EFFECT OF SOIL MOISTURE STRESS ON GROWTH AND YIELD OF BANANA cv. NENDRAN

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of soil moisture stress on growth and yield of banana cv. Nendran" is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other university or society to me.

Vellanikkara,
4-11-1989.

Jessy, M. D.

CERTIFICATE

Certified that this thesis entitled "Effect of soil moisture stress on growth and yield of banana cv. Nendran" is a record of research work done independently by ***Miss. Jessy. M. D.*** *under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.*

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We, the undersigned members of the Advisory Committee of **Miss. Jessy, M. D.**, a candidate for the Degree of Master of Science in Agriculture agree that the thesis entitled "Effect of soil moisture stress on growth and yield of banana cv. Nendran" may be submitted by her in partial fulfilment of the requirements for the degree.

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Introduction

INTRODUCTION

Water, a manageable input is one of the major factors influencing and usually restricting crop growth and food production. Efficient use of water for crop production has been a major concern for centuries. Today, this concern is greater than everbefore, because of the rising needs for food and fibre coupled with decreasing supplies of water for agriculture. Hence, it becomes necessary to make all possible efforts to maximise the production per every unit of water used for irrigation.

Kerala is endowed with plenty of rainfall. The mean annual rainfall of the State is about 3000 mm, but it is not well distributed. About 67 per cent of the annual rainfall is received during the Southwest monsoon season. About 19 per cent falls in the post monsoon season, from October to January, and the rest 14 per cent in the premonsoon months of February to May. Thus, the rainfall is effective only for a period of five to seven months, with a distinct dryspell occurring during the remaining period. Water is the most important factor restricting crop production throughout the State during this period.

Banana, a highly nutritious tropical fruit crop is among the oldest crops cultivated by man. It is a popular crop of India and stands next only to mango in terms of area and production of fresh fruits. The crop occupies an important place in the agricultural economy of Kerala, the State which has the largest coverage under this crop.

Among the many cultivars of plantains grown in Kerala, Nendran occupies an important place covering about 32 per cent of the total area under all plantains and about 45 per cent of the total production. It is the most important cultivar in terms of nutritive value and demand for table, culinary and industrial purposes. The crop gives an attractive net income and the production is largely market oriented.

To ensure high yield of superior quality bananas, irrigation is of paramount importance besides adequate manuring and other improved cultural practices. It is erroneously assumed that maximum yield of bananas is attained only when soil moisture is maintained at the optimum level throughout the period of growth and development. Actually crop water requirements vary between the stages of development and except during the critical stages, banana can withstand a slight water stress without significant reduction in the yield. Under conditions of limited water supply, the strategy, hence, is to obtain maximum benefit from each unit of water used i.e., by applying water when it is of most advantageous. However, in Kerala, no efforts were made so far to identify the critical stages of water requirement of banana by studying the effect of moisture stress on growth and yield of banana. Also, no detailed studies were undertaken so far to assess the effect of mulches (coconut husk) and hydrophilic gels in increasing water use efficiency. In view of the above, the present investigation was undertaken with the following objectives:

1. To study the effect of varying periods of soil moisture stress on growth and yield of banana cv. Nendran.

2. To schedule an economic irrigation under situations of limited water supply.

3. To study the effect of antistress formulation on banana cv. Nendran.

4. To study the influence of antistress formulation and mulches on conservation of moisture and reduction in irrigation requirement.

Review of Literature

REVIEW OF LITERATURE

Water, the earth's most abundant compound is the single most important factor limiting crop yield throughout the world. Water available for agriculture is decreasing and this coupled with the ever increasing demand of the growing population for food and fibre emphasize the need for attaining the maximum benefit from each unit of water used for irrigation. Mulches and hydrophilic gels play a very important role in the conservation of soil moisture.

Banana, a herbaceous mesophyte, has got a reputation for requiring a plentiful supply of water for higher production. Compared to many other fruit crops, banana is more sensitive to moisture stress. During the past many decades, lot of works were done to study the irrigation requirement of banana. However, there is very little information available on the effect of soil moisture stress on the growth and yield of banana. The relevant literature available on these aspects and on the role of mulches and hydrophilic gels in the conservation of soil moisture is briefly reviewed.

2.1 Consumptive Use and Water Requirement

Many researchers have contributed to an understanding of the water requirement of banana. The earlier recommendations made were based mainly on the emperical experiences of the farmers of the locality, and not on experimental evidences. Naik (1949) recommended to irrigate bananas at an interval of 5 to 10 days during dry spells. Roy (1950) suggested that bananas should be irrigated thrice in a month from December to June. Gandhi (1952) was of the opinion that banana needed irrigation at an interval of 10 to 15 days from October to February and 6 to 8 days from March to May.

Simmonds (1959) estimated the transpiration losses from a banana canopy as 30 to 63 m^3 depending on wind, insolation and humidity. He found that bananas could easily consume 900 to 1800 mm of water in 9 to 10 months. He reported the weekly water requirement of bananas in the tropics to be 1.0 to 1.4 times class A pan evaporation. To reduce runoff and for greater efficiency of water utilization by plant, he recommended to apply water twice or thrice weekly. He concluded that soil should be maintained at 80 to 100 per cent of field capacity for favourable growth and yield of banana.

Varma (1962) recommended that bananas are to be irrigated on alternate days. Results of an irrigation experiment conducted by Trochoulias (1971) showed that irrigation increased yields of banana over natural rainfall plots (average 60 to 70") by 177, 111, 84 and 5 per cent for the 90, 80, 60 and 30 per cent available water capacity treatments, respectively. In another irrigation trial conducted in Honduras, Ghavami (1974) got the highest bunch weight when irrigation was applied twice weekly. He noticed that a soil moisture tension of 0.3 to 0.4 atm. was most favourable for banana. In Israel, Shalhevet et al. (1976) tried to find out the water requirement of sprinkler irrigated bananas. They estimated the seasonal water consumption as 1120 mm applied in 30 irrigations. They recommended to replenish the lost water before more than 25 per cent of the available water was extracted from the root zone. On the basis of the experiments conducted in Brazil, Silva et al. (1977) reported that application of water at the rate of 1452 mm year $^{-1}$ at an interval of 10 days was most profitable.

An experiment conducted at Chalakudy, Central Kerala, indicated that application of 50 mm of water at an interval of 20 days gave maximum yield for banana cv. Nendran (KAU, 1978). In Tamil Nadu, Krishnan and Shanmugavelu (1979a) estimated the total consumptive use of banana cv. Robusta as 1841 mm in the driest treatment of 60 per cent depletion of available water and 2150 mm in the wettest treatment of 20 per cent depletion. It was found that the per day water consumption ranged from 4.81 mm to 6.11 mm which also increased with frequent irrigations. They recommended to maintain the soil in the range of 20 to 40 per cent depletion of available moisture for economic production.

Yield of banana was markedly reduced when irrigation was given at 75 per cent soil moisture depletion, compared to that at 10 per cent depletion (Kuruppuarachchi and Pain, 1981). On the basis of the experimental results obtained during three productive cycles, Camejo (1981) recommended to apply 45 mm of water at intervals of 10 days. Holder and Gumbs (1983) studied the response of banana cv. Robusta to three irrigation regimes in which the soil was brought to field capacity, when the available soil moisture levels were 75, 66 and 50 per cent, respectively. They found marked increase in fruit yield in treatments irrigated at 66 and 75 per cent of available moisture respectively, back to field capacity. While studying the influence of irrigation on banana, Robinson and Alberts (1984) got the highest annual yield of 45 t ha^{-1} when irrigation was given at 34 per cent depletion of plant available moisture, averaging 18 mm water in every 3.5 days. In Southern Kerala Abul Salam et al. (1988) estimated the consumptive use of August planted Nendran banana as 2032 mm and irrigation requirement as 860 mm.

IW/CPE ratio

Experiments conducted in Central Kerala have conclusively proved that scheduling irrigation at IW/CPE ratio of 0.9 was significantly superior to that at 0.6 in terms of bunch yield (KAU, 1981). Water use of bananas was highly correlated with pan evaporation and leaf surface area (Israeli and Nimri, 1986). In Israel, Lahav and Kalmar (1988) reported irrigation at IW/CPE ratio of 1.0 to be of most advantageous. In an experiment conducted at Pilicode, Northern Kerala, it was observed that irrigation at a depth of 20 mm water at IW/CPE ratios of 1.0, 0.75, 0.5 did not differ significantly considering yield ha^{-1}. Irrigation at IW/CPE ratio of 1.0 recorded the maximum consumptive use followed by that at 0.75 and 0.5. Irrigation at IW/CPE ratio of 0.5 recorded the maximum water use efficiency (Rajagopalan and Sudhakara, 1988).

2.2 Critical Stages

Most studies on water requirements of crops have laid stress on scheduling irrigations to maintain optimum soil moisture regimes throughout the period of crop growth. This approach permits maximum production per unit of land in areas where water is abundant and land is limited. But when water resources are limited, it is necessary to evolve judicious water management practices taking into account the critical periods of crop growth during which optimum supply of irrigation water has to be provided, while during the other periods, the supply may be reduced to the minimum without affecting the yield (Ali et al., 1973).

Many scientists have tried to identify the most critical stages of water requirement for a number of agriculturally important crops. The stage of development, generally, but not always, referred to as being the most critical or sensitive is the reproductive stage, in which flower initiation, anthesis, fertilization and grain filling or fruit maturation occur (Denmead and Shaw, 1960; Hiler et al., 1974 and Sionit and Kramer, 1977).

Crops in which bulk of the above ground portion constitute the economic yield require an adequate soil moisture supply throughout the growing season. However, when economic yield is derived from the reproductive portion only eg. the banana fruit, the crop yield appears to be less sensitive to inadequate water supply during non-critical growth stages. Very few efforts were made in this direction to identify the critical stages of water requirement of banana. In Tamil Nadu, Krishnan and Shanmugavelu (1979a, 1980) divided the life cycle of banana plant into two phases (vegetative and reproductive stages) and found that reduced water supply during both stages resulted in decreased yields. However, they observed that shortening the irrigation interval at the reproductive stage shortened the bunch filling period. Holder and Gumbs (1982), from their investigations on the effects of irrigation at critical stages of ontogeny on the growth and yield of banana cv. Robusta, found that irrigation during the first and second 60 days period after planting did not affect the final pseudostem height, girth and yield. However, irrigation during 120 to 180 days period increased pseudostem height and girth and raised the average number of hands and fingers per bunch. They concluded that irrigation during the first four months after planting had less effect compared to that period when induction and flowering took place.

Trials conducted at Kannara, Central Kerala indicated that irrigating the crop once in 10 days in alternate months from January to April gave maximum bunch yield (KAU, 1980). In another irrigation experiment conducted at Kannara, highest bunch weight was obtained when the soil was maintained at 60 per cent depletion of available water in the vegetative phase and 40 per cent depletion after flowering (KAU 1980).

2.3 Physiological Activities

Crop growth and yield are controlled by environmental factors (light, carbon dioxide, temperature, water and nutrients) interacting with the progressively more carbon resulting in the consumption of storage material. Lakso (1985) also reported dark respiration to be relatively insensitive to water stress. Significant reductions in net photosynthesis under conditions of water deficit were reported for wheat, sunflower and maize (Lawlor, 1979), rice (Bois, 1984), apple (Lakso, 1985), sourcherry *(Prunus cerasus* L. Montmorency), high bush *(Vaccinum corymborum* L. Jersey) and blue berry (Flore et al., 1985), pistachio (Behboudian et al. 1986), pant lemon (Tomer and Singh, 1986) and custard apple (George and Nissen, 1988).

Working with banana, Krishnan and Shanmugavelu (1979b) observed that stomata were most active and opened widest at a soil moisture content of 50 to 60 per cent of field capacity, but behaved irregularly and only 40 per cent were open at 20 per cent of field capacity. Stomatal closure induced by loss of turgor curtailed transpiration at the onset of stress itself (Shimshi et al., 1982). Similar reductions in transpiration under conditions of water stress were reported for citrus (Levy, 1983) and rice (Bois, 1984).

Severe and prolonged water deficits caused a reduction in cell division and cell enlargement (Kramer, 1955). Water stress also caused a reduction in translocation of carbohydrates and growth regulators and a disturbance of N metabolism, which added to the effects of reduced turgor and reduced growth (Verasan and Phillips, 1978). According to Lawlor (1979), water stress affected plant assimilation by altering metabolic activity either inhibiting a single metabolic sequence or enzyme reaction (which by feed back control prevented proper function of whole system) or changing the balance between parts of the system. He also noticed that prolonged or very severe stress would deplete reserved materials resulting in senescence. Radhamani (1985) opined that water stress affected the synthesis of growth regulators. According to her, the reduced synthesis of growth regulators in root and shoot tips was an important factor leading to the reduction of growth and senescence of leaves observed in plants subjected to water stress.

2.4 Growth and Growth Attributes

Growth retardation under conditions of soil water deficit is well documented. It had been the subject of interest of many investigators from very early times, and now there are many reports on various crops, which emphasize the need for maintaining the soil at a particular moisture tension suitable for each crop for favourable growth. Reports indicating a general growth reduction under limiting soil moisture are there for corn (Denmead and Shaw, 1960; Acevedo et al., 1971 and Verasan and Phillips, 1978), rice (Ali et al., 1973), sorghum (Lewis et al., 1974 and Eck and Musick, 1979), Barley (Sinha et al., 1979 and Dwyer and Stewart, 1987), cotton (Marani et al., 1985), straw berry (Gehrmann, 1985) and Cox's orange pippin apple (Irving and Drost, 1987).

Low levels of moisture enhancing the root production was reported by Hubbard (1938). Dry weight of roots increased with decrease in the available soil moisture. Similar results were reported by Bennet and Doss (1960) for forage crops. However, Klepper et al. (1973) observed that in cotton, under conditions of soil water deficits rooting density increased with depth, due to death and disappearance of roots in the upper horizons and the growth of new roots in the lower horizons. they also noticed that although the total quantity of roots did not decrease under stress, the root system did not maintain its effectiveness by growing into wet soil. In grapes, rate of root growth decreased with increasing levels of stress (El-Barkouki et al., 1977). Working with wheat and barley, El-Sharkawi and Salama (1977) demonstrated that root growth was unaffected by water deficits. Krishnan and Shanmugavelu (1980) investigated the effect of different soil moisture depletion levels on the root distribution of banana cv. Robusta. They found that the overall rootmass was not significantly affected, but tended to increase very slightly with increasing water stress. Lateral and vertical root spread also increased with decreasing available soil moisture.

Kramer (1963) opined that vegetative growth was particularly sensitive to moisture stress, because growth was closely related to turgor and loss of turgidity stopped cell enlargement and resulted in smaller plants. A general reduction in the growth of bananas under conditions of limiting soil moisture have been reported by many scientists (Simmonds, 1959;

Arscott et al., 1965; Ghavami, 1974; Trochoulias and Murison, 1981; Camejo, 1981 and Asoegwu and Obiefuna, 1987). Jagirdar et al. (1963) reported that the banana plants irrigated at an interval of six days were taller and stouter compared to those irrigated at an interval of 14 days. Teaotia et al. (1969, 1972) also observed continuous upward trend in the growth of banana with higher levels of irrigation. Based on his investigations on banana cv. Nanicao, Manica et al. (1975) noted reduced pseudostem height and girth at flowering and harvest with decreasing soil moisture. Water management levels significantly influenced the height and girth of plants at all stages of growth, maximum height and girth were recorded when the crop was irrigated on alternate days (KAU 1982). Watson and Daniells (1983), while investigating the effects of water stress on bananas, had pointed out that plant growth rate was markedly reduced under conditions of soil water deficits. Holder and Gumbs (1983) noticed that plants which were adequately watered throughout the growing period were significantly taller compared to those from unirrigated plots. In Israel, Lahav and Kalmar (1988) also observed reduced pseudostem height under conditions of limiting soil moisture.

Water stress is one of the most well known causes of the reduction in the rate of increase in leaf area. According to Miller and Duley (1925), plant leaf growth responded more readily to changes in soil moisture content than any other part of the plant. Simmonds (1959) noticed that under conditions of prolonged drought, leaves of banana turned pale green and began to fall. Results of a field trial conducted to delineate the effects of various levels of soil moisture regimes on the growth and yield of banana showed that plants which were adequately watered produced more leaves per plant (KAU, 1982). Watson and Daniells (1983) reported reduced green life under situations of limiting soil moisture. Reduced leaf production was also reported by Madramootoo and Jutras (1984) when the plants were stressed for water. Bhattacharyya and Rao (1986a) detailed the effects of water stress on phylacron of banana cv. Robusta. They found that the rate of leaf production (reciprocal of phylacron) was quickest (five days) at 20 per cent depletion of available soil moisture under black polyethylene, while it was slowest (15 days) at 60 per cent available soil moisture depletion in bare soil. Daniells (1986) observed higher leaf area index in plants which were adequately watered. Kallarackal and Milburn (1988) followed the rate of leaf emergence in banana cv. Williams in relation to the change in its water potential. They found that the emergence of leaves stopped when water potential was approximately 0.25 Mpa.

Bhattacharyya and Rao (1986b) reported that sucker production was not affected by various levels of soil moisture.

2.5 Yield and Yield Attributes

The effect of moisture stress on yield and yield attributes of different crops has been investigated by many researchers. Reduced yields under conditions of limiting soil moisture were reported for corn (Denmead and Shaw, 1960), pea (Hiler et al., 1974 and Maity and Jana, 1987), rice (Ali et al., 1973), sorghum (Lewis et al., 1974 and Eck and Musick, 1979), soybean (Sionit and Kramer, 1977 and Ashley and Ethridge, 1978), cowpea (Shouse et al., 1981), groundnut (Shinde and Pawar, 1984, Ike, 1986 and Patel and Golakiya, 1988) gram and lentil (Maity and Jana, 1987).

The yield and yield components of vegetable and fruit crops are highly sensitive to water deficits. Powell (1974) observed considerable reduction in fruit set under conditions of water deficits in apple. From his investigations on the effect of different grades of water stress (75, 50 and 25 per cent of the daily water consumption of the control) on the growth and yield of straw berries, Gehrmann (1985) demonstrated reduced yields in water stressed plants. The yield reduction was reported to be due to a decreased mean fruit weight, diminished fruit number and accelerated fruit maturity induced by stress. Water stress reduced fruit set in tomatoes (Wudiri and Henderson, 1985). Water stress influenced number of flowers produced, their abscission, fruit set, fruit development and finally yield in egg plant (Tedeschi and Zerbi, 1985). Widders and Janoudi (1988) studied the effects of water stress on cucumber productivity.

They observed that water stress reduced plant productivity. Water stressed plants set 32 to 42.3 per cent fewer fruit and had 25.5 to 46.4 per cent lower total fruit dry weight than nonstressed plants.

Reduced yields of banana under conditions of soil moisture stress have been reported by many scientists. Simmonds (1959) described the effect of water stress on banana as the reduction in the number of hands, finger length and finally yield. He reported that under conditions of severe water deficits, fruit becomes unmarketable. Jagirdar et al. (1963) observed that Basrai bananas irrigated at an interval of six days gave significantly higher yield with better grade bunches than those irrigated at 14 days interval. Trochoulias (1973) recorded increased number of hands and fingers, finger length and bunch weight of Giant Cavendish banana when irrigated with 7.7 mm water once in three to five days during dry periods. Manica et al. (1975) also noticed a linear decrease in the number of hands and fingers per bunch from the wettest treatment to the driest treatment. Krishnan and Shanmugavelu (1979a, 1980) while comparing the effects of different soil moisture regimes on the growth, yield and fruit quality of banana, observed that if the depletion of available soil moisture was maintained at 20 per cent in both vegetative and reproductive phases, Robusta banana had a potential to yield a bunch of 36 kg compared to 24 kg recorded when the depletion of available soil moisture was maintained at 60 per cent. The number of hands per bunch, fingers per bunch, weight of hands per bunch and finally total yield were positively correlated with the available moisture in soil (KAU, 1982). Results of a field trial conducted by Holder and Gumbs (1983) revealed marked decrease in fruit yield due to decreased number of hands and fingers per bunch under conditions of soil water stress.

Watson and Daniells (1983) detailed the effects of water stress on bananas. Stress prior to bunch initiation resulted in substantial reduction in bunch weight mainly through reduced hand and finger numbers, where as stress after bunch initiation through reduced finger size. Bhattacharyya and Rao (1985, 1986a, 1986b) also reported a reduction in bunch weight and the characters associated with it with increase in soil moisture deficit. The decreased bunch weight was explained based on the reduced female flower production, when there was a deficit of soil moisture, which was 115.2 under continuous soil water stress and 154.9 under conditions of unlimited water supply. They concluded that soil water deficit adversely affected yield despite other favourable conditions. Daniells (1986) observed that irrigation increased yield by 23 per cent and was a function of greater finger number per bunch and greater finger length. Lahav and Kalmar (1988) studied the response of bananas to water amounts and reported that increased water amounts led to an increased bunch yield.

2.6 Crop Duration

Taylor and Slater (1955) noted delayed maturity of the banana crop when water stress was imposed during the vegetative stage. Jagirdar et al. (1963) reported that Basrai bananas irrigated at an interval of six days produced mature fruit 83 days earlier than those irrigated at 14 days interval. Melin and Marseault (1972) also recorded early maturity of bananas with irrigation in Cameroon. Sudden or severe water stress had been known to delay floral initiation or prevent it altogether (Angus and Moncur, 1977). Results of a field trial conducted by Krishnan and Shanmugavelu (1979a) revealed a significant advance in shooting with frequent irrigations, the shooting to harvest time was also shortened. The total crop duration extended with increasing soil water deficit. Holder and Gumbs (1982) also reported earliness in bananas induced by frequent irrigations. Madramootoo and Jutras (1984) noticed significant reduction in the number of days to harvest, under favourable soil moisture conditions. Investigations on banana cv. Williams led to the conclusion that water stress delayed bunch emergence by one month, if the stress occurred before bunch emergence and that after bunch emergence lengthened the fruit filling period by 12 to 22 days (Watson and Daniells,1983).

Daniells (1986) investigated the effects of water stress on bananas and found that the time taken from planting to harvest was 14 per cent higher for stressed plants, compared to irrigated ones. Bhattacharyya and Rao (1986a) also observed considerable increase in the time taken for shooting and harvest when the plants were stressed for water. According to Asoegwu and Obeifuna (1987), time to 50 per cent shooting was shortest in the continuously irrigated plantains, the difference from the stressed plants being 111 days. Lahav and Kalmar (1988) reported an increased time to flowering under stressed conditions, in Israel.

2.7 Fruit Quality

Fruit quality is highly influenced by water management practices. However very little attention has been directed to the effects of water stress on the quality aspects of banana fruit, so far. Teaotia et al. (1972) observed marked increase in the concentration of total soluble solids, total sugars, acidity and TSS/acid ratio in fruits produced on water stressed plants. Krishnan and Shanmugavelu (1979a) could also observe a similar trend in fruit quality under conditions of soil water deficits. They noticed substantial increase in the concentration of total soluble solids, reducing sugars, total sugars and acidity of fruits under stressed conditions. But ascorbic acid content showed a reverse trend. Watson and Daniells (1983) found increased maturity bronzing (epidermal cell rupture on fruit during the later stages of filling) when bunch emergence occurred during or just after the water stress period.

2.8 Mulching

The application of organic materials to the soil as mulches is a well established cultural practice to improve plant performance in arid and semiarid regions, where limited and erratic precipitation often results in low crop yields and some times total crop failures (Daisley et al., 1988). Various benefits derivable from mulching include reduced runoff and erosion, favourable soil moisture and temperature, increased water infiltration, reduced leaching losses, weed control etc. Mulching effects on soil moisture and soil temperature are reviewed in detail.

2.8.1 Soil moisture

The beneficial effects of mulches on conservation of soil moisture have been studied in detail during the past many decades. Russel (1939) reported that mulches conserved water in periods of frequent rains, but are of little value during extended dry periods. Soil moisture was frequently higher in mulched soils than in bare soils (Harrold, 1947; Schaller and Evans, 1954; Moody et al., 1963; Lal, 1974; Unger, 1976; Mandal et al., 1987 and Varadan and Rao, 1988). Increased infiltration rate under mulched condition was reported by many workers (Goodman, 1952; Burrows and Larson, 1962 and Adams, 1966). When maintained at adequate levels, the crop residues and other plant waste products resulted in reduced evaporation and increased water contents (Hanks and Woodruff, 1958; Bond and Willis, 1971; Dixit and Agarwal, 1971 and Hazra et al., 1973).

Bhattacharyya and Rao (1985) studied the effect of soil covers on banana production. The soil was mulched with black polyethelene,sugarcane trash, banana trash and left uncovered. The corresponding yields were 112.9, 95.5, 85.6 and 76.8 t ha^{-1} respectively. Simpson and Gumbs (1985) observed positive effects of mulches on soil moisture conservation. Results of a field trial conducted by Daisley et al. (1988) indicated that field soil with a mulch cover conserved more moisture within the profile than when the soil was unmulched, the reason was assumed to be the reduction of surface evaporation.

2.8.2 Soil temperature

Rokhade et al. (1972) observed reduced daily soil temperature fluctuations in mulched soils. Evenson and Rambaugh (1972) found that soil temperatures were as much as 9°C lower in mulched plots, compared to bare plots. Lal (1974) found that mulching considerably reduced the maximum soil temperature measured at 5, 10 and 20 cm depths. In the initial stages of crop growth, he observed, temperature differences of upto 8°C between mulched and unmulched plots at 5 cm depth. He attributed the increased yield in mulched plots to the reduction in daily soil temperature fluctuations. Results of a field trial conducted by Varadan and Rao (1983), to find out the effect of mulches on soil temperature in humid tropical soils under coconut and banana revealed, the soil temperature at 5 to 10 cm below the surface to be 1 to 6°C lower under mulched condition than that under no mulch. They also noticed that mulching confined diurnal maximum to between 30 and 33°C, while with no mulch, the maximum rose to 40°C.

Bhattacharyya and Rao (1986c) studied the effect of soil covers on soil temperature in a banana plantation. Black polyethylene, sugarcane trash and banana trash were used as mulches. Polyethylene film maintained a soil temperature above bare soil, the temperature was 2 to 3°C higher. The other two mulching materials maintained almost equal temperature and at certain periods, even lower compared to bare soil. Varadan and Rao (1988) noticed that mulching with coconut trash decreased soil temperature from 36.7°C to 35.2°C.

2.9 Hydrophilic Gels or Water Absorbing Polymers

Hydrophilic gels are relatively recent introductions into the agricultural market. They absorb water and slowly release it to the environment. The use of these and similar materials have been recommended for use as container media amendments, seed amendments and transplant aids (Henderson and Hensley, 1986).

Tayel et al. (1981a) reported that soil moisture constants were affected in soils treated with hydrophilic soil conditioners. Moisture retained in the soil at pF 0 increased with increasing the amount of conditioners applied. But amount of moisture retained at pF 4.19 decreased and that at pF 2.01 and 2.54 increased with increasing rates of hydrophilic material. Soil conditioners convert soil water evaporation into plant transpiration and improve soil water regime. This cause an increase in dry matter production and water use efficiency (Tayel et al., 1981b). From their studies on the effect of hydrophilic gels on evaporation of soil moisture, El-Hady et al. (1981a) revealed that the rate of evaporation from the conditioned sandy soil decreased with increasing the amount of conditioner applied, which resulted in a corresponding increase in water retained in the soil. Result of another study conducted by El-Hady et al. (1981b) in corn showed that supergel treatments led to an increase in germination percentage and rate, plant height, dry matter production, urease and phosphatase activity in soil, water use efficiency and uptake of N,P,K,Mn and Zn. Tayel and El-Hady (1981) tried to find out the effect of supergel on soil water relations. They found that the gel increased the total porosity, the micropore relative to the total or the macropores, water holding pores, water retention and available water, though decreased bulk density, proportion of quickly drained pores, hydraulic conductivity, mean diameter, intrinsic permeability, transmissivity and evaporation. James and Richards (1986) reported that application of water absorbing polymers or hydrogels in to the potting media substantially increased the water available to container plants. They found that hydrogels improved the shelf life of plants in retail outlets where watering and maintenance were minimal. Henderson and Hensley (1986) investigated the efficacy of a hydrophilic gel as a transplant aid. Significantly greater leaf water potentials were noticed in new transplants in sand amended with gel than in control or root dipped plants. No effect on either leaf water potential or stomatal resistance was apparent in finer textured soils. They concluded that incorporation of hydrophilic gels in to media with low water holding may delay the effects of reduced moisture level on new transplants for a short time.

Working with *Lingustrum lucidum*, Taylor and Halfacre (1986) demonstrated that plants growing in polymer amended medium required irrigation less frequently than plants in nonamended medium. The water absorbent root dip caused less negative leaf water potentials in seedlings by increasing gravimetric soil water content around the roots. However this enhancement of water status was not found in the field (Nitzsche at al., 1988). Dutt (1989) described Jalshakti, a water absorbing polymer as a promising wonder for agricultural revolution. He detailed the benefits of Jalshakti as a water stress preventer in transplanting, retainer or conserver of soil moisture in plug planting and as a gel providing constant water supply to seeds.

The literature reviewed clearly indicate the role of water stress in restricting production of major agricultural crops, through its effect on various physiological activities, growth, yield and yield components. Under situations of unlimited water supply, maintaining the soil at a favourable moisture regime throughout the period of crop growth is advantageous for maximum growth and yield. However, when the water availability is limited, mulches and hydrophilic gels through their effects on evaporation and soil properties enhance the moisture regime of the soil. Under this condition, efforts be made for identifying the most critical stages of crop growth, during which a stress imposed will have maximum impact on yield. The present study is an attempt towards this direction.

Materials and Methods

MATERIALS AND METHODS

The present investigation was carried out to study the effect of soil moisture stress on growth, yield and fruit quality of banana cv. Nendran. The experiment was conducted at the College of Horticulture, Vellanikkara, Trichur, Kerala during the period from August 1988 to June, 1989.

The experimental area is situated at 10° 31'N latitude and 76° 13'E longitude, and is at 22 m above MSL. This area enjoys a typical warm humid tropical climate.

Cropping history

The experimental field was lying fallow during the previous years.

Soil

The soil of the experimental area was laterite of deep well drained sandy clay loam texture. The physical and chemical characteristics of the soil are presented in Table 1.

Table 1. Properties of the Soil

1. Mechanical composition

Fraction	Per cent composition	Procedure adopted
Sand	77.5	
Silt	5	Hydrometer method (Bouyoucos, 1962)
Clay	17.5	

2. Pysical constants of the soil

Field capacity (0.3 bars)	18%	Pressure plate apparatus (Richards, 1947)
Wilting coefficient (15 bars)	11.2%	Pressure plate apparatus (Richards, 1947)
Bulk density g cm^{-3}	1.43	Core method (Blake, 1965a)
Particle density g cm^{-3}	2.37	Pycnometer method (Blake, 1965b)

Chemical properties

Organic carbon	1.13%	Walkley and Black rapid titration method (Jackson, 1958)

Available nitrogen	0.122%	Micro-Kjeldahl method (Jackson, 1958)
Available phosphorus	0.003%	Chlorostannous reduced molybdo phosphoric blue colour method in hydrochloric acid system (Jackson, 1958)
Available potassium	0.008%	Flame photometry, neutral normal ammonium acetate extraction (Jackson, 1958)
Soil reaction (pH)	5.4	Soil water suspension of 1:2.5 (Jackson, 1958)
Electrical conductivity (mmhos cm^{-1})	1.8	Soil water extract of 1:2.5 (Jackson, 1958)

Weather conditions

The data on the weather conditions during the crop growth period are presented in Fig. 1 and 2 and Appendix I.

The total rainfall received during the period was 2270 mm, of which 56 per cent was received during the early vegetative phase.

FIG.1. WEATHER CONDITIONS DURING THE CROP GROWTH PERIOD

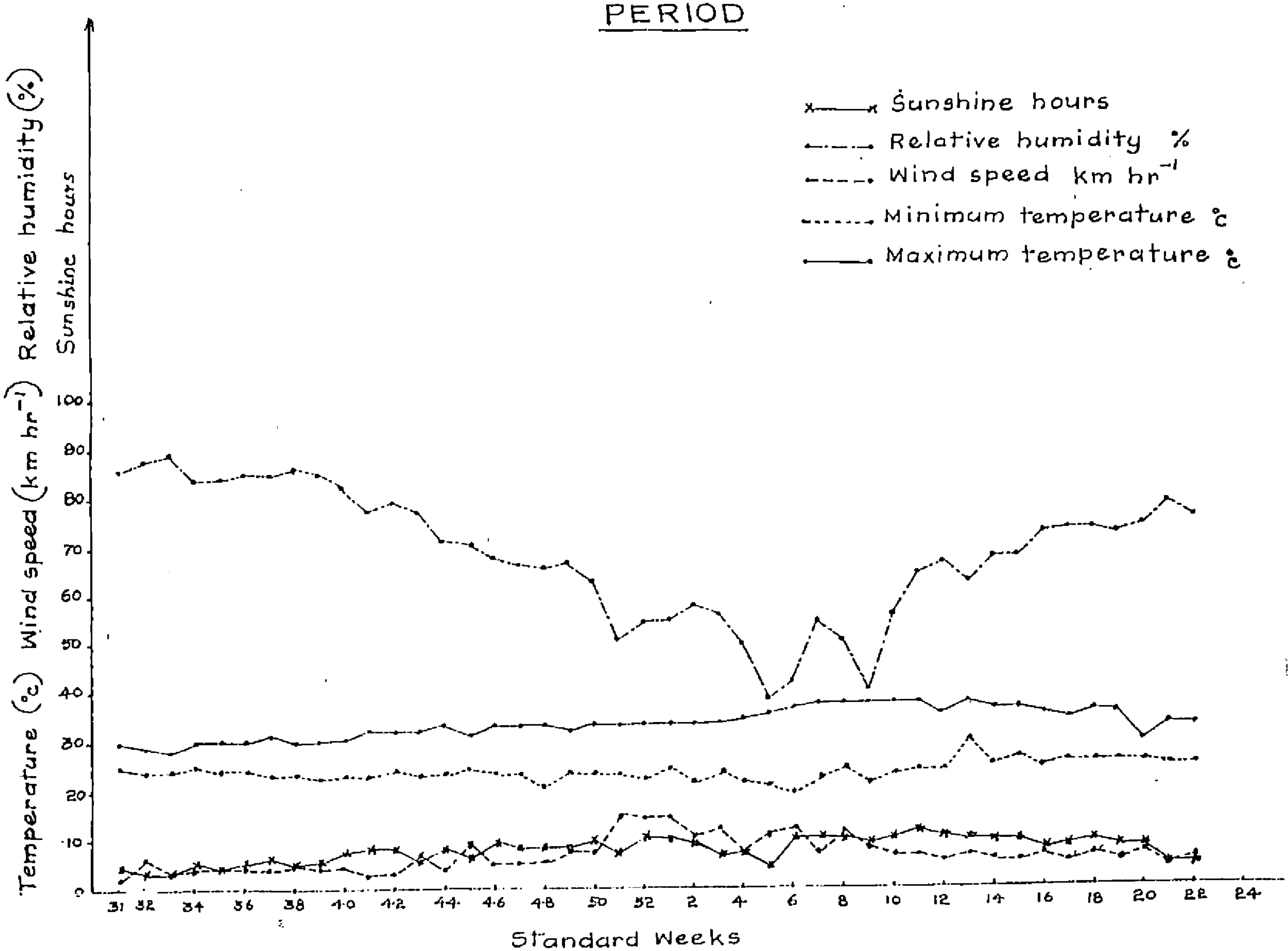
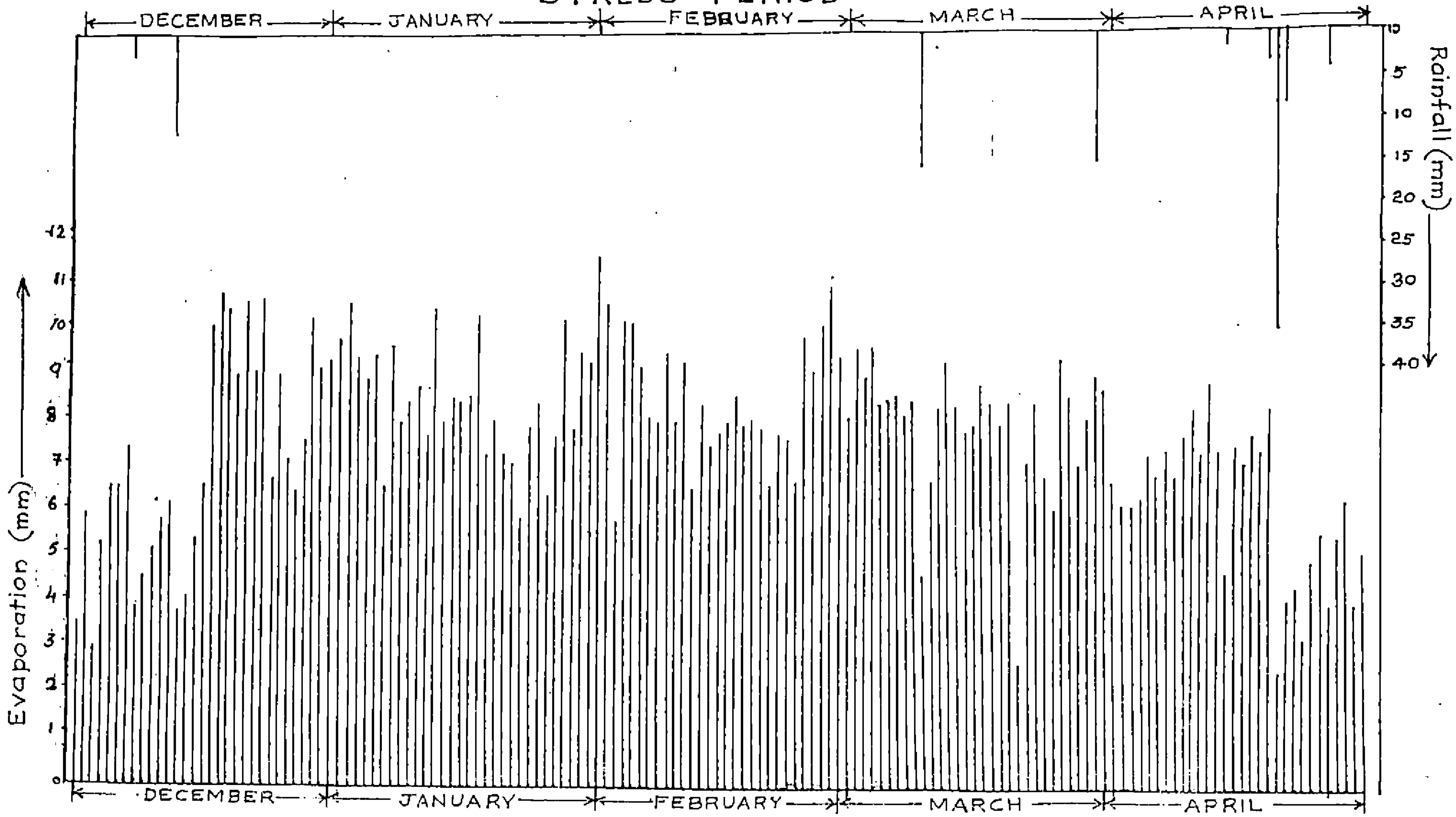


FIG.2. DAILY EVAPORATION AND RAINFALL DURING THE WATER STRESS PERIOD



The rainfall during December to April was very low (98.8 mm). Relative humidity was very low during this period and the record lowest value of 7 per cent was observed at 1400 hr LMT on 8-2-1989. The evaporative demand of the atmosphere was also very high during this period and the highest daily evaporation recorded was 11.7 mm on 31-1-1989.

The maximum temperature during the crop period ranged from 28.2°C to 39.5°C and the minimum temperature from 17.0 to 27.2°C. The wind speed was high, particularly during the flower initiation stage (December - January) and during some short gusts, the wind speed was as high as 30 km hr^{-1}. Thus the water stress experienced by the crop was very severe and it depended almost entirely on irrigation for its water requirement.

Suckers

Suckers of the cv. Nendran, having uniform size and age (3 months old) were selected from the Instructional Farm, Mannuthy. The pseudostem was headed back to a height of 15 to 25 cm. The suckers were further selected and those, weighing 2.00 to 2.50 kg. were smeared with cowdung solution and ash and dried in shade up to 15 days before planting.

Planting

Planting was done in pits of size 50 cm^3 at a spacing of 2 m either way.

Manures and fertilizers

Crop management practices were done as per the package of practices recommendations (KAU, 1986). A basal dose of 10 kg well decomposed Farm Yard Manure was given at planting. Urea, Factamfos and muriate of potash were applied to supply N, P_2O_5 and K_2O at the rate of 190:115:330 g $plant^{-1}$ in two equal splits, the first at two months after planting and the second, two months later.

Plant protection

Before planting, the suckers were dipped in BHC suspension (0.2 per cent) against rhizome weevil. As a prophylactic measure against banana bunchy top disease, thimet granules were applied at the rate of 25 g per pit at the time of planting. Second and third doses, 12.5 g each applied in the leaf axils, were given 75 and 165 days after planting. Spraying with Ekalux (0.5 per cent) was done twice at an interval of two weeks against *Spodoptera*.

Irrigation

Irrigation according to the treatments began in December.

Layout

The experiment was laid out in randomised blocks with ten treatments and three replications. In each plot, there were 16 plants, in four rows. The central four plants were selected as the observation plants, and the remaining being border plants(Fig.3).

Treatments

Details of the treatments are given below :

T_1 - Basin irrigation with 20 mm water at IW/CPE = 0.9 from December to April i.e., no stress period (without mulch).

T_2 - Basin irrigation with 20 mm water at IW/CPE = 0.9 in December only i.e., stress period - 4 months - January to April (with mulch).

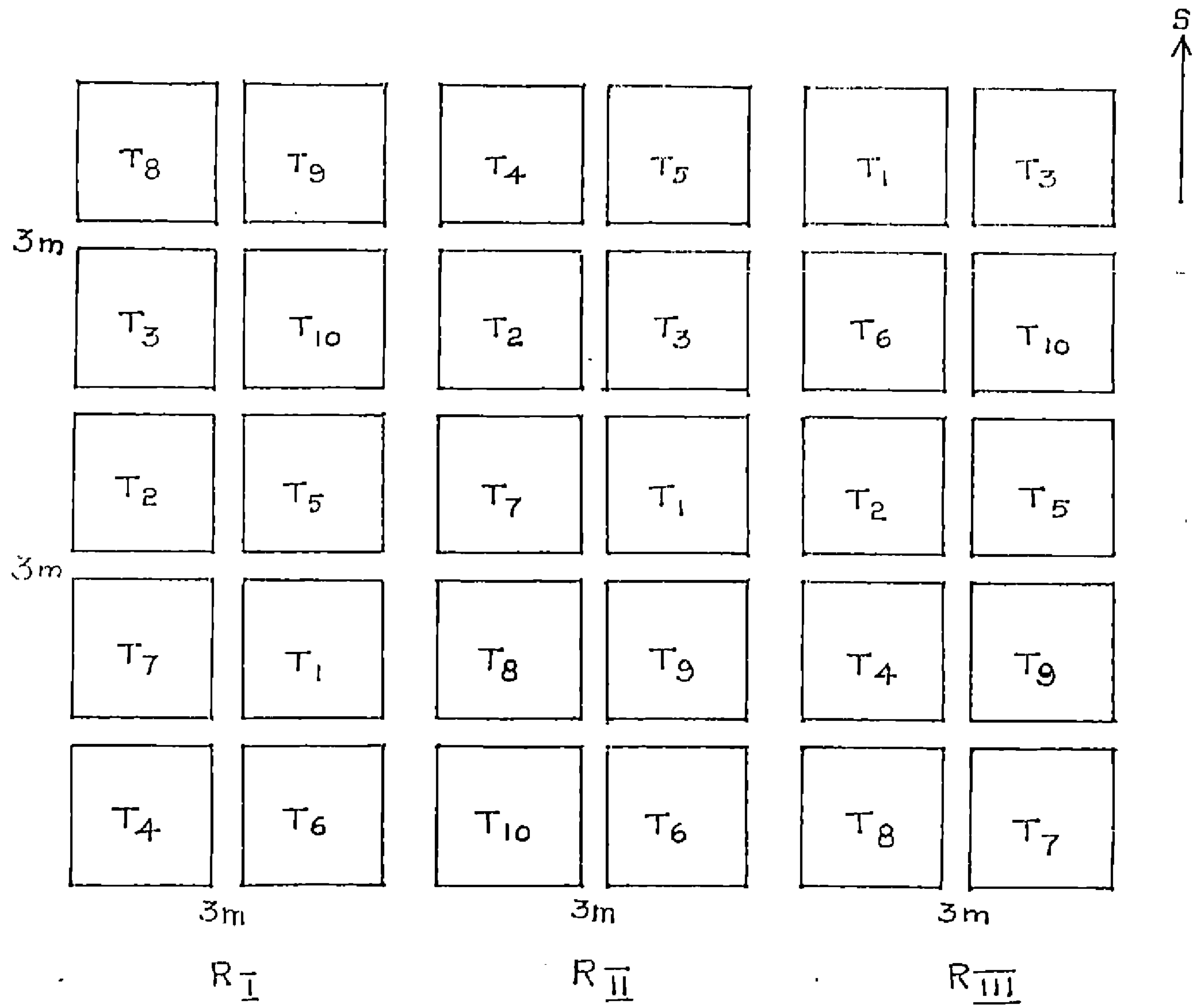
T_3 - Basin irrigation with 20 mm water at IW/CPE = 0.9 in December and January i.e., stress period - 3 months - February to April (with mulch).

T_4 - Basin irrigation with 20 mm water at IW/CPE = 0.9 from December to February i.e., stress period - 2 months - March and April (with mulch).

T_5 - Basin irrigation with 20 mm water at IW/CPE = 0.9 from December to March i.e., stress period - 1 month - April (with mulch).

T_6 - Basin irrigation with 20 mm water at IW/CPE = 0.9 in April i.e., stress period - 4 months - December to March (with mulch).

FIG.3. LAYOUT


S
T8
T9
T4
T5
T1
T3
3m
T3
T10
T2
T3
T6
T10
T2
T5
T7
T1
T2
T5
3m
T7
T1
T8
T9
T4
T9
T4
T6
T10
T6
T8
T7
3m
3m
3m
R I
R II
R III

T_7 - Basin irrigation with 20 mm water at IW/CPE = 0.9 in March and April i.e., stress period - 3 months - December to February (with mulch).

T_8 - Basin irrigation with 20 mm water at IW/CPE = 0.9 from February to April i.e., stress period - 2 months - December and January (with mulch).

T_9 - Basin irrigation with 20 mm water at IW/CPE = 0.9 from January to April i.e., stress period - 1 month - December (with mulch).

T_{10} -Application of antistress formulation *(Jalshakti) at the time of planting and at 25 days interval and irrigation with 35 litres of water at 25 days interval.

* - Jalshakti is a water absorbing polymer developed by National Chemical Laboratory (NCL), Pune.

Coconut husk was spread in the basins, as the mulch. The specified quantity of water 20 mm (80l) was measured and applied to basins as and when the cumulative class A pan evaporation reached the stipulated value of 22.2 mm. The effective rainfall if any, was also taken in to account while giving irrigation.

Observations

The various observations recorded and the procedures adopted are detailed below.

Morphological characters

Observations on various morphological characters were recorded from four months after planting to flowering at monthly intervals, adopting the method suggested by Yang and Pao (1962).

3.1 Growth Parameters

3.1.1 Height of the pseudostem

The height of the pseudostem, measured from the ground level to the youngest leaf axil, was expressed in cm.

3.1.2 Girth of the pseudostem

The girth of the pseudostem was measured at 20 cm above the ground level and expressed in cm.

3.1.3 Number of leaves per plant

Fully opened, functional leaves (more than 50 per cent green area) present at each observation were recorded.

3.1.4 Length of lamina

Length of the lamina was measured from the point of attachment to the tip and expressed in m.

3.1.5 Width of lamina

Width of the lamina was measured at the broadest part and expressed in m.

3.1.6 Leaf area per plant

Leaf area was computed using the formula given by Murray (1960) (length x breadth x 0.825), and expressed in m^2.

3.1.7 Sucker-production

The number of suckers produced were recorded at shooting and at harvest.

3.1.8 Days for shooting

The number of days taken from planting to shooting was recorded.

3.1.9 Days from shooting to harvest

The number of days taken from shooting to harvest was recorded.

3.2 Bunch Characters

The bunches were harvested when they were fully mature as indicated by the disappearance of angles, that is 'round full' (Simmonds, 1959). The following observations were made on the harvested bunches.

3.2.1 Weight of the bunch

Weight of the bunch including the portion of the peduncle (exposed outside the plant) was recorded in kg.

3.2.2 Length of the bunch

Length of the bunch was measured from the point of attachment of the first hand to that of the last hand and expressed in cm.

3.2.3 Number of hands per bunch

The number of hands on each bunch was counted and recorded.

3.2.4 Number of fingers per hand

The second hand from the base of the bunch was selected as the representative hand and the number of fingers present in it were counted and recorded.

3.2.5 Number of fingers per bunch

The total number of fingers per bunch were counted and recorded.

3.2.6 Length of the finger

The middle finger on the top row of the second hand (from the base of the bunch) was selected as the representative finger for recording the finger characters (Gottreich et al., 1964). Length of the finger was measured from the point of attachment to the tip using a thread and scale, and expressed in cm.

3.2.7 Girth of the finger

Girth of the finger was measured at the mid portion and expressed in cm.

3.2.8 Weight of the finger

Weight of the finger was recorded in g.

3.3 Fruit Quality

The fruits collected from well ripe bunches were used for quality analysis. Samples were taken from each fruit from three portions, top, middle and bottom, pooled and macerated in a waring blender. Quality estimations were done as described below.

3.3.1 Total soluble solids

Total soluble solids were estimated using a pocket refractometer, and expressed as percentage.

3.3.2 Acidity

Made up 25 g. of the macerated fruit sample to a known volume, using distilled water. A known volume of the filtered solution was titrated against 0.1 N sodium hydroxide using phenolphthalein as indicator. The acidity was expressed as percentage of citric acid (A.O.A.C., 1960).

3.3.3 Total sugars

Total sugars were determined as per the method described by A.O.A.C. (1960). To 50 ml of the clarified fruit solution, 5 ml. of concentrated hydrochloric acid was added and was kept overnight. The solution was then neutralised by adding sodium hydroxide and titrated against a mixture of Fehling's A and B solutions.

3.3.4 Sugar acid ratio

Sugar acid ratio was arrived at by dividing the values for the total sugars by that of the titratable acidity.

3.4 Meteorological Parameters

The daily values on various weather elements recorded at the meteorological observatory of the College of Horticulture, Vellanikkara were collected.

3.5 Soil Temperature

Soil thermometers at three depths of 5, 10 and 20 cm. were installed in 5 plots including one bare plot. Observations were taken twice daily at 0700 hr LMT (0725 hr IST) and 1400 hr LMT (1425 hr IST), at the three depths.

The diurnal ranges of soil temperatures for all the 5 plots were calculated at the three depths.

3.6 Soil Moisture

Soil sampling

Soil samples were collected at two depths, 0 to 15 and 15 to 30 cm using an auger, before and 24 hours after irrigation. Moisture estimations were made by gravimetric method and expressed as percentage on oven dry basis (A.O.A.C., 1962).

3.6.1 Consumptive use

Consumptive use was computed from the soil moisture depletion data (Michael et al., 1977). The potential evapotranspiration for the period "24 hours after irrigation" was computed from class A pan evaporation data. The effective rainfall, determined based on the soil moisture content and the potential evapotranspiration (Dastane, 1974), were also taken in to account for computing consumptive use. Seasonal consumptive use was calculated by summing up the consumptive use values for each sampling interval.

3.6.2 Soil moisture stress

To quantify the soil moisture stress experienced by the plants, the consumptive use from the soil layer, 0 to 30 cm was computed for all treatments taking in to account of the effective rainfall. The difference between the potential consumptive use (consumptive use for the treatment with no water stress for the period under consideration) and the actual consumptive use is considered as the soil moisture stress. Thus, the soil moisture stress values for all periods between successive irrigations for all treatments were calculated. Simple linear correlations between the various growth and yield characters, and the soil moisture stress for overlapping periods from December to April (4 months after planting to 8 months after planting) were worked out. The critical period of soil moisture stress influencing these characters were identified. A regression equation between soil moisture stress and bunch weight was developed. A comparison is made between the actual yield and the yield estimated from the regression equation.

3.7 Statistical Analysis

The data obtained were subjected to statistical scrutiny and interpreted adopting the methods suggested by Panse and Sukhatme (1985).

Results

RESULTS

During the course of the investigation, observations on various biometric characters and bunch characters were recorded to study the effect of soil moisture stress on the growth and yield of banana cv. Nendran. The data were subjected to statistical analyses and the results are presented below.

4.1 Growth Parameters

4.1.1 Height of the plant

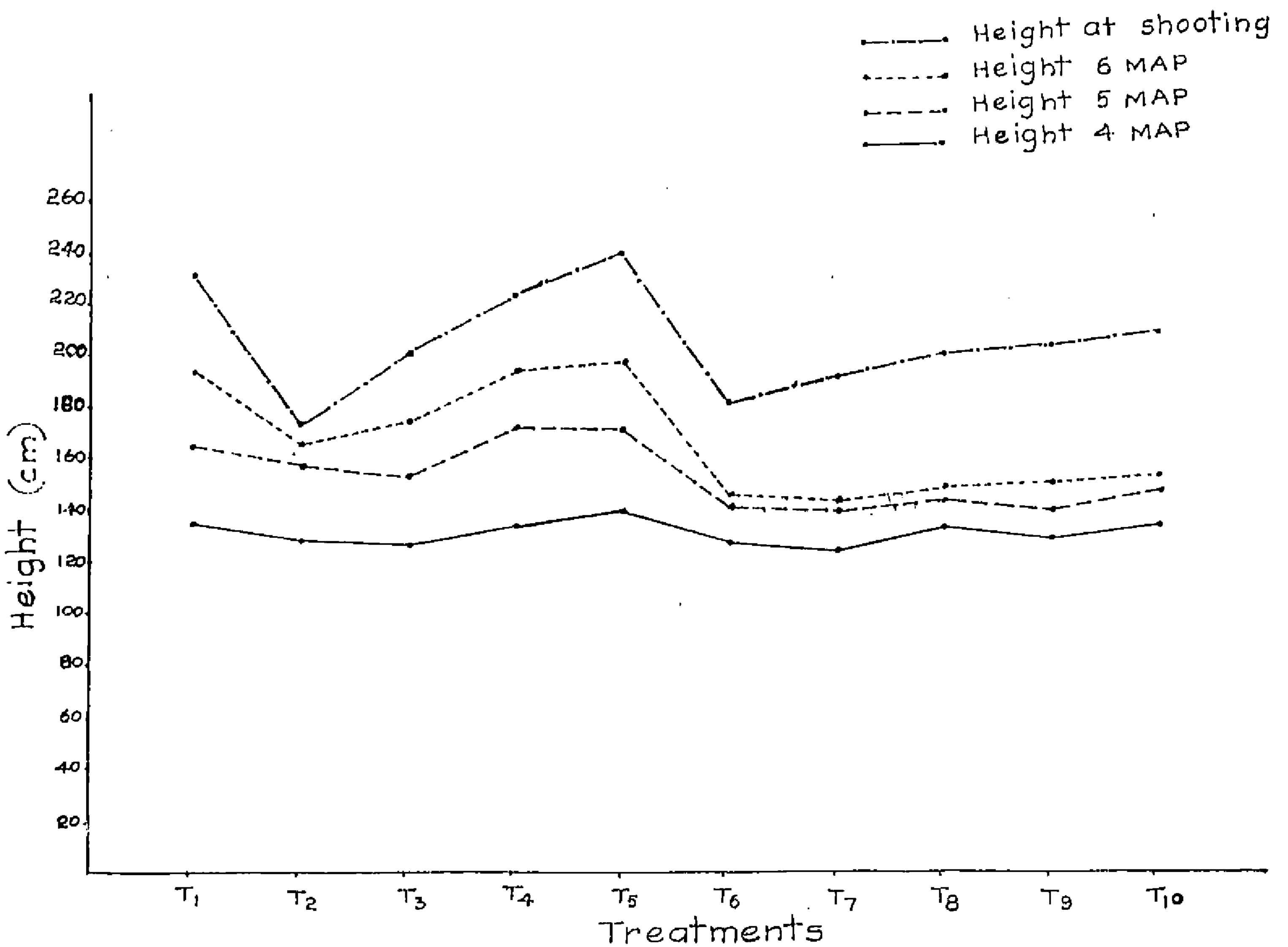
The mean values of the plant height recorded at various stages of growth are presented in Table 2 and illustrated in Fig. 4. The analysis of variance is given in Appendix II.

Plant height was significantly affected by soil moisture stress imposed during various stages of growth and development. Except at five months after planting, T_5 recorded maximum plant height, and was on par with T_1 and T_4. At five months after planting, T_4 had the highest value and was on par with T_1 and T_5. At flowering T_9 was also on par with T_5. T_7 recorded the lowest value until flowering, and was on par with T_6, T_8, T_9 and T_{10}. At flowering, T_2 was inferior to all other treatments, but was on par with T_6.

Table 2 Effect of soil moisture stress on the height (cm) of the plant at various stages of growth

Treatments	4 months after planting	5 months after planting	6 months after planting	At shooting
T_1	135.00	164.96	194.75	232.00
T_2	128.45	158.00	166.75	173.83
T_3	127.22	153.69	173.69	202.00
T_4	135.94	172.33	195.75	225.33
T_5	139.46	171.79	197.83	240.33
T_6	127.92	141.54	146.22	181.17
T_7	125.35	139.50	144.25	193.33
T_8	134.36	145.39	149.61	221.83
T_9	129.56	140.53	153.33	224.5
T_{10}	134.83	148.90	155.50	209.92
SEm±	2.88	4.35	5.15	6.17
CD (0.05)	8.55	12.93	15.29	18.33

FIG. 4. EFFECT OF SOIL MOISTURE STRESS ON THE HEIGHT OF PSEUDOSTEM AT VARIOUS STAGES OF GROWTH



4.1.2 Girth of the plant

The data pertaining to the girth of the plant are given in Table 3 and its analysis of variance in Appendix II.

As evident from the table, girth of the plant was highly influenced by the soil moisture stress. Highest girth was recorded by T_5 always, except at six months after planting. However it was always on par with T_1 and T_4. At six months after planting, T_4 had the highest girth. At flowering, T_9 improved and recorded a girth on par with T_1 and T_4. T_7 recorded the lowest girth of all the treatments and was on par with T_6 at flowering.

4.1.3 Number of leaves

The data on the number of leaves recorded at various stage of growth are given in Table 4 and the analysis of variance in Appendix III.

The number of leaves retained by the plant increased progressively with decreasing levels of stress. Up to six months after planting, T_5 recorded the highest value, which was on par with T_1, T_2, T_3 and T_4. At six months after planting, T_4 recorded the highest number of leaves, which was on par with T_1 and T_5. At flowering, T_9 was significantly superior to all other treatments in terms of number of leaves retained. Up to flowering, T_6 had the lowest number of leaves, and did not differ significantly from T_8. At flowering, T_3 recorded the lowest value, and was significantly inferior to the rest of the treatments.

Table 3 Effect of soil moisture stress on the girth of plant (cm) at various stages of growth

Treatments	4 months after planting	5 months after planting	6 months after planting	At shooting
T_1	37.61	43.83	48.06	50.17
T_2	36.33	41.00	41.11	41.83
T_3	35.89	40.33	43.85	46.83
T_4	37.67	44.13	48.11	50.17
T_5	38.82	44.13	47.31	50.41
T_6	35.83	36.04	37.13	39.33
T_7	36.33	35.50	37.69	38.50
T_8	36.71	37.62	38.69	42.83
T_9	36.39	35.30	40.25	47.67
T_{10}	37.83	38.70	39.42	42.25
SEm±	1.06	1.13	0.94	0.901
CD (0.05)	NS	3.36	2.78	2.68

Table 4 Effect of soil moisture stress on the total number of leaves at various stages of growth

Treatments	4 months after planting	5 months after planting	6 months after planting	At shooting
T_1	10.44	10.58	11.11	11.00
T_2	9.89	10.42	7.19	6.11
T_3	10.11	10.17	10.11	9.67
T_4	10.55	10.50	11.28	11.33
T_5	10.81	10.58	10.89	11.00
T_6	9.89	7.00	6.31	9.17
T_7	10.22	8.14	6.89	10.83
T_8	9.61	7.83	6.36	11.50
T_9	9.89	8.08	9.42	12.50
T_{10}	10.67	8.92	9.08	8.83
SEm±	0.21	0.35	0.33	0.271
CD (0.05)	0.62	1.05	0.98	0.80

4.1.4 Leaf area

The leaf area recorded at different stages of growth are presented in Table 5 and the analysis of variance in Appendix III.

As clear from the table, the leaf area recorded at different stages of growth showed significant variation depending on the levels of soil moisture stress imposed. Up to flowering, T_5 recorded the highest leaf area which was on par with T_1 and T_4. At flowering, highest value was recorded by T_4, which was on par with T_1, T_5 and T_9. At harvest, T_5 recorded the highest leaf area, and was on par with T_1, T_8 and T_9. T_6 recorded the lowest leaf area up to flowering, but at flowering and at harvest, T_2 was inferior to all other treatments, though did not differ statistically from T_6, T_7 and T_{10}.

4.1.5 Sucker production

The mean number of suckers produced by various treatments at shooting and at harvest are presented in Table 6 and its analysis of variance in Appendix IV.

The sucker production both at shooting and at harvest did not differ significantly between treatments. At shooting, T_5 produced the maximum number of suckers, and at harvest T_7 recorded the highest value, and both did not show any significant difference from other treatments.

Table 5 Effect of soil moisture stress on the total leaf area (m^2) at various stages of growth

Treatments	4 months after planting	5 months after planting	6 months after planting	At shooting	At harvest
T_1	4.36	5.93	7.18	7.09	4.05
T_2	3.42	4.95	4.12	4.05	1.72
T_3	3.79	5.18	5.89	6.19	2.35
T_4	4.02	5.69	6.75	7.68	2.90
T_5	4.39	6.17	7.31	7.35	4.06
T_6	3.82	3.41	3.18	4.11	2.52
T_7	3.95	4.18	3.59	4.30	2.39
T_8	3.90	4.15	3.34	4.85	3.68
T_9	3.82	3.93	4.78	7.16	3.85
T_{10}	4.47	4.64	4.64	4.80	2.68
SEm±	0.22	0.33	0.22	0.26	0.44
CD (0.05)	NS	0.97	0.66	0.78	1.31

Table 6 Effect of soil moisture stress on sucker production (No)

Treatments	At shooting	At harvest
T_1	2.17	3.80
T_2	0.78	1.78
T_3	2.00	2.83
T_4	2.33	2.83
T_5	3.28	3.14
T_6	0.83	3.44
T_7	1.17	3.94
T_8	3.00	2.83
T_9	2.00	3.08
T_{10}	1.33	2.89
SEm±	0.68	0.52
CD (0.05)	NS	NS

Table 8 Effect of soil moisture stress on bunch characters

Treatments	Weight of the bunch (kg)	Length of the bunch (cm)	Number of hands/ bunch	Number of fingers/ bunch	Number of fingers/ hand	Length of finger (cm)	Girth of finger (cm)	Weight of fruit (g)
T_1	5.07	35.70	4.93	34.58	7.43	22.90	12.67	108.67
T_2	2.70	26.67	3.90	23.93	6.33	17.10	9.83	69.10
T_3	3.15	27.93	4.57	29.17	6.57	16.87	9.70	65.37
T_4	3.78	34.03	5.00	33.50	7.00	17.20	10.07	110.33
T_5	5.00	35.37	5.10	34.57	7.80	21.70	11.93	109.37
T_6	3.07	26.67	3.67	19.00	5.33	17.33	10.50	61.67
T_7	3.75	33.83	4.33	27.33	5.67	19.60	11.77	82.33
T_8	3.71	33.67	4.87	36.67	7.40	18.90	10.97	84.17
T_9	4.16	36.43	5.10	36.43	7.30	21.60	12.13	90.17
T_{10}	2.63	26.00	3.67	20.67	5.67	14.00	9.50	62.67
CEm±	0.31	1.08	0.25	2.48	0.31	0.72	0.37	6.19
CD (0.05)	0.92	3.22	0.76	7.37	0.93	2.15	1.11	18.39

4.1.6 Crop duration

The data on crop duration are presented in Table 7 and is illustrated in Fig. 5. The analysis of variance is given in Appendix IV.

Highly significant variation was noticed between treatments with respect to the duration of the crop from planting to shooting and from planting to harvest. T_6 recorded the longest duration from planting to shooting and from planting to harvest (271.1 and 348.4 days). The lowest values for the days taken from planting to shooting and planting to harvest were recorded by T_5 (210.1 and 293.0 days), which were on par with T_1, T_4 and T_{10}. The duration from flowering to harvest was longest for T_2 (98.7 days) which differed significantly from the rest of the treatments. The lowest value was recorded by T_7 (69.4 days), which was on par with T_6, T_7, T_8 and T_9.

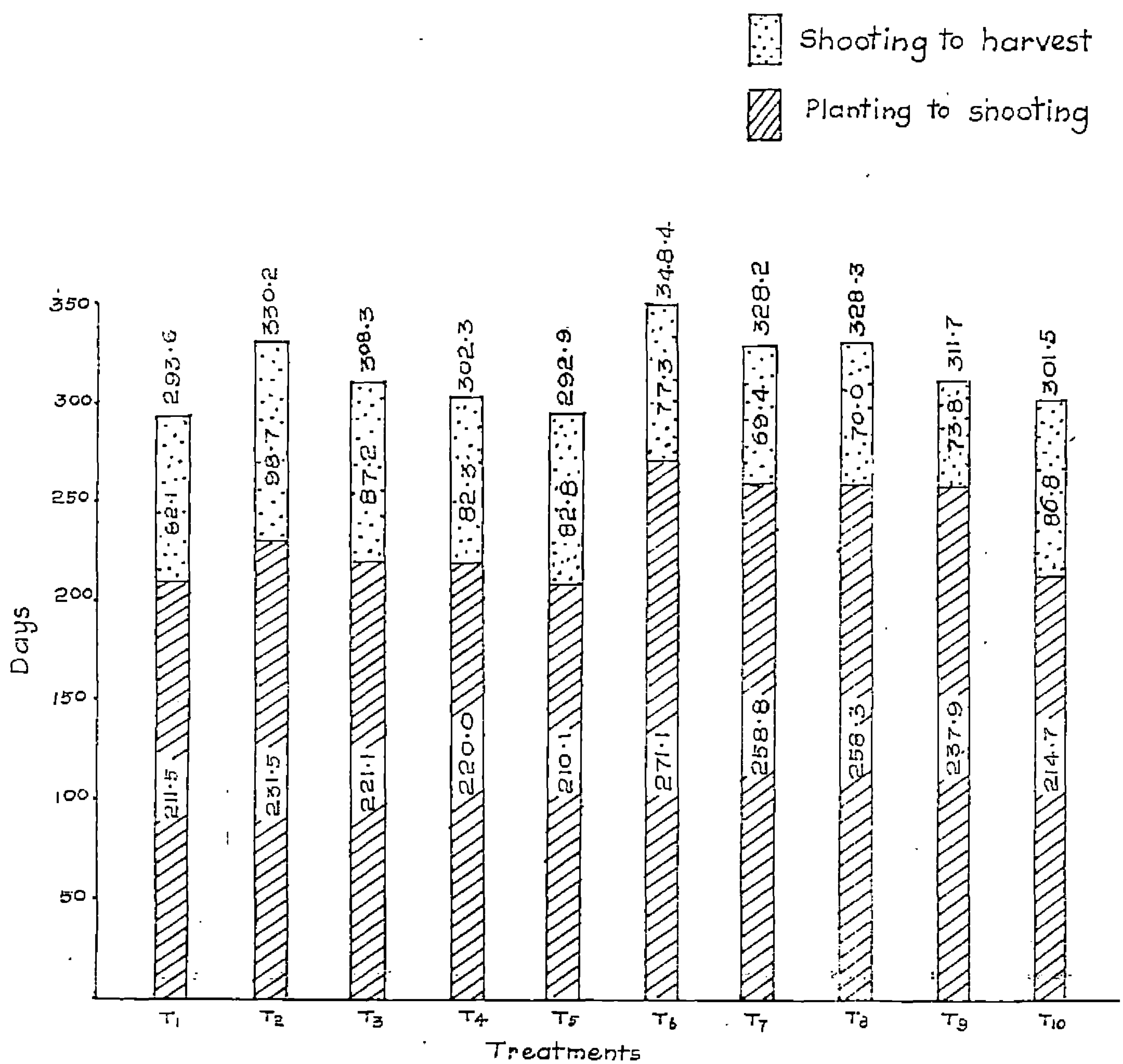
4.2 Bunch Characters

The data pertaining to the various bunch characters are presented in Table 8 and the analysis of variance in Appendix V.

4.2.1 Length of bunch

The maximum bunch length (36.4 cm) was observed in T_9, which was on par with T_1, T_4, T_5, T_7 and T_8. T_{10} recorded the minimum bunch length (26 cm) and it was on par with the rest of the treatments.

FIG. 5. EFFECT OF SOIL MOISTURE STRESS ON CROP DURATION



4.2.2 Number of hands per bunch

As evident from the Table 8 and Fig. 6, significant variations were observed between treatments with respect to the number of hands per bunch. The highest value (5.1) was registered by both T_5 and T_9, which was on par with T_1, T_3, T_4 and T_8. T_{10} recorded the lowest value (3.67) and it was on par with T_2, T_6 and T_7.

4.2.3 Number of fingers per bunch

The data on the number of fingers per bunch are illustrated in Fig. 7.

Like the number of hands per bunch, number of fingers per bunch also showed significant variation between treatments. T_8 carried the maximum number of fingers (36.7) followed by T_9, T_1, T_5 and T_4. T_6 recorded the lowest value (19.0) and it was on par with T_2 and T_{10}.

4.2.4 Number of fingers per hand

Significant differences were noticed between treatments with regard to the number of fingers per hand. The mean number of fingers per hand ranged from 7.8 (T_5) to 5.3 (T_6).

FIG.6. EFFECT OF SOIL MOISTURE STRESS ON NUMBER OF HANDS/BUNCH AND BUNCH WEIGHT

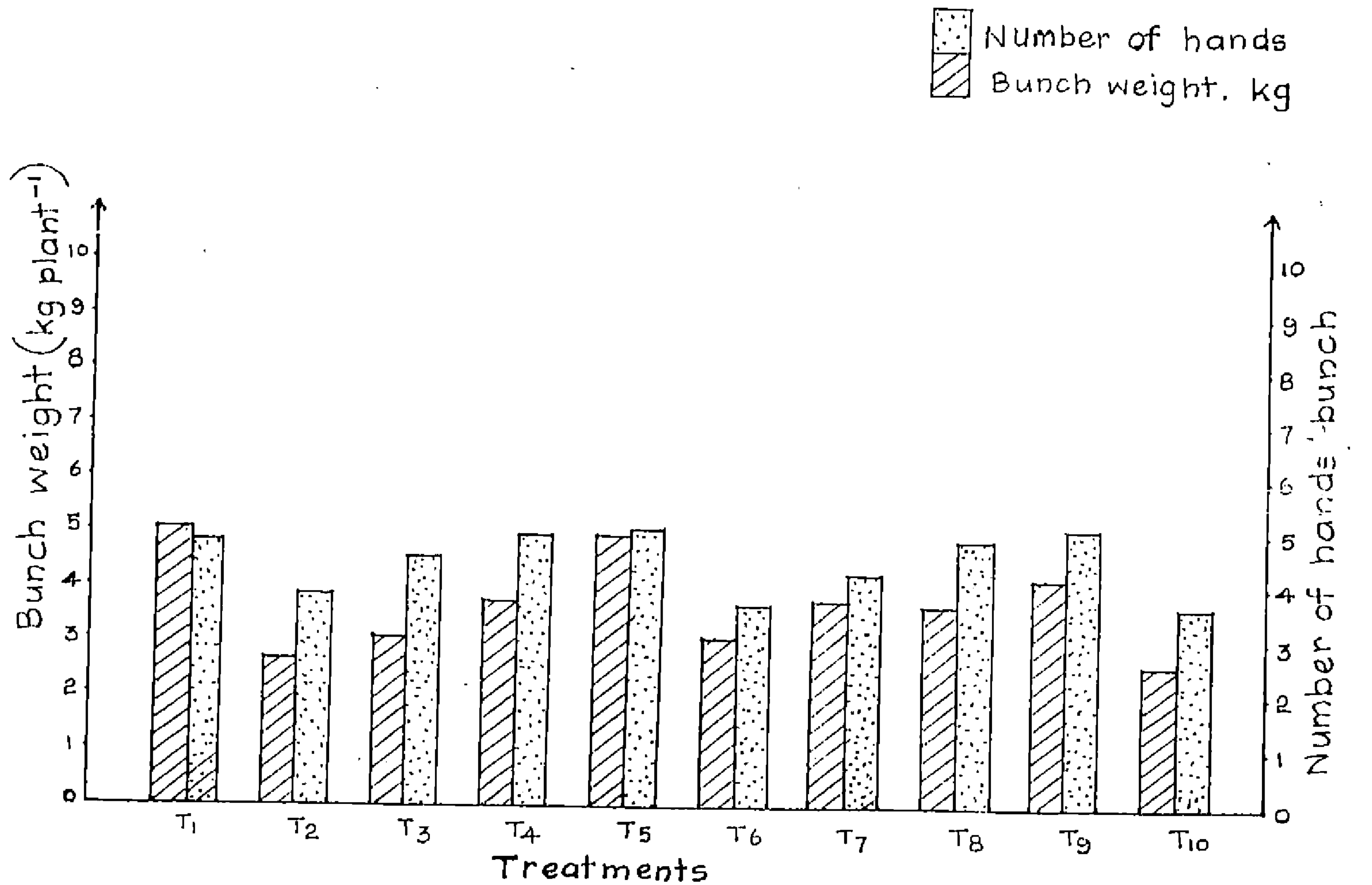
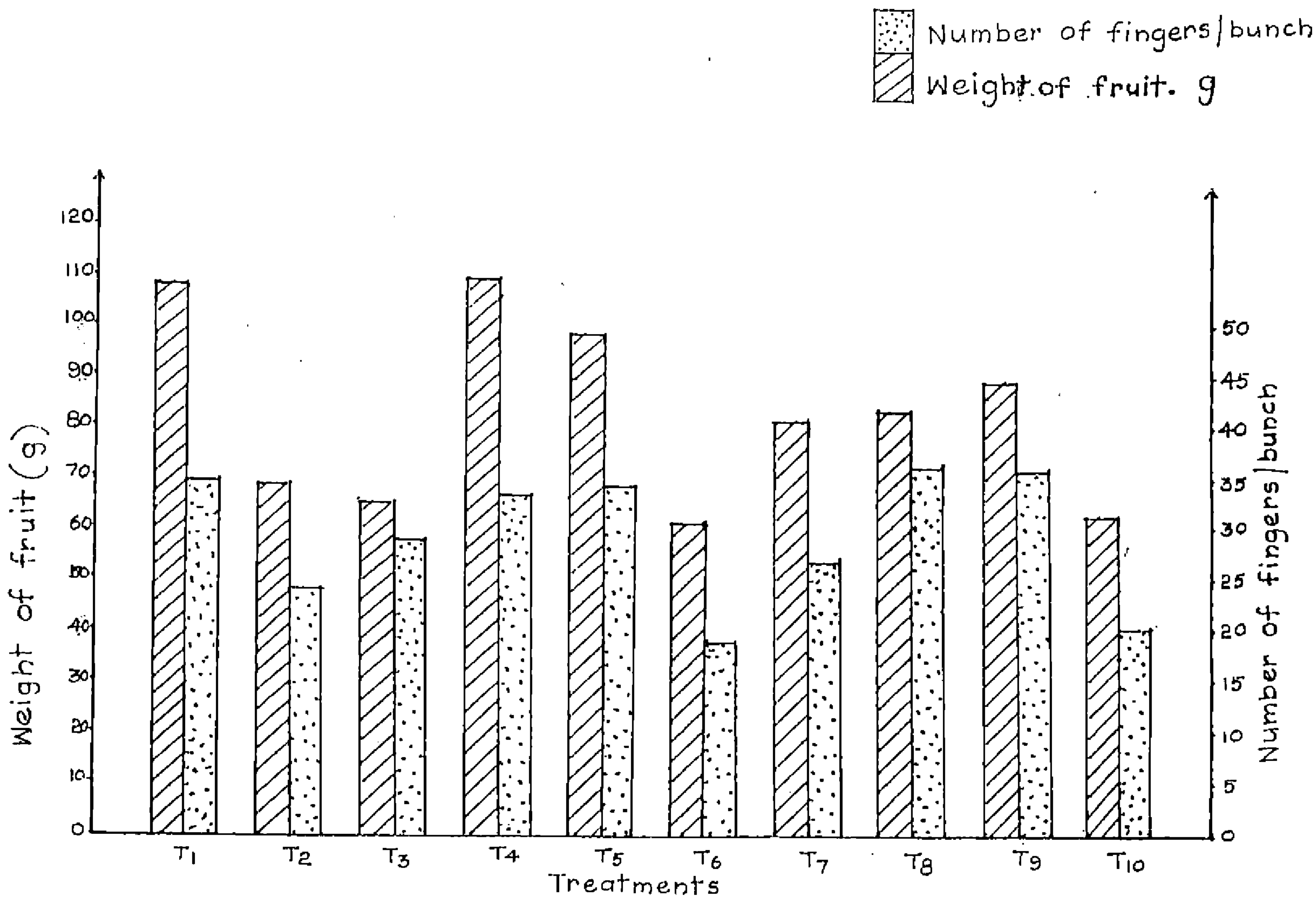


FIG. 7. EFFECT OF SOIL MOISTURE STRESS ON NUMBER OF FINGERS/BUNCH AND WEIGHT OF FRUIT



4.2.5 Length of finger

Length of finger was also highly influenced by available soil moisture. T_1 recorded the highest finger length (22.9 cm) and it was on par with T_5 and T_9. Lowest value of 14.0 cm was registered by T_{10}, which differed significantly from the rest of the treatments.

4.2.6 Girth of finger

Girth of finger followed the same trend of length of finger and the values ranged from 12.67 cm (T_1) to 9.50 cm (T_{10}). There was a progressive decrease in the girth of fingers recorded as the level of stress imposed increased.

4.2.7 Weight of fruit

As clear from Table 8 and Fig. 7, weight of fruit was highly influenced by the various treatments. T_4 recorded the highest value (110.30 g) and it was on par with T_1 and T_5. T_6 recorded the lowest fruit weight (61.67 g) and it was on par with T_2, T_3 and T_{10}.

4.2.8 Weight of bunch

The data on bunch weight are illustrated in Fig. 6, and it show highly significant differences between treatments. There was a progressive increase in bunch yield with decreasing levels of soil moisture stress. T_1 recorded the maximum bunch yield of 5.07 kg, which was closely followed by T_5 (5.0 kg). T_9 was also on par with T_1 and T_5. An yield reduction of 47 per cent was noticed for T_2, which was irrigated in December only. T_{10} recorded the lowest bunch yield (2.63 kg) which was only 52 per cent of the control plot without any moisture stress.

4.3 Fruit Quality

The data on various quality aspects of fruit are presented in Table 9 and the analysis of variance in Appendix VI.

4.3.1 Total soluble solids

The various levels of soil moisture stress imposed did not influence the total soluble solids content of the fruit. The differences obtained were not statistically significant.

4.3.2 Total sugars

The total sugar cont f the fruit showed an increasing trend with increasing level of so. isture stress. The maximum value of 17.35% was observed in T_2, w. was on par with T_3, T_4, T_6 and T_{10}. T_9 recorded the lowest value (15.42%) and it was on par with T_1, T_5, T_8 and T_9.

Table 9 Effect of soil moisture stress on fruit quality

Treatment	Total soluble solids (%)	Total sugars (%)	Acidity (%)	Sugar/ acid
T_1	26.67	15.64	0.68	23.59
T_2	27.00	17.35	0.45	38.93
T_3	26.33	17.18	0.48	35.80
T_4	27.00	16.85	0.45	37.86
T_5	28.00	16.01	0.47	34.80
T_6	26.67	16.94	0.51	33.36
T_7	27.33	16.06	0.49	33.27
T_8	27.00	15.63	0.47	33.01
T_9	26.00	15.42	0.54	28.91
T_{10}	25.67	16.75	0.63	22.26
SEm±	0.62	0.21	0.04	2.11
CD (0.05)	NS	0.62	0.11	6.27

4.3.3 Acidity

The acid content of fruit showed a reverse trend. The highest value was recorded by T_1 (0.68%), and it was on par with T_{10}. The lowest value was recorded by T_2 and T_4 (0.45) which was on par with all other treatments.

4.3.4 Sugar acid ratio

Sugar acid ratio followed almost a similar pattern as that of total sugars. T_2 recorded the maximum value of 38.93, which was on par with all other treatments except T_1, T_9 and T_{10}. T_1 recorded the lowest value of 23.59, and it was on par with T_9 and T_{10}.

4.4 Soil Temperature

The soil temperature data recorded daily twice at three depths i.e. 5, 10 and 20 cm for the five plots (bare, mulch with irrigation, mulch with no irrigation, no mulch with irrigation and Jalshakti) indicated that at 0700 hr LMT, the treatment - mulch with no irrigation always recorded high soil temperatures at two depths, 5 cm and 10 cm, where as, at 20 cm depth, the Jalshakti plot always recorded high temperatures except for a few days after irrigation. At 1400 hr LMT, the temperatures were always higher in the bare plot at all the three depths. The irrigated mulched plot recorded the lowest soil temperatures both in the morning and afternoon, at all the three depths.

For a better understanding of the diurnal variations in soil temperatures, the weekly mean diurnal range of soil temperatures for all the five plots at three depths is presented in Fig. 8. It can be seen from the figure that in the bare plot, the temperature ranges showed large variations with respect to time as well as depth. The irrigated plot with mulch showed the lowest such variations among the different treatments. It is interesting to note that for the unirrigated plot with mulch, the temperature range recorded at 20 cm depth was extremely low and assumed negative values more often than positive values indicating a slightly warm temperature in the morning compared to afternoon.

4.5 Soil Moisture

4.5.1 Consumptive use

The total consumptive use during the dry season (December to April) at two depths (0 to 15 cm and 15 to 30 cm) for all the treatments are presented in Table 10. T_1 recorded the highest consumptive use, 60.1 cm and 85.1 cm, and the consumptive use decreased as the level of soil moisture stress increased. The lowest values (23.8 cm and 34.1 cm) were recorded by T_{10} at both the depths. Monthwise consumptive use for all the treatments is shown in Fig. 9, for a better understanding.

FIG. 8. MEAN DIURNAL RANGE OF SOIL TEMPERATURES (°c)

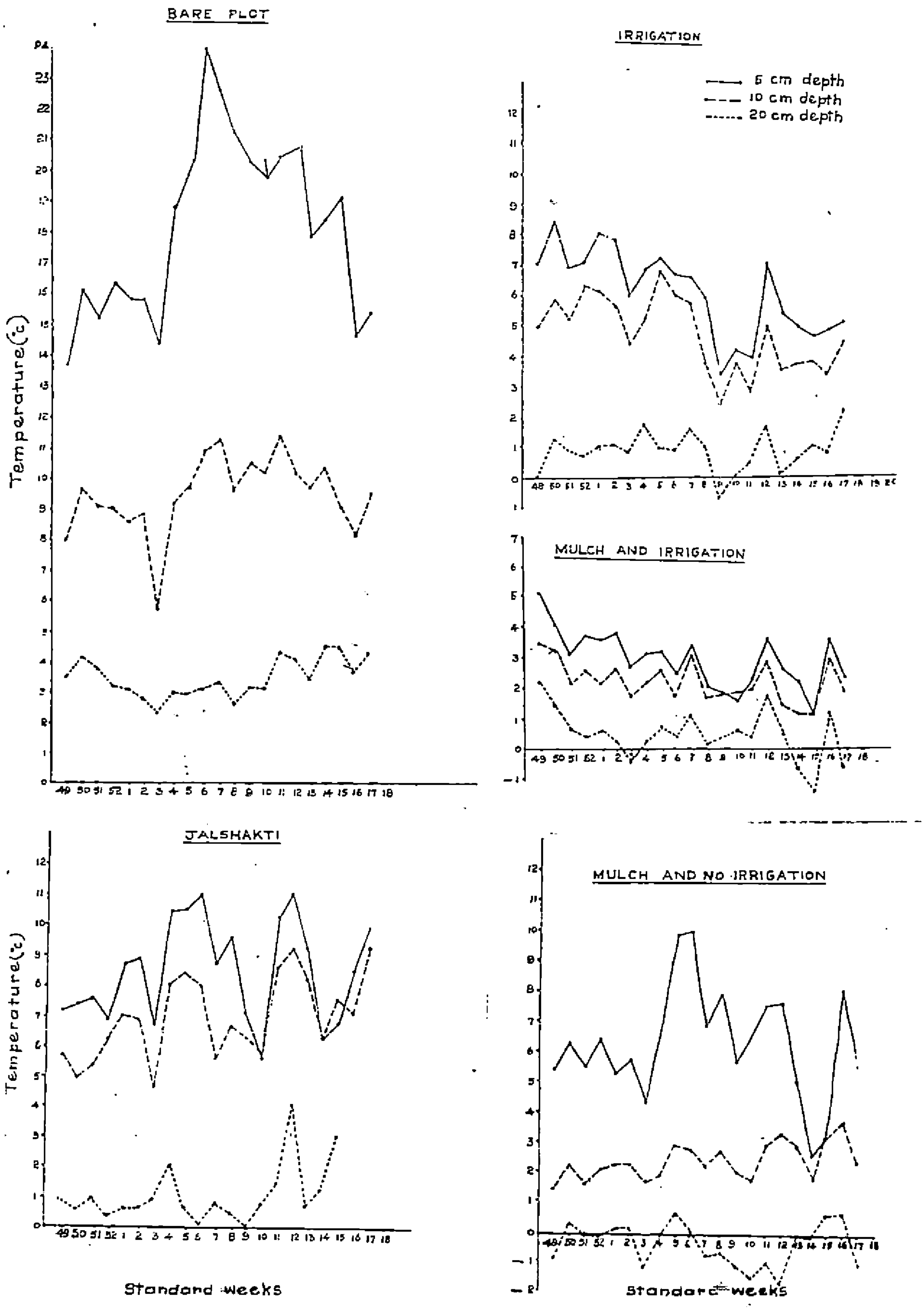
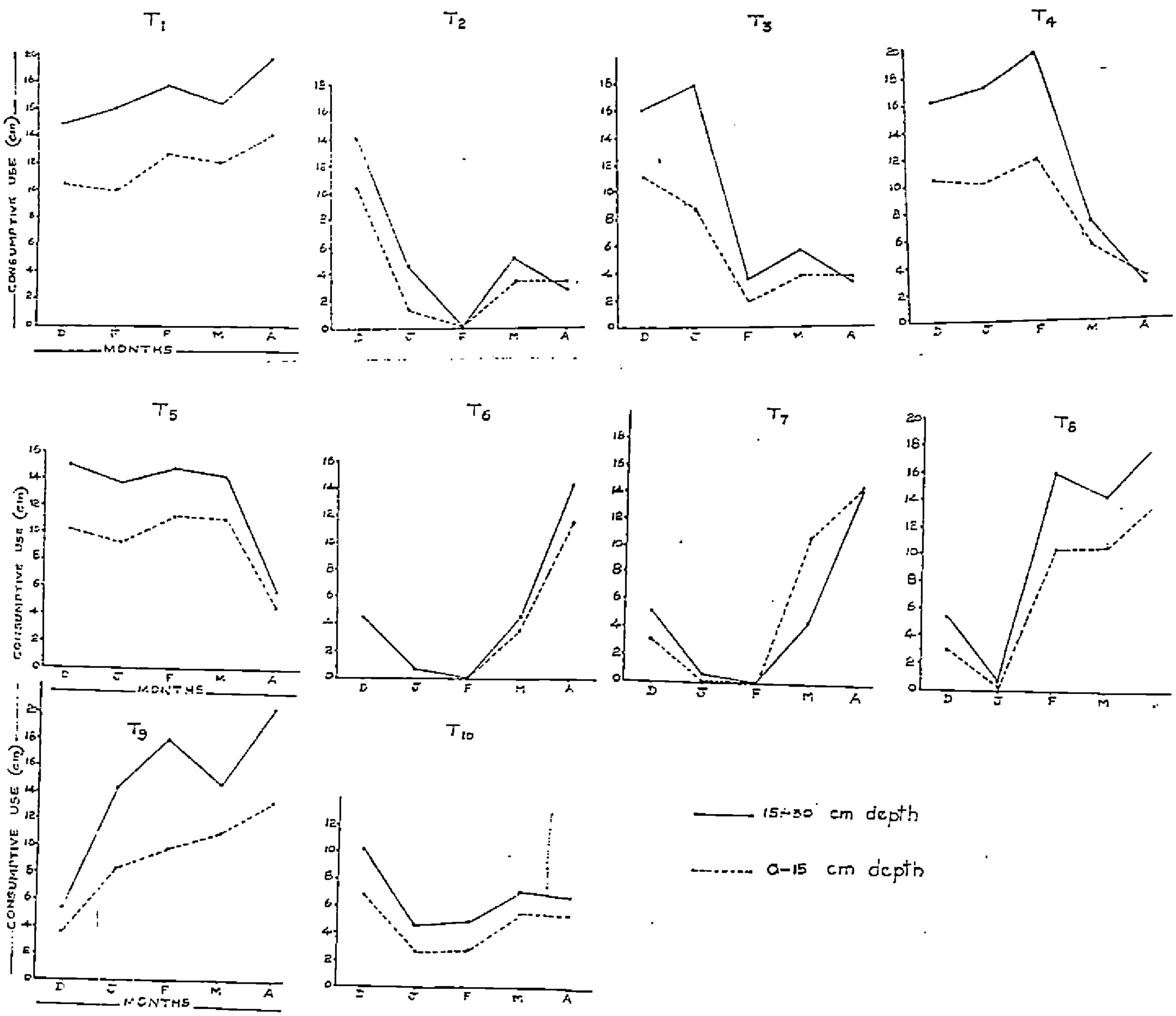


Table 10 Consumptive use (cm)

Treatments	0 - 15 cm	15 - 30 cm
T_1	60.1	85.1
T_2	18.7	25.9
T_3	28.7	46.6
T_4	41.7	63.6
T_5	47.0	63.8
T_6	18.9	24.2
T_7	28.5	28.6
T_8	38.6	55.7
T_9	48.5	70.6
T_{10}	23.8	34.1

FIG. 9. MONTHWISE CONSUMPTIVE USE (cm) DURING DRY PERIOD



4.5.2 Soil moisture stress

Soil moisture stress is a very important factor influencing various plant growth and yield characters. In the present study, the difference between the potential and actual consumptive use during the period between any two successive irrigations is considered as an indicator of the soil moisture stress experienced by the plant. There were 29 such periods during the dry season (December to April), and the soil moisture stress was computed for all the 29 periods and 10 treatments. Though, all the 29 periods influenced the crop, soil moisture stress during a certain critical period affected the crop mostly. To identify these critical periods, simple linear correlations were worked out between overlapping periods of soil moisture stress and growth characters like height, girth, leaf area and crop duration, and bunch characters like number of fingers, weight of fruit and weight of bunch. The correlation coefficients obtained are presented in Table 11. All the correlation coefficients were highly significant (at p=0.01) indicating a very strong influence of soil moisture stress on the growth and yield of banana. As the bunch weight is the most important yield character, a simple linear regression equation was developed between the critical period of soil moisture stress and bunch weight. The regression equation is $Y=-0.07\ SMS + 4.49$. Actual yield and the yield estimated from the regression equation are given in Table 12 and Fig. 10.

Table 11 Correlation coefficients between the soil moisture stress and plant growth and yield characters

Plant/yield character	Period	*Correlation coefficient
Height of the plant		
5 months after planting	4 MAP - 5 MAP	-0.908
6 months after planting	4 MAP - 6 MAP	-0.910
at shooting	6 MAP - shooting	-0.958
Girth of the plant		
5 months after planting	4 MAP - 5 MAP	-0.932
6 months after planting	4 MAP - 6 MAP	-0.950
at shooting	4 MAP - shooting	-0.988
Leaf area		
5 months after planting	4 MAP - 5 MAP	-0.901
6 months after planting	4 MAP - 6 MAP	-0.950
at shooting	4 MAP - shooting	-0.954
Crop duration		
From planting to shooting	4 MAP - shooting	+0.770
From planting to harvest	4 MAP - 7 MAP	+0.835
Number of fingers	Flowering stage	-0.895
Weight of fruit	Flowering stage	-0.865
Weight of the bunch	Flowering stage	-0.853

MAP - months after planting

* all are significant at p = 0.01

Table 12 Actual and estimated yield (kg $bunch^{-1}$)

Treatments	Actual yield	Estimated yield
T_1	5.07	4.47
T_2	2.70	2.85
T_3	3.15	2.92
T_4	3.78	4.10
T_5	5.00	4.49
T_6	3.07	2.81
T_7	3.75	3.39
T_8	3.71	4.38
T_9	4.16	4.42
T_{10}	2.63	3.19

FIG.10. ACTUAL AND ESTIMATED BUNCH WEIGHT FOR DIFFERENT TREATMENTS

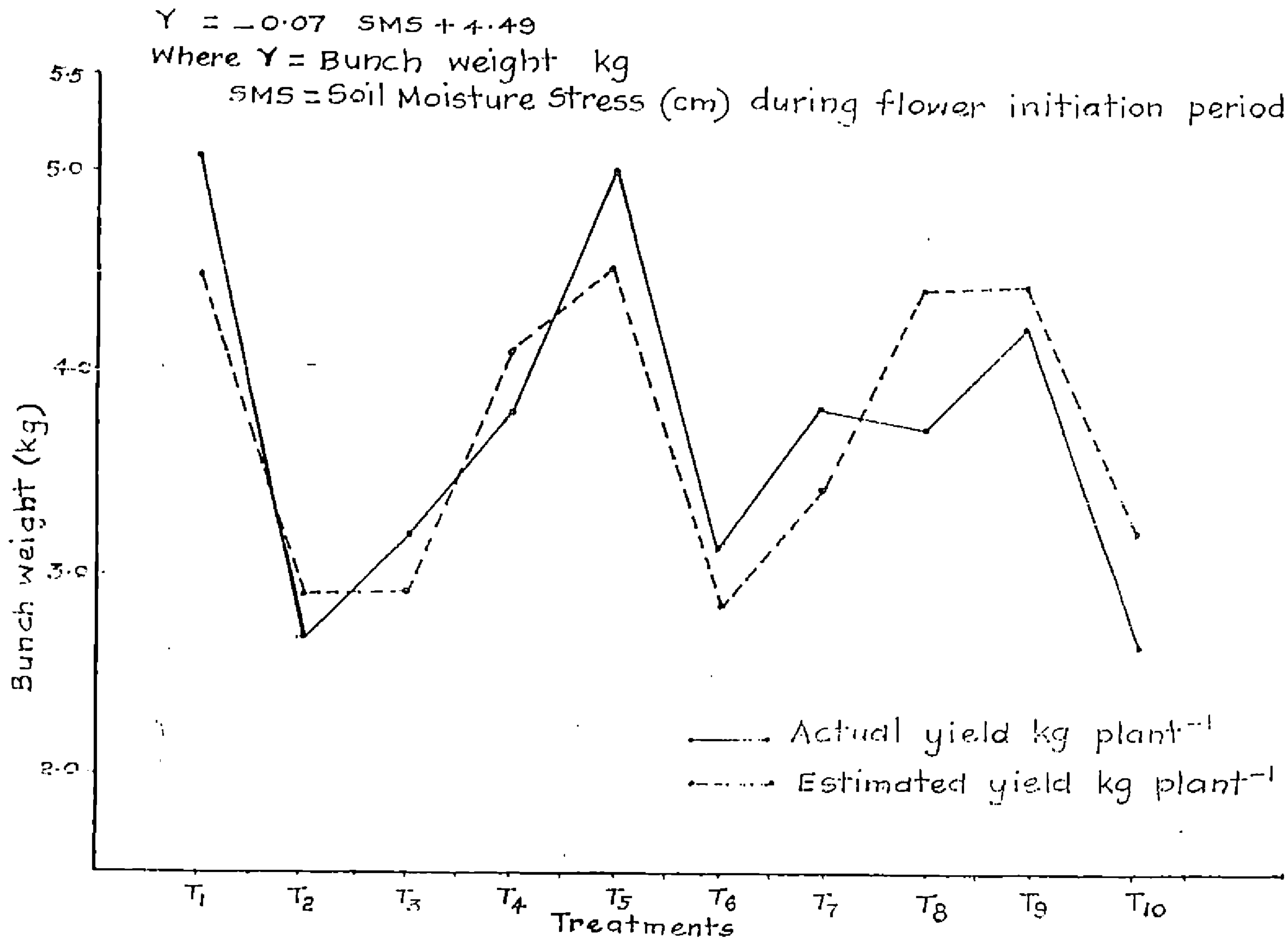


Plate 1 - Unmulched and irrigated plant

Plate 2 - Unmulched and irrigated plot

Discussion

DISCUSSION

The present investigation was taken up to study the effect of soil moisture stress on the growth and yield of banana cv. Nendran. The results obtained are discussed below.

5.1 Growth Parameters

Highly significant differences were noticed between treatments with respect to the various growth parameters of the plant. As evident from the results obtained, vigour of the plants increased progressively as the levels of soil moisture stress decreased. This is in consistency with the findings of Kramer (1963) and Watson and Daniells (1983).

The results obtained clearly indicate the strong influence of soil moisture stress on the height of the pseudostem (Table 2 and Fig.4). With increasing levels of stress, there was a continuous downward trend in the height of the plants. Plants which were adequately watered up to six months after planting showed almost a linear increase in plant height. After that, the growth rate was high upto shooting. T_5 recorded the maximum height at shooting and it was on par with T_1 and T_9. T_9, although subjected to water stress during December, might have taken advantage of the increased duration it took for shooting. T_2 recorded the lowest value at shooting, the next lowest being T_6. The reduced pseudostem height observed when subjected to a water stress can be attributed to the reduced cell division and cell enlargement, as earlier reported by Manica _et al._ (1975). Holder and Gumbs (1983) and Lahav and Kalmar (1988).

The girth of the plants followed almost a similar pattern as that of height (Table 3). Pseudostem girth is a function of number of leaves and an increase in girth results from a combination of radial growth of leaf sheaths and an increase in the number of leaf sheaths. Under conditions of water deficits, the number of leaf sheaths may remain constant or even decrease due to abscission and the cell expansion stops and the increase in girth with time will not follow a linear pattern. Similar results were reported by Holder and Gumbs (1982). To recover from stress after a severe water stress period, the plants may have a lag period, the duration of which depend on the intensity and longevity of the stress period (Denmead and Shaw, 1960). This might be the reason for the lowest pseudostem girth recorded by T_7 compared to T_6 at shooting. Although the longevity of the preceding stress period was longer for T_6, it took more time to shoot, and the growth during that period might have contributed to the higher girth at shooting(Ticho, 1971).

Significant differences were noticed between treatments with respect to the number of leaves retained (Table 4). The number of leaves retained by the plant is a function of rate of leaf production and its retention. Severe stress adversely affects both, as reported by O'Neill (1983), which explains the lower number of leaves retained by T_6 up to shooting. Sudden onset of stress before shooting resulted in early abscission of leaves of

T_3 leading to the retention of very few leaves. This finding is supported by the observations of Simmonds (1959), Madramootoo and Jutras (1984), Bhattacharyya and Rao (1986a) and Kallarackal and Milburn (1988).

As total leaf area is a function of number of leaves retained by the plant and leaf size, it followed the same trend of number of leaves (Table 5). Water stress is one of the most important causes of reduction in rate of increase in leaf area. The treatments T_1, T_4 and T_5, which were adequately irrigated upto shooting, were superior to the rest. At shooting, T_9 was also on par with T_1, T_4 and T_5. T_4 was subjected to water stress after shooting, and this might be the reason for the low leaf area maintained by it at harvest. T_2 had the lowest leaf area at shooting, early abscission of leaves and reduced leaf elongation (Renquist et al., 1982) being the attributed reasons. Similar results were reported by Miller and Duley (1925), Watson and Daniells (1983) and Daniells (1986).

There was no significant difference between treatments with respect to the number of suckers produced at shooting and at harvest (Table 6).

Highly significant variation was noticed between treatments with respect to the number of days taken from planting to shooting and shooting to harvest (Table 7 and Fig. 5). Time taken from planting to shooting and planting to harvest were shortest for T_5, and was on par with T_1, T_4 and T_{10}. The high C/N ratio which exists when there is adequate soil moisture has been reported to promote flowering (Katyal and Dutta, 1971). T_1, T_4 and T_5 received adequate irrigation up to flowering, and for T_{10}, though irrigation was given once in 25 days, sufficient moisture was available to initiate flowering. The early shooting could also be accounted for by the rapid production of leaves which would have elaborated more photosynthates and increased the flowering stimulus. The duration from planting to shooting and planting to harvest was longest for T_6. T_6 was subjected to severe water stress during the period of flower initiation (120 to 180 days after planting), which might have delayed flower initiation and subsequently shooting. Similar results were reported by Jagirdar et al. (1963), Krishnan and Shanmugavelu (1979a) Watson and Daniells (1983), Daniells (1986) and Asoegwu and Obiefuna (1987).

The duration from shooting to harvest was the shortest for T_7, and it was statistically on par with T_6, T_8 and T_9, which received adequate soil moisture during the maturity period. The time from shooting to harvest was the longest for T_2, which was subjected to water stress for the longest period. Krishnan and Shanmugavelu (1979a) reported that irrespective of the moisture regimes during the vegetative phase, the treatments which received adequate soil moisture during the reproductive phase resulted in early maturity of the fruit. This can be explained based on the rapid fruit development which occur when there is sufficient moisture available. Similar results were reported by Watson and Daniells (1983) and Daniells (1986).

5.2 Bunch Characters

Plants which were subjected to water stress produced shorter bunches, compared to those which were adequately irrigated, (Table 8). The maximum bunch length was recorded by T_9, and it was on par with T_1, T_4, T_5, T_7 and T_8. T_9 received continuous irrigation and was not subjected to any moisture stress after shooting. The shorter bunches produced by the stressed plants is due to the lower number of hands produced by them. This is in consistency with the findings of Jagirdar et al. (1963), Manica et al. (1975) and Krishnan and Shanmugavelu (1979a).

With increase in the duration of stress period imposed, there was a continuous downward trend in the number of hands and number of fingers carried by the bunch, (Table 8, Fig.6 and Fig.7). The highest number of hands (5.1) was registered by T_5 and T_9. T_8 carried the highest number of fingers (36.7) and was on par with T_1, T_5 and T_9. T_5 received continuous irrigation during the period of flower initiation and shooting and the number of hands and number of fingers produced by the plant was unaffected by the stress imposed during the later stages. T_8 and T_9 were subjected to water stress during the beginning of the dry season only, and then onwards given continuous irrigation leading to the production of more number of hands and fingers per bunch. According to Holder and Gumbs (1983), the period of flower initiation is the most sensitive stage to water stress for banana, and a stress imposed during this period will highly influence the number of axils bearing the female flowers and the number of female flowers produced. The lowest number of hands recorded by T_{10} indicate the severity of the stress experienced by the plants during the flower initiation period. Results in conformity with these have been reported by Trochoulias (1973), Manica et al. (1975), Holder and Gumbs (1983) and Watson and Daniells (1983).

A strong negative correlation was noticed between the number of fingers per hand and the duration of the stress period imposed (Table 8). T_5 recorded the highest number of fingers per hand (7.8) and T_6, the lowest (5.33). The lower number of female flowers produced when there was a water deficit might have been the reason for this, as reported by Trochoulias (1973) and Holder and Gumbs (1983).

Length and girth of finger followed the same trend (Table 8) and the highest values were registered by T_1 (22.9 cm and 12.67 cm) and it was on par with T_5 and T_9. T_1 and T_9 received continuous irrigation after shooting, and T_5 was subjected to a water stress of duration one month towards the end of the fruit filling period. Fruit size depends primarily on the conditions prevailing during the period of fruit enlargement, when considerable amount of carbohydrates and water are transported in to the developing fruit (Kaufmann, 1972) and this explain the trend noticed in this experiment. The lowest length and girth of finger were recorded by T_{10} (14.0 cm and 9.5 cm) indicating the severity of the stress experienced by the plants during the maturity period. Similar results were reported by Holder and Gumbs (1983) and Watson and Daniells (1983).

Weight of the fruit was also highly influenced by the various treatments (Table 8 and Fig.7). The maximum value of 110.3 g was recorded by T_4, and it was closely followed by T_5 (109.4 g) and T_1 (108.7 g). Weight of fruit is a function of length and girth of fruit and the higher values recorded by the above treatments contributed to their higher fruit weight. T_6 recorded the lowest fruit weight (61.67 g) and it was on par with T_2, T_3 and T_{10}.

Bunch weight and the characters associated with it were significantly influenced by the various treatments (Table 8 and Fig.6). There was a progressive increase in bunch weight from the driest to the wettest treatment. T_1 recorded the maximum yield (5.07 kg), closely followed by T_5 (5.0 kg), both were on par with T_9. T_{10} recorded the lowest bunch weight (2.63 kg) and the next lowest being T_2 (2.70 kg). From the results obtained, it is evident that though the amount and period of irrigation were the same, treatments which were irrigated during the beginning of the dry season were significantly inferior to those which were irrigated at the end of the dry season. This is in consistency with the findings of Salter (1957) who noticed that the adverse effect of water stress on the growth and yield would be greatest when a change was made from a wet to dry moisture regime, since this would subject many of the roots formed under wet regime to subsequent severe moisture stress resulting in poor uptake of nutrients. The result also indicate that the stress prior to bunch initiation resulted in substantial reduction of bunch weight mainly through reduced hand and finger numbers, where as stress after bunch initiation through reduced finger size and weight. Hence the reduced finger size and weight of T_2 and T_{10}

led to substantial reduction in bunch yield. According to Kramer (1969), reduction in the leaf area and drymatter production, which might have resulted in the multiple effects of water stress like reduced rate of photosynthesis and translocation of carbohydrates would have resulted in significant reduction in bunch weight in dry treatments. The increased bunch weight of T_1, T_5 and T_9 is due to the increased finger size and weight. This can be explained based on Watson's (1952) observation that continued active photosynthesis after shooting is the most important determinant of final yield. For T_{10}, the lower number of hands per bunch, fingers per hand and reduced finger size and weight might have contributed to the low yield indicating that the plants were subjected to severe water stress during all stages of growth and development. Similar results have been reported by Watson and Daniells (1983), Bhattacharyya and Rao (1985, 1986a and 1986b) and Daniells (1986).

Mulching has got significant influence on the conservation of soil moisture. T_5 and T_9, both mulched and subjected to a water stress for one month could produce bunch yields which were on par with the control plot with irrigation throughout and unmulched. Thus the results clearly indicate the positive effect of mulches on conservation of soil moisture and reducing the intensity of stress experienced by the plant.

5.3 Fruit Quality

The various levels of soil moisture stress imposed did not exert any significant influence on the total soluble solids content of the fruit (Table 9). Though not statistically significant, the plants which were subjected to water stress during the maturity period recorded higher values. Results in conformity with this have been reported by Krishnan and Shanmugavelu (1979a).

Significant differences were noticed between treatments with respect to the total sugar content of the fruit (Table 9). With increasing levels of stress, there was a continuous upward trend in the total sugar content of the fruit. The highest value of (17.35%) was recorded by T_2, and the increased sugar content under dry condition might be due to the increased starch hydrolysis with increasing moisture stress (Gates, 1968). Possibly, the increase in the net rate of starch hydrolysis with increasing moisture stress results from an increase in the amount of asparagine, because asparagine, which activates the enzymes amylase (Hartt, 1934) was found to increase with decrease in moisture content (Petrie and, Wood, 1938). Similar results were reported by Teaotia et al. (1972) and Krishnan and Shanmugavelu (1979a).

It is interesting to note that though the acid content was highest in T_1, there was no significant variation among the other treatments (Table 9). This might be due to the frequent showers received during the later phase of maturity period.

Sugar acid ratio followed a similar pattern as that of total sugars, (Table 9). T_2 recorded the maximum value of 38.93, and T_1 the minimum (23.59). This can be explained based on the total sugar and acid content of respective treatments. The results are in agreement with those of Teaotia et al. (1972) and Krishnan and Shanmugavelu (1979a).

5.4 Soil Temperature

Soil temperatures measured from the bare plot at 1400 hr LMT at 5cm depth were extremely high during the peak of the dry season. The lowest temperatures were measured from the irrigated plot with coconut husk applied as mulch, revealing that mulching and irrigation considerably reduced the soil temperatures. A reduction of temperature upto 19°C was observed at 5cm depth during certain days. In the unirrigated mulched plot also the temperatures, especially that measured at 5cm depth were considerably lower compared to the bare plot. Similar effects of mulches in reducing soil temperatures wore reported by Evenson and Rambaugh (1972), Lal (1974) and Varadan and Rao (1988).

The daily temperature fluctuations were also highly influenced by mulching and irrigation (Fig. 8). The highest values were observed in the bare plot and the lowest values in the irrigated mulched plot, indicating the effect of both irrigation and mulches in reducing the diurnal soil temperature variations. Rokhade et al. (1972) also reported similar reductions in diurnal soil temperature fluctuations under mulched conditions.

5.5 Soil Moisture

5.5.1 Consumptive use

It can be seen from the figure that the consumptive use in the 15-30cm layer was generally higher than that in the 0-15cm layer, for all the treatments, except T_7 (Fig.9). The consumptive use in the control plot with continuous irrigation showed no drastic variation during the dry season, though a slight increasing trend was observed, which might have accounted for the highest yield recorded by this treatment. Jalshakti applied plot also showed very little variation in the consumptive use during the dry season. However, the values were consistently lower than the control plot values. This might be the reason for the lowest yield recorded by the treatment. It is seen that the pattern of consumptive use of all the other treatments followed the corresponding irrigation schedule. The slight increase in the consumptive use in the 0-15cm layer compared to the 15-30cm layer for the treatments T_2, T_3 and T_4, is due to the summer showers received during April, which have moistened the top layer more than the deeper one. All these three treatments were not irrigated during March and hence the soil moisture levels were very low, particularly in the top 15cm layer.

5.5.2 Soil moisture stress

The plant height at five months after planting was negatively correlated with the soil moisture stress imposed during the preceding dry period (Table 11). Height at six months after planting and at flowering followed the same trend. Similar results were obtained for the girth of pseudostem and leaf area, indicating the adverse effect of soil moisture stress on the growth of banana. Results in conformity with this were reported by Manica _et al._ (1975) and Watson and Daniells (1983). It is interesting to note that the magnitude of correlation increased progressively with the crop growth.

A strong positive correlation was observed between soil moisture stress and time taken for shooting (Table 11). Earlier reports by Krishnan and Shanmugavelu (1979a) Holder and Gumbs (1982) and Watson and Daniells (1983) support this observation. Similar trend was noticed for the total crop duration also. Results in agreement with this were reported by Daniells (1986) and Bhattacharyya and Rao (1986a).

A significant negative correlation was observed between soil moisture stress and various bunch characters like number of fingers per bunch, weight of fruit and weight of the bunch during the whole dry season (Table 11). The correlation analysis using overlapping periods, however, identified the most critical period of the stress. The analysis indicated that the soil moisture stress imposed during the period "flower initiation to shooting" (five to seven months after planting) was mostly responsible for the variations in the yield characters. The soil moisture stress imposed before flower initiation and later stages of maturity had little influence. Results reported by Holder and Gumbs (1982) support this result. The regression equation Y = -0.07 SMS + 4.49 was developed between the most important yield character, bunch weight and soil moisture stress during the critical period i.e., flower initiation to shooting. About 73 per cent of the total variation in the bunch weight is explained by the soil moisture stress imposed during the critical period. The Fig.10 showing actual and estimated yields shows the good fit of the regression equation. The experiment showed that the soil moisture stress imposed during a certain critical growth/developmental stage (five to seven months after planting) can adversely affect the yield of banana. Thus, when the water availability is limited, banana can be cultivated without substantial reduction in yield by giving adequate irrigation during the critical growth/developmental stage and by reducing the quantity of irrigation water during the other stages.

Summary

SUMMARY

The present investigation was carried out at the College of Horticulture, Vellanikkara, Trichur during 1988-89 to study the effect of soil moisture stress on the growth, yield and fruit quality of banana cv. Nendran.

The experiment was laid out in RBD with three replications. There were 10 treatments with 10 levels of irrigations. Observations on various morphological characters, bunch characters and quality aspects were recorded during the course of the investigation. The daily values on various weather elements recorded at the meteorological observatory were collected. Soil moisture observations were taken before, and 24 hr after irrigation, and from the data obtained, consumptive use was computed taking in to account of the effective rainfall. Soil moisture stress experienced by the plants was worked out and correlated with the various growth and yield characters. Soil temperature observations were taken twice daily, 0700 and 1400 hr LMT to study the influence of mulches and irrigation on soil temperatures.

The salient results are summarised below.

1. The plant height was significantly influenced by the levels of soil moisture stress imposed. With increasing levels of stress, the plant height showed a continuous decreasing trend.

2. A very strong influence of soil moisture stress on the girth of pseudostem was noticed, at all the stages. With decreasing levels of stress, the girth increased progressively.

3. The number of functional leaves and leaf area decreased with increasing levels of soil moisture stress.

4. The various treatments did not influence the sucker production.

5. The crop duration was significantly altered by the various treatments. Plants which were subjected to a moisture stress of one month duration towards the end of the dry season (April) had the shortest duration, whereas plants which were water stressed throughout the dry season except at the end (April) had the longest duration.

6. All the bunch characters studied i.e., length of bunch, number of hands per bunch, number fingers per hand, number of fingers per bunch, length of finger, girth of finger, weight of fruit and weight of bunch were significantly influenced by soil moisture stress. All the characters showed a decreasing trend with increasing soil moisture stress.

7. The weight of bunch was found to be highly influenced by soil moisture stress. Highest yield was obtained from the plants which were adequately irrigated throughout the dry season (December to April). It was comparable with those plants which were mulched

and subjected to a moisture stress for one month duration at the beginning (December) and at the end of the dry season (April).

8. Among the quality aspects studied, total soluble solids was not influenced by soil moisture stress. Total sugar content and sugar acid ratio increased progressively with increasing levels of stress.

9. Mulching and irrigation influenced soil temperatures both at 0700 and 1400 hr LMT. The temperatures recorded at both the times and the diurnal range were always the lowest in the irrigated mulched plot. Unirrigated mulched plot recorded the highest temperatures in the morning, where as bare plot recorded the highest values in the afternoon.

10. The consumptive use computed from the soil moisture data showed wide variations between treatments. The plants which were adequately irrigated throughout the dry season recorded the highest value. With increasing levels of stress, consumptive use decreased.

11. Very strong negative correlation was obtained between the soil moisture stress and growth characters like height, girth number of leaves and leaf area and bunch characters like number of fingers per bunch, weight of fruit and weight of bunch. A positive correlation was obtained between crop duration and the soil moisture stress.

12. The correlation analysis indicated that the soil moisture stress imposed during the period "flower initiation to shooting" (five to seven months after planting) affected the final yield mostly. The soil moisture stress imposed before flower initiation and later stages had little effect.

From the present study, it can be concluded that the growth, yield and fruit quality of banana are highly affected by soil moisture stress. The adverse affect was more pronounced when stress was imposed during the critical growth/developmental stage 'flower initiation to shooting'. Banana needs continuous irrigation throughout the dry season to produce maximum yield. However, when the water availability is limited, banana can be successfully cultivated without substantial reduction in yield by giving adequate irrigation during the critical period. The quantity and frequency of irrigation water can also be reduced through soil moisture conservation by mulching with coconut husk.

References

REFERENCES

Abdul Salam, M., Hameed, S.S.M. and Tajuddin, E. 1988. Consumptive use and irrigation requirements of rice and banana in South Kerala - climatological approach. Paper presented in the III Indian Agrometeorological Congress. 28th to 30th April 1988.

Acevedo, E., Hsiao, T.C. and Henderson, D.W. 1971. Immediate and subsequent growth response of maize leaves to changes in water status. *Pl. Physiol.* **48** : 631-636.

Adams, J.E. 1966. Influence of mulches on runoff, erosion and soil moisture depletion. *Soil Sci. Soc. Am. Proc.* **30** : 110-114.

Ali, M.A., Mohan, C.J., Narayanan, T.R. and Morachan, Y.B. 1973. Critical periods of moisture stress injury in IR 8 rice. *Madras agric. J.* **60** (4) : 267-268.

Angus, J.F. and Moncur, M.W. 1977. Water stress and phenology in wheat. *Aust. J. agric. Res.* **28** : 177-181.

* A.O.A.C., 1960. *Official Methods of Analysis.* Association of Official Agricultural Chemists, Washington, D.C. pp. 225-226.

* A.O.A.C., 1962. *Official Methods of Analysis.* Association of Official Agricultural Chemists, Washington, D.C. pp. 214-217.

Arscott, T.G., Bhangoo, M.S. and Karon, M.L. 1965. Irrigation investigations of the Giant Cavendish banana - a note on the relationship between bunch weight and quantity of supplemental irrigation. *Trop. Agric.* **42** : 367-368.

Ashley, D.A. and Ethridge, W.J. 1978. Irrigation effects on vegetative and reproductive development of three soybean cultivars. *Agron. J.* **70** : 467-471.

Asoegwu, S.N. and Obiefuna, J.C. 1987. Effect of irrigation on late season plantains. *Trop. Agric.* **64** : 139-143.

Behboudian, M.H., Walker, R.R. and Torokfalvy, E. 1986. Effects of water stress and salinity on photosynthesis of pistachio. *Scientia Horticulturae.* **29** : 251-261.

Bennet, O.L. and Doss, B.D. 1960. The effect of soil moisture on root distribution of cool season forage species. *Agron. J.* **52** : 204-207.

Bhattacharyya, R.K. and Rao, V.N.M. 1985. Soil cover increases banana production. *Indian Hort.* **30** (1):5-8.

Bhattacharyya, R.K. and Rao, V.N.M. 1986a. Phyllochron and crop duration of 'Robusta' banana as affected by soil covers and soil moisture regimes. Paper presented in the XXII International Horticultural Congress. 83rd Annual Meeting of the American Society for Horticultural Science. 6th to 11th August 1938.

* Bhattacharyya, R.K. and Rao, V.N.M. 1986b. Sucker production of 'Robusta' banana as influenced by soil covers and soil moisture regimes. *Banana Newsl.* **9** : 10-11.

Bhattacharyya, R.K. and Rao, V.N.M. 1986c. Effect of soil covers on soil temperatures in a banana plantation. *Banana Newsl.* **9** : 8-9.

* Blake, G.R. 1965a. Bulk density-Core method. *In* Black, C.A. (ed.) *Methods of Soil Analysis.* Part I. American Society of Agronomy, Madison, U.S.A. pp. 375-376.

* Blake, G.R. 1965b. Particle density. *In* Black, C.A. (ed.) *Methods of Soil Analysis.* Part I. American Society of Agronomy, Madison, U.S.A. pp. 371-373.

Bois, J.F. 1984. Water stress response for some cultivars of upland and lowland rice II. Effects on CO_2 exchange and water use efficiency. *Pl. Soil.* **80** : 237-246.

Bond, J.J. and Willis, W.O. 1971. Soil water evaporation : longterm drying as influenced by surface residue and evaporation potential. *Soil Sci. Soc. Am. Proc.* 35 : 384-387.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analyses of soils. *Agron. J.* **54** : 464-465.

Bunce, J.A. 1977. Nonstomatal inhibition of photosynthesis at low water potential in intact leaves of a species from a variety of habitats. *Pl. Physiol.* 59 : 348-350.

Burrows, W.C. and Larson, W.E. 1962. Effect of amount of mulch on soil temperature and early growth of corn. *Agron. J.* **54** : 19-23.

* Camejo, L.E. 1981. Effect of irrigation scheduling on Macho bananas. *Abstr. Trop. Agric.* 4 : 51-71.

Daniells, J. 1986. The effect of volume of rootzone irrigated on yield and fruit quality of plant crop bananas. Paper presented in the XXII International Horticultural Congress. 83rd Annual Meeting of the American Society for Horticultural Science. 6th to 11th August, 1988.

Daisley, L.E.A., Chong, S.K., Olsen, T.J. Singh, L. and George, C. 1988. Effects of surface applied grass mulch on soil water content and yields of cowpea and egg plant in Antigua. *Trop. Agric.* **65** : 300-304.

* Dastane, N.G. 1974. Effective rainfall in irrigated agriculture. *Irrigation and Drainage Paper* No. 25. F.A.O. of the U.N., Rome. p. 62.

Denmead, O.T. and Shaw, R.H. 1960. The effects of soil moisture stress at different stages of growth on the development and yield of corn. *Agron. J.* **52** : 272-274.

Dixit, S.P. and Agarwal, M.C. 1971. Effect of rubber solution mulch on moisture regimes of soil and growth and yield of maize. *Indian J. agric. Res.* **5** : 74-78.

Dutt, S. 1989. Jalshakti : a promising wonder for agricultural revolution. *Sci. Reporter.* **26** (1) : 26-27.

Dwyer, L.M. and Stewart, D.W. 1987. Influence of photoperiod and water stress on growth, yield and development rate of barley measured in heat units. *Can. J. Pl. Sci.* **67** (1) : 21-34.

Eck, H.V. and Musick, J.T. 1979. Plant water stress effects on irrigated grain sorghum. I. Effects on yield. *Crop Sci.* **19** : 589-592.

El-Barkouki, M.H. Hifny, H.A.A. and Baghdadi, G.A. 1977. Some effects of water stress on growth of grape vine *Vitis vinifera* L. *Acta Horticulturae.* Fifth Africa Symposium on Horticultural Crops. **84** : 199-204.

El-Hady, O.A., Tayel, M.Y. and Abed, F.M. 1981a. Soil conditioners and water loss via. evaporation process. *Acta Horticulturae.* Third International Symposium on water supply and irrigation in the open and under protected cultivation. **199** : 231-235.

El-Hady, O.A., Tayel, M.Y. and Lofty, A.A., 1981b. Supergel as a soil conditioner II. Its effect on plant growth, enzymes activity, water use efficiency and nutrient uptake. *Acta Horticulturae.* Third International Symposium on water supply and irrigation in the open and under protected cultivation. **199** : 257-266.

El-Sharkawi, H.M. and Salama, F.M. 1977. Effects of drought and salinity on some growth contributing parameters in wheat and barley. *Pl. Soil.* **46** : 423-433.

Evenson, P.D. and Rambaugh, M.D. 1972. Influence of mulch in post- harvest soil temperature and subsequent regrowth of alfalfa *(Medicago sativa* L*). Agron. J.* **64** : 154-157.

Flore, J.A., Lakso, A.N. and Moon, J.W. 1985. The effect of water stress and vapour pressure deficit on stomatal conductance, water use efficiency and photosynthesis of fruit crops. *Acta Horticulturae.* First International Symposium on Water Relations in Fruit Crops. **171** : 207-218.

* Gandhi, S.R. 1952. Banana culture in Western India. *Poona agric. Coll. Mag.* **41** : 180-209.

Gates, C.T. 1968. Water deficits and growth of herbaceous plants *In* Kozlowski, T.T. (ed.) *Water Deficits and Plant Growth* Vol. II Academic Press, New York and London.

Gehrmann, H. 1985. Growth, yield and fruit quality of straw berries as affected by water supply. *Acta Horticulturae.* First International Symposium on Water Relations in Fruit Crops.**171**:463-469.

George, A.P. and Nissen, R.J. 1988. The effects of temperature, vapour pressure deficit and soil moisture stress on growth, flowering and fruit set of custard apple *(Annona cherimola x Annona squamosa)* 'African Pride'. *Scientia Horticulturae.* **34** : 183-191.

Ghavami, M. 1974. Irrigation of 'Valery' bananas in Honduras. *Trop. Agric.* **51** : 443-446.

Goodman, R.N. 1952. Orchard mulches in relation to effectiveness of precipitation. *Proc. Am. Soc. hort. Sci.* **59** : 119-124.

* Gottreich, M., Bradu, D. and Halevy, Y. 1964. A simple method for determining average banana fruit weight. *Ktavini.* **14** : 161-162.

Hanks, R.J. and Woodruff, W.P. 1958. Influence of wind on water vapour transfer through soil, gravel and straw mulches. *Soil Sci.* **86** : 160-164.

Harrold, L.L. 1947. Land use practices on runoff and erosion from agricultural water sheds. *Agric. Engng.* **28** : 563-566.

Hartt, C.E. 1934. Some effects of potassium upon the amounts of protein and amino-nitrogen, sugar and enzyme activity of sugarcane. *Pl. Physiol.* **4** : 453.

Hazra, C.R., Ray, S.B. and Biswas, T.D. 1973. Effect of stored soil moisture reserve through conservation practices and supplemental irrigation on wheat yield under dry land farming condition. *J. Indian Soc. Soil Sci.* **21** : 9-22.

Henderson, J.C. and Hensley, D.L. 1986. Efficacy of a hydrophilic gel as a transplant aid. *Hort. Sci.* **21** : 991-992.

Hiler, E.A., Bavel, V.C.H.M., Hossain, M.M. and Jordan, W.R. 1974. Sensitivity of Southern peas to plant water deficit at three growth stages. *Agron. J.* **64** : 60-64.

Holder, G.D. and Gumbs, F.A. 1982. Effects of irrigation at critical stages of ontogeny of the banana cv. 'Robusta' on growth and yield. *Trop. Agric.* **59** : 221-226.

Holder G.D. and Gumbs, F.A. 1983. Effects of irrigation on the growth and yield of banana. *Trop. Agric.* **60** : 25-30.

Hubbard, V.D. 1938. Root studies of four varieties of spring wheat. *J. Am. Soc. Agron.* **30** : 60-62.

Ike, I.F. 1986. Effects of soil moisture stress on the growth and yield of spanish variety peanut. *Pl. Soil.* **96** : 297-298.

Irving, D.E. and Drost, J.H. 1987. Effects of water deficit on vegetative growth, fruit growth and fruit quality of Cox's orange pippin apple. *J. hort. Sci.* **62** (4) : 427-432.

* Israeli, Y. and Nimri, N. 1986. Water use of banana plants in the Jordan Valley as studied by drainage lysimeters. *Alon Hanotea.* **40** (10) : 949-957.

Jackson, M.L. 1958. *Soil Chemical Analyses.* Prentice Hall. Inc. USA p. 498.

* Jagirdar, S.A.P., Bhutto, M.A. and Shaik, A.M. 1963. Effect of spacing, interval of irrigation and fertilizer application on Basrai banana *(Musa cavendishii* Lambert). *W. Pakist. J. agric. J.* **1** : 5-20.

James, E.A. and Richards, D. 1986. The influence of iron source on the water holding properties of potting media amended with water absorbing polymers. *Scientia Horticulturae.* **28** : 201-208.

Johnson, K.R. Frey, N.M. and Moss, D.N. 1974. Effect of water stress on photosynthesis and transpiration of flag leaves and spikes of Barley and Wheat. *Crop Sci.* 14 : 728-731.

Kallarackal, J. and Milburn, J.A. 1988. Effect of water stress on the growth of banana. Paper presented in III India Agrometeorological Congress. 28th to 30th April, 1988.

Katyal, S.L. and Dutta, C.P., 1971. Irregular bearing in mango and remedial measures. *Andhra agric. J.* 18 : 237-241.

K.A.U. 1978. Irrigation trials in Nendran. *Annual Report* 1977-78. Directorate of Research, Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

K.A.U. 1980. Effect of water stress on the growth and yield of banana var. Nendran. *Research Report* 1979-80. Directorate of Research, Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

K.A.U. 1980. Effect of water stress on banana and the critical growth stages of banana variety Nendran. *Annual Report*.1979-80. Directorate of Research, Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

K.A.U. 1981. Scheduling irrigation for banana based on IW/CPE ratio under mulched and exposed conditions. *Annual Report* 1981-82. Directorate of Research, Kerala Agricultural University, Vellanikkara.

K.A.U. 1986. *Package of Practices Recommendations*, Kerala Agricultural University, Directorate of Extension, Trichur, Kerala, India. pp. 123-129.

Keck, R.W. and Boyer, J.S. 1974. Chloroplast response to low leaf water potential III Differing inhibition of electron transport and photophosphorylation. *Pl. Physiol.* 53 : 474-479.

* Kaufmann, N.R. 1972. Water deficits and reproductive growth. *In* Kozlowski, T. (ed.) *Water Deficits and Plant Growth.* Academic Press, New York.

Klepper, B., Taylor, H.M. Huck, M.G. and Fismis, E.L. 1973. Water relations and growth of cotton in dryingsoil. *Agron. J.* 65 : 307-310.

Kramer, P.J. 1955. Water relations of plant cells and tissues. *Ann. Rev. Pl. Physiol.* 6 : 253-273.

Kramer, P.J. 1963. Water stress and plant growth. *Agron. J.*55:31-35.

* Kramer, P.J. 1969. *Plant and Soil Water Relationships - Modern Synthesis*. Tata Mc Graw Hill Publishing Company Ltd., Bombay.

Krishnan, B.M. and Shanmugavelu, K.G. 1979a. Studies on the water requirement of banana cv. Robusta, effect on morphological characters, crop duration, yield and quality of fruits. *Mysore J. agric. Sci.* 13 (4) : 433-441.

Krishnan, B.M. and Shanmugavelu, K.G. 1979b. A note on the effect of different soil moisture depletion levels on stomatal character of banana. *S. Indian Hort.* 27 (3 & 4) : 127-128.

Krishnan, B.M. and Shanmugavelu, K.G. 1980. Effect of different soil moisture depletion levels on the root distribution of banana cv. Robusta. *S. Indian Hort.* 28 (1) : 24-25.

Kuruppuarachchi D.S. and Pain, A.N. 1981. Effect of soil moisture depletion on yield and water use efficiency of chillies, onions and bananas on the latosols of the North West Dry Zone. *Trop. Agricst.* 137 : 109-121.

Lahav, E. and Kalmar, D. 1988. Response of banana to drip irrigation, water amounts and fertilization regimes. *Commun. Soil Sci. Pl. Anal.* 19 : 25-26.

Lakso, A.N. 1985. The effects of water stress on physiological processes in fruit crops. *Acta Horticulturae.* First International Symposium on water Relations in Fruit Crops. 171 : 275-290.

Lal, R. 1974. Soil temperature, soil moisture and maize yield from mulched and unmulched tropical soils. *Pl. Soil.* 40 : 129-143.

Lawlor, D.W. 1979. Effects of water and heat stress on carbon metabolism of plants with C_3 and C_4 photosynthesis. *In* Mussel, H. and Staples, R.C. (ed.) *Stress Physiology in Crop Plants.* John Wiley and Sons, New York. pp. 303-326.

Levy, Y. 1983. Acclimation of citrus to water stress. *Scientia Horticulturae.* 20 : 267-273.

Lewis, R.B., Hiler, E.A. and Jordan, W.R. 1974. Susceptibility of grain sorghum to water deficit at three growth stages.*Agron. J.* 66 : 589-590.

Madramootoo, C.A. and Jutras, P.J. 1984. Supplemental irrigation of bananas in St. Lucia. *Agric. Wat. Management*. 9 : 149-156.

Maity, P.K. and Jana, P.K. 1987. Effect of irrigation at different physiological stages on yields, yield attributes and consumptive water use of gram, lentil and pea. *Indian Agricist*. 31(1): 43-48.

*Mandal, B.B., Chowdury, B., Souda, G., Mandal, B.K., and Sinha, A.C. 1987. Effect of mulches on the growth and yield of latesown unirrigated mustard. *Indian Agricist*. 31 (4) : 279-284.

*Manica, I., Simao, S. and Scardua, R. 1975. Furrow irrigation and its influence on the growth and yield of banana *(Musa cavendishii)* cv. Nanicao mother plants. *Revista Cares*. 22(120):88-108.

Marani, A., Baker, D.N., Reddy, N.R. and Mc Kinion, J.M. 1985. Effect of water stress on canopy senescence and cation exchange rates in cotton. *Crop Sci*. 25 : 798-802.

Mc Cree K.J. 1974. Changes in the stomatal response characteristics of grain sorghum produced by water stress during growth. *Crop Sci*. 14 : 273-278.

*Melin, P. and Marseault, J. 1972. The value of banana irrigation in Cameroon. *Fruits* 27 : 495-508.

Michael, A.M., Hukkeri, S.B. and Singh, N.P. 1977. Estimating water requirement of crops. *In Water Requirement and Irrigation Management of Crops in India*. Water Technology Centre, IARI, Monograph NO. 4. pp. 91-150.

*Miller, M.F. and Duley, F.L. 1925. The effect of varying moisture supply upon the development and composition of the maize plant at different periods of growth. *Mo. agric. Exp. Res. Bull*: 76.

Moody, J.E., Johes, Jr. J.N. and Lillard, J.H. 1963. Influence of straw mulch on soil moisture, soil temperature and the growth of corn. *Soil Sci. Soc. Am. Proc.*. 27 : 700-703.

Murray, D.B. 1960. The effect of differences of the major nutrients on growth and leaf analysis of banana. *Trop. Agric*. 37 : 97-106.

*Naik, K.C. 1949. *South Indian Fruits and Their Culture*. Varadachari, P. and Co., Madras.

Nitzsche, P.J., Berkowitz, G.A. and Rabin, J. 1988. Effects of a wax emulsion antitranspirant, soil wetting agent and water absorbent root dip on the water status, growth and yield of transplanted *Capsicum annum* seedlings. Paper presented in 85th Annual Meeting of the American Society for Horticultural Science. 6th to 11th August 1988.

O'Neill, S.D. 1983. Role of osmotic potential gradients during water stress and leaf senescence in *Fregaria virginia*. *Pl. Physiol.* 72 : 931-937.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers* 4th ed. I.C.A.R., New Delhi. p. 353.

Patel, M.S. and Golakiya, B.A. 1988. Effect of water stress on yield attributes and yield of groundnut (*Arachis hypogaea*). *Indian J. agric. Sci.* 58 : 701-703.

Petrie, A.H.K. and Wood, J.G. 1938. Studies on the nitrogen metabolism of plants. I. The relation between content of proteins, amino acids and water levels. *Ann. Bot.* 2 : 33.

Plaut, Z. and Bravdo, B. 1973. Response of carbondioxide fixation to water stress. Parallel measurement in isolated chloroplast and intact spinach leaves. *Pl. Physiol.* 52 : 28-32.

Powell, D.B.B. 1974. Some effects of water stress in late spring apple trees. *J. hort. Sci.* 49(3) : 257-272.

Radhamani, J. 1985. Water stress and plant growth. *Green and Glory*. I.C.A.R. : 25-26.

Rajagopalan, A. and Sudhakara, K. 1988. Water requirement of banana cv. Nendran grown in clay loam soils. Paper presented in III Indian Agrometeorological Congress. 28th to 30th April 1988.

Renquist, A.R., Breen, P.J. and Martin, L.W. 1982. Influence of water status and temperature on leaf elongation in strawberry. *Scientia Horticulturae*. 18 : 77-85.

Richards, L.A. 1947. Pressure membrane apparatus. Construction and use. *Agric. Engng.* 28 : 451-454.

*Robinson, J.C. and Alberts, A.J. 1984. Influence of irrigation on the banana plant crop at Levubu. *Inf. Bull.* Citrus and Subtropical Fruit Research Institute. 138 : 6-7.

Rokhade, A.K., Faroogi, A.A. and Bojappa, K.M. 1972. A preliminary study on the evaluation of different mulches on soil moisture conservation in coconut plantation. *S. Indian Hort.* 27 (1 & 2) : 54-56.

*Roy, R.S. 1950. Thecultivation of banana in Bihar. *Indian Fmg.* 11 : 179-182.

Russel, J.C. 1939. The effect of surface cover on soil moisture losses by evaporation. *Soil Sci. Soc. Am. Proc.* 4 : 65-70.

Salter, P.J. 1957. The effect of different soil moisture regimes on the growth of the plants under glass III. Further experiments with tomatoes *(Lycopersicon esculentum* Mill.). *J. hort. Sci.* 32 : 214.

Schaller, F.W. and Evans, D.D. 1954. Some effects of mulch tillage. *Agric. Engng.* 35 : 731-736.

Shalhevet, J., Mantell, A., Bielorai, H. and Shimshi, D. 1976. Bananas. *In Irrigation of Field and Orchard Crops Under Semi-arid Conditions.* International Irrigation Information Centre. pp.97-98.

Shimshi, D., Mayoral, M.L. and Atsmon, D. 1982. Response to water stress in wheat and related wild species. *Crop Sci.* 22:123-128.

Shinde, G.G. and Pawar, K.R.P. 1984. Effects of water stress at critical growth stages on growth and yield of groundnut in summer season. *J. Maharashtra agric. Univ.* 9(1): 26-28.

Shouse, P., Dasberg, S., Jury, W.A. and Stolzy, L.H. 1981. Water deficit effects on water potential, yield and water use of cowpeas. *Agron. J.* 73 : 333-336.

Silva, J.F. Da., Campos, G.M., Mendes, W.C.R. and Goes, E.S.De. 1977. A study of evapotranspiration in banana - cultivar Nanicao. *Fruits.* 31 (12) : 731-737.

Simmonds, N.W. 1959. *Bananas* 1st ed. Longman, London. p. 431.

Simpson, L.A. and Gumbs, F.A. 1985. A system of crop and soil management for the wet season production of food crops on a heavy clay soil in Guyana : 1. Effect of mulching and tillage on soil properties and crop yields. *Trop. Agric.* 63: 305-310.

Sinha, N.C., Mehrotra, O.N. and Mathur, R.K. 1979. Studies of soil moisture stress in Barley *(Hordeum vulgare* L.). *Pl. Soil.* 52 : 581-584.

Sionit, N. and Kramer, P.J. 1977. Effect of water stress during different stages of growth of soybean. *Agron. J.* 69 : 274-278.

Tayel, M.Y., Abed, F.M. and El-Hady, O.A. 1981a. Effect of soil conditioners on water retention. *Acta Horticulturae.* Third International Symposium on water supply and irrigation in the open and under protected cultivation. **119 :** 199-203.

Tayel, M.Y., Abed, F.M. and El-Hady, O.A. 1981b. Effect of soil conditioners on plant growth and water use efficiency, (a green house experiment). *Acta Horticulturae.* Third International Symposium on water supply and irrigation in the open and under protected cultivation. **119 :** 223-226.

Tayel, M.Y. and El-Hady, O.A. 1981. Supergel as a soil conditioner. I. Its effect on some soil-water relations. *Acta Horticulturae.* Third International Symposium on water supply and irrigation in the open and under protected cultivation. **119 :** 223-226.

*Taylor, S.A. and Slater, C.S. 1955. When to irrigate and how much water to apply. *In Year Book of Agriculturae.* U.S.D.A. Oxford and IBH Pub. Co.

Taylor, K.C. and Halfacre, R.G. 1986. The effect of hydrophilic polymer on media water retention and nutrient availability to *Lingustrum lucidum. Hort. Sci.* 21 : 1159-1161.

*Teaotia, S.S., Tripathi, R.D., Tripathi, R.S. and Singh, R.D. 1969. Effect of irrigation frequencies and mulches on growth, yield and chemical composition of fruits of banana. *Hort. Sci.* **1:** 22-31.

Teaotia, S.S., Tripathi, R.S. and Gangwar, B.M. 1972. Effect of irrigation and fertilizer levels on growth, yield and quality of banana. *Progressive Hort.* 3(4) : 57-62.

Tedeschi, P. and Zerbi, G. 1985. Flowering and fruiting courses and yield of egg plant *(Solanum melongena* L.) plants grown in lysimeters with relation to different water regimes. *Acta Horticulturae* First International Symposium on Water Relations in Fruit Crops. **171 :** 383-390.

*Ticho, R.J. 1971. The banana industry in Israel. *Trop. Sci.* 13 : 289-301.

Tomer, N.S. and Singh, R. 1986. Effect of various soil moisture regimes on photosynthesis and photorespiration in pant lemon-I. *Indian J. Hort.* 43(1 & 2): 46-50.

*Trochoulias, T. 1971. Sprinkler irrigation of bananas. *Agric. Gaz. N.S.W.* 82 (1) : 55.

Trochoulias, T. 1973. The yield response of banana to supplementary watering. *Aust. J. exp. Agric. Anim. Husb.* 13: 470-472.

Trochoulias, T. and Murison, R.D. 1981. Yield response of bananas to trickle irrigation. *Aust. J. exp. Agric. Anim. Husb.* 21 : 448-452.

Unger, P.W. 1976. Surface residue, water application and soil texture effects on water accumulation. *Soil Sci. Soc. Am. J.* 40:298-290.

Varadan, K. M. and Rao, A.S. 1983. Effect of mulch on soil temperature in humid tropical latosols under coconut *(Cocos nucifera* Linn.) and banana *(Musa paradisiaca). Agric. Meteorol.*28:375-386.

Varadan, K.M. and Rao, A.S. 1988. Albedo and temperature effects of mulch materials. *MAUSAM* 39 (1): 115-116.

Varma, R. 1962. Nendran - unrivalled among bananas. *Indian Emg.* 12(6): 29.

Verasan, V. and Phillips, R.E. 1978. Effects of soil water stress on growth and nutrient accumulation in corn. *Agron. J.* 70 : 613-618.

Watson, D.J., 1952. The Physiological basis of variation in yield. *Adv. Agron.* 4 : 101-145.

Watson, B.J., Daniells, J.W. 1983. Banana - water stress effects. *Aust. hort. Res. Newsl.* 55 : 138-139.

Widders, I.E. and Janoudi, A.K. 1988. Effects of water deficits on pickling cucumber productivity. Paper presented in the 85th Annual Meeting of the American Society for Horticultural Science. 6th to 11th August, 1988.

Wudiri, B.B. and Herderson, D.W. 1985. Effects of water stress on flowering and fruit set in processing - tomatoes. *Scientia Horticulturae.* 27 : 189-198.

*Yang, P.S. and Pao, P.T. 1962. Studies on the effect of potash on banana. *Potash Rev. Sub.* 27 (4) : 31-37.

* Originals not seen

Appendices

Appendix I

Monthly weather data during the crop growth period

		Mean temperature °C		Total rainfall (mm)	Rainy days	Total evaporation (mm)	Mean relative humidity %	Mean wind speed km hr^{-1}	Mean bright sunshine hours
		Maximum	Minimum						
1988	August	29.2	24.3	507.8	25	97.6	86	4.1	3.7
	September	29.9	23.2	700.0	24	87.5	85	4.1	5.1
	October	31.7	23.3	116.6	9	113.7	78	3.4	7.1
	November	32.6	22.9	11.0	1	116.7	68	5.9	7.8
	December	32.6	22.3	14.9	2	206.3	57	10.0	9.0
1989	January	33.4	22.2	0	0	253.8	54	10.9	8.1
	February	36.3	21.2	0	0	227.7	45	7.1	9.8
	March	36.5	23.3	31.3	2	218.6	58	5.8	9.5
	April	35.3	25.1	52.6	4	179.2	69	5.4	8.2
	May	33.7	24.5	115.8	7	152.0	74	5.2	6.7
	June	29.4	22.7	784.6	27	83.0	86	4.5	3.2

Appendix II

Analysis of variance for the height and girth of the plant at various stages of growth

Source	df	Mean squares							
		Height				Girth			
		4 MAP	5 MAP	6 MAP	At shooting	4 MAP	5 MAP	6 MAP	At shooting
Block	2	155.09	37.22	176.34	177.81	8.03	1.47	0.32	5.21
Treatment	9	65.25**	478.22**	1367.69**	1506.68**	2.91	38.02**	56.33**	63.25**
Error	18	24.83	56.80	79.48	114.22	3.34	3.83	2.63	2.44

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix III

Analysis of variance for the number of leaves and leaf area at various stages of growth

Source	df	Mean squares								
		4 MAP	5 MAP	6 MAP	At shooting	4 MAP	5 MAP	6 MAP	At shooting	At harvest
Block	2	0.24	0.22	0.30	0.23	0.17	0.38	0.36	0.09	0.08
Treatment	9	0.47*	5.70**	12.13**	9.96**	0.32	2.54**	7.65**	6.55**	2.06*
Error	18	0.13	0.38	0.33	0.22	0.14	0.32	0.15	0.21	0.59

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix IV

Analysis of variance for sucker production and crop duration

Source	df	Mean squares				
		Sucker production		Crop duration		
		At shooting	At harvest	Days taken from planting to shooting	Days taken from shooting to harvest	Days taken from planting to harvest
Block	2	2.04	0.54	136.31	16.37	114.63
Treatment	9	2.21	1.11	1470.36**	244.48**	1021.31**
Error	18	1.39	0.82	50.58	24.24	50.36

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix V

Analysis of variance for bunch characters

Source	df	Mean squares							
		Weight of the bunch	Length of the bunch	Number of hands/bunch	Number of finger/ bunch	Number of finger/ hand	Length of finger	Girth of finger	Weight of fruit
Block	2	0.39	1.39	0.22	1.22	0.29	4.63	0.74	134.23
Treatment	9	2.20**	54.34**	1.02**	130.22**	2.29**	22.68**	3.95**	1169.27**
Error	18	0.29	3.53	0.20	18.44	0.29	1.57	0.42	114.90

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix VI

Analysis of variance for fruit quality

Source	df	Mean squares			
		Total soluble solids	Total sugars	Acidity	Sugar/acid
Block	2	1.43	0.54	0.001	5.10
Treatment	9	1.34	1.51**	0.02**	70.97**
Error	18	1.14	0.13	0.004	13.38

* Significant at 5 per cent level

** Significant at 1 per cent level

EFFECT OF SOIL MOISTURE STRESS ON GROWTH AND YIELD OF BANANA cv. NENDRAN

By

JESSY, M. D.

ABSTRACT OF THE THESIS

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ABSTRACT

An experiment was conducted at the College of Horticulture, Vellanikkara, Trichur during 1988-89 to study the effect of soil moisture stress on the growth and yield of banana cv. Nendran. The experiment was laid out in RBD with three replications. There were 10 treatments (unmulched and without any water stress, mulched with coconut husk and subjected to water stress from January to April, February to April, March and April, April only, December to March, December to February, December and January, December only and applied with Jalshakti). Irrigation was given with 20mm water at IW/CPE = 0.9.

Observations on various growth characters, bunch characters and quality aspects were recorded during the course of the investigation. The daily values on various weather elements recorded at the meteorological observatory were collected. Soil moisture observations were taken before, and 24 hr after irrigation to compute consumptive use and soil moisture stress. Soil temperature observations were recorded twice daily, at 0700 and 1400 hr LMT.

The results revealed that all the morphological characters studied, height of the plant, girth, number of leaves and total leaf area showed a decreasing trend with increasing levels of soil moistures stress. Mulched plants which received irrigation continuously from December to March were superior to the rest of the treatments with respect to the various growth parameters during most of the stages.

Plants which were water stressed from December to March took maximum number of days for shooting and harvest, and the plants which were water stressed in April only took the minimum number of days.

The highest yield was recorded by unmulched pla irrigation continuously from December to April. It was on par mulched plants which were subjected to water stress either in December or in April. The various yield attributing characters also showed a similar trend.

Among the quality aspects studied, total ε , was not affected by soil moisture stress. Total sugar content and sugar acid ratio increased with increasing levels of soil moisture stress.

The soil temperature recorded at 0700 and 1400 hr LMT and the diurnal range were always the lowest in the irrigated mulched plot. Unirrigated mulched plot recorded the highest temperature in the morning, whereas bare plot recorded the highest values in the afternoon.

Plants which were adequately irrigated throughout the dry season recorded the maximum consumptive use and it showed a decreasing trend with increasing levels of soil moisture stress.

A negative correlation was obtained between the soil moisture stress and growth characters like height, girth and leaf area and bunch characters like number of fingers per bunch, weight of fruit and weight of bunch. Crop duration was positively correlated with the soil moisture stress.

The soil moisture stress during the period 'flower initiation to shooting' (five to sevenmonths after planting) affected the yield mostly. The moisture stress imposed before flower initiation and later stages had little effect.

Results of the present investigation indicate that soil moisture stress imposed during all the growth/developmental stages adversely affect the growth and yield of banana. The adverse effect is more pronounced when the stress is imposed during the period 'flower initiation to shooting'. Hence banana can be successfully cultivated without substantial reduction in yield by giving adequate irrigation during the critical period. The quantity and frequency of irrigation water can also be reduced through soil moisture conservation by mulching with coconut husk.