drip condition compared to other methods.

As in the case of first year (Table 4.86) more percentage of roots accumulated in the drip zone, especially in the surface 30 *l* x 30 *d* zone. But in the subsurface drip irrigated condition, primary roots tended to grow more into deeper layer, rather than spreading laterally, while in the surface drip condition, the lateral spread was more.

4.9.9.2 Root weight

The fresh weight of primary, secondary and tertiary roots togethered was determined and is presented in Tables 4.87 and 4.88.

In the first year, surface drip produced more root biomass than conventional method, as it had the highest number of primary and secondary roots. Subsurface drip, which registered the lowest weight in the first year, recorded the highest weight in the second year, because the share of the primary roots was almost three-fold in the second year; resulting in highest root production.

Table 4.85. Length of primary, secondary and tertiary roots in the drip zone and non-drip zone of banana basin during second year at 6 MAP

Zone	Lateral distance from plant (cm)	Soil depth (cm)	Surface Drip				Subsurface Drip				Conventional			
			Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total
Drip	30	30	4179	238	411	4828	3818	144	482	4444	2469	404	413	3286
	30	60	695	300	162	1157	2900	518	151	3569	1351	278	403	2032
	60	30	1515	766	611	2892	2100	674	563	3337	1656	541	773	2970
	60	60	882	226	350	1458	618	669	214	1501	744	317	485	1546
	90	30	67	53	66	186	35	42	48	125	61	53	68	182
Total			7338	1583	1600	10521	9471	2047	1458	12976	6281	1593	2142	10016
Non-drip	30	30	1230	158	429	1817	1155	133	254	1542	2710	218	413	3341
	30	60	338	61	326	725	840	113	239	1192	1172	83	272	1527
	60	30	773	575	969	2044	398	201	463	1062	797	810	924	2531
	60	60	186	158	720	1064	441	54	286	781	285	110	644	1039
	90	30	38	45	57	140	47	32	50	129	38	38	75	151
Total			2565	997	2228	5790	2881	533	1292	4706	5002	1259	2328	8589
Drip + Non drip Total			9903	2580	3828	16311	12352	2580	2750	17682	11283	2852	4470	18605

Table 4.86. Percentage of total length of primary secondary and tertiary roots in the drip zone and non-drip zone of banana basin during second year at 6 MAP

Zone	Lateral distance from plant (cm)	Soil depth (cm)	Surface Drip				Subsurface Drip				Conventional			
			Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total	Primary	Secon-dary	Tertiary	Total
Drip	30	30	42.2	9.23	10.74	29.60	30.90	5.58	17.53	25.13	21.88	14.17	9.24	17.66
	30	60	7.02	11.63	4.23	7.09	23.48	20.08	5.49	20.18	11.97	9.75	9.01	10.92
	60	30	15.3	29.69	15.96	17.73	17.00	26.12	20.47	18.87	14.68	18.97	17.29	15.96
	60	60	8.91	8.76	9.14	8.94	5.00	25.93	7.78	8.49	6.59	11.12	10.85	8.31
	90	30	0.67	2.05	1.72	1.14	0.28	1.62	1.75	0.71	0.54	1.86	1.52	0.98
Total			74.10	61.36	41.79	64.50	76.66	79.33	53.02	73.39	55.66	55.87	47.91	53.83
Non-drip	30	30	12.42	6.13	11.21	11.14	9.37	5.16	9.24	8.72	24.02	7.64	9.24	17.96
	30	60	3.41	2.36	8.52	4.44	6.80	4.38	8.69	6.74	10.39	2.90	6.09	8.21
	60	30	7.81	22.29	18.18	12.53	3.22	7.80	16.84	6.01	7.06	28.44	20.67	13.60
	60	60	1.88	6.12	18.81	6.52	3.57	2.09	10.4	4.42	2.53	3.86	14.41	5.58
	90	30	0.38	1.75	1.49	0.86	0.38	1.24	1.81	0.73	0.34	1.33	1.68	0.81
Total			25.90	38.64	58.21	35.50	23.34	20.67	46.98	26.61	44.34	44.13	52.09	46.17

Table 4.87. Fresh weight (g $plant^{-1}$) of roots and percentage of total root weight in the drip zone and non-drip zone of banana basin during first year at 6 MAP

Zone	Lateral distance (cm)	Soil depth (cm)	Surface Drip		Surface Drip		Conventional method	
			Weight	% of total weight	Root weight	% of total weight	Root weight	% of total weight
Drip zone	30	30	870	24.72	335	14.49	570	21.26
	30	60	545	15.48	595	25.72	415	15.48
	60	30	450	12.78	250	10.82	345	12.87
	60	60	295	8.38	105	4.54	120	4.48
	90	30	55	1.56	27	1.17	30	1.12
Total			2215	62.92	1312	56.74	1480	55.21
Non – drip	30	30	380	10.80	200	8.65	420	15.68
	30	60	355	10.09	420	18.17	255	9.52
	60	30	385	10.94	225	9.74	375	13.99
	60	60	100	2.84	135	5.84	125	4.67
	90	30	85	2.41	20	0.86	25	0.93
Total			1305	37.08	1000	43.26	1200	44.79
Drip +Non-drip Total			3520	100	2312	100	2680	100

Table 4.88. Fresh weight (g plant^{-1}) and percentage of total root weight in the drip zone and non-drip zone of banana basin during second year at 6 MAP

Zone	Lateral distance (cm)	Soil depth (cm)	Weight	Surface Drip % of total weight	Sub Surface Drip		Conventional	
					Weight	% of total weight	Weight	% of total weight
Drip zone	30	30	500	17.30	600	17.49	500	16.13
	30	60	230	7.96	520	15.16	480	15.48
	60	30	735	25.43	470	13.70	460	14.84
	60	60	180	6.23	260	7.58	240	7.74
	90	30	15	0.52	20	0.58	20	0.65
Total			1660	57.44	1870	54.51	1700	54.84
Non - drip	30	30	450	15.57	490	14.29	560	18.06
	30	60	210	7.27	640	18.66	200	6.45
	60	30	385	13.32	240	7.00	370	11.94
	60	60	170	5.88	180	5.25	250	8.06
	90	30	15	0.52	10	0.29	20	0.65
Total			1230	42.56	1560	45.49	1400	45.16
Drip + Non drip Total			2890	100	3430	100	3100	100

4.9.10 Nutrient distribution in the rhizosphere

Variation in the content of applied nutrients, due to variations in the methods and levels of irrigation and fertilizer application was studied during 5 MAP of the crop in both the years. The data are presented in Tables 4.89 to 4.96. Contents were estimated from different points as in the case of moisture content estimation to obtain an idea of the movement of nutrients from the emitter, in the drip zone. The fertilizer level tried in the second year (F_{100}) was half the dose of that used in the first year (F_{200}).

4.9.10.1 Available N

In the first year, conventional method resulted in a higher content of available N, all around the plant. But surface drip could maintain a similar content in the drip zone at 30 *l* x 30 *d*. and at a higher irrigation level (I_{100}) the nutrient content was even higher under surface drip (332 kg ha^{-1}) than conventional method (308 kg ha^{-1}). Subsurface drip, had the highest content in the lower 30 *l* x 60 *d* layer. Increasing the moisture content to I_{75} offered a higher content of nitrogen available to the plants but further increasing to I_{100}, reduced the nutrient contents in the zone of application, i.e., 30 *l* x 30 *d* for surface drip and conventional and 30 *l* x 60 *d* for subsurface drip. But the movement downwards and laterally was increased with increase in the quantity of water.

In the second year, the content of total extractable nitrogen was higher than that of first year; but followed the same pattern as in the case of first year. The

Table 4.89. Effect of methods and levels of irrigation on the available N content ($kg\ ha^{-1}$) in the soil at 5 MAP in the first year

Treatment	Available N ($kg\ ha^{-1}$)			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	346.5	303.7	230.0	213.0
SS	245.1	331.3	259.0	207.3
C	328.1	296.0	322.0	277.7
CD (0.05)	21.69	11.52	11.47	16.09
I_{50}	297.3	312.1	272.7	214.3
I_{75}	323.2	312.5	265.3	241.0
I_{100}	299.2	306.4	273.0	242.7
CD (0.05)	13.95	NS	7.95	10.93
SI_{50}	313.6	291.2	214.0	196.0
SI_{75}	394.0	312.0	224.0	202.0
SI_{100}	332.0	308.0	252.0	241.0
SSI_{50}	248.0	333.0	296.0	213.0
SSI_{75}	229.6	341.6	235.0	202.0
SSI_{100}	257.6	319.2	246.0	207.0
CI_{50}	330.4	312.0	308.0	234.0
CI_{75}	346.0	284.0	337.0	319.0
CI_{100}	308.0	292.0	321.0	280.0
CD (0.05)	20.64	18.45	18.65	16.58

Table 4.90. Effect of methods and levels of irrigation on the Ammoniacal N content (kg ha^{-1}) in the soil at 5 MAP in the second year

Treatment	Ammoniacal N (kg ha^{-1})			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	39.0	44.8	37.3	40.1
SS	34.5	43.9	29.9	30.8
C	45.7	29.9	32.7	30.9
CD (0.05)	3.51	6.39	2.95	2.05
I_{50}	42.0	29.9	31.7	27.1
I_{75}	38.3	35.5	29.9	30.8
I_{100}	39.0	53.2	38.3	43.9
CD (0.05)	1.97	2.73	1.76	2.08
SI_{50}	39.2	30.8	36.4	28.0
SI_{75}	53.2	30.8	28.0	30.8
SI_{100}	24.6	72.8	47.6	61.6
SSI_{50}	30.8	28.0	28.0	28.0
SSI_{75}	28.0	47.6	25.2	33.6
SSI_{100}	44.8	56.0	36.4	30.8
CI_{50}	56.0	30.8	30.8	25.4
CI_{75}	33.6	28.0	36.4	28.0
CI_{100}	47.6	30.8	30.8	39.2
CD (0.05)	3.38	4.57	3.91	3.05

Table 4.91. Effect of methods and levels of irrigation on the Nitrate N content (kg ha^{-1}) in the soil at 5 MAP in the second year

Treatment	Nitrate N (kg ha^{-1})			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	467.3	290.3	243.3	212.0
SS	280.0	392.0	214.7	250.0
C	382.7	298.7	308.0	318.0
CD (0.05)	18.89	6.35	17.94	18.37
I_{50}	364.0	308.0	242.7	237.3
I_{75}	336.0	345.3	233.3	262.0
I_{100}	430.0	327.7	290.0	280.7
CD (0.05)	16.21	17.24	8.18	15.33
SI_{50}	420.0	280.0	224.0	216.0
SI_{75}	392.0	308.0	196.0	252.0
SI_{100}	590.8	283.0	310.0	168.0
SSI_{50}	280.0	364.0	168.0	216.0
SSI_{75}	252.0	420.0	196.0	280.0
SSI_{100}	308.0	392.0	280.0	254.0
CI_{50}	392.0	280.0	336.0	280.0
CI_{75}	364.0	308.0	308.0	254.0
CI_{100}	392.0	308.0	280.0	420.0
CD (0.05)	19.50	22.06	15.27	23.13

Table 4.92. Effect of methods and levels of irrigation on the Total N content ($kg\ ha^{-1}$) in the soil at 5 MAP in the second year

Treatment	Total N ($kg\ ha^{-1}$)			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	506.6	335.1	280.7	252.1
SS	314.5	435.9	244.5	280.8
C	428.4	328.5	340.7	348.9
CD (0.05)	24.81	19.97	31.74	24.38
I_{50}	406.0	337.9	274.4	264.5
I_{75}	374.3	380.8	263.2	292.8
I_{100}	469.3	380.9	328.3	324.5
CD (0.05)	21.67	16.54	17.43	20.83
SI_{50}	459.2	310.8	260.4	244.0
SI_{75}	445.2	388.8	224.0	282.8
SI_{100}	615.4	355.8	357.6	229.6
SSI_{50}	310.8	392.0	196.0	244.0
SSI_{75}	280.0	467.6	221.2	313.6
SSI_{100}	352.8	448.0	316.4	284.8
CI_{50}	448.0	310.8	366.8	305.4
CI_{75}	397.6	336.0	344.4	282.0
CI_{100}	439.6	338.8	310.8	459.2
CD (0.05)	25.38	29.30	24.20	26.92

Table 4.93. Effect of methods and levels of irrigation on the available P content (kg ha^{-1}) in the soil at 5 MAP in the first year

Treatment	Available P (kg ha^{-1})			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	66.78	26.20	24.10	17.97
SS	25.57	70.49	18.69	19.20
C	56.12	21.74	51.73	22.11
CD (0.05)	4.376	1.197	5.061	1.942
I_{50}	51.03	39.24	31.24	20.21
I_{75}	46.06	38.62	34.05	19.19
I_{100}	51.38	40.57	30.26	19.89
CD (0.05)	2.262	1.905	3.047	1.831
SI_{50}	68.90	22.41	21.40	18.71
SI_{75}	64.38	27.95	26.30	17.05
SI_{100}	67.08	28.24	24.70	18.16
SSI_{50}	23.75	75.65	17.64	18.25
SSI_{75}	22.34	65.45	20.57	18.62
SSI_{100}	30.61	70.36	20.85	20.73
CI_{50}	60.45	19.67	54.67	23.66
CI_{75}	51.46	22.45	55.28	21.91
CI_{100}	56.45	23.11	45.24	20.77
CD (0.05)	4.542	1.987	4.678	NS

Table 4.94. Effect of methods and levels of irrigation on the available P (kg ha^{-1}) at 5 MAP in the second year

Treatment	Available P (kg ha^{-1})			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	48.17	29.21	25.00	17.67
SS	28.57	42.14	19.77	21.12
C	42.66	19.89	35.64	17.54
CD (0.05)	1.499	3.432	3.118	1.519
I_{50}	37.88	30.44	25.22	19.51
I_{75}	42.07	28.89	26.67	19.58
I_{100}	39.46	31.91	28.53	17.25
CD (0.05)	2.808	1.967	2.322	NS
SI_{50}	48.33	29.20	24.62	17.64
SI_{75}	51.53	23.72	26.59	18.90
SI_{100}	44.66	34.70	23.80	16.47
SSI_{50}	20.06	42.93	19.20	23.44
SSI_{75}	31.75	44.29	18.71	22.91
SSI_{100}	33.90	39.21	21.40	17.02
CI_{50}	45.24	19.20	31.83	17.45
CI_{75}	42.93	18.67	34.70	16.93
CI_{100}	39.81	21.81	40.39	18.25
CD (0.05)	3.661	3.841	2.880	NS

Table 4.95. Effect of methods and levels of irrigation on the available K content ($kg\ ha^{-1}$) in the soil at 5 MAP in the first year

Treatment	Available K ($kg\ ha^{-1}$)			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	420	369	260	275
SS	328	342	268	267
C	370	236	319	297
CD (0.05)	21.9	23.5	31.3	18.9
I_{50}	408	289	253	272
I_{75}	344	353	293	250
I_{100}	364	306	301	317
CD (0.05)	37.0	24.8	12.7	22.7
SI_{50}	442	333	217	250
SI_{75}	408	375	295	225
SI_{100}	410	400	267	350
SSI_{50}	350	325	267	325
SSI_{75}	300	383	250	225
SSI_{100}	333	317	286	250
CI_{50}	433	208	275	242
CI_{75}	325	300	333	300
CI_{100}	350	200	350	350
CD (0.05)	28.6	42.8	46.8	NS

Table 4.96. Effect of methods and levels of irrigation on the available K content ($kg\ ha^{-1}$) in the soil at 5 MAP in the second year

Treatment	Available K ($kg\ ha^{-1}$)			
	30 *l* x 30 *d*	30 *l* x 60 *d*	60 *l* x 30 *d*	60 *l* x 60 *d*
S	325	242	314	275
SS	297	317	208	246
C	350	319	275	219
CD (0.05)	24.6	25.9	41.6	29.6
I_{50}	317	267	253	241
I_{75}	361	325	278	266
I_{100}	294	286	267	233
CD (0.05)	33.5	31.9	20.9	14.6
SI_{50}	342	225	258	267
SI_{75}	350	225	333	283
SI_{100}	283	275	350	275
SSI_{50}	267	300	250	247
SSI_{75}	325	400	225	266
SSI_{100}	300	250	150	225
CI_{50}	342	275	250	208
CI_{75}	408	250	275	250
CI_{100}	300	333	300	200
CD (0.05)	60.9	36.9	28.5	NS

available N was found increasing from 406.0 kg ha^{-1} to 469.3 kg ha^{-1}, as the irrigation was increased from I_{50} to I_{100}.

4.9.10.2 Phosphorus

Surface drip, in the first year, resulted in a higher content of available P (66.78 kg ha^{-1}) in the 30 *l* x 30 *d* layer, compared to subsurface drip (25.15 kg ha^{-1}), but its movement downwards was very low. In the subsurface drip, the highest concentration was in 30 *l* x 60 *d* zone. Conventional method, also had a higher concentration in the surface layers, but both 30 *l* and 60 *l* were comparable.

With a decrease in the level of fertilizer application, available P content decreased in the second year, in 30 *l* x 30 *d* zone of surface drip and 30 *l* x 60 *d* zone of subsurface drip. But the contents in the 30 *l* x 60 *d* of surface drip (29.21 kg ha^{-1}) and 30 *l* x 30 *d* zone of subsurface drip (28.57 kg ha^{-1}) were almost comparable with that in the first year (26.20 and 25.57 respectively), suggesting that the advance in the vertical direction was increased in the second year due to higher moisture content in the soil. Movement in the downward direction was low in conventional method.

4.9.10.3 Potassium

As in the case of phosphorus, surface drip in the first year registered a higher content of potassium in the surface 30 *l* x 30 *d* zone, followed by 30 *l* x 60 *d*. The surface 60 *l* x 30 *d* zone had a comparatively lesser content, showing that movement in the downward direction was more than that in the horizontal direction. Under subsurface drip, the variation between surface 30 *l* x 30 *d* layer

(328 kg ha^{-1}) and its lower 30 *l* x 60 *d* layer (342 kg ha^{-1}) was not marked. Increasing the quantity of irrigation from I_{75} to I_{100} increased the content in the 30 *l* x 30 *d* zone, but decreased the content in the 30 *l* x 60 *d* zone.

In the second year, when more water was applied, there was an increased lateral movement of potassium in the surface drip. The content in 60 *l* x 30 *d* zone was increased, when compared to that in the first year, and the difference between the contents in 30 *l* x 60 *d* and 60 *l* x 30 *d* was reduced considerably. Also increasing the quantity of irrigation from I_{50} to I_{100} increased the content in the 60 *l* x 30 *d* zone, but reduced the content in the point of application i.e., 30 *l* x 30 *d* zone. Under subsurface drip, more content was recorded is the surface layers (30 *l* x 30 *d*), with an increase in the quantity of irrigation.

4.11 Experiment III

Leaching loss of nutrients under flooded conditions

Loss of nutrients due to leaching in the form of ammoniacal and nitrate nitrogen, phosphorus and potassium were estimated under different irrigation levels. The irrigation levels tried were 100, 200 and 300 per cent PEC, once in three days. Fertilizers were given in six splits (S_1 to S_6) at 200-115-300 g NPK $plant^{-1}$, and the loss of nutrients after every fertilizer application was estimated for three consecutive irrigations (I_1 to I_3). To obtain the actual loss from the fertilizer, the loss of nutrients from the control plots, where in no fertilizers are applied, was deducted from the loss determined from the treatment pots. The losses in terms of percentage of the total nutrients applied in each split are presented in Tables 4.97 to 4.102.

4.11.1 Ammoniacal nitrogen

There was an increase in the loss of NH_4^+-N through irrigation water, with increase in the quantity of irrigation (Table 4.97). The loss at 100 per cent PEC was only 8.44 per cent, but it was raised to 14.36 per cent at 200 per cent PEC. The increase in loss was only marginal with further increase in irrigation.

In the first two splits of fertilizer application, the loss was less, but the third and fourth splits caused a greater loss of NH_4^+-N, and thereafter, the loss again decreased (Table 4.98).

NH_4^+-N was lost more in the initial days (one day after fertilizer application) and the loss decreased in further irrigations. The content of NH_4^+-N in the leachate collected in the third irrigation after fertilizer application was markedly less.

The highest loss of NH_4^+-N was obtained with irrigation at 300 per cent PEC given next day after fertilizer application, but was comparable with irrigation at 200 per cent PEC.

4.11.2 Nitrate - N

As in the case of NH_4^+-N, NO_3^--N loss also was increased with increase in quantity of irrigation from 100 to 200 per cent PEC, but further increase in loss with increase in irrigation quantity was obtained only after third and sixth split of

Table 4.97. Leaching loss of N (percentage of N applied) under different levels of irrigation

Treat-ments	Ammoniacal N							Nitrate N							Total N						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
100	7.96	6.78	11.11	16.36	3.06	5.37	8.44	16.39	18.28	31.34	27.76	29.61	26.74	25.02	24.35	25.06	42.45	44.12	32.67	32.11	33.46
200	16.55	12.65	20.26	14.17	15.66	5.87	14.36	17.59	29.36	28.45	45.63	42.13	31.65	32.46	34.14	43.01	48.71	59.80	57.79	37.52	46.82
300	16.72	10.68	24.15	18.64	16.32	6.73	15.54	15.40	19.25	41.48	30.43	34.72	39.07	30.06	32.12	29.93	65.63	49.07	51.04	45.8	45.60
CD	NS	7.344	9.378	6.942	8.244	8.88	-	4.32	NS	9.69	NS	8.199	NS	-	NS	10.32	12.309	NS	10.05	NS	-
Mean	16.46	22.30	33.76	34.61	35.49	32.48	29.18	13.74	10.37	18.51	16.39	11.68	5.99	12.78	30.20	32.67	52.26	50.99	47.17	38.48	41.96

Table 4.98. Leaching loss of N (percentage of N applied) at different irrigations after fertilizer application

Treat-ments	Ammoniacal N							Nitrate N							Total N						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
I_1	8.68	5.62	14.24	14.61	8.10	4.06	9.22	3.61	8.45	18.32	24.67	6.21	16.12	12.90	12.29	14.07	32.56	39.28	14.31	20.18	22.12
I_2	3.82	2.96	3.81	1.31	2.63	1.54	2.68	7.95	9.19	10.90	5.99	19.34	11.30	10.78	11.77	12.15	14.71	7.30	21.97	12.84	13.46
I_3	1.26	1.79	0.47	0.47	0.95	0.39	0.89	4.90	4.65	4.54	3.94	9.93	5.07	5.51	6.16	6.44	5.01	4.41	10.88	5.46	6.39
CD	1.44	1.272	3.23	2.303	2.733	0.54	-	1.671	2.448	3.126	2.314	2.748	2.96	-	3.174	3.44	4.103	9.28	3.35	5.145	-
Mean	4.59	3.46	6.17	5.46	3.89	1.99	4.26	5.49	7.43	11.25	11.53	11.83	10.83	9.73	10.08	10.89	17.42	16.99	15.72	12.82	13.99

Table 4.99. Leaching loss of N (percentage of N applied) as influenced by levels and sequence of irrigation

Treat-ments	Ammoniacal N						Nitrate N						Total N					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
100 I_1	3.68	3.27	7.22	16.14	1.52	3.06	3.00	6.18	15.15	17.97	2.26	11.90	6.68	9.45	22.37	34.11	3.78	14.96
100 I_2	2.87	1.73	3.84	0.10	0.80	2.05	6.83	7.70	15.83	6.29	16.70	10.42	9.70	9.43	19.67	6.39	17.50	12.47
100 I_3	1.41	1.78	0.05	0.12	0.74	0.26	6.57	4.40	0.36	3.50	10.65	4.42	7.98	6.18	0.41	3.67	11.39	4.68
200 I_1	10.40	7.98	15.29	11.56	9.93	4.52	3.66	8.57	17.95	33.43	6.15	14.13	14.06	16.55	33.24	44.99	16.08	18.65
200 I_2	5.04	3.17	4.35	2.00	4.06	0.98	8.62	13.85	2.04	7.29	23.35	12.20	13.66	17.02	6.39	9.29	27.41	13.18
200 I_3	1.11	2.50	0.62	0.61	1.67	0.36	5.31	6.94	8.46	4.91	12.63	5.32	6.42	9.44	9.08	5.51	14.30	5.61
300 I_1	11.95	5.62	20.20	16.13	12.84	4.61	4.16	10.60	21.85	22.61	10.24	22.33	16.11	16.22	42.05	38.74	23.08	26.94
300 I_2	3.57	3.97	3.23	1.82	3.04	1.58	8.41	6.03	14.83	4.41	17.97	11.26	11.98	10.00	18.06	6.23	21.01	12.84
300 I_3	1.26	1.09	0.72	0.69	0.44	0.54	2.83	2.62	4.80	3.41	6.51	5.48	4.09	3.71	5.52	4.1	6.95	6.02
CD	2.495	3.935	5.595	NS	4.735	0.935	2.895	4.24	5.414	4.009	4.759	5.126	NS	NS	7.107	NS	5.81	8.912

fertilizer doses. The mean loss of NO_3^- -N was 29.18 per cent of the total N - applied as fertilizer. Progressive loss was observed up to an addition of fifth split, but the loss was not proportional after the third split. In the later stages, the loss was found decreasing.

A higher loss of NO_3^- -N, in the first two splits occurred with the second irrigation, but later on, the loss in the first irrigation was more than that in the second irrigation. Third irrigation could result in only very low quantity of N through leaching.

4.11.3 Total Nitrogen

On an average 41.96 per cent of the nitrogen fertilizer applied was lost through leaching, and the loss of nitrogen increased with increase in the level of irrigation to 200 per cent PEC. Considerable increase in the total nitrogen was noticed in the third, fourth and fifth splits, but thereafter it decreased.

The loss was more in the first irrigation soon after fertilizer application. The content of N in the leachate decreased with subsequent irrigations.

4.11.4 Phosphorus

No blue colour could be developed in the estimation using ascorbic acid P determination method.

4.11.5 Potassium

Potassium was found leaching out through irrigation water, to an extent of 16.19 per cent of the fertilizer applied. The loss through irrigation was increased

Table 4.100. Leaching loss of potassium (% of K applied) under different levels of irrigation

Treatment % PEC	Potassium (% of K applied)						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
100	11.56	11.04	18.06	21.46	7.42	7.23	112.80
200	16.65	12.82	36.24	13.39	7.65	6.21	15.48
300	18.72	15.48	26.08	40.62	14.31	6.58	20.30
CD	NS	NS	1.11	NS	NS	NS	-
Mean	15.64	13.11	26.79	25.16	9.79	6.67	16.19

Table 4.101. Leaching loss of potassium (% of K applied) at different irrigations after fertilizer application

Treatment	Potassium (% of K applied)						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
I_1	5.79	7.39	14.49	13.21	3.81	4.04	8.12
I_2	7.11	3.84	10.00	2.12	4.35	2.37	4.97
I_3	2.75	1.89	2.30	9.82	1.63	0.266	3.11
CD	NS	0.241	0.431	1.46	NS	0.172	-
Mean	5.22	4.37	8.93	8.38	3.26	2.23	5.40

Table 4.102. Leaching loss of potassium (% of K applied) as influenced by levels and sequence of irrigation

Treatment	Potassium (% of K applied)					
	S_1	S_3	S_3	S_4	S_5	S_6
100 I_1	3.72	6.06	11.01	16.29	3.40	4.83
100 I_2	4.32	3.06	6.37	3.46	2.60	2.08
100 I_3	3.52	1.92	0.68	1.71	1.34	0.317
200 I_1	9.69	7.27	18.65	10.33	3.92	2.96
200 I_2	4.35	3.44	14.30	2.28	2.50	2.93
200 I_3	2.61	2.11	3.29	0.78	1.23	0.32
300 I_1	3.96	8.82	13.81	13.01	4.02	4.33
300 I_2	12.65	5.02	9.33	0.633	7.95	2.09
300 I_3	2.11	1.64	2.94	26.98	2.34	0.16
CD (0.05)	NS	NS	NS	NS	NS	NS

with increase in quantity of irrigation and maximum leaching was noticed with 300 per cent PEC.

As in the case of nitrogen, the loss in the first two splits was lower than that in the third and fourth splits. Also with the fifth and sixth splits, it again decreased considerably.

The percentage loss of potassium also was more in the irrigation given one day after fertilizer application. Subsequent irrigations had a lesser K content in the leachate.

DISCUSSION

5. DISCUSSION

5.1 Experiment 1

The research results obtained in the study on drip fertigation in Nendran banana conducted during 1997-98 and 1998-99 at Banana Research Station, Kannara are discussed in this chapter. The study aimed to test whether a regulated application of water through drip system is advantageous over conventional basin irrigation, whether fertilizer application can be integrated with drip irrigation, whether the varying frequencies of drip fertigation bring about measurable difference in crop growth and yield and rhizosphere characteristics under complete NPK nutrition through drip system and how the graded levels from 25 to 250 per cent of the present recommended fertilizer dose perform under fertigation in six and twenty four frequencies. The varying frequencies of drip fertigation introduced a component of dilution of nutrient solution, which have a profound influence on chemical characteristics of rhizosphere.

A preliminary analysis of crop growth and yield due to treatment effects in the first year hinted a water stress and hence the quantity of irrigation water was changed from a fixed 16 l day^{-1} to a quantity estimated daily based on previous day pan evaporation. This further introduced a dilution component of nutrient solution in the second year. The total quantity of irrigation water of 1968 l plant^{-1} in the first year was raised to 2620 l plant^{-1} in the second year, resulting in a 33 per cent increase in water application (Appendix-3). This consequently resulted in the dilution of nutrient solution applied. The water stress suspected in the first year could be corrected to a great extend in the second year by increasing the irrigation water and also by a 15.5 per cent less of total pan evaporation during the dry months as the pan evaporation varied from 887.8 mm in the first year to 750.3 mm in the second year.

5.1.1 Effect of method of irrigation and fertilizer application and frequency of fertilizer application on growth and yield

5.1.1.1 Growth attributes

Comparison of the different methods of irrigation and fertilizer application showed that drip fertigation resulted in taller plants with more girth, more number of leaves and leaf area. The overall growth performance in both the years showed that drip fertigation was better than conventional basin irrigation and fertilizer application in banana, more significantly in second year. Michael (1992) suggested that irrigating the plants more frequently with a volume of water approaching the consumptive use of the plants directly to root zone could have resulted in better growth performance. Hegde and Srinivas (1989) and Bosu *et al.* (1995) also observed better growth of banana under drip irrigated condition than conventional basin irrigation.

Increasing the frequency of fertilizer application through drip, from monthly intervals to weekly intervals produced more growth in terms of height, girth, number of leaves and LAI. Drip fertigation facilitated increased frequency of fertilizer application according to the crop demand thereby favouring better growth. Also this could optimize the nutrient balance by supplying nutrient directly to root zone in available forms and also could control the nutrient concentration in soil solution to effect proper supply (FAI, 1995). However, at very low levels of fertilizers coupled with higher frequency of application the performance of drip fertigation was not satisfactory. $D_{24}F_{50}$ and $D_{24}F_{25}$ failed to produce good growth and biomass accumulation in the first year and second year respectively, probably due to low nutrient concentration in the rhizosphere. However, with an increase in fertilizer level to F_{100} (recommended level), the superiority of D_{24} was more evident and growth performance was better up to F_{200}. This suggests that a higher level of fertilizer application is possible if we increase the frequency of fertilizer application and this is possible under drip fertigation.

When the frequency of fertilizer application was less (six splits), a higher level of fertilizer (F_{250} or F_{200} in first year and second year respectively) was found reducing the growth. The plants were shorter with less girth and number of leaves and LAI, compared to F_{100} and F_{150}. Excess nutrient application would have been responsible for higher induced acidity and consequent higher release and absorption of native elements and low metabolic utilization of applied elements. However the research findings of KAU (1997) showed that 380-115-600 g NPK per plant in six split was better than 190-115-300 g NPK per plant for conventional basin application.

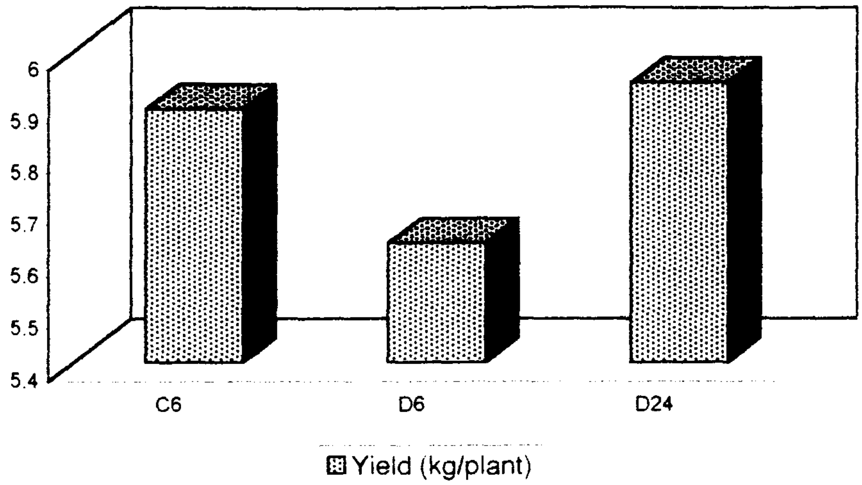
5.1.1.2 Yield attributes

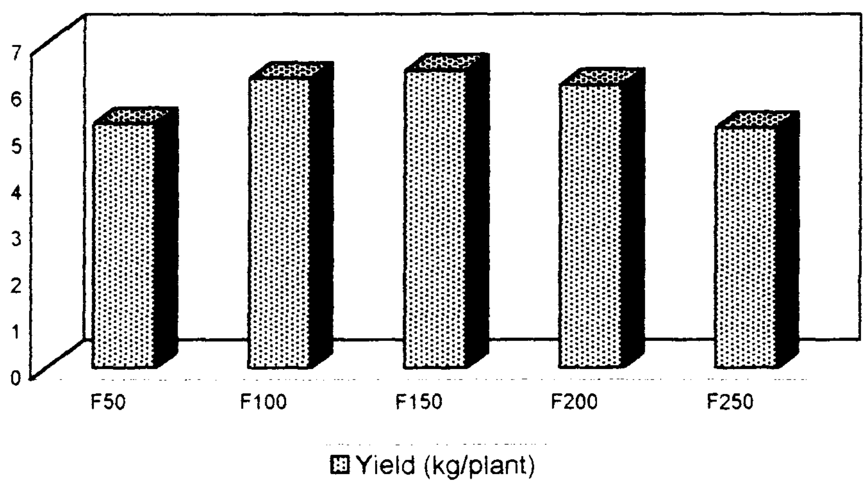
The superiority of drip fertigation over conventional method in the vegetative growth was not reflected in the yield attributing characters except D finger weight. In the second year, D finger weight was significantly more in drip fertigated banana, resulting in an increase in yield. ICAR (1993), KAU (1997) and MPKV (1998) also reported increased yield of banana under drip fertigation. In the first year, the effect of treatments was not significant (Fig. 5.1) as the crop in general had a reduced growth as it was grown under stress. Non significant effect in number of hands and fingers suggests that the crop in the second year also had a nutritional stress not necessarily due to lack of nutrients, but their imbalances, excesses or increasingly available native elements because of the altered soil reaction at the time of flower initiation and differentiation, which inturn affected the number of hands and fingers. Only the post flowering development was favoured by drip fertigation.

Comparison of different levels of fertilizers on yield and yield attributing characters in the second year reveal that the recommended level (F_{100}) produced the maximum number of fingers with highest finger weight and there by the total bunch yield (Fig. 5.2). Increased fertilizer levels could only remain comparable with F_{100}. However, when the frequency of fertigation was increased an increasing trend in yield was observed which could have been attributed to the maintenance of adequate nutrient concentration in soil solution through out the growth stages (Bar-Yosef, 1999).

Higher sucker production, irrespective of method of irrigation in the first year suggest that crop was under stress in the first year. A higher concentration of nutrients (increased levels of fertilizers) aggravated the situation resulting in more number of suckers. The nutritional stress might have induced a

Fig. 5.1. Effect of methods of irrigation, frequencies and levels of fertilizer application on yield of banana var. Nendran in the first year





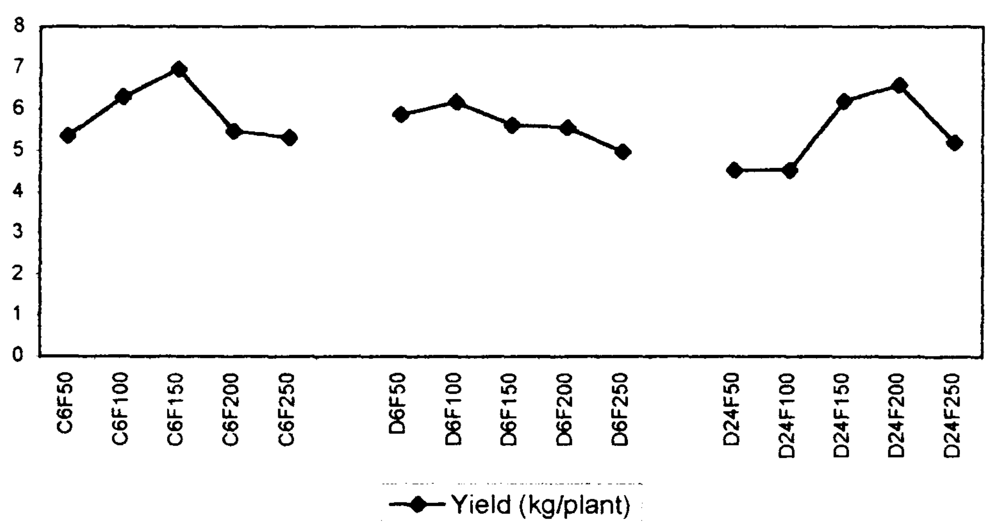
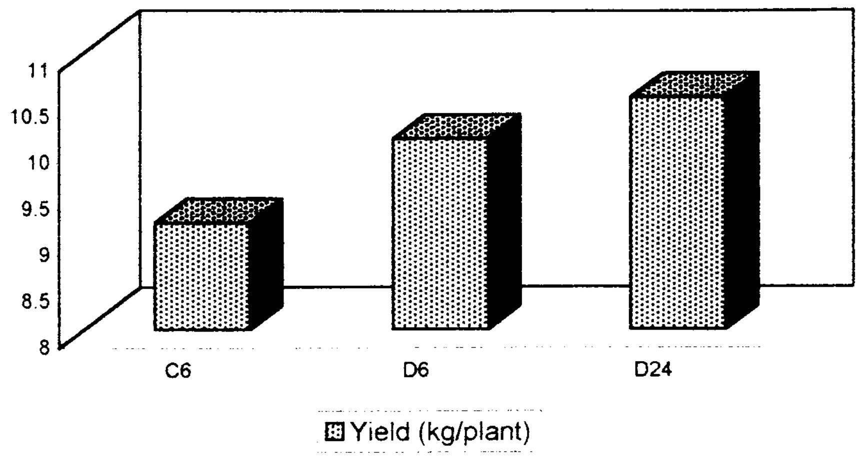
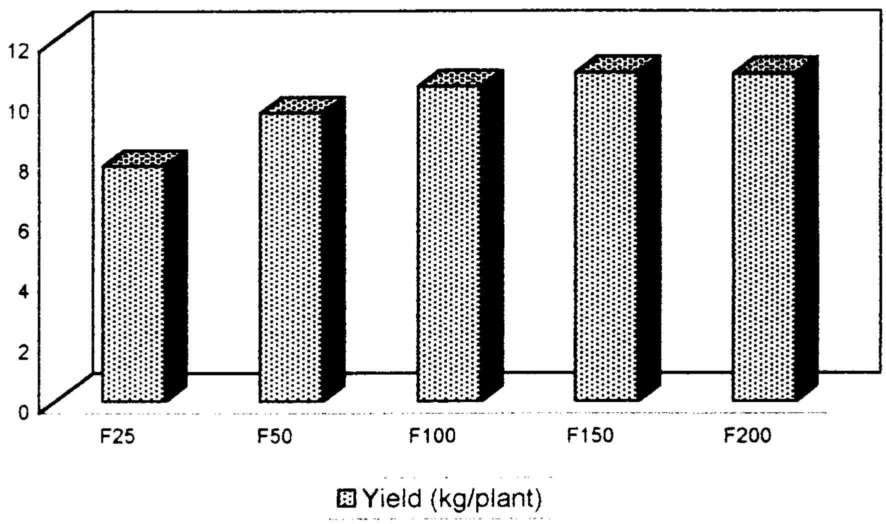
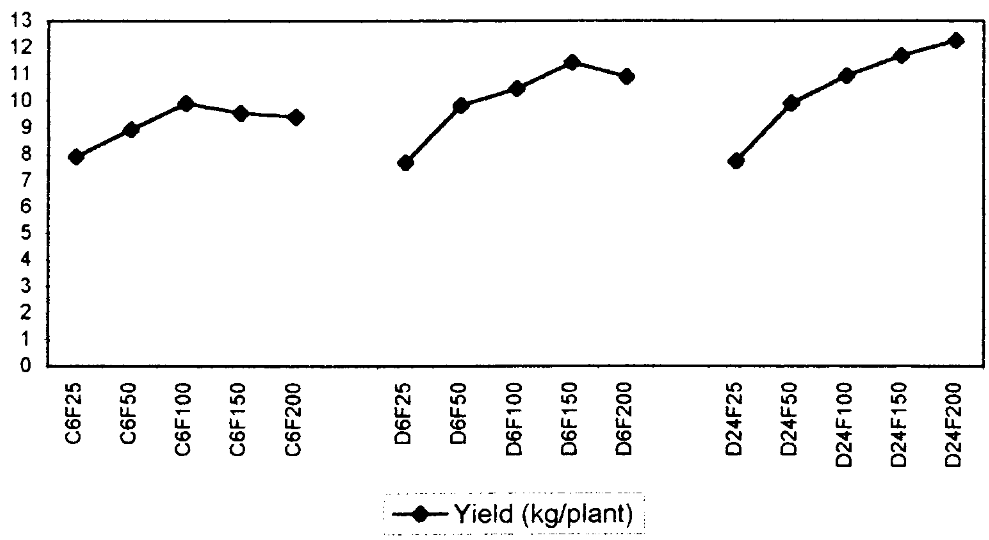


Fig. 5.2. Effect of methods of irrigation, frequencies and levels of fertilizer application on yield of banana var. Nendran in the second year







translocation inhibition of photosynthates to the pseudostem and floral parts, resulting in the production of excess suckers.

Higher biomass production especially that of pseudostem under drip fertigation noticed in the second year, also would have resulted in a higher yield. A lower yield associated with a higher rhizome weight (in the first year) confirms an inhibition of translocation induced by nutritional stress.

5.1.2 Effect of method of irrigation and fertilization and frequency of fertilizer application on the nutrient content and uptake

Plant nutrition plays a major role in the growth and development of the crop. The availability of nutrients at critical stages of growth in sufficient quantities is to be assured for getting maximum yield. In banana, the growth and development during pre-flowering stage decide the number of hands and fingers as the flower bud differentiation takes place 4-5 months after planting. The availability of major nutrients N, P and K and secondary elements like Ca and Mg are reported to play a major role in the growth and development of banana (Prevel, 1964 and Lahav, 1973).

Nutrient content in the plant was invariably increased by the adoption of drip fertigation in both the years. Feigin *et al.* (1982), Haynes (1988) and Parikh *et al.* (1994) also reported better absorption of nutrients under drip fertigation.

Three months after planting in the first year it was drip fertigation in six splits (D_6) that resulted in the highest content of P, K, Ca and Mg, while the content of all other elements varied nonsignificantly (Section 4.6). In the second year also, D_6 favoured the absorption of Ca, Mg and Fe while D_{24} favoured K absorption. This means that the nutrient concentration was very low in the rhizosphere where D_{24} was adopted resulting in lesser absorption of non applied elements. No significant response to higher levels of fertilizer in the case of N and P, in the first year and P and K in the second year, mean that the demand of the crop was very less in the initial stages.

However, at 4 MAP, the demand for N, P and K increased and increased frequency of fertigation started showing its effect. But when applied in six splits, Ca, Mg and Fe were highly absorbed under conventional method in the second year, and under drip fertigation (D_6) in the first year. This proves that a higher nutrient concentration in the rhizosphere could replace Ca and Mg by H^+ substitution and release Fe, which turn harmful because of their direct or indirect effects. The harmful effect of higher nutrient concentration is discussed in detail in section 5.1.3.2. Mn absorption was also more under C_6, in both the years.

At 5 MAP also, the same pattern of crop response was noticed.

At 6 MAP, the response to drip fertigation was not pronounced as the flower initiation was already over. Besides, crop during this time received pre-monsoon showers, which also reduced the effect of drip fertigation. More fertilizer resulted in more content of major elements as well as Mn.

At 7 MAP, in the second year N and P contents were maximum at F_{100} and increasing fertilizer level further had no positive effect. But K response was increasing up to F_{200}. This suggests that at flowering stage, the demand for potassium is more than that of N and P. But F_{200} was found increasing the content of Fe and Mn, and application in six splits caused more absorption.

Drip fertigation in 24 splits invariably resulted in a higher absorption of all major applied nutrients in the second year. This confirms that better uptake is possible under drip fertigation in more frequencies. But given in lesser frequency (six splits) through drip, a higher absorption of native non-applied elements like Fe, Zn, Ca and Mg (during 3 MAP and 7 MAP) occurs as that in the case of conventional method (basin application in six splits). In the first year also, a higher absorption of Ca, Mg, Fe, Mn and Zn happened under drip fertigation in six splits. This could have been due to the variations in the soil reactivity induced by fertilizer application. Change in reactivity affected the content and uptake much more than the level of application and hence it is more crucial in deciding the yield. In D_6, highly concentrated nutrient solution was added directly to limited root zone, resulting in the release and absorption of native non-applied elements, in higher quantities. In the first year, the concentration was so high enough to degrade the soil, releasing Ca and Mg from the exchangeable sites by hydrogen ion substitution.

Data on effect of levels of nutrients revealed that application of NPK in higher doses led to higher content of these elements, but failed to produce significant effect on growth, yield or yield attributes. This proves that absorption need not necessarily result in metabolic utilization. Bifunctional roles exist for elements in crop productivity viz., a metabolic function and a chemical function with the latter preceding the former. The absorbed elements may be chemically available, but not metabolically available. They might have been chemically inactivated and precipitated by some other elements and have blocked the system.

Data on use efficiency of nutrients (yield per kg of fertilizer nutrient applied) also showed that in the first year, the nutrients were not utilized effectively. This also points out the negative impact of addition of fertilizers in excess.

In the second year, drip fertigation resulted in a better efficiency of all the fertilizers applied, and giving in more frequencies had an added advantage. High frequency application under drip irrigation in tune with crop growth resulting in better efficiency was observed by Rolston *et al.* (1979), Goyal *et al.* (1985) and Kadam *et al.* (1993). Feigin *et al.* (1982) suggested better efficiency of nutrients due to reduced leaching loss.

Mean uptake of nutrients by different plant parts showed that, in the first year, maximum nutrients were accumulated in the rhizome, as the biomass of rhizome was very high. This indicated a reduced translocation of metabolised nutrients to the reproductive parts. But in the second year, bunch accumulated more N followed by rhizome. Similarly in the case of all other nutrients also, a considerable share was accumulated in the fruits. The percentage of accumulation of nutrients in the pseudostem increased when compared to that in the first year. This also confirmed that there was uninhibited translocation of nutrients to the above ground portion is the second year. The accumulation of nutrients in the rhizome in the first year resulted in more sucker production and poor biomass for the above ground portion and poor yield.

A higher biomass of pseudostem in the second year resulted in considerable N dilution as evidenced by 0.95 per cent in the second year as against 1.35 per cent in the first year. Lower N content also mean that more N was translocated to peduncle, fruit and male bud and a higher N content in these parts further confirm this. Similarly, the contents of P and K in the floral parts were also higher in the second year.

5.1.3 Yield variations in the first year and second year

Banana fruit is a vegetative midway differentiated terminally developed fruit and much variability in yield could be expected to relate to growth and development of the plant. Management efforts therefore are the key to yield realised. Expressed yield, being a function of the progressive growth and development of the plant, variation in their relation should serve as indices for effective management.

The increase in mean yield of 5.82 kg plant^{-1} in the first year to 9.92 kg plant^{-1} in the second year - a noticeable increase by 70.4 per cent - invite a detailed analysis of the factor responsible for it. In addition, significant variation in yield between conventional method and drip fertigation was observed only in the second year. Under a given set of varietal, soil and climatic situation growth and yield are mainly decided by the level of management. Thus the yield variation during first year and second year points to the level of management, particularly water and nutrients.

As pointed out earlier, a 33 per cent less water supply irrespective of method of irrigation caused moisture stress during the active vegetative growth and early reproductive stage. The crop in the first year, characterised by a higher average height of 185 cm against 137 cm in the second year at 4 MAP with corresponding mean girth of 42 cm and 40 cm, resulted in a height/girth ratio of 4.4 and 3.4 respectively. Greater height/girth ratio indicates the improportionate increase in height and girth. This normally results from an elongation of individual cells rather than cell multiplication which resulted in a weaker pseudostem. This is evident from the reduced pseudostem weight in the first year than that in second year. A relatively fragile pseudostem in terms of low dry weight would reduce the functional efficiency of translocation of nutrients and photosynthates.

A relatively lower area of the index leaf and production of more functional leaves after flower initiation would also have contributed to reduction in yield in the first year. This would have resulted in ineffective diversion of energy towards production of more sheaths and leaf pedicels.

The first year crop took only 210 and 295 days at an average for flowering and harvesting respectively while these were 243 and 326 respectively in the second year. Early flowering is a natural mechanism against any kind of stress and remarkable reduction in different phases and total duration would have largely affected the cumulative photosynthetic accumulation thereby affecting various growth and development process.

A longer bunch stalk in the first year with a mean length of 63.0 cm; weighed 0.691 kg, while the peduncle, in the second year was only 33 cm long, but weighed 0.581 kg. The weight of peduncle per cm length is more in the second year (18 g) than that in the first year (11 g) showing that the elongation was abnormal.

5.1.3.1 Productivity and morphological interrelation

Inter relations of morphophysiologic and yield attributes presented in Tables 5.1 and 5.2 will serve as indices of concurrent and progressional operations in yield negating processes along with normal growth process. A perusal of the data on inter relation of plant growth characters and yield showed that significant relationship of only 3 out of 16 characters in the first crop with mean yield of 5.82 kg $plant^{-1}$ and 10 out of 16 characters in the second crop with mean yield of 9.92 kg $plant^{-1}$ would suggest that interference in systematic and co-ordinated growth of banana is the factor that is responsible for yield variation. Similar results naturally imply that significant relationship of a still higher number of plant characters with a higher magnitude of relation should have resulted in far higher yields, than realised in the trial. These results therefore call for a reverse analysis of the data, which in this context will be ideal to characterise and quantify the negative influences by treatment effects.

Table 5.1. Interrelation of morphological characters with yield in banana var. Nendran in the first year

Character	Plant height	Girth	No. of leaves	Area of Index leaf	LAI	No. of suckers	No. of hands	Total fingers	D-finger weight	Pseud-ostem weight	Leaf weight	Pedun-cle weight	Male bud weight	Pedun-cle length	Rhizo-me weight	Yield	Total biom-ass
Plant height	1.00	0.012	0.274	0.312	0.393	0.593	0.072	0.118	0.57	-0.007	0.148	0.244	0.048	0.056	0.44	0.143	0.371
Girth	0.012	1.00	0.32	0.25	0.35	-0.047	-0.146	0.067	0.377	-0.092	-0.145	-0.023	0.126	-0.049	0.261	0.042	0.150
No. of leaves	0.274	0.318	1.000	0.087	0.544	0.218	-0.318	-0.225	0.019	-0.012	-0.166	0.249	0.125	0.322	0.090	-0.145	0.052
Area of Index leaf	0.312	0.251	0.087	1.00	0.882	0.185	0.26	0.323	0.285	0.15	0.116	-0.012	-0.140	-0.019	0.164	0.184	0.163
LAI	0.393	0.354	0.543	0.882	1.00	0.26	0.062	0.153	0.188	0.012	0.016	0.103	-0.046	0.129	0.169	0.073	0.147
No. of suckers	0.593	-0.047	0.218	0.185	0.259	1.00	0.129	0.214	0.063	0.071	0.071	0.088	0.057	-0.142	0.44	0.071	0.394
No. of hands	0.072	-0.146	-0.318	0.257	0.062	0.129	1.00	0.584	0.045	0.011	0.174	-0.047	-0.078	-0.063	0.314	0.349	0.300
Total fingers	0.118	-0.67	-0.255	0.323	0.153	-0.214	0.584	1.00	-0.044	-0.045	0.231	-0.101	-0.216	-0.019	0.294	0.375	0.265
D-finger weight	0.057	-0.377	-0.019	0.205	0.188	0.063	0.045	-0.043	1.00	-0.181	-0.043	-0.115	-0.221	-0.129	0.098	0.271	0.011
Pseudo-stem weight	-0.007	-0.092	-0.012	0.015	0.012	0.071	0.011	-0.045	-0.189	1.00	0.122	0.017	-0.308	-0.034	0.059	0.266	0.582
Leaf weight	0.148	-0.145	-0.165	0.116	0.016	0.071	0.173	0.231	-0.043	0.122	1.00	0.026	-0.174	0.048	0.138	0.224	0.280
Peduncle weight	0.244	0.023	0.249	0.012	0.103	0.089	-0.046	0.102	-0.115	-0.017	0.026	1.00	-0.245	0.426	0.142	0.180	0.159
Male bud weight	0.048	0.156	0.125	-0.140	-0.45	0.057	-0.078	-0.216	0.221	-0.307	-0.174	-0.245	1.00	-0.013	-0.102	-0.241	-0.266
Peduncle length	0.056	0.049	0.321	-0.019	0.129	-0.142	-0.063	-0.018	-0.128	-0.034	0.047	0.426	-0.012	1.00	-0.031	0.145	0.014
Rhizome weight	0.144	0.261	-0.090	0.163	0.168	0.440	0.314	0.293	0.097	0.059	0.138	0.149	-0.102	0.032	1.00	0.116	0.832
Yield	0.143	0.042	-0.145	0.184	0.073	0.071	0.349	0.375	0.271	0.266	0.224	0.180	-0.241	0.145	0.116	1.00	0.350
Total biomass	0.371	0.150	0.051	0.163	0.147	0.393	0.300	0.265	0.011	0.583	0.280	0.159	-0.266	-0.014	0.832	0.35	1.00

Table 5.2. Interrelation of morphological characters with yield in banana var. Nendran in the second year

Character	Plant height	Girth	No. of leaves	Area of Index leaf	LAI	No. of suckers	No. of hands	Total fingers	D-finger weight	Pseud-ostem weight	Leaf weight	Pedun-cle weight	Male bud weight	Pedun-cle length	Rhizo-me weight	Yield	Total biomass
Plant height	1.000	0.578	0.335	0.420	0.440	-0.232	0.389	0.429	-0.072	0.609	0.079	0.142	0.014	-0.405	0.354	0.633	0.553
Girth	0.578	1.000	0.538	0.637	0.709	-0.167	0.194	0.098	-0.097	0.391	-0.072	0.302	0.146	-0.405	0.137	0.440	0.315
No. of leaves	0.335	0.538	1.000	0.495	0.781	-0.058	0.010	-0.097	-0.104	0.111	-0.205	0.232	-0.114	0.029	0.054	0.111	0.088
Area of Index leaf	0.420	0.667	0.495	1.000	0.923	-0.054	0.173	0.096	-0.049	0.290	-0.121	0.250	-0.032	-0.024	0.110	0.376	0.276
LAI	0.440	0.709	0.781	0.923	1.000	-0.063	0.141	0.034	-0.104	0.244	-0.169	0.283	-0.080	-0.004	0.165	0.303	0.230
No. of suckers	-0.232	-0.167	-0.058	-0.054	-0.063	1.000	0.017	0.108	-0.032	-0.080	0.046	0.114	0.262	0.083	-0.002	-0.003	-0.039
No. of hands	0.389	0.194	0.010	0.173	0.141	0.017	1.000	0.450	-0.230	0.320	0.037	-0.037	0.013	-0.260	0.204	0.245	0.290
Total fingers	0.429	0.098	-0.097	0.096	0.034	0.108	0.450	1.000	-0.029	0.297	0.247	-0.085	0.034	-0.227	0.441	0.394	0.408
D-finger weight	-0.072	-0.097	-0.105	-0.049	-0.104	-0.032	-0.230	-0.029	1.000	-0.127	-0.224	0.113	0.178	0.156	-0.248	0.089	-0.179
Pseudo stem weight	0.609	0.391	0.111	0.290	0.244	-0.080	0.320	0.297	-0.127	1.000	0.395	-0.067	0.284	-0.325	0.659	0.756	0.927
Leaf weight	0.079	-0.072	-0.205	-0.121	-0.169	0.046	0.037	0.247	-0.224	0.395	1.000	-0.165	0.508	-0.220	0.536	0.430	0.538
Peduncle weight	0.142	0.302	0.232	0.250	0.283	0.114	-0.037	-0.085	0.113	-0.067	-0.165	1.000	-0.004	-0.146	-0.153	0.174	-0.090
Male bud weight	0.014	0.146	-0.114	-0.032	-0.080	0.262	0.013	0.034	0.178	0.284	0.502	-0.004	1.000	-0.3946	0.240	0.491	0.338
Peduncle length	-0.405	-0.405	0.029	-0.024	-0.004	0.086	-0.260	-0.227	0.156	-0.325	-0.220	-0.146	-0.3946	1.000	0.035	-0.377	-0.206
Rhizome weight	0.354	0.137	0.054	0.190	0.165	-0.002	0.204	0.441	-0.248	0.659	0.536	0.153	0.240	0.035	1.000	0.555	0.886
Yield	0.633	0.440	0.111	0.376	0.303	-0.003	0.245	0.394	0.089	0.756	0.430	0.174	0.491	-0.377	0.555	1.000	0.777
Total biomass	0.553	0.315	0.088	0.276	0.230	-0.009	0.290	0.408	-0.179	0.927	0.538	-0.090	0.338	-0.206	0.886	0.777	1.000

Another significant aspect of the relationships in the light of comparative evaluation of the treatments is the inadequacy of mere correlation studies. Comparative evaluation of the rate of growth of the crop in the first and second trials in the early stages indicated that the first crop with lower yield had manifested a higher vigour and accelerated growth than the latter. At the fourth month stage, all the growth attributes studied were higher in the first crop, but it failed to develop positive correlation. This has been due to the fact that the crop failed to maintain the rate of growth subsequently as against the accelerated growth in the second crop. These results would suggest that process evaluation is more critical and important than observations at any particular period especially at early stages.

A deep probing into the causes of failure in the first year to maintain the accelerated growth point out to the concentration stress of nutrient inputs. First crop had received a mean higher levels of nutrients than the second one, where as moisture receipt in the early period of pre-beginning irrigation had been the same. In the irrigated period, water receipt had been 33 per cent higher. Thus, the first crop had been subjected to a higher concentration stress, which might have been harmful. Any organism tends to reproduce early before succumbing to fatal stress. Here also the earliness of 33 days in bunching appears to be the sign of concentration stress. Thus, early-accelerated growth appears to be not a sign of positive growth, but stress effect, which inturn had led to unco-ordinated growth and poor yield. A combined quantitative and qualitative progressive analysis alone shall serve the purpose of differentiating between productive growth and stress expression.

Yield ultimately is the product of contributing components. In banana they are the number of hands, number of fingers per hand and mean finger weight. Number of hands and fingers are decided well before bunching whereas finger weight being a twin function of post-bunching photosynthesis and translocation, as well as translocation from pseudostem. Yield in banana can be viewed as a product of phasic co-ordination of growth. The result that only number of fingers alone were related to yield in the second crop is proof of inhibition of photosynthesis at initiation phase as well as translocation in the post-bunching phase.

The number of hands and fingers in the floral bud initiated early is naturally decided by the metabolic activity within the bud before emergence. The number of hands and fingers that ultimately develop into female flowers is by availability of required inputs at the progressive floral sheaths (bracts). A big floral bud is indicative of more hands, fingers, and yield, which is demonstrated by the significant positive correlation of the male bud. However, absence of any relationship with number of hands and fingers with the male bud is indicative of some specific differences immediately on and after primary differentiation. This again appears to be a stress as is evidenced by the highest correlation coefficient of 0.76 for pseudostem weight with yield, but a marginal relationship to hands and fingers. As against this, the male bud in the first crop had shown a negative relationship with yield. The relationship tended to be negative with number of fingers with variably no relationship to hands. In the context of performance of the second crop, data would suggest that differentiation of floral primordia itself was hindered in the first crop while only differentiation with the early bracts was affected in the second year. Thus, the first crop appeared to be subjected to two stress viz. input availability for primary differentiation followed by the development within the bract.

Distorted development is also brought forth by the significant correlation of leaf weight with yield with a tendency for negative relationship of leaf weight with D-finger weight. Leaves at harvest virtually can have no relationship with number of hands and hence it could be termed spurious. The trend of negative relationship of leaf weight with finger weight can only be an index of inhibited translocation to the bunch from leaves, which inturn would suggest presence of possible physical hindrance. The significant relationship possibly is only a reflection of vegetative growth and yield.

One of the most significant observations in the study has been the positive relationship of pseudostem weight with yield but its significantly negative relationship with peduncle length. Strong negative tendency in the relationships of number of hands and number of fingers with peduncle length suggested that, differentiation of hands and fingers were affected due to inhibited use of energy sources for the development of hands and fingers in them which lead to elongation of peduncle or vice versa.

The significant negative relationship of height and girth during 4 MAP with peduncle length suggested that increase in peduncle length was the resultant of inhibited growth and development. The increase in peduncle length itself was abnormal sign of growth, as it was not related with weight of the same. Thus, it was an enforced elongation of unit mass of material, which increase volume only. This could only have been to dilute the unfavourable components in unit mass of material. This would indirectly mean that the negative relationship between pseudostem weight and peduncle length further confirms the involvement of suppressing effects. Morphologically lanky and thin sheaths coupled with failure of area expansion of individual leaves shall be the sign of physiological inhibition.

The only negative relationship found in the growth attributes to total biomass further confirm this.

Absence of significant correlation of height or girth to yield in the first crop would suggest that cell elongation was not sufficient enough to dilute the unfavourable influences restricting yield in the first crop. The only relationship of significance of biomass to yield would suggest that expressed yield was merely a stress expression.

Significant relationship of plant height during 4 MAP with yield in the second year can be considered to be through dilution of factors responsible for lankiness and thin sheaths, thereby increasing the pseudostem weight which positively aided hands and finger development. The trend for negative relationship of peduncle length with peduncle weight and the most dominant role of girth of the plant favouring peduncle weight would suggest that girth at early stages can also serve as an equally efficient index for management. More over the data showed that girth and height together have shown positive relationship to all attributes showing positive relationship to yield. More over the two together shall represent balanced growth.

Observations individually of these attributes cannot serve, as indices for management as the comparative evaluation of the data on the two crops will show. Balanced growth does not include elongation enforced by unfavourable factors, though elongation shall be accelerating height, weight etc. Balanced growth is progressional, proportionate development and high yields would appear to be a product of balanced growth. The data would suggest that combined height and girth and their balance shall be the best index of balanced growth. Influence of varying nutritional and moisture regimes as well as other factors on productivity shall only be enhancing or degrading this balanced growth.

5.1.3.2 Productivity and nutrient interrelation

A critical and detailed evaluation of the direct and indirect effects of elements will help to explain yield forming or yield negating processes inside the plant. A perusal of the data on path coefficient of foliar content of nutrients during different growth stages showed that the plant content per se is not the contributing factor, but the indirect effect of one element on the activity of other element also influence the yield.

In the first year at 4 MAP (Table 5.3), nitrogen had a positive direct effect, but suppressed by P apparently and incipiently by other elements. P had a pronounced effect on suppressing response for N, which was counteracted by Fe. Ca by itself had a positive effect on crop, but the effect was suppressed by Mg and Fe and to some extent by Zn. Thus, native contents of elements were tending to suppress the possible positive effect Ca would have exerted. Effect of absorbed Mg consequent of native contents itself was negative and was enhanced by P and Zn apparently. The positive effect of Ca, however, tended to minimize the Mg effect.

The significant negative influence of Fe was evident from its direct effects, which however, was actually enhanced by N, but was counteracted by P and Ca. However, the negative effect of Ca and P could not be suppressed substantially leading to negative significant effect of Fe affecting crop production to the end. Fe also contributed in enhancing the harmful effect of Mn, though it did not reach significant levels.

The direct and indirect effects of elements in the second year (Table 5.4) had been profoundly different from the first year. However, the second crop registered apparently lower levels of P, Ca, Mg, Fe and Mn. Cu and Zn remained not materially affected, whereas N has shown an increase. Thus, the changes in results appeared to be due to increase in N and decrease in other elements.

Thus the effect of reduced P content, transformed its effect positively to a higher content of nitrogen. In spite of a reduction in direct N effect, P retained an effect on N whose value is of almost the same level as its direct effect. The reduced

Table 5.3. Direct and indirect effects of foliar content of different elements at 4 MAP on yield in the first year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	0.2552	-0.1043	-0.0045	-0.0619	0.0163	0.2958	0.0056	-0.0011	0.0103	0.4080
P	0.1164	-0.2258	-0.0044	-0.0222	-0.0156	0.2475	0.0038	-0.0062	-0.0325	0.0611
K	0.0689	-0.0603	-0.0164	-0.1075	0.0600	0.0448	0.0002	0.0006	0.0337	0.0240
Ca	-0.0431	0.0138	0.0049	0.3619	-0.1393	-0.1484	-0.0009	0.0007	-0.0982	-0.0486
Mg	-0.0230	-0.0198	0.0055	0.2831	-0.1781	-0.0510	0.0032	0.0009	-0.0971	-0.0762
Fe	-0.1692	0.1268	0.0017	0.1219	-0.0206	-0.4407	-0.0088	0.0018	-0.0097	-0.3969
Mn	0.0531	-0.0319	-0.0001	-0.0116	-0.0212	0.1455	0.0266	-0.003	-0.0167	0.1434
Cu	0.0145	-0.0753	0.005	-0.0135	0.0088	0.0434	0.0004	-0.0185	-0.0261	-0.0658
Zn	-0.0166	-0.0472	0.0035	0.2286	-0.1112	-0.0274	0.0029	-0.0031	-0.1555	-0.0126

$R^2 = 0.7157$

Table 5.4. Direct and indirect effects of foliar content of different elements at 4 MAP on yield in the second year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	0.1297	0.1488	0.0197	-0.0016	0.0772	0.0012	0.0539	-0.0124	-0.0058	0.4107
P	0.0446	0.4322	0.0060	-0.0171	0.0113	-0.0014	0.0148	0.0324	-0.0084	0.5145
K	0.0281	0.0285	0.0909	-0.0221	-0.0059	0.0092	0.0507	0.0043	0.0046	0.1883
Ca	0.0005	0.0175	0.0048	-0.4207	-0.0922	-0.0118	0.0740	0.0896	-0.0159	-0.3542
Mg	-0.0452	-0.0220	0.0024	-0.1749	-0.2217	-0.0180	-0.0362	0.0275	-0.0031	-0.4913
Fe	-0.0026	0.0102	-0.0138	-0.0823	-0.0659	-0.0606	0.0071	0.0449	0.0016	-0.1613
Mn	0.0453	0.0416	0.0298	-0.2018	0.0521	-0.0028	0.1542	0.0454	-0.0074	0.1565
Cu	-0.0051	0.0443	0.0012	-0.1194	-0.0193	-0.0086	0.0222	0.3158	0.0003	0.2314
Zn	-0.0126	-0.0607	0.0070	0.1113	0.0114	-0.0016	-0.0191	0.0014	0.0600	0.0971

$R^2 = 0.3365$

P content similarly transformed the direct effect of P to almost double fold (-2 to +4); which transformed the value recording the highest correlation coefficient of 0.51 in the data. Contrary to this, the reduction in calcium had increased its effect to the negative side. This had negatively affected the crop almost independently and directly. The similar trend is applicable in case of Mg. Elements like Ca, Fe and Mn. further enhanced the harmful effect of Mg. Thus a situation of reduced Ca, Mg and Fe content had a significant influence on Cu. It can be seen that a comparative perusal of data on Ca on first year and second year at 4 MAP testify that the direct effect of an element at the same level can be both positive and negative which is a function of the other elements.

A perusal of the data on path coefficient of foliar content of nutrient on 5 MAP in the first year (Table 5.5) showed that N, K and Ca had direct positive effects and P, Mn, Cu and Zn had exerted direct negative effects. Mn had exerted an indirect negative effect on N. The same trend was manifested by Ca, Zn, P and Cu in that order, though the positive direct effect of N could not be suppressed. On the contrary, the negative direct effect of P was supplemented by indirect effects of Mn, Cu, Zn and Ca. The positive indirect effect of N on P which was more than that of the direct effect of P could not nullify the negative net effects of P. Potassium had manifested a significant positive direct effect which was marginalised by the combined negative influences of other elements especially Ca.

The data will further show that the positive direct effect of Ca was neutralised by the negative effect of Mg as the positive and negative effects of both

Table 5.5. Direct and indirect effects of foliar content of different elements at 5 MAP on yield in the first year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	0.3194	-0.0599	0.0236	-0.0795	0.0769	0.0090	-0.1306	-0.0409	-0.0621	0.0559
P	0.1618	-0.1183	0.0644	-0.0370	0.0239	0.0099	-0.1818	-0.0568	-0.0489	-0.1827
K	0.0247	-0.0250	0.3053	-0.1154	0.0361	0.0044	-0.0282	0.0087	-0.0160	0.1945
Ca	-0.0714	0.0123	-0.0991	0.3555	-0.3254	-0.0061	0.0734	0.0234	0.0020	-0.0354
Mg	-0.0534	0.0062	-0.0239	0.2515	-0.4599	0.0011	0.0651	0.0053	-0.0311	-0.2392
Fe	0.0968	0.0397	0.0454	-0.0728	-0.0173	0.0296	-0.0702	-0.0187	-0.0428	-0.0897
Mn	0.1793	-0.0925	0.0370	-0.112	0.1287	0.0089	-0.2326	-0.0546	-0.0391	-0.1771
Cu	0.0988	-0.0508	-0.0201	-0.0630	0.0185	0.0042	-0.0961	-0.1322	-0.0813	-0.3219
Zn	0.1350	-0.0394	0.0332	-0.0048	-0.0974	0.0086	-0.0620	-0.0732	-0.1469	-0.2469

$R^2 = 0.6864$

Table 5.6. Direct and indirect effects of foliar content of different elements at 5 MAP on yield in the second year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	0.1769	0.1547	0.1983	-0.0118	0.0675	-0.231	-0.0331	0.0009	-0.0228	0.5074
P	0.0823	0.3325	0.1350	-0.0107	0.0434	-0.0130	-0.0223	0.0012	-0.1068	0.4416
K	0.0934	0.1195	0.3758	0.0080	0.0918	-0.0163	-0.0189	0.0171	0.0109	0.6814
Ca	0.0265	0.0452	-0.0384	-0.0787	-0.0652	0.0587	-0.0302	0.0120	-0.1169	-0.1871
Mg	-0.0622	-0.0753	-0.1800	-0.0268	-0.1918	0.0378	0.0256	-0.0058	-0.0263	-0.5046
Fe	-0.0335	-0.0353	-0.0502	-0.0379	-0.0594	0.1220	-0.0089	0.0048	-0.0425	-0.1409
Mn	0.0948	0.1201	0.1151	-0.0385	0.0796	0.0177	-0.0618	0.0223	-0.0845	0.2647
Cu	0.0015	0.0040	0.0628	-0.0092	0.0108	0.0057	-0.0134	0.1026	-0.0087	0.1560
Zn	0.0203	0.1790	-0.0207	-0.0463	-0.0254	0.0261	-0.0263	0.0045	-0.1985	-0.0872

$R^2 = 0.3961$

these elements were in the same magnitude. However, the potentiality of Ca to nullify Mg was low, which led to a significant net negative effect of Mg. The pronounced negative direct effect of Mn followed Mg in magnitude. Indirect effect of Ca and Mg were of the same magnitude and opposite in nature, ultimately leaving net Mn effect curtailed mainly by nitrogen. A significant observation on the direct and indirect effects of Cu and Zn had been their complementarity. The net effect of both these elements assumed significant levels primarily through their complementary effects.

A perusal of the data of the second year (Table 5.6), will show that the nature, pattern and extent of direct and indirect effects of foliar contents of elements was different in the second crop possibly due to dilutionary effects, on nutrients applied. This had brought in variations in the contents per se of the elements as well as in their direct and indirect effects.

An increase in the level of nitrogen in the tissue with a corresponding decrease in P, Ca, Mg and Mn can be seen to have altered the net effect of nitrogen. The reduced level of P converted the negative trend of P effect on nitrogen to positive and of comparable magnitude to the direct effect of nitrogen itself. Similarly the negative influence of Ca, Mn and Zn waned leading to a significant positive effect of N. On the other hand, a decreased P content made its direct effect significantly positive, which was enhanced by indirect negative effects of all other elements except Zn. A similar trend was observed in the case of potassium evidently due to its increased per se content as well as due to reduced net indirect negative effects of Ca and marginally enhanced effects of Mg. Observations on direct and indirect effects of Ca showed that Zn exerts a significant negative influence on Ca at its lower contents. A reduction in Mg content has only contributed to enhancement of its net negative effect, evidently through the enhancement mainly of K. A perusal of data on Fe will show that the positive effect of Fe was nullified by applied elements and the negative effect of Fe was the effect of other non-applied elements. The mere significant effect of Mn at reduced level of its content has been not due to its positive effect but due to the positive effects of applied elements facilitated probably through their metabolic release. The data on direct and indirect effects of Cu and Zn, the contents of which were < 20 ppm and remained unaffected by dilution has been positively influenced by other elements especially by K in the case of Cu and P in the case of Zn.

The path coefficient analysis of direct and indirect effects at 6 MAP of the first year (Table5.7) showed a drastic variation in the effect of elements on growth, both in their direct and indirect effects. Increase in N and P contents during 6 MAP, tended to reflect in the net effects, which was mainly a reflection of their direct effects. The direct effect of P was comparatively less than that of indirect effect of N on it. However, an increase in K had reduced the direct effect of this element. The increased contents of applied elements were found reducing the net negative effects of Ca and Mg possibly through the neutralisation effect of Ca and Mg.

Table 5.7. Direct and indirect effects of foliar content of different elements at 6 MAP on yield in the first year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	-0.6143	0.0733	-0.0413	0.0524	-0.1283	-0.0281	-0.0709	0.1243	-0.1313	0.4644
P	0.2539	0.1774	-0.0394	0.1363	-0.1409	-0.0422	-0.0266	0.1256	-0.1458	0.2984
K	-0.2236	-0.0617	0.1135	0.1391	0.1703	0.0311	0.0127	0.0294	-0.0003	-0.0677
Ca	0.0811	0.0610	-0.0398	0.3968	-0.2513	-0.0418	0.0230	0.0649	-0.1366	0.1573
Mg	0.2035	0.0646	-0.0499	0.2575	-0.3872	-0.0631	0.0249	0.0818	-0.1226	0.0095
Fe	0.1526	0.0662	-0.0313	0.1467	-0.2163	-0.1129	0.0233	0.0474	-0.1178	-00422
Mn	0.3731	0.0404	-0.0124	-0.787	0.0824	0.0225	-0.1168	0.0824	-0.0334	0.3604
Cu	0.2390	0.0697	0.0104	0.0806	-0.0991	-0.0168	-0.0303	0.3195	-0.1839	0.3891
Zn	0.2599	0.0833	0.001	0.1746	-0.1528	-0.0429	-0.0126	0.1893	-0.3104	0.1885

$R^2 = 0.5822$

Table 5.8. Direct and indirect effects of foliar content of different elements at 6 MAP on yield in the second year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	0.3454	0.0066	0.0059	-0.0118	-0.0054	0.0237	-0.0030	0.0023	0.0019	0.3656
P	0.0095	0.2418	0.0207	0.0020	0.0281	-0.0518	-0.0042	-0.0408	-0.0046	0.2007
K	0.0405	0.0989	0.0507	-0.009	0.0448	-0.1178	-0.0052	-0.0263	-0.0119	0.0728
Ca	0.0719	-0.0086	0.0008	-0.0569	-0.0470	-0.0709	-0.0050	0.0106	-0.0102	-0.1154
Mg	0.0097	-0.0354	-0.0118	-0.0139	-0.1920	-0.1506	0.0052	0.0194	0.0021	-0.3674
Fe	-0.0215	0.0330	0.0157	-0.0106	-0.0761	-0.3801	-0.0012	0.0060	-0.0096	-04445
Mn	0.0741	0.0735	0.0190	-0.0206	0.0717	-0.0327	-0.0139	-0.0424	-0.0190	0.1098
Cu	-0.0073	0.0896	0.0121	0.0055	0.0339	0.0206	-0.0053	-0.1100	-0.0095	0.0296
Zn	-0.0205	0.0352	0.0190	-0.0183	0.0126	-0.1152	-0.0083	-0.0331	-0.0317	-0.1605

$R^2 = 0.5751$

It can also be seen that the N and P effects on Fe, Mn, Cu and Zn had turned the net effects of these elements that too in favourable terms.

The characteristic feature of the path coefficients presented in Table 5.8 for 6 MAP of second year has again been the reflection of direct effects of N and P and marginally of K in the net effect as well as the net negative effect of Ca, Mg and Fe which had been virtually the sum total of synergistic as well as direct influence of these elements between them.

The observation during the seventh month (Table 5.9) had largely been in tune with the results in the previous month where the negative effects of native elements had either tended to disappear or disappeared already. Effect of P was the most conspicuous during the first year when the direct effect of P was almost as such available in the net effect. The net effect of Mn, which was significant, turned to be positive at this level possibly because of its own direct effect. The same was the case with Zn, while that of Cu was a reflection of the effect of P. The overall positive trend in the direct and indirect effect of P, possibly points to an absolute necessity of its availability in the period.

The data in the second year (Table 5.10) further confirmed the waning down of indirect effect of elements towards the seven month and onwards. The indirect influence of all elements excepting the interactions between Fe, Ca, Mg and Mn, other effects were virtually non-existent with direct effect, becoming more evident. Thus N, P, K and Ca showed positive direct effects with P and Ca assuming significant effects. The direct effects of N was enhanced by P, K and Ca

Table 5.9. Direct and indirect effects of foliar content of different elements at 7 MAP on yield in the first year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	-0.0338	0.0522	0.0044	0.0212	0.0364	0.0001	0.1457	-0.0017	-0.0020	0.2225
P	-0.0062	0.2835	-0.0042	-0.0034	0.0671	0.0026	-0.0606	-0.0244	-0.004	0.2541
K	0.0012	0.0097	-0.1219	-0.0268	-0.0095	-0.0047	0.0691	-0.0092	0.0361	-0.0559
Ca	-0.0127	-0.0170	0.0577	0.0566	0.0271	-0.0019	-0.0594	0.0064	-0.0185	0.0383
Mg	-0.0073	0.1132	0.0069	0.0091	0.1679	0.0007	-0.0913	-0.0148	-0.0236	0.1609
Fe	0.0001	-0.0365	-0.0278	0.0054	-0.0060	0.0205	-0.0191	0.0014	-0.0075	-0.1105
Mn	-0.011	-0.0386	-0.0189	-0.0076	-0.0345	0.0009	0.4444	-0.0041	0.0254	0.3560
Cu	-0.0013	0.1540	-0.0250	-0.0082	0.0554	0.0007	0.0403	-0.0449	0.0154	0.1865
Zn	0.0006	-0.0010	-0.0417	-0.0099	-0.0375	-0.0015	0.1071	-0.0066	0.1055	0.1179

$R^2 = 0.7349$

Table 5.10. Direct and indirect effects of foliar content of different elements at 7 MAP on yield in the second year

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	r
N	0.2036	0.0688	0.0199	0.0761	0.1444	0.0131	-0.1956	0.0021	-0.0157	0.3166
P	0.0407	0.3445	0.0466	-0.0199	-0.0236	0.0111	-0.0492	-0.0009	-0.0019	0.3473
K	0.0174	0.0688	0.2335	0.0103	0.1189	0.0202	-0.2204	0.0006	-0.0260	0.2752
Ca	0.375	-0.0166	0.0068	0.4135	-0.1580	-0.0119	0.0582	-0.0001	-0.0125	0.3158
Mg	-0.0654	0.0181	-0.0618	0.1454	-0.4493	-0.0170	0.2942	-0.0015	0.0212	-0.1251
Fe	0.0325	0.0468	0.0575	-0.0602	0.0930	0.0819	-0.0483	0.0017	-0.0031	-0.2019
Mn	0.0860	0.0366	0.1110	-0.0519	0.2853	0.0085	-0.4634	0.0049	0.0338	0.0509
Cu	0.0424	-0.0314	0.0142	-0.0059	0.0686	0.0139	-0.2284	0.0099	0.0166	-0.1002
Zn	-0.0326	-0.0068	0.0618	-0.0526	-0.0553	-0.0026	-0.1594	0.0017	0.0983	-0.1476

$R^2 = 0.5873$

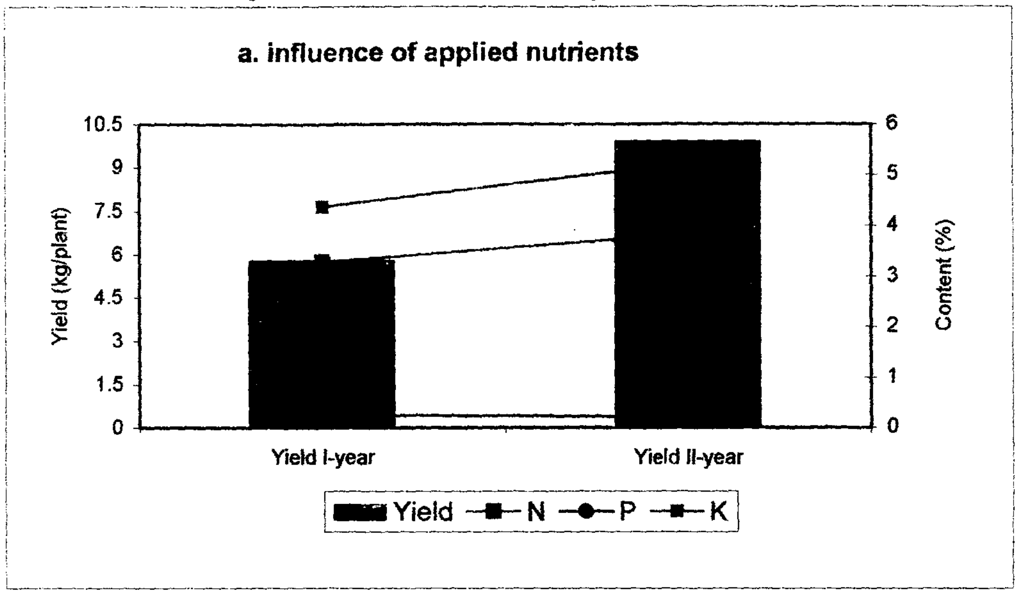
while that of K was influenced by N and P. However, Mg and Mn tended to react in opposite ways and the Mg effect nullifying Mn effect to almost 50 per cent.

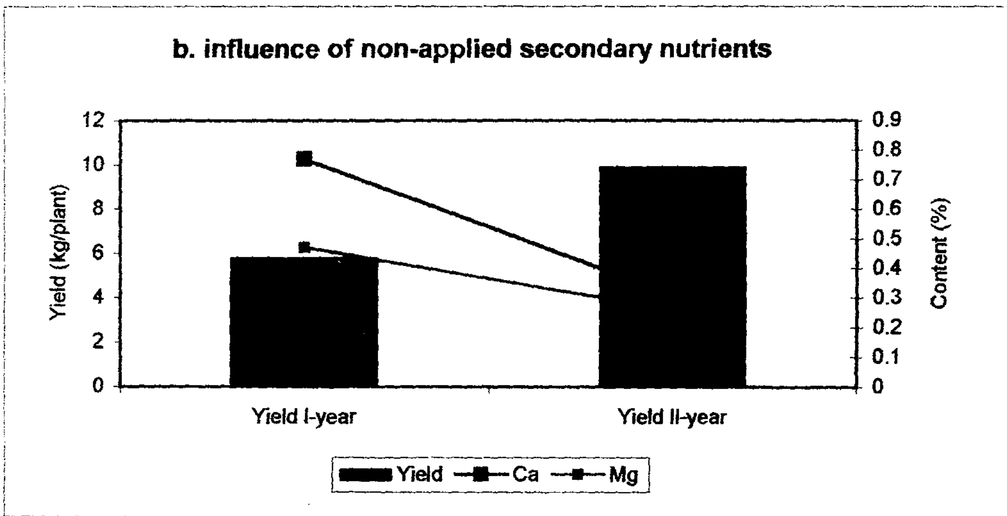
Data on the mean foliar contents of nutrients at different stages of growth proves that the higher yield in the second year was associated with a decrease in the foliar content of native non-applied elements but an increase in the content of applied elements like N and K (Fig. 5.3). This indicated that yield at any instance is not the resultant of the applied major elements alone but is the net product of interaction of applied as well as native non-applied elements. Native non applied elements absorbed by the plant though are essential, exceed the levels of the actual metabolic requirement and turn harmful to growth and may be capable of even suppressing the positive effects of the applied elements (Bridgit, 1999). So more than the content of individual elements, it is the net effect that affects the yield.

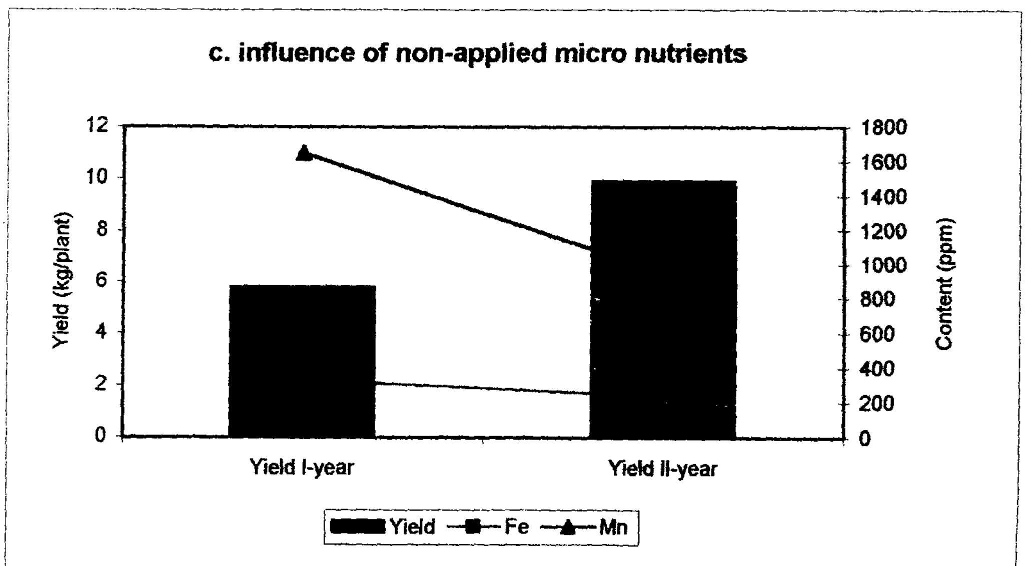
The crop in the second year had actually received a smaller quantity of total fertilizer input (25 to 200 per cent) instead of 50 to 250 per cent in the first year), but had resulted in a higher mean foliar content of N and K at 4 MAP and 5 MAP. This would mean that input level need not necessarily be an index of foliar content.

The total uptake of nutrients at harvest as in the case of mean content also shows that a higher application of fertilizer could result in an uptake of native non-applied elements in excess and turn harmful. Also a higher uptake of K in the second year, where a lesser quantity of fertilizer was applied, suggest that uptake

Fig. 5.3. Influence of leaf elemental composition at 4MAP on yield improvement during second year







of elements is not merely linked to the input levels alone, but some other factors as well. It would appear that the most important of these factors is the variation in soil reactivity. Observation showed that pH of the solution (Table 5.11) was very low, which was sufficient enough to disintegrate the clay lattice to its component silicates and alumina. Another significant observation was that the content and uptake of different elements varied independently which meant that magnitude of influence of different elements would be different.

Table 5.11. pH of fertilizer solutions

Urea	–	9.05
Single super phosphate	–	2.25
Muriate of Potash	–	8.5
Urea + SSP + MOP	–	2.5
NPK solution at D_6 concentration	–	2.7
NPK solution at D_{24} concentration	–	3.4

It can be noticed that though we had applied, on an average 165 g and 115 g P in the first year and second year respectively, the crop had taken up only 5 g of phosphorus, including the share from the soil. This suggests that the application of phosphorus was very much higher than that was required. Similar is the case of nitrogen fertilization also. The uptake and use efficiency of N also was very less. Since SSP is the major source of acidity, with urea serving as the latent source, reducing the quantity of these fertilizers could reduce the ill-effects of soil reactivity and thereby reduce the release of native non-applied elements.

Direct and indirect effects of foliar content of component elements on yield (Table 5.3) showed that in the first year at 4 MAP foliar N content had positive and significant correlation to yield and Fe content had significant negative effect. As the crop reached 5 MAP Mn, Cu and Zn also exerted direct negative effects. In addition, Mn had exerted an indirect negative effect on N. The direct negative effect of P was also supplemented by Mn. Thus at the range of 4.53 to 7.0 kg $plant^{-1}$ yield in the first year, the beneficial effect of N was overshadowed by Fe and Mn; and these elements became the major yield limiting factors. The differences in the elemental composition of different plant parts at harvest in the second year from that in the first year (Table 5.12), especially that of peduncle further confirms this contention. In peduncle N, P and K contents increased in the second year, while all non-applied elements decreased considerably.

Table 5.12. Mean difference in the elemental composition of different plant parts in the second year from that in the first year

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
Rhizome	-0.09	-0.053	-0.18	-0.15	-0.308	-992	-276	-4.3	-12.09
Root	+0.07	-	-3.01	-0.21	-0.082	+57	-48	-7.48	+6.55
Pseudostem	-0.407	-0.052	-0.53	+0.05	-0.17	-75.3	-13	-11.21	+9.13
Peduncle	+0.21	+0.042	+0.61	-0.044	-0.036	-79.0	-625.7	-12.09	-1.39
Fruit	+0.25	+0.026	+0.45	-	-0.019	-5.0	-103.0	-0.26	-0.21
Male bud	0.34	+0.095	+1.626	+0.026	+0.031	-87.7	-316.3	+2.12	+2.22

Interrelationship and variation tendencies on the content of Fe in leaf at 4 MAP, peduncle and yield manifested in the two years will show that

between Fe in leaf and Fe in peduncle $r = +0.293$ and

between Fe in penducle and yield $r = -0.391$.

This suggests that increasing Fe content in leaf will lead to its accumulation in the peduncle as well as a reduction in the yield. These results imply that peduncle is the seat of accumulation of excess contents of elements absorbed by the plant in the early stages, a reduction of which in turn will lead to high productivity. These results thus indicate that a management technology to reduce the Fe content in the leaf will automatically lead to a reduction in Fe in peduncle on one hand and increase in the yield of fruit on the other. Thus the Fe content in the peduncle becomes an indirect expression of realised yield in banana. As such yield projections can be worked out based on the Fe content in the peduncle. The data in the present study indicated that a 20 kg fruit yield is possible if the Fe content in the leaf at 4 MAP could be brought down to 128 ppm.

In the second year, a decrease in the content of Fe by 28 per cent from that in the first year, decreased its negative effect on yield and Ca and Mg became the major yield limiting factors. The significant negative effects of Ca and Mg on productivity are indirect indices that an ameliorative management system to further reduce Ca and Mg content shall increase the yield further. The fact that a higher content of N and K in the foliage of the second crop resulted simply by dilution of nutrients in fertigation suggest that fertigation may tend to improve the N content further and reduce Mg and there by calcium content. Besides Ca and Mg were reduced more on dilution and this would suggest that mere dilution alone can mitigate Ca and Mg effects and increase yield further.

Thus the overall results from the point of view of yield indicated that low realised yield levels at present has not been due to inadequacy of applied levels of major nutrients, but due to the high level of absorption of native non applied elements which interfere with production and efficient input use. Mainly these are Fe, Ca and Mg in that order with excess Fe limiting the yield below 6.0 kg $plant^{-1}$ and Ca and Mg limiting it below 10.0 kg $plant^{-1}$. The harmful effects of these elements shall be contained by regulatory management system by increasing the frequency of application and reducing the quantity of fertilizer application.

5.2 Experiment 2

Effect of three methods of irrigation and fertilizer application viz., surface drip fertigation, subsurface drip fertigation and conventional basin irrigation and fertilizer application on growth and yield of banana was studied in this experiment. The different levels of irrigation of 8, 12 and 16 l day^{-1} in the first year were changed to quantities based on daily pan evaporation. At the highest pan evaporation of 9.4 mm. the quantity of water applied at I_{100} was 38 l $plant^{-1}$ which was 22 litres higher than that in the first year. Thus, the differences in the quantity of water used at I_{100}, I_{75} and I_{50} were 652, 489 and 326 l $plant^{-1}$ between first year and second year. The fertilizer level was also reduced by 50 per cent, i.e. from 400-230-600 to 200-115-300g NPK per plant per year. Thus, the increase in quantity of water in different irrigation levels and decrease in the quantity of fertilizers together resulted in a lower concentration of nutrients in drip fertigation in the second year. As in the case of experiment 1, in this experiment also, a reduced growth and yield was observed in the first year due to inadequate water supply and consequent greater concentration of nutrients in irrigation water and rhizosphere and the reasons for reduced growth and yield were discussed in detail in Experiment 1. The direct effect of different methods of irrigation and fertilizer application is largely discussed here under.

5.2.1 Effect of methods and levels of irrigation on growth and yield

Good yield is resulted from a balanced growth of plant. The perusal of growth observations recorded in the first year shows that the plants were improportionately taller in the early stages as evident from a higher height/girth ratio of 4.46 as against a favourable 3.41 in the second year where growth and yield was normal.

Different methods and levels of irrigation could not develop any significant effect on growth parameters in the first year. This suggests that the crop, irrespective of the treatments was under severe stress, which affected the crop growth significantly (Plate 3).

Yield and yield attributes also support this contention. The mean yield in the first year was only 6.0kg plant^{-1} with very few number of hands (4.36) and fingers (41.22) with low finger weight (115.65g). Also the length of the peduncle was double (62.08cm) than that obtained in the second year (31.94cm). On the other hand, in the second year, because of dilution of nutrient solution, the mean yield increased to 9.65kg plant^{-1}, with more number of fingers (51.94) having more finger weight (154.77g) (Plate 4). In the first year, among different treatments, the crop performed better, though not prominent, under conventional method of

Plate 3 Influence of nutrient dilution on yield expression in the first year

Irrigation - 12 / day $^{-1}$ plant $^{-1}$; fertilizer - 400 - 230 - 600 g NPK plant^{-1}

a. Surface drip

b. Subsurface drip

c. Conventional basin method

Plate 4 Influence of nutrient dilution on yield expression in the second year

Irrigation - 75 PEC (range 12-28 *l* day^{-1} plant^{-1}); fertilizer - 200 - 115 - 300 g NPK plant^{-1}

a. Surface drip

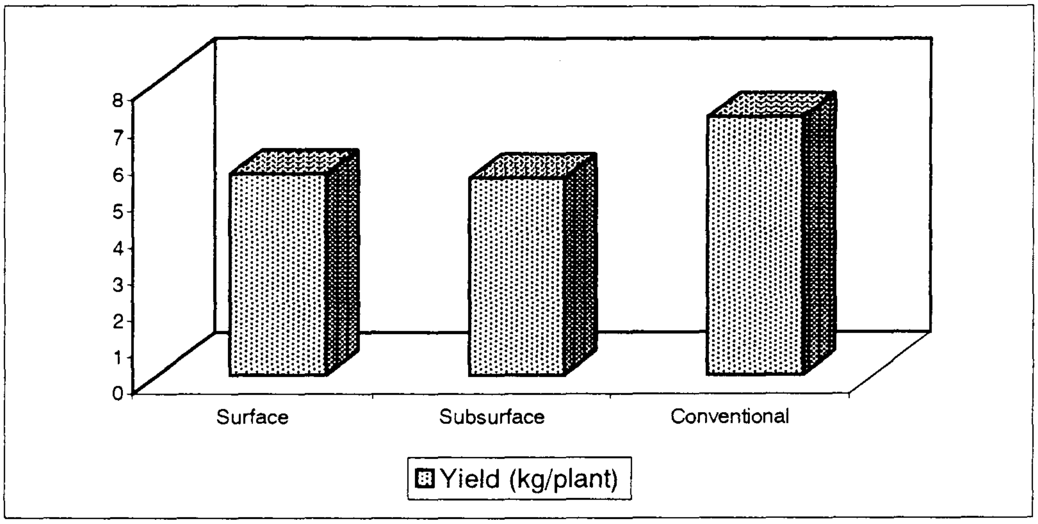
b. Subsurface drip

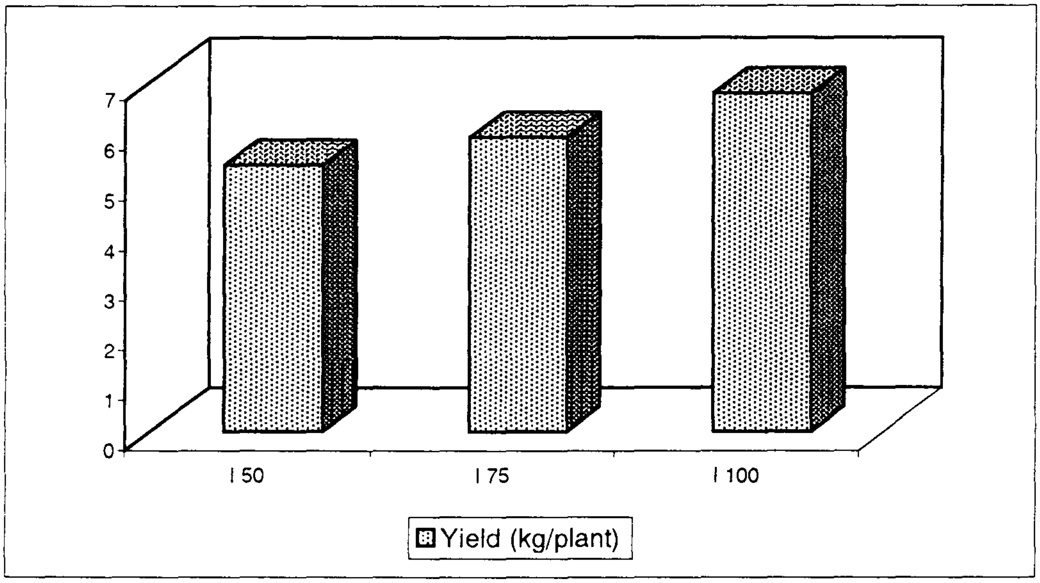
c. Conventional basin method

irrigation and fertilizer application (Fig.5.4). Conventional basin irrigation at 16 l day^{-1} resulted in a higher number of fingers and more finger weight and consequently more (7.06 kg $plant^{-1}$) yield. The length of the peduncle also was comparatively less. Even conventional method at lowest level (CI_{50}) was better than drip fertigation at the highest level though non-significantly (SSI_{100} or SI_{100}). This could be attributed to the low moisture content as presented in Table 4.81 obtained at different points around the plant under surface drip and subsurface drip. The irrigation provided was very low that even 0-30 cm depth of soil below the emitter itself could not be brought to field capacity. The non-applied elements released from the soil could not be leached out beyond rootzone level, resulting in higher absorption of these elements. Low moisture content combined with higher nutrient concentration (F_{200}) could have led to this situation.

In the second year, the response to the treatments was very much pronounced. Subsurface drip irrigation resulted in the highest yield, followed by surface drip (Fig.5.5). Number of hands and number of fingers, though marginally affected, D-finger weight was very much higher under subsurface and surface drip fertigation. Phene (1990) reported higher use efficiency of subsurface drip applied water due to reduced losses of evaporation and surface run off compared to furrow irrigation. Nutrients added to the centre of the root system where water content is relatively high and steady with time could have resulted in a better yield (Phene and Howell, 1984). In this case, apart from minimized losses in these ways, leaching down of undesired native elements and excesses of applied nutrients from the immediate root zone is supposed to have favoured the plant growth and yield.

Fig. 5.4. Effect of methods and levels of irrigation on yied of banana var. Nendran in the first year





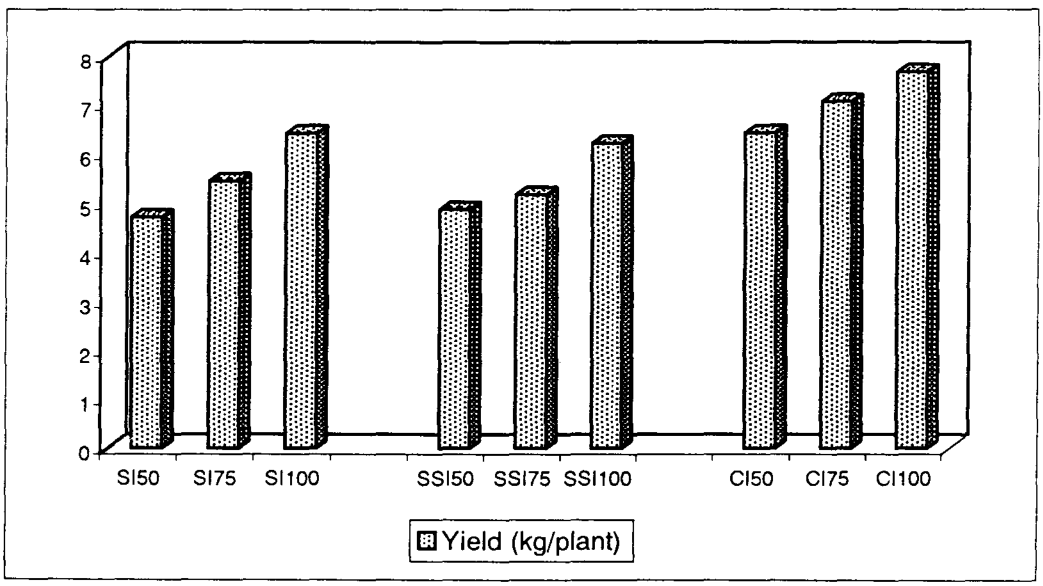
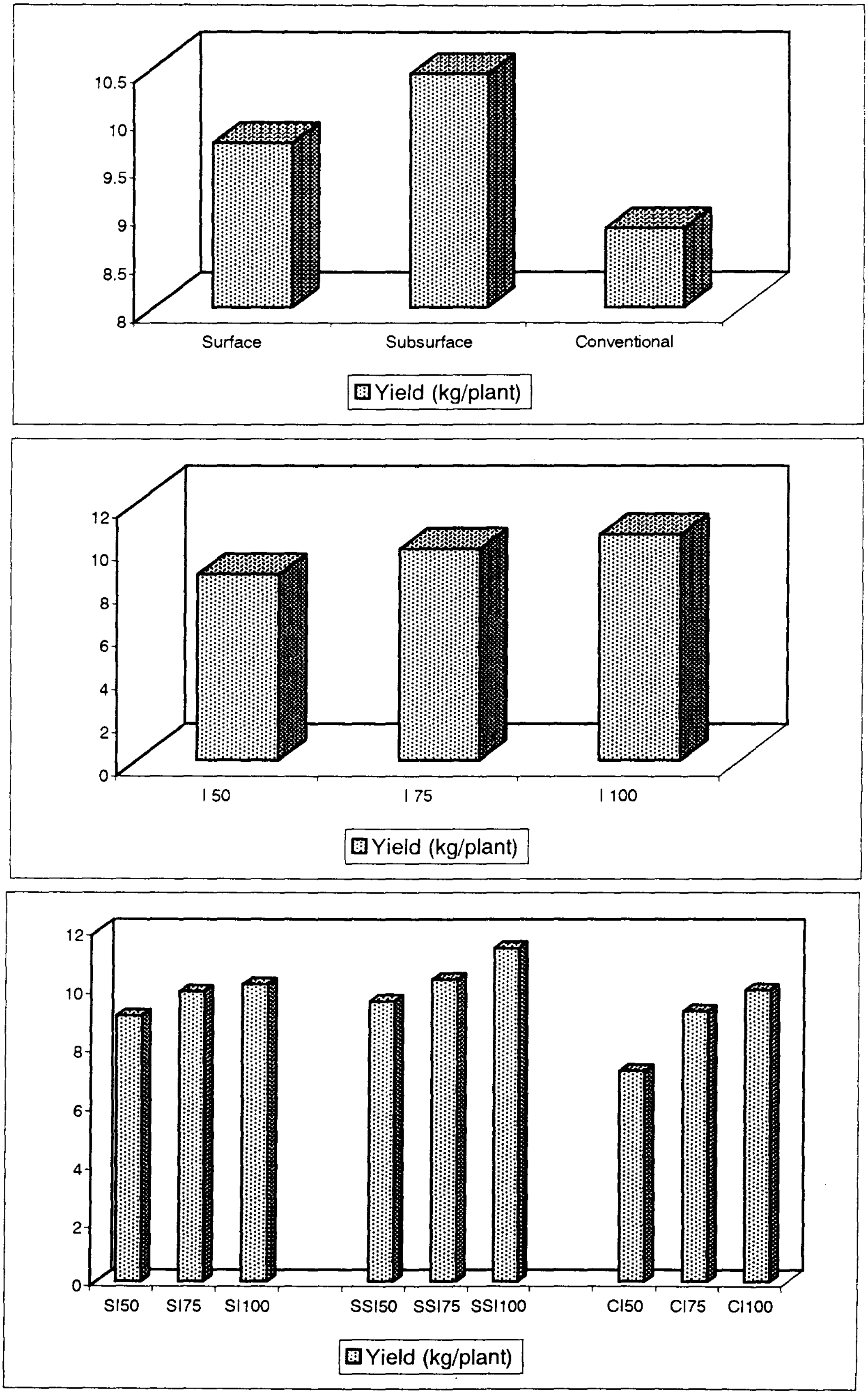


Fig. 5.5. Effect of methods and levels of irrigation on yield of banana var. Nendran in the second year



A shorter peduncle under subsurface followed by surface drip also indicated a higher yield.

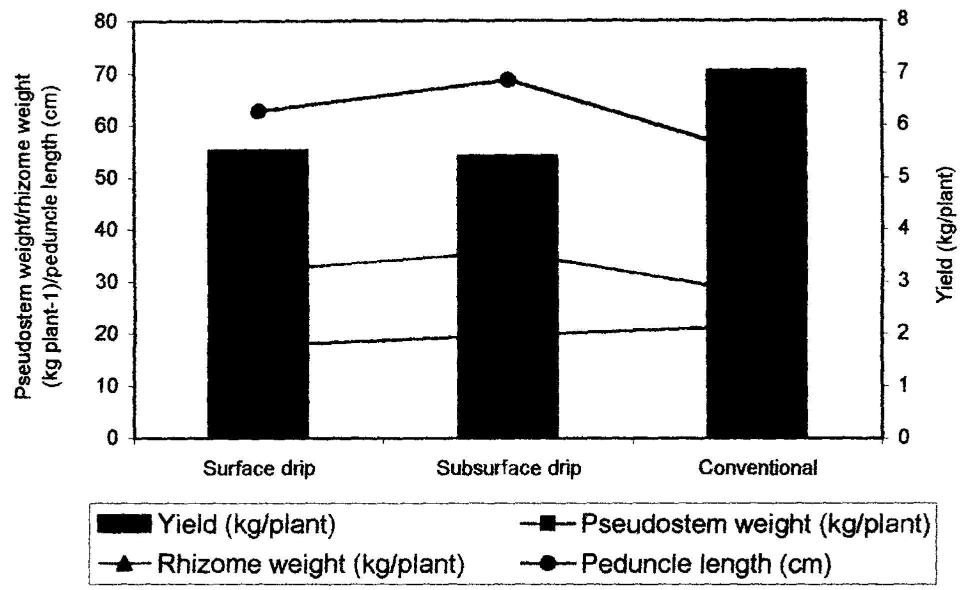
Evaporation compensation at 100 per cent (I_{100}) was found essential to meet the water requirement. Number of fingers and D-finger weight and therefore yield was increased up to I_{100}. Quantity of water applied should include that is required for evapotranspiration and to maintain the nutrient concentration in the soil solution to the desired level.

Surface drip at 75 per cent evaporation compensation (SI_{75}) was comparable with basin irrigation at 100 per cent evaporation compensation suggesting water saving of 25 per cent under drip fertigation. Also subsurface drip at I_{75} (SSI_{75}) was even better than SI_{100} which mean that efficiency of water could still further be increased at the same yield level. But the response to water up to I_{100} even under drip suggests that water requirement for banana is very high and saving in water may negatively affect the yield. As against this, Hegde and Srinivas (1990) could obtain optimum evaporation replenishment at 60 per cent pan evaporation under drip irrigation and Upadhyay (1995) obtained 56 per cent water saving under drip irrigation compared to surface method. However under drip fertigation of NPK where the nutrient concentration being a major factor ameliorating the rhizosphere environment, decreasing the quantity of irrigation may lead to an undesirable change in soil reactivity, resulting in the release of native elements, particularly in acid lateritic soils. Though the total biomass production was more under subsurface drip in the first year, the major share was accumulated in the rhizome, resulting in more suckers. But in the second year, drip fertigation resulted in a higher biomass production with a higher accumulation in pseudostem, bunch and male bud than that in the first year. This could be due to the inhibition of translocation of nutrients upwards through the peduncle resulting in poor yield in the first year. Intercorrelation analysis which showed highly positive correlation for pseudostem weight to yield and negative correlation for rhizome weight during first year, further confirm this result (Fig.5.6).

5.2.2 Effect of methods and levels of irrigation on nutrient content and uptake

The crop in the second year had received only half the dose of fertilizer applied in the first year, but resulted in a higher content of nitrogen and potassium. A comparison of the mean contents of primary nutrients in leaf at 3 to 7 MAP will show a differential concentration in the first year and second year. The N and K contents were higher during second year even with half the dose of nutrients applied in the first year. But at the same time, content of P and native non-applied elements were less. It is to be assumed that the rhizosphere environment was more favourable during second year for larger uptake of N and K and lesser content of P and non-applied elements. Excessive concentration of native elements viz., Ca, Mg, Fe, Mn and Cu is reported to have negative influence on the absorption and utilization of applied elements (Bridgit, 1999). The nutrient content in different parts at harvest also shows that the extent of non-applied elements were less in almost all parts in the second year. Peduncle had considerably lesser content of Mn and Fe in the second year. The enhanced soil reactivity induced by higher nutrient concentration in drip as well as by reduced volume of irrigation water in the first

Fig. 5.6. Interrelations of vegetative characters and yield as influenced by methods of irrigation and fertilizer application



year have caused this phenomenon. This proves that deficiency of major inputs is not the factor that limits productivity, but absorption of native non-applied elements.

Total nutrient uptake of N, P and K was not affected by method of irrigation, but was influenced by the level of irrigation. A higher level of irrigation increased the uptake of N, P and K, but reduced the uptake of native non-applied elements though non significantly (Table 4.79). This could have been due to a higher dilution and also due to leaching of excess elements to below root zone level.

The variations in redox environments caused by variation in irrigation, could have modified the release characteristics and this would have decided the extent of absorption of native elements. Water is the medium for release, uptake and utilization of nutrients. Depending upon the quantity and dilution the nutrient absorption spectrum would have changed.

5.2.3 Rhizosphere moisture distribution

A perusal of the data on the moisture distribution in the 0-60 cm depth four hours after irrigation showed that a higher moisture content was maintained in the conventional method in both the years, and the moisture content was almost uniformly distributed in the surface layers throughout 0-60 cm lateral distance. But both in the surface and subsurface drip, a 50 per cent area (opposite drip zone) recorded a lower moisture content in the 0-30 cm depth due to limited horizontal advance of the wetting front. Under inadequate moisture supply, as occurred in the first year, the moisture content in the non-drip zone was below permanent wilting point. However when water was applied at pan evaporation compensation as in the second year, the wetting zone was increased in area and content of moisture as deduced by a far higher moisture content in the drip zone in the second year. A lower moisture content in the surface drip compared to conventional method in the first year is probably due to the immediate and high evaporation of droplets released from the emitter. In the conventional basin method, large quantity applied in limited time caused less opportunity for high evaporation loss. However, when a higher quantity of water (I_{100}) was provided, the wet 30 *l* x 30 *d* and 30 *l* x 60 *d* zones under surface drip had comparable contents as that of conventional method at I_{100}. Carmi and Plant (1988) also could obtain a higher infiltration only when the evaporation was decreased.

In the subsurface drip water release at 30 cm depth have largely reduced the evaporation loss but a greater downward movement than an upward movement has resulted in lesser moisture content in the upper layer. This observation is supported by the nutrient contents of N, P and K in different soil layers after drip fertigation or conventional application (Tables 4.89 to 4.96). The nutrients were less in subsurface drip fertigation in 0-30 cm depth resulted due to a lesser upward movement of soluble fertilizers. Instead it concentrated in 30-60 cm depth or would have further leached down beyond 60 cm depth making them unavailable to the plants.

In the subsurface drip, the wetting of the upper layer of non drip zone was relatively less than that of the surface drip due to more downward movement of water from emitter, than the lateral movement. The situation is aggravated when subsurface drip is adopted with inadequate supply of water in the first year.

It was also observed that in the second year when quantity of water was increased to I_{100}, the moisture content in the 60 cm lateral layer was increased, but less than that in the bottom 60 cm layer. This shows that in lateritic sandy clay soils, under drip irrigation, vertical advance was more than the horizontal advance. Sivanappan *et al.* (1987) and Maheswarappa *et al.* (1997) also could observe a higher vertical movement than the lateral advance.

5.2.4 Root distribution pattern under drip fertigation

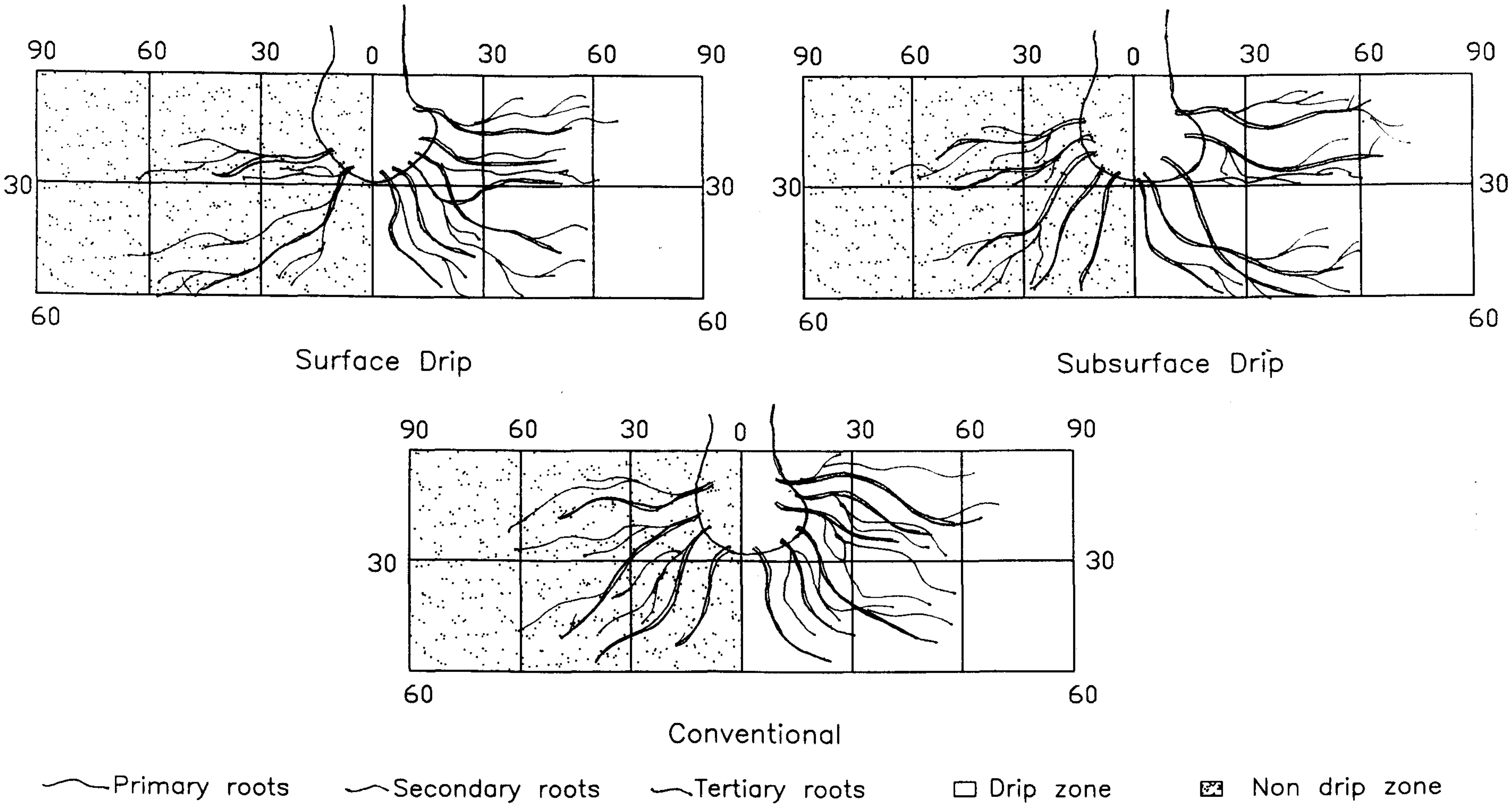
Total root length and fresh root weight observed during first year was relatively higher than that of second year, irrespective of treatments. The lower water supply and consequent less moisture content in the rhizosphere could have produced more roots in the first year. During moisture stress, the plants tend to strengthen its absorbing system to meet the demand of water. For this purpose, more photosynthates will be diverted for the production of more roots. Shobhana (1985) and Eapen (1994) observed more root production with rainfed banana, compared to irrigated banana.

While comparing surface drip and conventional methods, it could be seen that surface drip produced higher root length at low moisture content in the first year. But in the second year, when sufficient moisture was provided, surface drip had lower root length. The increased root length in the first year under surface drip was due to production of more secondary and tertiary roots and not due to increase in primary roots (Fig.5.7). This means that primary roots produced more secondary and tertiary roots for a higher water absorption.

It can also be seen that under drip fertigated conditions, the roots are mainly concentrated in the drip zone and under surface drip, the percentage of the total root length accumulated in the drip zone was 64 per cent as against 53 per cent in the conventional method. Bravdo and Proebsting (1993) and Bar-Yosef (1999) also observed a higher concentration of roots in the limited wetted volume.

Though more roots are tended to be produced under reducing soil moisture levels, in subsurface drip, there was considerable reduction in length of primary roots, particularly in 30 *l* x 30 *d* zone. This is attributed to a higher moisture stress as evidenced by the moisture content of 13.85 per cent which is nearer to permanent wilting point compared to 17.10 and 17.77 per cent in the surface drip and conventional method respectively. But in the second year, there was a three fold increase in the length of primary roots, which was more than that in the surface drip and conventional method and the moisture content in the 30 *l* x 30 *d* layer was 19.99, 18.13 and 18.02 in the surface drip, subsurface drip and conventional method respectively. It is also observed that subsurface drip has resulted in more root length in the lower 30 *l* x 60 *d* and a relatively good percentage in 60 *l* x 30 *d* layer also. Thus subsurface drip proved better with regard

Fig. 5.7 Root distribution pattern of banana under different methods of irrigation and fertilizer application in the first year



to the root production, provided, evapotranspiration was fully compensated (Fig.5.8).

The weight of total roots in subsurface drip (2312 g) in the first year was lower than that obtained in surface drip and conventional method. But in the second year, the root weight was the highest in the subsurface method with 3430 g. This shows the superiority of subsurface drip under sufficient water.

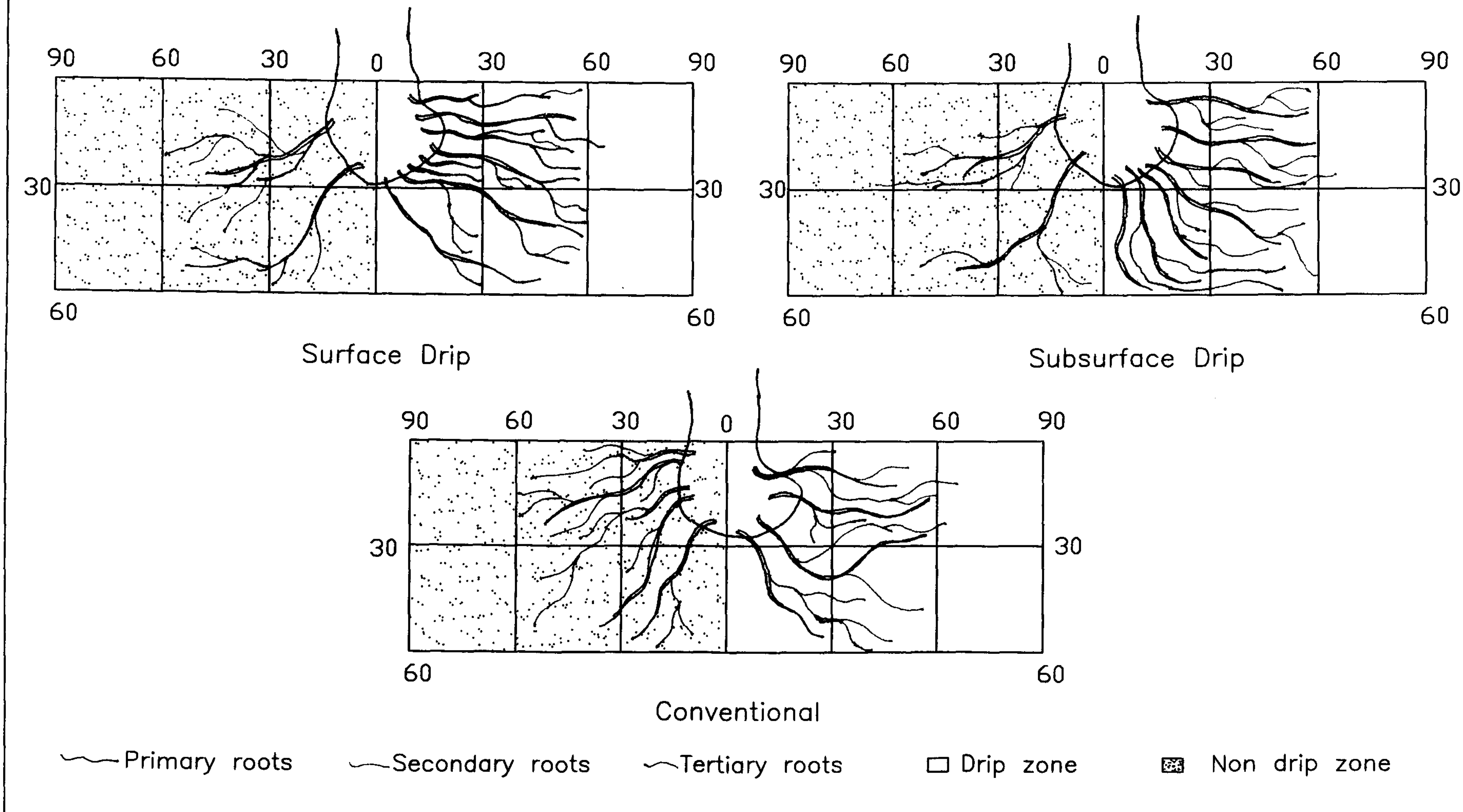
In a shallow rooted crop like banana, as the major percentage of roots were in 30 *l* x 30 *d* zone, subsurface drip proves disadvantageous under less quantity of irrigation water. The observation prompts to think that a subsurface drip at 15 cm depth would be better in shallow rooted banana in the angles of moisture and root distribution and checking of evaporation loss, which normally occur in surface drip.

5.2.5 Nutrient distribution in the rhizosphere

Nutrient content in the soil was estimated after the application of half the dose of N and K and full dose of P. To study the distribution of these nutrients, the contents in various points in the rhizosphere, as identified in the moisture content estimation, were determined in the drip zone.

In the drip fertigation treatments, the spread of nutrients was guided by the moisture distribution. Consequently the nutrient distribution could have varied resulting in a higher concentration of nutrient, in the drip zone, as against a

Fig. 5.8 Root distribution pattern of banana under different methods of irrigation and fertilizer application in the second year



uniform nutrient concentration in the conventional method. Also the quantity of fertilizer was double than that in the second year.

In the second year, extractable ammoniacal and nitrate nitrogen were estimated from the wet samples, and the total of these were compared with the available N in the first year estimated by alkaline permanganate method. So a higher content of nitrogen in the second year, at a fertilizer level of F_{100} instead of F_{200} in the first year, might be due to variation in the procedure for estimation.

Under surface drip and conventional method, a higher concentration of available N was obtained in the surface layers, while under subsurface drip, its lower layer registered a higher content. When the quantity of irrigation water was increased, there was an increase in movement of nitrogen downwards and horizontally under surface drip, but more in downward direction. Under subsurface drip the contents in 60 *l* x 30 *d* was less compared to that in surface drip, suggesting that nitrogen would have leached further down. Under conventional method, the spread was relatively uniform.

In the case of P, the difference in the dose of application between first year and second year was more apparent. When surface drip and conventional methods were adopted, a proportionate reduction was observed in the second year in the surface 30 *l* x 30 *d*. But in subsurface drip, the available P content in 30 *l* x 30 *d* was almost similar with 25.57 kg ha^{-1} during first year and 28.57 kg ha^{-1} in the second year, though a noticeably high 70.49 kg ha^{-1} of available P was accumulated in the lower 30 *l* x 60 *d* in the first year as against 42.19 in the second year. This reduction is due to reduced P application. However a reduced share of P in 30 *l* x 30 *d* in the first year could be attributed to a relatively lower upward movement of nutrient carrying irrigation water, that is directly applied at 30 cm depth through subsurface drip. It is also suspected that considerable amount of water applied through subsurface drip together with nutrients might have leached below 60 cm. This leaching would have increased with increase in moisture level. The available P observed in other soil layers also correspond with the soil moisture distribution pattern.

With respect to available K, a similar pattern is observed in the distribution in different layers. The available K was 420 kg ha^{-1} in 30 *l* x 30 *d* when nutrients were applied at F_{200}, but at F_{100} the same was only 325 kg ha^{-1}, under surface drip. In conventional method also a similar pattern was noticed. However under subsurface drip, a higher accumulation was in the lower layers, in both the years. This difference, as in the case of other applied nutrients, occurred due to placement of nutrients in the lower layer in the subsurface drip.

The soil moisture distribution pattern, the rooting pattern and nutrient contents in different soil layers and depths could be identified as factors responsible for yield variation in the different years as well as under different methods of fertilizer application and irrigation. In the first year the mean bunch yield of banana was considerably lower than that in the second year and the reasons are well explained in section 5.1.3.

Within different treatments, in the first year, conventional method of irrigation and fertilizer application had a significantly higher yield. The uniform spreading of the roots throughout the rhizosphere could extract water under limited supply, but with drip methods, the moisture content had gone below permanent wilting point and consequently less water absorption. The concentration of the nutrients in the moisture limited wet zone was very high, particularly soil P. Application of P as superphosphate through drip irrigation system is liable to increase the soil reaction, and consequently more absorption of native elements such as Fe and Mn resulted. Effect of unbalanced absorption of nutrients and contents in plant tissues on growth and yield was discussed in detail in section 5.1.3.2. In the second year, the highest yield of 10.44 kg was obtained through subsurface drip, followed by surface drip with 9.72 kg and conventional application registered the lowest bunch weight of 8.82 kg per plant. The spectacular phenomenon of a longer peduncle associated with poor bunch yield situation was reported as the result of unbalanced nutritional environment system. But in the second year, this phenomenon was quite absent in the plants. Plants fertigated through subsurface system had the shortest peduncle and further increase in surface drip, and conventional method resulted in concomitant yield reduction. It is deduced that in the second year, with reduced level of fertilizer application and adequate quantity of water, the nutrient concentrated in the rhizosphere was optimum under subsurface drip. The available N with 328.7 and 436 kg ha^{-1}; available P with 29.2 and 42.1 kg ha^{-1} and available K with 242 and 317 kg ha^{-1} in 30 *l* x 30 *d* and 30 *l* x 60 *d* respectively has generated a favourable nutritional environment. Releasing at 30 cm soil depth by the emitter, the upward movement of the nutrients was less. At the same time, the excesses of elements including native elements were leached down beyond the root zone. In the surface drip and conventional methods, higher accumulation of applied and non-applied nutrients particularly P occurred in the 30 *l* x 30 *d* layer, where much of the roots are concentrated.

An overall appraisal of the results shows that in drip fertigation, reduction in the volume of irrigation water below 100 per cent PEC is disadvantageous. Among subsurface and surface drip fertigation, subsurface drip is more effective under adequate water supply and lower nutrient concentration. From the analysis of rooting pattern and moisture distribution it is also suggested to lay subsurface drip at 15 cm depth for higher efficiency.

5.3 Experiment 3

The experiment was mainly to study whether there can be a proportionate increase in loss of applied fertilizer with increase in quantity of irrigation water.

The fertilizers were applied at 200-115-300 g NPK per plant (F_{100}) in six splits at monthly intervals. However P application was limited to two splits in the first two months. The mean quantity of water used for irrigation at 100 per cent PEC was 60 litres in 3 days and its 200 and 300 per cent were also tried. Though efforts were made to simulate the field soil condition in larger pots, the results obtained may not be true representative of the natural field conditions. However the losses of various nutrients were agreeable to those values reported else where under field crop situations.

5.3.1 Nitrogen

5.3.1.1 Ammoniacal N and Nitrate N

The leaching loss of total N in terms of NH_4^+-N and NO_3^--N was reported in Tables 4.97 to 4.99. The mean loss of NH_4^+- N through varied quantities of irrigation was only 12.78 per cent while that of NO_3^--N was 29.18 per cent. A rapid conversion of NH_4^+ to NO_3^- is favoured under adequate moisture and aeration. This NO_3^- is an anion which is very soluble in water and not influenced by soil colloids, consequently resulting in high mobility and lost in percolating water (Tisdale *et al.*, 1995).

When the quantity of water was increased from 100 per cent to 200 and 300 per cent PEC, a drastic increase of NH_4^+-N from 8.44 to 14.36 and 15.54 occurred, but such an increase was not observed with NO_3^- -N. Under higher moisture levels of 200 per cent and 300 per cent PEC, nitrification process was delayed and occurrence of more NH_4^+-N was noticed. But the very low CEC of the soil, could not retain this added NH_4^+-N, resulting in its loss in percolating water.

An analysis with the quantity of NH_4^+-N and NO_3^--N lost in different irrigations showed that the loss of NH_4^+-N decreased considerably in the second and third irrigations, a but the reduction of NO_3^--N loss was significant only in the third irrigation. In aerobic environments, nitrification of mineralised as well as applied NH_4^+-N sources was rapid and positively more leaching of NH_4^+-N took place in the initial days and further leaching was in the form of NO_3^--N.

Observations on the ionic form of N in different splits showed that NH_4^+-N forms was highest with the third and fourth splits in the case of 100 per cent PEC. Also with NO_3^--N ions, the leaching was increased with each split and a decreased loss was observed only at the sixth split, at lower water levels. The reasons for lower rate of NH_4^+-N leaching in the early stages could be explained as its higher demand to satisfy the adsorption sites. But the same in the later stages, prompts to assume that more NH_4^+-N was absorbed during the later stages. The data still points towards a preferential uptake of NH_4^+-N rather than NO_3^--N ions at later stages. Tisdale *et al.* (1995) has reported that preference of plants for either NH_4^+-N or NO_3^--N is determined by the age and type of the plant, and the environment.

5.3.1.2 Total nitrogen

The leachate collected from 60 cm soil depth contained 33.46 per cent total N of the applied N when given as urea in six equal monthly frequencies and when irrigation was at 100 per cent PEC. Santhakumari *et al.* (1990) also obtained an average leaching loss of 32.3 per cent of total applied N, from the alluvium sandy loam soils of Kerala. When the quantity of irrigation was doubled, the percentage loss was 46.82 per cent. But with an increase in quantity of irrigation to three fold, no further increase was observed. It is to be assumed that at the present applied level of N the maximum N that could be lost from lateritic sandy clay soils of Vellanikkara, through leaching from the rhizosphere would have taken place at 200 per cent pan evaporation. A reduction in loss beyond 200 per cent PEC would also mean that part of the applied N has been taken up by the crop or it is fixed as ammonium or adsorbed on the clay and root surface.

Among three consecutive irrigations after fertilizer application, the first irrigation resulted in a total N loss of 22.1 per cent which was reduced to 13.46 per cent and 6.39 per cent respectively in the second and third consecutive irrigations, given at an interval of three days. This is because of the considerable reduction in the ammoniacal and nitrate nitrogen with subsequent irrigations, the reduction being highly significant in the case of NH_4+-N.

N loss in the first two splits was lower than that in the third and fourth splits, irrespective of the levels of irrigation. It is assumed that the first two splits had saturated the adsorption sites and hence the application in the subsequent splits was subjected to higher leaching. A further reduction of N loss in fifth and sixth splits could be attributed to a higher uptake due to increased root density in the entire rhizosphere, which may act as a physical as well as biochemical barrier for nitrogen leaching. Reduced leaching of nutrients with advancement of growth due to rapid uptake of nutrients ensured by greater root mass was reported by Humphreys (1987) and Shanthakumari *et al.* (1990). However the reduction in leaching in the later stages was less at 100 per cent PEC and more with 200 and 300 per cent pan evaporation.

5.3.2 Phosphorus

Even a trace of P applied as single super phosphate in equal splits given in the first two months, was not observed in the leachate. In the lab experiment conducted for confirmation, wherein single super phosphate solution was passed through a 50 cm. soil column, the leachate collected also did not contain P. Lateritic soils with acidic pH and having heavy content of Fe and Mn would fix P, and prevent leaching.

5.3.3 Potassium

A perusal of the data on the leaching loss of K reveals that leaching of K (16.19%) in general was less than that of N (41.96%). Nitrate ion is the anion with least bonding strength, but K is much adsorbable with its positive charge, on the clay and root surfaces. Different K forms in the soil is dynamic in nature and exchangeable K and solution K equilibrate rapidly. After fertilizer application, the soil solution K go to exchangeable sites and a large scale leaching is prevented. It was also noticed that when the quantity of irrigation was increased from 100 per cent to 300 per cent PEC, the loss increased from 12.12 to 20.30 per cent of applied K. This difference could be explained on the basis of low CEC of the soil and its relatively lower degree of saturation. The unadsorbed K remaining in the soil solution was removed in leaching water, which increased with increasing the levels of irrigation. Also more K was leached in the first irrigation, and subsequent irrigations had less K through leaching.

Irrespective of increase in water, the highest leaching was observed in the third and fourth split of fertilizer application. A very low percentage loss occurred in the fifth and sixth splits. K being an abundantly consumed element by banana, more absorption of K is expected. The reduction in loss is also favoured by a physical and biochemical barrier offered by increased root length and surface area.

It is concluded that up to 33.46 per cent of N and 12.80 per cent of K can be moved beyond root zone by irrigation, the losses being even heavy under higher irrigation levels, in the lateritic soils of Kerala. However under field conditions, where more opportunities for lateral spreading is available and where the soil columns are not limited or disturbed, a lower loss due to leaching can be expected. Leaching of P beyond root zone was practically nil.

SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

Experiments of the research project entitled "Water and Fertilizer use efficiency in drip fertigated banana *Musa* (AAB) 'Nendran' " were conducted for two years during 1997-98 and 1998-1999 at Banana Research Station, Kannara and at College of Horticulture, Vellanikkara. The salient research results obtained are presented here.

1. Balanced growth leading to higher productivity of banana is reflected in positive interrelationship among different growth attributes like plant height, girth, leaf area index and area of the index leaf, of which plant height and girth were highly correlated (r = 0.633 and 0.440 respectively) with yield.
2. Lower height/girth ratio appeared to be a better index of balanced growth. A decline in the rate from 4.4 to 3.4 appeared to be a positive sign in increased productivity expressions in the later stages.
3. Production of more leaves after flower initiation resulted in ineffective diversion of energy leading to reduction in yield. A higher rhizome weight and more sucker production are resultant of improper growth consequently leading to low yield.
4. The present recommended fertilizer level of 200-115-300g NPK plant^{-1} was found sufficient for growth and yield, when the fertilizer application was in six splits and irrigated at 100 per cent pan evaporation compensation (PEC) through conventional basin method. Further improvement in yield was not achievable with increased fertilizer levels under conventional method, but

yield improvement was possible at higher levels in drip fertigation. Enhancing the frequencies from 6 to 24 linearly increased growth and yield up to 200 per cent of recommended fertilizer level.

5. At the present recommended fertilizer level and conventional method of irrigation and fertilizer application, the observed highest yield of 9.93 kg $plant^{-1}$ could be obtained with half the dose applied through drip irrigation systems, provided the irrigation is at 100 per cent PEC.

6. Very low levels of fertilizers (F_{25}) coupled with higher frequency (D_{24}) failed to produce good growth, biomass accumulation and yield when irrigated at 100 per cent PEC.

7. Higher levels of fertilizers above the present recommended level lead to higher leaf content of N and K, but failed to produce significant effect on growth and yield, when given in six splits either by drip or basin method. However, under drip fertigation in 24 splits (D_{24}) higher content at higher levels of fertilizers correspondingly increased the yield.

8. A complete solution of NPK being highly acidic with a pH of 2.5 favoured the release and absorption of native non-applied elements in excess quantities.

9. Greater nutrient content of fertilizer solution consequent of inadequate irrigation and higher rate of fertilizers as in first year favoured the release of native calcium. Natural release of calcium in acidic soil along with Fe and Mn can only be a sign of soil degradation. Thus, a management system

wherein all cations are released in excess becomes defective management system.

10. Low realised yield in the first year was associated with a higher content of native non-applied elements. Except N and K, all other elements were found decreased in the second year. This means that yield is not the direct effect of applied elements, but the net effect of all applied and non-applied elements.

11. Path coefficient analysis of leaf nutrient content and yield showed that direct effect of foliar N had always been positive but the direct harmful effect of non-applied elements like Fe, Mn, Ca and Mg as well as their negative influences on N were found to be responsible for low yield.

12. A decrease in the foliar P content in the second year increased its direct positive effect on yield ($r = 0.0611$ and 0.5145 at 4 MAP in the first year and second year respectively). A higher foliar content of Fe in the first year favoured the absorption of P, while a reduced Fe content in the second year had negative effect on P absorption. This means that Fe had combined with P and formed phosphates making P physiologically unavailable in the first year.

13. Fe at flower initiation (4 MAP) and Mn in the later stages (5 MAP) at a mean concentration of 331 ppm and 2006 ppm respectively limited the yield below 6.0 kg $plant^{-1}$ in the first year. Reduction in their contents to the extent of 28 and 38 per cent respectively reduced their negative effects in the second year.

14. The significant negative influences of Ca and Mg at concentrations of 0.31 and 0.26 per cent and correlations (r) of -0.3542 and –0.4913 respectively were the major yield negating factors that limited the yield between 7.7 and 12.27 kg plant $^{-1}$ when irrigated at 100 per cent PEC in the second year. The effect of Ca and Mg was mainly to reduce the positive effect of K. Zn indirectly increased the effect of Ca and Mg but decreased the positive effect of K.

15. A higher biomass of pseudostem in the second year resulted in considerable N dilution as evidenced by 0.95 and 1.35 per cent in the second and first year respectively, favouring more translocation to peduncle, fruit and male bud and thereby increasing yield. Similarly, the contents of P and K in the floral parts were also higher in the second year. The rhizome of the plants which produced higher yield as in second year accumulated less N (17.39 g plant^{-1}) while that in the plants with low yield as in the first year was 34.1 g plant^{-1} indicating an inhibited translocation of N to the bunches, in the first year.

16. Abnormally long peduncle was associated with low yield. A higher content of native non-applied elements like Ca, Mg, Fe, Mn, Cu and Zn and a lower content of N, P and K in the peduncle resulted in abnormal increase in its length. A longer peduncle was the mechanism of the plant to contain the excesses of native elements.

17. Inspite of higher application of N and P fertilizers, the crop had taken up only 25 and 4 per cent of the applied quantity respectively for N and P in the

second year, suggesting that their application level is not an index of absorption.

18. Drip fertigation resulted in better efficiency of water compared to basin irrigation. The efficiency of surface drip and subsurface drip were 390 and 440 kg ha^{-1} mm^{-1} respectively while that of basin irrigation was 380 kg ha^{-1} mm^{-1} when irrigated at 100 per cent PEC in the second year.

19. In the second year at 100 per cent PEC, surface drip and conventional method had comparable water use efficiency. However at low water supply (I_{75} and I_{50}), the efficiency of water was more under drip fertigation.

20. Among the two methods of drip fertigation, subsurface drip was better than surface drip fertigation when the scheduling of irrigation was based on pan evaporation. Subsurface drip at 75 per cent PEC produced comparable yields with that of surface drip at 100 per cent PEC.

21. Under inadequate supply of irrigation surface drip resulted in lower soil moisture content compared to conventional method due to immediate evaporation of droplets released from the emitter. Subsurface drip registered the lowest moisture in the surface layers due to greater downward movement.

22. Providing irrigation daily at 100 per cent PEC maintained the soil moisture of the surface layers almost at field capacity in surface and subsurface drip as well as in conventional basin method.

23. In the first year low moisture content in the soil due to inadequate irrigation resulted in more secondary and tertiary roots in the surface drip. Under

subsurface drip, the root production was largely affected as the surface layers were below permanent wilting point. In the second year, irrigation at 100 per cent PEC increased the production of more roots in the subsurface fertigated crop. More roots were present in the lower layers also compared to that in the surface drip irrigated plants.

24. At 100 per cent PEC, 74 per cent of primary roots concentrated in the drip zone but in the conventional method the roots were uniformly spread.

25. Under limited supply of water drip irrigation may prove better but under drip fertigation the nutrient concentration should be as dilute as possible in order to regulate the unfavourable release and absorption of native elements. Increasing the quantity of irrigation from 50 to 100 per cent PEC increased the uptake of applied elements but reduced the uptake of non- applied elements.

26. In lateritic sandy clay soils, downward movement of water is more than the horizontal advance. Increase in quantity of water resulted in more lateral advance of the wetting front. Movement of nutrients followed the pattern of movement of soil moisture, but the mobility of P was less compared to N and K.

27. Subsurface drip accumulated more nutrients in the lower layer while surface drip had a higher nutrient content in the upper layers.

28. Studies on the leaching loss of nutrients under flooded condition showed that leaching loss of N and K through irrigation water were to the extent of 33.46 and 12.80 per cent respectively even when irrigation was at 100 per cent

PEC and the fertilizer application at the present recommended level of 200 – 115 – 300g NPK per plant. Leaching of N increased with increase in quantity of irrigation up to 200 per cent PEC while that of K increased up to 300 per cent of PEC.

29. Immediate irrigation after fertilizer application was conducive to heavier leaching loss, which was 64.3 and 63.4 per cent higher for N and K respectively than the following irrigation. Subsequent irrigations tended to reduce the losses.

The study has conclusively proved that fertigation is an advantageous substitute for conventional irrigation cum fertilizer application. The clear-cut superiority of fertigation arises from its continuous maintenance of wetting, but not leading to totally reduced state of environment in the rhizosphere as well as minimizing the side effects of synthetic fertilizers affecting soil reactivity, reducing the unfavourable release and absorption of native elements like Fe and Mn and providing a prolonged but steady supply of major nutrients.

The study also convincingly established that it is not the quantity of nutrient applied or absorbed that decides the yield, but is the interaction and metabolic availability of these nutrients. Metabolic availability can be ensured through higher dilutions and steady applications of nutrients. Drip fertigation is the only effective tool to serve this purpose.

The effectiveness of drip fertigation can be further enhanced by avoiding or minimising the use of fertilizers like single super phosphate, which reduces the pH of the soil, and by scheduling the level of water application through fertigation. Deeper placement of drip emitter at 30 cm as tried in subsurface method may lead to losses and ineffectiveness. Therefore, placement of emitters at 15cm can make the system more efficient.

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APPENDICES

Appendix 1. Monthly weather data for the period October '97 to September '98

Month	Max. Temp. (^{0}C)	Min. Temp. (^{0}C)	Rainfall (mm)	Mean RH (%)	Sunshine (Hrs)	Evaporation (mm)
Oct'97	30.1	23.6	194.7	77	226.6	125.3
Nov '97	31.5	23.2	211.3	78	158.5	90.2
Dec.'97	30.5	23.8	66.7	72	223.6	135.3
Jan.'98	33.1	22.8	-	64	288.5	168.0
Feb.'98	34.4	23.6	-	64	269.2	167.4
March'98	36.2	23.6	11.0	67	310.4	189.8
April'98	36.5	25.6	61.4	68	270.2	241.7
May '98	34.1	25.2	203.0	77	235.4	120.9
June'98	30.2	23.3	809.3	87	103.1	86.6
July'98	29.2	23.6	752.9	88	101.6	87.1
Aug.'98	29.8	23.9	433.6	86	112.5	88.3
Sept.'98	30.2	23.3	571.3	87	123.4	86.0

Appendix 2. Monthly weather data for the period October '98 to September '99

Month	Max. Temp. (^{0}C)	Min. Temp. (^{0}C)	Rainfall (mm)	Mean RH (%)	Sunshine (Hrs)	Evaporation (mm)
Oct'98	28.0	22.8	452.8	85	148.5	88.9
Nov '98	31.5	23.1	109.4	78	214.6	91.2
Dec.'98	30.1	22.9	33.0	69	204.1	127.3
Jan.'99	32.4	21.5	-	58	288.3	174.4
Feb.'99	34.5	23.3	22.8	56	255.6	175.4
March'99	35.5	25.6	-	68	272.8	166.1
April'99	33.4	24.5	39.0	73	308.1	134.9
May '99	30.7	24.7	430.5	82	152.2	99.5
June'99	29.4	23.0	500.2	85	150.8	90.0
July'99	28.4	23.0	823.3	89	75.8	73.3
Aug.'99	29.8	22.9	260.1	76	213.7	96.1
Sept.'99	31.6	23.4	28.4	69	246.6	105.5

Appendix 3 Evaporation losses and irrigation provided during summer months

	I Year		II Year	
Month	Evaporation (mm)	Irrigation l plant $^{-1}$	Evaporation (mm)	Irrigation l plant $^{-1}$
January	168.0	496.0	174.4	698.0
February	167.4	448.0	175.4	686.0
March	189.8	496.0	166.1	664.0
April	241.7	368.0	134.9	469.0
May	120.9	160.0	199.5	103.0
Total	887.8	1968.0	750.3	2620.0

WATER AND FERTILIZER USE EFFICIENCY IN DRIP FERTIGATED BANANA *Musa* (AAB) 'NENDRAN'

By

DEEPA THOMAS

ABSTRACT OF THE THESIS

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ABSTRACT

Banana is well known to be extremely demanding for water and nutrients and supplemental application of these resources are pre-requisites for higher yield. Conventional method of application characterized by heavy doses at wider intervals lead to losses and reduced efficiency of these inputs. A near continuous system of application possible under drip fertigation minimize these disadvantages of conventional method of application. Three experiments under the project "Water and fertilizer use efficiency in drip fertigated banana *Musa* (AAB) 'Nendran' " were conducted during 1997-98 and repeated during 1998-99 at Banana Research Station, Kannara and at College of Horticulture, Vellanikkara. The study aimed to investigate the use efficiency of water and fertilizers in drip fertigated banana and to study the dynamics of nutrients applied through drip fertigation and conventional methods. The rooting pattern of banana as influenced by methods of irrigation and the leaching loss of nutrients beyond the root zone under excess water supply were also studied. Based on the results obtained in first year experimentation, a further dilution of nutrient solution was introduced in the second year by increasing the quantity of irrigation on pan evaporation basis and reducing the levels of fertilizer application.

Response of banana var. Nendran to different methods of fertilizer application (drip fertigation and basin application), to different frequencies of fertigation (six and twenty four fertilizer splits) and to five different levels of fertilizer at regular intervals (50 to 250 per cent of present recommendation in the first year and 25 to 200 per cent in the second year) were tested in the first experiment. Drip fertigation could register significant improvement in productivity and response to fertilizer levels over conventional means of fertilizer application and irrigation when frequency of application was enhanced. Efficiency of fertilizer application was decided not by quantity of fertilizers, but by dilution and frequency.

The yield obtained from basin application of the present recommended fertilizer level viz.. 200-115-300 g NPK $plant^{-1}$ in six splits was comparable with that obtained from drip fertigation at 100-60-150 g NPK $plant^{-1}$ suggesting an improved fertilizer use efficiency under drip fertigation.

The second experiment consisted of combinations of different methods and levels of irrigation. Methods of irrigation included surface drip, subsurface drip and conventional method, while levels of irrigation were 8, 12 and 16 l day^{-1} in the first year and 50, 75 and 100 per cent pan evaporation compensation in the second year. The efficiency of drip fertigation was enhanced by placing the emitters below the surface (subsurface drip) as evidenced by higher moisture content in the root zone and a larger production of roots in the limited wet zone. But higher nutrient concentration consequent to inadequate quantity of irrigation and higher fertilizer rate negated the benefits of subsurface drip fertigation in the first year. Water use efficiency of 570 kg ha^{-1} mm^{-1} of water could be obtained under subsurface drip fertigation as against 470 kg ha^{-1} mm^{-1} in conventional method resulting in an increased efficiency of 21 per cent in the second year.

Low moisture content in the soil in the first year resulted in the production of more roots especially secondary and tertiary roots and surface drip had more roots than conventional method. But when the quantity of irrigation was increased in the second year, more roots were present in conventional method than surface drip. Under surface drip 64 per cent of the root length was accumulated in the drip zone, while under conventional method, roots were more uniformly spread.

Pot culture study to estimate the leaching loss of nutrients under flooded condition showed that leaching loss through irrigation water were to the extent of 33.5 per cent and 12.8 per cent respectively for N and K, when the irrigation was at 100 per cent pan evaporation compensation and fertilizer application at the present recommended level. Further increase in quantity of irrigation increased N and K losses. No leaching loss of P was observed.

The study has conclusively proved that fertigation is an advantageous substitute for conventional irrigation cum fertilizer application. The superiority of fertigation arises from its continuous maintenance of wetting, but not leading to totally reduced state of environment as well as minimizing the side effects of synthetic fertilizers affecting soil reactivity, by reducing the unfavourable release of native element like Fe and Mn and providing prolonged but steady supply of major nutrients.

The study also convincingly established that it is not the quantity of nutrient applied or absorbed that decides the yield, but it is the interaction and metabolic availability of these nutrients. Metabolic availability can be ensured through higher dilutions and steady applications of nutrients. Drip fertigation is the only effective tool to serve this purpose.

The effectiveness of drip fertigation can be further enhanced by avoiding or minimizing the use of fertilizers like single super phosphate, which reduces the pH of the soil and by scheduling the level of water application through fertigation. Deeper placement of drip emitter at 30cm as tried in subsurface drip method may lead to losses and ineffectiveness. Therefore, placement of emitters at 15cm can make the system more efficient.